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AN AI-BASED INVESTIGATION OF REGIONAL MANUFACTURING SERVITIZATION LEVELS

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ABSTRACT

The paper presents the extent of the servitization level of companies in Austria, Germany, Italy, Hungary, Slovakia and Slovenia, as well as individual services offered based on the analysis of webpages using an in-house developed Artificial Intelligence algorithm. The research focusses on Advanced Manufacturers operating in NACE 26, 27 and 28. The paper partially confirms previous studies regarding the servitization extent of regions, however differences among specific service types have been identified. Therefore, more granular servitization levels depending on the service type are shown.

INTRODUCTION

Despite the increasing interest in servitization by manufacturers and academic researchers (Khanra *et al.*, 2021; Zhou and Song, 2021), a scarcity of studies about the regional extent of servitization levels can be seen (Mastrogiacomo, Barravecchia and Franceschini, 2019). Notably, previous research to quantify the extent of servitization worldwide and at country wide levels is limited by the methods of analysis used, which until now have been mainly surveys, questionnaires or interviews (Neely, 2007; Neely, Benedettini and Visnjic, 2011; Neely, 2013; Dachs *et al.*, 2014). Similarly, large-data analyses of servitization levels rely on databases from which personal, commercial and financial data are retrieved (e.g. Mastrogiacomo, Barravecchia and Franceschini, 2019). As databases are a possible source of bias (D'Haen, den Poel and Thorleuchter, 2013), the aim of this study is to use companies' websites operating in sectors of NACE 26, 27 and 28 as a more complete and more up-to-date source (D'Haen *et al.*, 2016) combined with web mining and an AI-based solution for identifying the servitization level of individual companies and hence, entire regions.

Servitization is a term coined for the organizational change of classic manufacturing companies coupling their traditional goods with the provision of associated services to create value and generate new revenue streams (Vandermerwe and Rada, 1988). Over the last decades manufacturing companies have changed the way in which services are produced and marketed. In the past, services have been seen more as an add-on to products (Gebauer, Fleisch and Friedli, 2005). Nowadays, more manufacturing companies are aware of the benefits of having services for their products and consider their developed service activities as a main differentiating factor in their offerings. In the value proposition, services are fundamental value-added activities, and the product is considered as just being part of the offering (Oliva and Kallenberg, 2003). A challenge for manufacturers is to successfully market and communicate the value proposition of their services. In other words, making the services tangible for the (potential) customers. One possible platform, manufacturers can use, is the online web presence, more specifically the webpage of the company.

In this paper, a newly developed Artificial Intelligent tool is used. The aim is to provide information on the servitization level of regions by investigating individual services promoted by local enterprises on their websites. The research tries to take it one step further as the servitization level is broken down into individual service categories and service offerings in the regions. Additionally, the research promotes the importance of a professional online presence for advanced manufacturers, also when it comes to promoting their service offerings. Almost 75% of buyers in the business-to-business segment favour searching and selecting goods and services online instead of communicating with a salesperson (Arli, Bauer and Palmatier, 2018; Koponen and Rytsy, 2020).

BACKGROUND ON SERVICE CATEGORIES

Prior literature offers many definitions of industrial services as well as terms to describe and study the convergence between manufacturing and services. Partanen *et al.* (2017, p.296) defines "industrial services as all value-adding activities that are consumed, but not possessed, by the industrial customer". In general, the field of industrial service business is vast and many-sided, the variety of classifications reflects the complexity of industrial services offerings. Partanen *et al.* (2017) attempts to summarize and categorize the different industrial service typologies and scales. In first studies the conceptual argumentation that the moment of transaction forms the traditional basis for classifying industrial services is used. Over the last years, studies put emphasis on the relational dimension of service business. Mathieu (2001) or Olivia and Kallenberg (2003) created typologies focusing on product versus process-based services, whereas Ulaga and Reinartz (2011) focus on input versus performance-based services. A classification based on quantitative evidence has been developed which examines the fit between the external environment and the strategy of manufacturing companies. This investigation by Gebauer (2008) resulted in four service offerings classifications (after sales services, process-oriented services, research and development services and operational services). A classification by Raddats and Kowalkowski (2014) based on two dimensions (single versus multi-vendor orientation and product versus customer orientation) results in three service typologies (product-attached services, operations services on companies' own products and vendor independent operations services). Baines *et al.* (2013) categorize service offerings into basic, intermediate and advanced services.

METHODOLOGY

For this study the research approach is derived from the promotion of service offerings on webpages of manufacturing enterprises. Therefore, a fitting taxonomy of industrial-related services (see appendix 1) has been created, which covers the most relevant service offerings of advanced manufacturers and is easy to understand. The following sections describe the methodology in more detail.

Development of industrial service taxonomy

This paper presents a new approach to measure the servitization level of different regions by analysing service offerings on webpages by using an in-house developed Artificial Intelligence tool. The research focuses on the webpages of companies in the field of advanced manufacturing. The European Union (2021) determines advanced manufacturing as "the use of knowledge and innovative technology to produce complex products […] and improve processes to lower waste, pollution, material consumption and energy use". To identify and structure relevant services the research consortium developed a service taxonomy (see appendix 1), based upon various service categorizations (Oliva and Kallenberg, 2003; Gebauer *et al.*, 2010; Baines *et al.*, 2013; Partanen *et al.*, 2017) and verified the taxonomy with experts from industry. The service typology focusses on services for three specific sectors: manufacture of computer, electronic and optical product (NACE 26), manufacture of electrical equipment (NACE 27) and manufacture of machinery and equipment (NACE 28). In respect to the servitization level, prior studies (Dachs *et al.*, 2014; Mastrogiacomo, Barravecchia and Franceschini, 2019) have investigated these sectors with different approaches, which means that comparable benchmarks exist to compare the findings of the Artificial Intelligent based approach in this research. The resulting twenty-one industrial-related services were grouped into six main categories (Presale Services, Product Support Services, Product Lifecycle Services, R&D Services, Operational Services, Financial Services) representing the service offerings of advanced manufacturers in this study.

Sampling

As the research activities were part of an Interreg Central Europe project called "ProsperAMnet" financed by the European Union Development Fund, the research focusses on and was conducted for the following regions in Central Europe: Austria, Bavaria, Hungary, Italy, Saxony, Slovakia and Slovenia. In total approximately 5,550 manufacturing company webpages (see table 1) were finally gathered and analyzed from national and international databases (like Europages, Aurelia and other) as well as public sources (e.g. Saxony Economic Development Corporation, National Tax and Customs Administration Hungary, Ajpes - Agency of the Republic of Slovenia for Public Legal Records and Related Services, ELEMACO InfoCamere) as well as purchased data collections (e.g. Bavarian Chamber of Commerce and Industry). The companies are characterized by having their main business activity in one of the specific industry sectors, with more than twenty employees regardless of whether they operate nationally or internationally. The filter of more than twenty employees was chosen, following Kohtamäki *et al.* (2013), which found that microenterprises have limited abilities to offer portfolios for services. Additionally, the analyzed companies have to have an online presence in form of a webpage. In this study different regions in Central Europe, according to Mastrogiacomo, Barravecchia and Franceschini (2019) characterized by perceived low, mediocre and high levels of servitization, were selected for comparison.

Table 1: Overview of regions and number of analysed companies

region	# companies	Level of Servitization (Mastrogiacomo, Barravecchia & Franceschini, 2019)
Austria	1394	high
Germany (Bavaria)	773	high
Germany (Saxony)	1382	high
Hungary	581	low
Italy (Veneto)	585	mediocre
Slovakia	606	mediocre
Slovenia	229	not given

Training and data collection

For the development of the Artificial Intelligent tool, relevant information about these services was retrieved from 1,800 company webpages in eight languages (Czech, English, French, German, Hungarian, Italian, Slovak and Slovenian) through twenty-two specially trained annotators. The annotators from seven different countries were carefully selected and trained. They were graduate or postgraduate students from the field of business and/or technology, had domain knowledge, and were native speakers of the languages (with the only exception being the English language). To ensure a mutual understanding of the chosen service categories and minimize the discrepancies between the different annotators, a trial process of annotation was applied. The gathered data was cross-checked, differences identified, and comprehensive feedback was presented to the researchers in order to improve the manual annotation process. The process was repeated in three loops to ensure a high quality of data collection. The collected data and conducted annotations were checked solely by domain knowledge experts of services in the relevant sectors.

Exemplifying one of the quantitative evaluation methods to align quality and consistency among the annotators, fifteen specific company websites were annotated by pairs of independent annotators. The annotation process was open ended, i.e., annotators were not provided with a fixed set of sub-websites from a given URL to check but just a base URL of a company. Then, they were allowed to check any of the in-domain webpages of the given URL. As such, a pair of annotators could find evidence of a particular service being offered by the specific company on two distinct pages of the same company website. In order to account for that, we aggregated the services found by the individual annotators at the company level. The result of each annotation with respect to a company website consisted of binary values, each one indicating whether the annotator deemed a service to be offered based on the contents of a company website.

Artificial Intelligence algorithm

These annotations served as basis for training and validating of an AI-tool applying Natural Language Processing and Machine Learning algorithms. Using machine learning can help improve the identification of services in text beyond what is possible with manually written rule-based systems as different companies may describe the same service in different ways and the descriptions can occur in various contexts (Verma *et al.*, 2021).

To develop a robust solution, the biggest issue was the question of different languages: most of the potential target companies came from non-English speaking countries and a large number of them have no English content on their websites. Moreover, there was not enough data to make an independent classifier for each of the languages. To deal with this situation, a multilingual solution was used by applying cross-lingual word embeddings (Joulin *et al.*, 2018). Word embeddings assign a vector to every word form in a way that words with similar meaning get assigned to vectors that are close to each other, for example, the vector of the “king” is close to the vector of the “emperor” but far from the vector of “sushi”. The cross-lingual word embeddings can do the same, but across different languages, for example, the vectors for the German word “König” and the English “king” are close to each other. With the chosen approach the webpages are “translated” by replacing the words with five of the most similar English words (and to make the database consistent, the same method is applied to the English data as well: the four most similar words have been added to each word form on the pages). In the research, Facebook’s fastText aligned vectors is used, which provide cross-lingual word embeddings for 44 languages.

After having dealt with the languages difference issue, a classifier that can analyze the individual servitization status of a company was developed. As the manually annotated and collected database contains the exact URL of each annotated service, this analysis could be done separately on each different URL (sub-webpage). This sub-webpage levels dataset describes a multi-label classification problem. Meaning that each of the sub-pages could be associated with zero or more service categories. In this study, a binary classification problem for each of the twenty-one service categories was used, where the deciding factor was if a sub-pages contains a service or not. For each of these tasks, a logistic regression classifier has been applied, which assigned a probability to each of the words.

Since most of the sub-webpages do not contain information about the servitization level, the database was extremely unbalanced. Therefore, the class weights have been inversely proportionally adjusted to the class frequencies. It increases the importance of the small number of service-related examples without dropping any of the non-service-related ones. This can help to get the most detailed representation of the different service classes. To find the related parts of the websites, the website crawling mechanism starts from the main page of a company and moves through in-domain links from page to page. In total the crawler investigates up to 200 pages and skips the URLs that are not reachable from the main pages within ten steps. This process gathers not just the visible content of the webpages but also extracts the title, the description, the keywords, and any metadata or other textual part of the source code.

To find the most relevant pages for the services, a priority value has been assigned to all the subpages. Based on this value, the system will prioritize the order of the downloads. The prioritization is generated by another classifier that requires only the URL as input and will order higher value to the pages where the probability of the occurrence of the services is higher. For example, it prefers URLs containing "/warranty/" over "/contacts/". As in the step before, a logistic regression model had been used, but in this case, it learns weights to all of the 3-5 length character subsequences of the URLs and it applied only two labels: one for the pages that contain services and one for the others. The priority is calculated by the probability of the label that refers to the services.

After the downloading and analyzing steps, the algorithm has predictions for each of the sub-webpages that ultimately have to be aggregated at the level of whole websites. In this step the algorithm just searches for any occurrence of the services. If a service is found, meaning the probability of a service label is higher than 50% in any of the sub-webpages, it will be found on the level of the whole website too.

Concluding, the developed algorithm finally investigates up to 200 sub-webpages per company domain including hidden information in the source code and assigns probabilities, whether certain services are offered on the company domain or not. A probability larger than 50% means that a certain service is deemed to be more likely offered than not. The figures in the result table (compare appendix 1) indicate the percentage for how many companies in the individual region the probability that the specific service was offered is larger than 50%. The resulting tool was checked with 20 company websites where the research consortium had deep insight into their service offerings. Additionally, the toll was presented in seven round tables with around eight firm representatives from each of the focused sectors, verifying the robustness of the results. These participants evaluated several company websites such as their own or those of competitors.

FINDINGS

The results of the sample analysis (see appendix 1) indicate strong differences among the six service categories as well as differences between the chosen regions. Product lifecycle services (such as repair services), product support services (such as technical user training) and R&D services (prototype design &

development) are overall better established in the analyzed enterprises (on average 24% of companies). In contrast, presale services (e.g. product demonstration) and operational services (project management) are trailing behind (between 12-15%). Whereas financial services (rental systems) are basically not promoted on the company webpages (on average only 2%) in all regions. Therefore, more granular servitization levels depending on the service type can be shown. The highest scores (59% and 53%) are detected for the service “prototype design & development” in the Saxony and Bavarian regions, which suggests a concentration of R&D activities of advanced manufacturers in Germany. In contrast, the services “Pay per Use” and “Instalment payment” score the lowest (on average 1% in all regions), which suggest a lack of financial service offerings for advanced manufacturers. This confirms partial results of the research by Mastrogiacomo, Barravecchia and Franceschini (2019), which attested financial services to be offered by manufacturers in the NACE sector 26, 27 and 28 on average at 3%.

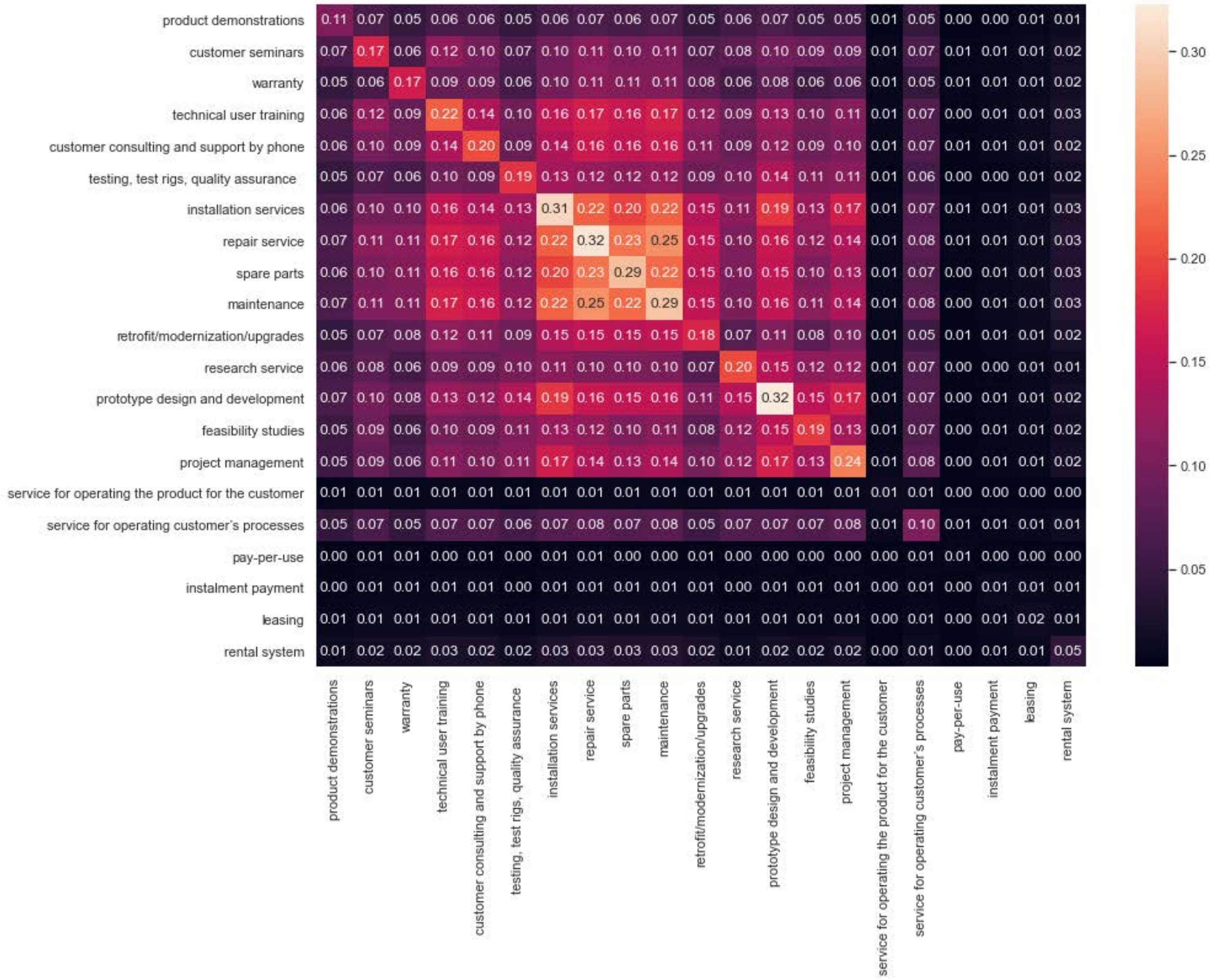
In table 2, the number of services detected per company in the individual regions is presented. Dachs *et al.* (2014) found in their investigation of servitization extent in nine European countries that Austria (85%) and Germany (83%) have a high figure for manufacturers providing at least one service. These findings are partially confirmed with our AI-based approach as well (compare table 2). Additionally, the AI-based approach enables a further step by counting the service offerings found per company to make the servitization levels of the different regions visible. Concerning the regions, Austrian, Bavarian and Saxon companies are more servitized. Although the different regions show similarities in the segment “1-5 services offered” (averaging around 37%), the different regions vary significantly in the segment “6-10 and 11-15 services offered”. This demonstrates that companies in the Austrian, Bavarian and Saxony region provide a higher range of different service offerings and suggest being in the front in the servitization journey in comparison to the other regions. Overall, the results confirm previous studies regarding the servitization level of different regions, although differences among specific service types have been identified.

Table 2: Number of services found

Number of services found	None	At least one	1-5	6-10	11-15	16-21
Austria	22%	78%	40%	23%	13%	2%
Germany (Bavaria)	19%	81%	38%	23%	17%	3%
Germany (Saxony)	26%	74%	39%	23%	12%	2%
Hungary	36%	64%	38%	18%	7%	1%
Italy (Veneto)	60%	40%	36%	4%	0%	0%
Slovakia	43%	57%	33%	14%	9%	1%
Slovenia	49%	51%	35%	12%	3%	1%
Total	36%	64%	37%	17%	9%	1%

Finally, the sample was investigated to ascertain if and which detected service offerings occurred together on the specific company webpages. The result is displayed in the heatmap “service co-occurrence distribution” (compare figure 1). The comparison demonstrates that companies offer services together more often from the same service category than from two different service categories. This supports the development paths discussed by Oliva and Kallenberg (2004) that developing an additional basic service is more favorable than developing an additional advanced service to a companies’ basic service portfolio. The highest scores are found in the service category “product lifecycle service” (installation service, repair service, spare parts, maintenance and retrofit, modernization and upgrades). This means that it is very likely that companies which offer installation service, also offer spare parts, do maintenance, and offer repair services. A concentration of paired service offerings can also be found between the service category “product lifecycle service” and “product support service”.

Figure 1: Service co-occurrence distribution



MANAGERIAL IMPLICATIONS

This paper discusses the results of an AI-based approach to investigate the servitization levels of individual regions, based on the promotion of industrial service offerings at webpages of enterprises operating in the sectors NACE 26, 27 and 28. Therefore, managers are able to derive service business strategies for their own market, based on which industrial services are already being offered. Having intelligence of their home market possibly indicates potential next steps in the development of their service offerings. The results of the service co-occurrence heat map might advertise which new service offerings complement the current portfolio.

Similar to the home market, managers are able to investigate regions for potential future service export activities. The tool demonstrates which industrial services are already offered by local manufacturer or competitors in the investigated regions. This may help managers to understand whether local customers have already been confronted with and hence are aware of a specific service category or whether the market has to be prepared for the target service (e.g. if the service is not offered at all by local companies).

Finally, the developed tool is publicly freely available (see https://www.prosperamnet.eu/). Therefore, managers can individually analyse their company website to understand whether their service offerings are visible on their webpage and how they perform in comparison with their competitors.

RESEARCH LIMITATIONS

Despite this novel approach to create a robust model, results depend on the professionalism of company webpages. Additionally, the AI-algorithm was trained with data collected by various annotators. Although the researcher conducted quality assurance measure methods (e.g. check of annotations, feedback etc.), the trainings data is exposed to different understandings of the domain knowledge and different preferences of labeling. Due to the focused investigation of industry sectors NACE 26,27 and 28 and specific regions, the study is exposed to industry and regional biases. Regional differences in the online service presentation may lead to deviations between communication and real service offerings. During the development of the Artificial Intelligent algorithm certain parameters were decided on by the research consortium which might expose the study to programming biases (e.g.: fuzziness - “noise” in the precision and recall ratio).

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APPENDIX 1: Results of service detected by the artificial algorithm

	Presale Service		Product Support Service				Product Lifecycle Services					R&D Services			Operational Services			Financial Services			
	product demonstrations	customer seminars	warranty	technical user training	customer consulting & support by phone	testing, test rigs, quality assurance	installation services	repair services	spare parts	maintenance	retrofit modernization upgrades	research service	prototype design & development	feasibility studies	project management	service for operating the product for the customer	service for operating customer's processes	pay per use	instalment payment	leasing	rental system
Austria	17%	27%	23%	31%	33%	23%	40%	41%	38%	40%	24%	24%	41%	28%	36%	2%	17%	1%	2%	3%	5%
Germany (Bavaria)	20%	33%	26%	38%	36%	30%	41%	41%	42%	41%	29%	28%	53%	33%	32%	2%	17%	1%	1%	3%	7%
Germany (Saxony)	14%	25%	21%	31%	29%	34%	48%	43%	37%	41%	26%	26%	59%	33%	34%	1%	13%	1%	2%	2%	6%
Hungary	8%	13%	19%	18%	17%	17%	32%	33%	32%	28%	18%	24%	26%	14%	22%	1%	9%	1%	1%	2%	2%
Italy (Veneto)	2%	3%	6%	3%	7%	5%	4%	9%	5%	7%	2%	11%	21%	11%	5%	0%	2%	0%	0%	1%	2%
Slovakia	14%	15%	15%	18%	20%	22%	22%	29%	24%	25%	11%	19%	23%	15%	23%	4%	12%	1%	2%	2%	2%
Slovenia	8%	6%	13%	10%	16%	15%	21%	20%	23%	19%	10%	15%	16%	8%	11%	1%	8%	0%	0%	0%	3%
Total	12%	17%	17%	21%	22%	21%	30%	31%	29%	29%	17%	21%	34%	20%	23%	2%	11%	1%	1%	2%	4%