USABILITY OF PERFORMANCE INDICATORS OF LOGISTICS INFRASTRUCTURE AVAILABILITY IN SUPPLY CHAIN DESIGNING

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Abstract

Level of supply chain performance is highly influenced by capability of logistics infrastructure as well as created network of activities and services operating at global, national, and regional scales. Dynamic environment can significantly influence expected availability and real capability of logistics infrastructure. The article represents possible analytical approach to supply chain design and identification of factors influencing logistics performance. In addition, the paper deals with application of key indicators and indexes to the classification of individual national levels of available logistics infrastructure. Clustering algorithms (k-means and hierarchical) and classification methods (decision trees, kNN and logistic regression) have been used for classification model construction and results evaluation. Furthermore, possible application for forecasting logistics infrastructure availability has been discussed.

Key words: logistic infrastructure, logistic performance index (LPI), country classification, clustering algorithms

1. INTRODUCTION

Logistics represents a close link between limited national resources and end-users, whether private, public or non-governmental entities. From the point of view of the armed forces, these factors are significant because they affect the ability of civilian entities, outsourcing companies and contractors to fulfil contractual relationships in favour of supported armed forces (Gontarczyk et al., 2016). For this reason, it is appropriate, from the point of view of the armed forces, to follow trends in the development of the growth of the global interconnection of national economies, which exert pressure on increasing competition, not only between the elements of logistic chains but also between the whole chains. Increase in the complexity of logistic chains is negatively influenced by the extent of the influence of a large number of influencing factors and their interrelations and interactions (Foltin et al., 2015). At the same time, there have been dynamic changes in the logistic chain implementation environment, when the intensity of existing factors has been changing and new factors, such as the expectations of final consumers (Suchánek & Králová, 2015), have occurred.

In addition to regional security changes, the pace of global trade growth is slowing down. In comparing the 2005-2010 and 2010-2015 periods, the growth of export and import in developed economies fell from 4.10% to 0.80%, in the case of transition economies from 9.44% to -2.68% and in the developing economies from 9.21% to 2.61% (UNCTAD STAT, 2016). Similarly, the average yearly financial volume of import into 28 EU countries decreased in 2003-2007 from 9.34% to 5.63% in 2008-2012 and further to 0.76% in 2013-2017 periods, based on EU Trade Help Desk, 2018. In the case of the USA, there is a decrease in average yearly import volumes of -0.29% in the 2012-2016 period (BusinessInfo.cz, 2018).

The pressure on deepening competition and changes in the security and economic environment creates room for risk factors influence, whether caused by intra-chain elements or distortions caused by external factors acting throughout the distribution chain as a whole (Manuj, Mentzer, 2008). This dynamics of the environment puts greater demand on the integration of logistical abilities as well as capabilities of logistics infrastructure elements.

The accompanying phenomenon of the effect of influencing factors is the current existence of a wide range of information that is continually collected by various organizations, agencies and entities with different goals and purposes. The methodology of collecting this information is also inconsistent, based on the primary purpose of the data usage (Mayer-Schönberger & Cukier, 2014). Simultaneously with the development of mobile and communication applications, the possibilities of secondary or tertiary usage of the originally acquired data which has already fulfilled its primary purpose have been increasing.

There are wide spectrum of publicly open indicators and composite indexes which can be used to monitor particular social, economic, security or environmental changes. These indicators describe the effects of influencing environment on logistics vertices and edges, their availability and long-term sustainability. For the needs of both public administration and armed forces, the understanding of the effect of influencing factors enables better understanding of the capabilities of civilian suppliers and promoters, their overall functioning and the possibilities of identifying

the trends, both in the possibilities of the logistics capabilities usage and available infrastructure, as well as in the logistics services usage.

The article is structured as follows: In the first part, research into the available scientific resources and approaches to identify potential disruptions to logistic chains has been carried out. The second part describes methodological definition of the chosen approach and formulation of limitations to the research carried out. The third part presents results of the research performed. Discussion and conclusion summarize the results of the study.

2. CURRENT APPROACHES TO IDENTIFYING AVAILABLE LOGISTICS INFRASTRUCTURES

In the global economy, individual entities continuously seek making the offered products and services more efficient, either by increasing the level of outsourcing, shortening product lifecycles as well as provided services. There is a competition in time and place which in turn results in the growing competition between the whole logistic chains (Foltin, Sedlačík, Šikolová, 2012).

For this reason, security and sustainability of the logistic chain functionality, i.e. the functionality of the individual elements and links of the logistic chain, is the basis not only for maintaining the business continuity of processes performed but also for the long-term sustainability of the processes and further development of the company (Urban & Hošková-Mayerová, 2017). From the point of view of the continuity of activities, this information is also important for ensuring the functionality of critical infrastructure of the evaluated country, especially transport and energy one (Rehak & Novotny, 2016). For individual countries, nodes and edges of logistic chains located on their territory, basic characteristics which tell us about the level of functionality of the given node (or element of the logistic chain), the level of services provided within it, but also the performance and overall efficiency of the corresponding element, can be defined while subsequently identify available sources of the necessary information.

2.1 Information on the Elements and Links of the Logistic Chains

The availability of information about the elements and links of logistic chains is a basic prerequisite for the functionality and reliability of the chain. In terms of the analysis of the logistic chain functionality, attention is paid to the nodes (i.e. elements of the logistic chain) and to the edges (i.e. links between individual elements of the logistic chain) which together create an available and usable logistic infrastructure.

As the edges of the logistic chain are considered:

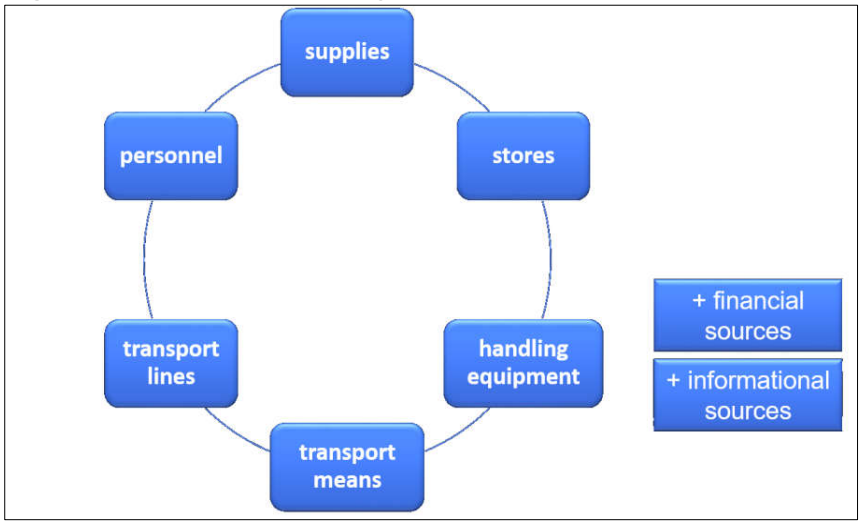
- Geographical links between individual logistic nodes, depending on the type of the transport chosen - they may be routes (or connections) between airports, ports, railway stations, road transhipment sites, etc.;
- Own transport infrastructure, i.e. roads, railways, air corridors, maritime routes, etc.

From the point of view of available and usable logistics infrastructure as logistics nodes are considered:

- Places where the mode of transport changes, i.e. there is a transhipment from one mode of transport to another (e.g. from sea to rail, from air to road, etc.);
- Places where the material is handled and stored (for short or long-term) and other material operations (assembly, technological refinement, etc.) are carried out;
- Places where, for predefined and defined reasons, there is a slowdown or stopping of logistic flows, in particular the flow of material (e.g. customs procedure, border check, etc.).

The impact of influencing factors on the individual nodes and edges, the extent of their impact and the way in which they affect the performance of the chain as a whole, is decisive. For each node, information about the sub-elements existing within the logistic node is of interest, especially those which can affect its functionality and overall efficiency. For more details see Figure 1.

Figure 1. Elements of the logistic chain



Source: author's own

Data on stocks, stores, handling and transport means, transport/transfer routes, as well as staff, along with financial and information resources, are crucial for individual logistic node. For individual types of nodes and edges, the weight of the component significance is different, so these indicators should be monitored separately for individual node. The total capacity level is then the sum of the regional/national capacities and the usable infrastructure level, consisting of the sum of the sub-capacities of individual elements (nodes and edges) (Foltin, et al., 2017).

2.2 Available Resources

Information represents the basis for planning and management. Its importance and usability grows with the expansion of mobile applications and the interconnection of information systems. For individual international logistic chains, their nodes and used modes of transport, etc., in terms of available information, three levels are being monitored:

1) Characteristics of the particular node or edge, i.e. individual capacity, node/edge efficiency, long-term sustainability of given capacities, etc.;
2) Aggregate indicators of the corresponding region or country logistical performance;
3) Characteristics of a given international logistic chain, i.e. its nodes and edges across regions or national states.

However, large distances between individual elements of logistic chains are disturbed by the whole range of influencing factors, both internal (endogenous risk factors) and external (exogenous risk factors) (Tang, 2006). It is problematic to determine the degree of influence of individual factors and the extent of disturbance of the logistic chain which they can cause (Loveček et al., 2017). Typically, the questionnaire surveys are used to determine the probable extent of possible disturbance (Business Continuity Institute, 2017). However, the relevance and validity of these questionnaires is limited to a narrow circle of respondents, which does not allow for identifying a possible disruption of the logistic chain as a whole (Roos & Kliemann Neto, 2017). In order to gain greater relevance of the information on the influencing factors observed and potential disruptions to the functionality of the logistics infrastructure, combinations of different approaches, e.g. quantitative evaluation is used (Rehak et al., 2016) to link primary data obtained by the questionnaire surveys complemented by selected indicators that can characterize the country or the region through which logistic chains goes through. For the combination of questionnaire survey and macroeconomic indicators, Katri Kauppie‘s team uses interconnection of primary questionnaire data with the secondary country level risk indexes (Kauppie et al., 2016). Questionnaire surveys are also used to investigate security risks for individual entities within the distribution chains (Ekwall & Lantz, 2017). The use of questionnaire surveys, however, carries risks of lower relevance and at the same time difficult collecting and evaluating of questionnaire data. For this reason, it is appropriate to look for alternative approaches that would minimize disadvantages of questionnaire surveys, e.g. the use of available indexes and indicators with appropriate predictive value.

Generally, indexes allow maintaining an overview, creating possible comparability and monitoring changes, however, they are generally limited to one particular problem. For this reason, the effort to increase the predictive value of the index by combining individual indexes into the aggregate indicator has been made. Regarding the availability of indexes and indicators about the infrastructure condition, three main types are generally maintained:

1) Mandatory (obligatory due to regulations, legislation or evidence of performance carried out);
2) Survey (optionally-compulsory, management of which is indirectly required, e.g. due to the demonstration of reported performance);
3) Voluntary (kept for internal or development purposes)

The indicative value and the relevance level of indexes and composite indicators are derived from the primary institution that creates the corresponding index or indicator. The general characteristics are presented in Table 1.

Table 1. Access to the institutional definition of indexes and composite indicators created

Type of organization/ institution	Reason	Example of organization/ institution	Example of index/indicator
International and multinational organizations	Usually for statistical and reporting purposes	- UN - EU - OECD - World Bank	- Human Development Index (HDI) - Retail Trade Index (RTI) - Business Confidence Index (BCI) - Logistics Performance Index (LPI)
National and governmental organizations	Due to mandatory monitoring and management of a particular area, fulfilment of development goals, or sector regulation	- Czech Statistical Office - National Agency of Waterway Transportation (ANTAQ), Brazil	- Producer Price Indexes (PPI) - Environmental Performance Index (IDA)
Private entities, NGOs and agencies	Primary an overview, function, keeping an overview of the development in particular area or industry, reporting, promotion, marketing and public relations	- DHL - SIPRI	- Global Connectivity index - Global Peace Index (GPI)

Source: Modified based on WebPages of UN, EU, OECD, World Bank, Czech Statistical Office, National Agency of Waterway Transportation, DHL and SIPRI.

Another problem with the use of indexes and indicators is complicated monitoring of time and pace of change (positive or negative) which has potential to cause disruption to the logistic chain and related logistics costs, decrease in the reliability of supply chains as well as decrease in predictability (Munim, Schramm, 2018). For this reason, key aspects of individual indexes, respectively following aggregate indicators, comprise the frequency with which they are continually updated. In the case of key elements of the logistics infrastructure, an annual or two-year update is sufficient, but in the case of disturbances to the nodes or edges of the distribution chain, information in real or near real time with the least delay possible can be considered to be ideal information.

2.3 Possible use of Logistics Performance Index (LPI)

One of the appropriate sources of information on the available logistics infrastructure can be the Logistics Performance Index (LPI) compiled by the World Bank. The index is also based on a questionnaire survey of a higher number of respondents; for example, in 2016 there were more than 5,000 ratings of more than 1,000 freight forwarders and logistics professionals in 147 countries (Arvis et al.,

2016). The World Bank monitors the following components by the compilation (The LPI methodology, 2015):

- The efficiency of customs and border management clearance;
- The quality of trade and transport infrastructure;
- The ease of arranging competitively priced shipments;
- The competence and quality of logistics services;
- The ability to track and trace consignments;
- The frequency with which shipments reaches consignees within scheduled or expected delivery times.

In spite of the wide scope of LPIs, it is not a diagnostic tool, just a state indicator that allows comparison between different countries and regions. It can also be considered as a logistic performance metric or a possible approach to dividing countries into groups that share the same features of available logistics infrastructure. On the other hand, however, the LPI was compiled in 2007, 2010, 2012, 2014 and 2016, with the number of evaluated countries increasing.

However, the possibility of using LPI to predict future development of logistics infrastructure availability can be seen as limited, mainly due to the low frequency of the LPI update and the gradual increase in the number of evaluated countries. The two-year interval also does not allow taking account of extreme short-term fluctuations such as natural disasters, short armed conflicts or a short-term humanitarian problem (such as the occurrence of a highly contagious disease such as Ebola or Avian flu).

3. OBJECTIVES, METHODS AND LIMITATIONS

The objective of the article is to draw attention to the use of indexes and indicators to analyze the level of suitability and availability of the logistics infrastructure in the countries or regions, together with simultaneous impact of the factors influencing their availability and usability, including their potential use for prediction of the future development of the effect of the influencing factors, and thus supporting planning and management of logistics support. Primary objective is to seek appropriate and available information resources allowing the use of indexes and composite indicators based on available long- time series for at least 20 years.

The underlying assumption is that the selection and application of suitable indexes and indicators makes it possible to create a classification of the countries according to the available logistics infrastructure, based on indexes and indicators built on long-time series, which will subsequently allow for a prediction of future development within the horizon of 6 to 12 months applying the decision tree method of a suitable approach at creating clusters of the evaluated countries.

From the methodological point of view, the study is based on available indexes and indicators that allow similar assessment of logistics infrastructure as LPI, however, over a time period exceeding the 20-year horizon. Alternative indexes and indicators which can provide derived information on the level of the economy and market with a possible link to the available logistics infrastructure of the individual

evaluated countries, have been chosen. Based on the assessment carried out, the countries are grouped in the clusters with similar levels of logistics infrastructure. For the primary data, the following World Bank indicators which are available for most African countries for the 1988-2014 period, have been selected (The World Bank, 2018):

- Total population (the total population of the corresponding country);
- Rural population (the total population living outside urban areas);
- GDP per capita;
- Military expenditures per capita.

Based on these indexes, clusters of the countries with similar characteristics have been created.

Subsequently, alternative sources of information available from UNCTAD Statistics have been tested, looking for a possible tendency of development similar to that of the primary indexes and indicators. These are the following indexes:

- Main religion (percentage of the nation's population professing the official main religion);
- Age range 15-24 (percentage of the country's population aged 15-24);
- Agricultural land (percentage of the territory of the corresponding country where the agricultural production takes place).

According to the scope of available indexes and indicators and the number of individual countries, this research was limited to the countries of the African continent. At the same time, due to the extent and availability of data, the research performed has been focused on identifying suitable data inputs for indexes and indicators available online. However, the study does not address the specifics of individual types and kinds of goods, similarly to a seasonal character of the demand, such as the end of the year, before the end of the Chinese New Year, seasonal fluctuations such as for agricultural products, etc.

4. RESULTS DISCUSSION OF SELECTED APPROACHES TO COUNTRY CLASSIFICATION

We used the following approach when analysing the countries:

- The first step includes grouping analysis. The aim is splitting the countries into separated groups based on the main indicators.
- In the second step we applied decission trees trying to understand and explain the generated groups in previous step based on the alternative sources and to find correlation between the main indicators and alternative data sources.

Grouping analysis has been used to classify the countries into groups. In the first stage, the k-means method which is based on tracking distances between points in space was used. Each country represents a point with attributes described above; the selected specific values are available in the following Table 2. The source data is stored in a table for each year and indicator. Data from tables has been converted into the internal format for the used Orange Data Miner tool.

Table 2. Selected values of monitored indicators (1988 to 2014)

Country Name	1988	1989	1990	1991	1992	2010	2011	2012	2013	2014
Algeria	2,402.8	2,202.6	2,394.4	1,721.6	1,766.1	4,473.5	5,421.7	5,457.6	5,504.2	5,498.1
Angola	632.2	924.1	898.6	996.2	477.0	3,886.5	4,745.0	5,084.3	5,295.2	5,423.6
Benin	345.8	310.6	391.9	383.3	315.2	690.0	745.4	750.6	804.8	825.3
Botswana	2,034.1	2,301.7	2,747.2	2,776.5	2,839.2	6,244.0	7,504.9	6,935.6	6,882.3	7,123.3
Burkina Faso	313.1	304.9	352.0	346.4	241.0	574.5	665.8	673.0	709.8	713.1
Burundi	204.8	204.2	201.7	202.7	183.7	214.2	240.6	244.2	259,4	286.0
Cameroon	1,098.8	950.8	923.9	1,000.3	809.6	1,147.2	1,258.9	1,222.2	1,331.2	1,429.3

Source: author's own.

Prior to grouping, the indicators required by the k-mean method were converted to a common scale. Percentage change in attributed values over the reference period was chosen. The k-means method requires a predefined number of clusters. The number of groups was used according to the recommendations based on the Silhouette scores group. In the case of this research, there were 5 groups, see Figure 2. Groups can be clearly visualized in a two-dimensional space. Different views can be selected, Figure 2 below shoes energy versus GDP per capita view.

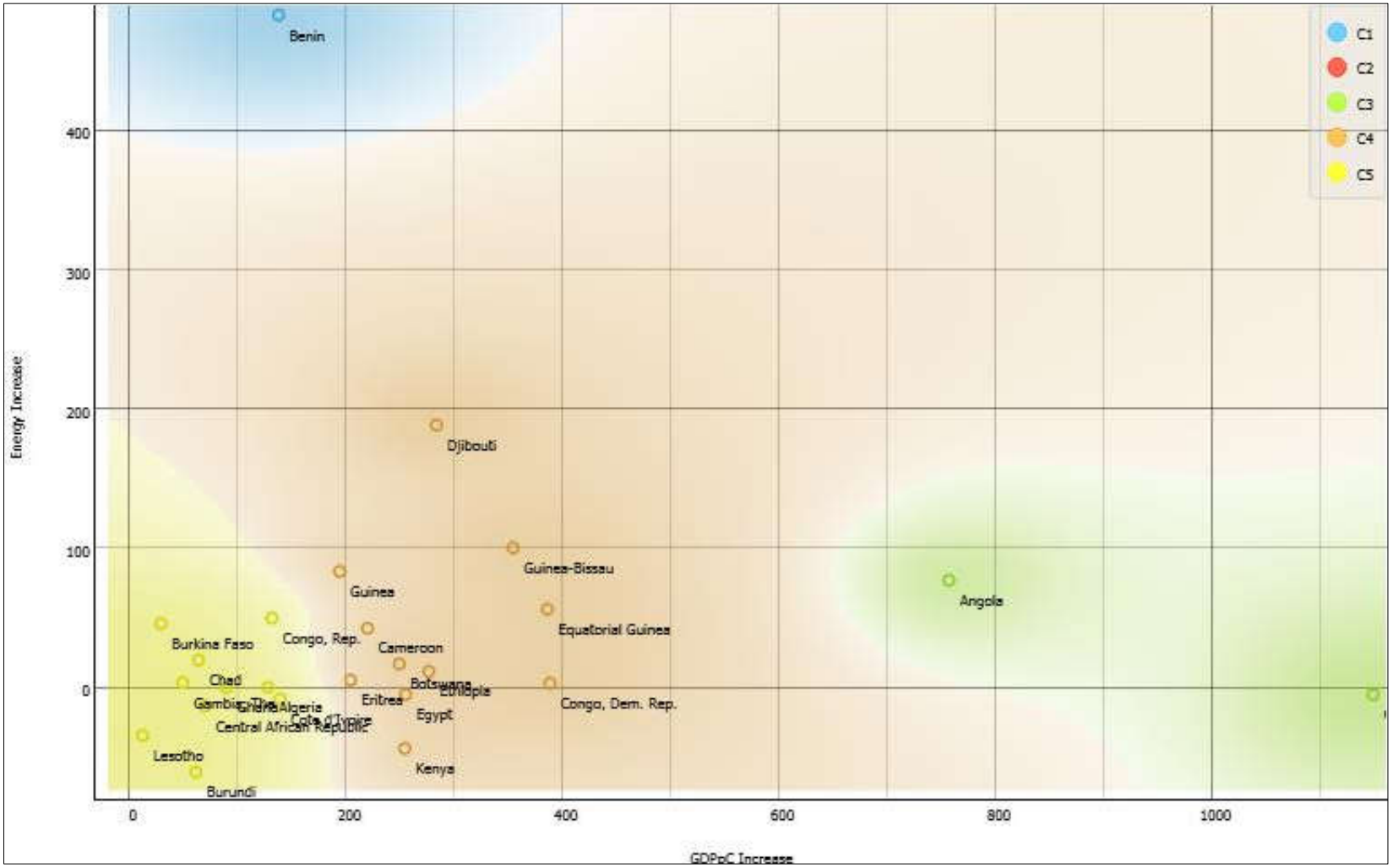
The resulting groups were further subject to a classification analysis. Created groups represent a target variable. A set of values whose values for the first seven countries can be seen from the following table, has been chosen (Table 3).

Table 3. Alternative sources of information for classification

Country Name	Country Size	Coast-line	Agri-cultural Land	Main Religion	Age 0-14	Age 15-24	Age 25-54	Age 55-64	Age 65-	Popu-lation Growth	Urban Popu-lation
Algeria	2,381,741	998	17.3	99.0	28.75	16.64	42.84	6.42	5.35	1.84	70.7
Angola	1,246,700	1,600	47.3	41.1	42.95	20.65	29.46	3.98	2.96	2.78	44.0
Benin	112,622	121	31.3	27.1	43.42	20.19	30.04	3.53	2.82	2.78	44.0
Botswana	581,730	0	45,8	71,6	32.66	21.49	37.31	4.48	4.06	1.21	57.4
Burkina Faso	274,200	0	43.0	61.6	45.2	20.08	29.13	3.14	2.45	3.03	29.9
Burundi	27,830	0	73,3	62.1	45.64	19.23	28.67	3.94	2.52	3.28	12.1
Cameroon	475,440	402	20.6	40.0	42.78	19.58	30.53	3.96	3.15	2.59	54.4

Source: author's own

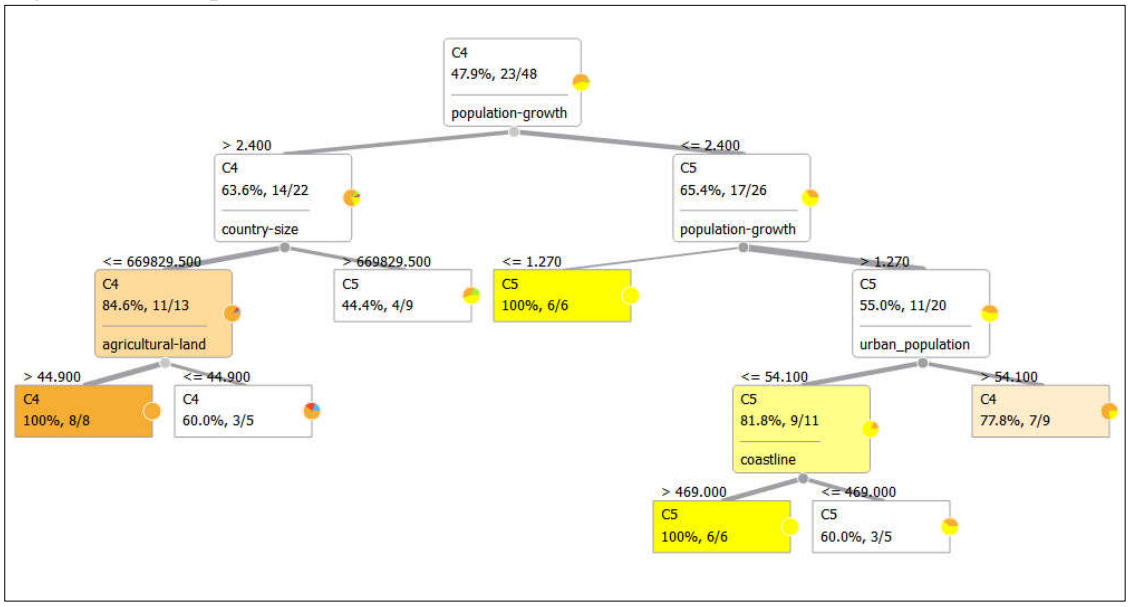
Figure 2. Generated groups (Energy versus GDP per capita)



Source: author's own

The method of classification trees has been chosen for classification analysis. Other methods (SVM, Logistic Regression, and Random Forest) have been also used. However, classification trees showed the best accuracy. During the analysis, more classification trees have been created based on the selected attribute values from alternative sources (see Figure 3).

Figure 3. Example of a classification tree



Source: author's own

Based on the chosen classification tree and the set rules for dividing African countries into groups (according to table 3), the rule of population-growth has emerged as the main rule according to which selected African countries can be grouped into groups with similar characteristics of available logistics infrastructure. We believe we can confirm our hypothesis that we can describe the groups and the main indictors using alternative data sources. We are trying to find the best trees describing generated groups. Each tree is constructed with a set of selected predictors. One set is a combination of alternative data source attributes based on Table 3. We can also compare the tree results with the past data (we have collected data over 20 years) and forecast the future based on expected changes and trends of the predictors in the trees.

5. CONCLUSION

Based on the performed analysis, it can be stated that the approach using suitable indexes and indicators makes it possible to compare available logistics infrastructure of the selected countries which is key assumption during the phase of design preparation and phase of realization of logistics activities. At the same time, indexes and composite indicators based on long-time series (20 years or more) allow to formulate predictions of future developments of selected indexes and indicators for

the forthcoming 6 to 12 months which is possible to use as an early warning signal during the supply chain management.

At the same time, some limitation in the use of indexes and indicators has been identified which is based on the fact that the correlation between the data does not have to imply clear causality, i.e. the basic characteristic that indicates the consistency with the element of a given group does not necessarily imply that the given logistics infrastructure element really belongs to the given category.

However, the chosen approach can be considered as a suitable complementary input for a decision-making process for designing the use of nodes and edges of the distribution chains, both in normal peace conditions and in crisis situations. The chosen approach can therefore be considered as a suitable alternative approach to the frequently used questionnaire surveys.

In the framework of further research, it will be appropriate to test the possible use of data-mining tools to track changes in the availability of logistics infrastructure. Another possible direction of the research effort can also be the creation of a logistic node model and the subsequent use of identified indicators and composite indexes as an input for verifying scenarios of possible use of a given node.

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