Studying integration of port and urban functions in port-city of Koper, using spatial analysis techniques and GIS tools

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Abstract

Ports and cities interact across many dimensions, but still lacking more detailed insight, how do port-cities integrate port and urban functions. To contribute to this question we employed spatial analysis and sophisticated GIS tools and studied the integration of port and urban functions in the port-city of Koper in Slovenia. Firstly we defined urban and port functions in Koper and proceeded with certain exploratory techniques to calculate central features, to measure orientation, to map density, and to measure spatial autocorrelation for both types of functions. Significant emphasis was given on the geovisualization of the results. They show that urban and port functions in Koper are clustered, with highest density of urban functions on the area of old town, and highest density of port functions in newer area of central activities east of the old town. Both urban and port functions have east-northeast to west-southwest orientation. From spatially point of view is the integration of urban and port functions in port-city of Koper reflected through specific land use, namely through concentration and orientation of urban and port functions and intertwining between both. The study can be useful in planning of port evolution and urban redevelopment.

Keywords: port functions, urban functions, port-city of Koper, geographic information systems, spatial analysis

1. Introduction

Ports have been interesting topic of research for several decades. Two basic geographical models fall within earlier period of research, namely the “anyport” model of Bird (1963), based on the idea that ports pass through several successive stages, and Hoyle’s (1988) model of the “port-city interface”, explaining changes in the interface between city and port. Olivier and Slack (2006) divide earlier research on ports to morphological and topographical. The first relates to the physical characteristics and the function of the port, and the second relates to the port as to the structural node in the transport network, which is inserted within transcending questions of regional or national development. Recent geographical research is more focused on specific, place-based analysis of ports and redevelopment proposals (McManus, 2007).

Historical development brought radical changes in ships and handling, which gave rise to new site requirements and brought out the changing relation between ports and their host cities (Rodrigue, Comtois and Slack, 2006). A closer look at last three decades shows that maritime networks have had an increasing influence on ports and port-city relationships, resulting important differences on this relationship between world regions (Ducruet, 2007). Today ports and cities still share common goals of which most relate to economic issues (Hayuth, 2007) although Noponen et al. (1997) notice a decline in competitive advantage that US port-cities derive from their ports. The reason for the last is in the containers revolution which has greatly reduced inland transport costs.

It is natural that specific functions develop in the port-city. Regarding the relationship between ports and cities, the researchers came up with a variety of conclusions. Although the relationship is more of a qualitative issue, a number of authors have proposed some indicators to allow a comparative approach (Ducruet, 2007). Ducruet (2007) finds that there is more of an opposition than a combination of urban and port functions on a world-scale. Only relatively small cityports still represent places, where the traditional intimacy between port and city has been generally maintained because of not particularly rapid urban growth and because port facilities have not adopted every new technological innovation (Hoyle, 1988). Also Hayuth (2007) finds that there are many issues that cause friction and disagreement between ports and cities, which is probably mostly due to the physical separation between city and port. More contemporary development encourages port-cities to find innovative ways to insert themselves into broader supply chain strategies (Wang and Olivier, 2007) and to become logistics and distribution centers that not only optimize the movement of goods and services within the entire transport and logistics chain, but also provide and add value to ultimate customers and users (Bichou, 2009).

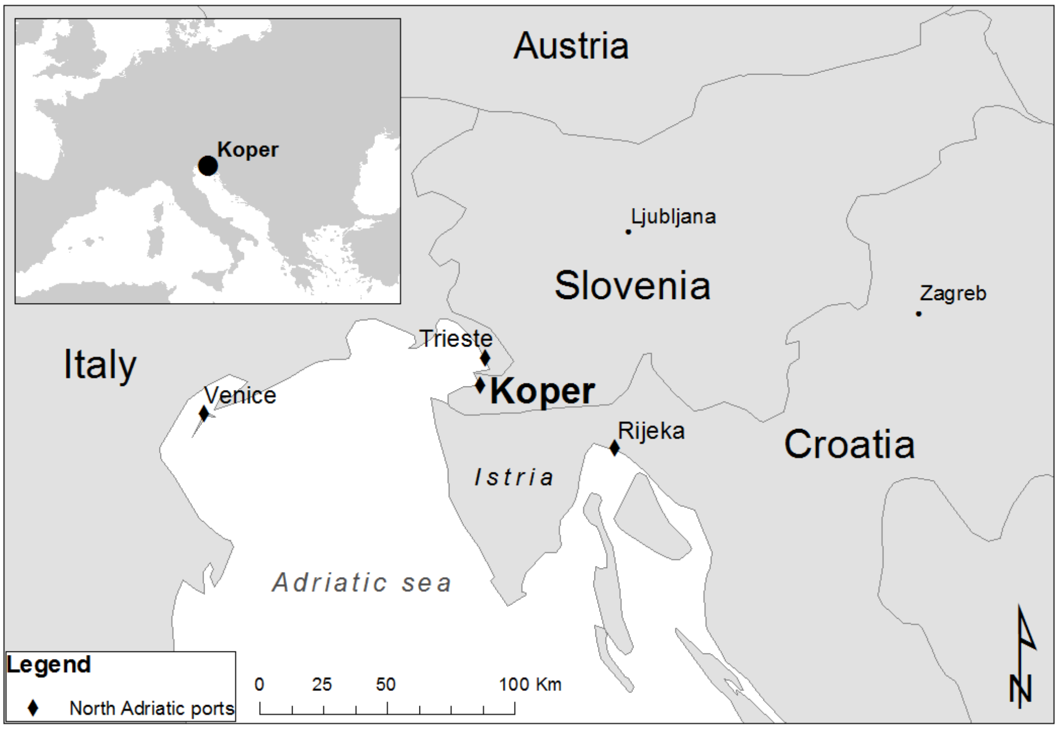
The question how do port-cities integrate port and urban functions is actually never-ending challenge. We may expect temporal and spatial changes, the latter referring to various ports and different world regions. We try to contribute to this answer with our research. Geographically we focus on Slovenian only Port of Koper, and methodologically on spatial analysis techniques and sophisticated GIS tools. Namely the geographic information technology is nowadays on enviable level and can help significantly in researching port-city relationship. Finally, we believe that the knowledge of port-city relationship can be important in planning of port evolution and urban redevelopment.

2. Presentation of study area

2.1 Brief look at the city of Koper

Koper is with 24.864 inhabitants the sixth largest city in Slovenia and the largest city on Slovenian 46,6 kilometers long coast (Statistical Office, 2014). It represents an important regional center, located on the northwest coast of the peninsula Istria, in the Bay of Koper (Figure 1). The city has developed on a rocky island in a shallow bay and was connected to the mainland in the 19th century. There was built the embankment in 1957 which separated the deepest part of the bay from the sea, and a harbor was built in front of the embankment (Orožen Adamič, et al., 1996).

Figure 1: The position of Koper in Europe and in northern Adriatic, on the northwest coast of the peninsula of Istria



The coastal position and maritime navigation, dating back to the late Hellenic period, had a decisive influence on the emergence and development of the city. The favorable natural and strategic position provided the town of Koper with vast opportunities for establishing ties and trade with the nearby and more remote hinterland (Jakomin, 2004). Today represents Koper the crossroad of economic, financial, transport and tourism flows.

The city has well-preserved old historical center, which is facing certain problem. Namely outside the old city center have developed other centers with equal character as old city center (Bugarič, 2004). The reason lies in economic, social and political changes, as the trade and other service activities moved to the periphery due to better development possibilities (Maršič, 2007).

2.2 Port of Koper

The most frequently exposed factor of the development of the Port of Koper at all spatial levels is its geostrategic position (Deranja, 2008). It was found that from the groups of development factors the political and administrative factors are the most prominent, especially the segment of spatial planning, and transport factors as global development factors (Deranja, 2008). Under the segment of spatial planning we mean the definition of Port of Koper as an important transport center of Slovenia, as a generator of the development at all spatial levels, and as an important factor of changing the environment.

The Port of Koper is a public limited company and operates as a holding. The entire port area, including the developmental area, extends over 1.600 hectares. There is assumed an expansion of port area in the northeast direction according to certain scenarios (Perpar, et al., 2010). The Central and Eastern European markets are very important For the Port of Koper (Twrdy, et al., 2012) because of larger bi-directional East-West flow of raw materials and consumer products within the European Union (Notteboom, 2009).

The Port of Koper is well equipped for handling various types of goods such as general cargo, livestock, containers, cars & Ro-Ro, timber, dry bulks, ores & coal, liquid cargo, alumina, and cereals (Table 1). In 2013 the Port of Koper achieved the total traffic of up to 17.999.662 tons of handled cargo. The container terminal handled 5.849.694 tons which is 11% more compared to 2012 (5.292.047 tons) (The Port of Koper, 2014). Exports and imports through the Port of Koper represent a minor share, whereas the traffic in transit has the major share: this proves that the port of Koper has predominantly a transit character. Significant shares of traffic of the port of Koper are with Austria and Hungary. Seventy percent of land traffic is transported by railway and thirty percent by road (Twrdy, et al., 2012).

Table 1: The Port of Koper is a multipurpose port, designed for handling of various types of goods, as shown for the year 2013

Types of goods	**Year 2013**	**%**
Dry bulk	6.988	39
General cargo	1.659	9
Liquid Fuel	2.841	16
Vehicles	662	4
Containers	5.850	33
Total	18.000	100

Source: The Port of Koper, 2014

The Port of Koper is one of the most relevant generators of the development of transport in Slovenia. The economic effects of port activity are multiplicatively reflected in direct surroundings and wider environment. Per one unit of generated value in a direct port activity, eight additional value units are generated in the whole Slovenian economy (Twrdy, et al., 2012). In future development is important to direct port’s efforts intensively to the hinterland and to the foreland to initiate and organize various participants (Trupac and Twrdy, 2010)

3. Spatial analysis techniques and GIS tools

In the research about the integration of urban and port functions in the port-city of Koper we put major emphasis on spatial analysis techniques and GIS tools. Spatial analysis or geospatial analysis or spatial data analysis means the problem-solving aspect of GIS (Allen, 2009) and represents only one context of broader concept of geographic information analysis that comes up also with other contexts: spatial data manipulation, spatial statistical analysis and spatial modeling (O'Sullivan and Unwin, 2010). Geographic information analysis is concerned with investigating the patterns that arise as a result of processes that may be operating in space (O'Sullivan and Unwin, 2010). A geovisualization has important place in this analysis (de Smith, et al., 2013). Today GISs typically include spatial data manipulation and spatial data analysis, and only recently have GIS begun to incorporate some of the statistical methods and only rarely include capability to build spatial models and determine their likely outcomes (O'Sullivan and Unwin, 2010).

GIS is a well-known term. It means a computer geographic information system that uses geographical data for the purposes of various management and analysis tasks on these data (Heywood, et al., 2011). As briefly mentioned, increasingly GIS packages are including analytical tools as standard built‑in facilities or as optional toolsets, add‑ins or analysts. Also a wide variety of web-based or web-deployed tools have become available without the need for local GIS software installation (de Smith, et al., 2013).

4. Results on urban and port functions in Koper

Every city consists of two types of functions: functions of production of goods and services or so-called economic functions, and functions of living and working of urban population (Vresk, 2002). The concept of urban functions may also be associated with the concept of basic life functions, deriving from the German social geography: living, working, education, nursing, recreation, and activities that support those functions interconnected, such as transport, information, and communication (cited in Vresk, 2002a).

Urban functions reflect in the functional structure of the city, or in other words, in urban land use (Rebernik, 2011). In order to study urban functions in the city of Koper, we obtained the data from Building cadastre from The Surveying and Mapping Authority of the Republic of Slovenia (2014). Our intention was to focus on non-residential functions, so we extracted only such buildings from the cadastre. Therefore we use the name “urban functions” further on only for non-residential functions. In the city of Koper we identified seven categories of urban functions/buildings, as can be seen in Table 2. The most frequently occurring are the categories of other non-residential buildings, trade and other service buildings, and administrative and office buildings.

Table 2: Categories and number of units of urban functions in the city of Koper

Categories of urban functions	Number of units
Buildings of general public importance	35
Industrial buildings and warehouses	43
Hotels and similar buildings	60
Buildings for transport and buildings for the implementation of the electronic communications	89
Administrative and office buildings	116
Trade and other service buildings	154
Other non-residential buildings	208

Source: The Surveying and Mapping Authority of the Republic of Slovenia, 2014

In the port-city develop also specific functions i.e. port functions. In the port-city of Koper we identified twelve categories of port functions, as can be seen in Table 3. The most frequently occurring are the categories of forwarding agents, and liner and shipping agencies. There are also others like regulation of marine safety, security, and environmental control, chartering agencies, supporting port activities, and so on. We added to the list of port functions also certain state institutions (e.g. Slovenian Maritime Administration, and Customs Administration of the Republic of Slovenia) and associations that are both located in the city of Koper and play important role in the port system. Further, we added to the list of port functions also certain affiliated companies which form the group Port of Koper, and some associate and controlled companies. With certain purpose to focus on spatial distribution and spatial interactions of the above mentioned functions, we left out cargo handling and storing activities, which are numerous and are spaced all over the port.

Table 3: Categories and number of units of port functions in Koper

Categories of port functions	**Number of units**
Associations	2
Affiliated companies that form the group Luka Koper	3
Rail carriers and multimodal operators	3
Ship repair	3
Associate and controlled companies	6
Ship chandlering	6
State institutions	6
Supporting port activities	9
Chartering agencies	12
Regulation of marine safety, security, and environmental control	16
Liner and shipping agencies	54
Forwarding agents	96

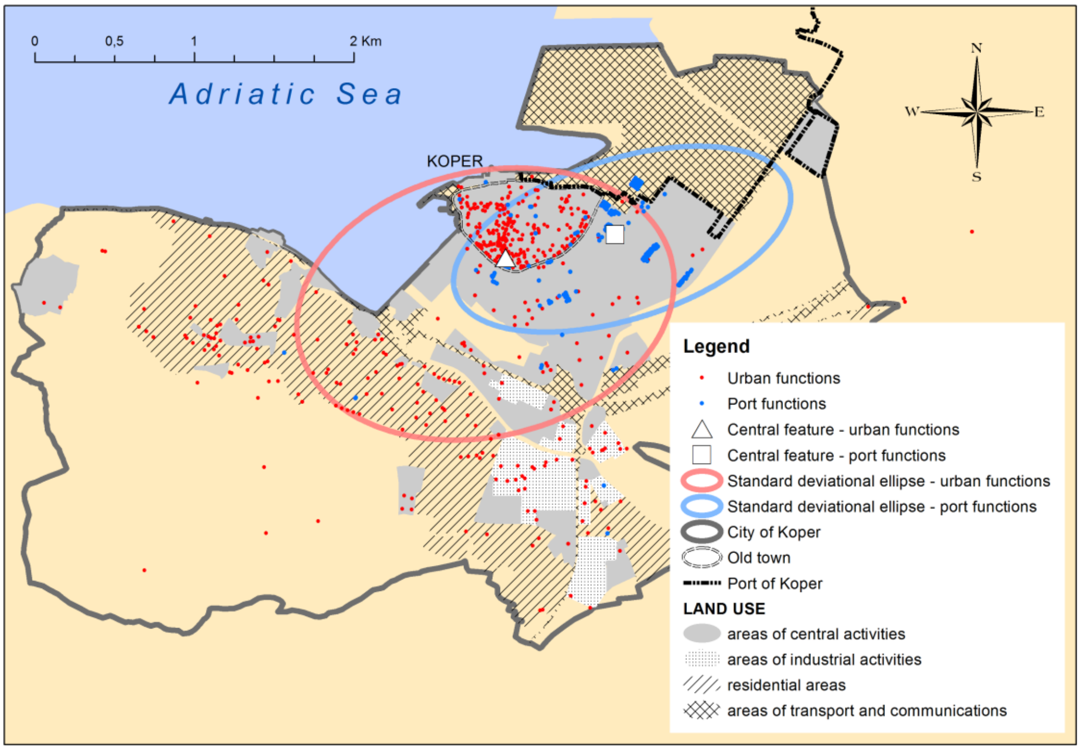
Source: The Port of Koper, 2014

4.1 Central features and spatial orientation of urban and port functions in Koper

Central feature represents the most centrally located feature in terms of Euclidean distance. In this research we are interested in the most centrally located urban function and port function. In the calculation the GIS totals the distance from each feature to every other feature. The feature with the lowest total distance to all other features is the central feature (Mitchell, 2009).

The results show the location of central feature of urban functions in the area of central activities in the southern part of the old town (Figure 2). The central feature of port functions is located in the newer area of central activities, east of the old town, on the southern periphery of the port area. The latter is the location of concentration of most liner and shipping agencies, and forwarding agents. The central features of urban and port functions are distant from each other by 0.7 kilometer.

Figure 2: Central features and standard deviational ellipses of urban and port functions in Koper



Measuring orientation lets us abstract the spatial trends in a distribution of urban and port functions. The result can be displayed as an ellipse, more specifically standard deviational ellipse. In the calculation is measured the standard deviation of the features from the mean center separately for the x-coordinates and the y-coordinates. To determine the orientation of the ellipse, the GIS employ a trigonometric function (Mitchell, 2009).

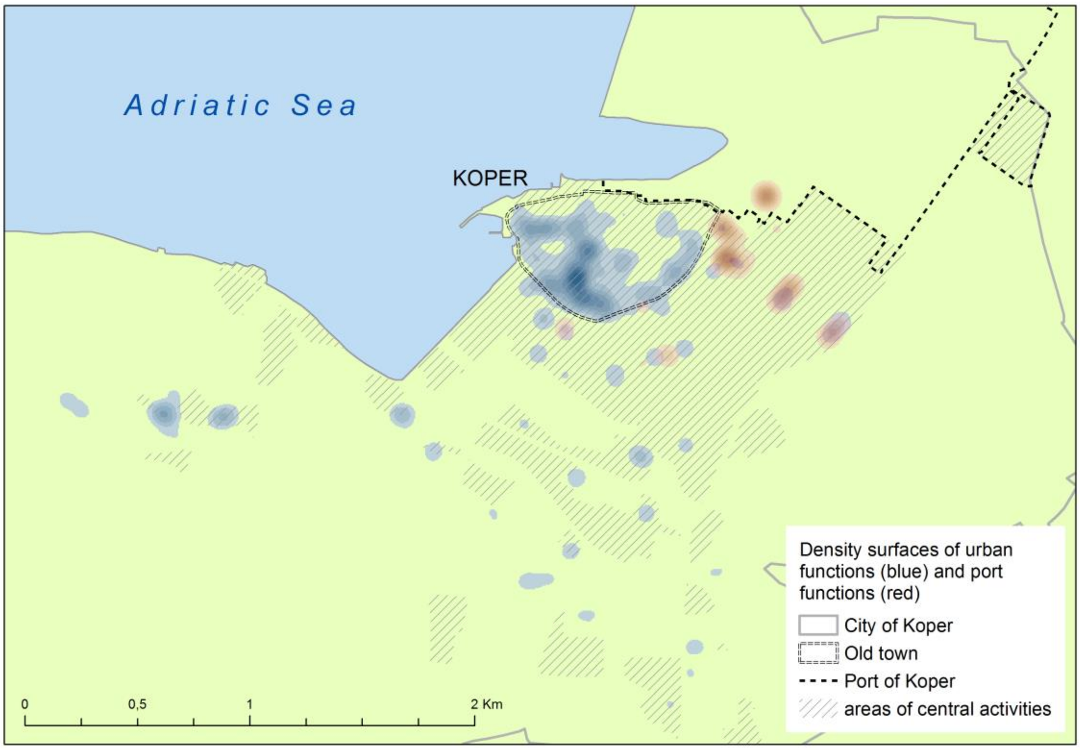
The results for Koper show east-northeast to west-southwest orientation of both urban and port functions. The standard deviational ellipse of urban functions extends on the area of central activities in the old town, the newer area of central activities south of the old town, and towards housing area southwest of the old town. Standard deviational ellipse of port functions extends from the southern part of port area, where many forwarding agents, liner and shipping agencies, supporting port activities, and associate and controlled companies are concentrated, then over the area of old town, and over newer area of central activities east and south of the old town. The intersection of both ellipses covers greater part of the old town and one part of newer area of central activities south and east of the old town. In the area of intersection are concentrated 46% of all urban functions and 68% of all port functions in Koper.

4.2 Density of urban and port functions in Koper

The essence of kernel density estimation is that the pattern has a density at any location in the study region – not just at locations where there is an event. It also provides a good way to visualize a point pattern to detect hot spots where the local density is estimated to be high (O'Sullivan and Unwin, 2010).

For the estimation of the density of urban and port functions in Koper, the density surfaces of both types of functions were created. Namely, a surface with contours gives us an indication of regions of high and low point density of urban and port functions (Figure 3). As a result we can recognize the highest density of urban functions in the southwest part of the old town, consisting mostly of trade and other service buildings, administrative and office buildings, hotels and similar buildings, and other non-residential buildings. In addition, hot spots can be recognized also in other parts of the old town and in newer areas of central activities west, south and east of the old town. The highest density of port functions can be recognized east of the old town, with the peak on the building that has the highest number of port functions, consisting mostly of forwarding agents, and liner and shipping agencies. Hot spots can be recognized also on the location of some neighboring buildings. The newer area of central activities south and east of the old town is an area where hot spots of port functions overlap with slightly less outstanding hot spots of urban functions. As we can see from Figure 7, the distribution of urban and port functions in Koper is consistent with future urban plan since the locations of both types of functions mostly overlap with the areas of central activities.

Figure 3: Density of urban and port functions in Koper



4.3 Measuring spatial autocorrelation of urban and port functions in Koper

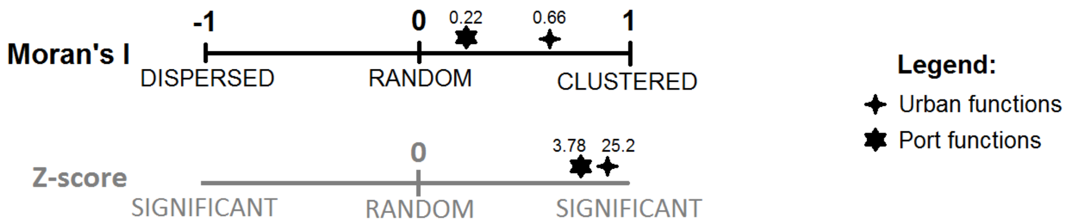
Measuring spatial autocorrelation belongs to the field of spatial statistics. According to Tobler’s First Law of Geography are the data from locations near one another more likely to be similar than the data from locations remote from one another (O'Sullivan and Unwin, 2010). To find out if this is true for urban and port functions in Koper we used ArcGIS Spatial Statistics tool and calculated Moran’s I index for both types of functions.

The Moran's I tool compares the values for neighboring features. A comparison is made of the differences in values between each pair of neighbors and all the other features in the study area. If the average difference between neighboring features is less than between all the features, the values are considered clustered (Allen, 2009).

We needed to aggregate the point data of urban and port functions into polygons, which resulted clusters of density. This was done by laying a grid of 100-by-100 meters over the point layers of urban and port functions, then urban and port functions in each grid cell were counted. Finally the Moran's I tool was run using the output grid as the features and the count of urban and port functions as the attribute value.

The result of the value of Moran's I index of urban functions is 0.66 with Z-score 25.2, and the result of the value of Moran's I index of port functions is 0.22 with Z-score 3.78 (Figure 4). The results show very high degree of likelihood that the urban and port functions in Koper are clustered.

Figure 4: Results of spatial autocorrelation of urban and port functions in Koper



5. Conclusions

GIS tools are useful in researching port and urban functions i.e. exploring and mapping point data of urban and port functions, measuring geographic distributions, and identifying patterns. Nowadays work can be simpler since many GIS packages automatically include tools for spatial analysis.

Since the question about integration of urban and port functions in port-cities still remains topical, we tried to contribute to the answer at least partly, from spatially point of view, on the example of Koper. In the research we calculated central features, measured the orientation, mapped density, and measured spatial autocorrelation of both types of functions. The results are presented descriptive, numerically and visually. Especially the last component, the geovisualization has a prominent role in the spatial analysis. We found out that urban and port functions in Koper are clustered, with highest density of urban functions on the area of old town, and highest density of port functions in newer area of central activities east of the old town. On the same areas are also located central features of both functions. Urban and port functions have both east-northeast to west-southwest orientation with intersection on the area of old town and newer area of central activities south and east of the old town. The integration of urban and port functions in Koper reflects through specific land use, i.e. concentration and orientation of urban and port functions, and intertwining between them.

When working with spatial statistics tools integrated in GIS packages, we need to recognize, that we are quite familiar with GIS, but we have often limited knowledge about statistics. Therefore there often remains a bit of doubt, whether our exploratory techniques are appropriate for our certain case, and whether our results are significant. In such situation an in-depth study of statistics theory and examples can help in diminishing these doubts.

When working with GIS and spatial analysis techniques, it is important to put attention to certain settings of the analysis. For example when calculating standard deviational ellipse, it is important to put attention to the borders of the study region chosen, since this is important for the sensitivity of the analysis. Furthermore it is important to put attention to the outlying features since the orientation and size of the ellipse can be skewed by a few outlying features. In the example of measuring spatial autocorrelation, it is crucial to determine the appropriate grid cell size since this also has an influence on the sensitivity of the analysis. Generally, when settings spatial analysis it is practical to try different settings and repeat the procedure several times before choosing the best result.

The results of our and similar research can be useful in planning of port evolution and urban redevelopment. The extension of the research could take place in studying the characteristics of urban and port functions through time and do the comparison between different periods. Another possibility is to analyze urban and port functions between different port-cities and do the comparison.

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