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COMPETITIVE TECHNICAL INTELLIGENCE: USING PATENT DATA TO DETERMINE SMART CITY TRENDS

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Abstract: The aim of this paper is to define a method for uncovering smart city technology trends using competitive technical intelligence processes focused on intellectual property analysis using data visualisation. The authors introduce ways of gathering relevant core bibliographic data on the desired technology together with search preparation and query building. For demonstration purposes, the authors have used the European Patent Office datasets. The aim of this paper is to define a method for smart city competitive intelligence analysis focused on the main innovative companies and organizations and specific technology trends. The time period between the years 1997 and 2017 is used. Based on the results, the authors have indicated that Samsung is the leader in intelligent city innovations in this period. Five main product invention categories were also identified.

Key Words: *Competitive Technical Intelligence, competitor analysis, intelligent city, patent classification.*

Introduction

Competitive Technical Intelligence (CTI) is a relatively new method for monitoring external competitors' activities, with technology fields as the main focus. Although there is no specific definition for summarizing the scope of these methods, we can define it as a strategic process of company information needs for planning, collecting, analyzing and distributing data, information and knowledge entities from the external enterprise environment to monitor market activities, where technology is the common factor (Coburn 1999, Porter et al. 2007, Cerny 2016, Zhang et al. 2016).

Our paper is focused on the technology collection and analyzing phases, therefore it is important to define technology information signals as information entities where patent information is a significant part of this functional technology intelligence framework. We can distinguish the following types of information from the external environment (Brenner 2005): social media technology signals; grey literature signals; scientific information signals; joint ventures signals; intellectual property information signals; production signals; market feedback signals.

The aim of this paper is to define a method for uncovering smart city technology trends using competitive technical intelligence processes focused on intellectual property analysis. We have chosen patent information signals as a key part of intellectual property to uncover smart city technology trends with these particular topics: analyses of the key players on the global market, the country where the applicants mostly seek patent protection and the key technologies. One of the reasons for our study is also the lack of knowledge about the potential data analysis and usage of patent entities to get a competitive advantage. This fact has appeared in the study of Černý et al. (2015), which demonstrated that only 8% of Czech companies use patent information for competitive analysis. The structure of this paper corresponds to the above.

The smart city can, without question, be defined as one of the leading technology fields within our society that is presently connected to the Internet of Things (Doucek et al. 2018). Pellicer et al. (2013) differentiated six main fields of smart city initiatives: Smart Economy (Competitiveness), Smart Governance (Citizen Participation), Smart People (Social and Human Capital), Smart Mobility (Transport and ICT), Smart Environment (Natural Resources), Smart Living (Quality of life). They conducted state-of-the-art searches for trends through patent databases with a simple keyword set consisting of the following terms: intelligent, digital, smart, efficient, city, cities, and urban citizen. The results from 2013 showed that China is the technology leader in this field and that the main innovating activity among all companies was directed towards traffic control systems. Arasteh et al. (2016), and Nassar et al. (2018) added insights into Internet-of-Things smart city applications and through their survey pinpointed the challenges in this field. Sadowski et al. (2017) use ICT company patent profiles to design the blue ocean strategy in the field of Internet-of-Things technology, and in one part of their study also focused on smart cities. They focused on five sectors: aviation and automobile, electronics and electric manufacturing, software and computing, networking equipment and wireless equipment. These examples underline the significance of patent applications as an information source for more than just technology landscape analysis.

For the purpose of this paper, we have defined the following key intelligence questions as a part of the planning phase:

1) Which company is the market leader within the smart city sector? (KIQ1)
2) Which technology group within the smart city sector is the most innovative? (KIQ2)
3) Which technology group within the smart city sector is the most patented, and in which geographic region? (KIQ3)

Patent information in the context of CTI

As far as technology is concerned, the power of patent information lies in its complexity. The full text of a patent application tells us the names of inventors, applicants, technology details, including drawings, and, least but not last, its legal status. To see these information entities in the context with competitor analysis, we will clarify the critical elements of patent applications.

Patent application structure

Patent application is considered as one of the crucial information sources of technology content with a rich and high-quality data structure. We are commenting on individual bibliographic fields below because of the legal differences within territories, and in order to exclude the significant language similarities of specific patent application fields.

A patent application is primarily identified by the application number, or by the publication number when it is available to the public through gazettes or databases, but it also consists of other interesting metadata that provides insights into R&D activities. A patent application should be considered as a complex information source and a competitive intelligence analyst should not avoid any part of its structure. We have summed up parts of a typical application according to WIPO (2005) and EPO (2016a) with a possible competitive intelligence context:

- Patent application number – The assigned number when an applicant is filing the application. Usually, it consists of a priority date (a date on which the right of priority is valid).
- Patent publication number – The assigned number that is created after the application was published. Usually, it consists of the date of publication and the state of the granting process.
- Title – The official title of the invention. If the applicant is aiming for a regional or international scope, it must be in a valid language (usually English is the primary

language). The searcher should be aware of the possibility of deliberately vague or obfuscatory language due to the patent strategy of an applicant.

- Abstract – The basic description usually provided by the inventor. The same problem can occur regarding the vague language.
- Inventor name – Responsible persons for inventions, usually with address and other contact information.
- Applicant (Assignee) – The owner of the invention and of the rights for protection. It should be noted that the entity names could be indexed in different formats and characters (e.g. the subsidiary company of an applicant is still a relevant and valid information for a competitive environment analysis).
- Classification code – The specific notation consists of numbers and letters within a hierarchical system that classifies an invention into a particular technology set. Classifications provide a possibility to get the latest technology trend analysis. They should be also used for a cross-keyword analysis.
- Designated country – When seeking regional or international protection, the applicant can use specific offices, such as the European Patent Office or the World Intellectual Property Organization. Only one application form, therefore, serves as the tool for applying the protection in more countries. Country information is especially important when conducting a patent family analysis.
- Drawings – Technical drawings that uncover the structure of the invention.
- Claims – Novelty is one of the crucial factors leading to the granted patent and it is described in the patent claims.
- Description – A detailed description of the invention together with the methods by which an average professional can assemble it.
- Search Report – Patent examiners are the officers who participate in the granting process. Their search and analysis of information outputs are identified in a search report that is a required document. The collection process for this type of document is important because of the examiners' technical expertise and opinions. We should note that search reports are publicly visible before patents are granted.
- Reference patents – The cited patents that the inventor has used during his innovation or invention activity.

Patent classifications

Classification schemes can be considered as a powerful tool to tune our search syntax with regard to the recall or precision of results sets. On the one hand, we can easily choose the general technology fields to collect relevant records; on the other hand, we are able to determine a very specific kind of technology. In this paper, we have used the International Patent Classification (IPC) for various reasons. Firstly, it is a global classification scheme; secondly, it is being regularly updated; and finally, it could be used in every significant patent databases.

The IPC follows this structure (WIPO 2016):

- Section (i.e. B)
  - Class (i.e. 60)
    - Subclass (i.e. R)
      - Main Group (i.e. 22/00)
        - Subgroup (i.e. 22/34)

For example, we will consider the patent application identified by the publication number WO/2017/117754 and the date of filling on 6th January 2016 with the title *Traffic Light*

Management Method and System in Fire Rescue Route for Smart City. The main IPC code for this invention is G08G 1/087 which can be translated as follows:
Section **G** Physics
Class **G08** Signalling
Subclass **G08G** Traffic Control Systems

Main Group **G08G 1/00** Traffic Control Systems for Road Vehicles
Subgroup **G08G 1/087** Override of traffic control, e.g. by signal transmitted by an emergency vehicle.

We must emphasize the point that the IPC is a hierarchical system and the subgroup defined above is hierarchically under the preferred subgroup **G08G 1/07** Controlling Traffic Signals.

The classification codes are also used as the tool for cross-search and for narrowing down the defined keyword set.

Patent families

Insofar, as we need to analyze the same technical content in a different number of applications with the common first filling and potential geographical validity, the patent families provide us with detailed insight. There are several patent family concepts, each operated by a different vendor, e.g. Questel Orbit, Derwent World Patent Index, Chemical Abstracts Service or INPADOC, operated by the European Patent Office. As we have used the Global Patent Index database to demonstrate our search performance in this paper, we have worked with the INPADOC concepts. There are two of these: simple patent family and extended patent family (EPO 2016b). Basically, the first concept provides, through several applications, insights into the company patent strategy regarding one invention with the same technology aspects in specific geographical territories. The extended patent family concept includes applications within the same technology field but with a wider diversity, e.g. two application have the same technology foundations but cover different inventions (Mailänder 2014), of course, with a territory analysis too.

CTI analysts use patent families for different perspectives. We can see the patent activity of a specific company in particular jurisdictions, when it updates the patent claims and other modifications of the application, and therefore effectively monitor if new art is added. Moreover, priorities may uncover the time frame of a given invention in the context of a development and production cycle.

Global Patent Index

The GPI belongs to one of the most comprehensive patent tools. As it was demonstrated in Černý (2017), this source brings unique opportunities regarding the patent landscape analysis, the legal status analysis and the detailed patent family analysis with an extensive patent data portfolio. Moreover, researchers have various search tools as standard for deep web search discovery (Table 1). To sum up, we have used the following ones:

- Boolean logic is represented by the AND, OR, NOT, ANDNOT operators.
- The special operator WITH narrows results when using classification schemes, INPADOC legal statuses, applicants, inventors, representatives, priorities and citations.
- Two types of proximity operators: /Xw (affects the distance between two terms regardless of the orderwhere X is the number), and +Xw where the two terms must be in the same order within a specific distance.
- Arithmetic operators (=, >=, <=, <, >).

Table 1

GPI facts

Entity	Global Patent Index
Data Coverage	Bibliographic records
Number of documents	104 979 040*
Updates	Weekly
Geographical Data Coverage	Countries under PCT (152) + Euroasian Patent Organization + European Patent Office + African Regional Intellectual Property Organization + 92 national offices*
Search modes	Easy, Detail, Expert
Advanced search syntax tools	Boolean, Proximity, Wildcards
Classification systems	IPC, CPC, US Patent Classification System, JP Classification (FI), JP Classification (F-Terms)
Legal status	INPADOC legal status codes
Patent family information	INPADOC patent family
Data analysis outputs	Simple statistics: IPC, CPC, FI, F-Terms, Applicant, Cited Applicant, Inventor, Publishing Office Cross-reference: IPC, CPC, Inventor, Applicant, Date of Filling, Date of Publication, Date of Priority
Data visualization	Simple statistics graphs, two dimensional graphs
Data export	Full records in RTF, PDF, or XML format, Result lists in PDF, XML, XLS or HTML, Statistics and Cross-reference graphs in JSON, CSV or PDF

**Data by 22th of September 2017*
Source: *Le Gonidec (2014), Černý 2017*

- Wildcards:
  * (asterisk) substitutes zero or more
  # (hash) substitutes one mandatory character
  ? (question mark) substitutes for one or zero character
  Wildcards must not be used when phrase searching.
- Brackets [] are used for a date range.
- Parentheses () affect the order of how the logic sets will be searched.

As mentioned, the GPI framework is further analyzed in Černý (2017).

Methodology

The Smart City is a massively occurring strategic direction that helps urban areas to become more efficient in all aspects of their daily life. Cities include smart city concepts consisting of advanced ICT and knowledge ecosystem implementations in their future planning.

Almost twenty years of research and development conducted by scientists, experts and managers from different fields have created interdisciplinarity in this field that is mainly directed toward economic efficiency, safety and social welfare. The definition of smart city therefore tends to affect a broad spectrum of different elements. For example, Deakin and Al Waer (2011) see the four main components of the intelligent city as: “a) the application of a wide range of electronic and digital technologies to communities and cities, b) the use of information technologies to transform life and work within a region, c) the embedding of such ICTs in the city, d) the territorializing of such practices in a way that bring ICTs and people together, so as to enhance the innovation, learning, knowledge and problem solving which they offer” (Deakin and Al Waer 2011). In another point of view, Komninos (2011) defined four areas that shape the present smart city framework through applications: a) economic activities, b) city infrastructure and utilities, c) quality of life and d) city governance.

The significance of smart city initiatives underlines the growing number of research activities and published peer-review articles (Fig. 1). As we have performed a survey search in the Web of Science (WOS) database based on the occurrence of the terms “smart city” and “smart

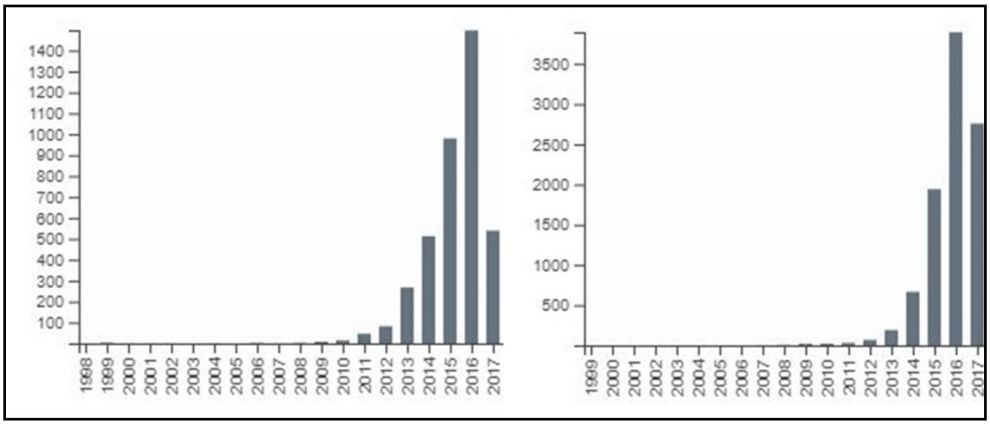

Fig. 1 **– The popularity of smart city in the scientific community. The number of peer-reviewed articles and the number of citations**

Source: *Clarivate Analytics (2017)*

Table 2

The main categories in the Web of Science database concerning the smart city topic

Category	Record count	% of 3961
Engineering Electrical Electronic	1274	32.164%
Computer Science Information Systems	922	23.277%
Computer Science Theory Methods	821	20.727%
Telecommunications	722	18.228%
Computer Science Interdisciplinary Applications	414	10.452%
Computer Science Hardware Architecture	350	8.836%
Computer Science Artificial Intelligence	329	8.306%
Computer Science Software Engineering	238	6.009%
Green Sustainable Science Technology	213	5.377%
Urban Studies	212	5.352%

Source: *Clarivate Analytics (2017)*

cities" in the title, abstract or keyword sections, we see in Table 2 the following main scientific streams through the Web of Science research categories in a set of 3961 results. As we have analyzed the smart city field from scientific perspectives, we will compare it with the market insights derived from the patent information.

Methods of analysis

Before any search is made, it is necessary to establish a relevant keyword set with an emphasis on recall. Two approaches to get the keywords have been chosen: a) the IEEE thesaurus analysis (IEEE 2017), b) the term tactics (Bates 1979), and they were put it into the following structure (Table 3). Bates's term tactics (1979) are providing different approaches on

Table 3

Keywords analysis

Central terms	Smart city
Superordinate terms	City, town, metropolitan, urban area
Related terms	Smart grids, internet of things, urban informatics, smart public health, smart community, smart government, smart energy, smart structures, intelligent structures
Synonymous terms	Intelligent city, digital city, virtual city
Specific terms	Wireless water meters, smart waste management, smart lighting, smart building, smart transportation, smart transportation system, intelligent vehicle, intelligent transportation, intelligent transportation system, water quality monitoring, smart car

Source: *own research*

how the searcher could analyse the possible relevant keywords for particular searches and use them with specific relevant search tactics. Bates's term and search tactics concept was firstly introduced at the end of the 1970s, when a complex database vendor infrastructure existed in the United States. Information overload was an emerging topic not only within the academic community and these methods significantly ensured its reduction. Moreover, they are still valid for the contemporary information environment.

Performing a patent search

We have chosen two search strategies. The first is focused on the recall of results and we have used a Boolean logic approach with the following syntax:

WORD = ((city OR cities OR town* OR metropolitan OR urban) AND ((city AND (smart OR intelligent OR digital OR virtual)) OR ("smart grid*" OR "internet of things" OR IoT OR "urban informatics" OR "smart public health" OR "smart communit*" OR "smart government*" OR "smart energy" OR "smart structure*" OR "intelligent structure*") OR ("wireless water" OR "smart waste management" OR "smart lighting" OR "smart building*" OR "smart transportation" OR "intelligent vehicle*" OR "intelligent transportation" OR "smart vehicle*" OR "smart car*"))

The field operator WORD performs searches within all text fields of a patent application. The result set contains 4056 patent documents in 3089 patent families.

The second search strategy leverages the precision. We have edited our syntax and used the proximity operator /10w in the syntax. Then each of the terms in the first logical group is being searched within 10 words of the second logical group:

WORD = ((city OR cities OR town* OR metropolitan OR urban) /10w ("smart city" OR "intelligent city" OR "digital city" OR "smart grid*" OR "internet of things" OR IoT OR "urban informatics" OR "smart public health" OR "smart community*" OR "smart government*" OR "smart energy" OR "smart structure*" OR "intelligent structure*" OR "wireless water" OR "smart waste management" OR "smart lighting" OR "smart building*" OR "smart transportation" OR "intelligent vehicle*" OR "intelligent transportation" OR "smart vehicle*" OR "smart car*"))

The result set contains 1340 patent documents in 888 patent families.

Results and Discussion

For the purposes of this paper, we will work with the first broader set of documents to discover trends within the smart city field, together with the key players, and to carry out a specific technology analysis to demonstrate the patent information entity role in the competitive intelligence process. When considering the planning phase, we first needed to define key intelligence questions directed towards the smart city field and to chose the particular patent index – in our case, the Global Patent Index that also provided international intellectual property context from bibliographic fields. The essential part of this phase is to carry out the keyword analysis and to prepare for the collection phase. The IEEE thesaurus has provided us with the relevant expert terms that are valid for this industry field and which are broadly used in the scientitific, research and technical literature. From our point of view, the thesaurus is neccessary when considering the relation between the search precision and recall. However, we are aware of the possible missing relevant hits so that the keyword analysis and preparation from unstructured texts is inevitable, so we have used Bates' search tactics, especially the term tactics and trace search tactics. Although Bates defined these tactics in the 1970s, they are still valid and very effective for keyword preparation. The collection within a patent sector can be performed on a national, regional or international level. We needed to consider which source was the most relevant for the purposes of our paper. The Global Patent Index, operated by the European Patent Office, is an up-to-date and well-structured source that provides significant insights based on complex keyword preparations including value-added Asian translation content fields. We were able to perform different patent search types within a global perspective and to get valuable business insights in the smart city field.

The Competitive Intelligence patent analysis phase starts with Table 4 (including the first ten companies and institutions) and it uncovers that Samsung is the leader within the smart city technology innovation activities in the recent years. The distribution over time (2015-2017)

Table 4

Key player analysis

Applicant	Number of patent applications
Samsung Electronics Co Ltd	354
Chengdu Qinchuan Tech Dev Co	25
State Grid Corp China	23
Shenzhen Shuangchuang Tech Dev Co Ltd	23
Univ Wuhan	16
Univ Southeast	15
Univ Shanghai Jiaotong	10
Univ Beijing Technology	10
Feng Xuanyu	10
Cai Jinhong	10

Source: *Le Gonidec (2014)*

shows a growing trend (Fig. 2). We are also able to specify where companies seek patent protection mostly by pinpointing the publishing offices (Table 5). An example of visualizing this

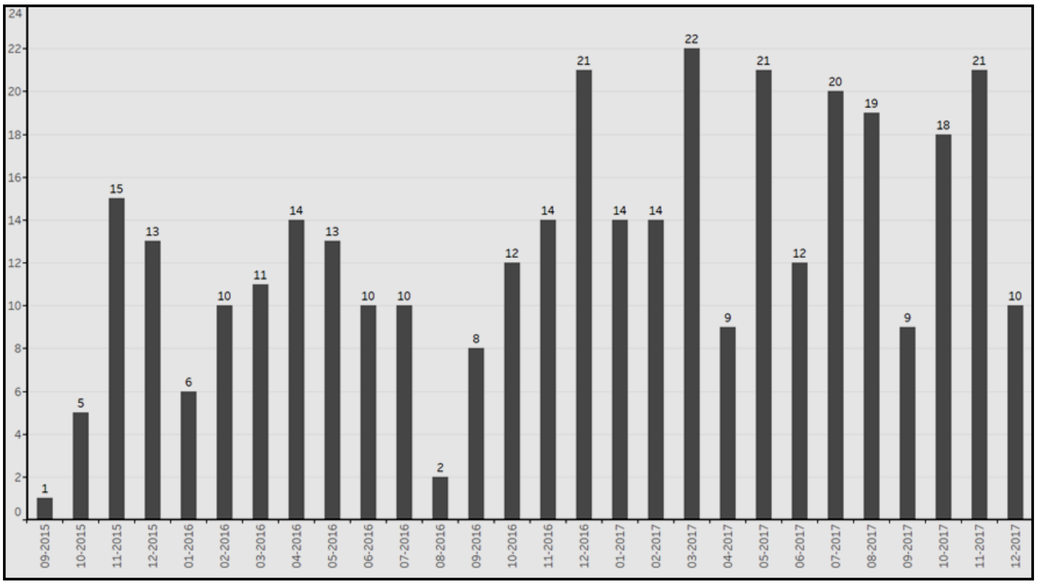

Fig. 2 **– Patent activity of Samsung between 2015 and 2017**
Source: *own research based on Le Gonidec (2014)*

Table 5

Publishing Offices analysis

Publishing Office	Number of patent applications
China	2357
WIPO (152 PCT countries)	218
United States	164
Republic of Korea	153
Japan	84
EPO (EU countries)	34
Great Britain	21
Taiwan	16
Germany	14
Russia	8
Canada	8
France	3
Australia	3
India	2
Slovakia	1
Netherland	1
Mexico	1
Greece	1

Source: *Le Gonidec (2014)*

data for Samsung is available in Fig. 3. Based on the map, it is possible to identify the countries and regions where the companies seek patent protection (in this case, Samsung). This map can be interactive and shared to support further analysis (Datig and Whiting 2018).

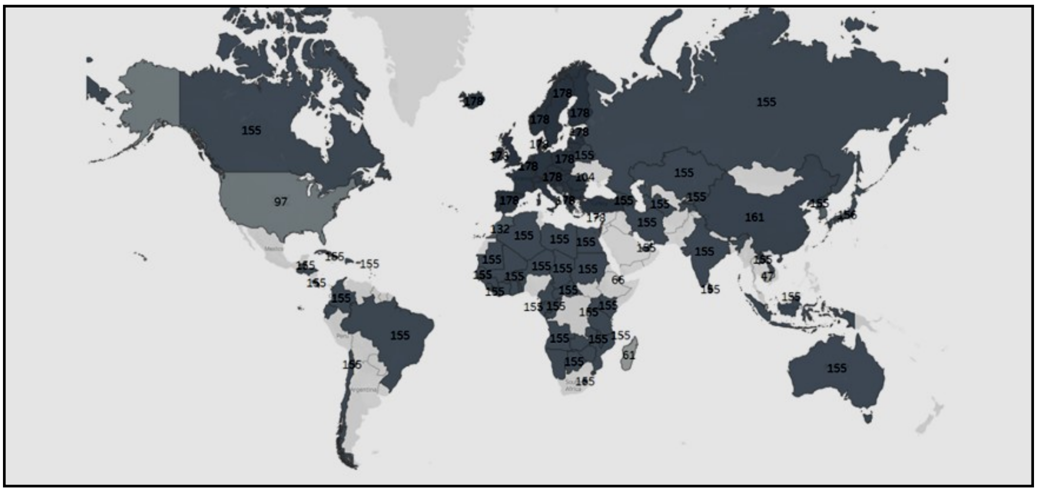

Fig. 3 – **Patent activity of Samsung between 2015 and 2017**
Source: *own research based on Le Gonidec (2014)*

If we use the primary IPC subgroup codes of the given patent applications, we can mine the information about technology directions in detailed definitions. In the following table (Table 6),

Table 6

Technology analysis

IPC code (subgroup)	Definition	Number of patent applications
H04L29/08	Transmission control procedure, e.g. data link level control procedure	233
H05B37/02	Controlling (in the main group Circuit arrangements for electric light sources in general)	160
G06F17/30	Information retrieval; Database structures therefore	126
G06Q50/26	Government or public services (in the main group Systems or methods specially adapted for a specific business sector, e.g. utilities or tourism)	115
H04N7/18	Closed-circuit television systems, i.e. systems in which the signal is not broadcast	102

Source: *Le Gonidec (2014)*

we have provided a technology insight with five particular technical solutions.

We have analyzed the patent activity going back 20 years (Fig. 4) and, as we can see, the patenting activity was more frequent than the peer-reviewed research. The Competitive

Intelligence distribution phase leads to two main conclusions: firstly, Samsung owns a major part of the intellectual property rights with the smart city sector; secondly, from its protection strategy, we can assume that it possibly controls and will control the smart city market. Our results also confirmed a strong Chinese intellectual property strategy on a national level that has been visible for several years. It could be estimated that the future smart city patented technology will be constantly produced by and exported from China.

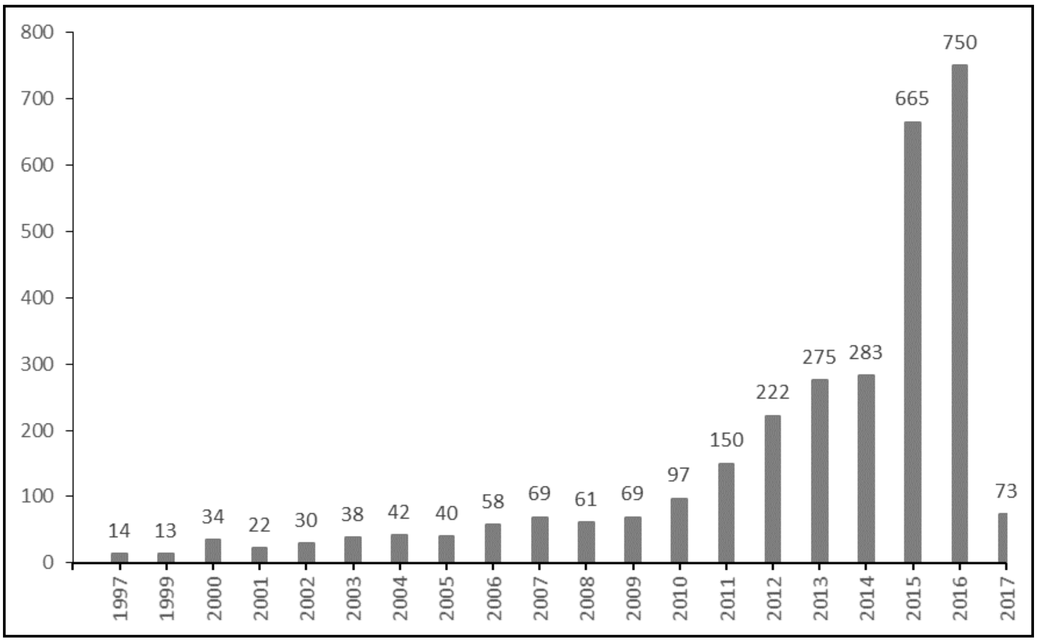

Fig. 4 – **Patent activity of Samsung between 1997 and 2017**
Source: *own research based on Le Gonidec (2014)*

Conclusions

This paper has described the use of patent information as one of the technology intelligence signals in the smart city field. Our aim has been to provide methods for uncovering innovation activities, determining key players on the market and the main technology concepts in this area. The recommended set of analyses, including their visualization, is also part of the output. The structure of the patent information is discussed in the first part of the paper, together with the patent classification and patent family importance.

The authors have prepared a keyword set through the analysis of the IEEE thesaurus and by using the information term tactics. The search for desired data has been conducted in the Global Patent Index with two approaches, one directed towards the broader relevant result set and one towards the set with the emphasis on precision.

To conclude, we have answered all of our defined key intelligence questions. Firstly, the role of Samsung can be presented as the long-term market leader in smart city technologies and that most inventions have been published in the past three years (KIQ1). Secondly, based on the Web of Science data, we can assume that the engineering electrical electronics belongs to the most researched category (KIQ2). Finally, the transmission control procedure, e.g. the data link level control procedure, is the most patented technology group (KIQ3).

Based on our former research considering the significant underestimation of patent information entities, our results provide a detailed method on how to gather relevant technology data and information, to put them into context and to get significant business insights in terms of the competitive technical intelligence process. We have shown the ability to use patent information as one of the most important key player activity sources focused on a specific detailed technology with further indications of a business early warning system within a specific business sector. Concurrently, this intelligence process could be also used as a strategic planning support, or a support for a patent strategy model. The setup of analytical services should be covered within further research.

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OPEN-SOURCE WEB GIS FRAMEWORK IN MONITORING URBAN LAND USE PLANNING: PARTICIPATORY SOLUTIONS FOR DEVELOPING COUNTRIES

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Abstract: This paper presents a Web GIS application development framework through an open-source software which aims to provide reliable open data services, required for policymaking in urban land use planning. The geodatabase model is comprehensively developed. It displayed a user interface using QGIS, MapServer, and Pmapper, with open source tools with PHP MapScript programming languages and integrated DB-SQL, to generate a complete digital map service with information on urban land use policy. The results of this Web GIS development can be publicly used with spatial databases suitable for public consumption, and as decision support systems for stakeholders, especially in the policy of urban land use planning. Thus, this application can serve as a model for land-use monitoring systems based upon the principle of information disclosure toward smart city and smart governance.

Key Words: *web GIS, smart city, smart governance, urban land use planning*.

Introduction

The current debates on what makes a smart city point to a wide array of factors. These include smart city factors like economy, mobility, environment, and governance, but one overriding factor is the extent to which information technology is integrated into primary urban functions (Gil-Garcia et al. 2016, Fietkiewicz et al. 2017, Lv et al. 2017). Claims about smart cities have been perceived as a market strategy to promote the influence of neoliberalism and distract from real problems in urban areas (Grossi and Pianezzi 2017). With considerable developments, the concept of smart cities has also affected developing countries such as Indonesia, which is now trying to realize that concept. Indeed, the realization of smart cities requires adequate preparation that will not only result in a utopian claim that a city is smart but will also benefit the people's quality of life (Kummitha and Crutzen 2017).

In recent studies, ten so-called smart cities, namely Tampere, Geneva, Seoul, New Songdo, Vienna, London, Washington DC, New York City, Hongkong and Melbourne, have shown the concept of open data for various development plans, as one of the principal aspects of being a smart city (Anthopoulos 2017). For open data to support smart people and smart governance, expensive information technology is required which must be adapted to the needs of the society. Although the concept of smart cities is not very utopian, it can be applied to resolving real problems in urban areas (Anthopoulos 2017, Grossi and Pianezzi 2017, Kim et al. 2017, Kummitha and Crutzen 2017). Moreover, open data also helps to educate people and the government, so it supports policymaking toward smart people and smart governance.

The principle of open data and information technology in realizing smart cities is crucial, and Geo-ICT (Aina 2017, Kim et al. 2017) is one such example. Geo-ICT helps us to understand urban issues and, in addition to its spatial potential, it is also highly informative (Buchori and Tanjung 2014, Buchori et al. 2015a, Purwanto and Bayuardi 2016, Aina 2017, Elmanisa et al.

2017). Although information technology is not the only aspect embodied in the concept of smart cities (Kummitha and Crutzen 2017), it is crucial to support the existence of a smart city (Aina 2017, Kim et al. 2017, Niaros et al. 2017). One form of open data in Geo-ICT is web-based GIS or Web GIS. The concept of Web GIS is the ability to provide an overview of spatial information with spatial data that provides information to support decision making (Thiebes et al. 2013, Buchori et al. 2015b, Sejati and Ramadhan 2015). For developing countries, Web GIS can be produced by exploiting open-source softwares, so that the cost is cheaper, and the purpose of open data especially in delivering public policy can be achieved (Nakayama et al. 2017).

In the broader context, smart cities support sustainable cities, where in general the concept of smart cities is an improvisation of sustainable cities, with some strengthening in innovation and technology (Buchori and Sugiri 2016, Ahvenniemi et al. 2017, Buchori et al. 2018, Sejati et al. 2018, 2019). Based on this statement, the strengthening of technology becomes very important for the realization of smart and sustainable cities. The technology in this paper is a technology that can realize the components of smart cities, one of which is smart governance.

Numerous studies on smart governance and ICT have focused on data acquisition for policy-making (Feltynowski 2015, Eom et al. 2016, Gil-Garcia et al. 2016, Fietkiewicz et al. 2017, Lv et al. 2017), the use of Web GIS for disaster information (Pessina and Meroni 2009, Nasaruddin et al. 2011, Dong et al. 2013, Thiebes et al. 2013, Fago et al. 2014), and policy-making in bridging the information gap between rural areas and civic education (Wirkus 2015, Müller et al. 2016, Stanković et al. 2016). The research to date has not focused on monitoring the implementation of infrastructure and urban land use policy, and so it has been unable to explain how the system is built based on real behaviors and problems with smart governance in urban infrastructure and land use management. To complement the previous studies, it is necessary to describe the development of Web GIS for policy-making following the characteristics of developing countries. On this basis, the purpose of this paper is to provide a framework for how the Open-Source Web GIS application can support decision making, especially in monitoring the implementation of land use policy in developing countries, particularly in Indonesia.

Methodology

Study area

The Web GIS framework in this research is applied in Balikpapan City, which is located in the fastest growing area in East Borneo (Fig. 1). In 2014, Balikpapan was named the most prosperous city by the 24th Eastern Regional Organization for Planning and Housing (EAROPH) Congress. The assessment was based on the Indonesian Most Livable City Index 2014. Besides, in 2015, Balikpapan also won an environmentally sustainable city award. With these achievements, Balikpapan has tried to develop the concept of a smart city by developing Web GIS as a decision support system, especially in infrastructure and spatial planning.

Economically, Balikpapan is large and growing due to its oil and gas industry, and the growth of the city and its infrastructure is supported by the success of this sector (Tarigan et al. 2017). In 2016, after several oil companies moved out from Balikpapan, the government wanted to be able to control post-oil industry changes, and so useful governance concepts in monitoring the implementation of spatial and infrastructure planning have become essential.

Web GIS development

Web GIS development uses several open-source components, such as Map-Server and Pmapper (Burger 2009). The open-source software model adjusts the purpose of making the system by defining layers and control layers (Gkatzoflias et al. 2013, Thiebes et al. 2013, Nakayama et al. 2017). The layer in Pmapper controls the attributes and the digital maps that appear in Web GIS. In this work, the required input data is a digital map of the Balikpapan area. Theoretically, the objects that exist in the space geography can be divided into two types of information. The first type is in accordance with the location on Earth, known as spatial data. The second type identifies the non-spatial property of the object and it is called the attribute data.

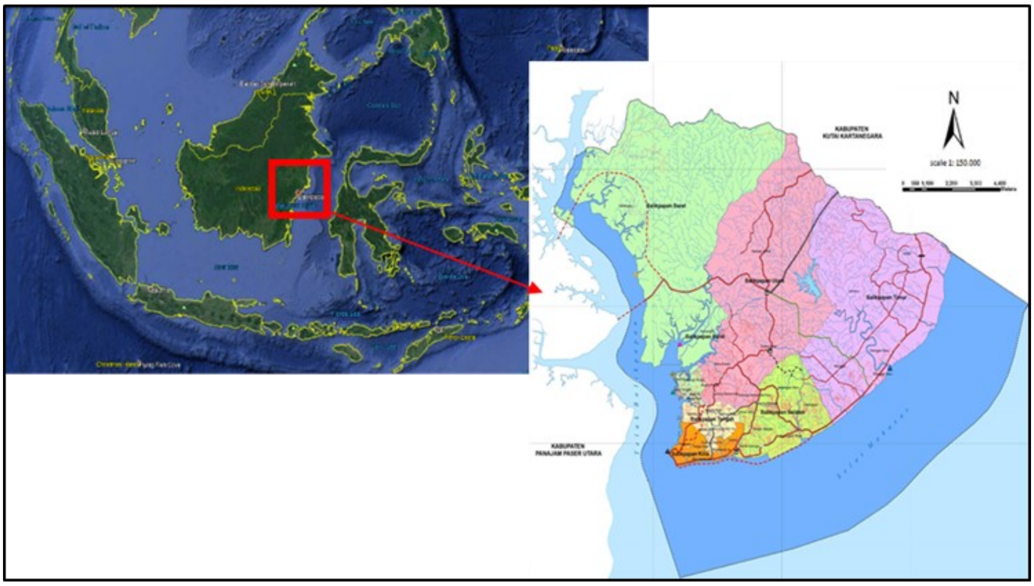

Fig. 1 – **Balikpapan City as study area**
Source: Google Maps and the Spatial Planning Agency of Balikpapan

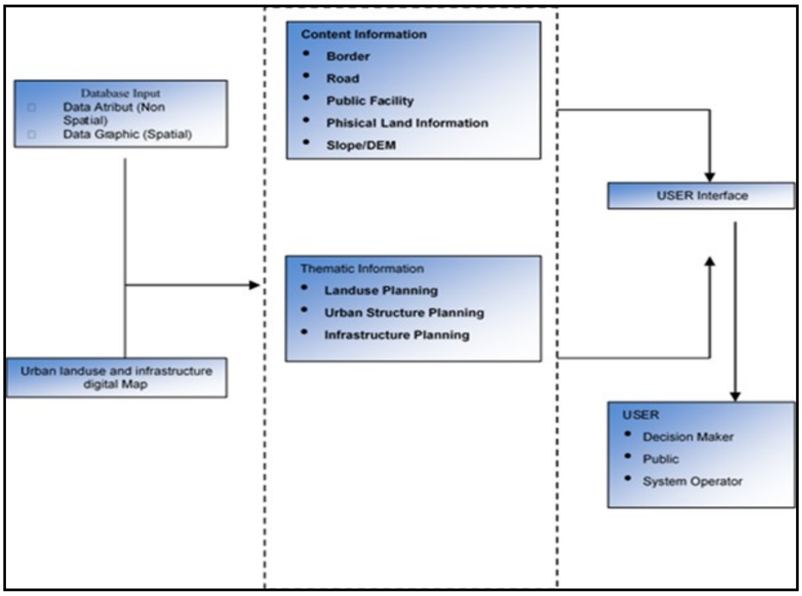

Fig. 2 – **Web GIS module content information**

Web-based GIS applications are built using Quantum GIS merging and open source software, including the Linux Operating System, Mapserver, PHP/Mapscript, and Pmapper framework. The facilities contained in this GIS application are: (1) Users can open apps from the web, so they can view thematic maps that include the basic map, infrastructure, and land use maps, (2) Users can select the desired legend/layer, (3) Users can customize the map size by zooming in on the map layout, (4) Users can search by the search option, and (5) Users can view the information through the info table view. The framework of the information module is as shown in Fig. 2, while the input data in this system can be seen in Table 1.

Table1

Data Input for Web GIS

Data	Type	Attribute data
Spatial	Road/Line (Vector)	Name of road, Length
	Administrative border / Polygon (vector)	Name of Area Area
	Shapefile Land use existing and land use planning (vector Polygon)	Name of land use
		Area
	Shapefile of infrastructure map	Point location and coordinates
Non-Spatial	Image of location	Location name, Area

User interface concept

To create a stable and reliable web-based system which can be used properly, the design of the system must first be considered. Its design is formed using the concept of multi-users. The concept diagram in Fig. 3 shows the process flow in demand by the users, with the request and receive/view processes in one region. The accommodated processes in this user interface are: (1) the initial process provides requests through the browser, with a selection of available legend layers, (2) the request is accepted by the webserver, in this case forwarded to the Mapserver application which processes spatial data, i.e. file maps, (3) the map file is returned in the form of an image accompanied by an HTML template, and (4) it then determines the desired information by zooming and query on the map on the browser side. When the information obtained by searching the location, or directly from the zooming/pan, is final, then the process ends. In the interaction between the users, the web browsers (client) and the server are divided into several classes. Each class has its own operation. The MapObj class is the part structure of the file with a .map extension, which has the major class. They are: legendObj, scalebarObj, referencemapObj, outputObj, layerObj, querymap, and webObj.

Results

Web GIS Balikpapan (beta version) was developed in Bahasa Indonesia. Thus, in some discussions, an explanation in English will be added. There is an agreement between researchers and the local government that infrastructure data and land use should only be displayed in Bahasa Indonesia. Web GIS Balikpapan's development results can show all data for the consumption of policymakers and the wider community. In accordance with the principle of open data (Danneels et al. 2017, Ruijer et al. 2017), the information submitted must support democracy in policymaking and benefit the quality of life in the community.

Furthermore, the forms of the information displayed are in the form of a combination of spatial data in digital map form as well as a data attribute in tabular form, as in Fig. 4. In detail, the concept of open data initiated in Web GIS Balikpapan is open information spatial data, so that each unit of data layer displays information according to the existing condition. This is in accordance with the idea of open data for democracy and good governance (Mccall 2003, Lv et al. 2017, Oliveira et al. 2017, Sadiq and Indulska 2017), where transparent data, especially in the implementation of development, has an impact on the level of public trust in the government.

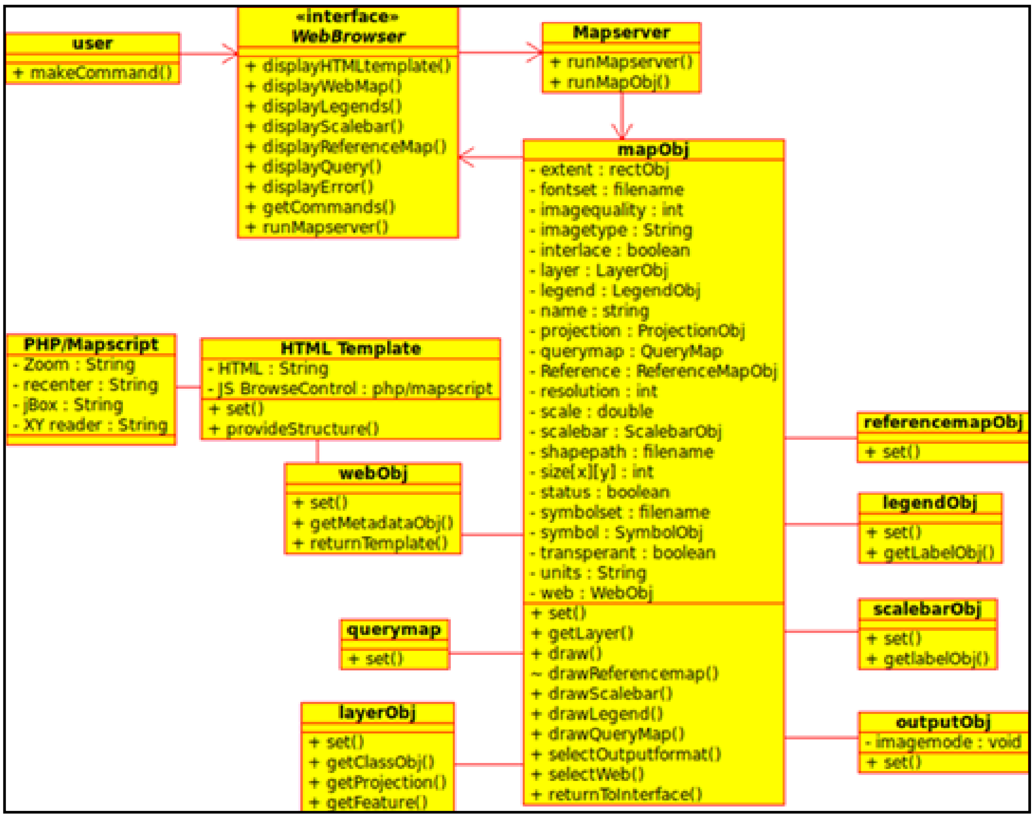

Fig. 3 **– User interface concept diagram**

Fig. 4 **– Open Data in Web GIS, a combination of spatial and tabular data**

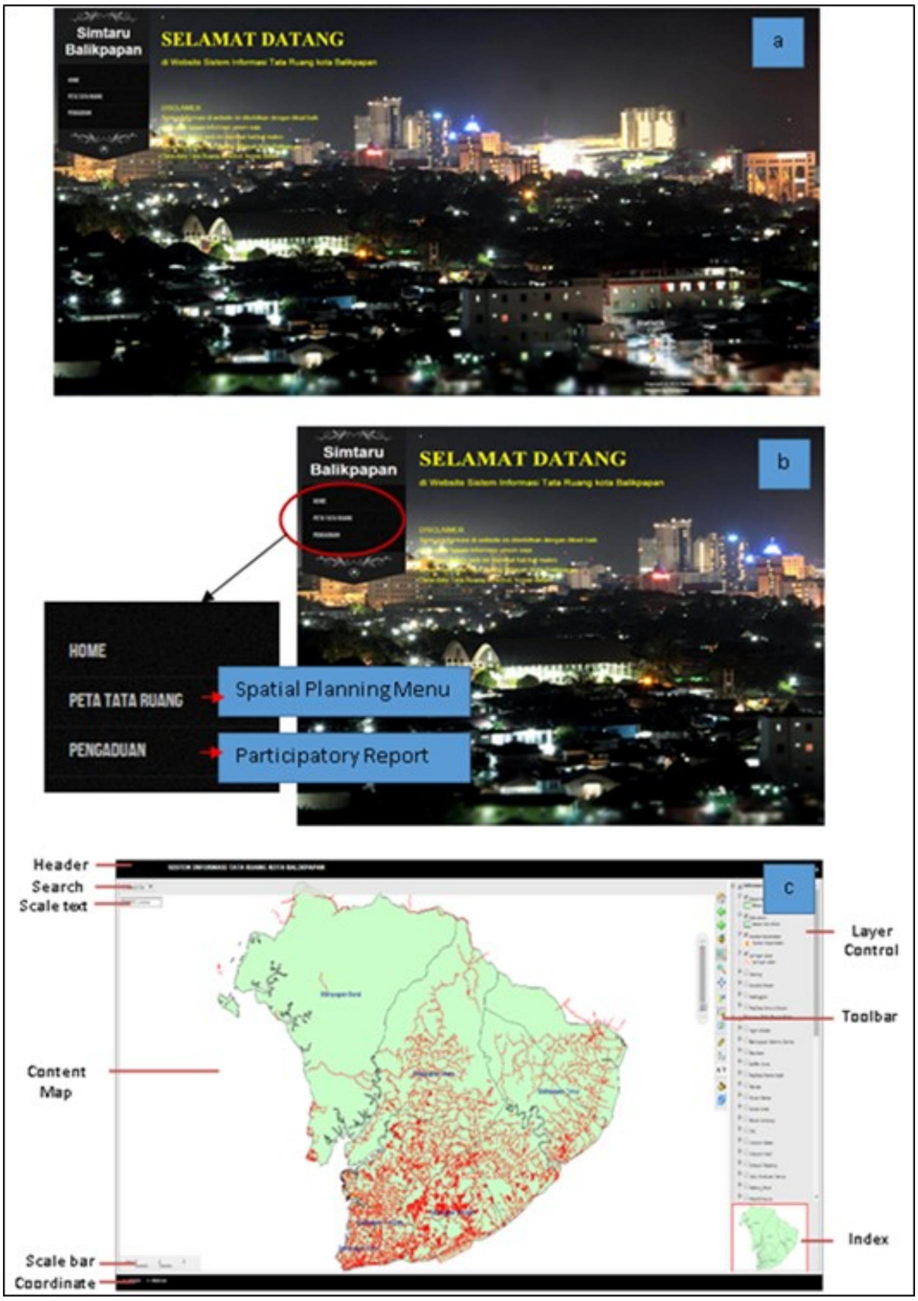

Fig. 5 – **(a) Web User Interface, (b) Web Menu, (c) Web GIS Description System**

In terms of the use of the user interface, some menus are provided to facilitate users in accessing the data. The menu includes (1) home, (2) spatial planning menu, (3) infrastructure planning menu, (4) search menu, and (5) report and tag point menu. The menus in Balikpapan's Web GIS are a little different from the standard menu in the Web GIS software developed for disasters (Dong et al. 2013, Thiebes et al. 2013, Fago et al. 2014). However, by upholding the principle of open data, Balikpapan's Web GIS menus not only facilitate inputting or reporting not only from the operator system but also provide an opportunity for the public to report on the implementation of infrastructure development and land use (Fig. 5). Hence, the display data on Balikpapan's Web GIS is sourced from two directions, namely from government-appointed operators, and from the public. This two-way open data principle is in line with the smart governance principles — data transparency and participatory data — so that people can contribute with data on regional development (Mccall 2003, Voss et al. 2004, Awoleye et al. 2014).

Discussion

Web GIS as supporting tools for monitoring urban land use planning

It is not easy to formulate a procedure for monitoring the implementation of land use planning policy, especially in a multi-sector and multi-planning field. The system should be able to define the involved parts and explain the job description of each user. In Balikpapan Web GIS, the system is able to unify multiple planning databases from multiple sectors to bridge multi-planning needs, and thus it requires unified data from multiple sectors for the same needs (Bíl et al. 2012, Zhou et al. 2017). The sectors are land use planning and infrastructure for the same purpose of regional development planning. Moreover, the concept of smart governance should be able to bridge communications between the public and the government (Eom et al. 2016, Lv et al. 2017) so that Balikpapan Web GIS becomes an effective communication medium.

The framework for Balikpapan Web GIS emphasizes the effectiveness of communication between the government, as planning policymakers, and the community, as users and planning objects. The user definitions are made separately so that each party can perform varying functions and activities according to the procedure (Fig. 6). These are: (1) user operator-mediated duties in in-outing data, and as a moderator of data input from the community, (2) government users and policymakers in charge of disseminating planning policy products with accurate data in accordance with local regulations, (3) public users, who have access rights to view the overall planning data, including land use plans and infrastructure as a basis for development in their respective areas. The integration of these three users is facilitated in one system so that the unified data concept (Bíl et al. 2012) works well.

After understanding these activities, the public user will obtain their rights, namely data about the planning and obligation in assisting the government to do participatory monitoring of the implementation of the development plan. The complete public facility display can be seen in Fig. 7. The complete land use data are divided by each layer of land use. Similarly, infrastructure data are also displayed in the form of digital maps and data attributes. Land use planning data are useful to apply for a development permit for the community, as well as the data on infrastructure development plans.

The reporting facility (Fig. 8) provided by Web GIS Balikpapan as a participatory monitoring function is beneficial in the implementation of land use planning, so as to reduce the violation of land use. The participatory monitoring system effectively guards the development process (Voss et al. 2004, Dunn 2007, Nackoney et al. 2013, Mialhe et al. 2015). This concept is in line with Kovacs et al. (2017), who stated that the principles of democracy and the contribution or involvement of stakeholders (community and government) strongly influence the effectiveness of land use management. Furthermore, proper land use and infrastructure should be based on community demand (Hessel et al. 2009, Wellman and Spiller 2012, Derr et al. 2013, Breuste et al. 2015, Mathey et al. 2015), so that the concept of a smart city supported by technology can be a sustainable city (Ahvenniemi et al. 2017), complete with community involvement using Web GIS.

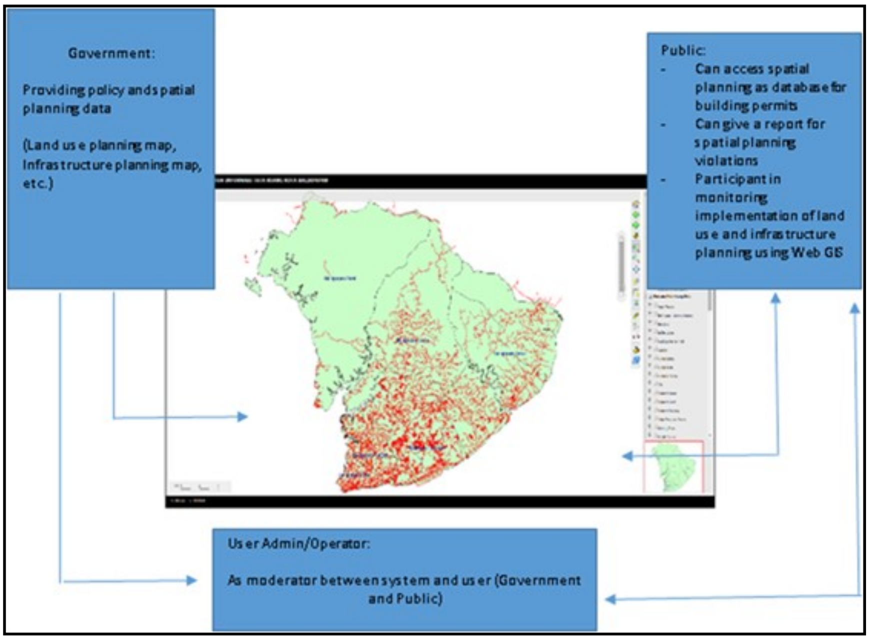

Fig. 6 – **User job description in the Balikpapan Web GIS Framework**

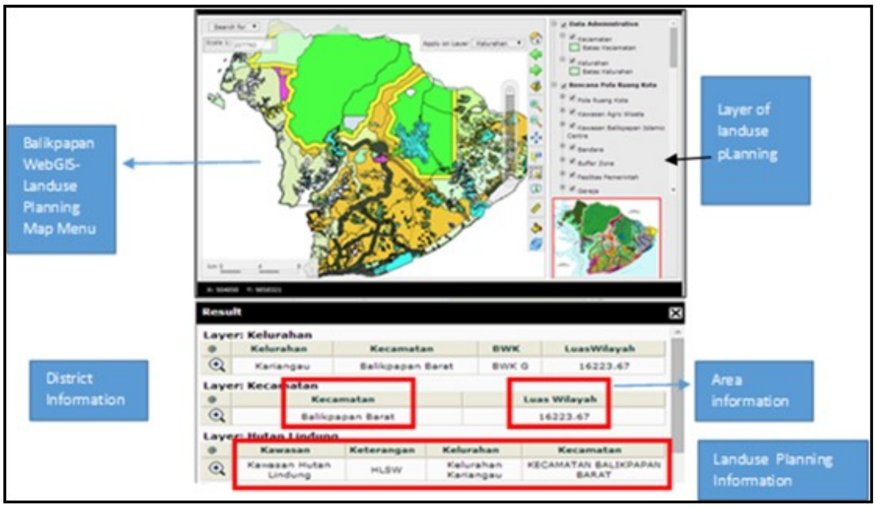

Fig. 7 – **User facilities and information**

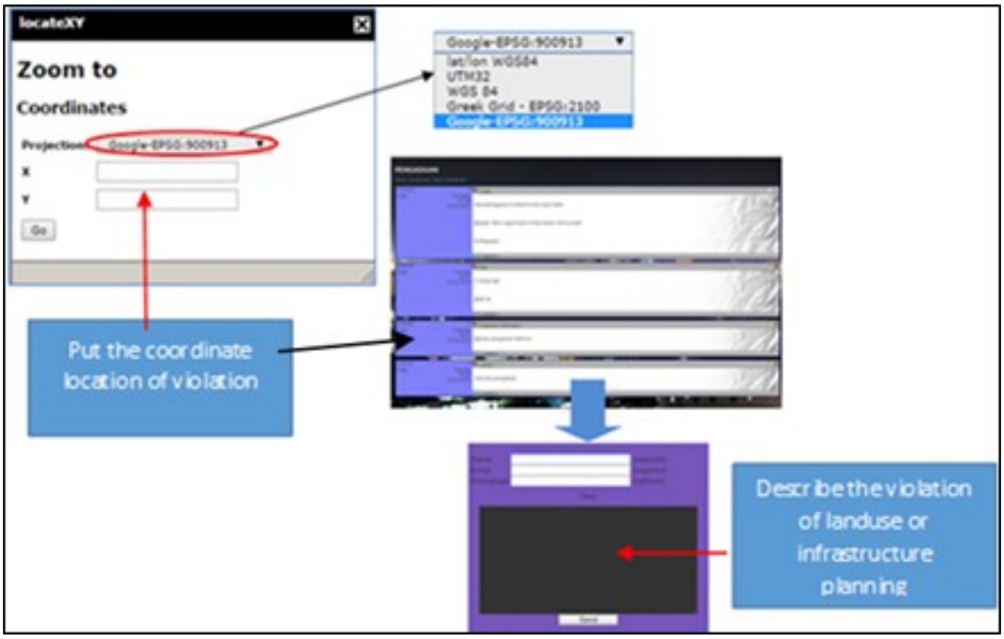

Fig. 8 – **Reporting facility for monitoring land use planning violations**

Looking at the workings and distribution patterns of both spatial and non-spatial databases, the Balikpapan Web GIS function is basically the same as Web GIS developed in previous studies (Pessina and Meroni 2009, Dong et al. 2013, Thiebes et al. 2013, Currenti et al. 2014, Fago et al. 2014, Grecea et al. 2016, Stanković et al. 2016), with various advantages that became the goal of making Web GIS. The benefits of the previous system are the early warning applications for disasters and the disaster history display in an area, while Balikpapan Web GIS can be used in the case of participatory monitoring to prevent land use and infrastructure planning.

In the GIS participatory process, the community's demands become the main point, especially in conveying information (Voss et al. 2004, Brown et al. 2017). The ease of delivering and receiving information responses is the critical factor to GIS participation so that the performance of the built system must match the needs of the users. From several tests conducted using a Focus Group Discussion (FGD) method intended to test Web GIS Balikpapan, one weakness which was found was that access time increases in line with an increasing number of users. The FGD invited representatives from each district in Balikpapan (25 users) to test the system usage. When ten users used the Balikpapan Web GIS, the access time was 3.6 s, but when 20 to 25 users used it simultaneously, the access time increased to 6.4 s and 8.1 s (Fig. 9). This is an important note because, in real application, many users will access the system at the same time. Hence, it is necessary to strengthen the access to the system, so that the loading time is not too long, and it is lightly used. This weakness will be part of future work when the system is implemented in Balikpapan City.

Overall, the framework is in line with the needs of the community, both from the availability of land use information and motivating the community to be involved in monitoring the implementation of land use and infrastructure planning policy. When the system is implemented, there must be some adjustments in particular to improve the system performance, such as strengthening the server capacity for data access so that the system is convenient to use and it provides many benefits.

Furthermore, the system developed by Balikpapan Web GIS is more focused on supporting systems to assist the government in a participatory way. With the right communication approach through Web GIS, both government and community can monitor even large areas well. A useful monitoring function with good technological support will enable smart governance so that the implementation of development plans can be safeguarded together. In accordance with the smart city spirit, a smart city is not only a utopian concept but also beneficial to the people living in it, and, in so doing, it can improve the quality of life and create good governance (Feltynowski 2015, Eom et al. 2016, Ahvenniemi et al. 2017, Fietkiewicz et al. 2017, Kim et al. 2017, Lv et al. 2017).

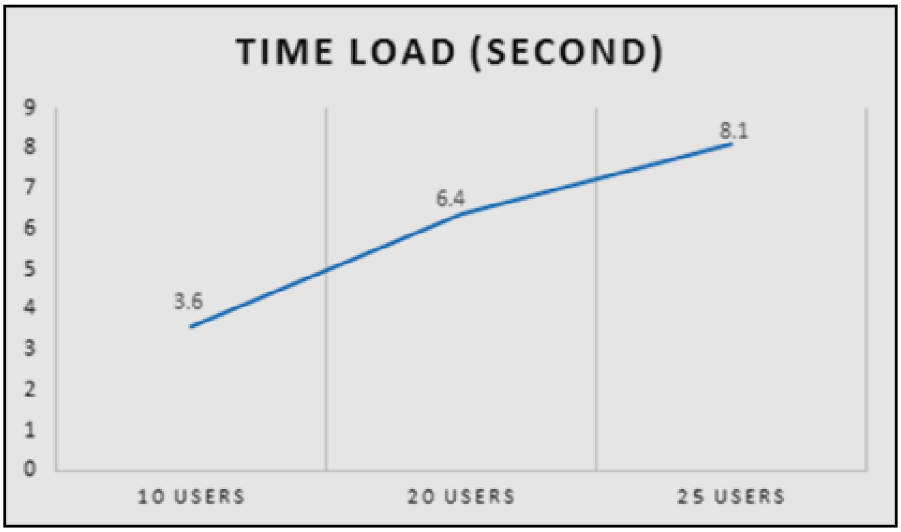

Fig. 9 – **Time load to access Balikpapan Web GIS**

The challenges in implementation

The problem of spatial planning is very complex and it requires the competence of experts from various fields and it involves policymakers with different interests. There is indeed no perfect solution for long-term spatial planning. However, the opportunities to improve the access to spatial information in support of participatory decision making need to be started as a solution in the future. In such circumstances, various parties are often involved, especially stakeholders who are directly involved in planning. They don’t need to be GIS experts to be able to take advantage of Web GIS and to contribute to urban land use planning because it can be designed to be more user-friendly by utilizing open source technology and freeware.

Some debate did arise in the use of open-source software in web GIS. Most of the focus of the discussion is on the validity of copyright and data status. However, there have been many recommendations for open science projects using open-source software. We believe that free open source is not only understood as the free software but it also gives users the convenience and freedom to modify it. This is consistent with the study of Chmielewski et al. (2018) which indicates the importance of open access solutions to meet the expectations of volunteers and scientists, especially in developing GIS web in developing countries.

The impetus from theoretical discussions about spatial planning to include digital domains further strengthens the role of participation in urban and regional planning (Van Casteren and Sneyers 2002, Alam et al. 2018). Combining the two worlds in one planning job adds new options, especially in enhancing the planning tools. In this case, the network-based technology is designed to develop in increasing the satisfaction of all actors involved in urban and regional planning, especially in detecting the dynamics of urban land-use change. Space that initially existed only in the real world is currently developing in the virtual space that allows for spatial simulation and information in policymaking. Furthermore, this method will enable users to comment on selected features on the map, including comments as input for urban development and reports on violations of spatial use rules. If developed in more detail, this system can be an intermediary in interactive landscape planning, which is possible in helping spatial exploration in WebGIS.

From an academic perspective, web GIS Balikpapan tries to provide an example of using software with unlimited licenses. This is important, considering that some web GIS service providers with paid software are costly and must renew their licenses every year. This limitation can be overcome by open source web GIS with multiple support provided by the user community (QGIS, Map-Server, P-Mapper, Open Layers, Open Street Map, Leaflets). GIS communities are free to create and share their GIS tools. This activity is possible to spread open science methods to the public. In addition, this is also an initiative to utilize open source web GIS, especially in developing countries like Indonesia.

Aside from cost issues, another major problem is creating lightweight and portable web GIS solutions without additional costs such as purchasing additional licenses, changing the operating system or the hardware configuration. Typically, cloud-based mapping platforms such as this can display data interactively and it can describe land use, especially for monitoring in urban areas. Some contemporary Geoinformatics activists are also heading towards cloud services solutions. They are moving to get real-time data processing by adding several tools, but this system requires a complex system architecture. Thus, the choice to use web GIS-based on open source is the most realistic option to implement even though there are disadvantages such as being unable to provide real-time data.

In more complex challenges, Indonesia has also begun implementing spatial information systems through the one map policy program but it has not yet reached districts/cities outside of Java, so efforts to create web GIS with good spatial data in realizing smart governance are urgently needed. Institutional reform and spatial data management also promote a trend towards democratization of decision making using new technologies (Nackoney et al. 2013, Natarajan 2017, Ruijer et al. 2017). New technology is used to support the planning and control of land use, especially in decision making and monitoring the implementation of spatial plans. No platform perfectly facilitates these needs, but Web GIS development and efforts to implement it are an influential driving factor for the development of spatial data openness.

Limitations also appear as an integral part of the implementation. As a developing country, internet infrastructure in Indonesia, especially Balikpapan, continues to develop with varying capacities. Unstable internet connections are the main obstacle because Web GIS performs reliable management and analysis of information when the connection is well connected. However, the spatial dimension plays a substantive role in understanding given phenomena and estimating possible scenarios, especially for certain cities outside of Java. Indeed, Web GIS alone cannot solve all problems in the planning process, but their integration with policymakers and digital infrastructure is able to offer a solution towards smart government.

Conclusions

Based on the results of the study, Web GIS development Balikpapan can assist the realization of smart governance. Built applications do not always have expensive costs, and as with the use of open source technology in the construction of Balikpapan Web GIS, the cost can be reduced. Furthermore, open-source Web GIS provides opportunities to develop many features that can help to bridge communications between government and communities in monitoring the implementation of land use and infrastructure planning policy. Some system adjustments for future work should be made, especially regarding the speed of access when multiple persons use it; therefore, future work is required for the development of system performance. Thus, it will facilitate communication between the community and the government.

With excellent communication and open data support between Web GIS system, government, and society, smart city implementation with smart people and smart governance will no longer be a utopian ideal. Moreover, further research needs to be done. One of them is researching the response of urban communities at all levels in using web GIS technology. This is important because urban communities are the subject and object of using Web GIS technology in land use monitoring systems. By doing so, this technology can be sustainable and useful to be implemented in all developing countries.

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NON-LINEAR AND LAGGING CONVERGENCE EFFECTS OF THE EU'S REGIONAL SUPPORT AT NUTS 3 LEVEL

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Abstract: Reduction of the territorial disparities in terms of their development level is the main aim of the European Union's (EU's) regional support. Most of the previous studies investigate the linear relationship between support and growth at countries' or NUTS1/2 disaggregation level, omitting the question on what is the impact of this support on regional convergence among NUTS3 regions and on whether non-linear effects occur. To fill this gap, we modified the difference-in-differences estimator to test empirically the non-linear convergence effects of the EU's regional support at NUTS 3 level over the 2000-2006 programming period, taking into account the possible lagging effect. The results revealed that the impact of regional support on convergence is positive with the diminishing marginal effect as the intensity of payments is increasing. Moreover, we find evidence that the return is higher for the post-intervention compared with the intervention period, i.e. the convergence outcomes of the EU's support occur in the long-run.

Key Words: *regional disparities, convergence, NUTS 3, non-linear effects*.

Introduction

The EU's regional support aims to ensure the growth of the least developed regions in order to reduce territorial disparities. To achieve this goal, the European Commission (EC) uses support from the Cohesion (CF) and Structural (SF) funds. Approximately 160 billion euro were allocated from these funds to the EU's Member States (MS) over the 2000-2006 programming period. The question of interest is whether this support has achieved its objectives, if it has boosted growth in the least developed regions and if it led to regional convergence. The analysis of previous research, however, disclosed that most of the papers investigate the impact of SF and CF on regional growth (GDP per capita and employment) at country, or NUTS1/2 disaggregation level, leaving open the question on what impact SF and CF have on convergence, especially at NUTS3 level.

The leading article by Becker et al. (2018), covering the four last programming periods, revealed the positive effect of the SF on economic growth in NUTS2 regions and it noted that this effect does not last long. Moreover, Becker et al. (2013) found that SF payments positively influence only about 30% of the EU-25 NUTS2 regions by revealing the heterogeneity of the effect. Kyriacou and Roca-Sagalés (2012) assessed the effects of SF transfers on the convergence among 14 EU countries and it also concluded that the effect of SF treatment is heterogeneous. Although studies (Rodríguez-Pose and Novak 2013, Pinho et al. 2015, Becker at al. 2018, Piętak 2018) show that EU's regional support has become more efficient over the last two programming periods, compared to the previous ones, the efficiency problem of SF and CF allocations persists as CP underestimates the importance of transfer intensity which might influence the return on support.

Just a few studies estimate the non-linear relation between the EU's regional support and economic growth or/and convergence ascertaining the potentially decreasing marginal effect when transfer intensity is increasing. Wostner and Šlander (2009), Kyriacou and Roca-Sagalés (2012), Becker et al. (2012), Pinho et al. (2015), Pontarollo (2016), Cerqua and Pellegrini

(2018), Di Cataldo and Monastiriotis (2020) investigated how the return on SF depends on the intensity of the transfers. They all have revealed that SF intensity should not exceed the maximum desirable levels in order to avoid the inefficiency of CP. Hagen and Mohl (2008) made a contrary conclusion that it does not matter which "dose" of SF transfers the regions have received because the impact of SF transfers on regional growth rates is not significant. However, the study could have revealed no significant impact since the long-term effects were not assessed. SF and CF can have both short-run and long-run effects. According to Cappelen et al. (2003: 16), "while the former occurs more or less instantaneously, the latter may take several years to materialise". Thus, it is crucial to evaluate the impact of SF and CF over both, i.e. financial intervention and post-intervention, periods.

All studies dealing with non-linear or lagged effects of SF treatment intensity estimated the impact on economic growth (except Kyriacou and Roca-Sagalés 2012), leaving open the question of what is the effect on convergence. Kyriacou and Roca-Sagalés (2012) investigated the non-linear SF effects on convergence, but their study (likewise Beugelsdijk and Eijffinger 2005, Wostner and Šlander 2009) covered the countries' disaggregation level. The research of Rodríguez-Pose and Fratesi (2002), Hagen and Mohl (2008), Mohl and Hagen (2008, 2010), Pinho et al. (2015), Bondonio and Pellegrini (2016), Pontarollo (2016), Cerqua and Pellegrini (2018), Di Cataldo and Monastiriotis (2020) covered NUTS1/2 regions. Just Becker et al.'s (2010, 2012) studies were conducted at NUTS3 level, but they do not evaluate the non-linear effects of SF on convergence. Hence, it is unclear whether SF and CF have non-linear effects on convergence, especially at NUTS3 level.

To fill these gaps, our paper aims to (i) develop a model suitable to examine the impact of EU's regional financial support on disparities; (ii) assess what effect the EU's regional financial support had on regional convergence one being the primary goal of the CP. We focus on rarely analysed NUTS3 disaggregation level and we take into account the possible diminishing marginal and lagging effects of EU's regional financial support.

The rest of the paper is structured as follows: the second section presents the review of contributions on non-linear and lagging effects of EU's regional support on growth and convergence, the third section describes the methodology and estimation strategy, the fourth section presents the estimation results, the next section presents the discussion, and the last section concludes the paper.

Literature review

There are a few studies that tested other than a linear functional form of the relationship between the intensity of SF and CF payments and the outcome variable (Table 1).

The analysis of previous studies, which estimate the non-linear relationship between SF and CF transfers and economic growth or convergence, has revealed, that, after a certain intensity threshold, additional payments are not associated with higher returns. However, too low intensity of SF and CF payments does not allow to achieve significant positive outcomes. According to Becker et al.'s (2012) findings, an optimal desirable level of transfer's intensity is 0.4% of regional GDP, and when the intensity of the transfers reaches 1.3% of GDP, additional payments do not generate positive returns. Pontarollo's (2016) findings supplemented the results of Becker et al.'s (2012) study. He concludes that the intensity of SF payments should not exceed 0.15-0.70% of the GDP and a particular desirable intensity level depends on the SF allocation (intervention) area. If SF expenditures on infrastructure development exceed 0.70% of the GDP, the marginal effect of SF transfers becomes negative. The intensity of SF payments for a productive environment should be even lower – not to exceed 0.15% of the GDP. Wostner and Šlander (2009), and Kyriacou and Roca-Sagalés (2012) investigate the non -linear relationship between the intensity of SF treatment, the amount of structural expenditure

Table 1

Estimation results of previous studies on the non-linear effects of SF transfers

Research by	Covered period	Disaggregation level	Applied method*	Outcome variable	Overall impact	Does SF transfer intensity matter?	Desirable level
Wostner and Šlander (2009)	1990-1993, 1994-1999, 2000-2006	EU-15, Country-level	FE	STREXP**	Positive, significant	Yes	Max ~2.33% of countries GDP, Optimal – ND***, Min ~1.75% of countries GDP
Becker et al. (2012)	1994-1999, 2000-2006	EU NUTS3 regions	MGPS	Economic growth	Positive, significant	Yes	Max ~1.3% of regional GDP; Optimal ~ 0.4% of regional GDP, Min – ND
Kyriacou and Roca-Sagalés (2012)	1994-1999, 2000-2006	EU-14, Country-level	Feasible GLS, SUR	Convergence	Positive, significant	Yes	Max – ND, Optimal – ND, Min ~1.6% of countries GDP
Pinho et al. (2015)	1995-1999, 2000-2006, 2007-2009	EU-12, NUTS 1/2 regions	FE	Economic growth	Positive, significant	Yes	Max ~ 3%, Optimal – ND, Min ~1,9 % of countries GDP
Bondonio and Pellegrini (2016)	1994-1999, 2000-2006, 2007-2013	EU-15, NUTS-2 level	PSM, GPS, RDD	Economic growth	Positive, significant	Yes	ND
Pontarollo (2016)	2000-2006	EU-15, 202 NUTS 1/2 regions	GAM, GLMs	Economic growth	Positive or negative depending on the intervention area, significant	Yes	Max – 0,15 -0,70 % of regional GDP depending on the intervention area. Optimal – ND, Min – ND.
Cerqua and Pellegrini (2018)	1994-1999, 2000-2006	EU-15, 208 NUTS 2 regions	RDD	Economic growth	Positive on GDP per capita growth, insignificant on GVA	Yes	Max – 305-340 € per capita, Optimal – ND, Min – ND
Di Cataldo and Monastiriotis (2020)	1994-2013	UK, 37 NUTS 2 regions	SLDV (FE), SPL (FE)	Economic growth	Positive, significant	Yes	ND

* MGPS – Method of Generalized Propensity Score, GLS – General Least Squares, SUR – Seemingly Unrelated Regression, FE – Fixed Effects Model, PSM – Propensity Score Matching, GPS – Generalised Propensity Score, RDD – Regression Discontinuity Designs, GAM – General Additive Model, GLMs – Semi-parametric Generalised Linear Model, LSDV – Least Squares Dummy Variables, SPL – Spatial Panel Lag.

** STREXP – Amount of structural expenditure, i.e. the sum of all public spending at all levels of government, for economic purpose.

***ND – No data presented.

and the convergence at the country level. The studies revealed the significant positive impact of SF transfers when their intensity reached approximately 1.6-1.75% of the countries' GDP. According to Wostner and Šlander (2009), when the SF transfers exceed 2.33% of the countries' GDP, they do not promote structural expenditures. According to Pinho et al.'s (2015) findings, this boundary lies at 3% of the countries' GDP, according to Cerqua and Pellegrini (2018) – at 305-340 € per capita. Bondonio and Pellegrini (2016), as well as Di Cataldo and Monastiriotis (2020), agree that the intensity of SF and CF transfer affects the returns, but do not provide a desirable level.

Beugelsdijk and Eijffinger (2005) provided a justification of the non-linear form of relationship using the *moral hazard phenomenon* and the *substitution effects*. We can argue that the regions, by using the SF support efficiently and inducing a faster growth of the desirable outcome(s), would later become ineligible for financial support. Regions receive structural financial support only below a certain level of development. If the level of regional development is at a critical eligibility level, which could reduce the EU financial support in the future, the regions may tend to manipulate the statistics. In other words, due to the moral hazard phenomenon, SF payments are used for an inappropriate project in a way to continue being financially supported. The difficulty of testing the effect of moral hazard is related to its measurement problem. Especially it can happen at the regional level because it is hard to disentangle from the other (unforeseen) types of inefficient use of funds. Beugelsdijk and Eijffinger (2005) included a corruption index in their model, but the results do not indicate that the countries with a higher corruption level use the regional support more inefficiently.

Another effect that might arise is the substitution effect. The distribution of EU funds is bound with the principle of additionality, which ensures that national and/or local resources accompany the EU's regional support (Wallace et al. 2015). The substitution effect is the result of inefficient public support schemes when beneficiary regions reduce their resources and amend them with the EU's regional support. The research (Beugelsdijk and Eijffinger 2005, Marzinotto 2012, Del Bo et al. 2011, Szitásiová et al. 2014) revealed that different substitution effects occur. In the long-run, the impact of the substitution of local resources with the EU's regional support is perceived as a lack of absorptive capacity of the local authorities. The reason is that once the public entities replace their resources with the EU's regional support, they would eventually have to invest even more in the case of a loss of external funding. Another reason is that, while replacing the local resources, EU's regional support loses its importance and, therefore, the investments become unnecessary without multiplicative impacts in the lagging regions. Barca (2009) emphasised that regional policies aim to encourage amendments in the behaviour of private actors in the regions where either inefficiency or a social exclusion trap exists, but not to compensate the inability of the local authorities to generate sufficient revenue from their sources to finance the regional development. Regional support in some cases even creates a culture of dependency. The other problem related to the substitution effect, which is highlighted by Ederveen et al. (2003), as well as Beugelsdijk and Eijffinger (2005), is that regional support may offset the impact of private investment if it finances the projects that are close substitutes for the private capital.

Becker et al. (2012) argued that the additional financial support has no effect on the outcome when the intensity of the support reaches the threshold level since SF transfers are mainly directed to investment projects and since investments are subject to *diminishing marginal returns*. The assumption of diminishing returns is naturally derived from the neoclassical theory of production. This assumption implies that the more investment projects are carried out, the lower return is expected from additional investments (or transfers) (European Commission 2016).

In the previous contributions, we can find arguments that some regions are using EU funding inefficiently if the intensity of transfers is increasing. If EU regional transfers are subject to diminishing returns, it is not sufficient to estimate that transfers *on average* have a positive effect on growth (Becker et al. 2012). It is also essential to estimate how the different levels of transfers' *intensity* are related to regional growth. This would allow seeing up to which level the transfers are fostering regional growth and beyond which level the further transfers become inefficient. If diminishing the marginal returns of transfers empirically manifest, we can identify a maximum desirable level of a transfers' intensity. In this case, beyond a determined maximum of desirable level of SF transfers' intensity, no additional (or even lower) growth effects would be generated. Becker et al. 2012, Pinho et al. 2015, Pontarollo 2016, Cerqua and Pellegrini 2018 argued that SF in the richer MS is now producing diminishing marginal returns with no visible value-added over what might be achieved by the national programmes. Gorzelak (2016) assumed that the effects of the diminishing marginal returns could appear as the different effects of the particular types of intervention in the different types of territories. Hence, the diminishing marginal returns of SF transfer intensity can differ among European regions depending on the development level, accumulated social capital, and potential demand (European Commission 2016).

Since incentives for misallocation, substitution effects, and diminishing marginal returns are all likely to correlate with a higher intensity of financial support, we can expect to observe an inverted U-shaped quadratic form of a relationship between the intensity of support and the outcome. It would indicate that with a higher level of regional financial support intensity, additional support may positively affect the desired outcome, but beyond some level of intensity, the marginal positive effects on the outcome might disappear or even become reverse.

Another limitation of previous studies on evaluating SF and CF returns is that in most cases research considers only short-term effects. However, CP treatment may have an effect over the long-run as well. There could be cases when the positive effect of regional support can occur over the current year of the investment and it can last for a couple of years, and cases when the positive effect can start to manifest a few years after the investment, depending on the SF and CF intervention area. For example, the positive effects of an investment in infrastructure may take several years to materialise. Just a few previous studies estimated the possible lagged effects of SF and CF (Table 2). It should be noted that all of them assessed the impact of SF and/or CF on economic growth (GDP per capita, employment), omitting the question of what is the lagged effect on convergence.

The analysis of previous studies on lagged or continuing SF and CF treatment effects has disclosed that, first, the overall positive effect of SF on economic growth may last three years ahead (Beugelsdijk and Eijffinger 2005), evaluating the impact at a country level. However, it is not clear how long the positive effect lasts at a regional level, especially in the case of convergence. Second, a significant effect of SF may be delayed, i.e. it occurs after a specific time lagging from 1 up to 6 years, depending on the intervention area (Rodríguez-Pose and Fratesi 2002, CSIL and DKM Economic Consultants 2012) or support Objectives (Becker et al. 2010, Mohl and Hagen 2008, 2010). This makes it reasonable to assert that the evaluation of SF and CF return has to cover estimations for both short-run and long-run effects.

Methodology

Aiming to examine the potentially non-linear relation between the regional support intensity and the desired outcome of the CP to diminish the disparities among EU regions, we ground our model on a difference-in-differences (DID) approach. The initial specification of the linear regression equation, which allows estimating the homogeneous DID parameter, is:

$$y_i = \delta_0 + \delta_1 \cdot t2 + \delta_2 \cdot s_i + \delta_{DID} \cdot t2 \cdot s_i + \varepsilon_i, \quad (1)$$

Table 2

Estimation results of previous studies on delayed and continuous SF impact

Research by	Period	Disaggregation level	Applied method	Outcome variable	Overall impact	Is the lagged effect set?	Time lag
Rodríguez-Pose and Fratesi (2002)	1989-1999	EU NUTS 2 regions	Pooled GLS, LSDV	Economic growth	Positive, significant of total payments. Positive, not significant of Obj. 1 payments	Yes	~1-3 years depending on the intervention area
Beugelsdijk and Eijffinger (2005)	1995-2001	EU-15, Country-level	One and two-step GMM	Economic growth	Positive, significant	No	Three years ahead
Mohl and Hagen (2008)	1995-2005	EU-15, 124 NUTS 1/2 regions	LSDV, GMM, spatial correlation	Economic growth	Positive, significant of Obj. 1 payments. Negative, significant of Objective 2 and 3 payments	Yes	~2-3 years
Becker et al. (2010)	1989-1993, 1994-1999, 2000-2006	EU-12, EU-15, EU-25 NUTS 2/3 regions	RDD, Pooled OLS, FE	Economic and employment growth	Positive, significant on growth, insignificant on employment	Yes	~4-6 years (Obj. 1)
Mohl and Hagen (2010)	1999-2007	EU-15, 130 EU NUTS 1/2 regions	GMM, SDP	Employment growth	No significant of total SF, vary from positive to negative, significant Obj. 1, 2, 3 payments	Yes	~1-4 years depending on payment type (Obj.)
CSIL and DKM Economic Consultants (2012)	1994-1999	EU-5 (Greece, Ireland, Italy, Portugal, Spain), Project level	Cost-benefit analysis	Economic growth	Positive, significant	Yes	~5 years

*GLS – General Least Squares, LSDV – Least Square Dummy Variable estimator, GMM – Generalized Method of Moments, RDD – Regression Discontinuity Designs, OLS – Ordinary Least Square, FE – Fixed Effects, SDP – Spatial Dynamic Panel approach.

where y_i is the GDP per capita in the *i*-th region. δ_0 is the estimate of the average y_i in the group of not supported regions (control group) over the reference period. *t2* is a dummy variable equal to 1 for the financial intervention period and equal to 0 for the reference period. δ_1 shows how y_i average in the control group changed over the financial intervention period, compared with the reference period, i.e. how regional GDP per capita has changed without regional support. s_i is a dummy variable equal to 1 if the region received support and equal to

0 otherwise. δ_2 shows how y_i average differed between regional support recipients and control group already before the financial intervention took place, i.e. it shows the initial (over the reference period) difference between the supported and not supported regions in terms of GDP per capita. We expect to estimate a negative parameter on δ_2 since CP focuses on less developed regions. δ_{DID} is the DID parameter which shows the effect of support, i.e. whether the initial negative differences between the support recipients and the control group became smaller due to regional support. A positive parameter on δ_{DID} would give evidence that the initial differences observed over the reference period became smaller over the financial intervention period, i.e. regional support contributed to regional convergence. e_i is the error term.

We assume that regions will not respond to SF transfers in the same way simply because the intensity of support is not the same across regions. To put in other words, the effect of regional support hinges on the intensity of regional support. Thus, we expect some heterogeneity in the impact across regions as well. We can estimate the DID assuming heterogeneity of the support effect by interacting s_i dummy with the regional support intensity, S_i. If a region does not receive financial support, s_i and S_i as well as their interaction are equal to zero. If a region receives support, s_i is equal to unity and its interaction with S_i is equal to S_i. Thus, s_i substituting with S_i we will estimate the effect of regional support intensity on the dynamics of the disparities:

$$y_i = \delta_0 + \delta_1 \cdot t2 + \delta_2 \cdot S_i + \delta_{DID} \cdot t2 \cdot S_i + \varepsilon_i, \quad (2)$$

where δ_{DID} now measures the effect of regional support intensity change by one unit on regional GDP per capita. δ_2 is expected to be negative since it shows the correlation between the regional support intensity over the financial intervention period and regional GDP per capita over the reference period.

To relax an assumption that the effect of S_i on the outcome is constant, i.e. that relationship is linear, we introduce the quadratic specification:

$$y_i = \delta_0 + \delta_1 \cdot t2 + \delta_{21} \cdot S_i + \delta_{22} \cdot S_i^2 + \delta_{DID1} \cdot t2 \cdot S_i + \delta_{DID2} \cdot t2 \cdot S_i^2 + \varepsilon_i. \quad (3)$$

Statistically significant and positive δ_{DID1}, and statistically significant and negative δ_{DID2} would give evidence of a quadratic form of relationship in the form of an inverted U-shaped letter with a marginal effect of regional support intensity on y_i calculated as:

$$\frac{\partial(y_i)}{\partial(S_i)} = \delta_{DID1} + 2 \cdot \delta_{DID2} \cdot S_i. \quad (4)$$

In the case of interactive Eqs. (1) and (2), after the first differencing or time-demeaned transformations, they collapse to simple additive models for the second (financial intervention) period and estimated standard errors on coefficients associated with DID parameter are general ones. These two alternative transformations are used to control all region-specific time-constant effects. For example, the geographical position of the region, which determines its access to infrastructure, such as seaports, highways, etc., or the economic linkages between regions, which can be an essential growth factor for the peripheral regions situated near core regions. The same transformations also help to control the effects that are subject to slow change over a relatively short time period, for example, the demographic or economic structure of the region. Having little possibility to control these effects by including all necessary variables at NUTS3 level, an unexplained variation which now would account for a part of the error term could lead to a correlation between ε_i and y_i as well as between ε_i and S_i. This correlation is very likely to occur since regional support is not randomly distributed among regions, but it depends on the regional characteristics, which are also related to its growth and thus impose an endogeneity problem.

However, in the case of the Eq. (3) the multiplicative term is retained after the first differencing or time-demeaned transformations for the second period (*t2*=1):

$$\ddot{y}_i = \delta_0 + \delta_1 \cdot (1) + \delta_{DID1} \cdot (1) \cdot \ddot{S}_i + \delta_{DID2} \cdot (1) \cdot \ddot{S}_i^2 + \varepsilon_i, \quad (5)$$
$$\ddot{y}_i = (\delta_0 + \delta_1) + (\delta_{DID1} + \delta_{DID2} \cdot \ddot{S}_i) \cdot \ddot{S}_i + \varepsilon_i,$$

where $\ddot{}$ stands for the time-demeaned variable. Using the first-differencing, we would yield quite the same equation, just δ_0 would not be retained. Therefore, not just the marginal effect of S_i on y_i, i.e. slope $(\delta_{DID1} + \delta_{DID2} \cdot S_i)$ is conditioned on the value of S_i itself, but following Friedrich (1982), we can argue that the standard error of the slope coefficient is also conditioned on S_i value and standard error of the sum $(\delta_{DID1} + \delta_{DID2} \cdot S_i)$ is:

$$SE_{(\delta_{DID1}+\delta_{DID2} \cdot S_i)} = \sqrt{var(\delta_{DID1}) + S_i^2 \cdot var(\delta_{DID2}) + 2 \cdot S_i \cdot cov(\delta_{DID1}, \delta_{DID2})}. \quad (6)$$

This implies that the estimated marginal effect of S_i on y_i can potentially be not significant over the whole range of observed S_i values, i.e. it is not necessary to reach the tipping point of S_i for the marginal effect not to differ from zero. In line with the usual logic of constructing for a coefficient, a test of statistical significance against the possibility that the population parameter is zero, the *t* value for the marginal effect of S_i on y_i can be calculated, when S_i^2 is added to the equation, as:

$$t = \frac{\delta_{DID1} + \delta_{DID2} \cdot S_i}{SE_{(\delta_{DID1}+\delta_{DID2} \cdot S_i)}}. \quad (7)$$

Having an empirical relationship between y_i and S_i in the form of an inverted U-shaped letter, Eq. (7) enables us to test what the minimum level of S_i is required for the marginal effect of S_i on y_i to become significant and whether the marginal effect of S_i is still significant when the turning point is reached and the marginal effect becomes negative.

The data for the empirical estimation at NUTS 3 aggregation level are collected from Eurostat and SWECO (2008). The regional GDP per capita at constant prices is considered as the dependent variable, i.e. y_i. Since the data on regional support are provided for the whole period rather than on a yearly basis, we calculated the regional support intensity, i.e. s_i as the ratio between the dedicated funds for a particular region over the 2000-2006 programming period and the overall regional GDP over the same period. Over the 2000-2006 programming period, all EU-25 MS were under CP's consideration, encompassing 1251 NUTS3 regions in total. 244 regions, which did not receive any support over the 2000-2006 programming period, will serve as a control group. Regional support intensity, i.e. s_i, for 1007 financially supported regions ranges from 0.00015676 per cent up to 13.506 per cent with an average and median values of 0.5043 and 0.1427, respectively. The correlation between s_i and the average y_i over the reference period is -0.4028 (n=1007, p-value<0.0001). Being statistically significant, the negative correlation suggests that the less developed regions were financially supported more intensively.

Since the earliest data at NUTS 3 level is available from 1995, the period of 1995-1999 in our research will be considered as the reference or pre-intervention period. The period's average y_i over 1995-1999 for financially supported regions was lower by 23.8 per cent, compared to regions in the control group. The 2000-2006 period is considered as the financial intervention period. Throughout 2000-2006, compared with the reference period, the difference between the support recipients and regions in the control group increased by 1 p. point. It is not evidence of CP's failure since we do not know how much the differences would have increased in the case that CP would not be presented at all. Estimating the effect of SF transfers on the convergence over 2000-2006 would allow examining the short-run convergence effects of regional support. One post-intervention period considered in our research is 2007-2011, over which the difference increased up to 25.7 per cent. Since the period of 2007-2011 encompasses the Great Financial Crisis, which at some point could distort the estimation results, and since the regions were able to spend the last allocation available until the end of 2009, what could affect the occurrence of the outcomes just after 2009, we alternatively consider 2010-2014 as the post-intervention period. Extending the period more, i.e. including the year 2015 or 2016, could, at some extent, cover the effects of the allocations of the next, i.e. 2007-2013, programming period. Estimating the effect of SF transfers on convergence over 2007-2011 and 2010-2014 allows examining the long-run convergence effects of regional support.

The DID approach requires that the group of regions granted for SF support and regions in the control group would meet the common trend assumption. That is, if the regional support has not been provided, there would not exist systematic differences in the outcome variable trend of changes between the two groups over time. Since the average growth rate of regional GDP per capita at constant prices over 1995-1999 was 2.36 and 2.62 per cent for control and financially supported groups, respectively, and since we did not fail to reject the null – trends of changes are equal, the difference in growth trends is used for the adjustment, and differential-trend-adjusted GDP per capita at constant prices is used as the dependent variable.

Results

The fixed effects estimates of Eq. (3), examining the non-linear relation between the regional support intensity and convergence, are reported in Table 3.

Table 3

Fixed effects estimates

Variable	Parameter	(1)	(2)	(3)
Intercept	δ_0	9.820***	9.819***	9.820***
		(0.002)	(0.002)	(0.002)
$t2$	δ_1	0.155***	0.214***	0.222***
		(0.004)	(0.005)	(0.005)
$t2 \cdot S_i$	δ_{DID1}	0.014*	0.042***	0.035***
		(0.008)	(0.011)	(0.011)
$t2 \cdot S_i^2$	δ_{DID2}	-0.001	-0.002**	-0.002**
		(0.001)	(0.001)	(0.001)
N		2502	2502	2502
Within R-squared		0.633	0.671	0.678

Notes: Robust (using HCCME) standard errors are presented in parentheses. *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. All estimates use logged differential-trend-adjusted GDP per capita at constant prices as dependent variables. Estimates in column (1) report effects for 2000-2006, column (2) over 2007-2011, column (3) over 2009-2013.

Est. (1) shows that there is no statistically significant unconditional linear or non-linear effect of regional support on convergence over the financial support period since we did not fail to reject the hypotheses that both parameters on DID are equal to zero at a standard significance level. It suggests that either the financial support period is too short for the convergence outcomes of regional support to occur or the significance of the effect differs depending on the intensity of the support. On the contrary, Est. (2) and (3), for both post-intervention periods, show similar DID parameters in terms of their size and significance. The estimated coefficients on the non-squared term being positive and on the squared term being negative, both statistically significant, suggest that the effect of regional support on reducing regional disparities over the long-run is positive but marginally diminishing. The estimated turning point (using Eq. (4)) occurs when S_i reaches around 8.59-9.24 per cent. This turning point covers almost the whole observed range of S_i, because there are just 2 regions (out of 1007) with the S_i level above the estimated tipping point.

Fig. 1 represents the estimated non-linear relation between the convergence and regional support intensity for the financial intervention period (Est. (1)) and both post-intervention periods (Est. (2) for 2007-2011 and Est. (3) for 2009-2013).

Since we do not observe regions with S_i values from 6.65 up to 12.75, Fig. 1 (a) does not picture that relation between convergence and S_i is non-linear, i.e. the marginal return on EU's regional support is conditioned on the level of support intensity. Fig. 1 (b) plots the same relationship, but with added not observed values of S_i. Our estimations provide evidence for that the return on the EU's regional support is positive and higher for the post-intervention period (over long-run), compared with the return over the financial intervention period (over short-run). The curves representing the relation over the post-intervention period are above the curve that represents the relation over the financial intervention period, i.e. at the same level of S_i, the return is higher over the long-run. Our estimations suggest that support has a way more significant effect when the programming period ends and when the support is fully absorbed, i.e. it takes many years for the considerable support effects to appear. Considering a strategic investment in infrastructure, human capital, etc., directed to promote long-run competitiveness, it can take decades for the effect to appear.

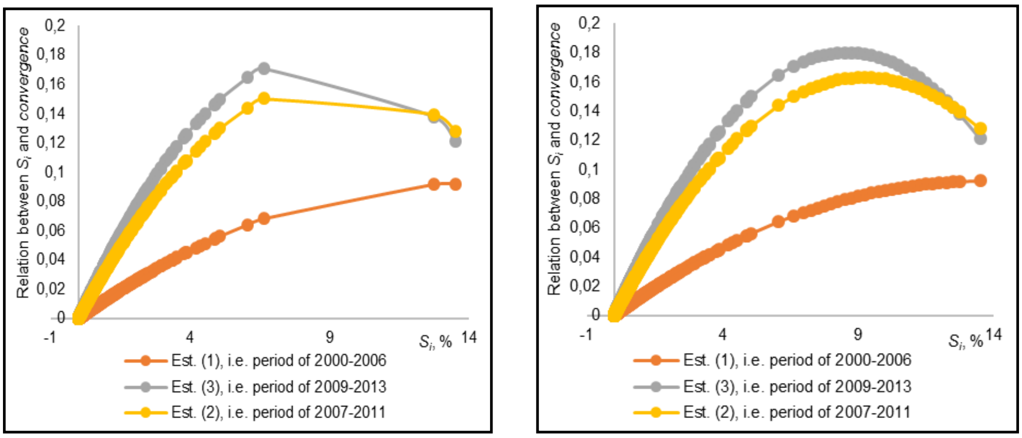

Fig. 1 – **The estimated non-linear relation between regional support intensity and convergence**
(a) over observed S_i values and (b) with additional S_i values

We also see that the relation between convergence and S_i is much more curved over the post-intervention period, compared to the financial intervention period, i.e. a curve being flatter for the financial intervention period shows that the marginal return is of less dependency on the regional support intensity, compared to the post-intervention period. Probably, it is more important to consider the non-linear relation modelling the return on EU's regional support over the long-run, while over short-run the non-linear effects do not manifest.

Having an empirical relationship between S_i and convergence in the form of an inverted U-shaped letter, Eq. (7) enables us to test what the minimum level of S_i is required for the marginal effect of S_i on convergence to become significant and whether the marginal effect of S_i is still significant when the turning point is reached and the marginal effect becomes negative. To illustrate this with our example, we took the earlier discussed estimations from Table 3. Table 4 reports the variance and covariance of estimated DID parameters.

Table 4

Variance – covariance of DID parameters

Variance-covariance	Estimates		
	(1)	(2)	(3)
$var(\delta_{DID1})$	6.06E-05	1.13E-04	1.11E-04
$var(\delta_{DID2})$	3.47E-07	9.17E-07	8.52E-07
$cov(\delta_{DID1}, \delta_{DID2})$	-4.42E-06	-9.19E-06	-8.94E-06

Using Eq. (6) and (7), we calculated the standard errors (Fig. 2) and t-ratios (Fig. 3) of slopes conditioned on S_i values. Part (a) reports the observed range of S_i and part (b) includes the additional unobserved S_i values.

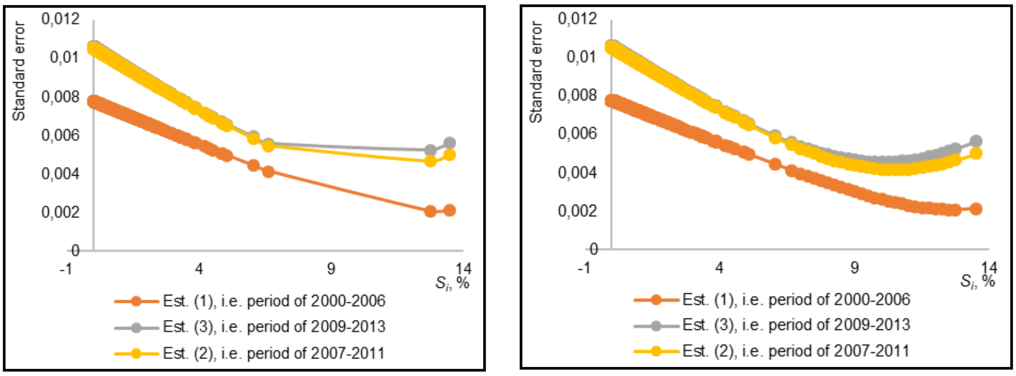

Fig. 2 **– The relation between the regional support intensity and the standard error of the slope (a) over observed S_i values and (b) with additional S_i values**

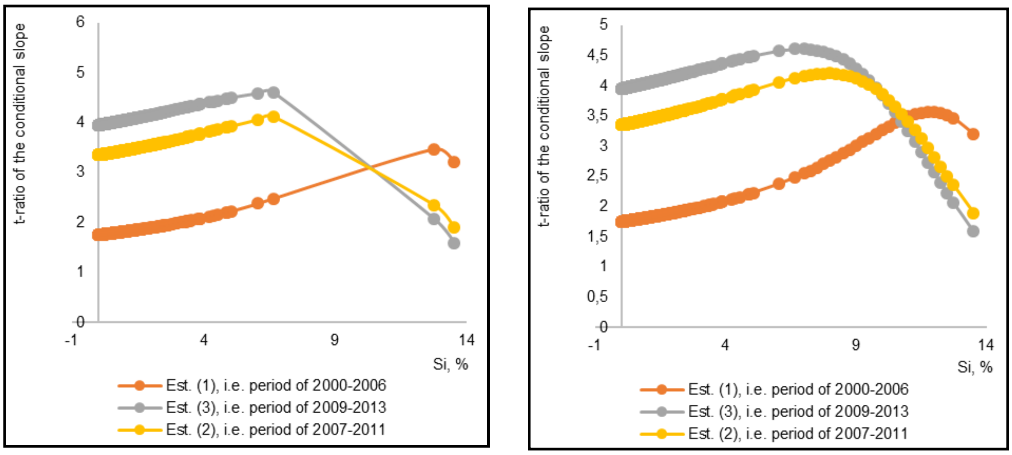

Fig. 3 **– The relation between the regional support intensity and the t-ratio of the slope (a) over observed S_i values and (b) with additional S_i values**

Fig. 2 and 3 clearly show that the standard error, as well as t-ratio, associated with the slope coefficient, are not constant and as marginal effect of S_i on convergence depends on the values of S_i. Having in mind that with 95% confidence level and with the degree of freedom above 1000, the critical value for the t distribution is 1.960, in Fig. 4 we presented the marginal effect of S_i on convergence over the range of S_i values for which this effect is statistically significant.

The estimations for the post-intervention period yield the marginal effects that are significant for all S_i values, except for the right-side extreme. This provides evidence that (i) there is no need for a minimum amount of regional support for the effect to become significant, i.e. even low intensity of the EU's regional support significantly reduces regional differences, i.e. it promotes convergence over the long-run, and (ii) the marginal effect of S_i after the turning point remains statistically significant although it is negative what suggests the overfunding and the faster overall convergence by redistributing the support to less intensively supported regions. Estimations for the financial intervention period provide evidence that the marginal effect is not significant for low values of S_i and it become significant when the intensity is above 2.5%. This could be because the low level of regional support intensity is not increasing the expenditures in the region enough to ensure the sufficient jump of regional GDP per capita over the financial intervention period for the regional disparities significantly to decrease.

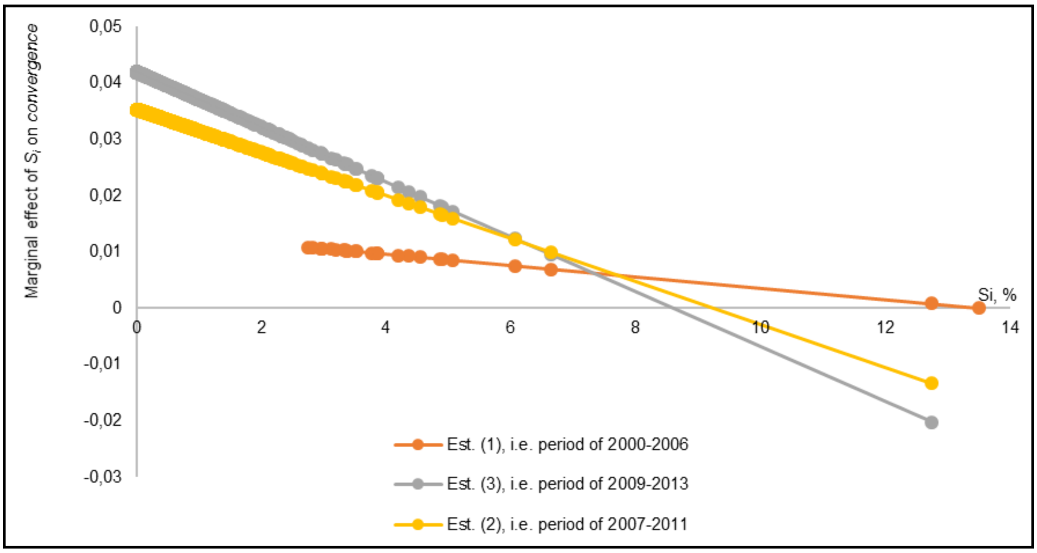

Fig. 4 **– The statistically significant marginal effect of regional support intensity on the convergence over the observed range of S_i values**

Summing up, we have found a stronger statistical evidence within the framework of our proposed model that over the post-intervention support period the relation between regional support intensity and convergence is non-linear, i.e. that the marginal effect of regional support intensity is conditional and it depends on the level of the intensity. We also showed that in the case of non-linear modelling, it is crucial to consider that not only slope but also the standard error associated with the slope coefficient is conditional too. This implies that the marginal effect of S_i on the outcome is not necessarily significant over all the values of regional support intensity, even though this effect is positive or negative.

Discussion

Our results considering the non-linear relation between regional support intensity and convergence are not directly comparable with the existing empirical evidence since we estimate the effect on convergence rather than on growth or unemployment, i.e. two primary outcomes mostly used in literature, and since we work with a smaller – NUTS3 – disaggregation level, while the previous studies focus at country and/or at NUTS1/2 level. Nevertheless, we can draw some similarities with the small number of contributions dealing with the non-linear effects of support. As in the majority of previous contributions, we find that SF and CF support generates positive outcomes. We also find that EU's regional support via

SF and CF has no constant effect and it depends on the amount of treatment. Our findings also support the view that the intensity of EU's funding is a subject to diminishing marginal returns, i.e. the bigger "dose" of the funding does not guarantee a higher level of the desirable outcome. Although our estimated turning points are way beyond the ones estimated by the previous research, our results suggest the need for SF and CF redistribution in favour of less intensively financed regions to speed up convergence. This conclusion is supported by the findings of Pieńkowski and Berkowitz (2016) and Becker (2012) who also argued that CP transfers should have been relocated from the regions receiving the highest transfer intensity to the regions receiving fewer funds and leading to a higher convergence among the regions.
Nevertheless, there is an undergoing debate that CP should continue investing in all regions, including the richer MS as well. CP is still keeping, in the new funding period, three categories of regions: less-developed, transition and more developed (more prosperous) regions (European Court of Auditors 2019), raising the question whether it will help to reallocate EU's funding in favour of low-income and low-growth regions to catch up. As Dellmuth and Chalmers (2018) underlined, there could be not enough spill-over e□ects on the rest of the EU from public investment in more prosperous regions, suggesting that the funding of the rich should come from either local or national, rather than EU, resources. Further, following Marzinotto (2012), who argued that SF and CF should be used to smoothen the regional level funding reallocation, we can add that it is crucial to create conditions for NUTS 3 regions within NUTS 2 regions to exploit their comparative advantage.

Considering our research results, some limitations of the study and directions for further research could be highlighted. Comparing long- and short-run effects, they show a similar pattern with the existing literature. Nevertheless, contrary to Mohl and Hagen (2008, 2010), and CSIL and DKM Economic Consultants (2012), we find an instant (over financial intervention period) positive marginal effect of support on convergence when the intensity of regional support is above 2.3%. It might suggest that we probably observe some dummy effects of EU's regional support, at least over the ongoing programming period, which should prevent us from the too early evaluation of support success. One possible explanation of that could be the fact that regional support, as additional expenditures in the region's economy, directly increases regional GDP per capita over the financial intervention period. Since S_i negatively correlates with GDP per capita, more regional support directed to the least developed regions leads to the bigger jump of regional GDP per capita over the financial intervention period. All that directly leads to smaller differences between regions over the same period, i.e. higher S_i corresponds to the higher jump of GDP per capita and lower disparities. However, over the long run, due to the reasons discussed in the literature review, regions which are more intensively supported and do not have the shortage of funds could potentially direct support to the unproductive areas what could turn into adverse outcomes, slower growth, and GDP per capita way below its potential level. It seems that facing the scarcity of regional support, regions are encouraged to use them more efficiently and to reach higher returns with less financial inputs.

Moreover, the success of one programming period becomes hard to distinguish from the investments made over the next programming period due to the overlapping effects. Even more, the results suggest that a more significant effect of regional support on the diminishing regional disparities occurs over a long period, but the potentially positive effect could be hard to isolate from other factors.

Conclusions

Despite the extensive literature on the impact of the CP on regional economic growth in general, there is little evidence of its impact on convergence, which is the primary goal of the CP. There is also limited evidence testing other than a linear form of relationship between the intensity of SF and CF payments and the policy outcomes. Even if, in theory, more EU transfers might generate a faster growth, in reality, it appears that there may well be decreasing marginal returns from the investment and investment-stimulating transfers. Therefore, the regional support should not exceed the maximum desired level of intensity, which might influence the return on support and also the overall policy effectiveness and regional growth in general, to avoid inefficiency and misuse.

Summarising the previous contributions, we can conclude that the moral hazard and substitution effects might cause a non-linear relationship between SF and CF commitments and economic growth or convergence. These effects can be related to the level of institutional quality that may cause the inefficient use of EU regional support if funds are spent on unproductive projects. The previous studies reveal the diminishing marginal growth returns of SF. Thus, it is crucial to understand how the varying treatment intensity (different amounts of EU transfers relative to GDP) affects regional convergence. The main limitations of previous research are as follows: (I) they do not assess the non-linear relationship between the intensity of SF and CF transfers and convergence to determine the desirable level of intensity; (ii) mainly short term effects are considered, however, CP transfers may have a long-run effect as well; and (iii) the main focus is at NUTS2 disaggregation level.

Filling this gap, we examined whether the intensity of SF and CF transfers has non-linear effects on convergence at NUTS3 regional level over short- and long-run. Modifying the standard DID specification to account for non-linear and heterogeneous effects of CP policy, we estimated the equation using fixed effects and we considered non-constant the standard errors and t-ratios of the estimated marginal effect of treatment intensity on convergence.

We have found evidence that the return is positive and higher for the post-intervention period, compared with the return over the financial intervention period, i.e. higher positive effect to diminish disparities is expected over long-run. Estimates of marginal effects for the post-intervention period are significant over all values of regional support intensity except for high extreme. On the contrary, estimations for regional support period provide evidence that the marginal effects are not significant for low values of SF payment intensity, thus giving an insight that not all less intense SF transfers, at least over short-run, significantly diminish disparities. All in all, the study confirms the initial assumption that the EU's regional support is subject to diminishing marginal effects and it points out that high levels of support intensity are highly unjustifiable in terms of CP's efficiency.

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TOWARDS GREEN RESILIENT CITIES IN EASTERN EUROPEAN UNION COUNTRIES

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Abstract: Investing in green facilities is a process of urban renewal that can transform cities by enhancing the quality of life, strengthening the local economy and reducing the environmental impact. Nevertheless, greener cities are not a guarantee for improved adaptive capacity when facing current local or global challenges. In this context, we have taken into account a series of sample cities from Central and Eastern European Union. Using the green cities typology proposed by the European Environment Agency, the present approach studies the statistical relationship between indicators of green infrastructure and different proxies for the resilience capacity and performance. The results distinguish between different types of green cities, indicating which are more resilient and, respectively, which are less resilient. The statistical relationship between the indicators shows that green infrastructures are developed in new urban areas, while the natural areas diminish the flood risk and air pollution and make cities more attractive; however, in older and higher density cities, the green is sacrificed for other uses that are considered more profitable. The conclusions highlight the contradictory characteristics in the territorial distributions of cities in relation to their green infrastructure and resilience features. The present assessment contributes to promoting an integrated vision that could be used in urban planning and in more coherent strategies for sustainable cities.

Key Words: *green infrastructure, green cities clusters, resilience capacity, resilience performance, vulnerabilities, post-socialist cities*.

Introduction

The conceptual framework regarding green and resilient cities

Nowadays, cities are more and more threatened by climate change and associated extreme events (drought, floods, heat waves, etc.), but they are also confronted with a mix of increasingly poignant internal challenges stemming from population growth, obsolete and inefficient urban infrastructure development, growing social inequality, increasing population mobility and other stressors (McPhearson et al. 2015).

Tackling these issues means a large range of strategies, measures and actions to be taken. Ianoș et al (2009) argue that any strategy for the sustainable development of a territorial system, any method, instrument or algorithm for the implementation of a policy in this field should be based on a good knowledge of the dynamics and interactions between the componens of both natural/physical environment and society. One of the main approaches that are taken into account for sustainable and resilient cities is promoting the development of urban green infrastructure (GI) and nature-based solutions (Calfapietra and Cherubini 2019). They may be defined as creative combinations of natural (green) and artificial (grey) structures able to fulfil certain resilience goals (flood mitigation, public health protection, air quality enhancement, etc.), if they are socially accepted and apply the appropriate technology (Staddon et al. 2018).

A green city is also an urban entity with clean and efficient energy, transportation, and building infrastructure, but also a healthier, more affordable, and more pleasant place to live, as it does not only focus on its environmental performance, but it also produces numerous social and economic benefits (Adjei Mensah 2016, EBRD 2016, Shimamoto 2019). Green infrastructure represents an interconnected network of green spaces including the urban tree canopy, urban forests, green corridors (streets and alleys) green lots, parks and protected natural areas, which provide, for the city, flood protection, cleaner air and cleaner water, and a wide range of other ecosystem services that are „green commons" (Colding and Barthel 2013, Jansson 2013, Chelleri et al. 2016). Meanwhile, it has been stated that investing in green facilities can transform cities by enhancing the quality of life, saving money, strengthening the local economy and reducing the impacts of climate change (including the high contribution of cities to climate change) (Antrobus 2011, Hammer et al. 2011).

In this context, the concept of urban resilience is highly significant and useful, through its inclusiveness and complementarity to green cities framework. In a larger definition, urban resilience is the ability of a city to absorb turbulences while maintaining its functions, structures and feedbacks (Lu and Stead 2013). It is also related to the capacity of a socio-ecological system to sustain a given set of ecosystem services in the face of uncertainty and change of a community (Ernstson 2013). Urban resilience can also be related to a set of urban ecosystems that provide benefits to urban livelihoods and well-being (McPhearson et al. 2015). They are a rather significant 'ingredient' of cities as systems and contribute to maintaining the 'metabolism' of cities by offering nature-based solutions to specific urban problems (Kennedy et al. 2011) and even to major shocks such as natural disasters. In this last case, green infrastructure should be designed to support an atypical state of operation by creating resilient purposeful systems that could sustain cities in difficult times (Hewitt et al. 2019). As far as the green infrastructure, resilience "is not just about the structures — grey, green, grey-green, etc. — that are intentionally designed or engineered, but also about how these are conceived, (co)created and integrated within complex socio-ecological–technical systems" (Staddon et al. 2018: 331). In this respect, an integrative approach is proposed within the framework of smart-green-resilient cities developed in the Eastern Asia, that seem much more suitable and better adapted to present environmental, societal and economic challenges of present times (Lau et al. 2016).
Nevertheless, the limits should be acknowledged: greener cities are neither a guarantee for social equity and (sustainable) economic development, nor for a better adaptive capacity in front of current local or globalized challenges (Campbell 1996). Moreover, there is not just "good resilience" i.e. preparedness, responsiveness and adaptation to the new regional and global challenges, but there are also forms of "bad resilience", i.e. resistance to change by inheriting and propagating obsolete, inefficient and harmful structures and practices and emerging vulnerabilities (Rufat 2012).

Meanwhile, the similarities and dissimilarities among the basic features of the two concepts should be discussed (Fig. 1). A resilient city is adaptive, capable of self-organization, flexible, economically diversified and having resources (even back-up capacities) and functional components that are properly connected and integrated by an efficient governance system. It can tackle adversities and learn from past errors in managing turbulences while innovating and transforming according to the context. A green city is by itself biophilic and oriented towards a sustainable urban metabolism, promoting biodiversity, energy performance, integrated environmental management and the transition towards the circular economy. Both resilient cities and green cities are oriented towards communication and mobility, relying on a (green) infrastructure that connects the city, assuring a certain diversity and redundancy (areas without an "intensive" economic use) while innovating to reduce the ecological footprint of urban areas.
As one main attribute, connectivity is taken into account both as an attribute of resilience in general, but also as an essential added value of green areas that are interlinked both functionally and physically and also linked to the surrounding green area, on an upper-scale, even to the regional ecological network (Galderisi and Treccozzi 2017). Meanwhile, multi-functionality, i.e. multiple ecological, social, and economic functions, goods and services that

are provided by green areas, means an integrated environmental management that takes into consideration green spaces as infrastructure correlated and/or subordinated, structurally and functionally, to the other urban infrastructures (Davies et al. 2015).

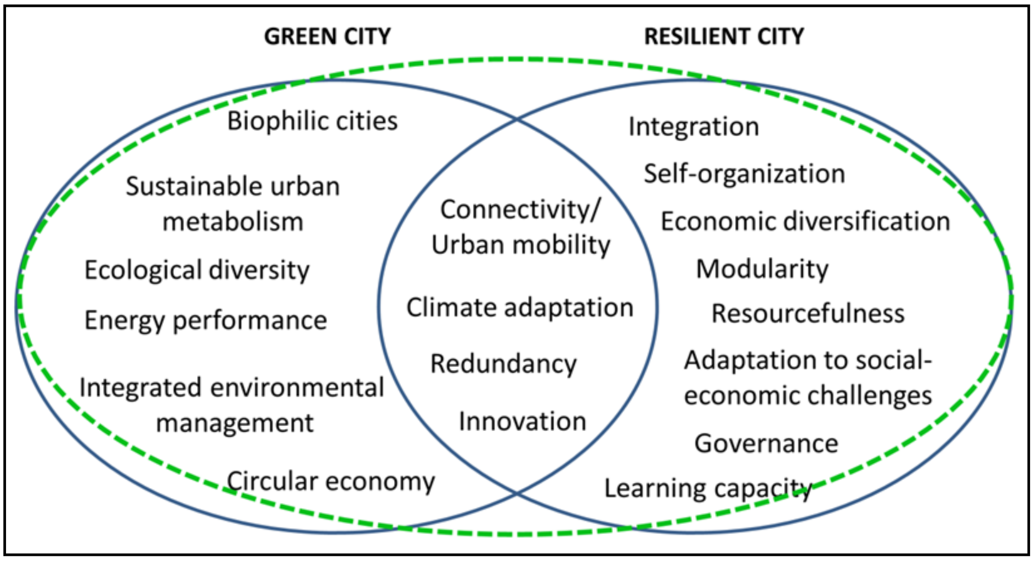

Fig. 1 **– Green and/or resilient city – conceptual framework**

Following an analysis of the abundant current literature, one can conclude that urban resilience is more comprehensive if it is analysed in at least five different dimensions: physical, natural (ecological), economic, institutional and social (Ribeiro and Gonçalves 2019). However, the allocation of urban space is a very important issue in planning resilient cities, as they also provide, directly or indirectly, many environmental, social-economic, aesthetic, physiological and psychological benefits (Borgström et al. 2006, Kumagai et al. 2015), which are essential attributes for inducing urban sustainability (Wolch et al. 2014, Raymond et al. 2017). There are many links between green cities performance and socio-economic indicators of resilience. As an illustration, GDP has a positive influence, population size, mainly a negative impact, while air quality influences green cities performance the most (Brilhante and Klaas 2018). The performance in education and innovation are also components of urban adaptation that can also result in implementing green assets and technologies (Lee 2018, Lv et al. 2018). Sometimes, green infrastructures can have direct economic benefits, also sustaining the overall city system resilience, for example when used for agriculture (Panagopoulos et al. 2018). There are numerous papers analysing the concept of green resilient cities and the planning issues of green areas, from the perspective of their role in improving resilience to climate change (Belčáková et al. 2019, Reinwald et al. 2019). The direct contribution of green infrastructure (integrated into the larger concept of nature-based solutions) to build general urban resilience by effective land-use planning is also demonstrated in the literature (Bush and Doyon 2019).

Socially inclusive green growth is a concept that is used by the European Commission when assessing the benefits of green infrastructure that might foster social cohesion while being the solution for certain societal challenges (European Commission 2015). Nevertheless scholars argue that green and greening strategies do not necessarily imply social inclusiveness or social sustainability, so their relations should be carefully analysed (Haase et al. 2017).

There are many issues related to greening the cities: one of the most obvious challenges for urban planners and managers is to balance the tension between urban green spaces and other functions with more direct benefits for different urban stakeholders (Afriyanie et al. 2018).

Even though most of the scholars and official reports state that a dense urban settlement is more environmentally friendly than urban and suburban sprawl (Millennium Ecosystem Assessment 2005), higher densities of population and buildings also put more pressure on the green areas that are sometimes replaced by other functionalities. There are also many problems related to scale mismatches or urban green and social organization in cities because of incomplete knowledge of ecosystems dynamics and institutional constraints (Borgström et al. 2006).

Finally, it is important to underline the fact that urban (green) resilience can provide a comprehensive framework for action from the part of municipalities, stressing on the impact of planning on urban ecosystems by developing a sound and effective green infrastructure able to meet environmental, social-economic and spatial challenges (Pichler-Milanovič and Foški 2015).

Green resilient post-communist countries

Urban areas in Eastern European Europe countries face numerous issues concerning different domains, not just technical-economic (lower degree of innovation, poor infrastructure, insufficient funds) and social (polarization of living conditions, lower governance level), but also environmental (inefficient green areas, increased traffic and air pollution, etc.) (Sýkora 2013, Berki 2014, Bodocan et al. 2018). The removal of restrictions after 1990 translated into a rapid heterogeneity of the Eastern European city from a social, spatial and economic point of view. The strictness of communist regulations has been replaced in most of the countries (at least until the integration in European Union) by more relaxed, inconsistent, sometimes contradictory legislation. The result consists in very large differences among cities, not only considering different Eastern European countries, but also within the same country, from one region to another (Sýkora and Bouzarovski 2012, Berki 2014).

The post-socialist city has an “original” population trend which is a combination of low birth rates, migration losses and moderate mortality leading to population ageing together with population decline (Lutz 2010). One can add that land-use instability limited the attempts at sustainable management, disfavouring peripheral urban centres, delaying the coagulation of metropolitan areas (except for the capital cities).

These challenges are only partially emerging from the communist inheritance: the Socialist period did not only promote largescale, seldom ineffective, industrial and housing projects (Nae and Turnock 2011) that are presently elements that sustain a “bad resilience” (Rufat 2012), but it also created a positive legacy: the rather extensive green space development in cities that were “lost in transition” after 1990 (Hirt 2013). The shift to the market economy and from prevalent public land ownership to private ownership encouraged an extensive and sometimes unplanned development of residential buildings and commercial spaces (Hirt 2012) often replacing green areas. Moreover, environmental problems were not a priority in the early transition, while citizens did not possess a genuine environmental culture. In this context, after 30 years from the fall of the communist regime, the post-socialist city is now struggling to increase the amount of green spaces (Badiu et al. 2019).

In the case of post-socialist cities, one assessed the fact that the accessibility to the green urban areas decreases from the inner centre to the peripheries, while green areas have the tendency to be clustered around the initial core of the city (Fuller and Gaston 2009, Sandu 2017).

The current paper has three main objectives. Firstly, it intends to describe the state of post-socialist cities from the viewpoint of their green infrastructure, starting from the EEA (2017) typology and observing the individual attributes of all types. Secondly, the authors evaluate, in the case of each type, the resilience capacity and performance of cities using as proxies different (available) indicators. The third objective is to compare and to test the statistical correlation between green and resilience indicators in order to assess the patterns that are able to describe the complex relation between the two overlapping goals of sustainable urban planning.

Methodology

The present approach takes into consideration 95 cities and agglomerations from nine former communist countries located in the Eastern part of the EU (Fig. 2). Their population size varies from 50 000 to more than 2.1 million inhabitants, while their selection was very much dependent on the availability of data. The original data and therefore the selection of cities were provided by the European Environment Agency (EEA 2017).

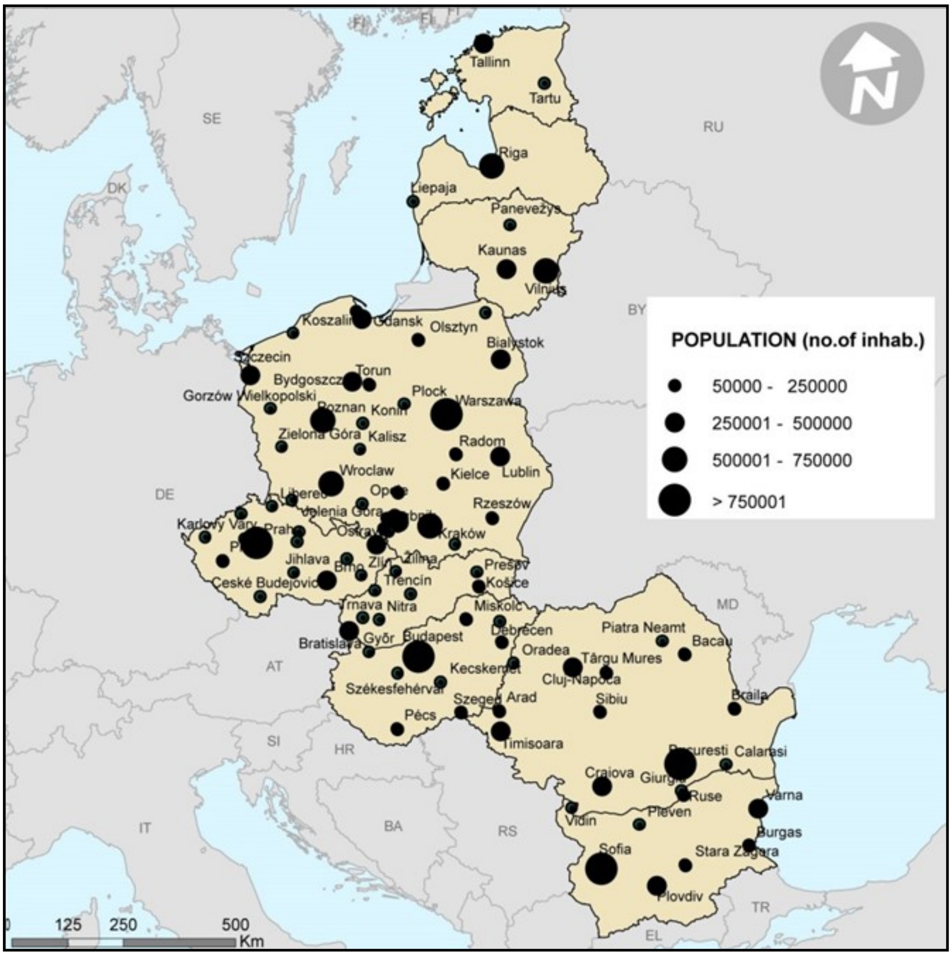

Fig. 2 **– Selected cities from Eastern European Union countries**

To achieve the objectives of the present paper, three methodological steps were taken. In the first stage, the EEA typology of green cities was selected and mapped for the studied area. The weight of each type of green infrastructure in the Central and Eastern Europe (EU countries) was calculated and each category was described according to the regional context. From the eight clusters identified at EU level, six categories of cities were identified in the Eastern European Union countries and they were used for further analysis. From the components that derived the Urban Green Infrastructure (GI) typology, five indicators were selected for further evaluation of the relation with the resilience proxies: green infrastructure and effective green infrastructure, the distribution of green urban areas, their accessibility and the share of water surfaces (Table 1).

Table 1

Selected urban green indicators

Indicator	Year/ Period	Spatial level/Unit	Description/Aggregation	Source
Green Infrastructure/ GREEN_INF	2006, 2010, 2016	CITY, METRO-POLITAN/% of total land area	Network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services.	Eurostat, GEOSPECS State of European cities 2016
Effective green infrastructure/ EFECT_GI	2016	CITY/mean % from total	The probability of finding a green infrastructure element in the territory or in the neighbouring area. Connecting (adjacent) green areas in the peri-urban area can effectively extend urban green areas.	EEA 2017
Distribution of green urban areas/ DISTRIB_GUA	2016	CITY/m/ha	The ratio of the length of the urban area perimeter to the urban area. Provides a proxy for the equal or non-equal distribution of green urban areas in the city. Increasing the green area and distributing it more evenly is an effective measure in reducing the undesired effects of clustered urban green areas.	EEA 2017
Access to green urban areas/ GREEN_ACCES	2012	CITY/%	The accessibility of green areas for the urban population by city, i.e. % people living within a distance of 500 metres from accessible green spaces.	State of European cities 2016
Urban water areas/WATER	2015	CITY/%	The share of urban water areas (%).	EEA 2017

Secondly, urban resilience was evaluated in the case of these former-socialist countries by each category and by taking into account two types of indicators: indicators of resilience capacity (which is the general adaptability and ability to bounce back when confronting challenging events or crises) and indicators of resilience performance (meaning the actual resilience in a given period and facing a certain shock such as the economic recession). The resilience performance indicators show the dynamics before and during the economic crisis that started in 2008 were taken into account (Table 2). Here, population change – given as a factor of resilience, as high positive values show a certain urban attractiveness – was calculated for the 2001-2011 period, both at city level and at the level of Functional Urban Areas (FUA), given the suburbanization processes, and it was completed by two other indicators: change in residential, industrial and commercial areas per inhabitant (during the same period), and the change of road accessibility, given the expected outcomes due to the TEN-T policy regarding transport networks.

Resilience capacity was estimated using as proxies a variety of rather 'static' indicators (absolute values for a certain year, after the end of the economic crisis) in illustrating several categories of resilience: social-demographic (weighted population density of cities, elder population, tertiary education), economic (such as GDP per capita and number of patents), physical (residential, industrial and commercial areas per inhabitant, road accessibility, share of old and new buildings). Also, certain shocks and territorial vulnerabilities that can decrease resilience capacities (or increase it if low values are registered) were also included in the analysis (air pollution – by taking into account two main urban pollutants: PM_{10} and NO_2, and flood risk).

The constraints of the approach are linked to the lack of more comprehensive data at city level, but, even so, the multiple indicators taken into account can give a general idea on the adaptive processes within the studied area. Given the missing indicators for certain resilience domains, no aggregated index was proposed, but rather multiple correlations were preferred in order to draw some conclusions regarding the complex relationship between all the variables in the urban context.

As the existing scientific literature argues that the green infrastructure has the capacity to induce a higher resilience capacity, the present empirical approach tries to test this assumption. The selected proxies for green cities were scaled and normalized using the min-max rescale scheme and they were included as dependent variables in the linear regression in order to highlight the statistical relationship between green and resilience indicators.

Results and Discussion

Assessing Green Infrastructure (GI) clusters for the study area

The current work has as a starting point the Urban Green Infrastructure (GI) typology made by the European Environment Agency that was intended to be a contribution for the assessment/ benchmarking of environmental performance in the case of EU cities regarding GI.
Nine parameters were taken into account: share of green urban areas (GUAs), degree of soil sealing, distribution of GUAs, effective GI, hotspot ratio, terrestrial urban blue areas, low-density areas, the share of urban forest and the share of Natura 2000 sites (EEA 2017). These indicators were included in a cluster analysis, so that 8 types of cities emerged (Table 3). In our paper, we only took into account the post-socialist cities from Eastern and Central Europe in order to have a more in-depth view on their characteristics in relation to the indicators of urban resilience and vulnerability. Only six out of the eight types of cities identified at EU level are also found in CEE countries (Fig. 3).

Table 2

Selected Urban Resilience-Vulnerability Indicators

Indicator	**Acronym**	**Dimension of resilience/ vulnerability**	**Year/ Period**	**Spatial level**	**Description/ Aggregation**	**Source**
RESILIENCE PERFORMANCE INDICATORS						
Population change (1)	POP_CHANGE_C	Social-economic resilience	2001-2011	CITY	Population change by city, 2001-2011	Eurostat, State of European cities 2016
Population change (2)	POP_CHANGE_FUA	Social-economic resilience	2001-2011	FUA	Change in population per functional urban area	Eurostat, State of European cities 2016
Number of patents in 2009	PATENTS	Social-economic resilience	2009	METRO	Number of patents per million inhabitants, by metropolitan areas	JRC, Urban Data Platform
Change in residential, industrial and commercial areas per inhabitant	BUILT_INH_CHANGE	Physical resilience	2006-2012	CITY	Change in residential, industrial and commercial areas per inhabitant per city	Eurostat, State of European cities 2016
Road accessibility change	ROAD_ACCES_CHANGE	Physical resilience	2013	FUA	Expected change in road accessibility due to the TEN-T network completion by FUA	State of European cities 2016
RESILIENCE CAPACITY/VULNERABILITY INDICATORS						
Air pollution	AIR_POLL	Shocks and vulnerabilities	2014	CITY	The concentration for PM10 and NO2, taking into account the limit values	Eurostat, State of European cities 2016
Flood risk	FLOOD_RISK	Shocks and vulnerabilities	2014	CITY	The category of flood risk of urban areas	EEA 2017

GDP per capita	GDP_INHAB_METRO	Economic resilience	2013	METRO	GDP per capita (PPS) by metro region	Eurostat, State of European cities 2016
Tertiary education	TERT_EDU	Social-Economic resilience	2014	METRO	Share of population that graduated tertiary education	JRC, Urban Data Platform
Elder population	ELDER	Social-Economic resilience	2012	METRO	Share of population 65 years and older	JRC, Urban Data Platform
Weighted population density of cities	POP_DENS_WEIGHTED	Social-Economic resilience	2014	CITY	Weighted average density of all land parcels that make up a city, with each parcel weighted by its population	Eurostat, State of European cities 2016
Road accessibility	ROAD_ACCES_FUA	Physical resilience	2013	FUA	Potential road accessibility	Eurostat, State of European cities 2016
Residential, industrial and commercial areas per inhabitant	RES_IND_COM_INHAB	Physical	2012	CITY	Residential, industrial and commercial areas per inhabitant	Eurostat, State of European cities 2016
Share of old buildings	OLD_BUILD	Physical resilience	2011	CITY	Share of constructions built before 1945 from total number of buildings	JRC, Urban Data Platform
Share of new buildings	BNEW_BUILD	Physical resilience	2011	CITY	Share of new buildings from total buildings	JRC, Urban Data Platform

Green outskirts cities (Type 2) – One of the most suitable category; it has high shares of green urban areas and high values of effective green infrastructure, but a rather medium (to high) distribution of green urban areas and medium degree of soil sealing. There are only seven cities in our study area, predominantly located in the Baltic countries, Poland and the Czech Republic representing 7.37% of the selected post-socialist cities. It is not represented in South-

Table 3

Green infrastructure city clusters/types in EU and CEE

Type	**Name**	**Number of cities in EU**	**%**	**Number of cities in the studied area**	**%**	**Differ-ence (%)**
1	Fragmented cities	49	12.73	0	0.00	-12.73
2	Green outskirts cities	42	10.91	7	7.37	-3.54
3	Natural cities	9	2.34	1	1.05	-1.29
4	Hotspot cities	3	0.78	0	0.00	-0.78
5	Green cities	113	29.35	28	29.47	0.12
6	Green-grey sealed cities	85	22.08	27	28.42	6.34
7	Forest cities	73	18.96	30	31.58	12.62
8	Natural blue cities	11	2.86	2	2.11	-0.75

Fig. 3 – **Types of green infrastructure in Central and Eastern European cities**
Source: EEA (2017)

Eastern Europe. Their distribution is significantly linked to the geographic position and climate correlated with the high share of forests of the nearby region and the lower population density, at least in the case of Baltic countries, but also in Ceske Budejovice and Gorzow Wielkopolski. Cracow seems to be an exception, but its inclusion among green outskirts cities is due to the large built-up area (327 km^2) and the proximity of the forested Malopolska Plateau.

Natural cities (Type 3) – These are usually cities situated near protected areas that are also included in their administrative territory. Therefore, they have a very high proportion of green areas, Natura 2000 sites and effective green infrastructure, while the degree of soil sealing is very low. In the Eastern European Union, only one city is included, Miskolc, the third city in Hungary size wise, an old industrial centre that lost most of this profile after 1990. Presently, the city has an extensive built-up area (236 km^2), especially in the Bukk mountains, and it capitalizes on its tourist potential (including thermal waters resources).

Green cities (Type 5) – Compared to natural cities, they also have a very high share of green areas and a low degree of soil sealing, but slightly lower values for the effective green infrastructure share. It is the most frequent type, both at European Union level and in Central Eastern Europe (about 30% of cities are included in this category), meaning that even though many cities have extensive green area, they still fail to transform them into effective green infrastructure. This cluster includes a significant number of cities in all CEE countries, except for the Baltic States. There are settlements situated in various geographic contexts, from depression areas to large rivers' valleys, sometimes including in their administrative areas (unplanned) green areas that are in the proximity.

Green-grey sealed cities (Type 6) – They also include numerous units at EU level (85), as well as at CEE level (27), a higher frequency compared to the EU average. They have a high share of soil sealing and a lower proportion of green areas, although it is relatively well distributed. Meanwhile, they have a very low share of effective green infrastructure, while they usually lack urban forests, Natura 2000 sites and they are quieter, lower populated places. Most of these cities are in Poland, Romania and Lithuania. Sometimes, the inclusion in this class is linked to the small built-up area or by the situation in densely populated areas that limits the access to green infrastructure. There are many industrial cities included in this cluster (Ostrava, Katowice, Presov, etc.). It can be considered the most representative type for Eastern Europe regarding the spatial planning with large industrial platforms at the periphery, extended areas covered by transport infrastructure and central areas that were completely regenerated (if one refers to the capitals Warsaw and Bucharest).

Forest cities (Type 7) – They have a high share of urban forests, but also a very high proportion of green areas and effective green infrastructure. Even though they have low soil sealing degrees, the share of low-density residential areas is not significant. It includes the highest share (31.58%) of Central and Eastern European cities, almost twice the frequency at EU level, where only 18.96% of cities are in this category. It is a predominant type for mountainous regions in the Czech Republic and Slovakia, but they are represented in almost all CEE countries where the built-up area was included or extended towards the nearby forested areas.

Natural blue cities (Type 8) – They have large urban blue areas and Natura 2000 sites, but only medium access to green areas in the city and its surroundings. This type includes only two cities in CEE: Szczecin, in the delta of Oder River in Northern Poland (siderurgical centre and the most important shipyard in the country, one of the most representative cities for this category at European level) and Burgas, an important port and a popular tourist area in Bulgaria – the shore of a Laguna at the Black Sea. In other parts of the EU, cities included in the same type (Venice, Cagliari, Valencia, etc.) share some common features, from the viewpoint of green-blue infrastructure, with the two cities from CEE.

Evaluating green city clusters' vulnerabilities and resilience

The relation between green areas and infrastructure compared to city population and built-up area is directly connected to the extension of the administrative unit of the city. The more extended the built-up area, the greener or blue the city. Therefore, one can notice that the natural cities (type 3) and the blue cities (type 8) have the most extended areas. If we compare types 5, 6 and 7, which have similar average areas, the population density becomes more important: the green-grey sealed cities (type 6) have the highest population densities which is a significant pressure on the green infrastructure, while, comparatively, green cities (type 5) have a lower demographic stress, therefore, a better green performance (Fig. 4).

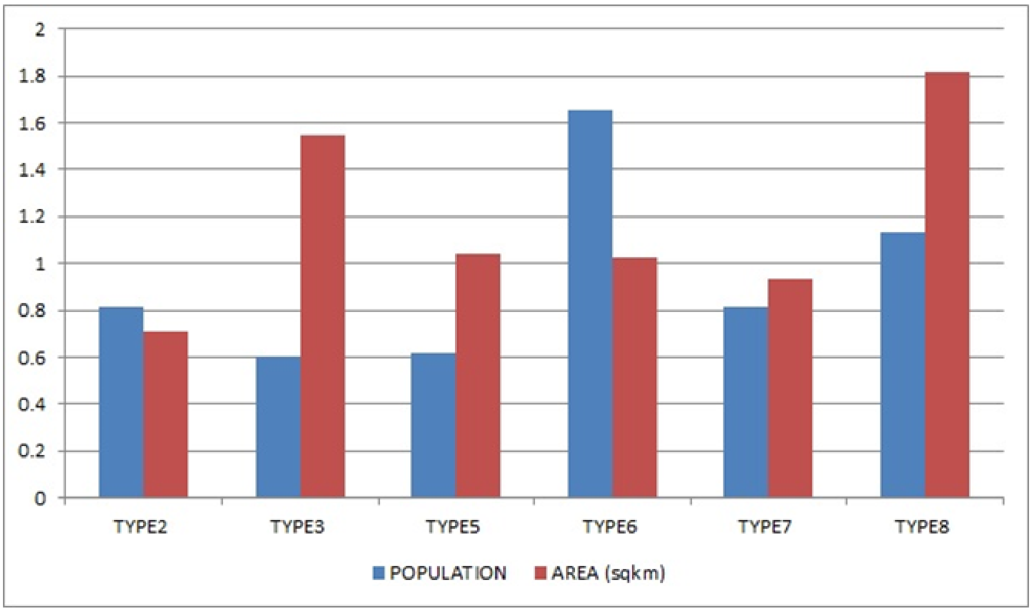

Fig. 4 – **Standardised mean values of population and urban area for each type**
Source: State of European cities (2016)

The six clusters identified in the CEE have different profiles regarding the presence of urban infrastructure within their built-up area: although forest cities are the most numerous and seem to have a dominant position in this regard, it is also a very heterogeneous cluster with big differences between the cities that were included in (Banska Bistrica, Karlovy Vary, Sibiu or Zilina have a much more extended urban infrastructure than Torun, Prague, Bratislava or Brno). By contrast, green outskirts cities share more similarities and are, on average, better positioned. The worst performance concerning green infrastructure is that of the green-grey sealed cities (Wroclaw, Bucharest, Poznan, etc.), while the so-called "green cities" cluster is also heterogeneous and still searching for a profile that will be in accordance with its name (lowest values in Calarasi, Nitra, Trnava etc.).

If we take into account the relation between the green performance of post-socialist EU cities and the different resilience-vulnerability indicators, we can notice very complex relations that need to be studied.

Population change is an indicator that shows a certain degree of urban resilience even though the densification itself can also create vulnerabilities within the city. The general demographic decline after 1990 continued after 2000, in relation to both urban shrinkage and suburban population growth – the so-called Hollowing Out or "Doughnut Effect" (Wiechmann 2009). The highest values regard: the two blue cities from the CEE that are the best situated, capitalizing on their port function which was favourable in the context of transition to the market economy, but also the forest cities, with large forested areas that might be important resources for development. On the other hand, natural cities and green outskirts cities had the steepest decrease during the crisis. Although losing population, the green outskirts cities are the most economically resilient, as well as forest cities and the more industrialised green-grey sealed cities. On the contrary, the natural city was very much affected by the economic crisis and it does not perform very well economically, even though the industrial pollution remains rather high. From this point of view, green-grey sealed cities have the worst performance, while the cleanest type of cities is the green outskirts city, followed by green cities.

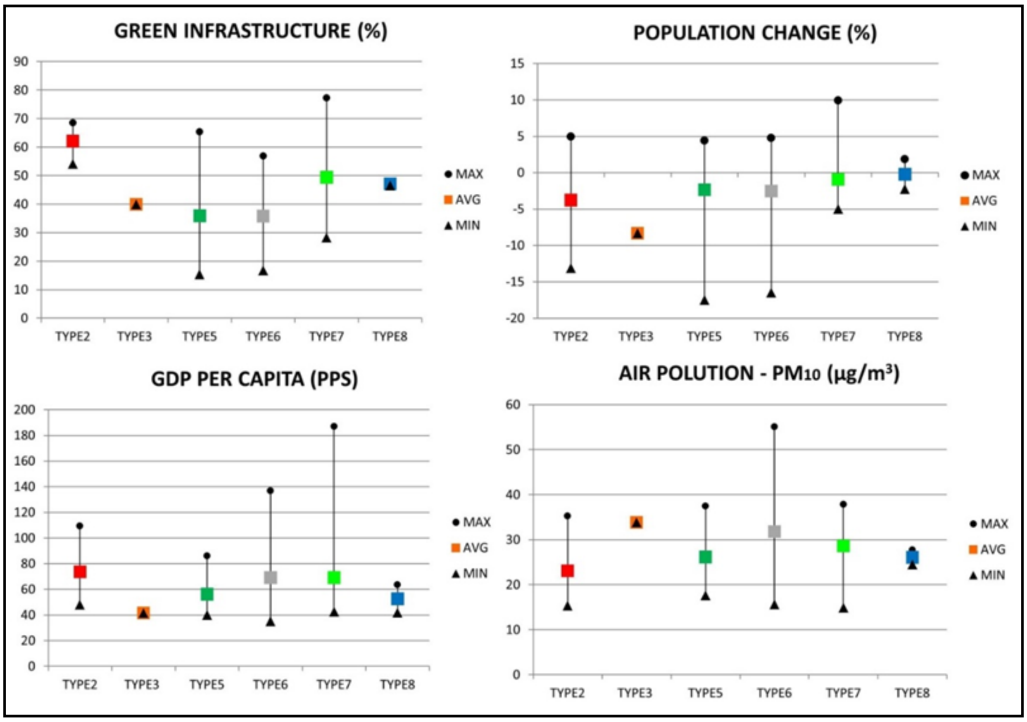

Fig. 5 **– Basic indicators of green resilient cities by cluster – descriptive statistics**

If we analyse the mean values for all resilience and vulnerability indicators taken into account (Fig. 5, Fig. 6) one could state the:

Green outskirts cities (Type 2) – They are performing very well in developing and applying green infrastructure strategies and in having a good economic performance during and after the crisis, together with a certain stability from the demographic and functional point of view, and a high share of population that attended tertiary education, which also relates to an increasing number of patents. They have lower population densities, but a rather efficient public transportation and the lowest pollution levels while they are less threatened by flood risks. These cities are also relatively isolated from the main EU road corridors and they have a lower airport accessibility (especially the Baltic countries cities) due to their peripheral situation. As a drawback, isolation in itself is not always a sign of a lack of resilience as they could be kept away from major shocks that might emerge.

Natural cities (Type 3) – They represent a cluster that includes only one city (Miskolc) within the studied area, but numerous others in Western and Southern EU (Trieste and Genova in Italy, Innsbruck in Austria, Arnhem in Netherlands). Compared to the other selected cities, Miskolc has a significant population decrease inside the city and in the functional urban area, a consequent aging of population, but also a significant loss of urban function translated in a low GDP per capita. Nevertheless, it has a rather high innovative potential (translated in the number of patents) that will presumably increase its resilience performance in the future. Presently, the city has a high level of air pollution and an extensive flood risk (although the share of water bodies in built-up areas is low).

Green cities (Type 5) – They have average values for most of the indicators, but they benefit from an increasingly high accessibility to EU road network. Although they have, comparatively, the lowest efficiency for public transport and lower education and innovation indicators, in the future, the cities forming this cluster have the potential to increase both their green infrastructures and their urban resilience capacity.

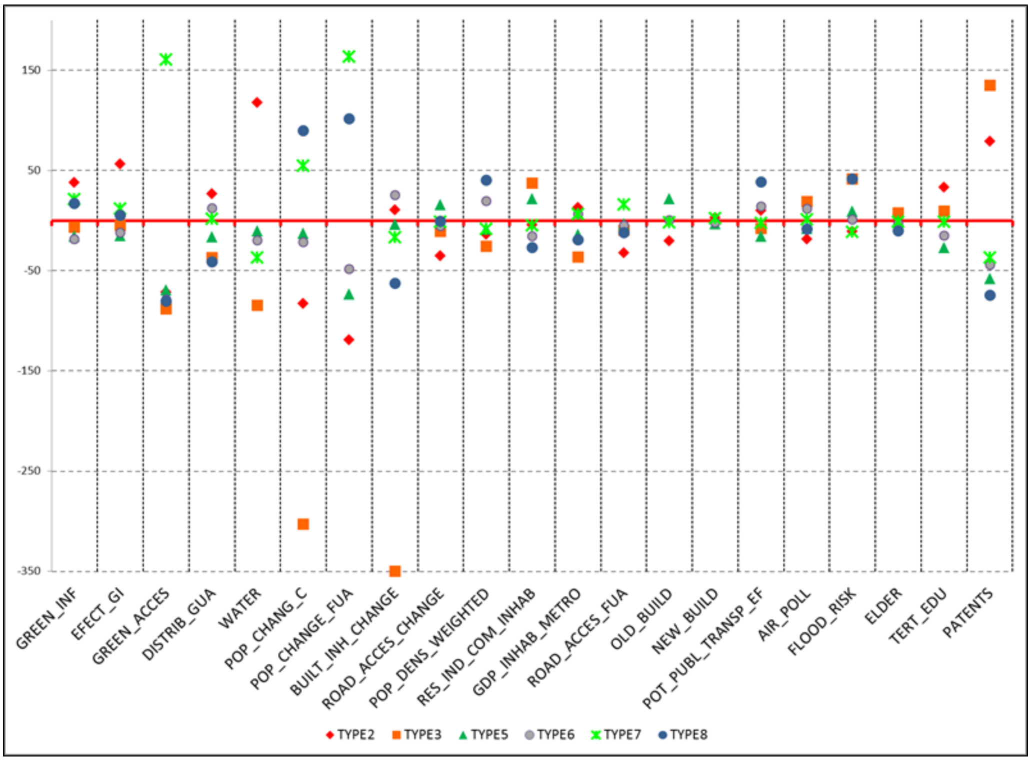

Fig. 6 **– Mean values for all selected indicators by cluster**

Green-grey sealed cities (Type 6) – Besides having the lowest performance in becoming green, they generally do not have a high, but a rather below average economic resilience performance, that is also related to the relatively lower level of education and innovation performance. Nevertheless, most of them are transforming or regenerating (the highest share of functional changes of buildings). Their densities remain rather high, despite their moderate population loss and so it is the number of vehicles that causes a high level of air pollution.

Forest cities (Type 7) – They have the highest access to green areas and they are also rather attractive urban settlements with positive population growth in the outskirts and only a small decrease within the city. The economic resilience indicators show a higher than average value, which might be correlated to a certain point to the high accessibilities to road network. They have also an average air quality and they are usually not under the risk of floods.

Natural blue cities (Type 8) – Although they have, naturally, a very good coverage with green and blue areas, they have a rather low attractiveness for economic activities in the outskirts where the population is highly decreasing. Nevertheless, they have the highest densities in the built-up areas, but a rather low economic performance, partly motivated by the lower accessibility to road and airport networks, but also by the reduced innovation capacity (lowest number of patents). The number of cars and the consequent air pollution are comparatively lower, but, due to the largest blue areas, they face a higher risk of floods.

Assessing the relations between green and resilience indicators in Eastern European Union countries

In order to better explain the relationship between the resilience indicators, the linear regression analysis shows some insightful results that can be used to describe the defining patterns of all selected cities (Table 4).

There is a slight statistical correlation between green infrastructure and population growth (0.174), which might create the assumption that cities with more green areas are generally more attractive, fact which was supported by other studies too (Kahn 2006). Moreover, one can notice significant negative correlations between population density and the presence of green areas (-0.281) and effective green infrastructure (-0.223). This leads to the conclusion that green cities are attractive to the population, but, once the density of people is very high, green areas are often sacrificed for other uses. The relation between green areas, population and its density was also studied, for another perspective, by other researchers, demonstrating that a higher urban pressure would produce the shrinkage of GI and it would increase its level of fragmentation (Petrişor et al. 2016, Blaschke et al. 2017). The presence of the higher share of elderly population is also related to a difficult access to green areas (-0.224) which might be an issue in post-communist countries, but it should be addressed accordingly in order to prepare for a sustainable urban future (Artmann et al. 2017). Meanwhile, the access to tertiary education and innovation (number of patents) correlates with an effective green infrastructure (0.241) and a proper distribution of green areas (0.183), which means that cities might be better planned and adapted to current necessities. In the same context, the emergence of new urban areas (by adding new buildings) is increasing the share of green areas (0.201) and of effective green infrastructure (0.296), as cities with newly constructed neighbourhoods usually integrate large green areas in order to increase general wellbeing (Ma et al. 2019). Contrariwise, a high share of old buildings is sometimes associated with a lack of open spaces with vegetation (-0.222 and -0.371). This is explained to a certain degree by the densification processes in interstitial suburban areas that replace, in time, the open spaces and the greenways by impervious surfaces (Ianoş et al. 2015).

In addition, the distribution of green urban areas is negatively correlated to the access to the road network (-0.322), to high densities of buildings (-0.275) and to large areas facing flood risks (-0.371). Intuitively, the presence of water correlates with the flood risk, but also with the access to the main road network as well as to more densely inhabited settlements. Interestingly enough, there is a high negative correlation between air pollution and green infrastructure (-0.201), and, even to a greater extent, with the effective green infrastructure (-0.294), which is in agreement with previous studies (Kabisch and Van Den Bosch 2017), but, in the case of the selected area, it is a research topic that might be explored in future.

Meanwhile, green infrastructure reduces the flood risk (0.291), which is sustained by the recent literature (Hammond et al. 2015, Berndtsson et al. 2019), but the effective green infrastructure is negatively correlated to the flood potential (-0.281).

Finally, green accessibility does not significantly correlate to any of the resilience-vulnerability indicators.

Table 4

Linear regression results

Dependant variables	**GREEN_ INF**	**EFECT_ GI**	**GREEN_ ACCES**	**DIS-TRIB_GUA**	**WATER**
POP_CHANG_C	0.171*	-0.001	0.156	0.106	-0.120
POP_CHANGE_FUA	0.160	0.025	0.071	0.081	-0.152
BUILT_INH_CHANGE	-0.171*	0.047	0.041	0.137	0.018
ROAD_ACCES_CHANGE	-0.054	0.025	-0.117	-0.322*	-0.009
POP_DENS_WEIGHTED	-0.281***	-0.223**	-0.024	-0.107	0.195*
RES_IND_COM_INHAB	-0.056	-0.114	-0.042	-0.274*	-0.107
GDP_INHAB_METRO	0.052	-0.070	0.008	0.078	0.004
ROAD_ACCES_FUA	0.083	-0.172*	0.103	0.050	-0.264***
OLD_BUILD	-0.222**	-0.371***	-0.165	0.134	-0.167
NEW_BUILD	0.218**	0.296***	0.014	-0.077	0.032
POT_PUBL_TRANSP_EF	0.051	-0.007	0.043	-0.020	0.188*
AIR_POLL	-0.201*	-0.294***	-0.118	-0.033	-0.113
FLOOD_RISK	-0.289***	-0.281***	-0.053	-0.372***	0.312***
ELDER	-0.068	-0.140	-0.224**	0.065	0.214**
TERT_EDU	0.169	0.241**	-0.014	-0.001	0.320***
PATENTS	0.063	0.083	-0.081	0.183*	0.162
R^2	***0.162***	***0.155***	***0.042***	***0.228***	***0.150***
Observations	95	95	95	95	95

The statistical significance at 0.1, 0.05, 0.01 level is indicated by *, **, ***

The results of the linear regression show the existence of correlations that certify the importance of green urban infrastructure, but also the irregularities of recent dynamics. Some of these can be explained by the administrative modifications of built-up areas and the lack of homogeneity in including certain uses that might be assimilated to the green infrastructure within cities (Bănică et al. 2017). The negative correlation of population density, and air pollution with green areas and the efficient green infrastructure is, in this regard, illustrative, showing the opposition between the social-economic growth/economic resilience and the greening of cities in the Eastern European Union. The fact that economic indicators, such as GDP_INHAB_METRO, are not significantly correlated to any green city indicators demonstrated, as other papers argued, the lack of sufficient integration of urban environmental issues in development actions (Bănică and Muntele 2017).

Conclusions

The analysis of the results highlights the importance of green infrastructure in enhancing resilience (capacity and performance), and, implicitly, the existence of complementarity between the two concepts: the green and the resilient city. Beyond the inaccuracies and the low degree of comparability of the available data (due to the high differences between the built-up areas), it was possible to observe several specific patterns of evolution, consistent with the influence of some geographic or social-factors. City size does not necessarily explain the variation in green performance, but it influences it, and, at the same time, size seldom influences the resilience capacity of cities (capitals are advantaged).

The analysis of the six clusters identified in the CEE shows that, while some cities maintained a positive trend, both in environmental, but also in urban resilience indicators, others seem more fragile as they cannot sustain the greener path which they have chosen by complementary economic and socially related improvements and adaptability. In this regard, cities with green outskirts and forest cities seem to be the most resilient, while green-grey sealed cities have the lowest capacity to bounce back after a shock.

All in all, the present assessment identified, in the case of selected post-socialist countries, a rather inconsistent model of urban development: usually, the most (economically) resilient cities do not sustain resilience by also becoming greener.

There are significant differences between cities from the same country and there is a high heterogeneity within the identified clusters, but one can identify a certain gradient northwest-southeast that involves both green and resilience capacity indicators.

In the case of selected cities in the CEE, the statistical relationship between the indicators show that, although green infrastructure (GREEN_INF) was developed in new urban areas (NEW_BUILD), the natural areas diminish the flood risk (FLOOD_RISK) and air pollution (AIR_POLL) and they make cities more attractive (POP_CHANGE), yet they are sacrificed for other uses that are considered more profitable in older (OLD_BUILD) or in higher density cities (POP_DENS_WEIGHTED).

There are obvious limitations to the present approach that derive mainly from the inconsistency or lack of availability of some indicators of resilience at city level. Also the lack of continuous time series data for all selected cities was a major drawback in validating the resilience performance across the physical and social-economic dimensions of resilience by considering certain shocks. The indicators that were chosen for illustrating urban resilience in relation to green infrastructure are proxies that were generally used by other scholars too, but they only partially succeeded in creating a comprehensive image in the case of each category of green cities taken into account in CEE.

Acknowledging these limitations, a broader study using long-term data series of urban resilience performance when facing certain disasters in relation to changes in green infrastructure, using the same sample of cities, would result in a clearer image of the interdependencies between greening cities and making them more resilient. Further studies could also assess, more in-depth, the relation between the two concepts at a lower geographic scale (at national and/or regional level), in order to find more detailed and comprehensive explanations and the causality mechanisms besides the general features discussed in the present paper.

Finally, it should be stated that a more integrated view on the two concepts in the decision making-process at city and metropolitan area level is highly important to make a real transition towards more place-specific policies and a more sustainable urban development model in Central and Eastern Europe, as being both green(er) and more resilient.

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MIGRATION AND INVESTMENT ACTIVITY IN THE REGIONS OF THE SIBERIAN FEDERAL DISTRICT OF THE RUSSIAN FEDERATION

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Abstract: This article analyses the migration and investment activity processes in constituent entities of the Russian Federation located in the Siberian Federal District (SFD). The research was performed on the basis of official statistical data with geographical visual reference. The study was performed in the mono-specialized cities of SFD regions on the basis of official statistics within the context of the creation of Priority Social and Economic Development Areas (PSEDA). A negative migration balance is registered in SFD regions and mono-specialized settlements. Investment activity in SFD territories, their regional potentials and risks were analyzed. Krasnoyarsk Territory, Tomsk Region, Irkutsk Region, Novosibirsk Region, and Kemerovo Region stand out among the SFD regions by their investment activity level and social and economic development. At the current stage of social and economic development, Priority Social and Economic Development Areas can be successfully created in the regions which are the most developed both industrially and innovatively and in the mono-specialized settlements with the most favorable start conditions.

Key Words: *migration of population, mono-specialized cities, investments, investment risk, investment potential, Priority Social and Economic Development Areas, Siberian Federal District.*

Introduction

Currently, the migration issue is one of the urgent problems in Russia. The attitude of the population towards migration actually reflects the level of its social and economic development, the quality of life in the region and the perspectives for development. Migration mobility reflects the peculiarities of the population retention in the region and the acclimation of the migrants, and thus it characterizes the functioning of the economic space and the influence of internal and external factors on the latter.

The relevance of the research on migration issues in the country is determined by the problems of transregional differences in the social and economic development of the territories, while migration factors of attraction and repulsion play the crucial role. A gradual decrease of population, decreased birth rates against the background of relatively high mortality and depopulation are observed in the remote and border regions of strategic importance in the context of geopolitical interests of the country. Problems arising at regional labor markets are intensified by the growing selective migration, and the declining working-age population and skilled personnel. Consequently, the necessity to ease this tension is an acute problem in specialized monosettlements which depend mostly on singular production, have less opportunities for the diversification of the economy and, correspondingly, are less viable under market conditions. Mono-specialization of economic development in the majority of settlements in the regions of the country has been maintained since the Soviet period; the transition towards market conditions has only worsened the spiraling social and economic crisis. The current degradation of the urban environment in depressed cities is accompanied by a considerable migratory mobility of their population, making the situation only worse.

Taking into account the growing migration of population from the eastern regions of the country to its western part, we should mention that the problem of formation and preservation of demographic and labor resources keeps getting worse not only in large cities, but particularly in mono-specialized settlements. Mostly this tendency is observed in the territories of Siberia and the Far East suffering from all the results of the “migration pump”.

The current situation with the demographics and the migration movement of the population in Russia requires the development of new government solutions on the socio-economic development of the country’s regions aimed at improving the living conditions of the residents. In order to improve the quality of life of the population in the regions and, accordingly, to reduce the migration outflow of the residents, the creation of territories of priority social and economic development is being proposed. To a greater extent, these measures are aimed at improving the socio-economic development of single-industry towns, diversifying their economies, and reducing the stress on the regional labor markets. The Federal Law No. 473-ФЗ On Creating Territories of Advancement of Socio-Economic Development (hereinafter referred to as PSEDA) was passed in 2014. It provides for the creation of territories within one or more municipal entities for 70 years with the right to extend, with a special legal regime for the implementation of–entrepreneurial and other activities in order to create an enabling environment for attracting investments while ensuring accelerated economic development and creating comfortable conditions for the livelihood of the population. Investing in PSEDA projects is supposed to be based on public-private partnerships. So, on the part of the state, the PSEDA resident companies are provided with preferences in the form of benefits for the payment of income and property, a reduction of more than 3 times the volume of insurance fees, as well as co-financing from the Monotown Development Fund. An urgent task is to attract anchor investors (i.e. large companies) including the foreign ones. According to the requirements for investment projects, the minimum amount of capital investments of a PSEDA resident into a project in the first year is of 5 million rubles, with the minimum number of permanent jobs created in the first year of the project being that of 20 jobs. Initially, such territories have been created in the Far East, then in Siberia and other regions. They are aimed at assisting in the economic development of mono-specialized cities and the improvement of the quality of life.

Given that one of the main features of this law is the investment component, the developers of this document rely not only on improving the life of the population of the single-industry towns, but also on preserving their labor resources, as well as on the movement of human capital after investments. And to a large extent this applies to the foreign migrants. In addition, the implementation of the law can contribute to the development of support for domestic investment, which will change the geography of migration flows within the regions – labor resources will be in demand at the place of residence, without the fly-out work trips and pendulum migration.

The well-known expression “migrants follow investments” (Javorcik et al. 2011, Fensore 2017, Kugler et al. 2017, Burchardi et al. 2019) gives hope for the stabilization of the migration flows of compatriots both at the national level and in individual settlements. Therefore, the authors of the article deem it important to, first of all, characterize the situation with the migration movement of the Russian population and the investment activity in the regions under consideration. The investment opportunities that the state offers in the form of this law can help to solve the problem of migratory loss of the population locally, at the micro level, by directing targeted assistance to rehabilitate the situation in single-industry towns. Modern migration is not only the result of not only the existing socio-economic development of the country and its regions, but it is also a deeper phenomenon of the transformation of the lifestyle of Russians, and changes in the entire rural-urban continuum. Therefore, it is necessary to perform regional research aimed at the analysis of the current mechanisms for the improvement of the social and economic quality of life of the population in the Siberian regions.

The existence of development problems of the specialized monosettlements, their restructuring and migrational non-wellbeing is a well-known problem in the world (Everitt and Gill 1993, Halseth and Sullivan 2003, Anas and Xiong 2005, Bartik 2009, Agrawal et al. 2010, Bański et al. 2016, Berube and Murray 2018). A unique specificity for each country is the choice of its own mechanisms and incentives to solve the existing problems. Recently, more and more works have been devoted to the issue of the functioning and socio-economic development of single-industry towns in the Russian Federation (Animitsa et al. 2010, Zubarevich 2012, Antipova and Titov 2016, Zamyatina and Pilyasov 2016, Gurova 2017, Dushkova and Krasovskaya 2018, Mingaleva et al. 2018).

Comparative studies and integrated assessments of migration processes in the regions of Eastern Siberia and the Far East were performed by many Russian scientists, including Mkrtchyan (2009), Vakulenko et al. (2011), Zayonchovskaya (2012), and Motrich (2016). Some authors described the influence of investments on regional development in their works. A study on the influence of the near-border location on the investment processes in Russia's regions using the methods of multivariance cluster analysis is presented in the work of Glazyrina et al. (2012); the influence of large investment projects on the social and economic development of Baikal region is described in the works of Dets (2014), and Sysoeva (2018). An analysis of the attraction and spatial distribution of direct foreign investments is given in the works of Dementyev (2017), and Minakir and Suslov (2018).

The aim of this article is to analyze the migration and investment activity in the regions and mono-specialized cities of the Siberian Federal District within the context of the Priority Social and Economic Development Areas creation and functioning.

Methodology

The methods of study include the analysis of statistical data, data processing and their geographical visualization. The statistical information from the databases of the Federal State Statistics Service was used to study the migration mobility issues. The analysis of the official statistics, investment projects summaries and data from the regional media concerning the implementation of projects were used for the study of the investment activity.

The rating of the investment attractiveness of SFD regions was analyzed based on the data of Expert-RA rating agency. Traditionally, it is based upon the official data from the Federal State Statistics Service and federal agencies. This rating estimates two parameters: the investment potential and the investment risk. The investment potential is composed of the presence of natural resources, labor force, fixed assets, infrastructure, and other factors influencing the potential investment volumes in the region. The investment risk includes the economic, social, financial, managerial, ecological and criminal risks.

Selection of the Study Area

This research is focused upon the administrative territories of the Russian Federation – regions of the Siberian Federal District (SFD) and their specialized single-industries, in which the Priority Social and Economic Development Areas were created: Irkutsk Region (Sayansk, Cheremkhovo, Usolye-Sibirskoye), Trans-Baikal Territory (Krasnokamensk), the Republic of Buryatia[1] (Selenginsk), the Altai Territory (Novoaltaysk, Zarinsk), Novosibirsk Region (Linyovo), the Republic of Khakassia (Abaza), Krasnoyarsk Territory, Kemerovo Region (Novokuznetsk, Anzhero-Sudzhensk, Yurga), Omsk and Tomsk Region (Fig. 1).

1) Until 3rd of November, 2018, the Trans-Baikal Territory and the Republic of Buryatia were parts of the Siberian Federal District; later, they were included in the Far Eastern Federal District by the Decree of the President of the Russian Federation.

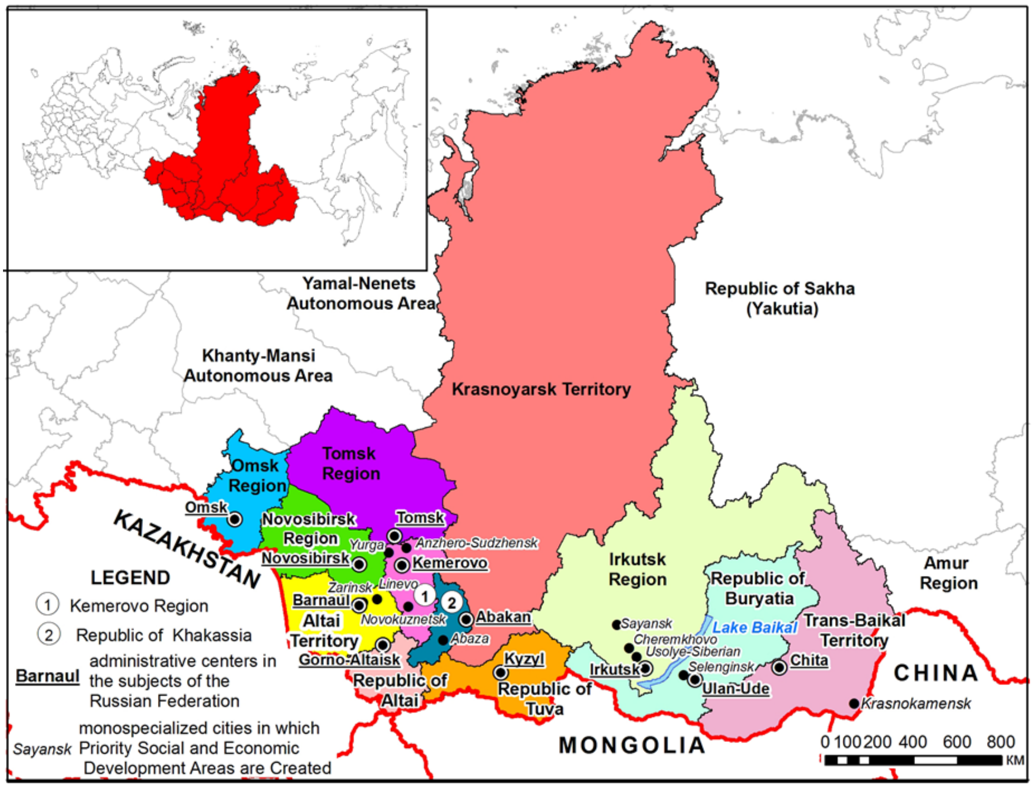

Fig. 1 **– Regions and Specialized Monosettlements with Priority Social and Economic Development Areas in the Siberian Federal District**
Source: *Drafted by the authors*

Results

Migration Activity in the Regions of the Siberian Federal District

Migration activity in the regions of the Siberian Federal District allows to describe the current tendencies and peculiarities of population redistribution at the present stage. Taking into account the absence of sufficient information concerning migration in specialized monosettlements, the general description of the regions allows to speak about the development of urban areas in general.

The available statistical data allow to perform an analysis by regions without regard to the migratory exchange with foreign countries – only interregional migration. In 2016, Omsk Region takes the leading position in migratory out flow (-10192 people). Considerable losses are also present in Kemerovo Region (-9391), the Altai Territory (-7952) and Trans-Baikal Territory (-6821). Population growth is present in Novosibirsk Region (2618 people) which possess considerable potential for scientific and technological development, and for the Republic of Khakassia (71 people) (Russian Federal State Statistic Service 2016).

The presence of a social and economic crisis is also confirmed by the net migration parameters per 10000 people. The most unfavorable situation is observed in the near-border Trans-Baikal Territory – in 2016, this coefficient amounted to -60. It is followed by the Republic of Tyva (-42), the Republic of Buryatia (-33), Irkutsk and Tomsk regions (-30). Positive dynamics is observed in Novosibirsk Region, Krasnoyarsk Territory, the Republic of Khakassia, and the Altai Territory (Regions of Russia 2018).

We should mention the importance of such parameter as the quantity of people born and living in the place of birth or beyond its borders. This parameter allows to characterize transregional and intraregional migration. Unfortunately, such statistical information is collected only during census years; therefore, the most recent data used in the study are the data from the 2010 census. According to Bulaev (1998), this parameter can be used to determine the stability of population cores in the regions. Based on the above, we can characterize the demographic development and migratory movements of the population in these territories. In SFD, the population core is formed by the locally born people, with the exception of the Republic of Khakassia (Shvorina and Faleychik 2018). In this Republic, the relative share of people born in the region and still living here exceeds 50%, which points to a considerable influence of the migratory movements of the population (Fig. 2).

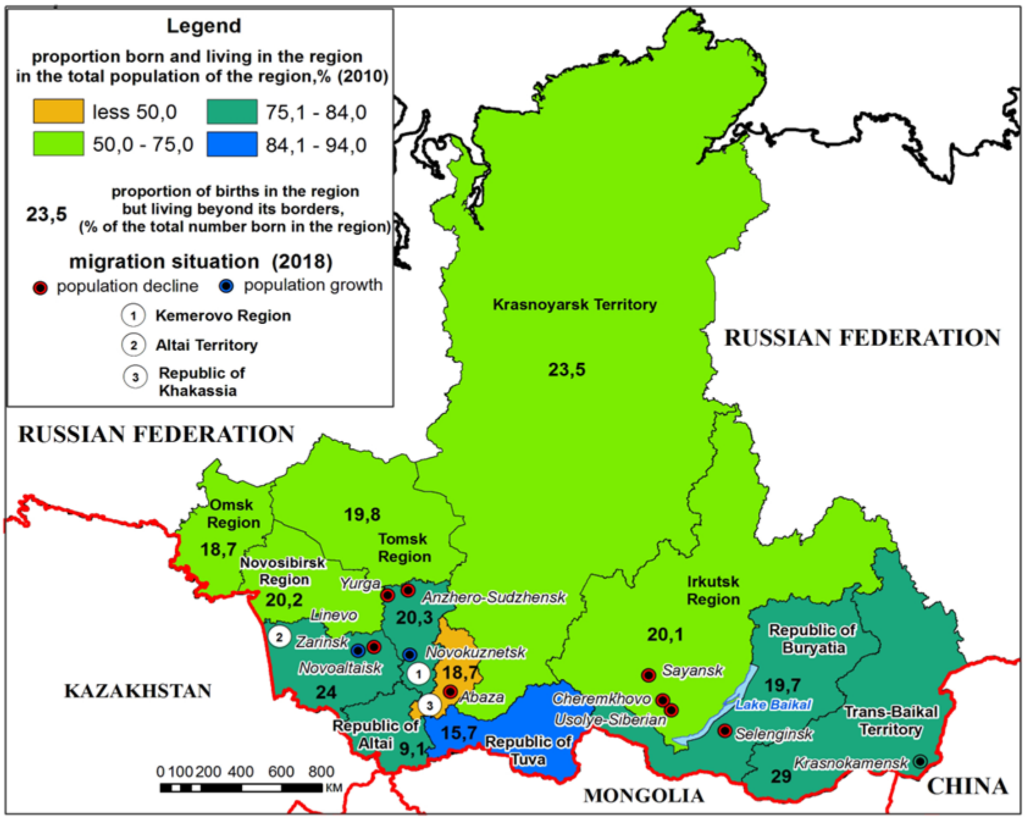

Fig. 2 **– Percentage of people born and living in the regions of the Siberian Federal District submitted to the 2010 All-Russian Census**
Source: *calculated by the authors using the data provided by Rosstat*

In order to characterize the internal mobility of the population, we have analyzed the data concerning the people born in SFD regions, but living in other regions of the Russian Federation. Among all SFD regions, the least migratory mobility is observed in the Republic of Altai – nearly 9% of its population have changed the place of residence. The largest dispersion throughout the territory of the country is characteristic of the Trans-Baikal Territory population – nearly one-third of 2010 census respondents. At large, non-alien population is preserved in SFD regions.

As for the specialized monosettlements in SFD regions, the migrational situation reflects an increasing degradation of urban areas. In 2018, virtually, all mono-specialized cities (except Novokuznetsk and Novoaltaysk), from the list of Priority Social and Economic Development Areas, show a rapid and uncompensated population loss. Formed by PSEDA in these specialized monosettlements and the declared volume of investments has not yet reflected in any way in the migration indicators. This may be explained by the inertia of the development mechanisms of PSEDA themselves, the problems of the bureaucratic nature and the difficulty of finding investors in the domestic market of the country. The qualitative and quantitative structure of the population is substantially worsening.The migratory portrait of the population of single-industry settlements includes residents of young ages and a more able-bodied population. By gender, among the inhabitants of the 12 considered settlements, in 8 of them there are more migrant women than men. Young people in search of better places for studying and work are striving for large cities – Moscow, St. Petersburg, Novosibirsk, Krasnoyarsk, hoping to stay there for permanent residence. The geography of similar routes is typical for able-bodied residents, while for many of them, unlike young people, there are difficulties in securing a family at a new place of residence. Socio-economic conditions are the main pushing migratory factors for the population – job search and decent wages are always the main requirements of the migrants. All this affects the qualitative and quantitative composition of the population of monofunctional settlements. The countryside, at the present stage, is not able to make up for the missing shortage of youth and the working population. Mono-specialized cities become hostages of a difficult socio-economic situation, which without the help of the state is quite difficult to solve.

Investment Activity in SFD Regions

The investment attractiveness of the regions serves as an important parameter of social and economic development of territories. Investment generally determines the well-being of the population and it is one of the factors decreasing the outward migration flow. The dynamics of these parameters reflect the possibilities of improvement of the basic premises for market development in these regions.

From 2010 to 2017, the Central Federal District (CFD) and the Ural Federal District (UFD) take the leading positions by the volume of investments in capital assets among the RF federal districts (Table 1). The volume of investment resources (in absolute measures), by federal districts, has increased by the year 2017 in comparison with 2010 and their share in the total volume of the Russian Federation has decreased in all districts, except for CFD and UFD. This points to the escalating differentiation of the regions and the territorial unevenness of the investment activity.

In terms of per capita investments in 2017, the Siberian Federal District is at the seventh place, while the Far Eastern one is at a second place, which, on the one hand, is explained by the larger population in the Siberian regions compared to the Far East and, on the other hand, it is caused by the implementation of major investment projects in the East of the country (Fig. 3).

Table 1

Investments in Capital Assets by the Federal Districts of the Russian Federation (USD)*

Federal District	Total Volume in 2010-2017**	2010***	2017****	Share of Federal District in the Total Volume by RF (%)	
				2010	2017
Russian Federation	2453491.6	301353.1	273638.4	100	100
Central	608300.6	69141.3	71516.0	22.95	26.13
Northwestern	276978.0	37352.8	32081.8	12.39	11.72
Southern	233737.4	29896.7	23947.2	9.92	8.75
North Caucasian	81274.9	10319.8	8634.9	3.42	3.15
Privolzhsky	349851.0	47331.9	41340.3	15.7	15.10
Ural	417406.3	49089.5	49187.1	16.28	17.97
Siberian	256082.0	32284.2	26067.8	10.71	9.52
Far Eastern	177928.5	25936.7	20862.9	8.60	7.62

*Source: *Federal State Statistics Service (2018), calculated by the authors*
***Average rate for the period of 2010-2017: 42.69 rubles for 1 US dollar*
****The average annual rate in 2010: 30.37 rubles per 1 US dollar*
*****Average annual rate in 2017: 58.35 rubles for 1 US dollar*

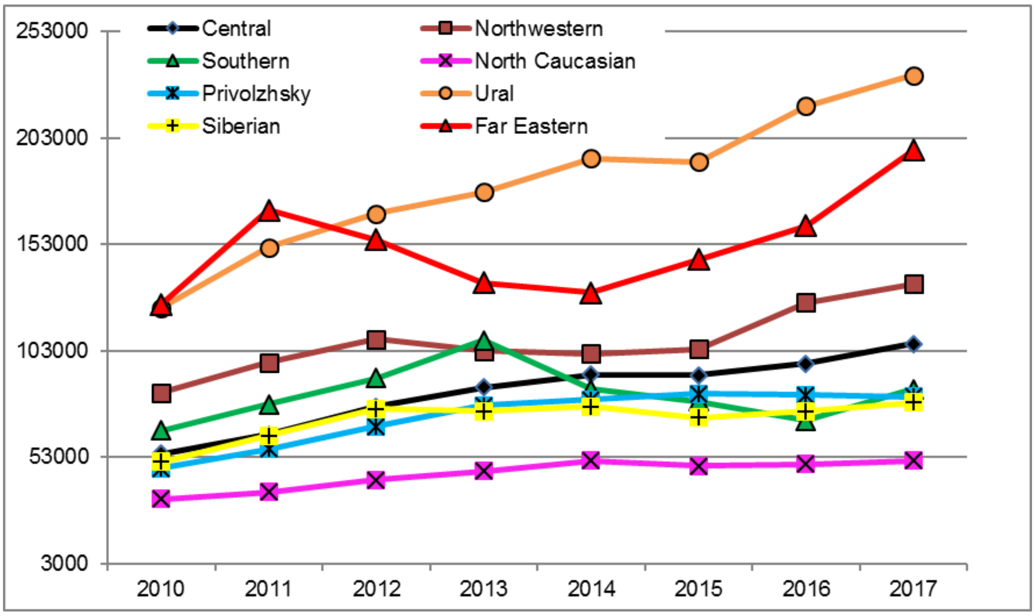

Fig. 3 – **Dynamics of Investments in Capital Assets per Capita (in Current Prices, Rubles), by Federal Districts**
Source: *Rosstat*

SFD regions in terms of investment dynamics into per capita capital assets do not show a significant growth in comparison with the Far Eastern Federal District, in which, after a stable decrease of this parameter during the 2012-2014-time period, a significant growth is being observed: from 2015 to 2017, increased investments in capital assets are reported. Nevertheless, the total volume of investments in the economy of the Siberian Federal District exceeds this parameter in the Far Eastern Federal District by 30.6 %. The negative dynamics of investment activity in the Far Eastern Federal District, observed from 2012 to 2015, is associated with the completion of major investment projects. The current growth of the investment activity in the Far East is, to some extent, associated with the creation of PSEDA in the Primorskiy Territory, the Khabarovsk Territory, the Amur Region, the Kamchatka Region, the Republic of Sakha (Yakutia), and Chukotka Autonomous Region. In 2015, nine such areas were created with 21 resident companies and the total amount of investments of 187 billion rubles, in 2016 – 14 PSEDA and 11 resident companies with the amount of investments of 450 billion rubles, and in 2017 – 18 PSEDA, 204 resident companies and 2175 billion rubles of investments.

As for the investments into the per capita capital assets, some significant intraregional differences are observed. According to the data, since 2015, decreased investments into the per capita capital assets have been virtually observed in all SFD regions, except Krasnoyarsk Territory, Trans-Baikal Territory, and Irkutsk Region (Fig. 4). The crisis events in the economy of Russia associated with the global oil price slumping and the imposition of sanctions have

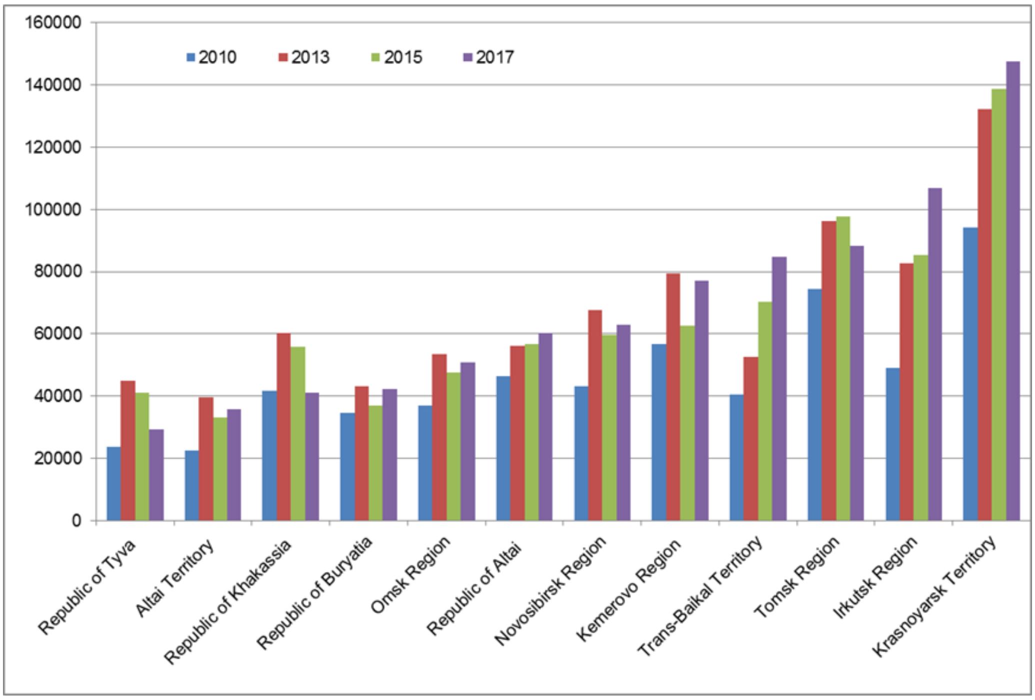

Fig. 4 **– Investments into Capital Assets per Capita by SFD Entities (in Current Prices, Rubles)**
Source: *Rosstat*

contributed to the problem. Among all SFD regions, the Krasnoyarsk Territory stands out in terms of social and economic development; also, it takes a leading position in the share of investments into capital assets in comparison with the total volume of investments in the district – 28% in 2017 (in absolute measures – 424.7 billion rubles). This region consistently has been taking the leading position by the attraction of investments since 2010. Irkutsk Region is at second place (16.9%, in absolute measures – 256.8 billion rubles). Over the period from 2010 to 2017, the Krasnoyarsk Territory has also been taking the leading position in the Siberian Federal District in the volume of investments per capita (1st place), Tomsk Region had been at 2nd place till 2015 and was replaced by Irkutsk Region in 2016; Kemerovo Region had been at 3rd place till 2015, and was replaced by the Trans-Baikal Territory in 2015. The Altai Territory had been last till 2017, and it was replaced by the Republic of Tyva in 2017.

In the Republic of Tyva, the Republic of Khakassia and Tomsk Region, the decline continued till 2017. The share of the Trans-Baikal Territory was 6% of the total SFD volume, in 2017. Recently, in the Trans-Baikal Territory, the investment activity has grown mostly at the expense of implementation of key investment projects of the region – "Russian Railways" JSC investment program implementation regarding the development and modernization of the Trans-Baikal Railway infrastructure, development of mineral deposits, machinery renewal of some production enterprises, implementation of agricultural investment projects, aimed at commercialization of 112.4 thousand hectares of farmland by 2020.

Among the regions in which PSEDA functioning is planned, a more favorable situation with the attraction of investments is observed in Krasnoyarsk Territory, as well as in Tomsk, Irkutsk and Kemerovo Regions, which are also the key regions of the district.

In the structure of investments into capital assets by sources of financing over the period from 2010 to 2017, the total share of internal funds in SFD has increased from 52.1% to 55.4%. In the majority of district regions (the Republic of Khakassia, the Altai Territory, Irkutsk, Novosibirsk, Kemerovo, Omsk and Tomsk Regions), the investment from internal funds

Table 2

Distribution of Investments in Capital Assets by Sources of Financing (excluding Small Business Enterprises, %)

Territory	2010 г.			2017 г.		
	Internal Funds	Involved funds	of which Federal Money	Internal Funds	Involved funds	of which Federal Money
SFD	52.1	47.9	10.1	55.4	44.6	7.1
Republic of Altai	7.9	92.1	48.2	26.8	73.2	18.7
Republic of Buryatia	31.6	68.4	14.2	48.8	51.2	24.1
Republic of Tyva	12.6	87.4	30.9	38.0	62.0	32.0
Republic of Khakassia	24.6	75.4	3.3	67.9	32.1	8.3
AltaiTerritory	42.3	57.7	11.6	50.3	49.7	5.8
Trans-Baikal Territory	21.1	78.9	30.4	27.3	72.7	4.7
Krasnoyarsk Territory	58.4	41.6	11.3	46.7	53.3	9.0
Irkutsk Region	58.5	41.5	5.4	65.4	34.6	6.0
Kemerovo Region	64.8	35.2	3.0	68.2	31.8	3.0
Novosibirsk Region	52.0	48.0	12.5	52.6	47.4	8.5
Omsk Region	51.2	48.8	7.3	76.1	23.9	3.7
Tomsk Region	46.1	53.9	5.4	70.8	29.2	2.8

Source: *Federal State Statistics Service (2018)* dominates over the borrowed funds and it amounts from 50.3% to 76.1%. In this regard, the Trans-Baikal Territory falls behind other entities of the Siberian Federal District with the lowest amount of internal funds since 2010 (27.3% in 2017). The share of federal money in the majority of district regions tends to be reduced (Table 2).

In the structure of investments into capital assets by economic activity in the regions, in 2017, mining, manufacturing, transportation and storage were the most attractive for business. Kemerovo Region (54% of all financial investments in the region in the mining sphere) and Omsk region (nearly 55% of the total investment volume of the region fell into manufacturing) are the leaders by the percentage of investments by economic sectors (Regions of Russia 2018).

Analyzing this parameter in the district as a whole, we can distinguish the territories which are the definite leaders of economic development characterized by a high investment attractiveness. Krasnoyarsk Territory has the largest share of investments in the district, virtually, in all economic sectors. It is followed by Novosibirsk Region, Irkutsk Region and the Trans-Baikal Territory. Investments into mining is characterized by the largest percentage: 36.5% of the total investment volume of the district in the Krasnoyarsk Territory (128.5 billion rubles in absolute measures), 22.9% — in the Kemerovo Region (80.5 billion rubles in absolute measures), and 22.0% – in the Irkutsk Region (77.5 billion rubles in absolute measures). The manufacturing percentage holds the second place in these regions: 38.9% in the Krasnoyarsk Territory (81.0 billion rubles), and 15.0% – in the Irkutsk Region (31.2 billion rubles). Investments in manufacturing, agriculture, forestry and hunting dominate in the Altai Territory and the Novosibirsk Region (Regions of Russia 2018).

According to the national rating agency, evaluating the investment attractiveness of Russian regions, the investment ratings of SFD entities are referred to the following categories:

1. with reduced potential and moderate risk (Altai Territory, Omsk Region, Republic of Buryatia and Tomsk Region);
2. with average potential and moderate risk (Kemerovo Region, Irkutsk Region, Novosibirsk Region and Krasnoyarsk Territory);
3. with low potential and extremely high risk (Republic of Tyva);
4. with insignificant potential and high risk (Republic of Altai);
5. with insignificant potential and moderate risk (Republic of Khakassia);
6. with reduced investment potential and high investment risk (Trans-Baikal Territory).

The Krasnoyarsk Territory is the largest region in SFD. By the volume of investments into capital assets per capita, the territory had been at the 14th place among the regions of Russia at the end of 2017 (Regions of Russia 2018). The Implementation of the investment project for Vankor oil and gas field development allowed to attract investments into the economy of the region. The territory is characterized by moderate investment risks, the main of which are legislative, political, financial, social, ecological, and criminal. Additional regional investments risks of the territory are the underdevelopment of infrastructure, severe climatic and natural conditions, deficiency of labor force. All these factors aggravate the problem of increasing the investment attractiveness (Cheremnykh 2015).

The Irkutsk Region is an industrial region with dominant mining and primary processing of natural resources: oil production and refining, aluminum, wood processing and chemical industry. The implementation of major investment projects in the oil production, from 2010 to 2013, has provided an inflow of investments in the region. The introduction of a zero rate mineral tax and a zero rate crude oil export fee has contributed to this inflow. Since 2013, the share of investment into mining has decreased (Violin 2016). A moderate investment risk is characteristic of the region. It has such regional peculiarities as problems with the transport infrastructure availability and staffing issues.

The primary industry of the Tomsk Region, besides other priority areas (information technologies, science and education, agriculture and timber processing), is the oil and gas sector. The share of oil and gas sector in the industrial output of the region is of approximately 50% (Sharf and Grinkevich 2016). Tomsk Region is an innovation-developed resource region of the Siberian Federal District. It is emphasized (Sevastyanova 2016) that the development of the innovation sector has improved the image of the region and it has increased the possibilities for investment and the availability of highly-qualified specialists. The moderate investment risk of the region is associated with social and ecological risks.

Kemerovo Region is a region with evident resource specialization where investment flows into the mining sector, therefore the investment risk is closely related to the economy of the region. The contribution of mining to gross added value of the region, in 2016, amounted to 29.7% (Regions of Russia 2018). The economic crises in the coal industry increased the investment risk of the region and it resulted in decreased investments and gross regional product.

The Omsk Region is a developed industrial and agricultural region with an advanced production and transport infrastructure (Mikhalyov 2018). The regional peculiarity of investment risks in the Omsk Region is associated with the deficiency of the labor force because of the high outward migration flow of the employable population.

The competitive advantage of the Novosibirsk Region is in its diversified economic potential including a developed industry, transport, communication, construction, agriculture, and commerce. The prospects of the region are associated with the development of science-intensive innovative manufacturing methods, which increase the investment attractiveness of the territory. Above that, it is mentioned (Zemtsov and Smelov 2018) that the region has favorable institutional conditions for investors and business owners. The main investment risks in the region are social, managerial and ecological.

The Altai Territory is one of the main agricultural regions of Russia. The contribution of agriculture, hunting and forestry into the gross added value of the region amounted to 20.1% in 2016 (Regions of Russia 2018). Such competitive advantages of the region as favorable natural and climatic conditions, advantageous geo-economic position, diversified economy, and advanced technologies (Uskova and Razgulina 2015, Gerauf and Zelenina, 2017) create a favorable environment for the attraction of investments. The resource potential of the Altai Territory agro-industrial complex, the availability of land areas, the high demand for environmentally-friendly and natural products increase the investment attractiveness. The main investment risks of the territory characterized as moderate are the social, managerial and economic ones.

The Republics of Tyva, Khakassia, Buryatia and Trans-Baikal Territory are the depressed regions characterized by a decline in the main economic sectors, a low diversification of economy, an outward migration flow, the growth of unemployment, and decreased income levels. The republics of Altai, Tyva, and Khakassia are characterized by the lowest parameters of investment activity among the other entities of SFD. From 2009 to 2017, the Trans-Baikal Territory, according to the rating of investment attractiveness, had been referred to as a region with a decreased investment potential and high investment risk.

Thus, the majority of SFD regions is characterized by a moderate investment risk, while a medium investment potential is present only in the regions with developed industry (Novosibirsk Region, Irkutsk Region, Kemerovo Region and Krasnoyarsk Territory). The regions located in an unfavorable natural environment (Republic of Tyva, Trans-Baikal

Territory) or with predominantly agricultural specialization – Altai regions and Republic of Buryatia – lag behind in the investment activity. In comparison with the migration indicators, the correlation with the investment migration growth is observed only for the Novosibirsk region.

Discussion

The migratory mobility of the population is caused by the unevenness of the social and economic development in the regions of the country. The regions of the country are differentiated by the population's quality of life; therefore, the parameters of migratory movements can serve as indicators of life quality in specific territories. The creation of Priority Social and Economic Development Areas can serve as a mechanism for quality of life improvement in the regions and, correspondingly, for decreasing the outward migration flow. These measures are mostly aimed at improving the social and economic development of mono -specialized cities and the diversification of their economy, while relieving the tension of regional labor markets. The investment activity of the residents of the studied territories, also, in many respects, serves as an indicator of the level of social and economic development of these territories and their perspectives. The creation of PSEDA causes a multiplicative effect – the creation of new work places and the reconstruction of the already existing ones in the different sectors of the economy. Generally, this contributes to the welfare of the population and to a positive migration balance.

The Ministry of Economic Development of the Russian Federation differentiated all specialized monosettlements in the country by the level of social and economic development. Within this context, among the SFD regions, only the cities of Novokuznetsk and Novoaltaysk (2018) have the most favorable situation among the regions of the Siberian Federal District (Fig. 5). Only in their case, cities are currently experiencing migration growth. In relation to the remaining mono-settlements, negative development trends are traced. For mono-settlements (Zarinsk, Sayansk and Cheremkhovo), there are risks of worsening the socio-economic conditions. Most mono-settlements (Yurga, Abaza, Usolye-Sibirskoye, Selenginsk, Anzhero-Sudzhensk and Krasnokamensk) belong to settlements with a difficult socio-economic situation. The significant complexity of the situation in the cities of Yurga and Krasnokamensk is indicated by the highest migration outflow of the population among all considered settlements. Migration indicators in this regard correlate with the standard of living of the population in these settlements, confirming the well-known thesis that “the population votes with its feet”.

In spite of the types of mono-specialized cities distinguished by the level of social and economic development, the volumes of planned investments in PSEDA also reflect their specific investment attractiveness. Mostly, this can be correlated to the existing specialization of the settlements and the activity of the residents. The investments in the monosettlements of the Siberian Federal District will be directed mainly to industrial production and wood processing. The largest volume of planned investments accounts for the city of Sayansk (49.8 billion rubles), where the construction of two plants for the production of methanol and natural-gas liquefaction, the creation of an added-value wood conversion center and works for PVC processing and the manufacturing of furniture are planned (Ministry of Economic Development of Russia 2018). Considerable investments into the economy of Usolye-Sibirskoye (18 billion rubles) and Anzhero-Sudzhensk (16 billion rubles) are planned. As for Usolye-Sibirskoye, these investments are planned for the creation of infrastructure for the “Cluster HIMPROM Usolye” (Usolye Chemical Production Cluster) industrial park. As for Anzhero-Sudzhensk, the investments are planned for the development of agriculture, the production of rubber and plastic items, construction materials, and pharmaceuticals (Bezformata 2016). The investments of the residents of other specialized monosettlements are substantially lower.

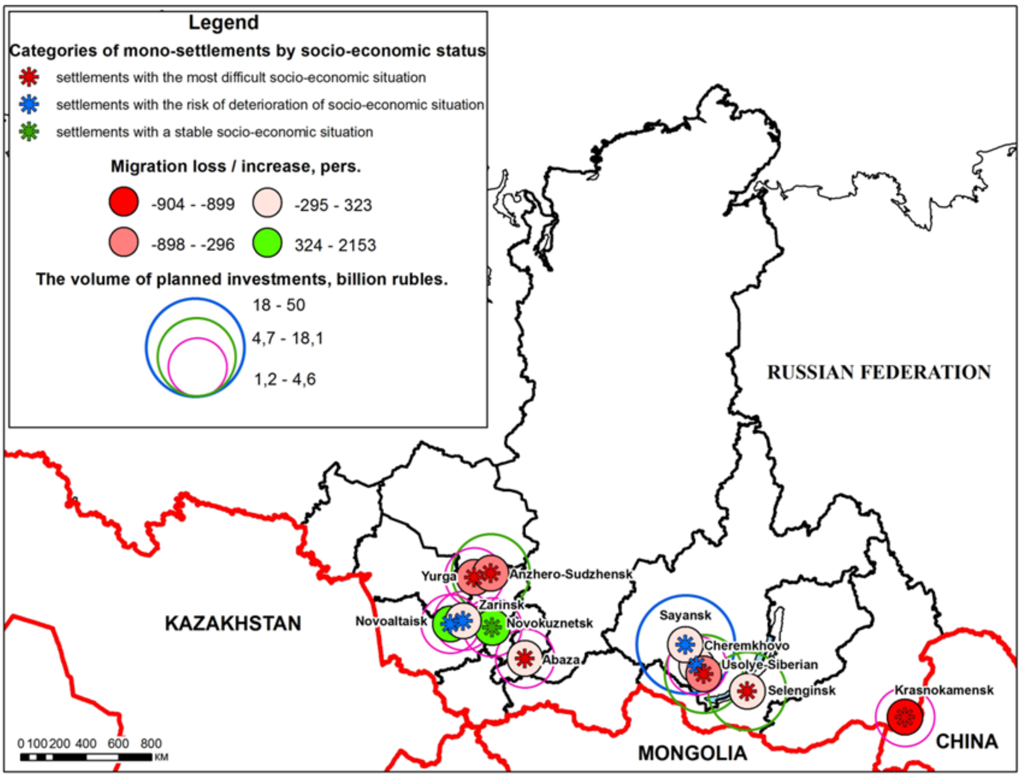

Fig. 5 **– Level of Social and Economic Development, Migration and Investment Activity in SFD PSEDA (2018)**
Source: *calculated by the authors using the data provided by Rosstat*

Taking into account the fact that the studied PSEDS in SFD, mainly, have just been created, and currently only several residents commenced the first stage of implementation for the investment projects, PSEDA has not yet had a noticeable effect on reducing the mono-dependence of the economy of settlements and the improvement of the quality of life. Above that, some problems with the organization and functioning of PSEDA also exist. In our opinion, it is possible that the specialized monosettlements will not be able to attract investors and to solve the problems of infrastructure availability, the deficiency of highly-qualified specialists, etc. Such problems significantly complicate the development of PSEDA in mono-specialized cities.

Conclusions

The current stage of economic development of the country determines the creation of new mechanisms for regional development and the management of territories. Thereby, new methods of "secondary social and economic development" of the territories and their regional management driven by the market economy do not mean the complex Soviet-type development of territories and the large-scale labor migration. Under modern conditions, the mechanism of targeted development (Priority Social and Economic Development Area – PSEDA) is actively used. Their functioning in SFD mono-specialized cities is based on resident companies – locomotives of economic development which can decrease the mono-specialization of settlements. However, the monoprofile type of economic development specific to these settlements and their current social and economic situation causes difficulties in the attraction of investors in spite of the particular state of policy favors.

The aspects of the migratory activity of the population within the regions and mono-specialized cities of SFD discussed in this article prove the presence of considerable migratory movements of population (mostly of employable age), which intensifies demographic risks. When studying migration flows and investment attractiveness in the subjects of the Siberian Federal District and their single-industry towns, the authors came to the conclusion that the relationship between these two processes, important for the socio-economic development, can be traced in the most industrially and innovative developed regions. The presence of a correlation between them is characteristic of only one such region (Novosibirsk region). For this period of time, in the context of the implementation of the law on the creation of PSEDA territories, the investments of the residents did not have a significant effect on the migration indicators in single-industry towns.

The greatest success in the development of PSEDA in the SFD based on regional analysis is possible in the Krasnoyarsk Territory, Irkutsk, Novosibirsk, Tomsk and Kemerovo Regions. An effective state and regional policy aimed at the maximum reduction of investment risks is necessary. To some extent, this is provided by such policy favors for PSEDA resident companies as tax exemptions and the priority development of the infrastructure at the expense of federal money.

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LAND COVER IMPACTS TOWARDS THERMAL VARIATION IN THE KUALA LUMPUR CITY

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Abstract: Physical geography and urban characteristics influence the urban climate conditions. Built-up areas, green urban parks, forest reserves, streets and terrain constitute the climatic interactions within urban areas. These have led to the variation of the urban climate condition throughout the world. Thus, in studying urban climate, the impacts of these factors are crucial to be examined. This study aims to examine the effects of six important factors, namely built-up areas, green covers, terrain elevation, building volume, surface roughness and land use type, which contribute to the variation of the urban climate condition within the Kuala Lumpur City. In this study, the effects of the six factors (urban parameters) towards the air surface temperature variation were statistically tested. Using the Weather Research and Forecasting (WRF) model and the remote sensing technique, the data needed for the analyses were extracted. The Geographical Information System (GIS) was employed as the analysis platform during the study. Based on the Spearman's rho and Mann-Whitney U tests, it was identified that the six urban parameters and the air surface temperature variation are correlated. The further investigation conducted using the Kruskall-Wallis test has identified that only five of the urban parameters showed significant effects toward the air surface temperature variation, which are built-up areas, green covers, terrain elevation, building volume and surface roughness while the land use type was excluded. The findings of this study are very crucial as a pioneer research to integrate the urban climatic information in the urban planning decision making in tropical cities like Kuala Lumpur.

Key Words: *urban climate, urban parameters, air surface temperature, tropical climate, Kuala Lumpur*.

Introduction

Tropical climate is described as hot and humid with little variations throughout the year. Southern Asia, Southeast Asia, Central America, Central Africa and the Caribbeans are the regions which experience the tropical climate condition due to their geographical locations. These regions are situated on the Equator, which is nearer to the sun, and they obtain direct sun exposure throughout the year (Amos 2017). Thus, more heat is accumulated within these regions as compared to other parts of the world. Other than that, these regions are significantly affected by the Madden-Julian Oscillation (MJO) and the El Niño-Southern Oscillation (ENSO) which are associated with the northeast and southwest wind blows (Ward et al. 2014). These phenomena fluctuate the annual weather of these tropical regions with intense heat, heavy rainfalls and tropical cyclones (Hwang et al. 2017).

Malaysia is situated in one of those tropical regions. As located near to the Equator, Malaysia experiences typical tropical climate behaviour which is also largely influenced by the Asian-Australian monsoon system (Tangang et al. 2012). In this region, the wind patterns create two tropical monsoons, namely the northeast and the southwest monsoons. The monsoons are caused by the changes in the atmospheric circulation and precipitations which occurred due to the unbalanced heating of land and sea. Both of monsoons bring heavy rainfall which increases the cumulative precipitation and humidity to the country (Wong et al. 2016). The northeast monsoon starts from October to March which brings heavy rainfall to the eastern part of Malaysia whereas southwest monsoon strikes in April to September and it brings more precipitation to the west coast regions. April and October are the transitional periods of both monsoons which also contribute to the fluctuate patterns of the annual climate of Malaysia (Tangang et al. 2012).

Previous studies have recorded that the rapid urbanization is responsible with the emergence of UHI (Elsayed 2012, Arifwidodo and Tanaka 2015, Alobaydi et al. 2016). As a developing country, Malaysia has been developed particularly in the west coast of Malay Peninsula. The emergence of important business areas, such as Sungai Besi, Damansara, Cheras, Wangsa Maju and others in this region, resulted in the huge conurbation of the Kuala Lumpur, the capital city of Malaysia. Previous climate-related studies on the Kuala Lumpur city reported that the urbanization process within and around the city leads to the formation of the urban heat island (UHI) phenomenon (Ibrahim and Samah 2011, Buyadi et al. 2013, Salleh et al. 2013).

Previous studies also documented the emergence of the UHI and its increasing rate of intensity within Kuala Lumpur was described as very distressing (Elsayed 2012, Tangang et al. 2012, Ooi et al. 2017). Elsayed (2012) has found that the UHI intensity in the Kuala Lumpur city is ranging from 4˚C to 6˚C under a clear view sky, since the first study conducted by Sani in 1972. A later study in the city recorded that the magnitude of the UHI intensity has increased up to 8.4˚C from 1997 to 2013 (Yusuf et al. 2014). Looking at how this situation has worsened, a recent study by Ramakreshnan et al. (2018) urges more studies regarding the UHI intensity with more comprehensive spatial analysis to be conducted in order to analyse the current state of the UHI issue in Malaysia, especially the Kuala Lumpur city. Additionally, mitigation measures on UHI issues should be well scrutinized as Malaysia is expected to have a blooming population and urbanization rate in the future (Yuen and Kong 2009).

UHI degrades the quality of the urban climate within the city. The alteration of the original climate behaviour is affecting the thermal comfort of city's dwellers in Kuala Lumpur (Shaharuddin et al. 2014). Most climate-related studies suggest that the urban climate behaviour should be well considered during development planning in order to reduce the alteration of the thermal environment within the city for comfortable living (Ibrahim et al. 2014, Acero et al. 2015). Therefore, introducing the urban climate information into the urban planning decision making is a must. In Malaysia, the urban climate aspect is not often considered during the urban planning decision making process. At the beginning of its resurrection from the economic downturn, urban developments are the top priorities leaving the environmental problem less important (Elsayed 2012). Early urban developments in the country gave very little consideration to the environmental aspect, especially the urban climate (Ibrahim et al. 2014). Subsequently, the current practice leads to many consequences of environmental problems.

Even though the urban climatic information is seldom considered in urban planning, this does not mean that the UHI issues are not critical, but rather difficult to assess and implement in real practice due to the lack of tools and expertise on climate-related knowledge among the urban planners (Giridharan 2016). The difficulty of presenting the sophisticated climatology and meteorology information in a way that suits the urban planners and policy makers complicate the integration of climatic information into the urban planning decision making (Grimmond et al. 2010). Recent discoveries have nurtured the importance of climatic knowledge for urban development strategies. Along with the nature of the climate, the urban planners should consider the response of the urban climate towards the urban physical characteristics.

Elsayed (2012) highlighted six main aspects that can alter the urban climate condition, namely the urban fabric and materials, the urban structure, the artificial heat production, evapotranspiration, pollution, and human activities. Among these six aspects, urban structures, which encompass the urban physical and geometry, such as building density/volumes, topography and land uses, are often documented as a significant contributor to the urban climate variation especially the thermal environment (Jamei et al. 2015, Kattel and Yao 2018, Isa et al. 2018a). Hence, this study is conducted with the aim to analyse the effects of six urban parameters (which represent the urban physical characteristics) on the air surface temperature of the Kuala Lumpur city.

Methodology

Study Area

The investigation was carried out in the Kuala Lumpur City. Located on the west-coast of the Peninsular of Malaysia, the city is surrounded by the state of Selangor (Fig. 1). The city is the heart of Greater Kuala Lumpur, where many economic activities and international conferences are held, making the city to be highly populated with citizens migrating to live in the city. The area covers about 243 km^2, with an extent of approximately 24 km from the north to the south, and with 17 km from west to east.

The Kuala Lumpur City owns a typical tropical climate, which is hot and humid throughout the year. Since the city is situated in Southeast Asia, the country faces two types of monsoon – the Northeast monsoon and the Southwest monsoon. The climate of the city is also influenced by the El Niño-Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and the Madden-Julian Oscillation, which leads to different climate experiences at regional scales.

This city was selected as the case study due to its heterogenous spatial variability. The different urban physical characteristics across the city allow deep examinations on the effects of the urban physical characteristics towards the urban climate condition. The city is made up of unplanned and well-planned urban areas and it has been developed with a various urban geometry.

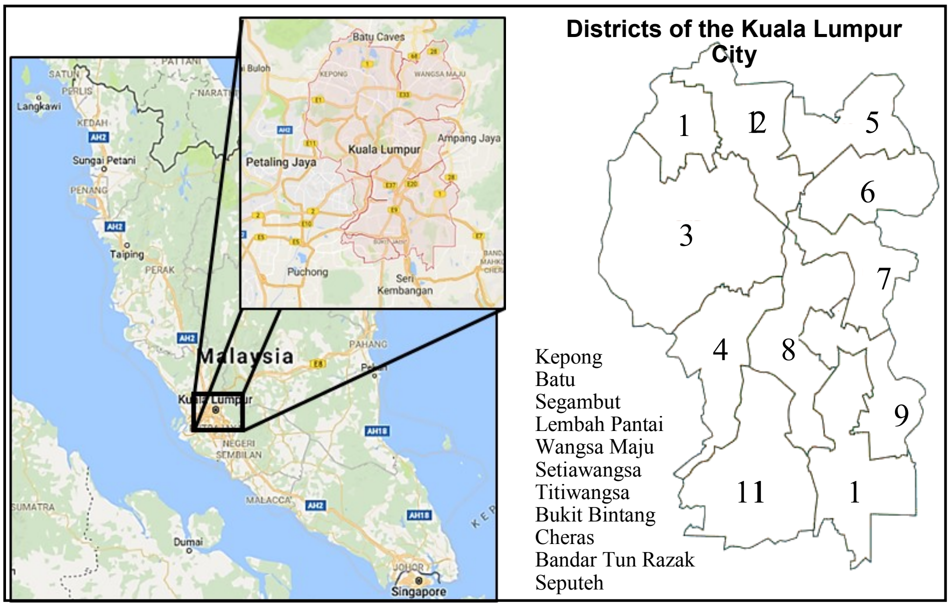

Fig. 1 – **Study area**

Kuala Lumpur is surrounded by four main towns which are: Batu Caves in the north, Seri Kembangan in the south, Ampang Jaya in the east, and Petaling Jaya in the west. The city is divided into eleven districts, which serve as administrative subdivisions under the Kuala Lumpur City Council authority.

Data and Materials

Five different types of datasets were used: Landsat OLI satellite images, LiDAR-based DEM, GIS-based datasets, WRF-ARW lateral boundary data and MMD ground observation data. Table 1 shows the list of used datasets and their related information.

Table 1

Datasets utilized during the research process

No	Type	Data	Date/Year	Source
1	Satellite image	Landsat 8 OLI image	24th March 2014	USGS
2	LiDAR-based DEM	Digital Terrain Model	2014	DBKL
		Digital Surface Model	2014	DBKL
3	GIS data layer	Building footprint	2014	DBKL
		Land use type	2014	JPBD
4	WRF-ARW input	Lateral boundary condition	24th March 2014	NCAR/NCEP
5	Ground Observation	Air surface temperature and wind speed	24th March 2014	MMD

The Landsat 8 OLI satellite image of 24th March 2014 was used in this study. The image was chosen due to its minimum cloud cover over the study area. The image of 24th March 2014 is chosen to coincide to the date of the LiDAR and GIS-based dataset and to form the basis to develop the urban climatic model.

The Landsat 8 OLI image was chosen due to the availability of bands used to extract two urban parameter layers, namely the built-up areas and the green cover. In this study, 8 bands (i.e. Band 3, 4, 5, 6, 7, 10 and 11) were used to extract these two urban parameters. These bands include the thermal bands and the bands which are ranging from red to the middle infrared spectrum. The image was also chosen due to its spatial resolution which is suitable for urban parameters mapping. Fig. 2 shows the satellite image utilized in the study. Table 2 shows the specifications of the used image.

Table 2

Landsat 8 OLI specifications

Name	Landsat 8 OLI
Data Format	TIFF
Spectral Resolution	11 bands
Spatial Resolution	Visible – NIR – SWIR = 30m
	Panchromatic = 15m
	Thermal IR = 100m
Temporal Resolution	16 days revisit
Swath	185 km wide

Fig. 2 – **The Landsat 8 OLI satellite image of 24th March 2014**

The LiDAR-based DEM of 2014 provided by the Kuala Lumpur City Council (DBKL), with a pixel resolution of 0.5 m, was also utilized. The dataset covers the entire area of Kuala Lumpur City. The dataset was chosen due to its high resolution, as well as it covers the entire study area. Using the LiDAR-based DEM, two urban parameters which are the terrain elevation and the surface roughness were derived.

The building footprint and the land use type data layer of 2014 are the two GIS-based vector datasets used in this study. The building footprint data layer was obtained from the Kuala Lumpur City Council (DBKL), while the land use layer was obtained from the Department of Town and Regional Planning of Malaysia (JPBD). The building footprint data layer was used to derive the building volume layer whereas the land use type data layer was used to classify the city into its land uses.

Both data layers are stored in a shapefile format. The building footprint layer consists of 231689 polygons presenting the footprints of each building within the Kuala Lumpur City. This layer is also attributed with the building height information which is used to estimate the building volume. The land use data layer consists of 185296 polygons, demarcating the city into their land uses and purposes. These polygons are classified into 18 different classes of land use types.

The Lateral boundary condition (LBC), or the global climate observation data, represents the boundary condition of the Earth surfaces. These data are required for the dynamic downscaling from mesoscale into regional scales. In nested domains, the LBC is provided by the parent domains for its nest/s. Although several previous studies have disputed the errors resulted from the LBCs, studies by Denis et al. (2002) and Amengual et al. (2007) have recommended several measures to minimize these errors. The more recent study of Davies (2014) has shown that the errors resulted from the LBCs can be controlled and they only contribute to small errors.

The present study utilized the NCEP GDAS/FNL 0.25 Degree Global Tropospheric Analyses and Forecast Grids lateral boundary condition datasets to simulate the climate variables using the WRF-ARW simulation. This dataset provides 36 climate variables including the variables needed for this study, namely the air surface temperature. This LBC is chosen since it is prepared for the troposphere layer and it represents a very similar situation to the study carried out by the author. This dataset was also chosen due to its higher spatial and temporal resolution as compared to other LBCs such as the ERA-Interim Project and JRA-25 datasets. The original lateral boundary condition dataset with a spatial resolution of 0.25˚ prepared for every three hours was used in this study.

Ground observation datasets (i.e. air surface temperature) were obtained from the Malaysian Meteorological Department (MMD). These datasets were used to validate the simulated air surface temperature. The diurnal pattern of the climate variables was compared against the ground observations. The data was supplied in text format and they contained hourly ground observations of air surface temperature at three different stations. Table 3 shows the MMD stations used for the observation date. The location of the stations on the ground is shown in Fig. 3.

Table 3

Ground stations involved during both dates

Date	**24 March 2014**
Station 1	Pusat Pertanian Serdang
Station 2	University of Malaya
Station 3	Subang

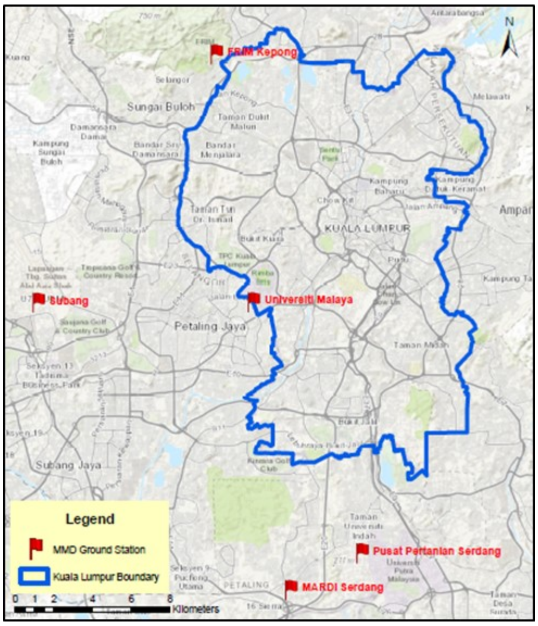

Fig. 3 – **Locations of MMD ground stations**

For the purpose of this study, six urban parameters were selected that covered the urban physical characteristics of Kuala Lumpur city, namely the green cover, the built-up areas, the terrain heights, the surface roughness, the building volume and land uses. These urban parameters were tested against the air surface temperature distribution in order to examine the effects of urban heating and urban cooling within the study areas. The evolution of technology through remote sensing, GIS and numerical modelling allows the present study to enhance the data acquisition that is able to cover a larger study area (Ramakreshnan et al. 2018). Therefore, the samples of used data were also improved using this type of technology. Green cover and built-up area were extracted from the remotely-sensed satellite image; terrain heights and surface roughness were derived from the Light Detection and Ranging (LiDAR) dataset; the building volume was estimated from the GIS data layer; the land uses were digitized using a GIS platform; and the air surface temperature was simulated using the Weather Research and Forecasting (WRF) simulation model.

The further analysis employed statistical approaches to identify the relationships between the urban parameters and the air surface temperature distribution of Kuala Lumpur city. In the present study, non-parametric statistical approaches were used due to the nature of the data samples produced that were not normally distributed. Though, the conducted tests were adequate to enlighten the effects of each urban parameter on the urban climate variation. The employed non-parametric statistical tests were the Spearman Rho's test, the Kruskal-Wallis H test and the Mann-Whitney U test. The Spearman's Rho's test was used to investigate the correlation between the urban parameters and the air surface temperature distribution. The Kruskall-Wallis H test was used to further the investigation in order to determine the urban parameters which have significant effects on the air surface temperature distribution. The Man-Whitney U test was applied to identify the relationship between the land use type and the air temperature since the urban parameter is a nominal data type.

In this study, two urban parameters were extracted from the Landsat satellite image, namely green cover and built-up area. The radiometric calibration prior to data extraction from the Landsat satellite used image is essential. This calibration was performed to reduce the radiometric errors contained in the image. The carried out calibration includes the conversion of the digital number (DN) value into a surface reflectance value and sun angle correction. Two algorithms were used to perform the radiometric calibration procedures. Equation 1 shows the algorithm used to convert the DN value into surface reflectance value. The band-specific multiplicative rescaling factor quantized, and the calibrated standard product pixel value and band-specific additive rescaling factor were obtained from the metadata provided.

$$\rho\lambda' = M_\rho \times Q_{CAL} + A_L \quad (1)$$

where ρλ' - surface reflectance without sun angle correction

M_ρ - band-specific multiplicative rescaling factor

Q_{CAL} - quantized and calibrated standard product pixel value

A_ρ - band-specific additive rescaling factor

Equation 2 shows the algorithm used to perform the sun angle correction on the converted surface reflectance value. The local sun elevation angle and the local solar zenith angle were obtained from the provided metadata.

$$\rho\lambda = \frac{\rho\lambda'}{\cos(\Theta_{SZ})} = \frac{\rho\lambda'}{\sin(\Theta_{SE})} \quad (2)$$

where Θ_{SZ} - Local sun elevation angle

Θ_{SE} - Local solar zenith angle

The green cover data layer was extracted using the Normalized Different Vegetation Index (NDVI). This index is commonly used to extract the green vegetation from satellite images using a specific algorithm. This index is also suitable to be used within regions which have a green cover of over 30%. Since the study area is rich of green vegetation (over 30%), this index was suitable to be employed.

The Near Infrared (NIR)/Band 5 and Red/Band 4 bands of Landsat 8 OLI images were used in order to generate the green cover data layers. These bands were used due to their properties that reflect and absorb specific spectrums within the sun radiation. Equation 3 shows the algorithm used to extract the NDVI values from the satellite images.

$$NDVI = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4} \qquad (3)$$

Due to the arguments on the performance of the original NDBI, this study has employed a new algorithm to enhance the built-up data layer. The new algorithm involved three existing algorithms in order to eliminate the confusion in classifying the built-up areas. The involved algorithms are: the Normalized Difference Built-up Index (NDBI), the Normalized Difference Vegetation Index (NDVI), and the Modified Normalized Difference Water Index (MNDWI). As shown in Equation 4, the new algorithm was formed using the combination of the three existing algorithms.

$$BuiltUp\ Area = NDBI - NDVI - MNDWI \qquad (4)$$

As suggested by Bhatti and Tripathi (2014), this study has performed the Principal Component Analysis (PCA) between Band 6 (Short-wave Infrared/SWIR1) and 7 (Short-wave Infrared/ SWIR2), as well as Band 10 (Thermal Infrared/TIRS1) and 11 (Thermal Infrared/TIRS2) in order to assign suitable pixel values. Equation 5 shows the algorithm used to extract the NDBI data layer. This algorithm employed 5 bands, namely Band 5, 6, 7, 10 and 11 in order to extract the built-up area. The NDVI layer was extracted using the same algorithm discussed in the previous subsection (referring to Equation 3). Shown in Equation 6 is the algorithm used to extract the MNDWI value. This algorithm used two different bands which are Band 3 and Band 7.

$$NDBI = \frac{(PCA\ Band\ 6{,}7 + PCA\ Band\ 10{,}11) - Band\ 5}{(PCA\ Band\ 6{,}7 + PCA\ Band\ 10{,}11) + Band\ 5} \qquad (5)$$

$$MNDWI = \frac{Band\ 3 - Band\ 7}{Band\ 3 + Band\ 7} \qquad (6)$$

In this study, two types of urban parameter layers, namely terrain elevation and surface roughness, were derived from the LiDAR-based DEM data.

The Digital Terrrain Model (DTM) layer derived from the LiDAR dataset was used to generate the terrain elevation layer. Since the pixel size of the climate variables is 500 m x 500 m, the grid size for the terrain elevation layer should be resampled to also 500 m x 500 m. The mean terrain elevation was assigned as the new pixel value. The nearest neighbour resampling technique was used. This resampling technique was chosen to maintain the original pixel values after the calculation was made. The technique is also chosen to avoid excessive pixel smoothing which will alter the original DTM values. Equation 7 shows the formula used to calculate the mean terrain elevation.

$$Mean\ Terrain\ Elevation = \frac{\sum pixel\ values\ within\ 500\ m\ \times 500\ m}{\sum number\ of\ pixels\ within\ 500\ m\ \times\ 500\ m} \quad (7)$$

The Digital Surface Model (DSM) obtained from the LiDAR-based dataset was used to produce the surface roughness. Due to the limitation to produce the Frontal Areal Index (FAI), this study has employed the technique suggested by Grohmann et al. (2011) in order to replace the FAI layer. Grohmann et al. (2011) has suggested that the surface roughness can be represented by calculating the standard deviation of the slope. This method was employed in this study to derive the surface roughness layer. To derive the standard deviation of the slope or the surface roughness, three different equations were used. DSM values were first converted into slope (in radian) values using Equation 8. Equation 9 was used to convert the slope values into a degree unit.

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$$slope\ (in\ radian) = \tan^{-1}\sqrt{\left(\frac{dz}{dx}\right)^2 + \left(\frac{dz}{dy}\right)^2} \quad (8)$$

$$slope\ (in\ degree) = \tan^{-1}\sqrt{\left(\frac{dz}{dx}\right)^2 + \left(\frac{dz}{dy}\right)^2} \times 180/\pi \quad (9)$$

where $\frac{dz}{dx}$ – rate of change of the surface in horizontal

$\frac{dz}{dy}$ – rate of change of the surface in vertical

Then, the standard deviation of the slope was derived using Equation 10. The produced layer was later resampled into 500 m x 500 m pixel resolution.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \quad (10)$$

where σ – standard deviation
N – number of samples
x – sample
μ – mean of samples

In this study, the building volume and the land use parameter layers were obtained and derived from the GIS-based vector datasets.

The estimation of the building volume within the city was made using Equation 11. The building height information in building footprint data layer was used as the third dimension to estimate the building volume. The building volume is converted into percentage using the highest building (over 500 m x 500 m area) as the highest volume. The building volume layer was converted into a raster data layer. The layer was then resampled into a 500 m x 500 m pixel resolution.

$$Building\ Volume(\%) = \frac{\sum (height \times footprint)}{\sum (highest\ height \times 500\ m \times 500\ m)} \times 100 \quad (11)$$

Land use type data layer was employed to represent the land use activities within the study area. In this study, the land use type data layer was obtained from the Department of Town and Regional Planning (JPBD) of Malaysia. The land use is classified into 18 classes. Table 4 shows the land use classes used by JPBD for the study area. Since this study was conducted using the 500 m x 500 m resolution, this data layer was also resampled to match the other urban climate parameter data layers.

Table 4

Land use types of the study area

No	Land use type	No	Land use type
1	Residential	**11**	Religion Purposes
2	Non-Developed Area	**12**	River and Drainage Reserved
3	Business Area	**13**	Parking Space
4	Utility	**14**	Cemetery
5	Institution	**15**	Temporary Business Area
6	Electric Reserved	**16**	Education
7	Open Space and Recreation	**17**	Forest Reserved
8	Industry	**18**	Roads
9	Rail Reserved		
10	Terminal Station		

The present study employed the WRF-ARW simulation to reproduce the air surface temperature for the specific date chosen. The simulation was spun up for two days (48 hours) to reconstruct the original weather on the selected dates (24^{th} March 2017). The date is selected to coincide with the Landsat satellite image used in this study. The lateral boundary condition was fed every six hours by utilizing the NCEP FNL Operational Global Tropospheric Analysis data. The data was supplied by the Global Data Assimilation System (GDAS) with a resolution of 0.25˚ × 0.25˚.

The chosen physics schemes were a set of well-tried options conducted by Isa et al. (2018b). This option has successfully simulated the diurnal air surface temperature and the wind components of Kuala Lumpur City with an accuracy of over 90% in agreement with the ground observations. Using the same physics schemes as the previous study by Isa et al. (2018b), this study has simulated the diurnal air surface temperature and the wind components of the study area. Table 5 shows the physics schemes employed during the study.

Table 5

Employed physics schemes

Physics Option	Scheme
Microphysics	WRF Single-Moment 6-class scheme
Longwave Radiation	RRTM scheme
Shortwave Radiation	Dudhia scheme
Surface Layer	MM5 similarity
Land Surface	Noah Land Surface Model
Planetary Boundary Layer	Yonsei University scheme
Cumulus Parameterization	Kain-Fritsch scheme

In the study, the diurnal air surface temperature and wind components were simulated using four nested domains with the grid size of 37.5 km (40 × 40), 12.5 km (88 × 88), 2.5 km (201 × 201) and 0.5 km (151 × 151). The dimensions in the parentheses are the grid dimensions designed in the easting and northing direction. Based on Fig. 4, the centre of all four domains were focused on the location of Kuala Lumpur City to provide a relaxation zone to the domains, intended to reduce the errors by employing the LBC (NCAR 2016). The largest domain (D01) covered a part of Southeast Asia region and the smallest domain (D04) was designed to focus on the Klang Valley region where the Kuala Lumpur City is located.

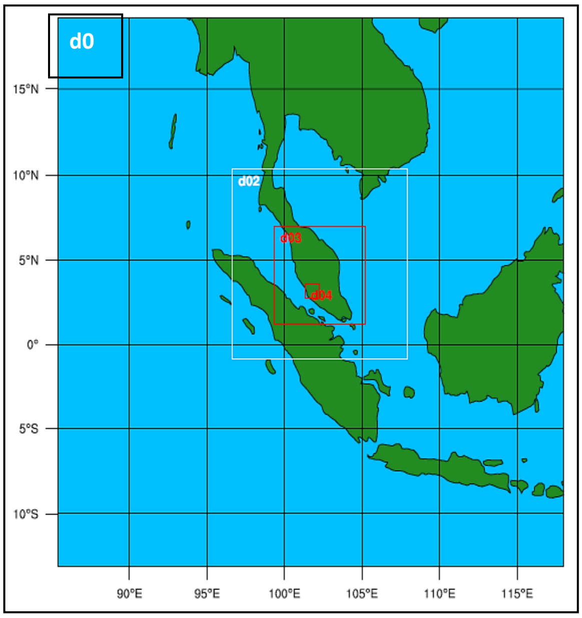


Fig. 4 – **Designed simulation domains**

The four domains designed for the simulation are shown in Fig. 4. The parent domain covers several countries such as Malaysia, Thailand, Myanmar, Indonesia, Singapore and Brunei. The second and third domains were focused on the Peninsular of Malaysia with a different area coverage, as well as pixel sizes. The smallest domain was designed to cover the entire Kuala Lumpur City with the pixel size of 500 m x 500 m in order to coincide with other prepared datasets.

The air surface temperature produced by WRF-ARW was stored in NetCDF data format. This format was converted into a GIS-based raster data layer to ease the data processing and analysis. Using the "Create NetCDF raster layer" tool developed in the ArcGIS software, hourly air surface temperature data layers were extracted. These layers were stored as a single raster layer for each hour.

The simulated hourly air surface temperature layers were then combined to produce the mean air surface temperature layer. The "Raster Calculator" tool was used to calculate the average of the air surface temperature layers. Since the simulated air surface temperature layers covered a large area, the masking technique was used to select the air surface temperature within the study area only.

Results

Air Surface Temperature Distribution

The distribution of the daily mean air surface temperature of Kuala Lumpur city simulated using the WRF-ARW simulation is shown in Fig. 5. Based on the result, it was found that the highest air surface temperature was of 30.3˚C whereas the lowest air surface temperature was of 25.8 ˚C. The highest air surface temperature was found in the south-western part of the city, near Sri Petaling, whereas the lowest air surface temperature was found in the north-eastern part, around Bukit Tabur.

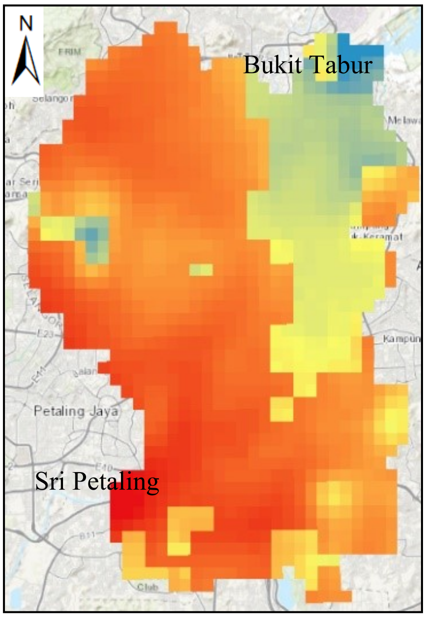
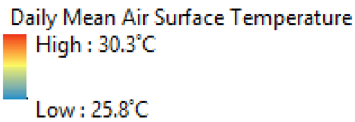


Fig. 5 – **The distribution of air surface temperature in Kuala Lumpur city**



Hourly air surface temperature layers were produced using the WRF-ARW simulation model. The layers were validated against the ground observations from the Malaysia Meteorological Department (MMD) prior to further analysis. A very good agreement between the simulated air surface temperature and the observed air surface temperature were determined with over 90% agreements for each station. Based on this study, the RMSE of the model in 2014 were 1.0°C, 1.1°C and 1.8°C for the Universiti Malaya, Subang and Pusat Pertanian Serdang stations respectively. Fig. 6 shows the agreements on linear relationships and the diurnal patterns of the air surface temperature produced by WRF-ARW and captured from the ground observations in three different stations.

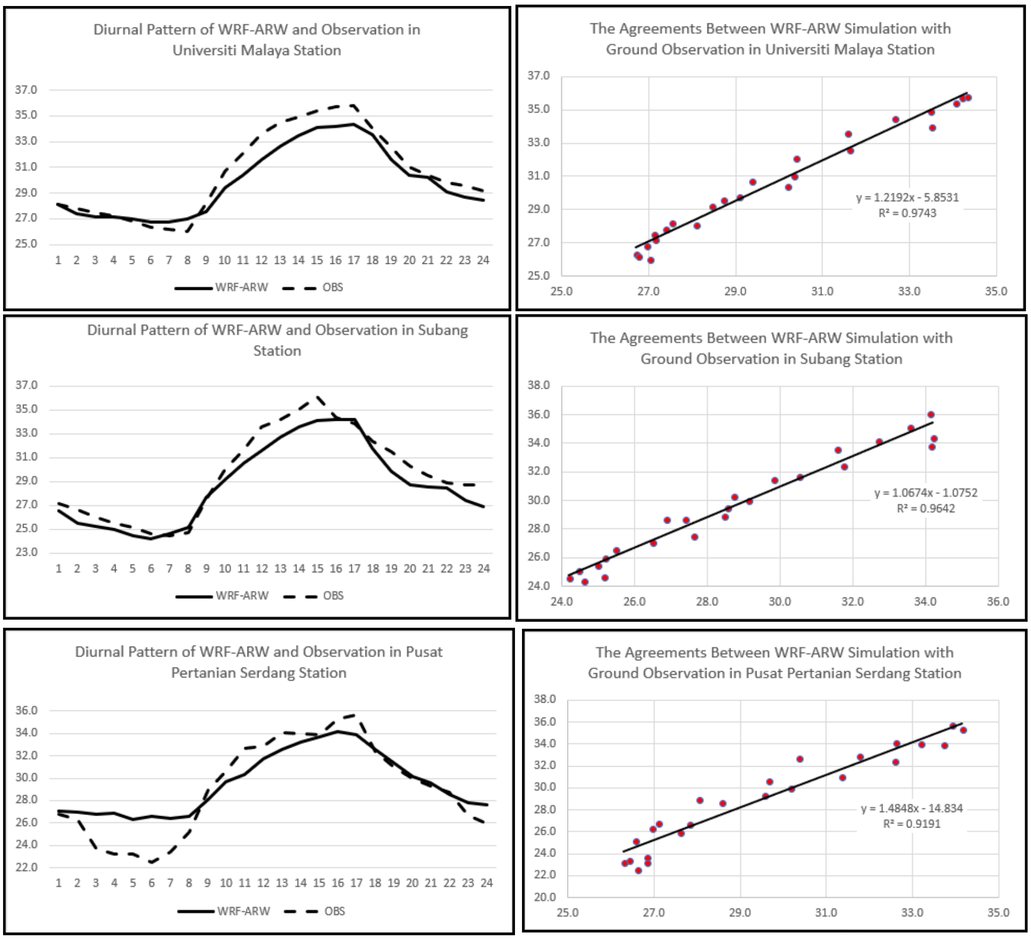


Fig. 6 **– The agreements and diurnal patterns of WRF-ARW simulation and ground observations in three different stations**

Urban Parameter Distribution

Fig. 7 shows the spatial distribution of the urban parameters extracted and derived using remotely-sensed and GIS-based datasets. Fig. 7 (a) shows the distribution of the green cover existed within the city. From the result, it was identified that the distribution of the dense green cover was very small as compared to the non-green cover and mixed areas with the percentage of approximately 12%. Most of the city was covered with the mixed built-up and green cover with approximately 83%. The distribution of the built-up areas is shown in Fig. 7 (b). Based on the result, the Kuala Lumpur city was dominated, with more than half, by built-up areas. However, the urban areas are fragmented by the non-built-up areas which consist of the green covers and water bodies. Fig. 7 (c) shows the terrain profile of the Kuala Lumpur city. The highest point was found in Bukit Tabur, whereas the lowest point was found in Sri Petaling. The city was divided by Klang River which flows from the mountainous region towards the lower region in Sri Petaling and Puchong which created a valley-like region across the city. Surface roughness is portrayed in Fig. 7 (d). From the figure, it can be said that most of the

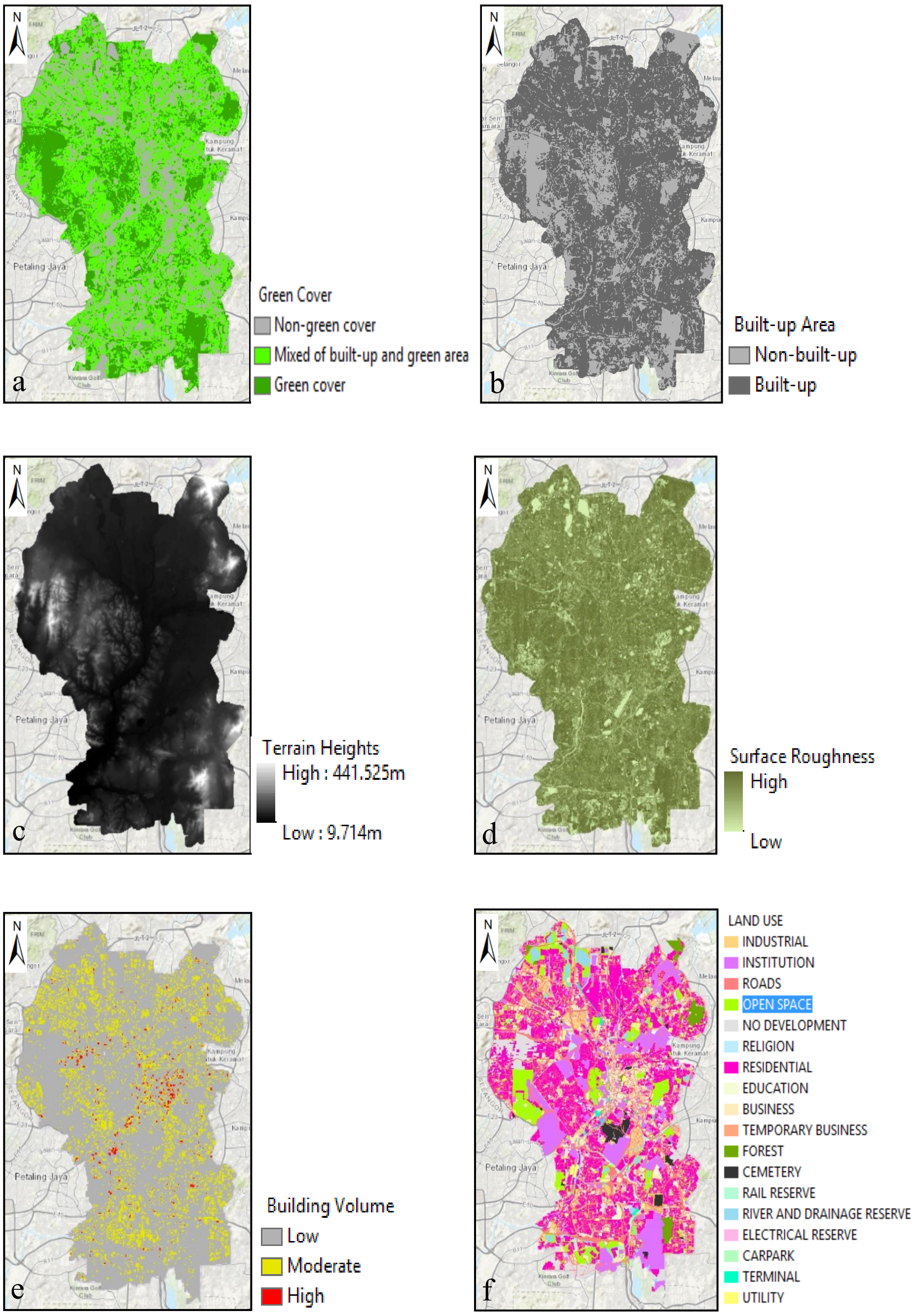


Fig. 7 **– The urban parameter layers produced are:**
(a) the green cover, (b) the built-up areas, (c) the terrain heights,
(d) the surface roughness, and (e) the building volume

Kuala Lumpur city surface was rough with only some places were indicated as flat, such as the lakes in Jinjang and the Subang Airport. However, there are no extreme changes of the surface roughness within the entire city. The building volume distribution is shown in Fig. 7 (e). The present study found that the Kuala Lumpur city is not packed with high volume buildings. This may be due to the sparse distribution of the buildings within the city leading to the reduction of building volume on certain regions. Land uses are shown in Fig. 7 (f). There are sixteen different land use classes found in the entire study area. This may be due to the previous development plans which concentrated to develop the city by separating different uses in different locations.

Urban Parameters' Correlation with the Thermal Environment

Based on the Spearman Rho's test, it was found that all six urban parameters tested correlated the air surface temperature variation of the Kuala Lumpur city. From the results shown in Table 6, it was found that the strongest correlation was indicated from the built-up areas with the R^2 of 0.701, whereas the weakest correlation was identified from the surface roughness with the R^2 of 0.178. The results also indicated that there were three urban parameters that contribute to the urban heating depicted by the positive (+) correlation whereas two of them contribute to the urban cooling indicated by the negative (-) correlation. Based on the Man Whitney test, the result revealed that the land use type is correlated to the air surface temperature distribution of Kuala Lumpur city. This is indicated by the significant difference values ($p < 0.05$) calculated between each land use type.

Table 6

The correlation between urban parameters and thermal variation

Urban Parameter	Tested value	Type of Correlation	Concluding Remarks
Green cover	$R^2 = 0.620$	Negative	High correlation – contributes to urban cooling
Built-up area	$R^2 = 0.701$	Positive	High correlation – contributes to urban heating
Terrain heights	$R^2 = 0.227$	Negative	Moderate correlation – contributes to urban cooling
Surface roughness	$R^2 = 0.178$	Negative	Low correlation – contributes to urban heating
Building volume	$R^2 = 0.358$	Positive	Moderate correlation – contributes to urban heating
Land Use	<0.05	-	Correlates with the air surface temperature

Significant Urban Parameters Affecting the Thermal Environment

In the previous section, the six urban parameters tested were correlated and associated with the climate variables used to represent the urban climate condition. Therefore, a further test to examine their significance towards the variation of the urban climate condition were conducted. Based on the conducted test, it was found that five from the six urban parameters were significantly affecting the air surface temperature variation. The urban parameters are: built-up area, green cover, terrain heights, building volume and surface roughness, leaving the land use type as the only urban parameter which is not significantly affecting the air surface temperature distribution within the city.

The decision made is based on the significant difference found in the urban parameters distribution as denoted by the p-value of each urban parameter. Since the test cutoff value is 0.05 to show there is a significant difference within the sample, the p-value of less than 0.05 indicates that the urban parameters tested were significant in describing the urban climate condition of the study area. Table 7 shows the p value obtained from the test for each urban parameter analysed in this study. The most significant urban parameter was the built-up area, whereas the least significant urban parameter was the building volume with the p-value < 0.05. Therefore, it can be concluded that the thermal loads aspect of Kuala Lumpur city was affected by the five significant urban parameters, either the effect is positive or negative.

Table 7

The p-value of each urban parameter tested using the Kruskal-Wallis H test*

Dependent	Variable	p-value	Actual p-value	Level of significance
Air Surface Temperature	Built-up areas	0.000	2.955 x 10-37	Significant
	Green cover	0.000	3.367 x 10-53	Significant
	Terrain elevation	0.000	4.853 x 10-13	Significant
	Building volume	0.000	3.000 x 10-6	Significant
	Land Use Type	0.185	4.340 x 10-23	Not Significant

*The null hypothesis was rejected, which indicated there was a significant difference within the urban parameters

Discussion

The correlation test revealed that the green cover within the Kuala Lumpur city contribute to the decrease in the air surface temperature. With the R^2 of -0.620, the correlation between the green cover and the air surface temperature was quite strong. Similarly, the previous studies in tropical climate cities also found that the existence of green cover is able to regulate and reduce the rising of the air surface temperature within urbanized areas (Buyadi et al. 2015, Isa et al. 2018b). This is because the green cover indicates the existence of chlorophyll which increases the rate of transpiration within plants which release oxygen as their waste product. As a result, the oxygen content within the environment increased which promotes new fresh air that maintains the air surface temperature at a low level (Isa et al. 2018b). Hence, the manipulation of the amounts of green cover to maintain the urban climate condition is a priority as been suggested by previous studies (Yusof 2013, Kanniah 2017).

Previously, many studies have documented that rapid urbanization leads to the fast conversion of green covers such as natural forests and croplands, which is the prime cause to the rise in the surrounding temperature that leads to the formation of UHI (Li 2018, Zhou et al. 2019). Due to urbanization, the green cover and croplands are replaced and fragmented with built-up areas (Salvati 2014) that increase the heat capacity storage which release more heat into the air, making the surrounding temperature to be hotter. Furthermore, the properties of the urban materials and the sky view factor obstructions lead to a slow rate of heat release within the city (Mohajerani et al. 2017). The present study also discovered similar phenomena occurring in the Kuala Lumpur city as documented by previous studies (Kanniah 2017, Ooi et al. 2017) with the R^2 of 0.701. The results of the present study are also in line with the results of the previous study which stated that the region with high built-up areas, such as Kg Baru, experienced high temperatures as compared to the area with less built-up areas (Isa et al. 2017). The urban parameter's effect was also tested to be significant as indicated by the p-value of less than 0.05.

The present study discovered that the terrain heights affect the air surface temperature variation within the Kuala Lumpur city with a moderate correlation (R^2 = 0.227) which coincided with the previous studies' findings. Since the correlation is negative, this showed that the higher the region, the lower the air surface temperature. The terrain height was also found to significantly affect the thermal distribution of the Kuala Lumpur city since the p-value of Kruskal -Wallis test is smaller than 0.05. In general, the temperature in the troposphere is dropping by 1˚C with every 150 m increase in altitude, making the high lands to be colder than the lower lands (Amos 2017). In higher regions, the human activities which release the anthropogenic heat occur less, making this region to be cooler than the downhill (Doan and Kusaka 2015). Even though the mountainous regions tend to slow down the wind speed, the top hill regions experience high wind blows since there are no obstructions found. Furthermore, the distribution of rainfalls and precipitations is higher in higher regions which leads to the reduction of the air surface temperature (Kattel and Yao 2018).

Another tested urban parameter which significantly affects the variation of the air surface temperature was the building volume. The conducted correlation test showed that the building volume correlated with the variation of the air surface temperature with a moderate correlation (R^2 = 0.358). In the previous study by Ng et al. (2011), the building volume is blamed to have the most significant impact towards the air surface temperature within the tropical environment. However, this study revealed that the effect of the building volume on the air temperature variation within the city is less significant. This might be due to the less compact areas in the Kuala Lumpur city as compared to Hong Kong. High volume buildings in Kuala Lumpur city are usually fragmented with green covers (Isa et al. 2017), making the urban parameter to be less dominant than the others based on the p-value obtained from the Kruskal-Wallis H test. However, the building volume was still listed as one of the significant urban parameters that can explain the variations of the air surface temperature within the Kuala Lumpur city.

In the study, the surface roughness was tested to be correlated with the variation of the air surface temperature in the Kuala Lumpur city with the R^2 of 0.178. However, this correlation was quite weak. Even though previous studies suggested that the surface roughness should be considered to enhance the air ventilation and wind blows within the city (Ren et al. 2011, Ng et al. 2012), this study identified that the urban parameter was less significant, affecting the variation of the air surface temperature of the Kuala Lumpur city since the p-value closes to 0.05. The contrast in the result might be due to the less compact urban areas in the previous studies. As mentioned before, the Kuala Lumpur city does have tall buildings with high building volumes which increase the building density of an area, but still, the roughness of the city's surface is not comparable to the other high-density cities such as Hong Kong and Taiwan. Moreover, it was found that Kuala Lumpur was developed on a flat plain with no extreme changes of terrain. Other than that, the higher roughness values are also associated with green covers which obstruct the wind blows, but at the same time, they have positive effects towards the thermal variation.

The last parameter tested in this study is represented by the land uses. The land use is classified based on the Malaysian local urban planning classes. Even though this parameter was tested to correlate with the variation of the air surface temperature, the further test revealed that this parameter does not significantly affect the variation of the thermal environment within the city. The little contrast found in this study may be due to the different populations within the city as compared to the previous study areas studied by Raghavan et al. (2015) and Morini et al. (2016). The human activities might also be different between these cities, and it therefore leads to less energy consumptions as compared to other cities.

Conclusions

In the tropical city of Kuala Lumpur, the green cover, built-up areas, terrain heights and the building volume strongly influenced the air surface temperature variation. As expected, the built -up area and the building volume contribute to the urban heating phenomenon, whereas the green cover and the terrain heights contribute to the urban cooling phenomenon. From this study, even though all six urban parameters correlated with the air surface temperature variation within the Kuala Lumpur city, only five of them significantly had an effect on the thermal condition of the city. Hence, the present study suggests that the variation of the thermal environment of the Kuala Lumpur city can be best explained by five urban parameters which are: the green cover, the built-up areas, the terrain heights, the building volume and the surface roughness. The divergence effects of all studied urban parameters enlightened the complex interactions of the urban physical characteristics on the urban climate of Kuala Lumpur city.

The present study has provided important evidences concerning the effects of the urban physical characteristics on the thermal variation of a tropical city like Kuala Lumpur. This discovery is valuable for examining the implications of the urban physical characteristics for urban climate sustainability to enhance the quality of the urban natural environment. As such, the findings of this study can be integrated with other climate-related aspects, namely the urban fabric and materials, the urban structure, the artificial heat production, evapotranspiration, pollution, and human activities, in order to emphasize the urban climate system complexity in tropical cities for a comprehensive understanding. Hence, the efforts of integrating the urban climatic information during the urban planning decision making can be accomplished. Such efforts have long been practised by the developed countries, but, the recent studies on implementing the climate-related aspects in urban planning have shown that decision making is increasingly undertaken in the developing countries. There is a potential of translating the urban climate condition into a simpler “language” using maps to inform urban planners and policy makers of the urban climate behaviour so that such information can be seriously considered during any development planning, and this will be our future research focus.

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Aims and scopes

Analysis of the urban and regional condition needs to be interdisciplinary. In reality, urban researchers usually tend to belong to a discipline reflecting their training whether as sociologists, geographers, planners or any number of subjects concerned with the study of space and place. Our training very often endorses an appreciation of how other disciplines explore the city. For the journal the acknowledgement of the many disciplines that concerned with understanding cities and regions will be indicated by the different disciplinary back-grounds reflected in the papers published. Articles will be published by geographers, sociologists, planners, economists, political scientists, to mention just few of the disciplines involved in urban and regional study.

The Journal of Urban and Regional Analysis plans to be a key outlet publishing topical articles dealing with cities and regions. In later issues we plan to include sections devoted to notes and comments as well as a policy section outlining and discussing state and non-state initiatives aimed at improving cities and regions, together with the problems confronted by their implementation.

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