IMPROVING INTERNATIONAL LOGISTICS PERFORMANCE MEASURING

IMPROVING THE LOGISTICS PERFORMANCE INDEX (LPI) BY ASSIGNING WEIGHTS TO ITS SIX CORE COMPONENTS, USING THE BEST-WORST METHOD

BY

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Summary

Trade between countries has developed over the past decades. Before the globalization countries were mostly competing with other countries in the region, whereas the globalization trend has increased the amount of competitors to almost all countries in the world. These developments have increased the importance of logistics in international trade and made it one of the key elements in the development of a country. The importance of logistics for the economy of a country also led to the need for measurement on a larger scale. To address this need the Logistics Performance Index (LPI) was created in 2007 by researchers commissioned by the World Bank. The LPI is an interactive benchmarking tool that countries can use to identify possible challenges and opportunities they face in their performance on trade logistics.). Since the first report in 2007, new versions have been published in 2010, 2012, 2014, and the most recent version in 2016. All of these versions featured a ranking of all the countries on which information was available, with 160 countries in the most recent ranking. To determine the scores of each country, experts from over the world are asked to score countries on six components. The average of the scores on these components is the overall LPI score. This score is then used to determine the ranking. Each of the expert is asked to score 8 different countries with a score between 1 (poor performance) and 5 (excellent performance) on each of the components. Table I presents the six components with an explanation as provided to the experts in the questionnaire used to create the LPI report.

Table I: core components

Core components	Description (Arvis et al., 2016)
Customs	The efficiency of customs and border management clearing
Infrastructure	The quality of trade and transport infrastructure
Services quality	The competence and quality of logistics services
Timeliness	The frequency with which shipments reach consignees within scheduled or expected delivery times
Tracking & Tracing	The ability to track and trace consignments
International shipments	The ease of arranging competitively priced shipments

Since the LPI is constructed by taking the average of the scores on the six components, it is assumed that all the components are of equal importance for logistics performance. No research has been done into the importance of each of the components for logistics performance. In reality it is unlikely that in all of the components are equally important for logistics performance, due to the many factors influencing the components. Addressing the relative importance of factors for logistics performance will provide a valuable insight into what determines how well a country performs. This insight could help countries in understanding where to focus projects and how to improve their performance in the most efficient way. To address this relative importance this research is the first research that assigns weights to the components of the LPI or to any factor in logistics performance. The following research question will be answered.

"How can the Logistics Performance Index (LPI) be improved by assigning weights to its six core components?"

Several methods for assigning weights to criteria (components) are available. For this research the Best-Worst method (BWM) is used because of several reasons: It needs fewer comparisons than other pairwise comparison methods and therefore achieves a higher consistency. Over 1100 experts from universities and companies were approached to answer an online questionnaire, leading to 107 respondents from 59 countries on all continents. They were asked to answer the questions related to the BWM, as well as where they are living, and on which countries they have the most information concerning the logistical situation of that country. Their questionnaire answers showed that infrastructure and services were considered to be the most important and tracking and tracing to be the least important component. Their answers led to the weights as shown in table II. The weights are in the following order: Customs (C), infrastructure (I), quality of services (S), timeliness (T), tracking and tracing (TT), and international shipments (IS). The table also presents the consistency indicator Ksi*, that shows the consistency of the weights, values below 1 are considered highly consistent.

Table II: component weights

	w(C)	w(I)	w(S)	w(T)	w(TT)	w(IS)	Ksi*
Universities	0,139459	0,237518	0,219531	0,169923	0,117777	0,115792	0,106905
Professionals	0,182237	0,232999	0,21391	0,148966	0,085047	0,136841	0,133204
Total	**0,159449**	**0,235406**	**0,216904**	**0,16013**	**0,102483**	**0,125628**	**0,119194**

Several group comparisons have been made to find significant differences between groups of respondents. The only significant weight difference between the respondent that work at universities and the respondents that are professionals in international logistics was found in the customs component. The country the respondent were living in or from which their company operates was used to determine the development group of that respondent, based on the income groups as provided by the world bank. The respondents were divided into the High group (GNI > $12,476) and the low development group (GNI < $12,476). No significant weight differences were found between these two groups. If the respondents were categorized based on if the countries they had information on were from the high or low income group, also no significant weight differences were found. The customs weight does differ based on the continent the respondent is from, Africa and North-America showed a significantly higher weight, whereas Australia considered customs less important. In general the differences between groups were small and the weights when all 107 respondents are included can be considered robust. These weights are significantly different from the weights that are found if every component is considered equally important, which are used for the creation of the LPI. The weights have serious implications for logistics performance measurement since this is the first time the relative importance of these factors have been addressed. The weights provide insight in where to focus logistics projects and how new projects could be implemented, proving that the LPI and logistics performance measurement in general can be improved by assigning weights to the six core components and thereby answering the research question.

The research identified several needs for further research, concerning further research into logistics performance measuring as well as research into the LPI methodology. More research is needed into the implications of the weights for actual projects, since they still have to be transformed into actual policy measures to improve logistics performance. In order to do so, further research is needed into

different projects that influence the weights along with the total costs and benefits of said projects. Also, the LPI questionnaire should be investigated further. The weights do not have a large influence on the ranking, due to high correlation between the scores on the different components. These high correlations, all above 0.902, lead to a correlation between the overall LPI score and the weighted LPI score of 0.9988. The reason for this high correlation could be common mode bias, where the way of questioning influences the outcomes of in this case the LPI questionnaire. Respondents are in many cases asked to score a random country on the six components, making it unlikely they have the needed information to rate each component separately and judge from a general idea of the country they have to rate. To test this theory, experts on several countries should be asked to only rate the country they have experience on and compare results with the LPI component score of that country. Besides the questionnaire of the LPI, the components should also be reviewed. Literature suggest that at least two factors in logistics performance have been left out. The first factor is innovation, which has an important impact on the countries possibilities to adopt new technologies and adapt to changing logistical systems. The second and probably most important factor is environment. The climate change has brought environment onto the political agenda and transport and logistics are an important factor in the climate change, mostly due to emission of CO2 and small particles. The world bank could review which factors should be added or left out before a new report is produced. The method of weight assignment that has been proposed in this report could be used to determine the weights of the components if their composition changes.

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Chapter 1: Research problem

Trade between countries has developed over the past decades. In the earlier years most countries were competing with other countries in the region, whereas globalization has increased the amount of competitors to almost all the countries in the world. These developments have increased the importance of logistics in international trade and made it one of the key elements in the development of a country (Marti, Puertas & Garcia, 2014; Razzaque, 1997). Erkan (2014) sums up logistics activities over time going back to 2700 B.C. when the pyramids were built. Other developments in logistics are the first rowing ships capable of crossing large seas, the introduction of railways, and the invention of the sea container. There has been discussion about the exact definition of logistics and many different definitions have been proposed over time by organizations, scientific journal articles, and companies. The first references in which the word logistics was used are from 1898 military applications and concerned the movement and quartering of troops and in a later article the technique of packing stores (Lummus, Krumwierde & Vokurka, 2001). A more recent definition that covers the basic concepts of logistics was given by Souza, Goh, Gupto, and Lei (2007, p. xiv):

"*Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements*"

Many research has been done to study the role of logistics in companies, supply chains, and worldwide. Most of these studies recognize the significant effects logistics has on the economic development of a country and international trade. Lambert and Stock (1993) reviewed the role of logistics in organizations and the effects on the economy. They concluded that logistics is one of the most important areas of study that can improve a country's standard of living. Razzaque (1997) describes that improving the logistical system of a country has a positive effect on productivity, distribution efficiency, interest rates, and trade volumes. Hoekman and Nicita (2011) emphasize the importance of logistics in developing countries. They studied different regulations aimed at increasing trade volumes. They concluded that improving logistics in a developing country is more effective than widely used restriction regulations, such as trade barriers and tariff regulations. The many studies into logistics have increased the awareness that improving the logistical system of a country can have significant positive effects for the economy. Therefore, many logistics related projects have been proposed and implemented by governments and companies worldwide. The increased awareness of the importance of logistics has also led to an increase in the need to monitor logistics performance of a country, especially in comparison to competing economies.

1.1 Logistics performance

An important indicator for how well a country and its government are performing is the economic situation in the country, which can be measured by metrics such as economic growth, Gross Domestic Product, and trade volumes. Logistics have an important influence on these metrics and therefore it is important for a country to assess its logistics performance, especially compared to other economies in the region. Also, it gives a country insight in its international position and gives insights in where

improvements can be made efficiently. However, there was no general standard for how to measure logistics performance. The many researches and definitions of logistics performance prove that many factors are involved and that probably not a single research or definition captures logistics performance completely. The studies that have been performed mostly focussed on logistics performance of single companies or supply chains and not on the performance of a country. Chow, Heaver, and Henriksson (1994) mention 19 different definitions of performance, based on both hard and soft measures. If logistics performance in measured using hard measures, the measures are based on quantitative data such as trade volumes, GDP, and productivity. The soft measures are based on qualitative data such as customer satisfaction and expert scores. Caplice and Sheffi (1994) compare different metrics for logistics performance to find trade-offs. The first trade-off they found is between the inclusiveness of the metric and the usefulness. Also, if a metric is more complex it loses its compatibility. Both of these trade-offs also seem useful when the performance of a country is concerned. Caplice and Sheffi (1995) studied the specifications of a good logistics performance measurement system. They found six criteria to which the system should comply: Comprehensiveness, casual orientation, vertical integration, horizontal integration, internal comparability, and usefulness. Graeml and Peinado (2011) mention that there still is not enough research into logistics performance on both company and international level and test a specific measuring system on the automotive industry. The realization that a global assessment of the logistics performance of countries on an international level was not available was one of the reason that led to the creation of the Logistics Performance Index (LPI) in 2007 (Arvis et al., 2007). This index was the first worldwide comparison method for countries concerning their logistical performance and has been used in many studies since.

1.2 The Logistics Performance Index

The Logistics Performance Index (LPI) was introduced in 2007 as a tool to give countries insight in their logistical performance. It is an interactive benchmarking tool that countries can use to identify possible challenges and opportunities they face in their performance on trade logistics (Arvis et al, 2016). These challenges and opportunities can be used to find possible policy measures a country could implement to effectively improve logistical performance. Since the first publication of the connecting to compete report in 2007, in which the LPI was introduced, new versions have been published in 2010, 2012, 2014, and most recently in 2016 (Arvis et al. 2007;2010;2012;2014;2016). Each version contained a ranking with all the countries of which the required information was available. The first report included 150 countries, the 2010 and 2012 reports ranked 155 countries, and the two most recent versions featured 160 countries. All the countries receive a score between 1 and five on six core components. The scores on these components determine the final score per country that determines the ranking. In the first edition there was a seventh component, domestic logistics costs, which was excluded in the following reports. The six components in the most recent versions are divided in two groups. The first group concerns the areas for regulations, which are inputs to the supply chain. The second groups consists of three components that are regarded supply chain performance outcomes. Table 1 shows the groups and their corresponding components, according to the most recent report. The scores on these components are based on expert survey results. Each of the components is scored between 1 and 5 by experts in international shipping and logistics. A selection method is used to determine which countries are scored by which expert (see section 2.1.1). The overall score is the average of the scores

on the components. The ranking is then drawn up based on the overall scores of the countries. In the two most recent versions of the report Germany was the top performing country, with an LPI score of 4.12 and 4.23 respectively. The worst performing country in the most recent report, with a score of 1.60, is Syria. The methodology behind the LPI and its selection of experts will be elaborated upon in chapter 2.

Table 1: Core components of the LPI

Core components	Description (Arvis et al., 2016)
Areas for regulation	
Customs	The efficiency of customs and border management clearing procedures.
Infrastructure	The quality of trade and transport infrastructure.
Quality of services	The competence and quality of logistics services..
Supply chain performance outcomes	
Timeliness	The frequency with which shipments reach consignees within scheduled or expected delivery times.
Tracking & Tracing	The ability to track and trace consignments.
International shipments	The ease of arranging competitively priced shipments.

Since the LPI is constructed by taking the average of the scores on the six components, it is assumed that all the components are of equal importance for logistics performance. This would mean that the quality of the infrastructure in a country is equally important as the ability to track an trace goods. As mentioned earlier many factors have influence on logistics performance. All the components from the LPI are likely to be important for how a country performs and improving the situation of each of the component would make the logistical performance better. However, it seems unlikely that these six factors are all equally important for determining the logistics performance of a country. If the importance of the components would differ, the LPI could be improved by addressing the relative importance of the components. This improvement could give a better understanding for countries on how to implement policy measures in the most effective way. Assigning weights to the different components of the LPI can be a viable option to achieve this improvement. Many methods of assigning weights to criteria (components) are available. The best method for this research will be identified based on the literature available on the subject. Besides the weights of the components, it is also questionable if the six components are the only (important) factors in logistics performance. A review will be done on the current factors that are included in the LPI and possible new factors will be determined. However, for the weight assignment the current LPI components will be used.

1.3 Knowledge gaps

Before assigning the weights to the components and determining if it is an improvement of the current Logistics Performance Index, knowledge on several subjects will have to be gathered. The first knowledge gap is that it is unknown what the best method is to assign weights to the different core components of the LPI. It is also unknown what effects weight assignment will have on the ranking presented in the LPI report and the implications the weights will have for logistics performance

measurement, since weights have never been assigned to the components. These uncertainties leave knowledge gaps that this research will aim to fill.

1. The best method to assign weights to the six core components on the Logistics Performance Index (LPI) in unknown at this time. This method should be determined by reviewing existing methods for Multi Criteria Decision making and choosing the best method suitable for this specific problem.
2. It is unknown if assigning weights to the core components of the Logistics Performance Index will lead to a more accurate ranking and thereby a better basis for policy measures and which metrics should be used to validate the weighted Logistics Performance Index.

1.4 Research objectives

The research will be aimed at creating a better tool for measurement of logistical performance for countries to help them gain a better insight in their global position and to help them implement more effective policy measures. These new measures can be identified because the weights assigned to the components will create a better picture of the importance of all the components. Also, it will create a better insight for countries in how their logistical position is compared to that of other countries (in the region). Therefore the research has two objectives, one being more theoretical and the other focusing on the effects of the research. The created method is reusable if in the future component will be added or if perception of importance of the different components changes. Therefore there are two different objectives for this research, one being a more theoretical/scientific one, and the other one focuses on the effects of the weighted LPI:

- The research aims to create a validated weighted Logistics Performance Index based on the current index, using the Best-Worst Method. The method used in this research should be re-usable when new components are added.
- The research aims to help countries get a better insight in their logistics performance and thereby help them take more effective measures to improve their logistics system and performance.

1.5 Research questions

To fulfil the objectives presented in the previous paragraph, several questions will have to be answered. The main research question for this research is:

"How can the Logistics Performance Index (LPI) be improved by assigning weights to its six core components?"

To answer this question, several sub-questions will have to be answered. Each of these questions focusses on a different part of the research and the goal is that if each of these is answered, the main research question can also be answered. In the last paragraph of this chapter the chapter in which each of the questions will be answered is visualised and explained. The sub-questions that will be answered in this thesis report are:

1. What is logistical performance?
    a. Are the current components indicators of logistics performance?
    b. Are there other possible factors besides the components that are important to assess the logistical performance of a country?
2. What other metrics and indexes are indicators of logistics performance?
3. Which are the most important factors in logistics performance?
    a. Which method should be used to determine the weights of the core components?
    b. What are the weights of the components?
    c. Are there any differences in component weights between different geographical or development groups?
4. How does the new ranking compare to the current ranking?
    a. What are the differences and similarities?
    b. What do these result imply?
5. What policies can be adopted by countries based on the results of this research?

Answering these sub-questions will happen throughout this report, the main research question will be answered in the last chapter, the conclusions & discussion.

1.6 Relevance

If the mentioned knowledge gaps can be filled the research will have both scientific and societal relevance. The many applications of the LPI as a basis for logistics analysis and even implementation of projects for improving logistics ensure that this research can have societal value. It has yet to be determined if assigning weights to the LPI will make the LPI more accurate. However, if this is proven, countries will have a better insight in their logistical position compared to competing economies and countries in the region or worldwide. This improved insight can lead to a better understanding on where measures should be taken to improve the logistics performance in the most effective way. The weights also give insight in what the most important factors in logistics performance are and therefore are useful for further research but also in determining where measures should be focussed.

Scientifically the research can be a basis for more researches concerning the logistical performance index and making it a better measuring tool for logistical performance. The factors that are important for logistics performance will be reviewed. One of the recommendations could be to review if the six core components really are the main components of logistics. If these components ever change, as has happened since the first version in 2007, the used methods from this research can be applied to the new components to assign the new weights. There have been combinations made of the LPI with other indexes, this would also be possible with the weighted LPI. Also, the application of a relatively new method on a globally used index might generate more attention to the method and provide possibilities for usage of this method on more research in the future.

1.7 Thesis outline

This research for this thesis consists of different stages, represented in different parts of this thesis. This paragraph will provide a short explanation of these parts and will give a visual representation of the outline of the thesis. The first part of the thesis will be the **exploration** phase, where the problem

field will be explored and the research questions will be formed and the objectives of the research will be presented. A review of existing research in the problem field will be executed, to form an image of the current state of literature on the subject. Chapter 1, of which this paragraph is the last one will explore the problem and chapter 2 will address the literature on the problem. In this phase of the thesis sub-questions 1 and 2 will be answered.

The second phase of this thesis will be the **execution** phase of the research. In this phase the methods used to find the result in this research will be described, as well as the methods for selection and approach of the respondents of this research. Chapter 3 will describe the methodology that forms the basis for the execution of this research. Sub-question 3a will be answered in this phase of the thesis.

The third phase of the research is the **interpretation** phase, This phase will use the outcomes of the selected method and present the weights of the components based on these outcomes. An interpretation of the weights that are found will be provided and possible differences between groups identified. The implications of the results will be used to create an advice for countries and policy makers. Chapter 4 will describe the results and present the new weighted LPI. Chapter 5 will provide an advice based on the outcomes found in chapter 4. Sub-questions 3b, 3c, 4, and 5 will be answered in this phase.

The last phase will be the **conclusion & discussion** phase, in which the research will be concluded and a discussion on the research presented in this thesis will be provided. Possible limitations of the study will be presented, along with recommendations for further research found by conducting this research. This phase will be described entirely by chapter 6, which will be the last chapter of this thesis report. Figure 1 provides a visual representation of the outline of this thesis. The sub-questions that will be answered are shows with the phases with the abbreviation SQ. each white box represents a chapter and provides a short description of the information the chapter will provide.

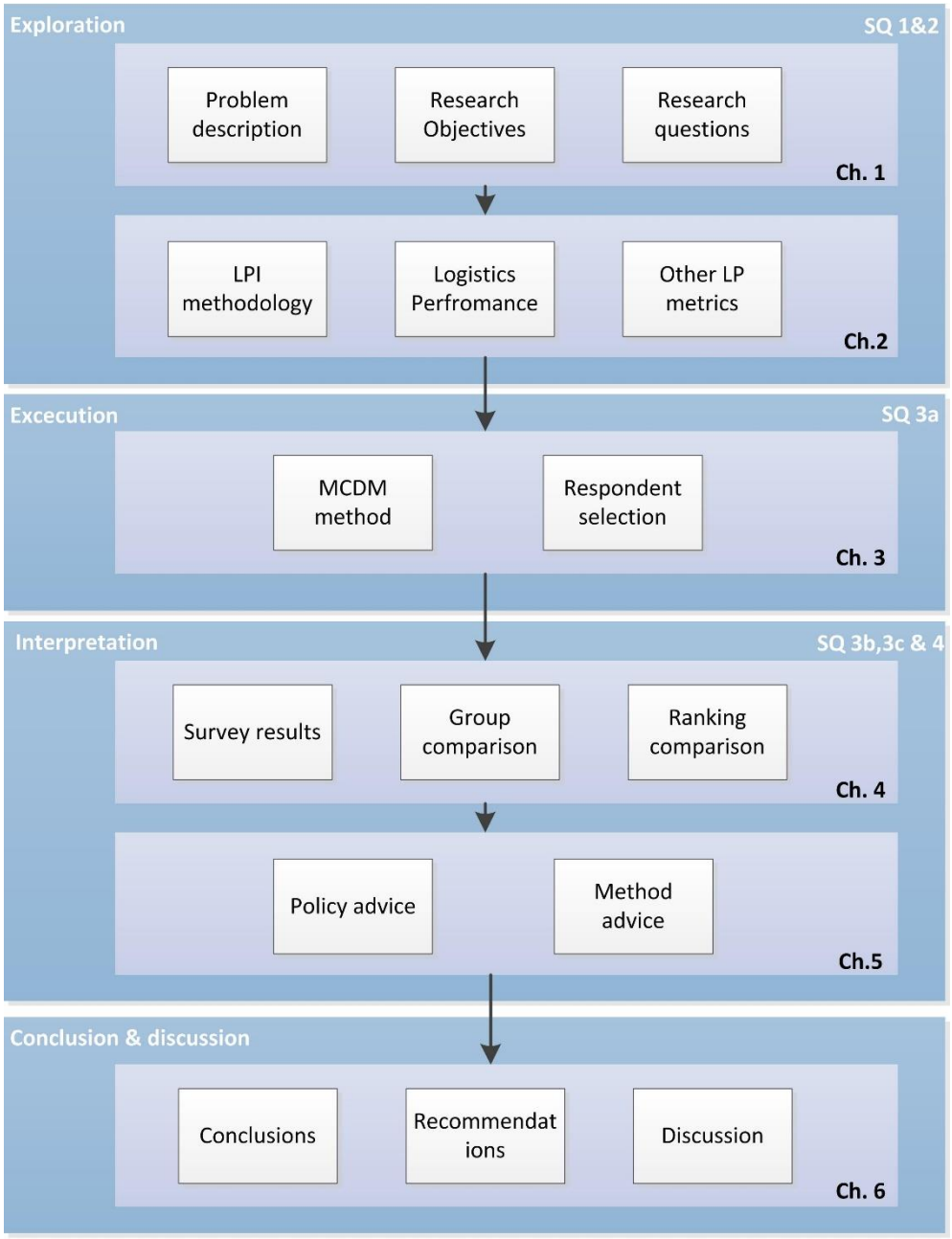

Figure 1: Thesis outline

Chapter 2: Literature review

In this chapter a review of the available and relevant literature for this research will be made. It will start with a review of logistics performance measuring methods besides the LPI. Then, the current LPI methodology, respondent demographics, and use in literature will be presented. The last section will review the current LPI components and their link to logistics performance will be presented. The last section will also identify possible factors in logistics performance that have not been included in the LPI.

2.1 The Logistics Performance Index (LPI)

This section will start with a description of the methodology, followed by a description of the demographics of the expert respondent and will be concluded by a review of the LPI in current literature.

2.1.1 LPI Methodology

The LPI is constructed based on an survey with respondents that are experts in the field of international shipping and logistics. For all the countries experts that are not based in that country are asked to give a rating between 1 and 5 on the six different components: Customs, infrastructure, quality of services, timeliness, tracking and tracing, and ease of arranging shipments. The reason experts are used to determine the logistical performance of a country is that other statistical cannot be assessed using only available hard data such as cost and time information (Arvis et al., 2016). These expert are found with the help of three expert organizations: The International Association of Freight Forwarders (FIATA), the Global Express Association (GEA), and Global Facilitation Partnership for Transportation and Trade (GFP).

Each of the survey respondents is asked to rate 8 overseas countries on the six components, these 8 overseas markets are randomly assigned based on the most important import and export markets in the country the respondent is located in. For landlocked countries (countries completely surrounded by other countries and not by the sea) the characteristics of the country determine which countries are rated by the respondent from the landlocked country. Figure 1 shows the country selection process. The reason this extensive selection is used is to ensure that the respondent has experience with the logistical performance of the country he has to rate. The respondents partake in the survey online. For the 2016 edition this happened in two different periods: October – December 2015, and March – April 2016.

	Respondents from low-income countries	Respondents from middle-income countries	Respondents from high-income countries
Respondents from coastal countries	Five most important export partner countries + Three most important partner countries	Three most important export partner countries + The most important import partner country + Four countries randomly, one from each country group: a. Africa b. East, South, and Central Asia c. Latin America d. Europe less Central Asia and OECD	Two countries randomly from a list of five most important export partner countries and five most important import partner countries + Four countries randomly, one from each country group: a. Africa b. East, South, and Central Asia c. Latin America d. Europe less Central Asia and OECD + Two countries randomly from the combined country groups a, b, c, and d
Respondents from landlocked countries	Four most important export partner countries + Two most important import partner countries + Two land-bridge countries	Three most important export partner countries + The most important import partner country + Two land-bridge countries + Two countries randomly, one from each country group: a. Africa, East, South, and Central Asia, and Latin America b. Europe less Central Asia and OECD	

Figure 2: Country selection respondents (Arvis et al., 2016)

Using the results on the six different components a principal component analysis is used to determine the LPI of a country. Principal component analysis (PCA) is a statistical analysis method used to reduce dimensionality and find object patterns (Wold et al., 1987). In the LPI case the inputs are the normalised averages of the scores given by experts on the six core components. A weighted LPI is the outcome of the analysis. The weights however are not based on the importance of the components but are selected to maximize the percentage of variation that is accounted for by the LPI. Table 2 show the weights of the different components used to calculate the LPI. The PCA has been redone for every of the LPI reports over the years but the weights have stayed almost the same, making the different version comparable to each other (Arvis et al., 2016).

Table 2: Components weights

Component	*Weight*
Customs	0.41
Timeliness	0.40
Tracking and tracing	0.41
Infrastructure	0.41
International shipments	0.41
Services quality	0.41

Since the weights are all very close to each other, the LPI is almost an average of the score on the six components. As mentioned in the introduction, this seems highly unlikely in the complex system that international logistics is. Therefore, assigning weights can be an improvement of the LPI and will be the aim of this research. This will be done using a method for Multi Criteria Decision making. This

research will aim at assigning weights to these components not based on finding the best underlying explanation (as done with PCA) but based on their relative importance to each other.

Due to the fact that the scores are based on survey results, confidence intervals have to be created to account for the errors. The confidence levels of the LPI scores are about 80 percent (Arvis et al., 2016). The equation used to determine the lower and upper limit of the confidence levels of the LPI for each country is the following:

$$LPI \pm \frac{t_{(0,1,N-1)}S}{\sqrt{N}} \qquad (1)$$

Where N is the number of respondents, S is the estimated standard error of the LPI score, t is the Student's t distribution. The number of respondents that rate a specific country determines the size of the confidence interval. Fewer survey results on a specific country mean that the interval becomes bigger. Therefore, the smaller and poorer countries are more likely to have a bigger confidence interval, since fewer respondents have information on those countries and it is harder to find respondents in those countries. The average difference between the upper and lower bound is 0.23 on a 1-5 scale. This is eight percent of the average score on the LPI. For the LPI the middle of the interval for each country is used as the final LPI score that determines the ranking. If for one country the upper or lower boundary of the confidence interval would be used and the rest stays the same, the average position change would be 20 places. This means that the scores are quite close together and small change can have significant impact on the ranking. Appendix A shows the full ranking of the LPI from the 2016 report. It also shows the score on each of the six components. For the rankings from earlier LPI's, the work of Arvis et al. (2007;2010;2012;2014) can be consulted.

The authors of the 2016 LPI report mention two limitations of the methods used for the construction of the LPI. The first limitation is that for the poorer countries, large international freight forwarders might not represent the broader logistics environment. This is caused by the fact that these poorer countries mostly rely on more traditional smaller operators. What this means is that the opinions of the expert on the poorer countries could be different than the real situation. The smaller operators are mostly not included in the respondents. Also, different freight forwarders can have different experiences with the same country. It is likely that large international operators have different experiences with government officials, such as custom officers, than regional smaller operators. The opinion of the respondent on the quality of services will be based on his experience with the service providers in that country, which especially in the poorer countries differ per provider. The second limitation concerns the landlocked countries and small island states. Landlocked countries are completely surrounded by land or closed seas and therefore have no direct access to the sea and no ports. For the landlocked countries and small island the LPI might reflect access problems that are outside of the countries concerned. Therefore it is possible that a low rating for a landlocked country is not the correct reflection of the country's trade facilitation, since these countries are unable to take measures to correct the deficiencies in the countries surrounding them.

2.1.2 Development groups and respondents

The LPI uses a distinction between different groups of countries based on how developed they are. The groups used are the groups as defined by the World Bank income classification. This classification is based on the average income of the country. The differentiation between groups is also interesting for this research since the respondents will have to come from different income groups to determine possible relationships between weights assignment and degree of development. This section will therefore present where the current respondents come from and will also provide other possible ways to distinguish between countries that later can be used to find usable and interesting relationships.

As mentioned before the World bank income groups are based on gross average income. The World bank atlas method is used to calculate these gross national incomes. This method is used to decrease the effects of exchange rate fluctuations in the comparison of national incomes (Arvis et al., 2016). Six different groups have been made, which are show in table 3. This table also shows the amount of respondents in each group for the most recently published version of the LPI. As can be seen most of the respondents come from middle and high income countries. For the low income countries it is significantly harder to find respondents with the needed expertise to participate in the research.

Table 3: World Bank income groups

Group name	GNI per capita	Respondents in 2016 LPI
Low income	< $1,025	116
Lower-middle-income	$1,026 – $4,035	322
Upper-middle-income	$4,036 - $12,475	218
High-income OECD	$12,476 >	276
High-income non-OECD	$12,476 >	119

Other possibilities for ranking countries based on how developed a country is have been introduced over time. The United Nations development programme (1993) introduced the Human Development Index, with the newest version being presented in 2015. This Index is based on The GNI per capita, the educational standards (mean years of education and expected years of schooling), and life expectancy. The method was introduced by the Pakistani economist Mahbub ul Haq and the method is used in yearly in the report of the United Nations development programme. Like the LPI it contains a ranking of all the countries based on the earlier mentioned development criteria. It could be interesting to compare the weighted LPI with this index to find similarities between the two indexes. Another known method is the Physical Quality of Life (PQLI), which uses the literacy rate, the infant mortality rate, and the life expectancy to calculate the Quality of life per country (Morris, 1980). The method is not used as much as the Human Development Index and therefore seems less useful for this research.

Another measuring method is the Happy Planet Index. This method was introduced by the New economics foundation, with the latest version published in 2016. The method uses four factors to determine the HPI score for all the countries with data available. The HPI is calculated using the Life expectancy, experienced wellbeing, inequality of outcomes and the ecological footprint. The experienced wellbeing is measured by the answer on a survey question and is a number between 1 and 0. The inequality of outcomes is a measure of how unequal the distribution of life expectancy and

experienced wellbeing scores are within a particular country (NEF, n.d.). The ranking of the HPI is very different than the LPI ranking. Costa Rica is at the top in the HPI, whereas it is only ranked 89th in the LPI ranking. The number one of the LPI, Germany, is ranked 43rd on the HPI ranking. It is therefore questionable how usable this index is for comparison with the weighted LPI that will be created. Other methods that might be used for comparison and possible validation will be identified in section 2.2.3.

2.1.3 LPI in literature

The LPI report has been used in many studies and researches since its introduction in 2007. This paragraph will identify the reports and articles that have used the LPI and summarize how the LPI was of importance. The current usage of the LPI can be an important indication of how the weighted LPI that will be constructed in this research can be useful for countries to identify policy measures and for further research into logistics performance. Many researches acknowledge the LPI as a way of addressing the logistics performance of a country. Solakivi et al. (2014) used it to describe the logistics system in Finland, and uses the LPI as method of comparing Finland to its neighbouring countries. The International Transport Forum (ITF, 2015) describes the LPI and its components extensively and present a case study on the logistical performance of Turkey based on the components of the LPI. They address each of the components separately and conclude that Turkey's logistics performance has increased since 2007 based on the ranking provided in the LPI report. Jumadi & Zailani (2010) research the need for greener logistics in Malaysia and use the LPI to address Malaysia's logistic situation and compare it with other economies, concluding that Malesia scores significantly worse than OECD countries but better than most countries in the region. Dekker, de Looff, Roelofsen, and van Roekel (2016) took the LPI ranking of Costa Rica as one of the reasons to decide that there was room and need for improvement. They also took the low scores on customs and infrastructure as a starting point for strategies and alternatives.

Besides studies that use the LPI to address the situation in a specific country there are also studies that use the LPI or components of the LPI to find relations or create new Indexes. Hoekman & Nicita (2011) review different indices of the world bank that concern trade restrictiveness and trade facilitation and apply them to developing countries. The goal of the research is to assess the effects of different sources of trade costs on an international level. The LPI score is used as a reflection of logistical performance that can be influenced by certain policy measures. Besides the LPI, the trade across border component of the doing business report is also used to measure trade facilitation. They then calculate what the effect on trade would be if a low development country would implement measures that would make them a middle development country in each of the indexes. For the LPI score this means an increase in the score from 2.8 to 3.0. They conclude that the largest increases in trade are associated with measures improving the logistics scores (LPI). They score significantly better than measures concerning trade restrictiveness, such as the tariff measures and non-tariff measures (NTM). Table 4 shows the table with the identified effects on trade. For the tariff measures a change from low to middle development in the tariff trade restrictiveness index (TTRI) was made and for the non-tariff measures a change in the non-tariff components of the overall tariff restrictiveness index (OTRI).

Table 4: Effects on trade

Measure	Increase in imports (%)	Increase in exports (%)
Trade policy Tariff	6.5	10.6
Trade policy NTM	4.9	1.0
Doing business	5.0	1.9
LPI	8.5	15.1

A change in the overall score of the LPI from 2.8 to 3.0 leads to an increase of 8.5% in import and 15.1% in export. The conclusion therefore is that when policy measure should be implemented to increase trade, measures concerning logistics are the most effective.

The aim of the research by Kim and Min (2011) was to examine whether some countries achieve high logistical performance by undermining environmental quality. To combine logistical performance and environmental friendliness they created a hybrid index called the Green Logistics Performance Index (GLPI). Logistics performance is measured by the LPI and the green component by the Environmental performance index (EPI). The EPI is published by a collaboration of the World Economic Forum and some universities. The EPI has ten core policies with a total of 25 indicators that all have different weights. Only the components of the LPI that can directly influence the indicators of the EPI, infrastructure and timeliness, were used for the research. Equation 2 is used to calculate the GLPI.

$$GLPI = \frac{Sum\ of\ selected\ LPI\ data\ (output)}{Sum\ of\ selected\ EPI\ data\ (input)} \qquad (2)$$

After calculation of the GLPI a ranking is made of the countries for which data was available on both the LPI and the EPI, which are 146 countries. There are significant differences between the GLPI ranking and the LPI ranking. The highest difference in ranking is achieved by Laos with a 115th place on the LPI and a 12th place on the GLPI. The most important conclusion that were drawn from the research were that Asian and European countries with export-oriented economies scored substantially lower on the GLPI than on the LPI, Nordic countries scored higher on the GLPI, and that there is less association between the GLPI and the Gross National Income (GNI) than between the LPI or EPI and the GNI.

Marti, Puertas, and Garcia (2014) present a study on the importance of each of the components of the LPI for trade in emerging economies. This research can be interesting to compare with the weighted LPI to see if there are similarities. To assess the importance of the components a gravity model is constructed. This model is constructed by finding the relation between the scores on the component and the total trade between two countries. The study also attempts to find possible advances is logistics in developing countries that are grouped by region. The research used the LPI scores for five different regions: South America, Africa, Middle East, Far East, and Eastern Europe. Table 5 shows the result of the gravity model.

Table 5: Results gravity model

		LPI	Customs	Infrastr.	Services	Tracking	Timelin.	Int. Ship
All	export	11,48***	6,91***	7.501***	9.035***	8.793***	8.449***	11.621***
	import	4,01***	2,50***	3.081***	2.929***	3.161***	3.719***	3.528***
Africa	export	10,21***	6,67***	6.597***	7.423***	6.894***	7.673***	10.450***
	import	4,73***	2,231***	3.605***	3.746***	3.160***	4.127***	4.075***
E-Europe	export	2,21***	1,05**	2.571***	2.915***	3.247***	.963*	1.883***
	import	4,16***	2,25***	3.129***	2.992***	3.547***	3.949***	3.845***
Far East	export	8,94*	8.244***	3.785**	11.285***	2.496	8.548*	14.812***
	import	2,53	1.616*	1.396	1.755***	2.117*	1.670	2.286**
S-America	export	17,4***	8.496***	11.286***	13.008***	11.519***	8.623***	17.228***
	import	4,3***	2.664***	2.929***	2.499***	3.562***	4.094***	3.970***
Mid. East	export	3,852***	5.341***	4.858***	2.718***	.974**	1.663***	3.803***
	import	2,92***	2.239***	1.996***	2.381***	2.252***	1.729***	2.575***

In this table three start mean statistical significance at the 1% level, two at the 5% level, and one at the 10% level. The conclusions that can be drawn from the gravity model are that all the components scores have a positive relation with the amount of international trade, meaning that they all are factors that facilitate trade. Services is the only component that is significant for each region for both importers and exporting countries. The highest scoring component is international shipments, scoring especially high with the exporting countries, this seems logical since sending shipments is essential for export. What also is interesting is that the values differ a lot for the different regions, which might also show when the expert have to assign weights.

Çemberci, Civelek, and Cambolat (2015) studied the moderator effect of the Global Competitiveness Index (GCI) on the LPI. They perform a hierarchical regression analysis on each of the components of the LPI. The hypothesis for the test is: H_x: Global Competitiveness Index has moderator effect on the influence of *(Customs/Infrastructure/Services/Timeliness/Tracking & tracing/International shipments)* on Logistics Performance Index. This hypothesis tests if a higher score on the GCI can be achieved by implementing measures that would improve the score on that certain component of the LPI. They mention in their research that no earlier study has been done into the two indexes combined, and that therefore it can be seen as a breakthrough that they found significant results. Three of the component showed significant values: Capability of arranging competitively priced shipments, Tracking and Tracing, and timeliness. So if a country wishes to have a higher rank on the GCI, improvements in these sectors of logistics can help them achieve that. A similar study has been performed by Civelek, Uca, and Çemberci (2015). This study also used hierarchical regression analysis but to analyse the mediator effect of the logistics performance index on the relation between global competitiveness index and gross domestic product. First, the relation between the LPI and the GCI, between the LPI and GDP, and between the GCI and GDP were calculated. All these relations were found statistically significant. The last hypothesis tests if there is a significant relation between the LPI and the relation between the GCI and the GDP of a country. This last hypothesis was also found significant meaning that the logistics ability of a country dominated the relation between competitiveness and prosperity. Another study using hierarchical regression analysis was performed by Uca, Ince, and Sumen (2016). This study in

almost the same as the previous one mentioned but this study is about the mediator effect of the LPI on the relation between the Corruption Perception Index (CPI) and Foreign Trade Volume (FTV). The research was performed in the same way as the one by Civelek et al (2015) and concluded that the logistics ability of a country trigger the relation between corruption and foreign trade volume.

Another research that concerning the GCI and the LPI was done by Ekici, Kabak, and Ulengin (2016). The aim of this research is to prove there is a close connection between the Global Connectivity Index and the LPI. The relation is analysed using an artificial neural network (ANN). They have selected the GCI indicators that might have an influence on each of the LPI components, based on an expert survey in which respondents were asked to link GCI indicators with LPI components, see the second column of table 6. Then the found relationships are analysed using the ANN. An ANN is a network is a multiple layer network that works well for pattern recognition and when nonlinear data is used. In this network the input variables are similar to independent variables in a regression analysis whereas the output variables are similar to the dependent variables. The difference with the regression analysis is that where regression assumes linearity, the ANN does not. The research by Cemberci et al. (2015) and Civelek et al. (2015) discussed in the previous paragraph both assume a linear connection between the indexes, whereas Ekici et al. (2016) assume this is not necessarily true.

Table 6: connected GCI indicators

LPI components	Linked GCI indicators	Most important GCI indicator
Customs	12	Reliability of police services
Infrastructure	25	Fixed broadband internet subscriptions
Services	54	Extent of staff training
Tracking & Tracing	10	Intellectual property protection
International shipments	23	Legal rights index
Timeliness	18	Fixed broadband internet subscriptions

The conclusions from this research are focussed on Turkey only and therefore not useful for this research. However, the last column of table 6 shows the most important GCI indicators per LPI component, produced by the ANN. This can give an indication of which are the most important factors that determine how well a country scores on each component, and therefore determine effective policy measures.

Erkan (2014) researched the connection between the infrastructure-weighted indicators of the GCI and the LPI. The infrastructure components of the GCI that were used are Quality of Roads, Quality of Railroad Infrastructure, Quality of Port Infrastructure, Quality of Air Transport Infrastructure, Value Chain Breadth, and Company Spending on R&D. A regression analysis is made with data of 113 countries to determine if there is a significant relation between the overall LPI score and each of the indicators. The conclusion is that only two of the six indicators have a significant relationship with the overall LPI score. These indicators are quality of port infrastructure and quality of quality of road infrastructure, meaning that to improve logistics performance these the focus should be on these two indicators primarily.

Vaillancourt and Haavisto (2015) studied the relation between the state of logistics in a country and the impact of different types (epidemic, flood, and storm) of disasters. To do this they did a regression analysis for each of the components of the LPI with disaster impact variables from the International Disaster Database (EM-DAT). The analysis is done with the data from the LPI and EM-DAT from 117 different countries. When disaster impact in the form of people affected the relation with the LPI overall score proves to be significant ($p<0.01$). The relation between each of the components and the impact is significant for all the components except for the quality of services component. As a result from this study can be concluded that logistics is a substantial factor in the impact of disasters. However, it is also possible that this relation is not entirely determined by logistics since countries that have better logistics are likely to have better emergency protocols and resources to decrease the impact of a disaster.

2.2 Logistics performance

This section will review logistical performance. Tis will start with a brief description of different logistics performance measurement systems. After that, the components of the LPI will be reviewed using literature on why these components are important for logistics performance. Then, factors not included in the LPI will be identified. When the factors are identified, other indexes and indicators will be compared with the LPI. Finally, hard metrics for each of the components will be reviewed to search for possible alternatives for the expert scoring.

2.2.2 Components of the LPI

The first component to be addressed will be customs, in the latest LPI report described as the efficiency of customs and border management clearing. Another definition if provided by the ITF (2015). They mention that the customs component in the LPI measures the effectivity and efficiency of custom procedure in terms of speed, simplicity, and predictability. Many researches have been done in the role of customs in logistics and international performance. New technologies (ICT) and the formation of customs unions have had a huge impact on the way customs were handled over time (Lewis, 2009). These differences have led to major differences between countries in how they handle and secure their incoming and outgoing goods. Widdowson (2007) mentions that in current times it is hard to define the exact role of customs, since this role is different per country. Safety, trade facilitation, and revenue generation can all be objectives for customs authorities. Therefore, it is hard to define efficient customs. Heaver (1992) confirms the different possible goals of custom procedures and states that relatively small changes in customs procedures will enable more efficient logistical services. Devlin & Yee (2005) state that especially in relatively poor regions relatively small changes in custom procedures can result in much more efficient transport and thus better logistical performance. The LPI scores on customs shows that the best performing country is Singapore, whereas Syria is the worst performing, for the other scores consult the first column of Appendix A. Arvis et al. (2016) mention in the 2016 report of the LPI that customs is the globally lacking component. Especially in low-income and middle-income countries the component is one of the two significantly lower components. The trend over the years however is that they are improving rapidly but are still lagging behind. This may be due to technologies that are not yet available in the low income countries, such as state of the art security systems and ICT systems. ITF (2015) offers some insights on what policies could have effect on the

effectiveness and efficiency of customs clearance: Risk management, cooperation with other border control agencies, and transparency through information on laws and regulation.

Infrastructure seems like a very logical factor in logistical performance since it is one of the basic needs to facilitate transportation of goods. The definition of this component in the last LPI report is the quality of trade and transport infrastructure. Transport infrastructure can be defined as the physical component of infrastructure, meaning the quality of the roads, ports, and terminals. Trade infrastructure contains also the quality of telecommunications and other information sharing systems that are crucial for trade facilitation. Many studies can be found in literature that link the state of transport infrastructure to economic growth and a growth in trade volumes. Examples are Gillen and Waters II (1996) and Vickerman, Spiekermann, and Wegener (1999). The first study summarizes literature of infrastructure investments and their effects on economic growth and concludes a clear connection. The study by Vickerman et al. (1999) conclude that infrastructure development leads to more regional trade. They also have a remark on telecommunications, stating that it can lead to an increase in trade since new markets can be created. A remarkable conclusion is made by Korinek and Sourdin (2011), they state that for low-income countries extra investments and improvements in port infrastructure do not have a significant effect on trade. The other barriers in the countries, such as problems with customs or the inability to transport the goods from the port to other destinations could be an explanation. A selection of studies on ICT and other information infrastructures in transportation has been made by Perego, Perotti, and Mangiaracina (2011). The LPI ranking (Appendix A) shows that Germany has the best infrastructure and Syria has the worst. ITF (2015) mention that the government has a very important role in developing and maintaining the infrastructure. To improve infrastructure the essential factors are: Flexible systems, resource allocation, and higher utilisation of existing infrastructure (ITF, 2015).

The third component is services, in the LPI report defined as the competence and quality of logistic services. Logistic services are mostly performed by private parties, and include all services performed to move goods from the producer to the customer. Examples of services are transportations, packaging, warehousing, freight-forwarding, and inventory managing. These services therefore are concerned with both the actual movement of goods (transportation), as all the other aspects in the supply chain. There are many companies available that provide all the services needed from production to delivery with the customer, both national as international. The results of the LPI show that for both low, middle, and high-income countries quality of services is an indicator of logistics performance (Arvis et al., 2016). The competence of these companies will have significant effect on the quality of the logistics process. As mentioned earlier, one of the limitations of the LPI is caused by the difference in services quality between companies in low-income countries. Several studies have been performed on how the quality of logistics can be measured (Franceschini, Cignetti & Caldara, 1999; Franceschini & Rafele, 2000). Chapman, Soosay and Kandampally (2003) studied the effects of innovations in services and concluded that they have significant advantages for supply chains, such as higher efficiency and customer satisfaction. Daugherty, Stank, and Ellinger (1998) found that high levels of logistics services have an indirect positive effect on economic indicators. Korinek and Sourdain (2011) conclude that this factor is hard to influence with policy measures, since the services are

provided by private parties. ITF (2015) mentions some of the important factors in services: managerial capacity, develop quality standards, and standardisation of operations. The quality of services is the highest in Germany and the lowest in Syria.

The latest LPI defines the component timeliness as the frequency with which shipments reach consignees within scheduled or expected delivery times. Timeliness refers to whether orders arrive at the time they are supposed to arrive, but also to the time between order placement and receipt (Mentzer, Flint & Hult, 2001). This factor is not only about fast delivery but mostly on the predictability of when the shipments will arrive. Timeliness can be a source of competitive advantage over other companies and enables a firm or group of firms to respond to competitive trends and changing markets (McGinnis & Kohn, 1990). Since the logistic situation of a country is represented by the organizations in said country it is likely that timeliness will have effect on logistical performance. Deardoff (2002) states that timeliness is an essential factor in international trade and had become even more important over the past years. Hummel (2001) concluded that a 1% decrease in the processing time of a container at the exporter can lead to 0.4% more bilateral trade, while 1% less variability in shipping times can lead to up to 0.2% increase in bilateral trade (ITF, 2015). Luxembourg has the highest predictability of shipments and therefore the highest timeliness score, followed by Sweden and Germany. Haiti is the worst performer on this component. Competition can have a positive effect on the timeliness in a country, since the companies that have a higher timeliness are more likely to get a competitive advantage (ITF, 2015).

Tracking and Tracing is the fifth component of the LPI. It is described in the report as the ability to track and trace consignments, meaning that at every certain point in time a company knows where his products are located. Van Dorp (2002) shows that there is no uniform definition of the term tracking and tracing. In his study eleven different definitions are given, showing that there are many perceptions of what tracking and tracing includes. Studies have been performed into different tracking and tracing systems and how effective they are. Shamsuzzhoa and Helo (2001) summed up the at time current tracking and tracing systems and concluded that these techniques are essential for customer service and the efficient managing of logistic networks, implying that tracking & tracing is an important factor in logistics. Huvio, Grönvall and Främling (2002) mention different tracking and tracing methods and note that the need for exact tracking and tracing depends on the sort of goods that have to be delivered. Korinek and Sourdain (2011) mention that it is likely that tracking and tracing will be a major area for investments in the close future since all the parties in the supply chain can benefit from improved ability to locate their products. The ability to track and trace is highly influenced by the introduction of new (ICT) techniques. Currently, especially the developing countries lag behind in their tracking and tracing abilities due to their inability to adopt new technologies and ICT systems. Also, in poorer countries companies tend to focus more on internal processes and problems then on relations with other parties in the supply chain (Arvis et al., 2016). The best performing country on this component is Sweden, while Somalia performs the worst. Policy in this area should be focussed on keeping up with the fast changing technology sector (ITF, 2015).

The last component is International shipments, defined as the ease of arranging competitively priced shipments. The term international shipments is easy to understand, it concerns all shipments to and

from the specified country than originated in another country. However, competitively priced is a term that is harder to understand since it is unclear who the competition is. This competition can be both other countries in the region as worldwide. Stronger dynamics have led to an increase in competition between freight forwarders. This increase, especially in the last decade, has led to more competitive prices in shipping (Marti, Puertas & Garcia, 2014). Literature on the exact role of easiness of arranging shipments could not be found. It is likely that the competence of the logistics companies in a country determine the easiness of arranging shipments, since these shipments are mostly arranged by specialized companies in freight transport. Bernard & Jensen (1999) mention that these companies become more effective as they grow in size. Hausman, Lee, and Subramanian (2013) calculated the effect of prices on trade and concluded that 1% cheaper shipping leads to 1.4% more trade. Also, a reduction of 1% in total costs can lead to a 0.4% increase in trade. It is also likely that the quality of the customs system has influence on the ease of arranging a shipment, thereby creating overlap with the customs component. The best performing country on this component is Belgium, followed by Sweden and China. The worst performing country is the number last on the LPI ranking, Syria.

Some conclusions can be drawn from the literature on the six core components of the LPI. Literature was found on all six of the component that linked the component with economic growth or a better logistics system. All the components therefore really are factors in logistics performance and should be included in the LPI. The relative importance of the components to each other is not known and could not be found in existing literature. Another conclusion is that the definition of the components can be up for discussion. Many of the components have different definitions in different researches. If the definitions differ in researches it is likely that they will also differ among people involved in logistics, and therefore under respondents in the LPI survey and the survey in this research.

2.2.3 Factors not included in LPI

As mentioned before it might be possible that the components are not the only important factors in logistics performance. In this paragraph literature will be presented on factors other than those included in the LPI. These factors will also not be included in the weighted LPI but can be an important basis for further research into the LPI.

Due to the climate change the world is currently experiencing and the increased awareness for the environment, changes have been made in many sectors to decrease emissions and become more environmental friendly. These trends are also visible in the transportation and shipping sector, which have a significant influence on the emissions worldwide. Maritime transport is responsible for 2.5% of the worldwide greenhouse gas emissions in 2014. The expectation is that these emissions will have increased with between 50% and 250% in 2050 (International Maritime Organization, 2014). As a reaction to these expected results many rules and guidelines for the transportation section have been proposed worldwide. The International Maritime Organization has proposed different measures to decrease shipping emissions with up to 75%. Examples of these measures are the Energy Efficiency Design Index (EEDI), which sets compulsory standards for new ships, and the Ship energy efficiency management plan (SEEMP), a plan for ship owners to manage their ships and waste less energy (EC, 2013). This raises the question if environment should be a factor in logistics performance and thus could be a component of the LPI. Many studies have been performed on how supply chains,

transportation, and shipping can become more environmental friendly. Over the last two decades at least 1500 articles or have been published on green supply chain management (Srivanstava, 2007). Kim and Min (2011) combined the logistics performance index (LPI) with the Environmental Performance Index (EPI) to create the Green Logistics Performance Index (GLPI). This resulted in a new ranking with Kazakhstan as the top performer, located at the 61th place in the LPI. To get the GLPI scores the sum of selected LPI values is divided by the sum of the selected EPI scores. The research also found an interdependence of 0.512 between the LPI and the EPI, meaning that it is possible that environment could be a factor in logistics performance. Wu & Dunn (1994) researched how logistic chains and their value adding businesses could become more green to concede to the (at that time) new environmental standards. Goldsby and Stank (2000, p. 199) provide empirical support for the relationship between the logistic performance of a company and how responsibly their environmental practices are. Zhu and Sarkis (2004), and Rao and Holt (2005) confirm this relationship. Both studies were performed for companies and did not focus on nationwide logistics, it is however likely that if it applies to companies it will also apply to the system of companies (nations economy). In the current LPI the environment is not considered as one of the key components. However, it acknowledges that environment is becoming a more important factor. The 2016 report states that environmental friendly logistics is gradually becoming a common feature in most advanced logistics environments (Arvis et al., 2016). The answers on one of the questions in the survey show that there is an increased realization that supply chains need to become greener. This question the respondents are asked is: How often do shippers ask for environmentally friendly options? Especially the respondents from high performance economies report high values. If logistics is only seen as a factor to facilitate trade and better logistics therefore mean an increase in trade it is not proven that being more environmental friendly will mean a better logistics performance. As mentioned some studies found a relationship between performance and environmental practices in single companies. The importance of the environment on the worldwide political calendar makes it likely that a component in the LPI dealing with the environmental friendliness of a country could be an addition in order to give a better assessment of its logistics performance.

Besides environmental factors, innovation could also be an important factor in logistics performance. Innovation is essential in all sectors to keep on improving performance. There are several possibilities for innovation, such as new technologies, new processes, or better cooperation possibilities. Increased global trade and new technologies have led to new possibilities for innovation (Johannessen, Olsen & Lumpkin, 2001). Innovations have led to significant changes in the shipping industry, examples are the introduction of containers is 1958 and the application of Radio Frequency Identification (RFID) (Grawe, 2009). Grawe (2009) also presents different studies on innovation in businesses and supply chains which all show that innovation is essential to gain a competitive advantage. Chapman, Soosay, and Kandampally (2002) researched the drivers for innovations in the logistics sector and concluded the effects of these innovations on the competitiveness of companies. They conclude that investments in knowledge and ICT can lead to a higher efficiency, better decision making, and better supply chain management. This implies that these innovations can lead to a better logistics performance. Panayides and So (2005) state that logistics innovation has a positive relationship with the effectiveness of logistic service providers. The effectiveness is increased due to the innovations in organizational learning. The

question remains however if innovation should be a component in the LPI. Arguably innovation has a positive effect on the other components. It is likely that countries that are more innovative will adopt new technologies quicker and better, and therefore score higher on for example the components infrastructure and tracking & tracing. The many researches and their outcomes however do show that innovation has an influence on logistics performance and should be considered. Future research should determine if including it as a factor will make the LPI more accurate.

2.2.4 LPI and other indicators

This paragraph will find the relationship between the LPI and other indicators and indexes. Many reports are presented with all kinds of indexes that might be correlated with the LPI. This paragraph will visualize this correlation. The first is the doing business 2017 report. It is published by the World Bank, just like the LPI reports (World Bank Group, 2016). The first doing business report was published in 2004 and the latest one is the 2017 report, in between a version has been published every year. Just like the LPI the report contains a ranking of (almost all) countries, in this case 190. The doing business report aims to show how easy it is to do business in a country and focusses on regulatory issues. The scoring is based on the 11 different indicators visible in table 7.

Table 7: Doing business indicators (World Bank, 2016b)

Indicator set	What is measured?
Starting a business	Procedures, time, cost and paid-in minimum capital to start a limited liability company
Dealing with construction permits	Procedures, time and cost to complete all formalities to build a warehouse and the quality control and safety mechanisms in the construction permitting system
Getting electricity	Procedures, time and cost to get connected to the electrical grid, the reliability of the electricity supply and the transparency of tariffs
Registering property	Procedures, time and cost to transfer a property and the quality of the land administration system
Getting credit	Movable collateral laws and credit information systems
Protecting minority investors	Minority shareholders' rights in related-party transactions and in corporate governance
Paying taxes	Payments, time and total tax rate for a firm to comply with all tax regulations as well as post-filing processes
Trading across borders	Time and cost to export the product of comparative advantage and import auto parts
Enforcing contracts	Time and cost to resolve a commercial dispute and the quality of judicial processes
Resolving insolvency	Time, cost, outcome and recovery rate for a commercial insolvency and the strength of the legal framework for insolvency
Labour market regulation	Flexibility in employment regulation and aspects of job quality

Some of these indicators have little to do with logistics performance and thus it is likely that the doing business index may not be the most useful for comparison with the LPI. However, indicators such as Resolving insolvency, labour market regulation, Trading across borders, and starting a business can have influence on the indicators of the LPI. One of the biggest differences is that the doing business report uses quantitative data gathered in the different countries, whereas the LPI uses survey results. The similarities however could make it useful to compare the differences of the LPI and the proposed weighted LPI to find similarities and differences. Figure 3 shows the correlation between the LPI score and the Doing business 2017 score.

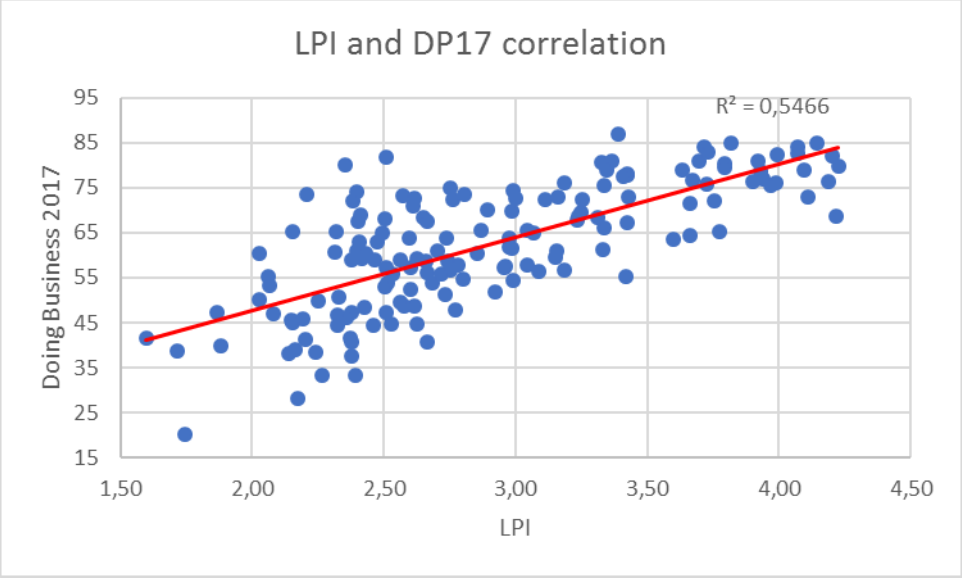

Figure 3: LPI and DB17 correlation (World Bank, 2016b)

The second index to be addressed is the Global Competitiveness Index. The Index is presented by the World Economic Forum (2016) and has been published yearly since 2004. The aim of the report is to gain insight in the competitiveness of different economies. The ranking consists of 138 countries ranked on different indicators. In total statistical data on 114 indicators is used to construct the ranking. These indicators are divided under 12 pillars of competitiveness in three different groups, table 8 shows the groups with their pillars.

Table 8: GCI pillars of competitiveness (WEF, 2016)

Global Competitiveness Index		
Basic requirements	**Efficiency enhancers**	**Innovation & sophistication factors**
1. Institutions	5. Higher education and training	11. Business sophistication
2. Infrastructure	6. Goods market efficiency	12. Innovation
3. Macroeconomic environment	7. Labour market efficiency	
4. Health and primary education	8. Financial market development	
	9. Technological readiness	
	10. Market size	

The pillars have something in common with the LPI. Infrastructure is both a pillar in the GCI as a component in the LPI. Goods market efficiency can be improved by better logistics and innovation can also form an important factor in a logistics system. Also it is likely that education, labour market efficiency and market size have influence on logistical performance. The infrastructure pillar is calculated by 9 different indicators of which 4 could be useful for the LPI validation. These indicators are quality of Ports, quality of roads, quality of overall infrastructure, and quality of railroad transportation. These indicators are available for all the countries meaning and are likely to influence the LPI component score on infrastructure. Comparisons between the LPI and the GCI have been made in different researches, some even combined the two or parts of the two. Figure 4 shows the correlation between the two indexes.

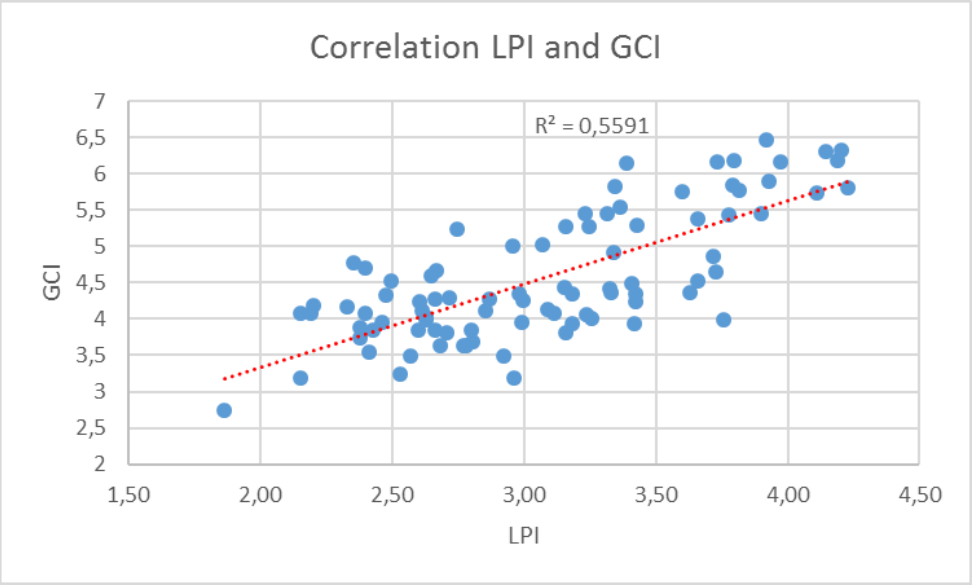

Figure 4: Correlation LPI and GCI (Data: World bank 2016a, and World economic forum, 2016b)

The Liner Shipping Connectivity Index (LSCI) is an index created by the United Nations Conference on Trade and Development (UNCTAD). It is an index that indicates how well a country lies in the shipping network. The aim of the report is show a country how it can improve its access to the global trade markets. A high ranking in the index means that a country has easy access to this network and is likely

to have a well-developed economy and trading system (Hoffmann & Fuguzza, 2015). When the index was presented it was an analysis of the connectivity starting in 2004 and analysing the countries until 2015. To do this five different parameters were created. Table 9 shows the five parameters with their explanations.

Table 9: LSCI parameters

Parameter	Explanation (Hoffmann & Fuguzza, 2015)
Fleet deployment	The number of ships that are calling a port each year for import, export or transhipment purposes. However, a high level of transhipment can be misleading since it is not an indicator for connectivity to global trade, but indicates the country has a transhipment hub. Measured per capita.
Carrying capacity	The availability of containers for the concerned country, measured in TEU. Fleet deployment is an indicator of frequency whereas carrying capacity concerns size of shipments. Measured per capita.
Liner companies	The amount of liner companies that include a port in this country in their shipping lines. Also includes the number of ships per liner that service the country per year.
Liner services	The amount of companies that offer a service that will increase the rotation of containers in the concerned country.
Maximum vessel size	The maximum size of a vessel that can load or unload goods in the concerned country, gives an insight in economies of scale.

In general there is a high correlation between the LSCI and the LPI. However, countries such as China will score very high on the LSCI due to the high amount of container movements but lags behind on the LPI. Hoffmann (2010), the leading scientist at UNCTAD and the OECD on this topic, provides different causes for this correlation. The first one is that a better perceived logistics performance, thus a higher LPI score, makes it more attractive for carriers, which will lead to a higher LSCI score. This means that a higher LPI will lead to a higher LSCI. Another cause for correlation is that if a country has a high LSCI this means the services are better, which are also a component in the LPI and will lead to a higher LPI score. Also, for both indexes trade is critical, so it is likely that even though they have some different components, more trade will lead to a higher score on both indexes. Figure 5 shows the correlation between the two indexes.

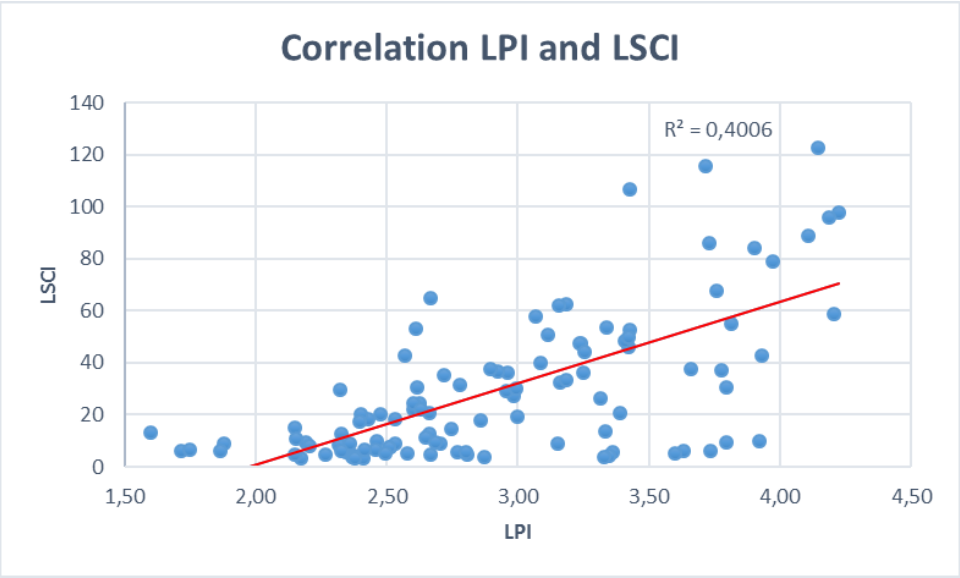

Figure 5: Correlation LPI and LSCI (Data: World bank 2016a, and World bank 2016b).

The authors of the LPI report also address the differences and similarities of the two indexes. They indicate that there is indeed a relation between connectivity and logistics performance and that connectivity is needed to achieve high logistics performance and vice versa (Arvis et al., 2016).

Some other statistics can be compared to the LPI. One of the hard metrics that has been proposed to review against the LPI is the Gross Domestic Product (GDP) of a country. The GDP of a country is the sum of the consumption, investments, government spending, and net volume of the exports. To review this per country the GDP per capita is used for this comparison. In general the GDP gives an impression of how developed a country is and it is likely that there is a correlation between the logistics performance and the GDP of a country. Figure 6 shows the correlation between the two for the 142 countries for which data on both was available.

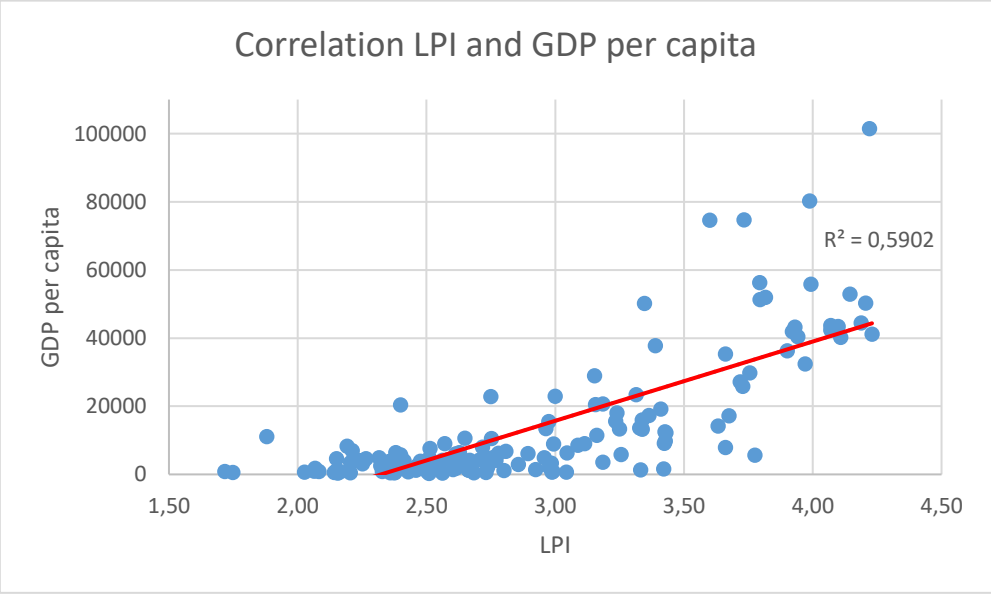

Figure 6: Correlation LPI and GDP per capita (data: World bank, 2016a and World bank, 2015a)

What can be found when the GDP and the LPI are compared is that many countries with a high GDP also score high on the LPI. The reason the regression coefficient is not even higher is that some countries with a very high GDP, such as Luxembourg, Switzerland, and Qatar do not score higher on the LPI than countries with a lower GDP but with a high LPI, such as Germany and the Netherlands. Also, some countries with a very low GDP, such as Uganda and Bangladesh, score relatively good on the LPI.

The Gross National Income (GNI), is the GDP plus the incomes earned by foreigners in the country, minus the salaries earned by non-residents. It is likely that the correlation between the LPI and the GNI will be about the same as the correlation found between the LPI and the GDP in the previous paragraph. Figure 7 shows that this is indeed true.

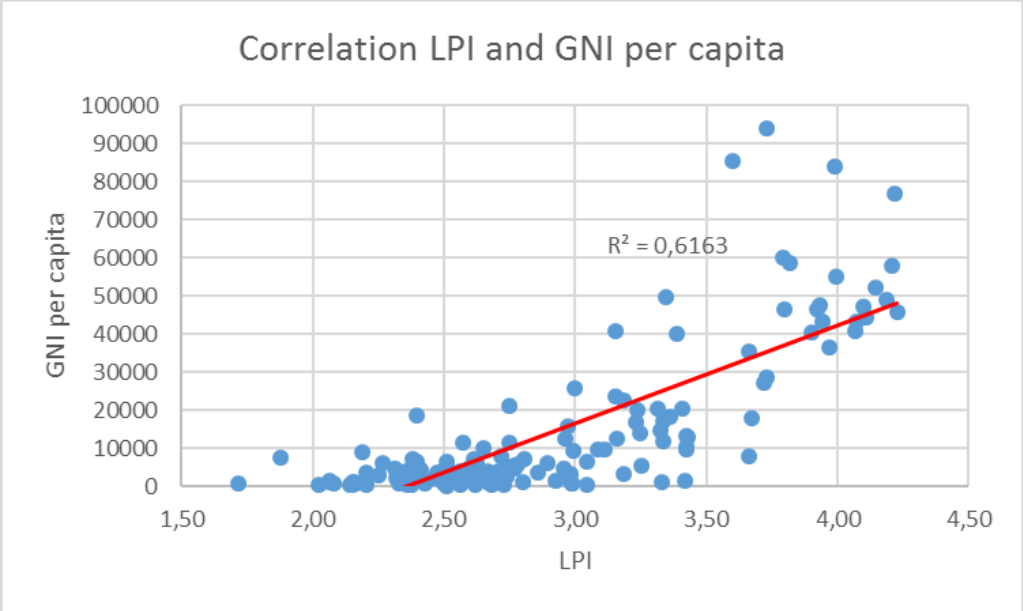

Figure 7: Correlation LPI and GNI per capita (data: World bank, 2016a and World Bank, 2015b)

2.2.5 Hard metrics for components

To compose the LPI experts are asked to score the six core components with a number between 1 and 5. Expert opinions are soft metrics for how well a country performs on the components. This paragraph will identify hard measures for each of the six components, to see if expert opinions is the only/best way to address the performance of countries. These metrics could be used for further research in combination with the weights that will be identified in this research.

The first component, Customs, mentioned in the LPI report as the efficiency of border procedures can also be measured with hard metrics. Biljan and Trajkov (2012), in their case study for Macedonia, use four different metrics to measure customs performance, based on workload scope, employees and collected duties. The first metric is the collected duties per employee. This metric shows the efficiency per employee. The second metric is the collected duties per import declaration. The third metric measures the number of import and export declaration per employee, which together with the first metric shows the efficiency of the personnel. It is notable that in their report they mention the customs component of the LPI in their research, as an alternative indicator for customs performance. Gubin (2011) mentions a very extensive measurement system for the Russian federal customs service. This

system uses 21 indicators with carious sub-indicators that can all be measured. It can therefore be concluded that it is possible to measure customs performance with hard metrics but it can be a time consuming process to do this for all countries. Infrastructure performance is a very extensive factor to measure in hard metrics, due to the many factors that should be addressed separately. Road infrastructure, rail infrastructure and airline infrastructure can all be seen as separate systems of which performance can be measured. Road infrastructure performance could be measured by indicators such as: Road density (km/inhabitant) or good quality road density (km of good quality roads/inhabitant) (Queiroz & Gautam, 1992). It would require more research to determine which metrics should be included to find a complete set of metrics to address infrastructure performance in total. It is questionable if it possible to gather all the information needed of each country that is required to form a ranking such as the LPI ranking. For services, many researches are available on how the quality of service providers can be measured. However, there is no literature available on how the complete performance of all the service providers in a country can be objectively addressed. Mentzer, Flint, and Kent (1999) mention a indicators for good quality of logistics service providers, such as: Good quality, which can be measures as the percentage of goods that arrive undamaged. Another metric is the Order accuracy, which can be measured by the number of shipments that contain the right items in the right quantity. These measured could be applied to all the shipment from a certain country to determine the services quality. However, this would require a large amount of data from each of the service providers. It is therefore unlikely that all this data can be gathered from each country. Timeliness and tracking and tracing seem to be the easiest component to measure objectively, timeliness as the percentage of shipments that arrive on time and tracking and tracing as the percentage of time for which the location of an exact container is known. It is questionable is it is realistic that this information is actually available for all goods. On the ease of arranging international shipments, no literature on hard metrics could be found.

In general there are metrics available on most of the components and it might be possible to measure all component, except for international shipment objectively. However, this would require a large amount of data. It is unlikely that all this data could be gathered from each of the countries that are included in the LPI. However, if only one country wishes to address its logistical performance, these objective metrics might give a better representation of logistics performance than expert scores.

2.3 Conclusions literature review

Several conclusion can be drawn from the literature review. The six components of the LPI are all factors in logistics performance based on literature found on the individual components. However, no literature is available on how important they are compared to each other. That this information is not available underlines the need for the assignment of weights to the different factors in logistics performance. To address logistics performance, it is important that all factors are taken into consideration. Besides the six components, two other factors have been identified from literature as important factors in logistics performance, innovation and environment. Especially environment is becoming an important factor due to climate change and the regulation and guidelines concerning environment in the shipping and transport industry. Many research has been done into the role of environment in logistics, to underline the importance of this factor. Innovation is also a widely

described factor in logistics. However, one could argue that innovation is not a factor in itself but has influence on the components. The LPI and its factors have been used in many researches since its introduction, both to address the logistics situation of a country as to use for further research. The results of the researches that used the scores of the LPI could have produced different results if weights were assigned to the components. Objective measures have been found for all components except for international shipments. It is unlikely that all data that has to be gathered for all the countries can be acquired to produce a complete ranking such as the LPI ranking. This research will use the LPI scores and the six components, discussion on the relationship between environment and the components will be provided in the final chapter of this report.

Chapter 3: Methodology

This chapter will describe the methodology used for this research. It will start with the research approach used to perform the research. Then, the methodology of Multi Criteria Decision Making (MCDM) will be addressed as well as the method of choice for this research. Finally it will cover how the respondents were selected and the tool for analysing the results will be described.

3.1 Research approach

Figure 8 gives a visual representation of how the research is conducted.

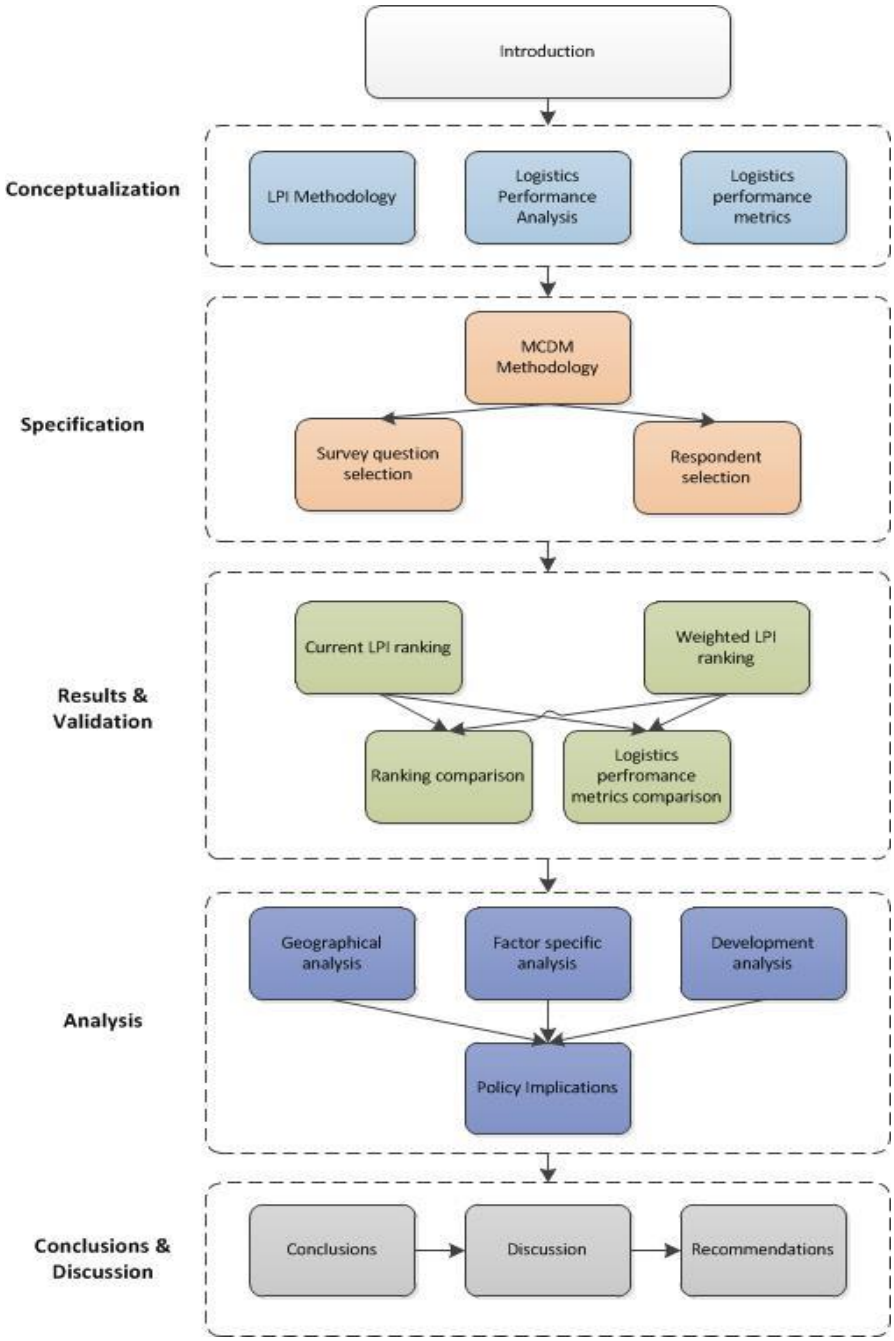

Figure 8: Research approach

The research approach consists of 5 main elements, the first element is the conceptualization. The goal of this stage is to get a clear image of the concept to be dealt with in the research. This will be done by reviewing current literature on the topic. This information then can be used to start the specification stage, in which the methods will be chosen that will be used. In this stage the survey will also be constructed and sent out to the chosen respondents. After this stage the first results can be gathered and the weighted LPI can be constructed and compared to the current LPI. To validate the new ranking it will be compared not only with the old LPI but also with other metrics that have been identified in the conceptualization stage. Then some analysis will be done on the results from the survey. Similarities and differences between weights in different continents and developments groups will be reviewed. The components will also be reviewed independently and in groups to identify interesting relationships. The final section of the analysis phase will deal with the policy implications the results might have for governments and other institutions that can use the weighted LPI. Finally, conclusions will be drawn and a discussion about the research will be done to address its (possible) shortcomings. Then, recommendations for further research will be given to provide starting point for further research into the LPI and the w-LPI. The stages have been divided over the chapters, the conceptualization was addressed is chapter 2, the specification in this chapter (chapter 3), the results and validation will be chapter 4&5, the analysis chapter 6, and finally the conclusion and discussion in chapter 7.

3.2 Multi Criteria Decision Making

This section will start with an explanation of Multi Criteria Decision Making (MCDM) and its many forms and application. Then, the selected method for this research will be presented and the different steps of the method will be explained.

For most of the problems where the best action to take (alternative) has to be found multiple factors determine what this best alternative is. In order to deal with these decisions, Multi-criterion decision making was introduced. One of the first extensive descriptions of MCDM was provided by Keeney & Raiffa (1976). Since its introduction it has been further developed and accepted as a useful tool for decision making in many different sectors (Figueira, Greco & Ehrgott, 2005). The MCDM problems can be divided into two different groups. The first group deals with continuous problems with infinite non-predetermined alternatives and is called Multi-Objective Decision making (MODM). The problems in the second group are of discrete nature and it is assumed that people are driven by money or other forms of profit. This second class of problems is called Multi-attribute Decision Making (MADM) (Zavadskas, Turskis & Kildiené, 2014). MCDM is commonly used to describe the discrete problem that are the subject of this research, therefore the term MCDM will be used in this research (Rezaei, 2015a). A typical MCDM problem can be described in the form of a matrix as presented in equation 3 based on the matrixes presented in Rezaei (2015) and Triantaphyllou (2000).

$$D = \begin{array}{c} \\ (w_1 \\ \end{array} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \\ w_2 & \cdots & w_n) \end{array} \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{bmatrix} \quad (3)$$

In this matrix the top row ($C_1, C_2, \ldots, C_n$) represents a set of decision-making criteria used to determine which alternative is best. ($A_1, A_2, \ldots, A_m$) Are the alternatives that will be scored on the criteria. ($p_{11}, \ldots, p_{mn}$) represent the scores of the different alternatives on the Criteria. p_{2n} for example is the score of alternative A_2 on criterion C_n. The goal is to select the best alternative based on the provided criteria. A common way to determine what the best alternative is, is to assign weights w_j ($w_j \geq 0$, $\Sigma w_j = 1$) to the different criteria and calculate the value of the alternative (V_i) using the weight additive function shown in equation 4 (Rezaei, 2015a).

$$V_i = \sum_{j=1}^{n} w_j p_{ij} \quad (4)$$

Important is how the weight is assigned to the different criteria. Different MCDM techniques have different methods to assign these weights. Since the introduction many MCDM methods have been proposed, some more popular than others. This part of the literature study will use several comparisons of these methods to identify the most important and promising ones.

Several studies have presented the most used MCDM methods. Triantaphyllou (2000) names the weighted sum model (WSM), the analytic hierarchy process (AHP), the revised AHP, the weighed product model (WPM), the ELECTRE method, and the TOPSIS method as most widely used. Most of these techniques are also mentioned by Figueira, Greco, and Ehrgott (2005). These authors also mention the Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) methods. Rezaei (2015) mentions newer techniques such as the superiority and inferiority ranking (SIR) method, step-wise weight assessment ratio analysis (SWARA), and multi-attribute evaluation using imprecise weight estimates (IMP). Rezaei (2015) also presents a new technique, the Best-Worst Method (BWM). This method is a comparison based method that uses structured comparisons. It outperforms other methods since fewer information is required but the comparisons are more consistent (Rezeai, 2016). Table 10 presents an overview of the different techniques along with the studies in which they are introduced or extensively described. For more information on the different methods the mentioned sources can be consulted. An overview of literature that compares the different methods is also provided.

Table 10: MCDM methods

MCDM method	Authors	Description
WSM	Fishburn, 1967	Simple additive model that maximizes the sum of the products of the weights and the criterion scores
AHP	Saaty, 1980, 1994	Used to make decision making easier by arranging decision factors hierarchical descending from an overall goal to criteria, sub criteria and alternatives in successive levels.
revised AHP	Belton & Gear, 1983; Trianthaphyllou & Mann, 1994	A shortcoming of the normal AHP was that the that the AHP may reverse the ranking of the alternatives when an alternative identical to one of the already existing is introduced. Revised AHP deals with this problem by dividing each column in the matrix by its maximum entry.
WPM	Miller & Star, 1969	Similar to the WSM method, but multiplication of ratios for each criterion is used instead of addition.
ELECTRE	Benayoun, Roy & Sussman, 1966	Method using outranking, indifference, and preference thresholds, making it especially useful for
TOPSIS	Hwang & Yoon, 1981; Hwang, Lai & Liu, 1994	Based on the idea that the most preferred alternative should be the shortest distance from the ideal solution and the longest distance from the negative ideal solution (Figueira, Greco & Ehrgott, 2005, p. 998).
PROMETHEE	Brans, 1982; Brans & Mareschal, 1992	Method using pairwise comparison, multicriteria preference degree, and multicriteria preference flows to determine best alternative.
SIR	Yu, 2001	Extension of the PROMOTHEE method, introducing superiority and inferiority matrixes into the existing method.
SWARA	Kersuliene & Turskis, 2000	Method that gives decision makers the chance to decide based on the current situation of environment and economy. In this method, expert has an important role on evaluations and calculating weights (Solfani & Saparauskas, 2013).
IMP	Jessop, 2014	Method that uses a suitable probability distribution to capture imprecision in weight assignment.
BWM	Rezaei, 2015; Rezaei, 2016	Method that uses pairwise comparison to compare all the criteria with the most important and least important criterion to assign weights.
MCDM comparison studies	Authors	Description
	Triantaphyllou, 2000	Chapter of the book of 2013 from the same author, comparing the most used methods from the introduction of MCDM until 2000.
	Triantaphyllou, 2013	Covers most of the same methods as the 2000 book by the same author, with some extra possibilities for using MCDM.
	Figueira, Greco & Ehrgott, 2005	Comparison of the most used methods until 2005 with very extensive descriptions of the methods.
	Ehrgott, Figueroa & Greco 2010	Methods from 2005-2010, with the newest trends.

3.2.1 Best Worst Method

This section will describe the MCDM method that is used for this research, the Best Worst Method (BWM). As mentioned in the previous section this method is developed by Rezaei (2015) and it uses a specific set of pairwise comparisons to assign weights to selected criteria. There are several reasons the BWM is chosen to assign the weights for this research. Pairwise comparison methods face mainly two problems. The first problem is that due to the all the comparisons that have to be made for a full pairwise comparison matrix, the process is lengthy (Sadegi, Rasouli & Jandaghi, 2016). The second problem is the inconsistency between the comparisons, which can be caused by several reasons, such as lack of concentration or lack of information (Forman & Selly, 2001). By using only two vectors instead of a complete pairwise comparison matrix, the BWM requires less comparisons than other pairwise comparison methods. Less comparison lead to a less lengthy project and higher consistency between the comparisons. Therefore, the problems of pairwise comparison are reduced by using the BWM. Another advantage of the BWM is that it uses a very structured and understandable way of gathering the data needed for the pairwise comparisons, which results in highly reliable results that are easy to understand by the evaluator and can be revised easily to increase consistency (Salimi & Rezaei, 2016). The BWM was introduced in 2015 and is therefore a relatively new method. However, it has been succesfully applied in researches in different sectors. Rezaei, Wang, and Tavasszy (2015) used the BWM to link supplier development to supplier segmentation, helping organisations use managerial resources more efficiently . Rezaei, Nispeling, Sarkis, and Tavasszy (2016) used BWM to find the most suitable supplier from a pre-selected base of suppliers in the edible oil industry. Sadaghiani, Ahmad, Rezaei, and Tavasszy (2015) increased the effectiveness of sustainable supply chains in the oil and gas industry using the BWM. Salimi and Rezaei (2016) used the BWM to assign weights to the inputs and outputs of Ph.D projects to address efficiency. Yang, Zhang, You, and Chen (2016) use non-lineair BWM to scientifically evaluate and classify overseas talents for China. The method has also been applied in risk management (Torabi, Giahi & Sahebjamnia, 2016) and innovation management (Gupta & Barua, 2016). In different researches two types of BWM models have been proposed, a non-linear minmax model, and a linear model. The linear result of the linear model is a unique set of weights, whereas the minmax model will result in multiple optimal solutions (Rezaei, 2016). For this specific research unique weights are wanted and therefore the linear model will be applied.

Pairwise comparisons consists of stating the preference of in this case one criterion over the other criteria available to assess the value of the alternatives. In order to do this, both the strength and the direction of the preference of criterion *i* over criterion *j* are stated. The direction is in most cases relative easy to state. However, the strength in many cases is harder to assess. It can be argued that one will always consider the best and worst alternative when determining the strength of one criterion over another criterion. Rezaei (2015) provides an example of a comparison of trees based on their height. If a number has to be assigned between 1 and 9 to determine the preference of one tree over another based on their height, where $a_{ij} = 1$ meaning equally important and $a_{ij} = 9$ meaning an extreme preference of *i* over *j,* one will not assign a 9 to the relationship if *j* is not the lowest tree. Therefore it can be argued that the highest or lowest tree will always be considered in any of the comparisons. Because of this consideration the comparisons can be divided into two different groups (Rezaei, 2015):

Reference comparisons

Comparison a_{ij} is defined as a reference comparison if *i* is the best element and/or *j* is the worst element.

Secondary comparisons

Comparison a_{ij} is defined as a secondary comparison if *i* nor *j* are the best or the worst elements and $a_{ij} \geq 1$.

If a pairwise comparison is done for n criteria the total number of comparisons is n^2, n of these comparisons are a comparison of a criterion with itself. The rest is n(n-1) comparisons of which half has a $a_{ij} > 1$. The other half are reciprocals of the first half. Of the n(n-1)/2 comparisons, n-2 comparisons are Best-to-other comparisons, n-2 are Worst to other comparisons, and one is a best-to-worst comparisons, leaving a total of 2n-3 reference comparisons and the rest being secondary comparisons. Figure 9 shows the reference comparisons and one of the secondary comparisons (in red colour).

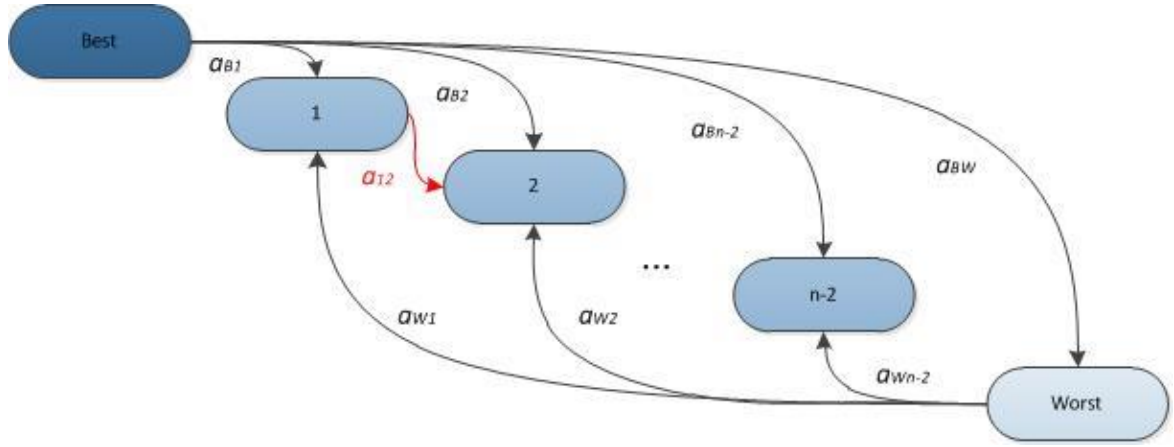

Figure 9: Reference criteria

The reason that the BWM needs less data than the other pairwise comparison methods is that it only uses the reference criteria to assign weights to the criteria. The methods uses a five step approach to determine these weights, as described below.

***Step 1**: Determine a set of decision criteria*

In the first step a set of criteria {C_1, C_2, … , Cn} is considered that should be used by the decision maker to come to a decision on the best alternative. An a set of criteria for choosing which house to buy from available houses could be {location (C_1), price (C_2), size (C_3), style (C_4)}.

***Step 2:** Determine the best (most important) and worst (Least important) criteria.*

In this step the decision maker has to identify the best criterion and the worst criterion in general. A comparison between the criteria is not yet made at this stage. In the example a decision maker could pick location (C_1) as the most important criterion and style (C_5) as the least important criterion when buying a house.

Step 3: *Determine the preference of the best criterion over the other criteria.*
The decision maker has to state the preference of the criterion he/she selected as most important over the other criteria using a number between 1 and 9. Selecting a 1 indicates equal importance and selecting a 9 indicates that the criterion is extremely less important than the most important criterion. This will lead to a Best-to-other vector A_B:

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$$

In this vector $A_{BB} = 1$, since this indicates the preference of the best criterion over itself. In the example the vector would include the preference of location (C_1) over the other four criteria.

Step 4: *Determine the preference of the criteria over the worst criterion.*
The decision maker has to state the preference of all the criteria over the criterion he/she selected as least important using a number between 1 and 9. Selecting a 1 indicates equal importance and selecting a 9 indicates that the criterion is extremely more important than the least important criterion. This will lead to a Worst-to-other vector A_W:

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW})$$

In this vector $A_{WW} = 1$, since this indicates the preference of the worst criterion over itself. In the example the vector would include the preference of all the other criteria over style (C_5).

Step 5: *Find the optimal weights*
In this step the optimal weights ($w^*_1, w^*_2, \dots, w^*_n$) are identified. As mentioned earlier two different models have been proposed for BWM, the first one could lead to multiple optimal solution, and the second one aims at finding unique weights. This linear model will be used for this research to come to unique weights.

The set of optimal weights for the linear model is the one where the maximum absolute difference for the following set $\{|w_B - a_{Bj}w_j| , |w_j - a_{jW}w_w|\}$ is minimized. The sum of the weights has to equal to 1 and none of the weights can be negative, leading to equation 5 to find the optimal solution.

$$\min \max_j \{\left|w_B - a_{Bj}w_j\right| , \left|w_j - a_{jw}w_w\right|\}$$

s.t

$$\sum_j w_j = 1$$
$$W_j \geq 1 , for\ all\ j \qquad (5)$$

This problem can be solved by transferring it to a linear programming problem, equation 6.

$$\min \xi^L$$

s.t.

$$\begin{aligned} \left|w_B - a_{Bj} w_j\right| &\leq \xi^L, for\ all\ j \\ \left|w_j - a_{jW} w_W\right| &\leq \xi^L, for\ all\ j \\ \sum_j w_j &= 1 \\ W_j &\geq 1, for\ all\ j \end{aligned} \tag{6}$$

Solving this linear programming problem will lead to a single solution in which the optimal weights (w^*_1, w^*_2, … , w^*_n) and ξ^L are obtained. ξ^L is a direct indicator of the consistency of the comparisons that are made in the method. The value for ξ^L shows the reliability of the outcomes based on how consistent the comparisons are. A value close to zero indicates a high consistency and a thereby a high reliability. A full consistency is reached when a_{Bj}x a_{jW} = a_{BW} for all j.

3.3 Questionnaire & Respondent Selection

In the previous section the Best-Worst Method was presented as the chosen method for assigning weights to the six core components of the LPI. This method requires specific data which will be obtained by a questionnaire to be answered by experts in the field of international logistics. This section will present the questionnaire that was sent to the experts as well as the process of selecting the respondents.

3.3.1 Questionnaire

As mentioned the BWM requires specific questions to be answered. In order to acquire this data, four questions related to the BWM were presented to the respondents. Step 2 from the BWM, as described in paragraph 3.2.1, requires the best (most important) and worst (least important) to be selected. The questionnaire presents this as two different questions where the respondents are asked to select their best and worst criterion from the six core components. It is only possible to select one component per question. If criteria are deemed equally important, one should be selected and later on others can be scored to be equally important. The respondents then are asked to state the relative preference of their most important criterion, which is automatically excluded from the answer possibilities, over the other criteria. An explanation of the meaning of the scores 1 and 9 is presented to help with answering the question. The question can be answered by selecting one of the boxes representing the number 1-9. The question for selecting the preference of the other criteria over the worst criterion is constructed in the same way and is the last question of the questionnaire.

Besides the questions related to the BWM other questions are added to the questionnaire to find differences between certain groups of respondents. The respondent are divided into two groups, the professionals and the people working in education. These groups will be elaborated on more in paragraph 3.3.2. For these two groups different extra questions have been formulated. The

educational respondents are asked in which country they are living and what their nationality is. The professionals are only asked to state from which country they or their company are operating. These questions are used to find differences between weights assigned based on geographical location, but can also be used to determine if weights vary between people from different development groups. Both of the groups are also asked to state on which countries they have the most information. These answered can be used to analyse if the countries that a respondents deals with affect the importance of the six components.

The survey is presented to the respondents online. The survey was constructed using the software provided by SurveyGizmo. This software was chosen based on the fact that it was fairly easy to exclude the answers given by the respondent on their most and least important criterion in the questions where they were asked to state the relative preference. The survey was taken anonymously by the respondents and besides their nationality or country of residence no personal information was required. Complete versions of the two different questionnaires can be found in Appendix B.

3.3.2 Respondent selection

This paragraph will describe the process of selecting the experts that were approached and asked to take the questionnaire. Firstly, the respondents of the original LPI were reviewed. All these respondents are experts in the field of shipping and are working in the industry. No experts from universities or relevant research institutes have been approached to answer the survey presented by the world bank (Arvis et al., 2016). The total number of respondents was 1051 and they were from all continents and answers were provided by experts from all the different development groups as presented by the world bank. It was decided that for this research, experts will be approached that work at universities as well as professionals in the field of international shipping. The aim is for both of these groups to have approximately the same size. This will also create an extra option for comparison of the final weights that the expert answers will lead to. To have the possibility to compare between development groups, experts are approached from High, middle, and low world bank development countries to identify if this influences their perception of the importance of the criteria. In total 1000+ experts were approached in the hope to get enough respondents (100+) to do a serious analysis on the weights and new ranking. The next paragraphs will describe how the experts from the different groups were found and approached. It is important to acknowledge that these are the approached experts, not the actual respondents, those will be addressed later in the results section.

Educational experts

With educational experts, the approached experts that are working in educational institutes, such as universities or relevant research institutes are indicated. The experts were found online and were only approached if they met certain criteria. All the expert have at least an Msc. diploma in a relevant field or have a Msc. diploma in another field but have sufficient experience in the field of international logistics, international shipping, or international supply chain management. These three fields were focused on in the search for experts. The aim was to approach about as many experts from each of the 6 continents, except Australia which should have less due to its size. The considered continents are Europe, North-America, Asia, Australia, Africa, and South-America. In practice it proved hard to find experts online especially in Africa and South-America due to the language barriers and the online

availability of information in these continents. Also, information in the countries in the lowest World bank income group, which are mostly located in Africa proved very hard to find. Table 11 provides information on the experts that were approached working in universities and research institutes.

Table 11: Information on university experts

	Amount
Total experts	539
Different countries	56
Different continents	6
Different univ/instit	128
Development groups	
High	358
Middle	180
Low	1

Figure 10 shows the distribution of approached experts over the different continents.

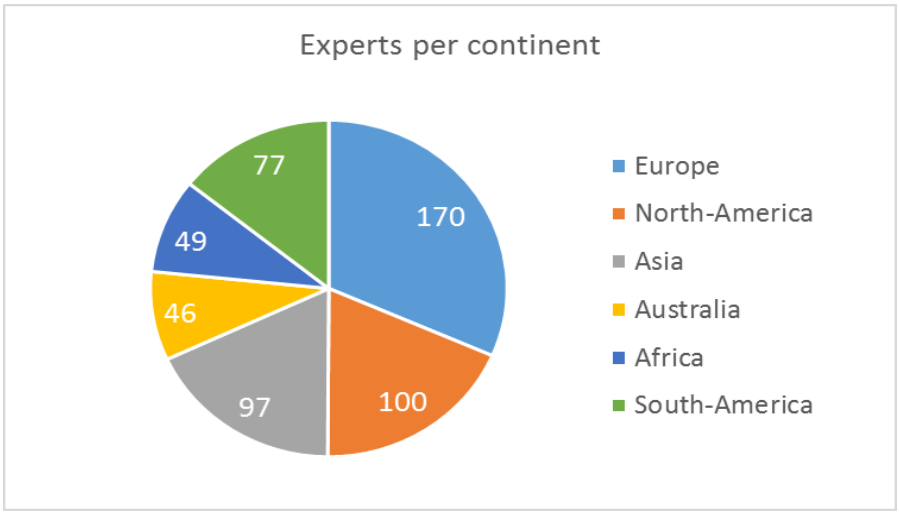

Figure 10: Respondents per continent

In many cases an experts could be found but their email addresses were not available online, in those specific cases the expert were not approached and are therefore not included in the numbers above. Sometimes more experts from the same institute or university were available but another institute from the same country was chosen to create more variety in the experts. Besides the approached experts the survey was also posted on some LinkedIn profiles so it is a possibility that some of the actual responses resulted from this. To inform the experts on the topic of the questionnaire, the email consisted of a description of the goal of the research and a short description of the LPI and its components. The complete email can be found in Appendix B, along with the survey the respondents found when opening the link in the email.

Professional experts

The professionals selected to answer the questionnaire are all working in the international shipping industry and amount to about 50% of the total amount of experts that were approached. The experts were found using LinkedIn, the largest professional network available. In order to find the possible respondents, over 500 persons were asked to make a professional connection on LinkedIn. It was

impossible to contact the experts directly with an invite in the link description and therefore each of the experts had to accept the request to make a connection on LinkedIn before the actual questionnaire could be sent to them. The experts were selected based on their experience in the field of international shipping and most of them were found by being a member of one of the following groups on LinkedIn; The Supply chain management group, the Logistics and Supply Chain management group, the Supply Chain Management group, and the shipping network. The experts were selected based on the country they originated from and the country from which their company was operating. The aim was to find experts from all the continents and from all the different development groups. Once again it proved that in practice it was very hard to find people that originated from countries that are marked as low development countries and people from countries in south-America. Table 12 shows the data about the experts that were approached.

Table 12: Information on professionals

	Amount
Total experts	536
Different countries	58
Different continents	6
Development groups	
High	305
Middle	211
Low	20

Figure 11 shows the distribution of approached experts over the different continents.

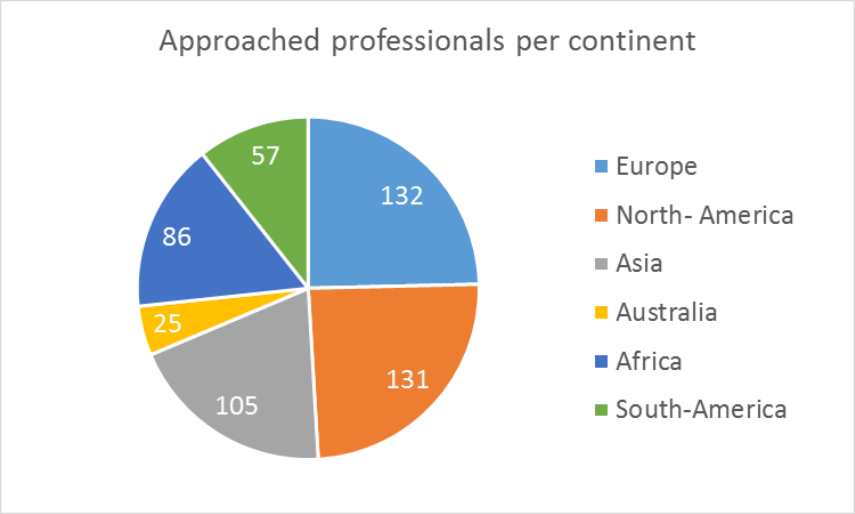

Figure 11: Professionals per continent

The limited amount of characters that can be used in the friend request on LinkedIn limited the possibilities to inform the experts on the aim of the questionnaire. For both the professionals and the educational experts the actions that were taken and the respondents are addressed in the next chapter where also the results of the survey will be presented. The next paragraph will describe how the survey answers will be analysed.

3.4 Data analysis tool

The answerers to the questionnaire will provide a dataset that should be analysed to find relevant results and differences in weights between different groups. The weights will be calculated using an excel model that is constructed based on the Best-Worst methodology. This model will calculate the weights per respondent. These weights along with the answers on the other questions will be placed in a single excel file, holding all the data needed for the analysis. The tool that will be used to analyse the result will be SPSS statistics version 24. SPSS is a tool used for statistical analysis of (large) datasets. The tool can be used to check for significant differences between groups, visualize distributions and compute new variables which will all be useful for the result acquired in this research. In the results section when SPSS is used a description of the actions taken in SPSS will be provided.

Chapter 4: Results

In this chapter the results will be presented and analysed. It will start with a description of the respondents to the questionnaire. Then, the answers these respondents provided will be presented and visualised. After that the weights for the w-LPI will be provided along with the new w-LPI ranking. This ranking will be compared with the LPI ranking and possible implications for countries will be identified.

4.1 Respondents

Section 3.3 presented all the experts that were approached for this research. This section will present the actual respondents. Table 13 provides information on when the experts were approached and how many people responded to each of the actions.

Table 13: Respondent approach actions

Date	Action	LinkedIn connections	Respondents
28/10/2016	E-mail experts universities		33
11/11/2016	Reminder experts universities		24
14/11/2016	LinkedIn request Europe	47	16
15/11/2016	LinkedIn request North- America	28	10
16/11/2016	LinkedIn request Asia & Australia	30	7
16/11/2016	LinkedIn request Africa	33	12
19/11/2016	LinkedIn request South-America	16	5
Total			**107**

The first two actions concerned the experts that were approached to answer the questionnaire that was developed for people working at universities and research institutes and the LinkedIn requests were sent to professionals. The third column shows how many professionals accepted the initial LinkedIn request, whereas the last column shows how many actual respondents the actions delivered. Only the respondents that finished the questionnaire and were not excluded based on their answered are mentioned in table 13. Table 14 shows further statistics on the respondents as well as the completion and response rate.

Table 14: Respondent statistics

Approached experts	1075
Total respondents	107
Universities	57
Professionals	50
Uncompleted	11
Empty	72
Excluded	3
Response rate	9,95%
Completion rate	56,99%

Table 14 differs between uncompleted questionnaires and empty questionnaires. A response is marked as empty when the link in the email or LinkedIn message was clicked on but the respondent did not go further than the cover page of the questionnaire. It is however possible that they have completed the questionnaire at a later stage, since it is possible to click the link they were sent more than once. A response was marked as uncompleted when not all the questions were answered but it was clear that an effort was made. In most cases respondents would quit the survey before the questions where they were asked to rate the preference of the best criterion over the other criteria. Three responses had to be excluded because the respondents marked the same criteria as the most and least important criterion but did not score the preferences of the other criteria as being of equal importance. If they did, the response would not have to be excluded since it would mean that the respondent considers all criteria of equal importance for logistics performance. Table 15 provides information on the respondents from the two questionnaire groups and the combined total.

Table 15: Respondent information per group

	Professionals	Universities	All respondents
Total respondents	50	57	107
Different countries	33	30	47
Different continents	5	6	6
Development groups			
High	25	39	64
Middle	22	18	40
Low	3	0	3

What can be found is that most respondents come from the high or middle income group as was expected after the respondent selection. This will make it impossible to compare result from this group with the other groups. A solution for this problem will be provided later in section 4.4 where a comparison will be made for the different groups that were identified by the answers in the questionnaire. Figures 12, 13, and 14 visualise the distribution of the respondents over the different continents for the universities, professionals and the combined total. Australia and South-America are relatively under-represented in the continent distribution. No professionals from the Australian continent answered on the LinkedIn invitations. The experts from universities were asked to fill in both their nationality and the country they are living in. The country they are living in is used to decide to which continent group they are assigned.

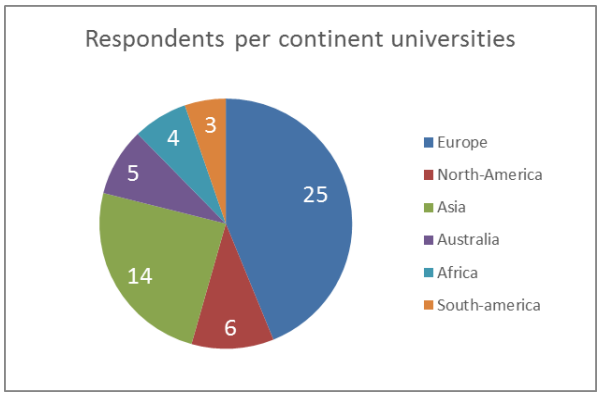

Figure 12: Respondents universities

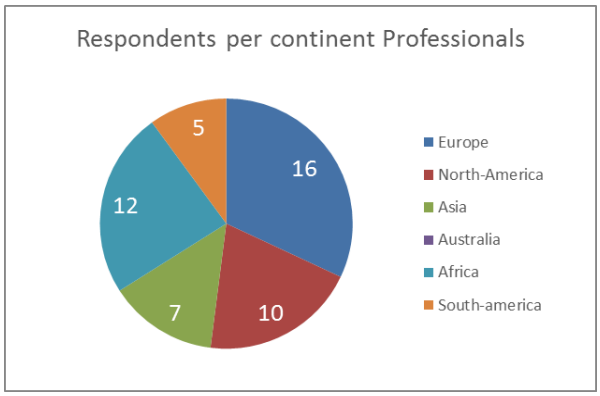

Figure 13: Respondents professionals

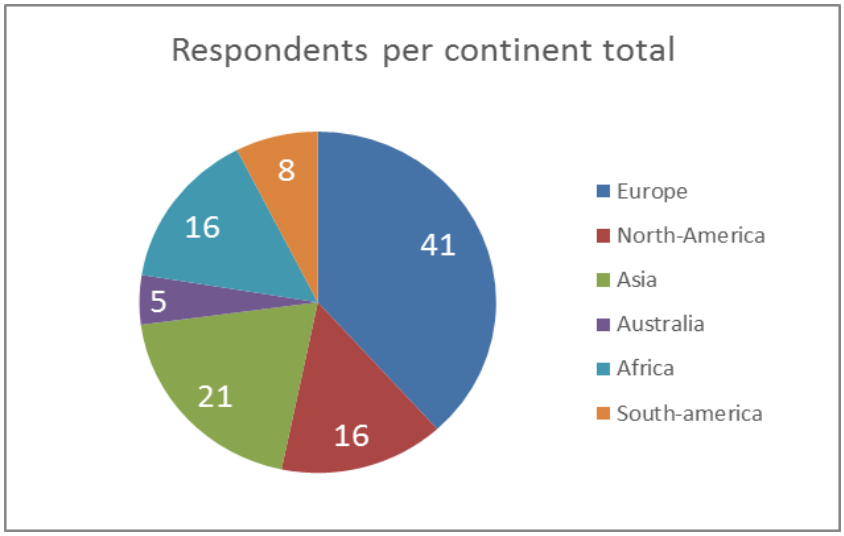

Figure 14: Respondents total

The next paragraph will address the answers the respondents provided in the questionnaire.

4.2 Questionnaire answers

In the two different questionnaires the respondents are asked to answer several question, this paragraph will provide the answers they gave to these question and analyse these answers. The answers are used to find the weights that provided in the next paragraph. The first question asked the respondents either in which country they are living for the university respondents or from which country their company is operating from for the professional respondents. As can be seen in the

respondents paragraph this resulted in respondents from 47 different countries. The country the respondents are living in or working from is also used to determine the World bank income group the respondent belongs to. For more information on these groups see paragraph 2.1.2. Based on the low amount of respondents from the lowest income group, it was decided to combine the respondents from the middle income group with the low income group for the remainder of this research. This new group will be addressed as the low income group from now on. After combining these groups a total of 64 respondent are in the high income groups and 43 respondents are from the low income group. In a later stage the weights for these different groups will be compared to identify differences in weights based on income of the country of origin.

The first question that is used to determine the weights of the different components was: To Evaluate the overall logistics performance of a country, what is the MOST important criterion? Figure 15 visualizes the answers to this question given by the university respondents and professionals and their combined totals.

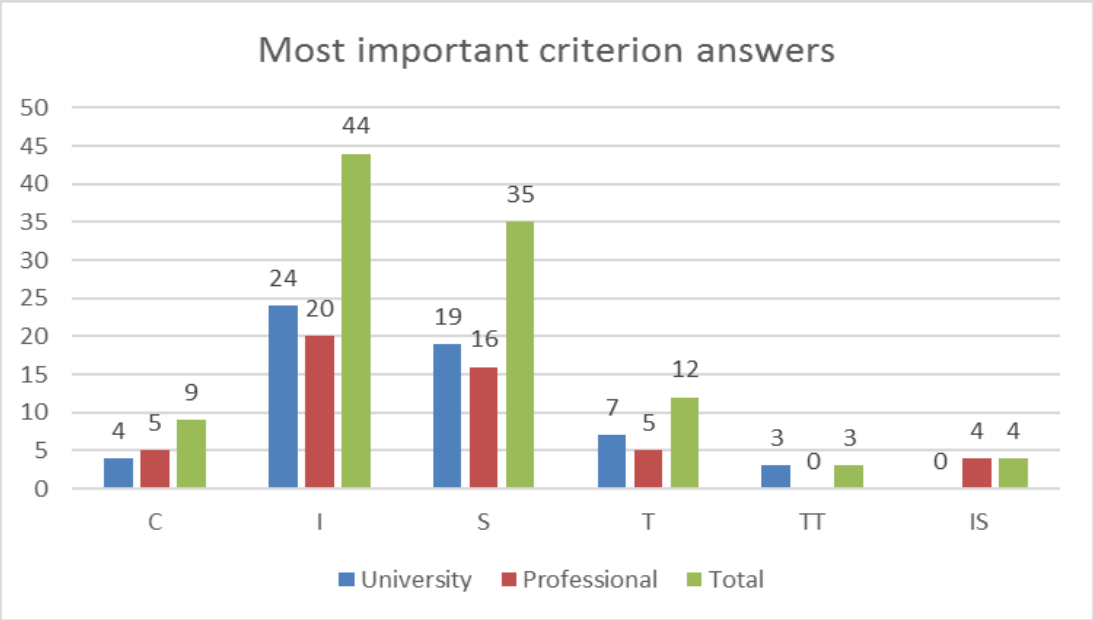

Figure 15: Most important criterion answers

Several conclusions can be drawn from Figure 15. Infrastructure is selected by 44 out of the total of 107 respondents, followed by services with 35 respondents. Tracking & Tracing is only deemed the most important by three respondents, which are all experts from universities. The easy of arranging competitively prices shipments is only considered the most important by four experts, all professionals. At least all the components have at least been named as most important, making it very likely that they are at least an important factor in logistics performance. Figure 16 shows the

percentiles for the criteria. Three third of the respondent considered either infrastructure or services to be the most important criterion.

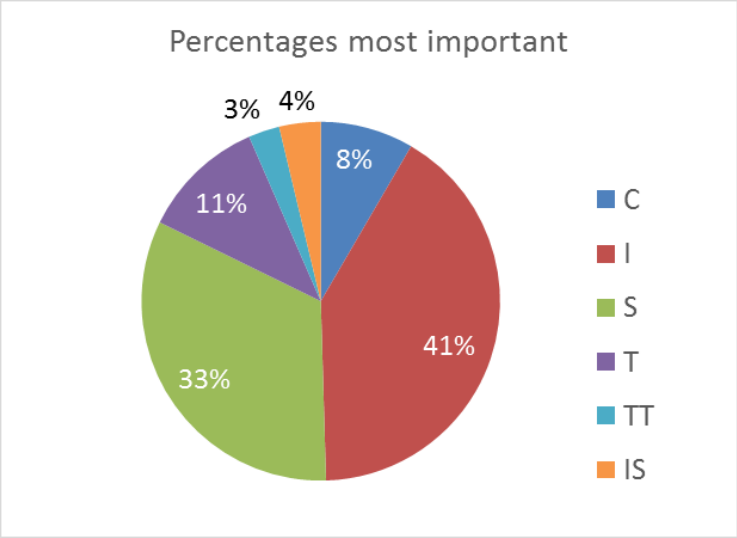

Figure 16: Percentages most important criterion

The second question concerning the BWM method is: To Evaluate the overall logistics performance of a country, what is the LEAST important criterion? Figure 17 shows the answers given by the respondents. And figure 18 the percentages of how much of the responses considered the criteria the least important.

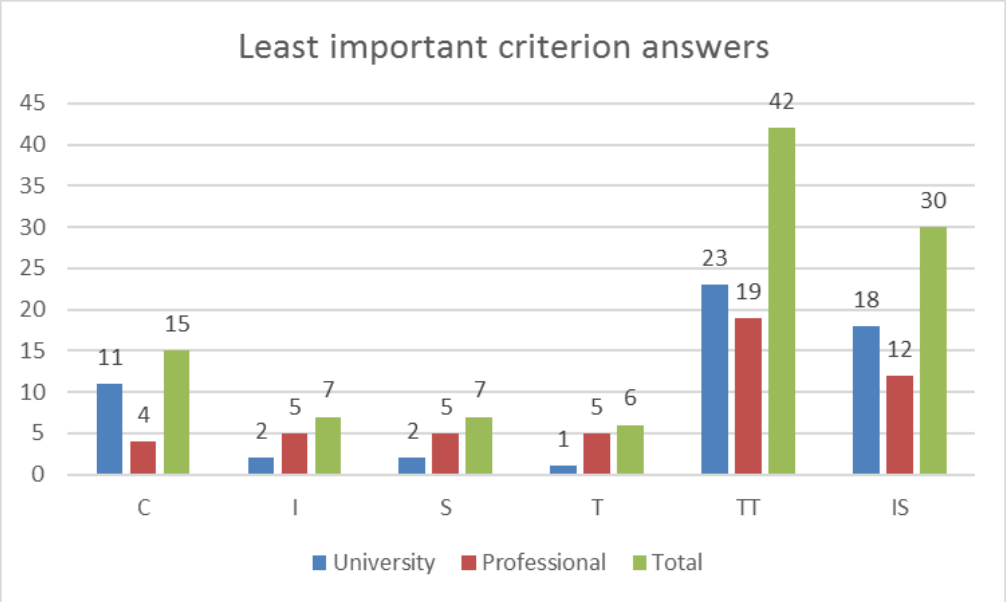

Figure 17: Least important criterion answers

Tracking & tracing is deemed the least important criterion, followed by International shipments. Figure 18 the percentages for each of the criterion. For customs, it is interesting that 11 respondents from universities think it is the least important, where only four professionals share that opinion. For Infrastructure this is the other way around, of those components the professionals think they are less important. At least all the component are considered the least important criterion by one of the respondents from each group. Looking at the percentages, Tracking & tracing and International

shipments together are considered to be the least important criterion by almost three third of the respondents.

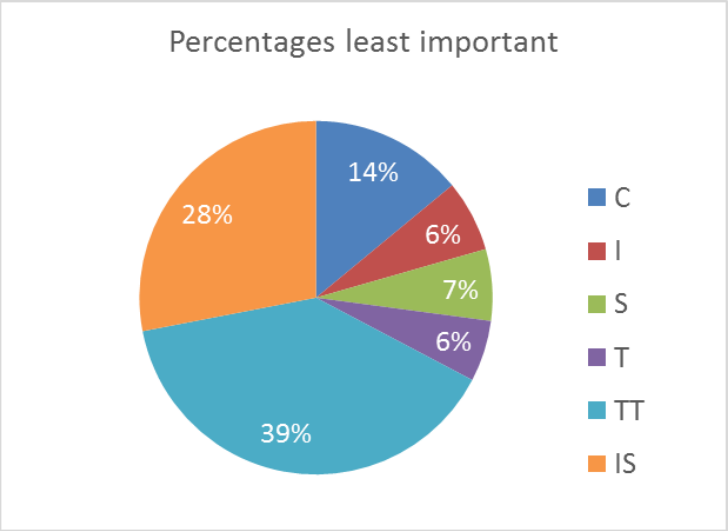

Figure 18: Percentages least important criterion

It is interesting to compare the answered to the questions that determine the most and least important criteria. Figure 19 shows a comparison of the answers given by both groups on both questions.

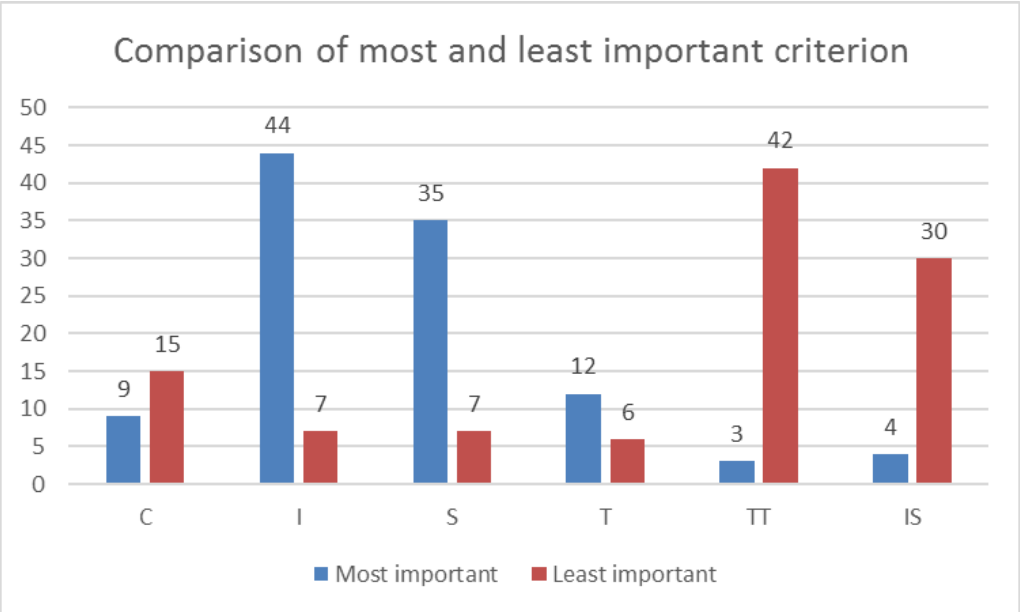

Figure 19: Comparison most and least important

It is quite clear that infrastructure and services are considered to be the factors driving logistical performance, whereas tracking & tracing and ease of arranging international shipments are the least important criteria. It is remarkable that the criterion that the fewest people have selected as the least important, timeliness, is by few respondents considered to be the most important criterion.

In the questionnaire the respondents are asked to name between one and five countries on which they have the most information concerning their logistical performance. This question was included to identify if the country someone deals with the most influences their perception of the importance of the components. When the results were reviewed it became clear that many of the respondents had

not filled in five countries, and several even only one. To make it possible to analyse the answers, the respondents are divided into groups based on the development group of the countries they gave as an answer. The same groups, high and low, as mentioned earlier in this section are used for respectively high income countries and low/middle income countries. If the majority of countries mentioned by the respondent is from the high income group, the respondent is marked high, if the majority is from the middle/low income group, he/she is marked as low. SPSS is then used to decode these variables into 1 for the high income group and 2 for the low income group, so that in a later stage the possible differences in weights between the two groups can be made visible. If a respondent has information on as many high as middle/low countries his answer to this question is excluded. A total of six respondent's answers to this question were excluded. From the remaining 101 respondents, 23 respondents had information mainly on the low income countries whereas the remaining 78 respondents had information on high income countries. The comparison between the two groups will be made in paragraph 4.4 where along with this comparison, other groups will be compared.

The remaining questions are the questions in which the respondents are asked to state the preference of the most important criterion over the other criteria and the preference of the other criteria over the least important criteria. The answers will be the input for the BWM and will not be discussed in this section, but are used to determine the weights.

4.3 Component weights

The weights for the six core components will be determined using the BWM as described earlier in this report. The weights will be determined per group first and then the weights for the combined groups will be presented. Table 16 presents the weights for both groups and the weight for all the respondents. The consistency indicator is also provided.

Table 16: Component weights

	w(C)	w(I)	w(S)	w(T)	w(TT)	w(IS)	Ksi*
Universities	0,139459	0,237518	0,219531	0,169923	0,117777	0,115792	0,106905
Professionals	0,182237	0,232999	0,21391	0,148966	0,085047	0,136841	0,133204
Total	**0,159449**	**0,235406**	**0,216904**	**0,16013**	**0,102483**	**0,125628**	**0,119194**

As mentioned in section 4.2, infrastructure and quality of services were the components most often considered to be the most important criterion. As expected these components also have the highest weights after applying the BWM to the answers provided by the respondents. The consistency indicator for both groups and for the total is relatively close to zero. This indicates a high consistency which is one of the advantages of the used method.

The difference in weights between the expert from universities and the professionals seem small. The component that has the largest weight difference is the customs component, with 0,139 for the university experts and 0,182 for the professionals, a difference of 0,043. To see if there are any significant differences between the two groups a one-way ANOVA test is applied to the data. Table 17 shows the results. The null hypothesis for the ANOVA test for each component is H_0: There are no significant differences between the university experts and the professionals. The hypothesis to be tested is H_1: There is a significant difference between the university experts and the professionals.

These hypotheses are tested for each of the components. To reject the null hypothesis, the P-value has to be below 0.05. The last column in the table represents the p-values. As can be seen, only for the customs components the difference in weights between the groups is considered to be significant with a P-value of ,035. This means that for the other components the differences between the components are not significant. The research from now on will therefore focus on the weights from the total group of respondents. Appendix C consists of a list of individual respondents and their weights.

Table 17: ANOVA test results weights

ANOVA

		Sum of Squares	df	Mean Square	F	Sig. (P-value)
wS	Between Groups	,001	1	,001	,055	,815
	Within Groups	1,614	105	,015		
	Total	1,614	106			
wT	Between Groups	,012	1	,012	1,552	,216
	Within Groups	,791	105	,008		
	Total	,803	106			
wTT	Between Groups	,029	1	,029	3,906	,051
	Within Groups	,767	105	,007		
	Total	,796	106			
wIS	Between Groups	,012	1	,012	1,419	,236
	Within Groups	,873	105	,008		
	Total	,885	106			
wC	Between Groups	,049	1	,049	4,573	,035
	Within Groups	1,119	105	,011		
	Total	1,168	106			
wI	Between Groups	,001	1	,001	,025	,874
	Within Groups	2,268	105	,022		
	Total	2,269	106			

The minimum values, maximum values, means and standard deviation for each of the individual weights is presented in table 18.

Table 18: weight statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Customs	107	0,021605	0,589655	0,159449	0,104965
Infrastructure	107	0,024194	0,614634	0,235406	0,146299
Services	107	0,029499	0,589655	0,216904	0,123411
Timeliness	107	0,021739	0,472906	0,16013	0,087043
Tracking & tracing	107	0,018868	0,506634	0,102483	0,086635
Int. shipments	107	0,026316	0,545038	0,125628	0,091386

Each of the component weights has a minimum score close to zero and a maximum score between 0,47 and 0,61, which is relatively high since the maximum average weight is the weight of the component infrastructure which is 0,235. What can be concluded from this is that the respondents have very different opinions on what defines logistical performance. This was also indicated earlier by the answers the respondents gave when they were asked what the most and least important criteria are. Figure 20 shows the distributions of the weights, with the weights as red lines.

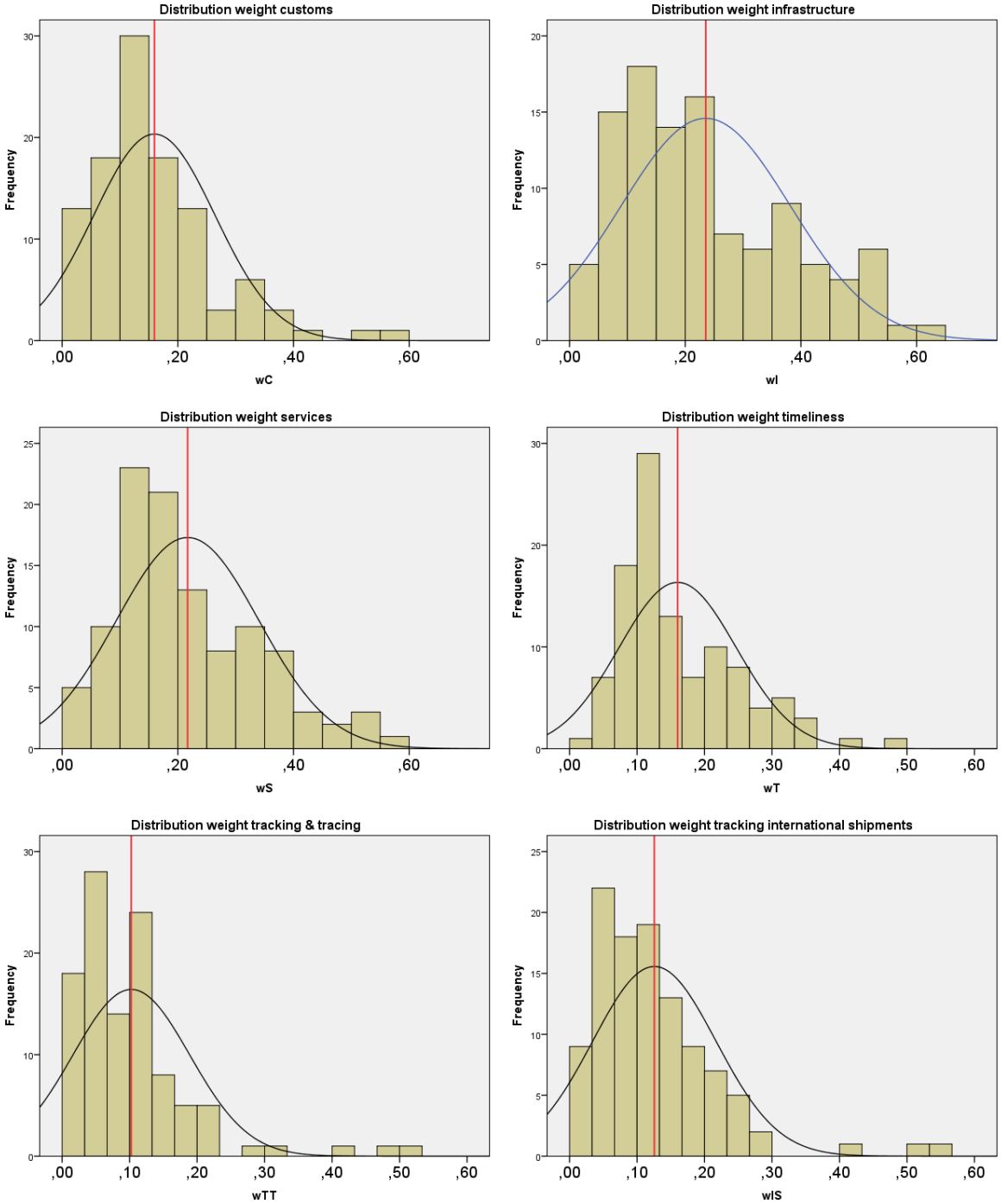

Figure 20: Weight distributions

The distributions clearly show that for the components that were assigned a lower weight by the respondents the maximum values from table 18 are exceptions, whereas for infrastructure and services and infrastructure the frequency of weights over 0,4 is higher. The boxplot in figure 21 shows

the distribution of the components, but also the outliers and extreme values. In this boxplot the outliers are represented by the small dots above and the extreme values with a small star. The weight assigned by a respondent is considered an outlier if the weight is between 1.5 and 3 times the interquartile range, which contains the middle 50% of the recorded values. If the weight is above 3 times this range it is considered an extreme value.

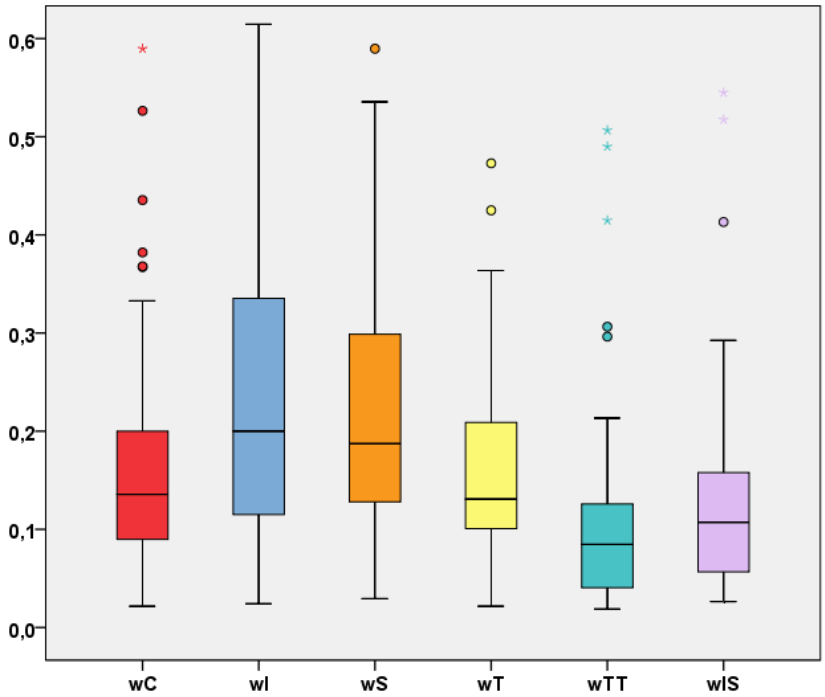

Figure 21: Boxplot component weights

The plot shows that the only component where no outliers or extreme values were recorded is infrastructure. Timeliness and services have outliers but no extreme values and customs, tracking & tracing, and International shipment have both outliers and extreme values. There can be several reasons these outliers and extreme values are recorded. The first one is that respondents really value some of the components with relatively low weights, such as tracking & tracing and international shipment way higher than the other respondents. This doesn't seem unlikely since some of the respondents considered both of these components to be the most important. However, even if they consider either one of these component the most important component, weights above 0,5 seem questionable even for the components with a higher weight. The second possible reason that outliers and extreme values can occur is that some of the respondents did not fully understand how the last two questions should be answered. If this would be true, some of the respondents answers should have a high consistency index. Appendix C shows all of the respondents weights with their consistencies. The highest extreme value belongs to the customs component and the answers from the respondent that recorded this value has a consistency index of 0,25, which is significantly higher than the average consistency but not high enough to say that someone did not fully understand the questions. Still, it can be informing to recalculate the weights if the outliers and extreme values are excluded. In order to do so the outliers and extreme values are excluded in SPSS and the weights are recalculated. Table 19 presents the weights (means) and the minimum, maximum, and standard errors with the excluded values. The second column shows the weights found when no cases are excluded.

Table 19: Statistics without excluded values

	wC	wIS	wI	wS	wT	wTT
Mean	0,147231	0,116509	0,255698	0,228754	0,16194	0,089868
Weights	0,159449	0,125628	0,235406	0,216904	0,16013	0,102483
Std. Deviation	0,0776	0,069915	0,148946	0,118115	0,079918	0,054606
Minimum	0,021605	0,026316	0,024194	0,029499	0,021739	0,018868
Maximum	0,332847	0,292524	0,614634	0,535523	0,363636	0,213333

The result show that the weights without the outliers and extreme cases do not differ much from the original weights. The only thing that has changed is that the maximum values for all the components except infrastructure is lower, which was expected since infrastructure had no outliners or extreme values. The weights that will be used for the creation of the new index will be the weights found when all the respondents are included, since excluding the outliers and extreme values sorts no effect.

If the LPI score is composed by taking the average off the scores on all the components, as has been done in the LPI reports, the weight of each component would be 1/6 = 0,16667. To check if the weights are significantly different than these averages a one sample t-test is performed with 0,16667 as test value. Table 20 presents the result of this test for all the components. If the p-value is above 0,05 there is no significant difference between the component weight and the test value. As can be seen only Customs and Timeliness do not have a significantly different weight from this test value. Since the other components weights are significantly different, not all components are equally important. This is the first time this is concluded by a research in this field.

Table 20: Weight significance

One-Sample Test						
	Test Value = 0.16667					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
wC	-0,712	106	0,478	-0,007221	-0,027339	0,012897
wI	4,860	106	0,000	0,068736	0,040696	0,096777
wS	4,211	106	0,000	0,050234	0,026581	0,073888
wT	-0,777	106	0,439	-0,006540	-0,023223	0,010143
wTT	-7,664	106	0,000	-0,064187	-0,080792	-0,047582
wIS	-4,646	106	0,000	-0,041042	-0,058558	-0,023527

4.3.1 Weights in literature

In paragraph 2.2.2 the core component and their role in logistics performance were reviewed. The conclusion of this literature search was that it is likely that each of the components is of some importance to assess the logistical performance of a country. Now that the weights have been found, they can be compared to the literature found earlier in this report. Al the references in this paragraph are discussed more extensively in paragraph 2.2.2. As mentioned in the literature review no research on the relative importance of the different components on the logistics performance of a country was found, making these weights the first indicator of the relative importance of different factors on

logistics performance. A short review on the weight and found literature on the components will be done to determine if they are consistent.

Customs was the only component of which the weight differed significantly between the university expert and the professionals. The literature suggested that the role of customs is higher in poorer and less developed countries. This could explain the difference between the two groups since the continent Africa, where many of the poorer countries are, was better represented in the group of professionals than in the university expert group. It also is one of the two components with the most outliers and extreme values. One of the explanations for this was provided in the literature review by Widdowson (2007), who stated that the role of customs differs per country and therefore is different per country. This also implies that the importance is different for different countries. Infrastructure was considered to be the most important criterion for logistics performance. The research found in the literature was only a small portion of the amount of studies available on the direct effect of infrastructure on trade and logistics performance. Therefore, it is not surprising that infrastructure is considered to be the most important criterion. The same goes for the component services, in many researches the quality of the companies providing logistic services were found to have significant effects on the efficiency of supply chains and therefore on logistical performance. The experts agreed on this and the weight of services is the second highest, only topped by the weight of infrastructure. Timeliness was considered to be the 3rd most important criterion. This relatively high importance was backed-up by the researches of Deardoff (2002) and Hummels (2001) that explained the increasing importance of timeliness and the effect on trade. Tracking & tracing was considered the least important criterion. Literature found on this component suggested that it had effects on customer service performance and could benefit complete supply chains. The low eight could also be explained by the fact that the definition of tracing & tracing is not clear (van Dorp, 2002). There was no research linking tracking & tracing with logistical performance or trade efficiency. On the last component, international shipments, was the least research available. Therefore it could be predicted that the weight of this component would be one of the lowest. The experts awarded the component to be the second lowest weight.

In general the weights and the literature found for the literature seems to be consistent. However, since there was no literature available on the relative importance of the components, the exact weights cannot be verified in literature. For example, that Infrastructure is more than twice as important as tracking & tracing is a relationship that has never been addressed before.

4.4 Group comparisons

In this paragraph the weights that have been found will be compared between the different groups that can be made using the results from the questionnaire. Also, a cluster analysis will be performed to find groups of respondents based on how they have assigned the weights. A short explanation on the groups will be provided along with the results from the ANOVA test for each of the group comparisons will be provided. The null hypothesis for the ANOVA test for each of the comparisons is H_0: There are no significant differences between the groups. The hypothesis to be tested is H_1: There is a significant difference between the groups that are tested. To reject the null hypothesis and accept H_1, the P-value has to be below 0.05.

The first test will be if there is a significant difference in weights based on geographical location. To do this a test will be performed based on the continents the respondents are located.

Table 21: ANOVA continents

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
wC	Between Groups	,152	5	,030	3,014	,014
	Within Groups	1,016	101	,010		
	Total	1,168	106			
wI	Between Groups	,165	5	,033	1,584	,171
	Within Groups	2,104	101	,021		
	Total	2,269	106			
wS	Between Groups	,153	5	,031	2,110	,070
	Within Groups	1,462	101	,014		
	Total	1,614	106			
wT	Between Groups	,048	5	,010	1,281	,278
	Within Groups	,755	101	,007		
	Total	,803	106			
wTT	Between Groups	,016	5	,003	,424	,831
	Within Groups	,779	101	,008		
	Total	,796	106			
wIS	Between Groups	,035	5	,007	,831	,530
	Within Groups	,850	101	,008		
	Total	,885	106			

Table 21 Shows that only for the customs component the weights are significantly different based on geographical location. To review this further table 22 shows the weights for each of these groups for the customs component. The conclusion is that in north- and middle America and Africa the weights for customs are higher than in the other continents. For Australia the weight is lower than the average. These three weights also have the highest standard deviation. Since only the customs component is significantly different the conclusion can be drawn that geographical location does have only a very small effect on the perception of logistics performance.

Table 22: Customs component weight per continent

Continent	Customs weight	Standard deviation
Europe	0,13217	0,01280
North America	0,21326	0,03750
Asia	0,14208	0,01598
Australia	0,09191	0,03088
Africa	0,21703	0,03117
South America	0,15418	0,02547

Besides the geographical differences, the differences in how developed the country of origin of the respondent could also influence the weights he or she will assign to the components. Therefore, the next factor that will be tested is development. This will be done based on to which development group the country the respondent is living in is assigned. Since there are too few respondents from the lowest income group, the high income group will consist of the respondents from the high income group and the low and middle countries will be assigned to the low income group. The comparison will then be made between these two groups. Table 23 shows the result of the ANOVA test. It shows that for none of the components there are significant differences between the two groups, meaning that degree of development does not significantly influence the perception of what is important for logistical performance.

Table 23: ANOVA development groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
wC	Between Groups	,026	1	,026	2,369	,127
	Within Groups	1,142	105	,011		
	Total	1,168	106			
wI	Between Groups	,015	1	,015	,684	,410
	Within Groups	2,254	105	,021		
	Total	2,269	106			
wS	Between Groups	,000	1	,000	,009	,926
	Within Groups	1,614	105	,015		
	Total	1,614	106			
wT	Between Groups	,006	1	,006	,828	,365
	Within Groups	,797	105	,008		
	Total	,803	106			
wTT	Between Groups	,001	1	,001	,075	,785
	Within Groups	,795	105	,008		
	Total	,796	106			
wIS	Between Groups	,028	1	,028	3,415	,067
	Within Groups	,857	105	,008		
	Total	,885	106			

The last test will be performed to find differences in weights based on the information the respondent has on other countries. For a description of how the groups are composed, see section 4.2. table 24 shows the result for the test. There are no significant differences in weights between the groups, meaning that which country a respondent has dealt with the most does not influence the perception of what is important for logistical performance.

Table 24: ANOVA info on development group

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
wC	Between Groups	,003	1	,003	,295	,588
	Within Groups	1,059	99	,011		
	Total	1,062	100			
wI	Between Groups	,000	1	,000	,002	,963
	Within Groups	2,185	99	,022		
	Total	2,185	100			
wS	Between Groups	,000	1	,000	,021	,885
	Within Groups	1,498	99	,015		
	Total	1,498	100			
wT	Between Groups	,006	1	,006	,827	,365
	Within Groups	,768	99	,008		
	Total	,774	100			
wTT	Between Groups	,003	1	,003	,448	,505
	Within Groups	,603	99	,006		
	Total	,606	100			
wIS	Between Groups	,000	1	,000	,001	,969
	Within Groups	,870	99	,009		
	Total	,870	100			

Besides the comparisons between different groups using the ANOVA tests, a cluster analysis is performed using SPSS to find relevant groups of respondents. These clusters show how groups of respondents have the same pattern of weights. The differences between the clusters can be analysed for significant differences in location or development groups. The used method is the k-means cluster analysis, where a specifies amount of cluster is formed. This specified amount is used in this case to ensure that the clusters have enough respondents in them needed for analysis. Therefore, the specified amount of clusters is chosen as 5. If the 5 clusters are formed, the lowest amount of respondents in a cluster is 13, whereas with 6 clusters this would only be 5 respondents. Table 25 shows the centres of the clusters and the number of respondents and the percentage of total respondents in each cluster. The last column shows the weights found in this study, to compare with the weights found in the different clusters. All 107 respondents have been placed in a cluster. Almost all cluster show a relatively high weight on one of the components. Cluster 1 has a high weight for Customs, 2 for tracking & tracing, 3 for services, 4 for international shipments, and 5 for infrastructure. Cluster 1 has the fewest respondent in it with 13 and cluster 3 is the largest cluster with 34 respondents. An extra variable is created in SPSS that tracks the cluster each of the respondents is in.

Table 25: Cluster centres

Cluster centres						
	Cluster					
	1	2	3	4	5	Weight
Weight Customs	0,3658	0,1161	0,1352	0,1249	0,1364	0,159449
Weight Infrastructure	0,1698	0,1475	0,1627	0,1610	0,4274	0,235406
Weight Services	0,1447	0,1507	0,3611	0,1648	0,1439	0,216904
Weight Timeliness	0,1387	0,1914	0,1564	0,2228	0,1267	0,16013
Weight tracking & tracing	0,0704	0,2565	0,0898	0,0551	0,0774	0,102483
Weight Int. shipments	0,1105	0,1378	0,0947	0,2714	0,0882	0,125628
Respondents (% of total respondents)	13 (12,1%)	15 (14,0%)	34 (31,8%)	15 (14,0%)	30 (28,0%)	

To analyse the clusters the number of respondents from each development group and continent per cluster is reviewed. Table 26 shows the number of respondent in each of the groups per cluster as well as the percentage of the total in that group per cluster.

Table 26: Respondents per group per cluster

Respondents per group per cluster											
		1		2		3		4		5	
		#	%	#	%	#	%	#	%	#	%
Development group	High	4	7,27%	7	12,73%	20	36,36%	9	16,36%	15	27,27%
	Low	9	17,31%	8	15,38%	14	26,92%	6	11,54%	15	28,85%
Continent	Europe	2	4,88%	5	12,20%	16	39,02%	8	19,51%	10	24,39%
	North-America	4	25,00%	3	18,75%	3	18,75%	2	12,50%	4	25,00%
	Asia	2	9,52%	3	14,29%	4	19,05%	2	9,52%	10	47,62%
	Australia	0	0,00%	1	20,00%	3	60,00%	0	0,00%	1	20,00%
	Africa	4	25,00%	3	18,75%	4	25,00%	2	12,50%	3	18,75%
	South-America	1	12,50%	0	0,00%	4	50,00%	1	12,50%	2	25,00%

For the development groups it can be interesting to compare the percentages of respondents in each of the clusters with the percentages of total respondents in the clusters. For clusters 2, 4, and 5 the percentages are similar to when the complete set of respondent is considered. 12,1% of the respondents is in cluster 1, when all 107 respondents are included. When only the high income group is considered 7.27% is in cluster one and when the low income group is considered 17,31% is placed in cluster 1. As can be seen in table 25, cluster 1 represents respondents that consider customs to be relatively important and weigh infrastructure and services significantly lower than the average weights. Cluster 5 is the cluster that has a relatively high weight for services and when all the respondents are considered has 31.8% of the respondents in it. Respondents from the high income group are overrepresented in this group with 36,36% against 26,92% for the low income group. For the continents it is harder to compare the percentage since there are not many respondents from Australia and south-America. Therefore, only the two continents with the most respondents will be analysed, Europe and Asia. Respondents from Europe are overrepresented in clusters 3 and 4 and

underrepresented in cluster 1. This means that they are most present in the clusters that have a relatively high weight for Infrastructure or International shipments. The cluster in which they are underrepresented has a high weight for customs. Almost half of the respondents from Asia are in cluster 5, that values infrastructure very high. They are underrepresented in the other clusters. The relatively small number of respondents per continent make it harder to draw significant conclusions from the cluster analysis, but they do provide some insights in the weight patterns per respondent group.

The comparisons between the groups show that the only significant difference in weight is for the customs component when comparing between different continents. This means that the weights that are found when all the respondents are included are robust and that apparently the weights are considered to be the same for all people with experience in the logistics field. The total weights will be used to create a new ranking in the next paragraph.

4.5 Weighted LPI ranking

The LPI ranking and the weight found in the previous section are used to create a new ranking of countries, called the weighted logistics performance index (w-LPI). The ranking uses the scores on the six core components as provided by the latest LPI report. These scores are then multiplied by the identified weights for the components. When all the scores are added, the w-LPI score is found. This paragraph present the complete w-LPI ranking and will provide statistics on the new ranking and a comparison with the 2016 LPI ranking. Table 27 provides the complete ranking, with from left to right in the columns: The w-LPI ranking, the country, the (old) LPI score, the w-LPI score, the scores on the different component, the (old) LPI ranking, the place difference, and the percentile difference in score.

Table 27: w-LPI ranking

		LPI	w-LPI	C	I	IS	S	TT	T				
	Weights			0,159	0,2354	0,126	0,217	0,102	0,1601				
Rank	**Country**	**score**	**score**	**score**	**score**	**score**	**score**	**score**	**score**	**LPI rank**	**Rank dif**	**% dif**	
1	Germany	4,230	4,265	4,12	4,44	3,86	4,28	4,27	4,45	1	0	0,838	0,8378
2	Sweden	4,205	4,215	3,92	4,27	4,00	4,25	4,38	4,45	3	1	0,254	0,2537
3	Netherlands	4,188	4,211	4,12	4,29	3,94	4,22	4,17	4,41	4	1	0,566	0,5657
4	Luxembourg	4,219	4,211	3,90	4,24	4,24	4,01	4,12	4,80	2	-2	-0,198	0,1984
5	Singapore	4,144	4,160	4,18	4,20	3,96	4,09	4,05	4,40	5	0	0,383	0,3834
6	Austria	4,098	4,102	3,79	4,08	3,85	4,18	4,36	4,37	7	1	0,091	0,0913
7	Belgium	4,109	4,098	3,83	4,05	4,05	4,07	4,22	4,43	6	-1	-0,246	0,2464
8	UK	4,070	4,093	3,98	4,21	3,77	4,05	4,13	4,33	8	0	0,577	0,577
9	Hong Kong	4,069	4,070	3,94	4,10	4,05	4,00	4,03	4,29	9	0	0,03	0,0297
10	United States	3,992	4,016	3,75	4,15	3,65	4,01	4,20	4,25	10	0	0,599	0,5991
11	Switzerland	3,987	4,016	3,88	4,19	3,69	3,95	4,04	4,24	11	0	0,725	0,7251
12	Japan	3,970	3,994	3,85	4,10	3,69	3,99	4,03	4,21	12	0	0,6	0,6003
13	Canada	3,931	3,960	3,95	4,14	3,56	3,90	4,10	4,01	14	1	0,739	0,739
14	UAE	3,942	3,950	3,84	4,07	3,89	3,82	3,91	4,13	13	-1	0,216	0,2162
15	Finland	3,921	3,942	4,01	4,01	3,51	3,88	4,04	4,14	15	0	0,543	0,543

16	France	3,901	3,913	3,71	4,01	3,64	3,82	4,02	4,25	16	0	0,321	0,321
17	Denmark	3,816	3,832	3,82	3,75	3,66	4,01	3,74	3,92	17	0	0,416	0,4164
18	Australia	3,793	3,804	3,54	3,82	3,63	3,87	3,87	4,04	19	1	0,285	0,2852
19	Ireland	3,795	3,782	3,47	3,77	3,83	3,79	3,98	3,94	18	-1	-0,331	0,3309
20	South Africa	3,775	3,775	3,60	3,78	3,62	3,75	3,92	4,02	20	0	-0,01	0,0099
21	Italy	3,755	3,760	3,45	3,79	3,65	3,77	3,86	4,03	21	0	0,111	0,111
22	Norway	3,732	3,753	3,57	3,95	3,62	3,70	3,82	3,77	22	0	0,559	0,5589
23	Spain	3,727	3,727	3,48	3,72	3,63	3,73	3,82	4,00	23	0	-0,021	0,0211
24	Korea, Rep,	3,717	3,726	3,45	3,79	3,58	3,69	3,78	4,03	24	0	0,231	0,231
25	Taiwan, China	3,698	3,710	3,23	3,57	3,57	3,95	3,59	4,25	25	0	0,346	0,3457
26	China	3,661	3,664	3,32	3,75	3,70	3,62	3,68	3,90	27	1	0,076	0,076
27	Israel	3,660	3,651	3,50	3,49	3,38	3,60	3,72	4,27	28	1	-0,248	0,2476
28	Czech Republic	3,674	3,637	3,58	3,36	3,65	3,65	3,84	3,94	26	-2	-1,028	1,0284
29	Lithuania	3,632	3,622	3,42	3,57	3,49	3,49	3,68	4,14	29	0	-0,271	0,2711
30	Qatar	3,599	3,598	3,55	3,57	3,58	3,54	3,50	3,83	30	0	-0,044	0,0442
31	Hungary	3,429	3,430	3,02	3,48	3,44	3,35	3,40	3,88	31	0	0,023	0,0229
32	Turkey	3,424	3,425	3,18	3,49	3,41	3,31	3,39	3,75	34	2	0,037	0,0374
33	Malaysia	3,426	3,419	3,17	3,45	3,48	3,34	3,46	3,65	32	-1	-0,224	0,2237
34	New Zealand	3,388	3,415	3,18	3,55	2,77	3,22	3,58	4,12	37	3	0,783	0,7834
35	India	3,420	3,408	3,17	3,34	3,36	3,39	3,52	3,74	35	0	-0,345	0,3447
36	Poland	3,426	3,397	3,27	3,17	3,44	3,39	3,46	3,80	33	-3	-0,844	0,8437
37	Portugal	3,409	3,362	3,37	3,09	3,24	3,15	3,65	3,95	36	-1	-1,399	1,3986
38	Estonia	3,363	3,353	3,41	3,18	3,07	3,18	3,25	4,08	38	0	-0,306	0,3063
39	Panama	3,338	3,324	3,13	3,28	3,65	3,18	2,95	3,74	40	1	-0,423	0,423
40	Slovak Republic	3,337	3,321	3,28	3,24	3,41	3,12	3,12	3,81	41	1	-0,485	0,4853
41	Kenya	3,331	3,315	3,17	3,21	3,24	3,24	3,42	3,70	42	1	-0,501	0,5005
42	Latvia	3,327	3,314	3,11	3,24	3,28	3,29	3,42	3,62	43	1	-0,387	0,3868
43	Iceland	3,346	3,307	3,13	3,02	3,32	3,26	3,42	3,88	39	-4	-1,143	1,1427
44	Bahrain	3,314	3,296	3,14	3,10	3,33	3,38	3,32	3,58	44	0	-0,549	0,5493
45	Oman	3,234	3,255	2,76	3,44	3,35	3,26	3,09	3,50	48	3	0,629	0,6288
46	Thailand	3,255	3,232	3,11	3,12	3,37	3,14	3,20	3,56	45	1	-0,714	0,7136
47	Greece	3,240	3,225	2,85	3,32	2,97	2,91	3,59	3,85	47	0	-0,457	0,4572
48	Slovenia	3,185	3,186	2,88	3,19	3,10	3,20	3,27	3,47	50	2	0,032	0,0325
49	Chile	3,248	3,173	3,19	2,77	3,30	2,97	3,50	3,71	46	-3	-2,308	2,3084
50	Egypt	3,185	3,172	2,75	3,07	3,27	3,20	3,15	3,63	49	-1	-0,418	0,4178
51	Croatia	3,161	3,150	3,07	2,99	3,12	3,21	3,16	3,39	51	0	-0,356	0,3557
52	Saudi Arabia	3,156	3,146	2,69	3,24	3,23	3,00	3,25	3,53	52	0	-0,316	0,3163
53	Brazil	3,088	3,093	2,76	3,11	2,90	3,12	3,28	3,39	55	2	0,15	0,1502
54	Mexico	3,114	3,087	2,88	2,89	3,00	3,14	3,40	3,38	54	0	-0,865	0,8654
55	Kuwait	3,152	3,084	2,83	2,92	3,62	2,79	3,16	3,51	53	-2	-2,133	2,1326
56	Malta	3,069	3,041	2,78	2,94	3,09	2,85	3,12	3,61	56	0	-0,929	0,9289
57	Botswana	3,045	3,032	3,05	2,96	2,91	2,74	2,89	3,72	57	0	-0,452	0,4518
58	Uganda	3,043	3,017	2,97	2,74	2,88	2,93	3,01	3,70	58	0	-0,867	0,8672
59	Cyprus	2,999	3,012	3,11	3,00	2,80	2,72	2,54	3,79	59	0	0,425	0,4247
60	Romania	2,993	2,971	3,00	2,88	3,06	2,82	2,95	3,22	60	0	-0,736	0,736

61	Tanzania	2,990	2,969	2,78	2,81	2,98	2,92	2,98	3,44	61	0	-0,709	0,709
62	Uruguay	2,975	2,968	2,78	2,79	2,91	3,01	2,84	3,47	65	3	-0,233	0,2326
63	Indonesia	2,985	2,948	2,69	2,65	2,90	3,00	3,19	3,46	63	0	-1,23	1,2296
64	Vietnam	2,977	2,942	2,75	2,70	3,12	2,88	2,84	3,50	64	0	-1,156	1,1565
65	Argentina	2,963	2,941	2,63	2,86	2,76	2,83	3,26	3,47	66	1	-0,73	0,7297
66	Rwanda	2,986	2,939	2,93	2,62	3,05	2,87	3,04	3,35	62	-4	-1,586	1,5857
67	Jordan	2,957	2,924	2,55	2,77	3,17	2,89	2,96	3,34	67	0	-1,103	1,1035
68	Pakistan	2,923	2,895	2,66	2,70	2,93	2,82	2,91	3,48	68	0	-0,975	0,975
69	Peru	2,893	2,863	2,76	2,62	2,91	2,87	2,94	3,23	69	0	-1,058	1,0585
70	Brunei	2,870	2,833	2,78	2,75	3,00	2,57	2,91	3,19	70	0	-1,311	1,3105
71	Philippines	2,856	2,810	2,61	2,55	3,01	2,70	2,86	3,35	71	0	-1,629	1,6288
72	Bulgaria	2,808	2,776	2,40	2,35	2,93	3,06	2,72	3,31	72	0	-1,129	1,1289
73	Algeria	2,770	2,754	2,37	2,58	2,80	2,91	2,86	3,08	75	2	-0,57	0,5698
74	Namibia	2,745	2,751	2,65	2,76	2,69	2,63	2,52	3,19	79	5	0,236	0,2359
75	Bahamas, The	2,750	2,749	2,65	2,72	2,80	2,74	2,64	2,93	78	3	-0,036	0,0361
76	Ecuador	2,779	2,739	2,64	2,47	2,95	2,66	2,65	3,23	74	-2	-1,438	1,4383
77	Burkina Faso	2,731	2,738	2,55	2,67	2,73	2,78	2,49	3,13	81	4	0,254	0,2542
78	Serbia	2,763	2,738	2,50	2,49	2,63	2,79	2,92	3,23	76	-2	-0,907	0,9067
79	Kazakhstan	2,752	2,737	2,52	2,76	2,75	2,57	2,86	3,06	77	-2	-0,539	0,5393
80	Cambodia	2,801	2,736	2,62	2,36	3,11	2,60	2,70	3,30	73	-7	-2,316	2,3164
81	Ukraine	2,737	2,699	2,30	2,49	2,59	2,55	2,96	3,51	80	-1	-1,373	1,3727
82	Lebanon	2,717	2,687	2,73	2,64	2,84	2,45	2,75	2,86	82	0	-1,113	1,1129
83	El Salvador	2,706	2,650	2,37	2,25	2,82	2,66	2,78	3,29	83	0	-2,045	2,0446
84	Bangladesh	2,664	2,646	2,57	2,48	2,73	2,67	2,59	2,90	87	3	-0,653	0,6533
85	Ghana	2,661	2,640	2,46	2,48	2,71	2,54	2,52	3,21	88	3	-0,792	0,7919
86	Morocco	2,666	2,634	2,22	2,46	3,09	2,59	2,34	3,20	86	0	-1,19	1,1902
87	Nigeria	2,628	2,619	2,46	2,40	2,43	2,74	2,70	3,04	90	3	-0,343	0,3428
88	Guyana	2,667	2,616	2,40	2,24	2,66	2,66	2,90	3,12	85	-3	-1,922	1,9223
89	Iran	2,601	2,614	2,33	2,67	2,67	2,67	2,44	2,81	96	7	0,498	0,4984
90	Bosnia and Herzegovina	2,596	2,610	2,69	2,61	2,28	2,52	2,56	2,94	97	7	0,528	0,5281
91	Mozambique	2,684	2,606	2,49	2,24	3,06	2,44	2,75	3,04	84	-7	-2,902	2,9021
92	Colombia	2,612	2,603	2,21	2,43	2,55	2,67	2,55	3,23	94	2	-0,354	0,3536
93	Dominican Republic	2,627	2,596	2,39	2,29	2,67	2,68	2,63	3,06	91	-2	-1,209	1,2087
94	Costa Rica	2,649	2,594	2,33	2,32	2,89	2,55	2,77	2,98	89	-5	-2,079	2,0788
95	Côte d'Ivoire	2,603	2,593	2,67	2,46	2,54	2,62	2,62	2,71	95	0	-0,371	0,3705
96	Moldova	2,614	2,579	2,39	2,35	2,60	2,48	2,67	3,16	93	-3	-1,342	1,3417
97	Togo	2,618	2,572	2,49	2,24	2,62	2,46	2,60	3,24	92	-5	-1,73	1,7304
98	Russia	2,571	2,572	2,01	2,43	2,45	2,76	2,62	3,15	99	1	0,025	0,0252
99	Paraguay	2,561	2,568	2,38	2,45	2,58	2,69	2,30	2,93	101	2	0,242	0,2417
100	Comoros	2,579	2,566	2,63	2,36	2,58	2,60	2,44	2,82	98	-2	-0,497	0,4975
101	Nicaragua	2,531	2,533	2,48	2,50	2,50	2,55	2,47	2,68	102	1	0,061	0,0605
102	Niger	2,562	2,531	2,59	2,22	2,63	2,50	2,35	3,02	100	-2	-1,189	1,1888
103	Maldives	2,513	2,523	2,39	2,57	2,34	2,44	2,49	2,88	104	1	0,396	0,3962
104	Macedonia, FYR	2,510	2,518	2,21	2,58	2,45	2,36	2,32	3,13	106	2	0,314	0,314

105	Tunisia	2,497	2,497	1,96	2,44	2,33	2,59	2,67	3,00	110	5	0,01	0,0096
106	Sudan	2,530	2,488	2,23	2,20	2,57	2,36	2,49	3,28	103	-3	-1,658	1,6582
107	Mali	2,503	2,488	2,45	2,30	2,48	2,46	2,36	2,93	109	2	-0,592	0,5925
108	Papua New Guinea	2,511	2,483	2,55	2,32	2,46	2,35	2,58	2,78	105	-3	-1,099	1,0989
109	Mongolia	2,506	2,459	2,39	2,05	2,37	2,31	2,47	3,40	108	-1	-1,877	1,8769
110	Burundi	2,510	2,453	2,02	1,98	2,42	2,46	2,68	3,45	107	-3	-2,25	2,2504
111	Myanmar	2,459	2,447	2,43	2,33	2,23	2,36	2,57	2,85	113	2	-0,483	0,4826
112	Guatemala	2,476	2,443	2,47	2,20	2,41	2,30	2,46	2,98	111	-1	-1,333	1,333
113	Benin	2,428	2,429	2,20	2,39	2,55	2,47	2,23	2,69	115	2	0,041	0,0413
114	Uzbekistan	2,405	2,424	2,32	2,45	2,36	2,39	2,05	2,83	118	4	0,812	0,8119
115	Solomon Islands	2,417	2,415	2,60	2,21	2,28	2,43	2,18	2,76	116	1	-0,105	0,1052
116	Honduras	2,463	2,412	2,21	2,04	2,58	2,44	2,53	2,91	112	-4	-2,057	2,0567
117	Zambia	2,430	2,411	2,25	2,26	2,51	2,42	2,36	2,74	114	-3	-0,76	0,7604
118	Trinidad and Tobago	2,398	2,395	2,38	2,34	2,31	2,28	2,28	2,79	121	3	-0,143	0,1432
119	Congo, Rep,	2,377	2,386	2,00	2,60	2,37	2,26	2,48	2,57	125	6	0,377	0,3768
120	Albania	2,412	2,383	2,23	1,98	2,48	2,48	2,15	3,05	117	-3	-1,235	1,2352
121	Jamaica	2,400	2,378	2,37	2,23	2,44	2,31	2,38	2,64	119	-2	-0,923	0,9234
122	Venezuela, RB	2,391	2,375	1,99	2,35	2,47	2,34	2,48	2,71	122	0	-0,651	0,6508
123	Belarus	2,399	2,364	2,06	2,10	2,62	2,32	2,16	3,04	120	-3	-1,47	1,4701
124	Ethiopia	2,377	2,351	2,60	2,12	2,56	2,37	2,18	2,37	126	2	-1,072	1,0725
125	Nepal	2,377	2,341	1,93	2,27	2,50	2,13	2,47	2,93	124	-1	-1,499	1,4988
126	Cuba	2,346	2,341	2,38	2,31	2,31	2,25	2,31	2,51	131	5	-0,25	0,2504
127	Congo, Dem, Rep,	2,376	2,341	2,22	2,01	2,33	2,33	2,37	2,94	127	0	-1,482	1,4821
128	Montenegro	2,380	2,337	2,22	2,07	2,56	2,31	2,37	2,69	123	-5	-1,793	1,7925
129	Senegal	2,328	2,334	2,31	2,23	2,25	2,39	2,15	2,61	132	3	0,269	0,2694
130	Guinea	2,359	2,328	2,28	2,01	2,38	2,54	2,54	2,38	129	-1	-1,304	1,3039
131	São Tomé and Principe	2,326	2,322	2,24	2,12	2,26	2,42	2,14	2,75	133	2	-0,146	0,146
132	Georgia	2,353	2,315	2,26	2,17	2,35	2,08	2,44	2,80	130	-2	-1,611	1,6112
133	Fiji	2,316	2,314	2,33	2,25	2,21	2,25	2,25	2,60	136	3	-0,107	0,1073
134	Djibouti	2,323	2,301	2,37	2,30	2,48	1,96	2,09	2,69	134	0	-0,948	0,9478
135	Guinea-Bissau	2,371	2,298	2,44	1,91	2,57	2,07	2,41	2,74	128	-7	-3,082	3,0817
136	Bhutan	2,321	2,281	2,21	1,96	2,50	2,30	2,20	2,70	135	-1	-1,726	1,7261
137	Libya	2,264	2,267	1,88	2,04	2,40	2,50	1,85	2,83	137	0	0,115	0,1147
138	Angola	2,241	2,229	1,80	2,13	2,37	2,31	2,21	2,59	139	1	-0,537	0,5373
139	Turkmenistan	2,211	2,223	2,00	2,34	2,37	2,09	1,84	2,59	140	1	0,544	0,5444
140	Armenia	2,206	2,213	1,95	2,22	2,22	2,21	2,02	2,60	141	1	0,353	0,3533
141	Bolivia	2,251	2,207	1,97	2,11	2,40	1,90	2,31	2,79	138	-3	-1,976	1,9764
142	Liberia	2,204	2,182	2,07	2,01	2,22	2,07	2,07	2,73	142	0	-0,991	0,9914
143	Cameroon	2,151	2,179	2,09	2,21	1,98	2,32	2,04	2,29	148	5	1,292	1,292
144	Gabon	2,192	2,174	2,07	2,05	2,28	2,12	2,07	2,52	143	-1	-0,799	0,7986
145	Eritrea	2,172	2,172	2,01	2,06	2,16	2,25	2,03	2,50	144	-1	0,021	0,021
146	Madagascar	2,155	2,143	2,33	2,12	2,17	1,93	2,01	2,35	147	1	-0,533	0,5326
147	Chad	2,164	2,142	2,08	2,07	2,41	2,06	2,07	2,25	145	-2	-1,057	1,0569

148	Kyrgyz Republic	2,156	2,118	1,80	1,96	2,10	1,96	2,39	2,72	146	-2	-1,769	1,7687
149	Afghanistan	2,141	2,116	2,01	1,84	2,38	2,15	1,77	2,61	150	1	-1,173	1,1725
150	Iraq	2,150	2,110	2,01	1,87	2,33	1,97	1,98	2,66	149	-1	-1,851	1,8505
151	Zimbabwe	2,082	2,103	2,00	2,21	2,08	2,13	1,95	2,13	151	0	1,004	1,0045
152	Tajikistan	2,063	2,071	1,93	2,13	2,12	2,12	2,04	2,04	153	1	0,39	0,3903
153	Lao PDR	2,067	2,047	1,85	1,76	2,18	2,10	1,76	2,68	152	-1	-0,994	0,9937
154	Lesotho	2,026	2,041	1,91	1,96	1,84	2,16	1,92	2,35	154	0	0,75	0,7503
155	Sierra Leone	2,025	2,017	1,91	2,07	2,31	1,85	1,74	2,23	155	0	-0,409	0,4085
156	Mauritania	1,866	1,835	2,14	1,54	2,00	1,74	1,54	2,14	157	1	-1,639	1,6391
157	Equatorial Guinea	1,879	1,834	1,88	1,50	1,89	1,75	1,89	2,32	156	-1	-2,389	2,3886
158	Somalia	1,747	1,740	1,29	1,57	1,86	1,85	1,51	2,35	158	0	-0,419	0,4188
159	Haiti	1,716	1,693	1,70	1,47	1,81	1,68	1,56	2,02	159	0	-1,359	1,3591
160	Syrian Arab Republic	1,598	1,541	1,11	1,24	1,36	1,39	2,10	2,40	160	0	-3,572	3,5722

4.5.1 Statistics and comparison

Looking at the LPI and w-LPI ranking, the first thing that stands out is that both the ranking and the score seem very similar for the different countries. To analyse the similarities and differences further some of the statistics are gathered from the rankings and presented in table 28 The differences between both rankings and scores are very small. In the top of the lost the changes are very small, as can be seen only 9 of the 25 top ranking countries are on a different place in the ranking, and almost all of these increases or decreases are just two countries switching a position. When looking at the whole ranking there are 110 countries that have a different place in the w-LPI ranking than in the LPI ranking. However, the place difference is very low with 1,56 on average. This means that even though 110 out of 160 countries are in a different place in the ranking, the changes in position are in general very small. Both the highest increase in rank as the biggest decrease is 7 places.

Table 28: Ranking comparison statistics

Statistics w-LPI	
Number of countries with diff rank	110
Average rank difference	1,56
Average percentile score difference	0,82%
Top 5 rank increase	
Iran	7
Bosnia Herzegovina	7
Congo	6
Namibia	5
Cuba	5
Top 5 rank decrease	
Cambodia	-7
Guinee-Bissau	-7
Mozambique	-7
Costa Rica	-5
Togo	-5

The small differences between the LPI and the w-LPI ranking also show in figure 22 where the horizontal axis represents the LPI score and the vertical axis the w-LPI score. The regression between the two scores is 0,9988. This means that the score of the w-LPI can be predicted almost perfectly from the LPI score.

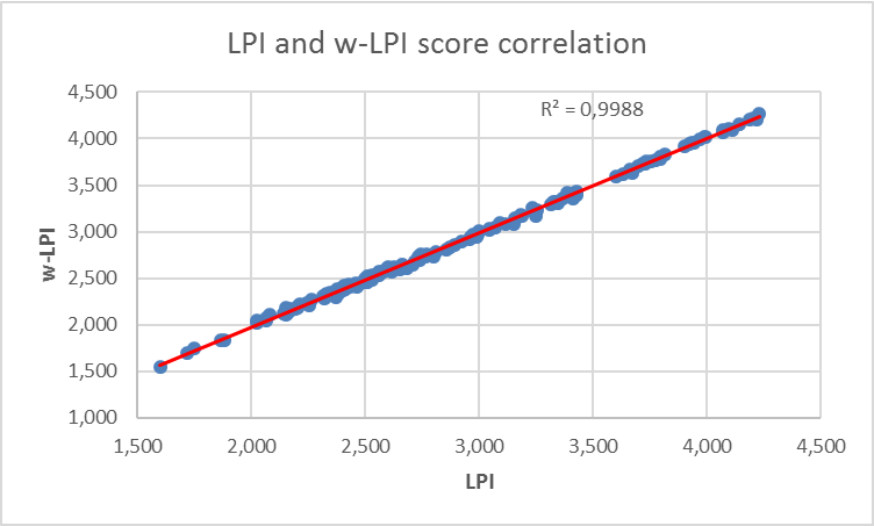

Figure 22: LPI and w-LPI correlation

The figure shows that there are no countries for which the score differs from the trend line. This means that there are no exceptions to the fact that the correlation between the LPI and the w-LPI. For each country the w-LPI score could be predicted almost perfectly from the LPI score since they all have a correlation close to 1. In the first chapter of the research one of the objectives for this research was defined as: aim to help countries get a better insight in their logistics performance and thereby help them take more effective measures to improve their logistics system and performance. What can be concluded from the new ranking is that this ranking itself will not provide countries with a better insight in their logistics performance due to the high correlation with the LPI ranking and the relatively small changes in ranking for almost all of the countries. In the literature review several other indexes and metrics such as: DB2017, LSCI, GDP, GCI, and GNI have been compared to the LPI index. The aim was to also compare the new w-LPI index with these other indexes and metrics. If the w-LPI ranking would have a higher correlation with these indexes than the LPI this could mean that the w-LPI would represent logistical performance better than the LPI. However, the high correlation between the LPI and the w-LPI makes it useless to compare these indexes and metrics with the w-LPI since the result would be very close to the results found when the LPI was compared with these indexes.

The found weights for the six core components are significantly different from each other, meaning that not all the components are equally important when measuring logistics performance. Even though the components are not equally important, apparently this does nog influence the ranking enough to make a real difference. That the ranking does not differ much from the LPI ranking does not mean that the weights do not tell anything about the importance of different factors in logistics performance measuring. In the next sections the possible reasons for the very high correlation between the two scores will be explored. The policy advice that will be given later in this report will be based on the weights found in this chapter rather than on the ranking as was expected beforehand.

4.6 LPI and w-LPI correlation

The previous section identified the high correlation between the LPI and the w-LPI score even though the weights for the six core components are significantly different. This paragraph will aim to find the reason for this high correlation and draw conclusions from this about the LPI and the w-LPI.

The high correlation between the LPI and the w-LPI even with the significant difference in weights suggests that there is a correlation between the scores on the different components. A high correlation between the scores on two components would mean that if a country scores high on a certain component it will also score high on the other component. If the correlation between all the components is high this would mean that the LPI score could be predicted by just looking at the scores on one of the components. This would also mean that assigning weights to the components will not affect the ranking much. If the correlation between the different components would be low, the differences in ranking for a country on each of the components would be higher and assigning weights will have a higher effect on the w-LPI score and therefore a higher effect on the ranking. Table 29 shows the correlation between the LPI score, the w-LPI scores and the components: Customs (C), Infrastructure (I), International shipments (IS), Services (S), tracking & tracing (TT), and timeliness (T).

Table 29: Component correlations

Correlations

		LPI	wLPI	C	I	IS	S	TT	T
LPI	Pearson Correlation	1	,999**	,968**	,976**	,966**	,982**	,976**	,960**
	Sig. (2-tailed)		,000	,000	,000	,000	,000	,000	,000
	N	160	160	160	160	160	160	160	160
wLPI	Pearson Correlation	,999**	1	,968**	,982**	,962**	,984**	,973**	,955**
	Sig. (2-tailed)	,000		,000	,000	,000	,000	,000	,000
	N	160	160	160	160	160	160	160	160
C	Pearson Correlation	,968**	,968**	1	,946**	,924**	,941**	,929**	,902**
	Sig. (2-tailed)	,000	,000		,000	,000	,000	,000	,000
	N	160	160	160	160	160	160	160	160
I	Pearson Correlation	,976**	,982**	,946**	1	,927**	,961**	,944**	,909**
	Sig. (2-tailed)	,000	,000	,000		,000	,000	,000	,000
	N	160	160	160	160	160	160	160	160
IS	Pearson Correlation	,966**	,962**	,924**	,927**	1	,940**	,926**	,917**
	Sig. (2-tailed)	,000	,000	,000	,000		,000	,000	,000
	N	160	160	160	160	160	160	160	160
S	Pearson Correlation	,982**	,984**	,941**	,961**	,940**	1	,953**	,926**
	Sig. (2-tailed)	,000	,000	,000	,000	,000		,000	,000
	N	160	160	160	160	160	160	160	160
TT	Pearson Correlation	,976**	,973**	,929**	,944**	,926**	,953**	1	,939**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000		,000
	N	160	160	160	160	160	160	160	160
T	Pearson Correlation	,960**	,955**	,902**	,909**	,917**	,926**	,939**	1

	Sig. (2-tailed)	,000	,000	,000	,000	,000	,000	,000	
	N	160	160	160	160	160	160	160	160

**. Correlation is significant at the 0.01 level (2-tailed).

Table 29 shows very high correlation between both the LPI and the w-LPI score with each of the components. The correlation earlier found between the LPI and w-LPI of 0,999 is shown in the second column of the first row. The correlation between the LPI score and each of the components is shown on the first row. The range of the correlations is between 0,960 for timeliness and 0,982 for services. These high correlations mean that the effect of using multiple components is very low and the ranking would not differ much if only one of the components would have been used. The components also have a high correlation with each other. The lowest correlation between components is 0,902 for timeliness and customs. This is regarded as a very high correlation. These high correlations are the reason for the small effects assigning weights to the core components has on the overall score and thereby the ranking. This raises questions about the LPI and the way it is calculated. The components are very different from each other but if the LPI represents logistical performance this performance could be calculated using only one of them.

Correlation between the component could have been expected beforehand since it is likely countries that are more developed will invest more in improving on all the different factors in the logistical system. However, the correlation between the LPI scores on the components seems to be too high to be realistic and if they would be really this high, it is useless to include all six components when determining logistics performance. What is more likely is that the correlation is caused by how the scores on the components are determined. This can have several reasons, but the most likely is that the way of questioning or the selected respondents cause the high correlations. When outcomes are different than the real situation due to the way of questioning, this is known as common method bias (Podsakoff, MacKenzie, Lee & Podsakoff, 2003). Method biases are a known error in different fields of science and can threaten the validity of the dataset or the measurements. Podsakoff et al. (2003) mention that systematic measurement errors can provide a set of outcomes that are highly influenced by the method of questioning and therefore these outcomes do not represent the real situation as well as they could. It is possible that methods errors are present in the LPI scores, due to the respondent selection method.

Paragraph 2.1 of the literature review addressed the methodology used to construct the LPI of 2016. To create the index, 1051 respondents were asked to rate countries between 1 and 5 on the six different components. Each of the respondents is asked to rate 8 countries. These 8 countries are determined based on the most important import and export countries of the respondents home country and some are determined randomly. This means that each country on average is scored by 52,55 respondents. In general 52 is a low number to find significant results. For the LPI report some of the respondents will be randomly assigned, meaning that for example a respondent from the Netherlands could be asked to score Lesotho on the components. It is unlikely that a respondent from the Netherlands has sufficient information on and experience with this country to provide an educated score. This increases the chance respondents will answer based on some general idea they have of a

country, and therefore do not differentiate between the components based on knowledge. This would be common method bias, since the scores are not constructed based on the real situation of realistic scores on the components, but on a general of the logistics performance of a certain country, or even a general idea about a country.

The idea of the LPI is that the components combined should form an overall image of logistics performance, the LPI score. The previous paragraph described that it is possible that some respondents rate the components based on a general idea they have of a country, e.g. Poor/rich. The difference between these two methods of determining scores is the difference between formative and reflective measurement. The LPI is supposed to be formative, where indicators determine a construct (Coltman, Devinney, Midgley, & Venaik, 2008). In the LPI the indicators are the components and the scores on these components are supposed to determine the score of the construct, logistical performance. Instead, if some of the respondents would score the indicators based on a general idea about a country, the construct would determine the indicator scores. This is called reflective measurement. If in reality the LPI in constructed based on a reflective approach by the respondents the questionnaire becomes useless since the respondents could just be asked to score the logistics performance of a country. To find out what the approach of the respondents is further research on the subject is needed. It could be possible to ask several experts on a certain country and ask them to each rate one of the components of a country. If the scores are then combined and are similar to the scores of the LPI, the LPI is constructed right. If the scores differ the questionnaire of the LPI should be changed to come to more relevant results. Also, more respondents from different countries can ensure that all the respondent have relevant information on the countries they have to score. More respondents would eliminate the need for respondents to score countries that are randomly assigned, all the countries that have to be scored by a country could then be import or export partners of the country of origin.

Chapter 5: Advice

In the first chapter of this thesis the goals for this research were presented. One of these goals was to help countries get a better insights in their logistical position and help them focus logistics projects better. This chapter will provide a short-term and a long-term advice based on the weights found in the previous chapter. Besides this part, the chapter will also present an advice on how the LPI methodology could be improved, so it can become a better tool for logistics performance measuring. The chapter will end with a discussion on the advice, stating how this advice should be used.

5.1 Policy advice for countries

The weights found in the previous chapter show that some factors are more important for logistical performance than others. However, that infrastructure and services have the highest weights does not means that the focus should always be on improving these two factors and neglecting the others. Each type of country requires a specific approach both for the short-term as the long-term. The next paragraphs will provide a general advice for the coming years (short-term) and for the coming decades (long-term).

5.1.1 Short-term advice

The weights clearly show that the quality of infrastructure and the competence and quality of logistics service providers are the most important factors in logistics performance, followed by timeliness and customs. For the short-term it is important that measures are found that have immediate effect and that can be implemented relatively fast. Changes to the existing infrastructure or the implementation of new infrastructure is a timely and expensive manner. In many countries it will take years to plan a new infrastructural project and to get the approval of the public and the political support to execute the project. Therefore, even though it has the highest weight, on the short term projects concerning large infrastructure will not sort the best effects. The quality of services in a country is highly dependent on the companies that provide these services. These companies provide all the services that are needed to transport goods from their origin to their destination. These services include transportation, warehousing, packing, and freight-forwarding. The key to improve the quality of services in a country is trying to get these companies to become more efficient. Therefore, this paragraph will provide some suggestions, based on literature, to improve efficiency in the logistics services sector. Sink and Langley (1997) describe the trend that an increasing number of companies are using third-party logistics services. This third party provides all the services needed to move the finished goods to their destinations. The research provides important steps companies have to take to select the right supplier of these services and how these services should be evaluated constantly. For a government it will be hard to influence the choice of a company for the right supplier, since each company is free to select the one that is the best fit for that company. However, Sink and Langley (1997) also state that is important that both the company that is selecting the services provider as the services provider should have enough training in the field of logistics to come to the best alliance. The government is able to influence the education on logistics provided by schools and universities through subsidies and marketing. Wu (2007) concluded that the need for education in logistics differs for developed and developing nations. In the developing countries the need for education on transporting

is high, whereas in the developed countries the need for education on transportation alone is not enough and the focus should be on education in overall logistics and operations management. For developing countries it is possible that the knowledge to improve the logistics education is not available. For these countries it can be beneficial to find this knowledge in other more developed countries. An example is Costa Rica, which signed a Memorandum of Understanding (MoU) with the Netherlands. This MoU included a collaboration on logistics and transportation related education, aimed to improve the quality of logistics in Costa Rica and more task specific education. Yildriz (2015) confirms the relation between the quality of logistics education and the logistics performance of a country. He concludes that there is need for research to investigate the direct skills needed to increase logistical performance. In general the advice for countries is that education will affect the quality of logistics services in a country. Therefore, countries should invest in task-specific education and training. The task-specific training can have effect on a short term since the companies will profit almost immediately from better trained employees. Improving the education on schools and universities will probably take longer, but will also sort a long-term effect for logistics personnel in the future.

For developing countries short-term improvements can be implemented in the customs sector. This component does not have the highest weight, but some of the solutions in this sector are easy and relatively cheap to implement. Also, Arvis et al. (2016) mention that the customs component score is lagging behind the other component score, making it relatively easy to stand out for a country by improving customs procedures. Developing countries tend to lag behind on this factor due to the absence of new technologies and the bureaucratic problems in the government. Devlin & Lee (2007) mention that in most developing countries many customs organizations are active and they obstruct each other in their work. Another concern was that the goal of customs organizations in these countries is to make a profit, instead of trade facilitation as is common in most western countries. A few relatively simple and cheap solutions are provided to deal with the typical customs problems in developing countries. The first solution is to expand the role of ICT in border procedures (Devlin & Yee, 2007). In the last few years many systems have become available that reduce the border clearance time, if they would be used more the clearance process would become more organised and logistics performance will increase. Another possibility for developing countries is increased collaboration with neighbouring countries. Currently when crossing the border, there are two lengthy border procedures, both from the country from which the truck is travelling as the country to which the truck is going. If these countries could reduce this to one border clearance procedure, in which they work together this could reduce clearance times. Both of these measures can be implemented relatively quick and will sort immediate effects.

5.1.2 Long-term advice

When countries have to create a strategy for the long-term, the focus should be on improving their infrastructure and services. As mentioned in the previous section, creating education that focusses on logistics will increase the skill level of university graduates that can apply for a job in logistics. This will increase the long-term quality of services. Many projects concerning infrastructure are proposed and implemented in almost all countries. How well they affect the logistical performance is hard to evaluate and that makes it harder to give an advice based on the weights found in this research.

Therefore, some trends in infrastructure development will be identified for developing and developed countries. Infrastructure measures can concern hard as well as soft infrastructure. Hard infrastructure is tangible infrastructure, such as roads, rails and port structures. ICT infrastructure is also considered to be hard infrastructure. The soft infrastructure consists of protocols, business environment, and other institutional intangible aspects (Portugal-Perez & Wilson, 2012). Portugal-Perez and Wilson (2012) tested the effects of measures in four different components of infrastructure on the total export of the country. Two of these were indicators for hard infrastructure: ICT and physical infrastructure and two of them are soft infrastructure indicators: business environment and transport efficiency. They found out that for developing countries the improvement of the physical infrastructure sorted the most effect. This physical infrastructure consists of roads, rails, ports and airfields in their research. Furthermore they found that the lower the income of a country, the lower the impact of transport efficiency and the business environment. Besides this relation they also found out that the higher the income of a country, the higher the marginal impact of improvements in ICT structure and physical infrastructure. The only concern with this outcome is that it is relatively expensive to implement large infrastructure projects and there are significant financial risks. In most developed countries, the physical infrastructure can still be improved but is in general of high quality. The relationship found in the previous paragraph suggests that also for the richer countries, physical infrastructure development remains an important factor. For these countries it is important to find projects that improve the connectivity of different infrastructures to create more efficient supply chains in their country.

5.2 LPI methodology advice

Besides the advices for policy makers in the country, the weights and the ranking that resulted from the weights also pointed out some flaws in the LPI. This paragraph will consist of a short advice on how to improve the LPI methodology. As mentioned earlier common method bias poses a problem with the LPI. It is likely that the way of questioning influences the outcomes and thereby the ranking. The relatively low number of respondents for each country, 52 on average, and the fact that some of the respondents are asked to judge randomly assigned countries on specific components leads to biased results. This leads to high correlations between the components and a very high correlation between each of the components and the LPI score. This is also the reason that the LPI and the w-LPI ranking are almost identical. To improve the LPI it is advised to use the weights found in this report, since they are significantly different from the weights when all the components are considered equally important. Besides this, the way of questioning should be changed. If the number of respondents is increased, respondents can be asked to only score the countries on which they have sufficient information on all the components. This will ensure that the LPI score is based on scores on the components, instead of based on a general idea a respondent has of a country, see section 4.6. To test the current LPI, a research into one or several countries can be done, where expert from one country are asked to rate their own country to see if the scores are close to the scores found using the LPI questionnaire. If they are different, this suggests that the questionnaire of the LPI should be changed.

Besides the questionnaire of the LPI, the components should also be reviewed. Literature suggest that at least two factors in logistics performance have been left out. The first factor is innovation, which has an important impact on the countries possibilities to adopt new technologies and adapt to

changing logistical systems. The second and probably most important factor is environment. The climate change has brought environment onto the political agenda and transport and logistics are an important factor in the climate change, mostly due to emission of CO2 and small particles. The world bank could review which factors should be added or left out before a new report is produced. The method of weight assignment that has been proposed in this report could be used to determine the weights of the components if their composition changes.

5.3 Discussion on weights and advice

An advice based on the weights found was provided in this chapter. The advice determines to focus on services for the short term and on infrastructure for the long term. These advices are very general and cannot directly be used by countries to start projects or implement measures. This paragraph will provide a discussion on why the advice is only generic.

Services and infrastructure are both components that can be influenced in many different ways. Many factors have influence on the total infrastructure system and how this system functions. For each country it is different what the best measures would be to increase the efficiency of the infrastructure, based on what is still lacking in their country or which component of the infrastructure system is lagging behind. It is therefore out of the scope of this research to determine which projects will prove the most effective way of increasing logistical performance. The same goes for the quality of services, these services are performed mostly by private parties. These parties can be local companies or large multinationals performing these services worldwide. How to influence these services will differ per country and will be based on what company they deal with. A possibilities for countries to determine which measures should be implemented is a cost-benefit analysis. In this analysis several measures van be included to test which one will have the highest benefits on the long term. The proposed measures in this chapter, such as focus on ICT in border procedures and invest in hard infrastructure are therefore only suggestions that could be taken into account for further research.

Chapter 6: Conclusion & discussion

This chapter will be the conclusion of this research and this report. It will provide the answers to the main research question presented in the first chapter as well as the answers to the sub-questions. Recommendations for further research based on this study will be provided. The final section of this report will include a discussion on the fulfilment of the research objectives and provide limitations to this research.

6.1 Conclusions

The main research question for this research is:

"How can the Logistics Performance Index (LPI) be improved by assigning weights to its six core components?"

The answer this question, several sub-questions were composed which will be answered in this paragraph, that in the end will produce the answer to the main research question.

Sub-question 1: What factors define logistical performance?

To answer this question two sub-sub question were formulated:

a. *Are the current components indicators of logistics performance*?

Research on existing literature showed that for each of the six components of the LPI: Customs, Infrastructure, services, timeliness, tracking & tracing, and international shipment literature was available on the effects of the component on trade. This indicates that all six of the components are indeed factors in logistical performance. The relative importance of each of these factors is not described in literature.

b. *Are there other factors besides the components that are important to assess logistical performance*?

Besides the components two other factors that determine logistics performance were found, which are not included in the LPI: Innovation and Environment. Especially environment is an important factor and is becoming even more important due to the increasing awareness for climate change.

Sub-question 2: What other metrics and indexes are indicators of logistics performance?

Several indexes and metrics showed to have a correlation with the LPI index. The Doing Business report 2017 and The Global Competitiveness Index both have a correlation of around 0,55 and the Liner shipper connectivity index has a correlation of 0,40 with the LPI. The gross domestic product and the gross national income have correlations of 0,59 and 0,62 with the LPI. These metrics can be seen as indicators of the economic state of a country of which logistics is an important part. The goal of identifying these indexes and metrics was to compare the score of the w-LPI with them to check if the correlation would be higher which could indicate that the w-LPI was more accurate. However, comparing these indexes and measures with the w-LPI was found useless due to the high correlation between the LPI score and the w-LPI score.

Sub-question 3: Which are the most important factors in logistics performance?

To answer this question the following questions were formulated:

a. *Which method should be used to determine the weights of the core components?*

Assigning weights to the criteria (components) is a Multi Criteria Decision Making (MCDM) problem. The preferred MCDM method to assign the weights is the Best-Worst method. This method requires less comparisons than other methods and is proven to have a higher consistency.

b. *What are the weights of the components?*

To find the weights of the different components, experts were approached and asked to fill out a questionnaire. Two groups of experts were approached, experts from universities and professionals. This is resulted in a total of 107 respondents, 50 professionals and 57 university experts. The most important component was found to be Infrastructure and the least important component is tracking and tracing. The BWM was used to determine the weights, which are presented in table 30.

Table 30: Component weights

	w(C)	w(I)	w(S)	w(T)	w(TT)	w(IS)	Ksi*
Universities	0,139459	0,237518	0,219531	0,169923	0,117777	0,115792	0,106905
Professionals	0,182237	0,232999	0,21391	0,148966	0,085047	0,136841	0,133204
Total	**0,159449**	**0,235406**	**0,216904**	**0,16013**	**0,102483**	**0,125628**	**0,119194**

These weights proved to be significantly different from the weights assumed by the LPI reports where each of the components was considered equally important. Only the weight of the customs component differed significantly between the professionals and the university experts. Therefore, the total of respondents was used for further analysis.

c. *Are there any differences in component weights between different respondent groups?*

The respondents can be placed in different groups based on several answers they provided to the questions on the questionnaire. A distinction was made between respondents from different continents, different development groups and on whether they had information on countries with high or low development. The development groups are based on the income groups provided by the World Bank. The results showed that there were no significant differences between respondents from a high income country and a low income country. Also, if they had information on high or low income country does not have a significant effects on the weights. The weights of the customs component was significantly different between respondents from different continents. It showed that the weights in Africa and North-America are significantly higher and in Australia significantly lower. In general there were only very small differences between groups, which is an indication that the weights are robust and that not all the components are equally important.

Sub-question 4: How does the new ranking compare to the current ranking?

To answer this question the following questions were formulated:

a. *What are the differences and similarities?*

The created weighted-LPI (w-LPI) proved to have a very high correlation with the LPI. The w-LPI and LPI score have a correlation of 0,999 with each other. The average percentile difference between the scores for a country is only 0,82% and the average ranking difference is 1,56 places. With a maximum increase and decrease in places of 7.

b. What do these result imply?

The similarity between the LPI and the w-LPI implies that even though the weights are significantly different, this does not influence the ranking. This indicates that if a country scores high on one of the components it is very likely to score high on the other component. The correlations between the components were tested and proven to be very high (between 0,902 and 0,961). Due to these high correlation the weight assignment does not sort the effect it was expected to do. A possible explanation for the high correlation is common method bias. Common method bias indicates that the outcomes are highly influenced by the way of questioning. Respondents are asked to rate random countries of specific components of which it is unlikely that they have enough knowledge. Therefore, it is likely that they judge the components based on a general idea they have of a country.

Sub-Question 5: What policies can be adopted by countries based on the results of this research?

The research provided weights for the different components of the LPI and thereby can help countries focus their projects on the factors that influence logistics performance the most. For the short term countries should not focus on infrastructure since implementing new infrastructure or adapting current infrastructure is a timely and costly process. The quality of logistics service providers however can be improved on a relatively short term by stimulation job-specific education. For the long-term infrastructure investments should improve logistics performance. Studies found that investments in physical infrastructure are the most effective for developing countries and network investments are advised for developed countries.

The answers to the sub-questions provide the answer to the main research question. The LPI can be improved by assigning weights to the components using the Best-Worst Method. The weights found using this method are significantly different from the weights found when each component is considered equally important. This is the first time weights have been assigned to factors in logistics performance and therefore these weights can provide helpful insights for countries in how to implement new projects. Also, these weights can be the starting point for further research into logistics performance measurement using weight assignment for different factors in logistics.

6.2 Discussion

This paragraph will provide a critical view on the research executed for this report and will reflect on the objectives described in the first chapter. This discussion will also include a discussion on the implications some of the conclusions of the literature review might have for further research and on the current LPI.

6.2.1 Discussion on objectives

In chapter 1 of this report the intentions for this research have been presented. Which resulted in the research questions and two objectives this research aimed to meet. To review the success of the

research this paragraph will discuss on if and how the objectives are met. The two objectives of this research are:

- To create a weighted Logistics Performance Index based on the current index by using the Best-Worst Method. The method used in this research should be re-usable when new components are added.
- To help countries get a better insight in their logistics performance and thereby help them take more effective measures to improve their logistics system and performance.

At the start of this research it was expected that the weights of the six core components would be significantly different, since it seemed highly unlikely that all these factors were equally important in logistics performance measuring. This also led to the believe that applying these weights to the component would lead to a difference in ranking, based on which countries would be provided with a better insight in their position concerning logistic. This better insight combined with the newly found weights could then help countries determine where new logistics project should be focussed and what is most important for their country to improve. When executing the research, weights were found that differ significantly from the weights used for the LPI. This is the first time weights have been assigned to the components of the LPI and it is the first time this method has been used in the logistics and shipping sector. The weights will help countries get a better insight in the important factors in logistical performance and thereby help them focus new logistics projects ore change existing ones. The countries are probably not provided with a better insight in their international position, since the w-LPI ranking does not differ much from the LPI ranking. The first objective as stated in the beginning of this paragraph is met. The method used in this research can be used again if in the future the component might change or it is needed to research if the weights have changed over the years. The BWM has proven a structured method that uses understandable questions to get to a consistent and significant result. The second objective is partly met. The countries are provided with a better insight in how to focus projects and are able to take more effective measures based on the weights found in this research. It is however questionable if they are also provided with a better insight in their current logistical performance, since the w-LPI ranking is not that different from the LPI ranking. The weights however to provide context to the scores on the component, which could lead to a better understanding of logistical performance.

The small difference between the two rankings is the first point of discussion. The small difference between the two rankings, with an average place difference of 1.56 is caused by the high correlation between the LPI score and the w-LPI score. This correlation between is caused by the high correlation between the six components. If the high correlations between the scores on components was foreseen before the start of the research the expectations would have been different. A more critical look at the LPI and its methodology could have been provided earlier in the research so that the focus could have been more on the significance of the weights that are found in the research and the implications these weights have for logistical performance measuring.

A limitation to the research are the respondents that are found, especially the professionals. The professional respondents were selected based on their LinkedIn profiles. The approached professionals all work at international shipping companies and have experience in the field. However,

it is not 100 percent certain that all the information on the profiles is true and that they indeed have the knowledge needed to answer the questions. Their answers however are very similar to the ones by the university experts, which suggests that they did have enough knowledge to assign the weights. Another limitation was that it proved very hard to find respondents from the lowest income group. This income group consist of countries with a very low income and for which it is likely that internet access is not always possible. Therefore, the middle and low income groups were combined into one group.

6.2.2 Discussion on literature review results

In the literature review two important factors in logistics performance have been identified that are not present in the LPI reports. This paragraph will provide a discussion on what the effects could be of including these factors and how they could influence the current LPI and its components.

The first factor that was proposed is innovation. It is likely that improving innovation in a country does affect the performance on the other components. Countries that are the most innovative are likely to be countries that support the companies in their country that innovate. These countries are likely to have a relatively high standard of living, since innovation is not the main priority when spending money. Innovation in current times is closely related to technology. Therefore it is likely that innovation will have an effect on the tracking & tracing and customs components since those components involve the most ICT. The second proposed factor is environment. The environmental score does not directly influence the scores on the other components since it is a factor in itself. However it is likely that countries that have a good infrastructure will score higher on the environmental performance since they have less waiting times, congestions, and a better traffic flow. All these factors lead to less CO2 emission and a better environment. The two proposed factors also influence each other. Innovation is linked with new environmental practices and technologies that will lead to a better environmental logistics performance.

6.3 Recommendations

This research identified several needs for further research, concerning further research into logistics performance measuring as well as research into the LPI methodology. The first recommendation is a study on the factors that determine logistics performance. Existing literature suggest that the six components of the LPI are not the only factors of importance considering logistics performance. A study into these factors can increase the reliability of the LPI and ensures its results are up-to-date with the trends and developments in logistics. The literature especially suggest extra attention for the environment, since this is a topic of many discussions and logistics and transportation play a vital role in climate change and the CO_2 debate.

More research is also needed concerning the implications of the weights that are found in this research. These weights prove to be significantly different for each other and have implications for what determines logistical performance. However, these weights still have to be transformed into actual policy measures to improve logistics performance. In order to do so, further research is needed into different projects that effect the scores and this weights to determine what projects are the most efficient to invest in as a country.

It is also advised to further research and change the LPI methodology. If the number of respondents is increased, respondents can be asked to only score the countries on which they have sufficient information on all the components. This will ensure that the LPI score is based on scores on the components, instead based on a general idea a respondent has on a country, see section 4.6. To test the current LPI, a research into one or several countries can be done, where expert from one country are asked to rate their own country to see if the scores are close to the scores found using the LPI questionnaire. If they are different, this suggests that the questionnaire of the LPI should be changed. Besides the questionnaire of the LPI, the components should also be reviewed. Literature suggest that at least two factors in logistics performance have been left out. The first factor is innovation, which has an important impact on the countries possibilities to adopt new technologies and adapt to changing logistical systems. The second and probably most important factor is environment. The climate change has brought environment onto the political agenda and transport and logistics are an important factor in the climate change, mostly due to emission of CO2 and small particles. The world bank could review which factors should be added or left out before a new report is produced. The method of weight assignment that has been proposed in this report could be used to determine the weights of the components if their composition changes.

Bibliography

Arvis, J.F., Mustra, M.A., Panzer, J., Ojala, L., & Naula, T. (2007). *Connecting to Compete: Trade Logistics in the Global Economy,* World bank, Washington DC.

Arvis, J.F., Mustra, M.A., Ojala, L., Shepherd, B., & Saslavsky, D. (2010). *Connecting to Compete: Trade Logistics in the Global Economy,* World bank, Washington DC.

Arvis, J.F., Mustra, M.A., Ojala, L., Shepherd, B., & Saslavsky, D. (2012). *Connecting to Compete: Trade Logistics in the Global Economy,* World bank, Washington DC.

Arvis, J.F., Saslavsky, D., Ojala, L., Shepherd, B., Busch, C., & Raj, A. (2014). *Connecting to Compete: Trade Logistics in the Global Economy,* World bank, Washington DC.

Arvis, J.F., Saslavsky, D., Ojala, L., Shepherd, B., Busch, C., Raj, A., & Naula, T. (2016). *Connecting to Compete: Trade Logistics in the Global Economy,* World bank, Washington DC.

Belton, V., & Gear, T. (1983). On a Short-coming of Saaty's Method of Analytic Hierarchies. *Omega*, *11*(3), 228-230.

Benayoun, R., Roy, B., & Sussman, N. (1966). Manual de reference du programme electre. *Note de synthese et formation, 25*, Direction Scientifique SEMA, Paris, France.

Bernard, A.B. & Jensen, J.B. (1999). Exceptional exporter performance: cause, effect, or both, *Journal of International Economics*, *47*, 1-25.

Biljan, J., & Trajkov, A. (2012). Risk management and Customs performance improvements: The case of the Republic of Macedonia. *Procedia-Social and Behavioral Sciences*, *44*, 301-313.

Brans, J.P. (1982), L'Ingéniérie de la décision. Elaboration d'instrument d'aide la décision. Methode PROMETHEE, *Colloque d'Aide la Décision*, Université Laval Quebec, Canada, 183-213.

Brans, J.P., & Mareschal, B. (1992), How to discriminate hard and soft multicriteria problems in the discrete case (the PROMETHEE VI procedure), *Internal Report CSOOTW/257*, Vrije Universiteit Brussel.

Caplice, C., & Sheffi, Y. (1994), A Review and Evaluation of Logistics Metrics. *The International Journal of Logistics Management*, *5*(2), 11 – 28.

Caplice, C., & Sheffi, Y. (1995), A Review and Evaluation of Logistics Performance Measurement Systems, *The International Journal of Logistics Management*, *6*(2), 61 – 74.

Çemberci, M., Civelek, M.E., & Canbolat, N. (2015). The moderator effect of global competitiveness index on dimensions of logistics performance index. *Procedia-Social and Behavioral Sciences*, *195*, 1514-1524.

Chapman, R.L., Soosay, C., & Kandampally, J. (2002). Innovation in logistic services and the new business model : a conceptual framework*. Managing service quality*, *12*(6), 358-371.

Chapman, R.L., Soosay, C., & Kardampally, J. (2003), Innovation in logistics services and the new business model: a conceptual framework, *International Journal of Physical Distribution & Logistics Management*, *33*(7), 630-650. .

Chow, G., Heaver, T.D., & Henriksson, L.E. (1994) Logistics Performance: Definition and Measurement*, International Journal of Physical Distribution & Logistics Management*, *24*(1), 17 – 28, DOI: 10.1108/09600039410055981.

Civelek, M. E., Uca, N., & Cemberci, M. (2015). The mediator effect of logistics performance index on the relation between global competitiveness index and gross domestic product. *European Scientific Journal*, *11*(13).

Coltman, T., Devinney, T. M., Midgley, D. F., & Venaik, S. (2008). Formative versus reflective measurement models: Two applications of formative measurement. *Journal of Business Research*, *61*(12), 1250-1262.

Daugherty, P. J., Stank, T. P., & Ellinger, A.E. (1998). Leveraging logistics/distribution capabilities: The effect of logistics service on market share, *Journal of Business Logistics, 19*(2), 35-42.

Deardoff, A.V. (2002). *Time and trade: The role of time in determining the structure and effects of international trade, with an application to Japan*. Analytic studies in U.S.-Japan international economic relations, Cheltenham, U.K. Edward Elgar publishing Inc.

Dekker, M.J., Looff, E.J. de, Roelofsen, D.S., & Roekel, W.S. van, (2016). *Improving the logistical situation of Costa Rica*. Delft: TU Delft

Devlin, J., & Yee, P. (2005). Trade Logistics in Developing Countries: The Case of the Middle East and North Africa, *The World Economy*, *28*(3), 435-456.

Dorp, K.J. van, (2002), Tracking and tracing: a structure for development and contemporary practices. *Logistics Information Management, 15*(1), 24 – 33.

Ehrgott, M., Figueira, J., & Greco, S. (2010). *Trends in multiple criteria decision analysis*. Berlin: Springer.

Ekici, Ş. Ö., Kabak, Ö., & Ülengin, F. (2016). Linking to compete: Logistics and global competitiveness interaction. *Transport Policy*, *48*, 117-128.

Erkan, B. (2014). The importance and determinants of logistics performance of selected countries. *Journal of Emerging Issues in Economics, Finance and Banking*, *3*(6), 1237-1254.

Figueroa, J., Greco, S., & Ehrgott, M. (2005). Multiple Criteria Decision Analysis, State of the art surveys. Boston, MA, Springer Science Business, Inc.

Fishburn, P.C. (1967) Letter to the Editor—Additive Utilities with Incomplete Product Sets: Application to Priorities and Assignments, *Operations Research, 15*(3), 537-542.

Forman, E. H., & Selly, M. A. (2001). *Decision by objectives: how to convince others that you are right*. World Scientific.

Franceschini, F., Cignetti, M.E., & Caldara, M. (1999). Comparing tools for service quality evaluation. *International Journal of Quality Science*, *3*(4), 356-367

Franceschini, F., & Rafele, C. (2000), Quality evaluation in logistic services. *International Journal of Agile Management Systems*, *2*(1), 49 - 54

Gillen, D.W., & Waters II, W.G. (1996). Introduction: Transport infrastructure investment and economic development, *Logistics and Transportation Review, 32*(1).

Goldsby T. J., & Stank T. P. (2000) World Class Logistics Performance and Environmentally Responsible Logistics Practices. *Journal of Business Logistics*, *21*(2), 187–208.

Graeml, A.R., & Peinado, J. (2011). Measuring Logistics Performance: the Effectiveness of Mmog/Le as Perceived by Suppliers in the Automotive Industry, *Journal of supply chain management, 4*(1).

Grawe, S. J. (2009). Logistics innovation: a literature-based conceptual framework. *International Journal of Logistics Management*, *20*(3), 360–377.

Gubin, A. (2011). Developing performance measurement for the Russian Customs Service. *World Customs Journal*, *5*(2), 45-61.

Gupta, H., & Barua, M. K. (2016). Identifying enablers of technological innovation for Indian MSMEs using best–worst multi criteria decision making method. *Technological Forecasting and Social Change, 107*, 69-79

Hausman, W. H., Lee, H. L. & Subramanian, U. (2013). The Impact of Logistics Performance on Trade. *Production and Operations Management, 22*(2), 236–252.

Heaver, T.D. (1992) The Role of Customs Administration in the Structure and Efficiency of International Logistics: An International Comparison. *The International Journal of Logistics Management*, *3*(1), 63 - 72

Hoekman, B., & Nicita, A. (2011). Trade Policy, Trade Costs, and Developing Country Trade. *World Development, 39*(12), 2069–2079, DOI: 10.1016/j.worlddev.2011.05.013

Hoffman, J. (2010). Introduction. At OECD experts meeting on transport services. Retrieved from http://www.oecd.org/tad/services-trade/46483066.pdf on October 12th, 2016.

Hoffman, J., & Fuguzza, M. (2015). Liner connectivity shipping. Retrieved from http://unctad.org/meetings/en/Presentation/tdc_7th2015_JHoffmann_MFugazza_en.pdf on October 12th, 2016

Hummels, D. (2001). *Time as a Trade Barrier. Working paper,* West Lafayette, IN.: Purdue University, department of Economics.

Huvio, E., Grönvall, J., & Främling, K. (2002). *Tracking and tracing parcels using a distributed computing approach*, NOFOMA'2002 Conference, Trondheim, 13-14 June.

Hwang, C.L., & Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Applications*. New York: Springer-Verlag.

Hwang, C.L., Lai, Y.J. & Liu, T.Y. (1993). A new approach for multiple objective decision making. *Computers and Operational Research, 20***,** 889–899.

International Maritime Organization (IMO, 2014). *Third IMO Greenhouse gas study 2014,* Publication of International Maritime Organization, Micropress Printers, Suffolk, UK.

International Transport Forum (ITF, 2015). *Drivers of Logistics Performance: A Case Study of Turkey,* corporate partnership report, OECD.

Jessop, A. (2014). IMP: A decision aid for multiattribute evaluation using imprecise weight estimates. *Omega*, *49*, 18-29.

Johannessen, J.A., Olsen B. & Lumpkin, G.T. (2001), Innovation as newness: what is new, how new, and new to whom?, *European Journal of Innovation Management*, *4(*2), 20 – 31

Jumandi, H., & Zailani, S. (2010). Integrating Green Innovations in Logistics Services Towards Logistics Services Sustainability: A Conceptual Paper. *Environmental Research Journal*, *4(*1), 261-271, DOI:10.3923/erj.2010.261.271.

Keeney, R., & Raiffa, H. (1976). *Decision Analysis with Multiple Conflicting Objectives: Preferences and Value Trade-Offs*, New Yok, Wiley.

Kim, I., & Min, H. (2011). Measuring supply chain efficiency from a green perspective. *Management Research Review*, *34*(11), 1169-1189.

Korinek, J., & Sourdin, P. (2011). *To What Extent Are High-Quality Logistics Services Trade Facilitating,* OECD Trade Policy Working Papers, No. 108, Paris: OECD Publishing.

Keršulienė, V., & Turskis, Z. (2011). Integrated fuzzy multiple criteria decision making model for architect selection. *Technological and Economic Development of Economy*, *17*(4), 645-666.

Lamber, D.M., & Stock, J.R. (1993). *Strategic logistics management 4th ed*, Singapore. McGraw-Hill.

Lewis, G. (2009). The role of ICT in Customs. *Worlds customs journal*, *3*(1), 3-13.

Lummus, R.R., Krumwiede, R.W., & Vokurka, R.J. (2001). The relationship of logistics to supply chain management: developing a common industry definition*, Industrial Management & Data Systems*, *101*(8), 426 – 432, DOI: 10.1108/02635570110406730.

Martí, L., Puertas, R., & García, L. (2014). The importance of the Logistics Performance Index in International trade. *Applied Economics*, *46*(24), 2982-2992, DOI:10.1080/00036846.2014.916394.

McGinnis, M.A., & Kohn, J.W. (1990). A Factor Analytic Study of Logistics Strategy. *Journal of Business Logistics, 11(*2), *41*-63.

Mentzer, J.T., Flint, D.J. & Hult, G.T.M (*2001*). Logistics Service Quality as a Segment-Customized Process. *Journal of Marketing*, *65*(4), 82-104.

Mentzer, J. T., Flint, D. J., & Kent, J. L. (1999). Developing a logistics service quality scale. *Journal of Business logistics*, *20*(1), 9.

Morris, D. (1980). The physical quality of life index. *Development Digest*, *18*(1), 95–109.

Miller, D.W. & Starr, M.K. (1969), Executive Decisions and Operations Research, second edition, Prentice Hall, Englewood Cliffs, NJ.

New Economics Foundation (NEF, n.d.). *About the HPI.* Retrieved from: http://happyplanetindex.org/about/ on November 9, 2016.

Panayides, P.M., & So, M. (2005), Logistics service provider-client relationships. *Transportation Research Part E: Logistics and Transportation Review*, *41*(3), 179-200.

Perego, A., Perotti, S. & Mangiaracina, R. (2011), ICT for logistics and freight transportation: a literature review and research agenda. *International Journal of Physical Distribution & Logistics Management*, *41*(5), 457 – 483.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of applied psychology*, *88*(5), 879.

Portugal-Perez, A., & Wilson, J. S. (2012). Export performance and trade facilitation reform: Hard and soft infrastructure. *World Development*, *40*(7), 1295-1307.

Queiroz, C. A., & Gautam, S. (1992). *Road infrastructure and economic development: some diagnostic indicators* (Vol. 921). World Bank Publications.

Rao, P., & Holt, D. (2005), Do green supply chains lead to competitiveness and economic performance?. *International Journal of Operations & Production Management*, *25*(9), 898 – 916.

Razzaque, M.A. (1997). Challenges to logistics development: the case of a Third World country - Bangladesh*. International Journal of Physical Distribution & Logistics Management*, *27*(1), 18 – 38

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega (United Kingdom), 53*, 49-57.

Rezaei, J., Wang, J., & Tavasszy, L. (2015). Linking supplier development to supplier segmentation using Best Worst Method. *Expert Systems with Applications*, 9152-9164.

Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model, *Omega, 64*, 126-130.

Rezaei, J., Nispeling, T., Sarkis, J., & Tavasszy, L. (2016). A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method. *Journal of Cleaner Production*, *135*, 577-588.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*, New York: McGraw-Hill

Saaty, T.L. (1994). How to make a decision: the analytic hierarchy process, *Interfaces*, *24*(6), 19–43.

Sadaghiani, S., Ahmad, K. W., Rezaei, J., & Tavasszy, L. (2015, April). Evaluation of external forces affecting supply chain sustainability in oil and gas industry using Best Worst Method. *In Gas and Oil Conference (MedGO), 2015 International Mediterranean* (pp. 1-4). IEEE.

Sadeghi, S., Rasouli, N., & Jandaghi, G. (2016). Identifying and prioritizing contributing factors in supply chain competitiveness by using PLS-BWM techniques (case study: Payam shoes company). *World Scientific News, 49*(2), 117.

Salimi, N., & Rezaei, J. (2016). Measuring efficiency of university-industry Ph. D. projects using best worst method. *Scientometrics, 109*(3), 1911–1938.

Shamsuzzoha, A., & Helo, P.T. (2011). 'Real-time tracking and tracing system: potentials for the logistics network'. *Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management*. 22–24 January, Kuala Lumpur, Malaysia.

Sink, H. L., & Langley Jr, C. J. (1997). A managerial framework for the acquisition of third-party logistics services. *Journal of Business Logistics*, *18*(2), 163.

Solakivi, T., Ojala, L., Laari, S., Lorentz, H., Toyli, J., Malmsten, J., & Viherlehto, N. (2015). *Finland state of logistics 2014,* Turun Kauppakorkeakoulun Julkaisuja Sarja E-1:2015.

Souza, R. de, Goh, m., Gupta, S., & Lei, L. (2007). *An Investigation into the Measures Affecting the Integration of ASEAN's Priority Sectors (Phase 2): The Case of Logistics*, REPSF Project No. 06/001d Regional Economic Policy Support Facility, Association of Southeast Asian Nations, Manila

Srivanstava, S.K. (2007). Green supply-chain management: A state-of the-art literature review, *International Journal of Management Reviews,* DOI: 10.1111/j.1468-2370.2007.00202.x.

Torabi, S. A., Giahi, R., & Sahebjamnia, N. (2016). An enhanced risk assessment framework for business continuity management systems. *Safety Science*, *89*, 201-218.

Triantaphyllou, E. (2000). Multi-criteria decision making methods. In *Multi-criteria Decision Making Methods: A Comparative Study*, 5-21, USA:Springer

Triantaphyllou, E. (2013). *Multi-criteria decision making methods: a comparative study*, *44*, USA: Springer.

Triantaphyllou, E. & Mann, S.H. (1994). A computational evaluation of the original and revised analytic hierarchy process. *Computers & Industrial Engineering, 26*(3), 609-618, http://dx.doi.org/10.1016/0360-8352(94)90054-X.

Uca, N., Ince, H., & Sumen, H. (2016). The mediator effect of logistics performance index on the relation between corruption perception index and foreign trade volume. *European Scientific Journal*, *12*(25).

United nations development programme (1993). *Human development Report,* Oxford university press, New York.

Vaillancourt, A., & Haavisto, I. (2015). Country logistics performance and disaster impact. *Disasters*, *40*(2), 262-283.

Vickerman, R., Spiekermann, K. & Michael Wegener (1999). Accessibility and Economic Development in Europe. *Regional Studies*, *33*(1), 1-15, DOI:10.1080/00343409950118878

Widdowson, D. (2007). The changing role of Customs: evolution or revolution, *Worlds customs journal*, *1*(1), 31-38

Wold, S., Esbensen, K., & Geladi, P. (1987). Principal Component Analysis, *Chemometrics and Intelligent Laboratory Systems*, *2,* 37-52.

World Bank (2015a). Full GDP dataset 2015, retrieved from http://data.worldbank.org/indicator/NY.GDP.MKTP.CD.

World Bank (2015b) Full GNI dataset 2015, retrieved from http://data.worldbank.org/indicator/NY.GNP.PCAP.CD?year_high_desc=true.

World Bank (2016a). Full LPI data set 2016, retrieved from http://lpi.worldbank.org/

World Bank (2016b). Data Liner Connectivity Shipping Index (2016), Retrieved from http://databank.worldbank.org/data/reports.aspx?source=2&series=IS.SHP.GCNW.XQ&country=

World Bank Group (2016). *Doing Business 2017: Equal Opportunity for All*, Washington, DC: World Bank. DOI: 10.1596/978-1-4648-0948-4

World Economic Forum (2016a). *Global Competitiveness report 2016-2017,* World economic forum, Geneva, ISBN-13: 978-1-944835-04-0

World Economic Forum (2016b). GCI Dataset 2016, retrieved from www3.weforum.org/docs/GCR2014-15/GCI_Dataset_2006-07-2014-15.xlsx

Wu, H.J., & Dunn, S.C. (1995). Environmentally responsible logistics systems*, International Journal of Physical Distribution & Logistics Management,* 20 – 38.

Wu, Y. C. (2007). Contemporary logistics education: an international perspective. *International Journal of Physical Distribution & Logistics Management*, *37*(7), 504-528.

Xu, X. (2001). The SIR method: A superiority and inferiority ranking method for multiple criteria decision making. *European journal of operational research*, *131*(3), 587-602.

Yang, Q., Zhang, Z., You, X., & Chen, T. (2016). Evaluation and classification of overseas talents in China based on the BWM for intuitionistic relations, *Symmetry 2016, 8*(11), 1-18.

Yildiz, T. (2015). An empirical study on the relationship between logistics performance and education. *Business, Management and Education*, *13*(2), 249-275.

Zavadskas, E.K., Turskis, Z. & Kildienė, S. (2014). State of art surveys of overviews on MCDM/MADM methods, Technological and Economic Development of Economy, *20*(1), 165-179.

Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises, *Journal of Operations Management*, *22*, 265-289.

Appendix A: LPI ranking 2016 report

This appendix shows the complete LPI ranking from the 2016 LPI report (Arvis et al., 2016). The list shows each of the countries that was included in the ranking with their overall score and the scores on the six core components. The overall score is the average of the six scores on the components.

	overall LPI score		*Customs*	*Infrast-ructure*	*International shipments*	*Quality of services*	*Tracking & Tracing*	*Timeliness*
Country	***score***	***rank***	***score***	***score***	***score***	***score***	***score***	***score***
Germany	4,23	1	4,12	4,44	3,86	4,28	4,27	4,45
Luxembourg	4,22	2	3,90	4,24	4,24	4,01	4,12	4,80
Sweden	4,20	3	3,92	4,27	4,00	4,25	4,38	4,45
Netherlands	4,19	4	4,12	4,29	3,94	4,22	4,17	4,41
Singapore	4,14	5	4,18	4,20	3,96	4,09	4,05	4,40
Belgium	4,11	6	3,83	4,05	4,05	4,07	4,22	4,43
Austria	4,10	7	3,79	4,08	3,85	4,18	4,36	4,37
United Kingdom	4,07	8	3,98	4,21	3,77	4,05	4,13	4,33
Hong Kong SAR, China	4,07	9	3,94	4,10	4,05	4,00	4,03	4,29
United States	3,99	10	3,75	4,15	3,65	4,01	4,20	4,25
Switzerland	3,99	11	3,88	4,19	3,69	3,95	4,04	4,24
Japan	3,97	12	3,85	4,10	3,69	3,99	4,03	4,21
United Arab Emirates	3,94	13	3,84	4,07	3,89	3,82	3,91	4,13
Canada	3,93	14	3,95	4,14	3,56	3,90	4,10	4,01
Finland	3,92	15	4,01	4,01	3,51	3,88	4,04	4,14
France	3,90	16	3,71	4,01	3,64	3,82	4,02	4,25
Denmark	3,82	17	3,82	3,75	3,66	4,01	3,74	3,92
Ireland	3,79	18	3,47	3,77	3,83	3,79	3,98	3,94
Australia	3,79	19	3,54	3,82	3,63	3,87	3,87	4,04
South Africa	3,78	20	3,60	3,78	3,62	3,75	3,92	4,02
Italy	3,76	21	3,45	3,79	3,65	3,77	3,86	4,03
Norway	3,73	22	3,57	3,95	3,62	3,70	3,82	3,77
Spain	3,73	23	3,48	3,72	3,63	3,73	3,82	4,00
Korea, Rep,	3,72	24	3,45	3,79	3,58	3,69	3,78	4,03
Taiwan, China	3,70	25	3,23	3,57	3,57	3,95	3,59	4,25
Czech Republic	3,67	26	3,58	3,36	3,65	3,65	3,84	3,94
China	3,66	27	3,32	3,75	3,70	3,62	3,68	3,90
Israel	3,66	28	3,50	3,49	3,38	3,60	3,72	4,27
Lithuania	3,63	29	3,42	3,57	3,49	3,49	3,68	4,14
Qatar	3,60	30	3,55	3,57	3,58	3,54	3,50	3,83
Hungary	3,43	31	3,02	3,48	3,44	3,35	3,40	3,88
Malaysia	3,43	32	3,17	3,45	3,48	3,34	3,46	3,65
Poland	3,43	33	3,27	3,17	3,44	3,39	3,46	3,80
Turkey	3,42	34	3,18	3,49	3,41	3,31	3,39	3,75

India	3,42	35	3,17	3,34	3,36	3,39	3,52	3,74
Portugal	3,41	36	3,37	3,09	3,24	3,15	3,65	3,95
New Zealand	3,39	37	3,18	3,55	2,77	3,22	3,58	4,12
Estonia	3,36	38	3,41	3,18	3,07	3,18	3,25	4,08
Iceland	3,35	39	3,13	3,02	3,32	3,26	3,42	3,88
Panama	3,34	40	3,13	3,28	3,65	3,18	2,95	3,74
Slovak Republic	3,34	41	3,28	3,24	3,41	3,12	3,12	3,81
Kenya	3,33	42	3,17	3,21	3,24	3,24	3,42	3,70
Latvia	3,33	43	3,11	3,24	3,28	3,29	3,42	3,62
Bahrain	3,31	44	3,14	3,10	3,33	3,38	3,32	3,58
Thailand	3,26	45	3,11	3,12	3,37	3,14	3,20	3,56
Chile	3,25	46	3,19	2,77	3,30	2,97	3,50	3,71
Greece	3,24	47	2,85	3,32	2,97	2,91	3,59	3,85
Oman	3,23	48	2,76	3,44	3,35	3,26	3,09	3,50
Egypt, Arab Rep,	3,18	49	2,75	3,07	3,27	3,20	3,15	3,63
Slovenia	3,18	50	2,88	3,19	3,10	3,20	3,27	3,47
Croatia	3,16	51	3,07	2,99	3,12	3,21	3,16	3,39
Saudi Arabia	3,16	52	2,69	3,24	3,23	3,00	3,25	3,53
Kuwait	3,15	53	2,83	2,92	3,62	2,79	3,16	3,51
Mexico	3,11	54	2,88	2,89	3,00	3,14	3,40	3,38
Brazil	3,09	55	2,76	3,11	2,90	3,12	3,28	3,39
Malta	3,07	56	2,78	2,94	3,09	2,85	3,12	3,61
Botswana	3,05	57	3,05	2,96	2,91	2,74	2,89	3,72
Uganda	3,04	58	2,97	2,74	2,88	2,93	3,01	3,70
Cyprus	3,00	59	3,11	3,00	2,80	2,72	2,54	3,79
Romania	2,99	60	3,00	2,88	3,06	2,82	2,95	3,22
Tanzania	2,99	61	2,78	2,81	2,98	2,92	2,98	3,44
Rwanda	2,99	62	2,93	2,62	3,05	2,87	3,04	3,35
Indonesia	2,98	63	2,69	2,65	2,90	3,00	3,19	3,46
Vietnam	2,98	64	2,75	2,70	3,12	2,88	2,84	3,50
Uruguay	2,97	65	2,78	2,79	2,91	3,01	2,84	3,47
Argentina	2,96	66	2,63	2,86	2,76	2,83	3,26	3,47
Jordan	2,96	67	2,55	2,77	3,17	2,89	2,96	3,34
Pakistan	2,92	68	2,66	2,70	2,93	2,82	2,91	3,48
Peru	2,89	69	2,76	2,62	2,91	2,87	2,94	3,23
Brunei Darussalam	2,87	70	2,78	2,75	3,00	2,57	2,91	3,19
Philippines	2,86	71	2,61	2,55	3,01	2,70	2,86	3,35
Bulgaria	2,81	72	2,40	2,35	2,93	3,06	2,72	3,31
Cambodia	2,80	73	2,62	2,36	3,11	2,60	2,70	3,30
Ecuador	2,78	74	2,64	2,47	2,95	2,66	2,65	3,23
Algeria	2,77	75	2,37	2,58	2,80	2,91	2,86	3,08
Serbia	2,76	76	2,50	2,49	2,63	2,79	2,92	3,23
Kazakhstan	2,75	77	2,52	2,76	2,75	2,57	2,86	3,06
Bahamas, The	2,75	78	2,65	2,72	2,80	2,74	2,64	2,93
Namibia	2,74	79	2,65	2,76	2,69	2,63	2,52	3,19

Ukraine	2,74	80	2,30	2,49	2,59	2,55	2,96	3,51
Burkina Faso	2,73	81	2,55	2,67	2,73	2,78	2,49	3,13
Lebanon	2,72	82	2,73	2,64	2,84	2,45	2,75	2,86
El Salvador	2,71	83	2,37	2,25	2,82	2,66	2,78	3,29
Mozambique	2,68	84	2,49	2,24	3,06	2,44	2,75	3,04
Guyana	2,67	85	2,40	2,24	2,66	2,66	2,90	3,12
Morocco	2,67	86	2,22	2,46	3,09	2,59	2,34	3,20
Bangladesh	2,66	87	2,57	2,48	2,73	2,67	2,59	2,90
Ghana	2,66	88	2,46	2,48	2,71	2,54	2,52	3,21
Costa Rica	2,65	89	2,33	2,32	2,89	2,55	2,77	2,98
Nigeria	2,63	90	2,46	2,40	2,43	2,74	2,70	3,04
Dominican Republic	2,63	91	2,39	2,29	2,67	2,68	2,63	3,06
Togo	2,62	92	2,49	2,24	2,62	2,46	2,60	3,24
Moldova	2,61	93	2,39	2,35	2,60	2,48	2,67	3,16
Colombia	2,61	94	2,21	2,43	2,55	2,67	2,55	3,23
Côte d'Ivoire	2,60	95	2,67	2,46	2,54	2,62	2,62	2,71
Iran, Islamic Rep,	2,60	96	2,33	2,67	2,67	2,67	2,44	2,81
Bosnia and Herzegovina	2,60	97	2,69	2,61	2,28	2,52	2,56	2,94
Comoros	2,58	98	2,63	2,36	2,58	2,60	2,44	2,82
Russian Federation	2,57	99	2,01	2,43	2,45	2,76	2,62	3,15
Niger	2,56	100	2,59	2,22	2,63	2,50	2,35	3,02
Paraguay	2,56	101	2,38	2,45	2,58	2,69	2,30	2,93
Nicaragua	2,53	102	2,48	2,50	2,50	2,55	2,47	2,68
Sudan	2,53	103	2,23	2,20	2,57	2,36	2,49	3,28
Maldives	2,51	104	2,39	2,57	2,34	2,44	2,49	2,88
Papua New Guinea	2,51	105	2,55	2,32	2,46	2,35	2,58	2,78
Macedonia, FYR	2,51	106	2,21	2,58	2,45	2,36	2,32	3,13
Burundi	2,51	107	2,02	1,98	2,42	2,46	2,68	3,45
Mongolia	2,51	108	2,39	2,05	2,37	2,31	2,47	3,40
Mali	2,50	109	2,45	2,30	2,48	2,46	2,36	2,93
Tunisia	2,50	110	1,96	2,44	2,33	2,59	2,67	3,00
Guatemala	2,48	111	2,47	2,20	2,41	2,30	2,46	2,98
Honduras	2,46	112	2,21	2,04	2,58	2,44	2,53	2,91
Myanmar	2,46	113	2,43	2,33	2,23	2,36	2,57	2,85
Zambia	2,43	114	2,25	2,26	2,51	2,42	2,36	2,74
Benin	2,43	115	2,20	2,39	2,55	2,47	2,23	2,69
Solomon Islands	2,42	116	2,60	2,21	2,28	2,43	2,18	2,76
Albania	2,41	117	2,23	1,98	2,48	2,48	2,15	3,05
Uzbekistan	2,40	118	2,32	2,45	2,36	2,39	2,05	2,83
Jamaica	2,40	119	2,37	2,23	2,44	2,31	2,38	2,64
Belarus	2,40	120	2,06	2,10	2,62	2,32	2,16	3,04
Trinidad and Tobago	2,40	121	2,38	2,34	2,31	2,28	2,28	2,79
Venezuela, RB	2,39	122	1,99	2,35	2,47	2,34	2,48	2,71

Montenegro	2,38	123	2,22	2,07	2,56	2,31	2,37	2,69
Nepal	2,38	124	1,93	2,27	2,50	2,13	2,47	2,93
Congo, Rep,	2,38	125	2,00	2,60	2,37	2,26	2,48	2,57
Ethiopia	2,38	126	2,60	2,12	2,56	2,37	2,18	2,37
Congo, Dem, Rep,	2,38	127	2,22	2,01	2,33	2,33	2,37	2,94
Guinea-Bissau	2,37	128	2,44	1,91	2,57	2,07	2,41	2,74
Guinea	2,36	129	2,28	2,01	2,38	2,54	2,54	2,38
Georgia	2,35	130	2,26	2,17	2,35	2,08	2,44	2,80
Cuba	2,35	131	2,38	2,31	2,31	2,25	2,31	2,51
Senegal	2,33	132	2,31	2,23	2,25	2,39	2,15	2,61
São Tomé and Principe	2,33	133	2,24	2,12	2,26	2,42	2,14	2,75
Djibouti	2,32	134	2,37	2,30	2,48	1,96	2,09	2,69
Bhutan	2,32	135	2,21	1,96	2,50	2,30	2,20	2,70
Fiji	2,32	136	2,33	2,25	2,21	2,25	2,25	2,60
Libya	2,26	137	1,88	2,04	2,40	2,50	1,85	2,83
Bolivia	2,25	138	1,97	2,11	2,40	1,90	2,31	2,79
Angola	2,24	139	1,80	2,13	2,37	2,31	2,21	2,59
Turkmenistan	2,21	140	2,00	2,34	2,37	2,09	1,84	2,59
Armenia	2,21	141	1,95	2,22	2,22	2,21	2,02	2,60
Liberia	2,20	142	2,07	2,01	2,22	2,07	2,07	2,73
Gabon	2,19	143	2,07	2,05	2,28	2,12	2,07	2,52
Eritrea	2,17	144	2,01	2,06	2,16	2,25	2,03	2,50
Chad	2,16	145	2,08	2,07	2,41	2,06	2,07	2,25
Kyrgyz Republic	2,16	146	1,80	1,96	2,10	1,96	2,39	2,72
Madagascar	2,15	147	2,33	2,12	2,17	1,93	2,01	2,35
Cameroon	2,15	148	2,09	2,21	1,98	2,32	2,04	2,29
Iraq	2,15	149	2,01	1,87	2,33	1,97	1,98	2,66
Afghanistan	2,14	150	2,01	1,84	2,38	2,15	1,77	2,61
Zimbabwe	2,08	151	2,00	2,21	2,08	2,13	1,95	2,13
Lao PDR	2,07	152	1,85	1,76	2,18	2,10	1,76	2,68
Tajikistan	2,06	153	1,93	2,13	2,12	2,12	2,04	2,04
Lesotho	2,03	154	1,91	1,96	1,84	2,16	1,92	2,35
Sierra Leone	2,03	155	1,91	2,07	2,31	1,85	1,74	2,23
Equatorial Guinea	1,88	156	1,88	1,50	1,89	1,75	1,89	2,32
Mauritania	1,87	157	2,14	1,54	2,00	1,74	1,54	2,14
Somalia	1,75	158	1,29	1,57	1,86	1,85	1,51	2,35
Haiti	1,72	159	1,70	1,47	1,81	1,68	1,56	2,02
Syrian Arab Republic	1,60	160	1,11	1,24	1,36	1,39	2,10	2,40

Appendix B: Questionnaires & Cover Letter

This appendix shows the message that was included in the e-mail to the approached experts at universities and research centres. It also contains the two different questionnaires that were sent to the university experts and the professionals.

Email sent to experts

Dear Sir/Madam,

I am currently conducting the research for my thesis at the Delft University of Technology to complete my Msc. program. For this research I need respondents that have experience in the field of logistics on an international level. You have been selected based on information found available online. The aim of my research will be the creation of a weighted Logistics Performance Index (w-LPI), based on the current LPI published each two years by the World Bank. I kindly ask you to fill in the following questionnaire, as it would be of great help in my research.

The LPI is a ranking of all the countries based on their logistics performance, judged by practitioners. The current LPI is composed by taking the average of the scores given on six components. Practitioners all over the world are asked to rate (between 1-5) countries on: Customs, Services quality, Infrastructure, Timeliness, Tracking & Tracing, and International shipments. However, these components might not be of equal importance for logistics performance. If that is the case, then the assignment of weights to these components give a beter representation of logistics performance.

The questionnaire will take about 5 minutes. Descriptions on how to fill in the questions are provided in the online questionnaire (link: http://www.surveygizmo.com/s3/3106756/w-LPI). Except for your nationality, no personal information will be required and all answers will be used for the report anonymously. If you have any questions, please feel free to email me.

Thank you in advance,

Wilco van Roekel
TU Delft
w.s.vanroekel@student.tudelft.nl

Questionnaire professionals

Page 1

Dear respondent,

Thank you for taking this questionnaire, it will take about 5 minutes to complete. Instructions for answering the questions will be provided in the question description. After finishing the questionnaire the result will be automatically saved and the window can be closed. The result will be used for the creation of a weighted Logistics Performance Index (w-LPI) as part of a research for the Delft University of Technology.

Kind regards,
Wilco van Roekel

Page 2

1. Which country do you or does your company operate from?

2. What are the 5 countries you or your company does business with the most?

The following questions concern the six core components of the LPI. The World Bank describes the six components as:
Customs - The efficiency of customs and border management clearance.
Infrastructure - The quality of trade and transport infrastructure.
Quality of services - The competence and quality of logistics services—trucking, forwarding, and customs brokerage.
Timeliness - The frequency with which shipments reach consignees within scheduled or expected delivery times.
Tracking & Tracing - The ability to track and trace consignments.
Ease of arranging shipments - The ease of arranging competitively priced shipments.

3. To Evaluate the overall logistics performance of a country, what is the MOST important criterion?

Component	Most important
Customs	
Infrastructure	
Services	
Tracking & Tracing	
Timeliness	
International shipments	

4. To Evaluate the overall logistics performance of a country, what is the LEAST important criterion?

Component	Least important
Customs	
Infrastructure	
Services	
Tracking & Tracing	
Timeliness	
International shipments	

Page 3

You have selected _____ as the MOST important criterion.

Description: Select a number between 1 and 9 to indicate the preference of _____ over the other criteria. Selecting a 1 meaning that the criterion is equally important as _____, and selecting a 9 meaning _____ is extremely more important than the criterion.

Criteria	1	2	3	4	5	6	7	8	9
Customs									
Infrastructure									
Services									
Tracking & Tracing									
Timeliness									
International shipments									

Page 4

You have selected _____ as the LEAST important criterion.

Description: Select a number between 1 and 9 to indicate the preference of the other criteria over _____. Selecting a 1 meaning the criterion is equally important as _____ , and selecting a 9 meaning the criterion is extremely more important than _____.

Criteria	1	2	3	4	5	6	7	8	9
Customs									
Infrastructure									
Services									
Tracking & Tracing									
Timeliness									
International shipments									

Page 5

Thank you for finishing this survey, the result will be used for the report anonymously.

End of Questionnaire

Questionnaire University experts

Page 1

Dear respondent,

Thank you for taking this questionnaire, it will take about 5 minutes to complete. Instructions for answering the questions will be provided in the question description. After finishing the questionnaire the result will be automatically saved and the window can be closed. The result will be used for the creation of a weighted Logistics Performance Index (w-LPI) as part of a research for the Delft University of Technology.

Kind regards,
Wilco van Roekel

Page 2

1. In which country are you living?

2. What is your nationality?

3. On which five countries do you have the most information on their logistics performance?

The following questions concern the six core components of the LPI. The World Bank describes the six components as:
Customs - The efficiency of customs and border management clearance.
Infrastructure - The quality of trade and transport infrastructure.
Quality of services - The competence and quality of logistics services—trucking, forwarding, and customs brokerage.
Timeliness - The frequency with which shipments reach consignees within scheduled or expected delivery times.
Tracking & Tracing - The ability to track and trace consignments.
Ease of arranging shipments - The ease of arranging competitively priced shipments.

4. To Evaluate the overall logistics performance of a country, what is the MOST important criterion?

Component	Most important
Customs	
Infrastructure	
Services	
Tracking & Tracing	
Timeliness	
International shipments	

5. To Evaluate the overall logistics performance of a country, what is the LEAST important criterion?

Component	Least important
Customs	
Infrastructure	
Services	
Tracking & Tracing	
Timeliness	
International shipments	

Page 3

You have selected _____ as the MOST important criterion.

Description: Select a number between 1 and 9 to indicate the preference of _____ over the other criteria. Selecting a 1 meaning that the criterion is equally important as _____, and selecting a 9 meaning _____ is extremely more important than the criterion.

Criteria	1	2	3	4	5	6	7	8	9
Customs									
Infrastructure									
Services									
Tracking & Tracing									
Timeliness									
International shipments									

Page 4

You have selected _____ as the LEAST important criterion.

Description: Select a number between 1 and 9 to indicate the preference of the other criteria over _____. Selecting a 1 meaning the criterion is equally important as _____ , and selecting a 9 meaning the criterion is extremely more important than _____.

Criteria	1	2	3	4	5	6	7	8	9
Customs									
Infrastructure									
Services									
Tracking & Tracing									
Timeliness									
International shipments									

Page 5

Thank you for finishing this survey, the result will be used for the report anonymously.

End of Questionnaire

Appendix C: Weights per respondent

This appendix shows the weights for each of the respondents that were acquired using the BWM. The consistency indicator Ksi is also presented. The final weights are the average of the weights found in this table. The weights are in the following order: Customs (C), Infrastructure (I), Services (S), Timeliness (T), Tracking & tracing (TT), and ease of arranging international shipments (IS).

Resp #	*w(C)*	*w(I)*	*w(S)*	*w(T)*	*w(TT)*	*w(IS)*	*Ksi*
LPI 1	0,166667	0,404762	0,166667	0,119048	0,047619	0,095238	0,071429
LPI 2	0,113924	0,151899	0,227848	0,303797	0,050633	0,151899	0,151899
LPI 3	0,2	0,333333	0,133333	0,133333	0,133333	0,066667	0,066667
LPI 4	0,382075	0,188679	0,113208	0,09434	0,033019	0,188679	0,183962
LPI 5	0,039063	0,132813	0,296875	0,199219	0,132813	0,199219	0,101563
LPI 6	0,142857	0,214286	0,214286	0,285714	0,035714	0,107143	0,142857
LPI 7	0,101695	0,101695	0,514124	0,045198	0,118644	0,118644	0,19774
LPI 8	0,129151	0,472325	0,103321	0,103321	0,0492	0,142681	0,04428
LPI 9	0,057971	0,095652	0,336232	0,191304	0,127536	0,191304	0,046377
LPI 10	0,135593	0,20339	0,237288	0,20339	0,084746	0,135593	0,033898
LPI 11	0,081301	0,162602	0,243902	0,341463	0,04878	0,121951	0,146341
LPI 12	0,039378	0,373359	0,10209	0,255226	0,170151	0,059796	0,137093
LPI 13	0,114094	0,114094	0,496644	0,114094	0,114094	0,04698	0,073826
LPI 14	0,36715	0,26409	0,122383	0,122383	0,032206	0,091787	0,10306
LPI 15	0,233766	0,155844	0,155844	0,363636	0,058442	0,032468	0,103896
LPI 16	0,070111	0,214022	0,273063	0,140221	0,02952	0,273063	0,066421
LPI 17	0,216867	0,337349	0,144578	0,144578	0,108434	0,048193	0,096386
LPI 18	0,2	0,2	0,142857	0,142857	0,2	0,114286	0,085714
LPI 19	0,1875	0,1875	0,276786	0,1875	0,035714	0,125	0,098214
LPI 20	0,166205	0,099723	0,404432	0,124654	0,166205	0,038781	0,094183
LPI 21	0,097561	0,195122	0,439024	0,073171	0,146341	0,04878	0,146341
LPI 22	0,149733	0,385027	0,224599	0,112299	0,074866	0,053476	0,064171
LPI 23	0,3125	0,3125	0,1875	0,09375	0,03125	0,0625	0,0625
LPI 24	0,332847	0,029197	0,20146	0,20146	0,10073	0,134307	0,070073
LPI 25	0,053775	0,375329	0,375329	0,096795	0,029631	0,06914	0,108648
LPI 26	0,027972	0,146853	0,216783	0,272727	0,188811	0,146853	0,076923
LPI 27	0,174847	0,251534	0,251534	0,174847	0,116564	0,030675	0,09816
LPI 28	0,2	0,2	0,15	0,2	0,15	0,1	0,1
LPI 29	0,12094	0,103663	0,530753	0,103663	0,103663	0,037319	0,194886
LPI 30	0,1079	0,531792	0,1079	0,1079	0,052023	0,092486	0,115607
LPI 31	0,123779	0,258958	0,371336	0,092834	0,123779	0,029316	0,112378
LPI 32	0,221258	0,147505	0,329718	0,147505	0,110629	0,043384	0,112798
LPI 33	0,097222	0,194444	0,194444	0,291667	0,027778	0,194444	0,097222
LPI 34	0,026667	0,12	0,213333	0,213333	0,213333	0,213333	0,093333
LPI 35	0,137374	0,307071	0,10303	0,206061	0,040404	0,206061	0,105051
LPI 36	0,166667	0,166667	0,166667	0,166667	0,166667	0,166667	5,55E-17
LPI 37	0,368008	0,115948	0,368008	0,066256	0,051532	0,030247	0,095783
LPI 38	0,098244	0,542477	0,098244	0,087328	0,042715	0,130992	0,243474

LPI 39	0,177127	0,438968	0,132846	0,106276	0,038506	0,106276	0,092414
LPI 40	0,168142	0,241888	0,029499	0,336283	0,112094	0,112094	0,094395
LPI 41	0,102518	0,032374	0,136691	0,318345	0,205036	0,205036	0,091727
LPI 42	0,230769	0,25641	0,153846	0,153846	0,153846	0,051282	0,205128
LPI 43	0,166667	0,166667	0,259259	0,259259	0,111111	0,037037	0,074074
LPI 44	0,069178	0,392775	0,161414	0,242121	0,096849	0,037663	0,091468
LPI 45	0,03645	0,108674	0,16301	0,093149	0,490044	0,108674	0,161998
LPI 46	0,10757	0,573705	0,083665	0,083665	0,10757	0,043825	0,179283
LPI 47	0,037078	0,093437	0,363367	0,155729	0,116796	0,233593	0,103819
LPI 48	0,119177	0,071506	0,178765	0,292524	0,045504	0,292524	0,065005
LPI 49	0,033212	0,091664	0,378612	0,152773	0,11458	0,22916	0,079708
LPI 50	0,081633	0,183673	0,306122	0,183673	0,122449	0,122449	0,061224
LPI 51	0,032258	0,153226	0,201613	0,153226	0,306452	0,153226	0,104839
LPI 52	0,136808	0,525244	0,114007	0,09772	0,040717	0,085505	0,158795
LPI 53	0,243147	0,162098	0,038141	0,081049	0,414779	0,060787	0,071514
LPI 54	0,04222	0,084439	0,135103	0,135103	0,506634	0,096502	0,168878
LPI 55	0,043611	0,401221	0,165722	0,165722	0,124291	0,099433	0,095944
LPI 56	0,083019	0,249057	0,162264	0,237736	0,018868	0,249057	0,086792
LPI 57	0,075933	0,519974	0,113899	0,113899	0,039617	0,136679	0,16342
LPI 58	0,227273	0,227273	0,333333	0,090909	0,030303	0,090909	0,121212
LPI 59	0,196429	0,130952	0,130952	0,315476	0,029762	0,196429	0,077381
LPI 60	0,15	0,05	0,075	0,425	0,15	0,15	0,175
LPI 61	0,196429	0,315476	0,196429	0,130952	0,029762	0,130952	0,077381
LPI 62	0,053435	0,085496	0,109924	0,109924	0,096183	0,545038	0,224427
LPI 63	0,148148	0,355556	0,355556	0,055556	0,055556	0,02963	0,088889
LPI 64	0,178964	0,249608	0,33438	0,119309	0,089482	0,028257	0,10832
LPI 65	0,13486	0,514519	0,089906	0,101145	0,115594	0,043976	0,294639
LPI 66	0,326902	0,294748	0,182208	0,091104	0,032154	0,072883	0,069668
LPI 67	0,216606	0,108303	0,281588	0,216606	0,032491	0,144404	0,151625
LPI 68	0,135802	0,135802	0,061728	0,234568	0,296296	0,135802	0,17284
LPI 69	0,080189	0,35967	0,324292	0,100236	0,035377	0,100236	0,076651
LPI 70	0,323051	0,323051	0,070667	0,126192	0,056085	0,100953	0,181716
LPI 71	0,435484	0,145161	0,145161	0,145161	0,032258	0,096774	0,145161
LPI 72	0,021605	0,246914	0,246914	0,246914	0,049383	0,188272	0,058642
LPI 73	0,105634	0,512324	0,047535	0,105634	0,105634	0,123239	0,227113
LPI 74	0,329472	0,030888	0,252252	0,063063	0,072072	0,252252	0,175032
LPI 75	0,12717	0,399677	0,25434	0,101736	0,032297	0,08478	0,109003
LPI 76	0,236842	0,236842	0,236842	0,236842	0,026316	0,026316	0
LPI 77	0,197044	0,039409	0,098522	0,472906	0,073892	0,118227	0,118227
LPI 78	0,105263	0,210526	0,210526	0,105263	0,210526	0,157895	0,105263
LPI 79	0,061889	0,139251	0,476384	0,139251	0,139251	0,043974	0,080619
LPI 80	0,036237	0,250032	0,166688	0,071438	0,062508	0,413097	0,086968
LPI 81	0,130435	0,26087	0,188406	0,130435	0,028986	0,26087	0,072464
LPI 82	0,076923	0,246154	0,153846	0,307692	0,153846	0,061538	0,061538
LPI 83	0,246753	0,142857	0,142857	0,181818	0,038961	0,246753	0,103896
LPI 84	0,289474	0,052632	0,184211	0,236842	0,078947	0,157895	0,131579

LPI 85	0,082927	0,614634	0,082927	0,082927	0,082927	0,053659	0,131707
LPI 86	0,093103	0,093103	0,589655	0,093103	0,093103	0,037931	0,248276
LPI 87	0,187387	0,425225	0,187387	0,036036	0,07027	0,093694	0,136937
LPI 88	0,028056	0,088176	0,332665	0,220441	0,11022	0,220441	0,108216
LPI 89	0,589655	0,093103	0,093103	0,037931	0,093103	0,093103	0,248276
LPI 90	0,185923	0,446215	0,139442	0,111554	0,037185	0,079681	0,111554
LPI 91	0,12963	0,496914	0,111111	0,111111	0,054012	0,097222	0,280864
LPI 92	0,258389	0,060403	0,04698	0,211409	0,211409	0,211409	0,16443
LPI 93	0,52641	0,102059	0,048344	0,102059	0,102059	0,119069	0,188004
LPI 94	0,121739	0,104348	0,091304	0,121739	0,043478	0,517391	0,213043
LPI 95	0,195652	0,195652	0,195652	0,021739	0,195652	0,195652	0
LPI 96	0,107185	0,46447	0,160778	0,107185	0,128622	0,031759	0,178642
LPI 97	0,126761	0,084507	0,356808	0,206573	0,056338	0,169014	0,150235
LPI 98	0,152201	0,084556	0,535523	0,084556	0,034449	0,108715	0,225483
LPI 99	0,127962	0,21327	0,21327	0,21327	0,018957	0,21327	0,042654
LPI 100	0,235378	0,117689	0,363766	0,156919	0,032097	0,094151	0,10699
LPI 101	0,27112	0,381139	0,13556	0,090373	0,090373	0,031434	0,1611
LPI 102	0,117284	0,487654	0,117284	0,117284	0,04321	0,117284	0,098765
LPI 103	0,306818	0,215909	0,125	0,125	0,193182	0,034091	0,090909
LPI 104	0,086406	0,024194	0,300691	0,300691	0,144009	0,144009	0,131336
LPI 105	0,112863	0,366177	0,331064	0,035113	0,064493	0,09029	0,085274
LPI 106	0,146853	0,195804	0,440559	0,083916	0,083916	0,048951	0,146853
LPI 107	0,153846	0,230769	0,346154	0,115385	0,115385	0,038462	0,115385