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Smart Logistics Infrastructure in Peripheral Region

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Abstract:

Purpose: *The main aim of the article is to find out the extent to which enterprises in Central Pomerania, which is an example of a peripheral region, are equipped with smart logistics infrastructure and infrastructure, indicating the conditions for the development of enterprises towards the use of smart logistics solutions.*
Approach/Methodology/Design: *The empirical part is based on a survey conducted on a sample of enterprises (n = 353) located in the region of Central Pomerania. The research model covers the key areas of smart logistics infrastructure used in enterprises. In the analytical part, basic statistical methods were used, based on the CHI-square test of independence, enabling the assessment of the dependence of enterprise infrastructure on the type of business activity.*
Findings: *The obtained results indicate that there is a relationship between the type of business activity and the enterprise's infrastructure and smart solutions. This applies to both Internet of Things (IoT) devices as well as devices for communication and digitization. The industry that has the least developed in its activities Smart Logistics is tourism, gastronomy and entertainment, trade and construction. . Industrial processing and transport stand out positively in this respect.*
Practical Implications: *Practical implications boil down to identifying which enterprises develop the SL function less and encounter development barriers, which in turn may be helpful in creating a support policy.*
Originality/Value: *Study is one of the few that provides knowledge on the use of SL in a wide group of enterprises. It provides knowledge about the relationship between the type of enterprise and the development of its logistics functions in the context of the use of smart solutions and technologies.*

Keywords: *Smart logistic infrastructure, peripheral, Central Pomerania of Poland.*

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1. Introduction

The development of the economy 4.0 will not be possible without the wide application of innovative IT solutions in the socio-economic ecosystem. Flows of intangible information and knowledge, as well as material flows of goods and services should take place both vertically and horizontally. This means that enterprises, knowledge institutions and local authorities co-create an intelligent system that obtains higher efficiency the higher the level of investment in logistics infrastructure, including IT and communication infrastructure.

The main aim of the article is to find out the extent to which enterprises in Central Pomerania, which is an example of a peripheral region, are equipped with intelligent logistics infrastructure and infrastructure, indicating the conditions for the development of enterprises towards the use of intelligent logistics solutions. We searched for answers to research questions, does the nature of the business activity affect the implementation of intelligent solutions in the field of communication devices, software, computing devices, digitization devices and the Internet of Things into logistic processes, and what are the barriers to the development of SL in the peripheral region? The research hypotheses were reduced to suppositions:

1. There is a dependence of the level of use of various IT devices on the section to which the entity was classified in terms of its business activity.
2. The type of business activity determines the variety of computer software used.
3. The variety (diversification) of communication and communication devices used in enterprises depends on the type of activity (sections).
4. The level of use of digitization and communication devices in economic activity depends on the affiliation to a section.
5. The type of business activity affects the level of use of IoT solutions.

The rest of the article is organized as follows. Section 2 provides an overview of the literature. Section 3 provides the methodology. Section 4 presents the results of the tests performed, while section 5 summarizes.

2. Theoretical Background

Based on the literature review, it can be observed that smart logistic is not an unambiguous concept and has many different definitions. This section presents the most common definitions of smart logistic.

Wind and Hülsmann (2007) Smart Logistic is characterized by such features as, decentralized decision-making (delegation of decision power to individual system elements); autonomy (in Decision-making); interaction (induce reactions after communication with other system elements and elements outside the system), heterarchy (fewer superordinate and subordinate relationship between logistic elements, increasing independency between system elements and a central coordinating entity), heterarchy (fewer superordinate and subordinate relationship between logistic elements, increasing independency between system elements and a central coordinating entity) and non-determinism (system behavior is non-predictable). In addition, the authors drew attention to the conditions and barriers to the development of SL, which include, decentralization and autonomy of decisions, reactive action of SL elements increasing independence of peripheral elements and the reaction of the SL system is unpredictable.

According to Uckelmann (2008) Smart Logistics embraces Smart Services as well as Smart Product and is derived from a technology driven approach, and thereby subject to change. In addition, smart logisic frees humans from (control) activities that can be delegated to Smart Products and Services, are invisible and calm and can, therefore, be described as transparent, are connected, thus they communicate and possibly interact with their environment, facilitate state-of-the-art (innovative and available) data processing (which may include, but do not require, software agents), integrate existing logistic technologies, such as material handling systems, and enable these to react and act in a correspondingly smart manner and include state-of-the-art billing, payment or licensing as integral component. Author include the following conditions and barriers to the development of SL:

- the volatility of SL results from the dynamics of technological development,
- SL reduces the amount of human control activities,
- SL strives for a systemic approach to its environment,
- SL integrates logistics technologies,
- software integrating devices and logistics technology.

According to Hribernik *at al.* (2010) in the technical literature, it is possible to distinguish two categories of smart logistics entities, namely smart resources and smart products / shipments. In addition, SL has the ability to connect entities, their resources and the flow of materials (shipments) between them.

From a logistics and supply chain management perspective, the multi-channel revolution has a number of implications. Ideally all channels should be served by the same logistics infrastructure, e.g. sharing distribution assets such as distribution centers, vehicles and, in particular, inventories. If this can be achieved then significant benefits can be obtained through gaining incremental revenue greater than the additional cost.

Often multi-channel operations imply an increase in home delivery as many of these emerging channels are primarily aimed at end-users who require delivery to a specific address rather than collecting it themselves. Whereas a bricks and mortar retailer have the ‘last 50 meters challenge’, i.e., how to manage the significant cost of getting the product from the delivery vehicle onto the shelf in the most costeffective way, the online retailer is concerned with the ‘last mile’ costs. Because most home deliveries are for a single case equivalent or less, the problem is how to ensure that the cost of delivery does not erode profitability. With the advent of agreed delivery times and the use of dynamic vehicle routing and scheduling tools this problem should reduce (Christopher, 2011). Christopher (2011) includes the following factors in the development of SL:

- multi-channel SL,
- delivery to an individual customer (last 50m),
- ideal model – all common channels, sharing distribution centers, stocks, etc.,
- the last stage – e.g., parcel locker,
- optimization of delivery routes (positioning, specialized software).

As indicated by Blecker, Kersten, and Ringle (2012) SL contains the application of ubiquitous technologies for efficiency improvement in transport, warehousing and storage processes. On the other hand, Tiejun (2012) defines SL as oversight of materials, information and finances as they move in a process from supplier to manufacturer to wholesaler to retailer to consumer. It involves coordinating and integrating these flows both within and among companies. Recent studies are investigating the benefits from SL are being applied for increasing the accuracy and timeliness of the information and reducing the cost in the Logistics and transportation operations. Thus SL "supervises" the material and non-material flow in logistics supply chains; keeps information accurate and up-to-date and reduces logistics costs (Tiejun, 2012).

The definition of Smart Logistics was also presented by Miragliotta, Perego and Tumino (2012), according to which these are solutions for supply chain traceability, brand protection (anti-counterfeiting, prevention of grey markets), cold chain monitoring, fleet management (truck localization and monitoring of its conditions), and safety and security within logistics facilities. Thus, SL identifies elements (protects e.g. a brand), provides data security in the supply chain and locates and manages the fleet (Miragliotta *et al.*, 2012).

According to van Woensel (2012) Smart Logistics equals 3P + I (i.e., Planning, People, Policy and Infrastructure), and is the synchronized interplay of these four key domains. ICT infrastructure is an enabler for planning and scheduling via providing the right information Resources at the right time and place. Nowadays, larger quantities along with more detailed and faster information are available. This allows for better planning and scheduling. But this is also a challenge as many planning and scheduling tools are not able to handle this amount and quality of information.

In the opinion of Jabeur *et al.* (2017) Smart Logistics is basically aiming to efficiently aligning planning and scheduling, Information and Communication

Technology (ICT) infrastructure, people and governmental policymaking are the four main pillars of smart logistics. ICT infrastructure supports the planning and scheduling processes with the relevant information resources at the right time and place. These processes are interpreted and implemented by people who should be sufficiently trained to properly understand and manage the inherent complexity. Governmental policy making represent an important player in smart logistics especially since policy has a central impact on logistics costs.

According to Kirch, Poenicke and Richter (2017) Smart Logistics Zones define a multiple use concept of technical systems for the identification, localization and condition monitoring of different object levels in logistics and production processes. Furthermore, a spatial reference needs to be integrated into the definition, as transport and production related logistics processes are defined by moving and handling objects along space and time. By that, several spatial and object levels have to be considered along typical supply chains, individuals (staff), single objects (goods/freight), mobile resources, infrastructures.

Singh, van Sinderen and Wieringa (2017) emphasize that Smart logistics consists of a number of activities that contribute towards desired goals. These activities can be mapped to an EA that in turn facilitates a gap analysis. EA allows enterprise to devise a step-wise plan towards smarter logistic services. Arumugam *et al.* (2018) add that Smart Logistics solution implements the end-to-end tasks starting from performance based supplier recommendation, contract negotiation, logistics planning to contract controlled asset monitoring and contract fulfillment.

However, as Tang (2020) emphasizes Smart logistics refers to a logistics distribution network system that integrates informatization, intelligence and systemization by using the Internet of Things technology and information technology. It mainly uses high-tech and modern management methods to achieve high efficiency and low efficiency of the logistics distribution system.

The analysis of the content characterizing SL and Economy 4.0 indicates the time coincidence in their definition, dated 2007-2011. The differentiation in the approach to SL is related to the economic practice on the basis of which an attempt was made to define its essence. The systematization of conditions and barriers to the development of SL in economic practice indicates the decentralization and autonomy of decisions, the reactive operation of SL elements, the growing independence of peripheral elements and a predictable reaction of the SL system (Wind and Hülsmann, 2007).

SL striving for a systemic recognition in its environment reduces the number of people's control activities by "supervising" the material and non-material flow in the supply chain (Tiejun, 2012), integrates logistic technologies (Hribernik *et al.*, 2010), using appropriate software (Uckelmann, 2008), allows to reduce logistics costs and increase the efficiency of transport processes (Blecker *et al.*, 2012), through e.g., fleet location and management (Miragliotta *et al.*, 2012), ensures the security of data flow. In addition, SL considers the territorial (spatial) and object-oriented aspect of functioning e.g., in an enterprise, local market, region (Kirch *et al.*, 2017), allows for mapping and assessment of gaps in processes (Singh *et al.*, 2017), monitoring and integration of resources using IoT, planning and implementation of contracts and the use of advanced enterprise management tools (Arumugam *et al.*, 2018; Tang, 2020). In the ideal SL model, suppliers and recipients use channels together and share distribution centers and stocks to optimize deliveries using logistics technology and specialized software (Christopher, 2011).

In conclusion, the concept of SL is dynamic, and it is rather a sequence of activities thanks to which the environment and its participants can react faster to new micro and macro challenges of the environment. SL is also an intelligent combination of technology, administration and human activities that allows to predict problems and minimize their impact in a given area, coordinate resources in order to effectively achieve the assumed goals and eliminate communication barriers between the involved elements of the supply chains.

From the point of view of the end user (recipient), the greatest value of SL is data and new services based on end devices (sensors and beacons), the access network and back-end infrastructure. The essence of creating these values can be illustrated in the form of appropriate layers. The first layer is created by the object / data. It is usually a physical element that provides the first direct, physical benefit to the user (e.g., beacon - location of the site, location of service points (medical point, restaurant, shop, etc., parking space - parking possibility, accessibility) to the location and can provide benefits from this layer only in the immediate vicinity.

The second layer consists of sensors and an actuator. In this layer, the physical object is equipped with a minicomputer with a sensor and possibly an actuator (relay, actuator, etc.). The sensor measures local data , and the actuator provides a local service, thus generating a local benefit (e.g., a delivery vehicle - the position sensor transmits data about the current position of the vehicle, which can be translated (using the tools of higher layers into, among others, information about the expected time of arrival and possible

The third layer consists of communication systems. It is worth noting that the previous layers connected to the Internet become available all over the world (the sensor transmits its status to authorized subscribers anywhere in the world using the built-in transmission module). The back-end infrastructure consists of the fourth layer. In this layer, raw data is collected from end devices and data sources, which is checked for reliability and classified. The back-end infrastructure provides contextual information that, when combined with raw data, generates new value.

The fifth layer is made up of digital services provided by the layers below, e.g., as a web service or a mobile application. Modeling SL in a layer system is determined by the necessity to create layers in a logical connection, simultaneously – SL layers cannot be created independently of each other (Korczak and Kijewska, 2019).

3. Materials and Methods

An attempt to define the concept of Smart Logistics was made on the basis of a literature review and a systematic review procedure (Booth *et al.*, 2012). The review focused on the definition of the concept (Andersen and Bergdolf, 2017) and the scope of its application in business practice. In the search phase, the free-text searching method was used by searching the Google Scholar database and using the following keywords, Smart Logistics, Economy 4.0. During the search process, over 159,000 addresses with keywords were displayed. The review used the criteria for inclusion in the research process, the time period of literature from 2000, full availability of the text, analysis of abstracts. After removing duplicates, checking titles and abstracts, evaluating full texts for eligibility (including qualitative, quantitative - qualitative or conceptual studies), 48 publications were included in the review.

The reference point of the research was a study conducted in 2003 (n = 243), 2004 (n = 194) and 2006 (n = 181) in randomly selected SMEs in Central Pomerania (Korczak, 2008), which allowed for the definition of the basic requirements of SME logistics systems, including selected infrastructure elements logistics.

Developed in 2020 in cooperation with the Koszalin Chamber of Industry and Commerce, the Association of Entrepreneurs and Employers, Koszalin Branch and the Northern Chamber of Commerce, Koszalin Branch, the research sheet was sent by e-mail to members of economic organizations (CAWI) and supplemented with the CATI method. The research sheet contained 13 closed questions (multiple choice) and was completed by n = 353 entrepreneurs based in the area of Central Pomerania. Detailed questions concerned the identification of the elements of the organizational structure, logistic infrastructure of enterprises, cyclicality of deliveries and receipts of goods to and from the enterprise, IT infrastructure (IT equipment, software, means of communication, other devices) and training sessions attended by the employees of the enterprise. The sheet's record identified sections of PKD 2007, size and registered offices of entrepreneurs.

The sample size allowed for the verification of the hypotheses based on the Chi-square test of independence, and thus the assessment of the determinants of differentiation in the level of the use of SL methods and devices. Data analysis was mainly based on variables showing the degree / level of use of devices, software and training in enterprises. These variables representing the number of indications in multiple-choice questions were compared with the grouping variable: economic activity section. Then, a statistical Chi-square test of independence was carried out for them, supplemented with a measure of the strength of the relationship - the Czuprow coefficient of convergence.

Due to the large number of categories of the studied dependent variables and in order to meet the required assumptions of the Chi-square test, the categories of these variables were grouped. In order to compare the significance level of the shown dependencies and the strength of the tested compounds, the test probabilities and the values of the Czuprow coefficient of convergence were determined. Interpretation of the obtained results is illustrated graphically in the form of interaction charts.

4. Results

4.1 Characteristics of the Surveyed Enterprises

The territorial distribution of enterprises shows that representatives of 63 communes (72.4%) participated in the study, most of them from Koszalin (111), Kołobrzeg (20), Sławno (20), Białogard (15), Sianów (15) and Słupsk (14). Rural communes were represented by entrepreneurs from 13 (Będzino) to 1 (Kobylnica). Analyzing the size of the enterprise, the most were represented by 129 small enterprises (36%) and 120 micro-enterprises (34%). In the survey, medium-sized enterprises were identified 70 (20%), and large enterprises – 34 (10%).

The classification of economic activity made it possible to identify the key specializations of the research group. Most were registered in the following sections: transport and warehouse management (48), activities related to accommodation and services (43), wholesale and retail trade; repair of motor vehicles (42), construction (39) and industrial processing (34). The smallest number of entrepreneurs conducted their activities identified in the sections, professional, scientific and technical activities (3), activities in the field of administration services and supporting activities (4) and activities related to the real estate market (5). Searching for an answer to the main problem of the study, groups of devices operating in the SL area of the surveyed SMEs in Central Pomerania were identified. The identified device groups are: IT devices, software, communication devices, advanced digitizing and localization devices and Internet of Things (Table 1).

Table 1. *Elements of Smart Logistics occurring in the enterprise*

Equipment group in the SL area	Equipment list
IT devices	server, desktop computer, laptop, tablet
Software	accounting, warehouse, Excel, ERP, HR, tax, logistics, transport
Communication devices	mobile phone, Internet / landline connection, mobile / radio Internet, landline phone, satellite phone
Advanced digitizing and localization devices	barcode scanner, etc., router, GPS - equipment positioning systems, Beacon - mini Bluetooth transmitter, RFID - (remote) radio identification systems

Internet of Things	offices (etc., printer, scanner, computer, smartphone, etc.), webcams, industrial cameras, transport (vehicles, control rooms, etc.), production process (machines, devices, etc.), logistics (warehouses, internal roads, power supply, etc.)), motion sensors, service cells / service stations (service of machines / devices, repair of machines / devices, technological maintenance, cleaning etc.), other cells / stations, temperature sensors, humidity sensors

Source: *Own study.*

Table 2. *Average number of devices, software and IoT by section or group of sections*

Section or group of sections (number of entities)	IT devices	Software	Communication devices	Advanced communication and digitization devices	Internet of Things
Agriculture, forestry (26)	2.269	3.346	2.5 (min)	1.615	4.538 (MAX2)
Industrial processing and mining (38)	2.789 (MAX)	5.105 (MAX)	2.947 (MAX2)	2.132 (MAX2)	6.368 (MAX)
Service activities (54)	2.63 (MAX2)	4.093	2.852	1.741	4.315
Construction (39)	2.205 (min2)	3.333 (min2)	2.641	1.513 (min2)	3.538 (min2)
Trade[Δ] (42)	2.095 (min)	3.429	2.524 (min2)	1.714	3.857
Transport[Δ] (48)	2.542	4.75 (MAX2)	3.167 (MAX)	2.188 (MAX)	4.479
Tourism, gastronomy, entertainment (64)	2.266	2.859 (min)	2.766	1.328 (min)	3.406 (min)
Administration, education, healthcare (42)	2.5	3.952	2.929	1.524	3.857

Note: *Agriculture, forestry[Δ] (section A), Manufacturing and mining (sections B and C), Service activities (sections D, E, J, K, L, S and T), Construction (Section F), Trade [Δ] (Section G),Transport[Δ] (section H), Tourism, gastronomy, entertainment (sections I, R), Administration, education, healthcare (sections M, N, O, P, Q).*
Source: *Own study.*

4.2 Equipping Enterprises with Smart Logistics Elements

For each of the analyzed characteristics of enterprises, there is a statistically significant dependence of their value on whether the enterprise belongs to a PKD section or a group of sections included in the study (test probabilities are lower than 0.05). It can therefore be concluded that the type of business activity affects the level of use in enterprises modern devices and software to improve, inter alia, the production, sales and communication processes. The strongest impact of the type of activity conducted is observed in the case of the Internet of Things and software (relatively higher values of the Czuprow coefficient of convergence). The weakest - in the case of IT and communication devices. However, the strength of all the aforementioned relationships is not high, although statistically significant.

Table 3. *Results of the chi-square test of independence*

Independence test parameters CHI-square	**IT devices**	**Softwa re**	**Communicati on devices**	**Advanced digitization and localization devices**	**Internet of Things**
Pearson Chi-square	18.7711	36.538	14.8601	34.8244	60.5248
Test probability	0.0089	0.0000	0.0378	0.0000	0.0000
Czuprow coefficient	0.14	0.20	0.13	0.19	0.25

Source: *Own study.*

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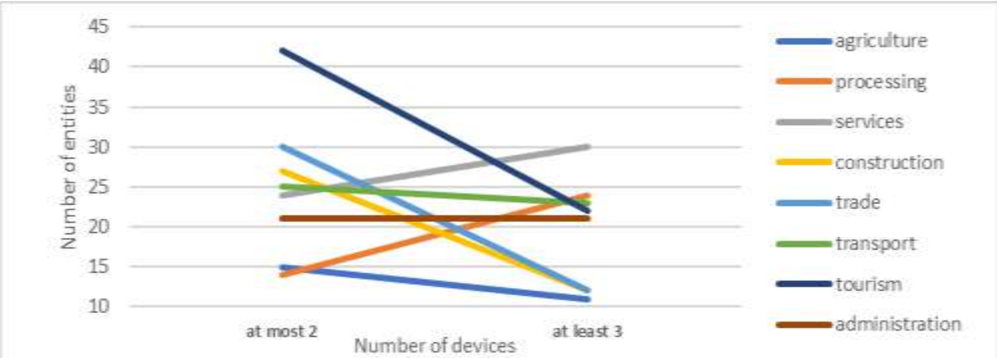
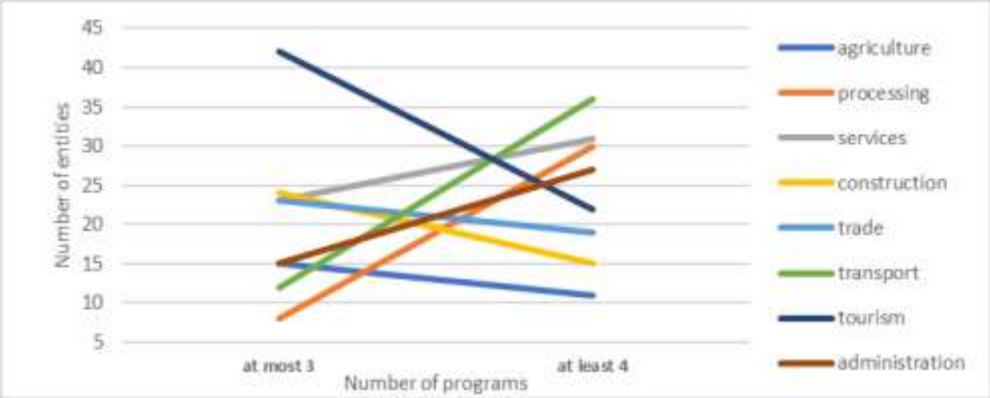
Figure 1. *Number of entities by possession of smart logistics devices and affiliation to sections*



Source: *Own study.*

Manufacturing and services stand out with the highest average number of IT devices of various types. In these groups of enterprises, economic entities with a relatively larger number of different IT devices are more common (Figure 1). In the case of the remaining sections, the opposite is true, with the greatest disproportions (differences between the number of enterprises with at least 3 different devices and the number of enterprises with at least 2 different devices) in the group of sections: tourism, gastronomy, entertainment, trade and construction. In these groups, entities with a small number of the devices mentioned above appear clearly more often.

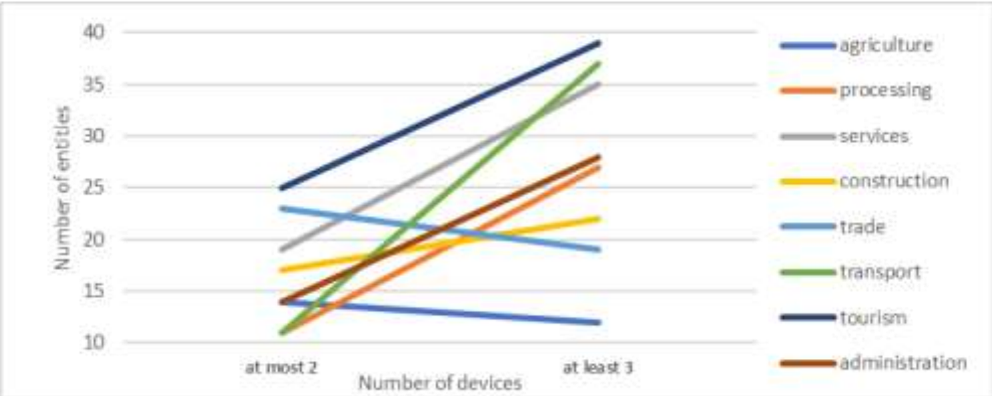
Figure 2. *Number of entities by software usage and section affiliation*



Source: *Own study.*

In terms of the variety of software used, processing and trade stand out. Moreover, also in services and administration, the majority of units with the number of computer programs used is 4 or more (Figure 2). The least favorable group in this respect is: tourism, gastronomy and entertainment, where entities with such a number of computer programs are almost twice as rare.

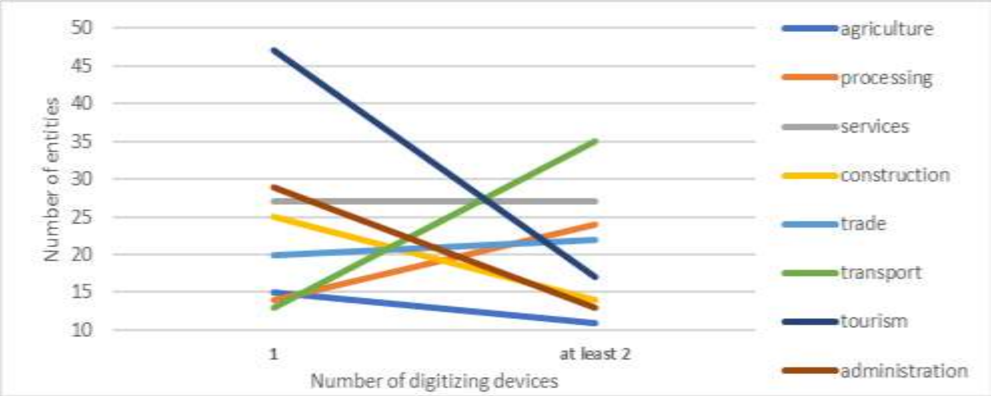
Figure 3. *Number of entities by ownership of communication devices and affiliation to a section*



Source: *Own study.*

In the case of devices facilitating communication in most sections, enterprises with a relatively larger number of such devices are more common (Figure 3). On average, the largest number of them is observed in transport, and the smallest in agriculture and trade, which are the only ones distinguished by the advantage of entities with the number of such devices equal to at most 2.

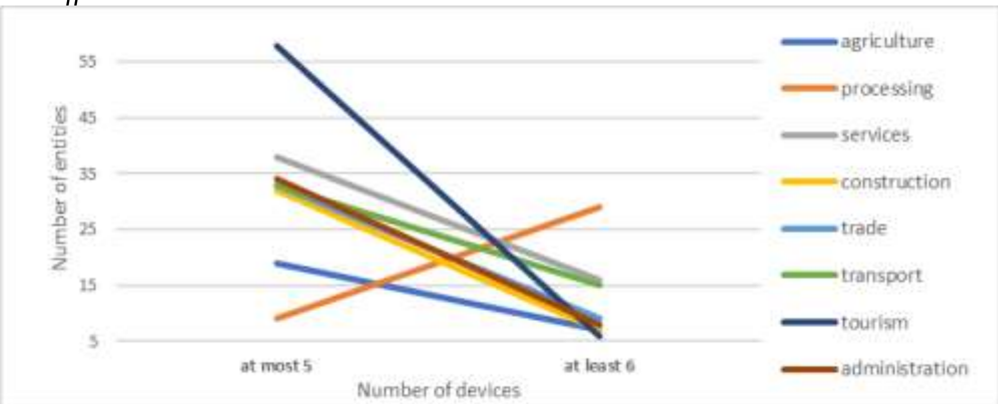
Figure 4. *Number of entities according to possession of digitization and communication devices and affiliation to sections*



Source: *Own study.*

Advanced digitization and localization devices are a clear domain of transport, but also processing (Figure 4). In most of the remaining sections or the analyzed groups of sections, the majority of entities have only one such device.

Figure 5. *Number of entities according to possession of Internet of Things devices and affiliation to the section*



Source: *Own study.*

Economic entities belonging to the industrial processing section are clearly distinguished by the greater number of entities with at least 6 Internet of Things devices (Figure 5). Their average number in this section is 6.4. In all other sections and groups of sections, such enterprises are in a minority. On average, the smallest number is found in the sections of tourism and construction.

5. Conclusions

The obtained results indicate that there is a relationship between the type of business activity and the enterprise's infrastructure and smart solutions. This applies to both Internet of Things (IoT) devices as well as devices for communication and digitization. The industry that has the least developed in its activities Smart Logistics is tourism, gastronomy and entertainment (especially in the field of software, advanced digitization and localization devices, and the Internet of Things), trade (especially due to the low variety of IT devices) and construction. The identified differences in industries in the use of Smart Logistics solutions result mainly from barriers such as the SL development policy at the regional level, the level of advancement of SL infrastructure or the training of personnel in the use of SL. Industrial processing and transport stand out positively in this respect.

The proposed directions of support / policy include the use of SL as an integrator of supply chain elements using IoT, SL devices and tools, and the use of technologically advanced management methods. Practical implications boil down to identifying which enterprises develop the SL function less and encounter development barriers, which in turn may be helpful in creating a support policy. One of the proposed directions of the support policy may be the creation of local innovation systems in the area of creating, absorbing and diffusing knowledge about SL in various types of enterprises.

The originality / value of the article comes down to the conclusion that this study is one of the few that provides knowledge on the use of SL in a wide group of enterprises. It provides knowledge about the relationship between the type of enterprise and the development of its logistics functions in the context of the use of smart solutions and technologies. An additional value of the work is the concentration of research in the region, which is considered to be a peripheral region with weak conditions and numerous barriers to the development and absorption of innovations related to the development of economy 4.0.

Subsequent research in this area should focus on identifying the conditions for the application of local innovation systems in the field of creation, absorption and diffusion of knowledge and practical applications of SL in enterprises located in peripheral regions.

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