Level of application of advanced technologies for transformation into intelligent systems of enterprises in the regions

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Abstract. In the regions, the transformation of intelligent systems should not follow a single approach for all regions. Researchers need to take into account the market demand formed by small, medium-sized and large enterprises. The authors propose to use 5 types of advanced technologies to build an intelligent system in the enterprise. The researchers selected the percentage of enterprises applying these technologies in the region. The authors have calculated the levels of application of advanced technologies. It was calculated on the basis of the cluster method for 33 countries as of 2023 A minimum number of European countries (Belgium, Denmark and Finland) have a high level of application of advanced technologies for intelligent systems. A total of 33 European countries were in the third cluster (minimum level of application of advanced technologies for the intelligent system) among SMEs (from 0 to 9 persons employed) for each of the 5 types of technologies. A total of 33 European countries were in the second cluster (average level of application of advanced technologies for the intelligent system) among SMEs (from 10 to 249 persons employed) for each of the 5 types of technologies and among large enterprises (from 250 persons employed or more). This cluster analysis contributes to the growth of investor attraction in projects for the implementation of intelligent systems in enterprises. Regions are shifting towards developing domestic markets due to the decline in global trade. Therefore, regions will have to rethink strategies into advanced technologies to build intelligent systems in enterprises.

1 Introduction

At present, many countries are trying to move towards the use of advanced technologies to develop intelligent systems in enterprises [1, 2]. D. Jaspert et al. believe that for regions the presence of enterprises that use intelligent systems is a factor of economic growth [3]. R. Cohen noted the proliferation of enterprises applying intelligent systems in developing countries [4]. In another paper, it is revealed that EU companies invest in enterprises that apply intelligent systems mainly in their own regions [5]. Only a few studies have estimated the number of enterprises applying or planning to apply intelligent systems in countries [4,

6, 7]. K. Hyujung on the example of South Korea concluded that there is no difference in the economic effect of innovation implementation for the intelligent system at a large enterprise or SME [8]. In his opinion, and also according to S. Jang, SMEs can achieve higher efficiency in building intelligent systems than large firms [9]. S. Denicolai and K. Johanson argued that SMEs can innovate for intelligent systems, if they access the foreign market [10, 11]. N. Chonsawat, Hoa proposed a division of SMEs by innovation readiness levels for intelligent systems [12, 13]. N. Chonsawat, A. Widayani, A. Garzoni assessed the level of readiness of SMEs to build intelligent systems [12-15]. J. H. Kahle described an ecosystem for implementing intelligent systems in SMEs [16]. According to L. Gumbi, the implementation of intelligent systems is a priority for large enterprises. Low-income countries (no large enterprises, mainly SMEs) need to apply a different strategy for the implementation of intelligent systems [17]. F. Appio et al. analyzed innovation performance in the development of intelligent systems [18-22]. Thus, gaps currently exist in the research of enterprises applying or planning to apply intelligent systems in countries.

2 Materials and methods

The purpose of this paper is to investigate the level of application of advanced technologies for building intelligent systems in enterprises in the regions. The researchers had to consider the demand from SMEs and large enterprises. The hypothesis of the research is that the transformation of intelligent systems in the region cannot be carried out according to a single approach for all regions. It is necessary to take into account the market demand (SMEs and large enterprises).

The study consisted of 3 stages.

At the first stage of the study the authors selected an indicator of percentage of enterprises applying advanced technologies to build intelligent systems. this indicator was grouped by the researchers according to 2 criteria: by 3 sizes of enterprises (by the persons employed); by 5 types of advanced technologies necessary for building an intelligent system. The study was based on data from the European Commission [1, 2].

Based on the cluster method, at the 2nd stage of the study, the authors calculated the levels of advanced technology application (determined at the 1st stage) for 33 countries. Cluster analysis was performed using Microsoft Office Excel. The authors identified a cluster for each region. We considered three possible cluster options for the region. Researchers considered three possible cluster options. If a region had a minimal share of advanced technology applications, it was a Type 3 cluster. If a region had an average share of advanced technology applications, it was a type 2 cluster. If a region had the highest proportion of advanced technology applications, it was a Type 1 cluster. The authors needed to identify a cluster for each of the 5 types of advanced technologies.

At the 3rd stage of the research this indicator is grouped by 2 criteria: by 3 sizes of enterprises (by the number of employees); by 5 types of advanced technologies necessary for building an intelligent system. Then, by the arithmetic mean method, the authors determined the overall level of the cluster in the region (by the share of advanced technologies).

3 Results

At the 1st stage, the authors identified 5 types of advanced technologies necessary to build an intelligent system in the enterprise. Based on a review of the scientific literature, we conclude that there is a general notion of what technologies are needed for an intelligent system. Therefore, we propose to use the 5 types of technologies that are used in the

European Commission [1, 2]. According to the authors, the final of the intelligent system is a fully 100% built model of the enterprise, in which of 5 types of technologies function at all stages of the product life cycle (it include communications with the external and internal environment). These technologies include: additive technologies, robotics, artificial intelligence, big data, and the internet of things.

The researchers selected the percentage of enterprises applying these technologies in the region. It is an indicator determining the level of application of advanced technologies for building intelligent systems. All data were current as of 2023 for 33 regions in Europe.

Further this indicator was grouped by the authors according to 2 criteria: by 3 sizes of enterprises (by the persons employed); by 5 types of advanced technologies necessary for building an intelligent system. Based on the cluster method, at the 2nd stage of the study, the authors calculated the levels of advanced technology application (determined at the 1st stage) for 33 countries. Cluster analysis was performed using Microsoft Office Excel. The authors identified a cluster for each region. We considered three possible cluster options for the region. The smaller the cluster number it means higher level of advanced technology application for intelligent system and vice versa.

At the 3rd stage of the research this indicator is grouped by 2 criteria: by 3 sizes of enterprises (by the number of employees); by 5 types of advanced technologies necessary for building an intelligent system.

Then, by the arithmetic mean method, the authors determined the overall level of the cluster in the region (by the share of advanced technologies).

The results of the cluster analysis (Table 1) show that only Spain and Portugal had the highest share of technology application for building intelligent systems among SMEs (S - from 0 to 9 persons employed) of 33 countries in 2023. We assigned Spain, Portugal to the first cluster. The second cluster wasn't there. The remaining 31 countries were included in the third cluster with a minimum share of enterprises applying technologies for building intelligent systems.

In 33 countries in 2023 by advanced technology groups, the leading SMEs (S - from 0 to 9 persons employed) were: additive technology – Germany, Spain, Portugal; internet of things – Germany; robotics – Spain, Portugal; big data – Spain, Portugal; artificial intelligence – Spain, Portugal.

However, the totals of 33 European countries among SMEs (S- from 0 to 9 persons employed) were in the third cluster for each of the 5 types of technologies (Table 1). This means a minimum share of SMEs (S- from 0 to 9 persons employed) that have applied technology to build intelligent systems.

Table 1. Level of application of advanced technologies for building an intelligent system at enterprises from persons employed, for 2023.

Country	Level (cluster)															Average level for all technologies		
	Additive technology			Internet of Things			Robotics			Big data			Artificial intelligence					
	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L
Belgium	3	2	1	3	2	2	3	1	1	3	1	2	3	1	1	3	1	1
Bulgaria	3	2	2	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3
Czechia	3	2	1	3	2	2	3	2	1	3	2	1	3	2	2	3	2	2
Denmark	3	1	1	3	2	2	3	1	1	3	1	2	3	1	1	3	1	1
Germany	1	1	1	1	2	2	3	2	2	3	2	2	3	1	2	3	2	2
Estonia	3	2	2	3	3	2	3	2	2	3	2	1	3	2	2	3	2	2
Ireland	3	3	2	3	2	2	3	3	2	3	1	2	3	2	2	3	2	2
Greece	3	3	3	3	2	3	3	3	3	3	3	2	3	2	3	3	3	3
Spain	1	2	2	3	2	2	1	1	2	1	2	2	1	2	2	1	2	2
France	3	2	2	3	2	2	3	2	2	3	1	2	3	2	2	3	2	2
Croatia	3	2	2	3	2	2	3	3	1	3	2	2	3	2	2	3	2	2
Italy	3	2	2	3	2	2	3	1	2	3	2	2	3	2	2	3	2	2
Cyprus	3	2	2	3	2	2	3	3	3	3	3	2	3	2	2	3	2	2
Latvia	3	2	2	3	2	1	3	2	2	3	2	2	3	2	2	3	2	2
Lithuania	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2
Luxembourg	3	2	2	3	2	2	3	2	2	3	2	3	3	1	1	3	2	2
Hungary	3	2	2	3	2	2	3	3	1	3	2	1	3	3	2	3	2	2
Malta	3	1	2	3	2	2	3	2	2	3	1	1	3	1	2	3	1	2
Netherlands	3	2	2	3	2	2	3	2	2	3	1	2	3	1	2	3	2	2
Austria	3	2	1	3	1	1	3	2	2	3	2	2	3	2	2	3	2	2
Poland	3	2	2	3	3	2	3	3	2	3	2	2	3	3	2	3	3	2
Portugal	1	2	2	3	2	2	1	2	2	1	2	2	1	2	2	1	2	2
Romania	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Slovenia	3	2	1	3	1	1	3	2	1	3	3	3	3	2	1	3	2	1
Slovakia	3	2	2	3	2	2	3	2	2	3	3	1	3	2	2	3	2	2
Finland	3	1	1	3	1	2	3	1	1	3	2	1	3	1	1	3	1	1
Sweden	3	2	1	3	1	2	3	2	2	3	2	2	3	2	2	3	2	2
Norway	3	2	2	3	2	2	3	2	2	3	2	3	3	2	2	3	2	2
Bosnia and Herzegovina	3	2	2	3	3	2	3	2	3	3	3	3	3	2	3	3	2	3
Montenegro	3	1	3	3	2	2	3	3	3	3	2	2	3	2	3	3	2	3
North Macedonia	3	2	3	3	3	2	3	2	2	3	2	3	3	3	3	3	2	2
Serbia	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3
Turkey	3	2	2	3	2	3	3	2	2	3	2	2	3	2	2	3	2	2
Average level for all country	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2

The results of the cluster analysis (Table 1) show that only Belgium, Denmark, Malta, Finland had the highest share of technology application for building intelligent systems among SMEs (M - from 10 to 249 persons employed) of 33 countries in 2023. We have included these countries in the first cluster. 5 countries (Bulgaria, Greece, Poland, Romania, and Serbia) were included in the third cluster with the minimum share of enterprises that applied technologies to build intelligent systems. The remaining 24 countries were included in the second cluster with an average share of enterprises applying technologies for building intelligent systems.

In 33 countries in 2023 by advanced technology groups, the leading SMEs (M - from 10 to 249 persons employed) were: additive technology – Denmark, Germany, Malta, Finland, Montenegro; Internet of Things – Austria, Slovenia, Finland, Sweden; robotics – Belgium, Denmark, Spain, Italy, Finland; big data – Belgium, Denmark, Ireland, France, Malta, Netherlands; artificial intelligence – Belgium, Denmark, German, Luxembourg, Malta, Netherlands, Finland.

The totals of 33 European countries among SMEs (M - from 10 to 249 persons employed) were in the second cluster for each of the 5 types of technologies (Table 1). This

means an average share of SMEs (M - from 10 to 249 persons employed) that have applied technology to build intelligent systems.

The results of the cluster analysis (Table 1) show that only Belgium, Denmark, Slovenia, Finland had the highest share of technology application for building intelligent systems among large enterprises (L - from 250 persons employed or more) of 33 countries in 2023. We have included these countries in the first cluster. 5 countries (Bulgaria, Greece, Romania, Bosnia and Herzegovina, Montenegro and Serbia) were included in the third cluster with the minimum share of enterprises that applied technologies to build intelligent systems. The remaining 23 countries were included in the second cluster with an average share of enterprises applying technologies for building intelligent systems.

In 33 countries in 2023 by advanced technology groups, the leading large enterprises (L - from 250 persons employed or more) were: additive technology – Belgium, Czechia, Denmark, Germany, Austria, Slovenia, Finland, Sweden; internet of Things – Latvia, Austria, Slovenia; robotics – Belgium, Czechia, Denmark, Croatia, Hungary, Slovenia , Finland; big data – Belgium, Denmark, Ireland, Malta, Netherlands, Finland, Sweden; artificial intelligence – Belgium, Denmark, Luxembourg, Slovenia, Finland.

The totals of 33 European countries among large enterprises (L - from 250 persons employed or more) were in the second cluster for each of the 5 types of technologies (Table 1). This means an average share of large enterprises (L - from 250 persons employed or more) that have applied technology to build intelligent systems.

Currently, most countries do not have an enterprise with a fully 100% built out intelligent system. Some of these businesses only have plans to implement a smart system. Most enterprises do not apply all 5 types of technologies. It applies only some of these types.

The hypothesis was confirmed that the transformation of intelligent systems in the region cannot be carried out according to a single approach for all regions. It is necessary to take into account the market demand (SMEs and large enterprises). This is due to the fact that each region has different levels of technology adoption for SMEs and for large enterprises. The proof is the results of cluster analysis (Tables 1).

As in the work of R. Cohen, the authors noted the proliferation of enterprises that applied intelligent systems in developing countries [4]. Most European countries have not yet built 100% intelligent systems in enterprises, especially in enterprises with 0 to 9 persons employed. This result is in contrast to the conclusions of the paper "Digital Factories 2020 Shaping the future of manufacturing". In this paper it was written that EU companies are investing a lot to build intelligent systems in the enterprises of their regions [5]. In our work, as well as in the works of N. Chonsawat, A. Widayani, A. Garzoni, we assessed the level of readiness of SMEs to build an intelligent system. In contrast to the above authors, in this study the assessment was carried out for large enterprises [12 – 14]. In contrast to studies that analyzed 1, less often 2 countries, we calculated levels of advanced technology adoption for a larger number of countries (33 countries). In addition, in this paper, the authors quantified each level of regions using the cluster method, unlike the above-mentioned authors who did not quantify.

The practical significance of the study is that the cluster analysis of 33 countries can be used to make investment decisions on the introduction of intelligent systems at enterprises. Investors will be able to determine the level of risk depending on the size of the company selected for investment in each region. They will also be able to choose a region suitable for investment. The importance of the research is increasing due to the problems in the foreign markets in the world. Therefore, the regions should promptly change the strategy for the introduction of intelligent systems at enterprises. Researchers will be able to see new markets by analyzing the level of application of advanced technologies to build intelligent systems.

4 Conclusions

Thus, it can be concluded that a total of 33 European countries as of 2023:

- SMEs (from 0 to 9 persons employed) for each of the 5 types of technologies are in the third cluster (minimum level of application of advanced technologies for the intelligent system);

- SMEs (from 10 to 249 persons employed) for each of the 5 types of technologies are in the second cluster (average level of application of advanced technologies for the intelligent system);

- Large enterprises (from 250 persons employed or more) for each of 5 types of technologies are included in the second cluster (average level of application of advanced technologies for intelligent system).

A minimum number of European countries (Belgium, Denmark, Finland) have a high level of application of advanced technologies for smart systems for 2023. These 3 countries have built intelligent systems only 66% out of 100%. The author's analysis of the level of application of advanced technologies for building intelligent systems takes into account the demand of SMEs and large enterprises. And it also allows to see its disparities in the region.

The study was conducted for 1 period, but it is necessary to track changes in the regions in dynamics (taking into account time). The authors make the following recommendations in the future. Researchers of this topic will need to analyze more regions. Regions should constantly monitor the creation of new enterprises that implement intelligent systems and survey existing enterprises that want to modernize in order to move to the construction of intelligent systems.

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