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## **THE APPLICATION OF CONCEPTNET FOR KNOWLEDGE MANAGEMENT OF TEXTS IN THE POLISH AND ENGLISH LANGUAGES**

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In the paper, the possibility of ConceptNet application for knowledge management of texts in the Polish and English language is discussed. ConceptNet is a freely-available semantic network, designed to help computers understand the meanings of words that people use, it contains concepts from many languages. The semantics of ConceptNet is presented in the context of the semantics of the EuroVoc which is based on the SKOS standard. Indexing tool, created by authors, based on ConceptNet is briefly described. Tests of texts indexing with the use of papers in Polish and English language were performed. Results are analyzed and evaluated. At the end, some conclusions about the quality of results are formulated.

Keywords: Knowledge management, Semantic network, Text indexing

### **1. Introduction**

Nowadays people have the enormous amount of information contained in the various types of documents. Excess information makes it difficult to find the content people looking for. Fortunately, summaries and keywords can help during a selection of the most interesting texts. Today documents are stored primarily in digital form in huge computer archives. To manage archives of documents, software tools that perform tasks such as automatic indexing are very useful. Especially in the Internet, search engines use specific algorithms for texts indexing to help find interesting information. Such tools like Google or Bing work very well. How-

ever search engines are not always the best solution, although using the advanced search option. It is often important that the theme and vocabulary should be precisely defined and then we need tools based on the dictionaries built on precisely specified standards. Additionally, it is important to search for semantically similar information. To ensure this, we need thesauruses or ontologies that contain semantic relationships between words. Moreover, in today's organizations information must be available at the same time in different languages. This is the case in international corporations and also in UN agencies or the EU institutions. It means that tools must enable simultaneous search in multiple languages.

The main aim of the work was to evaluate the usefulness of ConceptNet [1], a freely-available semantic network, for multilingual, Polish and English, indexing. Especially we concentrated on the quality of semantic relations included in ConceptNet and use them to determine the keywords. An essential part of the task was to perform a short review of standards, especially SKOS and EuroVoc dictionary, which support semantic relationships and multilingualism and compare them with ConceptNet. An additional goal was an implementation of the simple indexation system based on ConceptNet to test its capabilities in practice.

The rest of this paper is organized as follows: in Sect. 2 the standards of thesauri together with analysis of semantic possibilities are discussed. In Sect. 3 ConceptNet capabilities are presented together with indexation application based on them. We finish with test results presenting, evaluation of usefulness of ConceptNet and brief final remarks in Sect. 4.

## 2. Multilingual thesauri standards

For management of knowledge included in texts, we need dictionaries with a lot of information about the word semantic relationships. The most interesting type of dictionary is a thesaurus. Two standards for thesauri were defined by ISO. The first, ISO 2788, is titled "Guidelines for the establishment and development of monolingual thesauri"; it was published in 1974 and revised in 1986. The second, ISO 5964, was published in 1985 and titled "Guidelines for the establishment and development of multilingual thesauri"; it is connected with the ISO 2788. The two mentioned standards were joined and extended as ISO 25964 "Information and documentation - Thesauri and interoperability with other vocabularies" [2]. This standard contains two parts: "Thesauri for information retrieval" published in 2011, and "Interoperability with other vocabularies" published in 2013. Semantic in ISO 25964 is based on *Thesaurus Concept*, this is something that exists in the mind as abstract entities independent of terms used to express them; word or phrase used to label a concept is called *Thesaurus Term*. Every concept has the *Preferred Term* and may have *Simple Non Preferred Term*. Between synonyms and near-synonyms we have equivalence relation - *USE*. It suggests the use of a different term (pointed

by *USE*). Relation *UF* - use for – means reciprocal to *USE*. There is additionally defined *Compound Equivalence* when a phrase corresponds to a particular term. Hierarchical relationship (between broader and narrower concepts) can be defined by *Broader Term* (BT) and *Narrower Term* (NT). Each concept can have a pointer linking it to the concept at the top of any hierarchy in which it occurs. Associative relationship *Related Term* (RT) is defined between concepts that are closely related in some non-hierarchical way and represents a preferred term for the concept that has an association with the one. Possibility of adding attributes and labels make semantic stronger. Moreover, groups of sibling concepts, which have a common parent concept, may be organized into arrays introduced by node labels. We have to note that the old standards are still important in the sense that multiple implementations of thesauri are based on old versions. Relations in older standards are analogous to 25964 but everything is based on terms (i.e. term are not clear distinguished from concept).

W3C recommendation Simple Knowledge Organization System (SKOS) [3] is a part of Semantic Web standards. SKOS is an XML dialect built upon RDF and RDFS, other parts of the Semantic Web family of standards. Additionally SKOS was extended by extension for labels (SKOS-XL), which was defined to provide additional support for describing and linking lexical entities [4]. SKOS was designed with a big influence of described above ISO-2788/5964 standards. Generally, it is a big correspondence between them and it is easy to convert one to the other, details about this correspondence are described in Appendix of [5] and [6, 7]. The main difference is that ISO standards focus on how to build and manage a thesaurus, but SKOS focuses on how to publish a vocabulary in a format easy to process by computer and compliant with the Semantic Web standards. The SKOS data model is concept-based. SKOS supports rich semantics for classes (Concept, Collection, Concept Scheme), object properties (has broader, has broader match, has broader transitive, has close match, has exact match, has member, has member list, has narrower, has narrower match, has narrower transitive, has related, has related match, has top concept, is in mapping relation with, is in semantic relation with), and annotation properties (preferred label, alternative label, note etc.). More information about other similar standards was presented in [8].

Multilingual thesaurus EuroVoc [9] is an example of ISO standards implementation and at the same time SKOS and SKOS-XL implementation. It is multidisciplinary and covers all issues relating to the activities of the European Parliament and contains terms in 23 EU languages (Bulgarian, Croatian, Czech, Danish, Dutch, English, Estonian, Finnish, French, German, Greek, Hungarian, Italian, Latvian, Lithuanian, Maltese, Polish, Portuguese, Romanian, Slovak, Slovenian, Spanish and Swedish), 24-th version Gaelge i.e. Irish is under translation. Moreover EuroVoc has versions in three languages of UE candidate countries: Macedonian (македонски - mk), Albanian (shqip - sq) and Serbian (српски - sr). The dic-

tionary is intended for use during simultaneous translation, preparation of documents and to provide a controlled vocabulary for the information management software tools. It contains over 7000 terms grouped into domains and subdomains. SKOS and SKOS-XL implementation (file in RDF format) The EuroVoc is available in ISO standards through web page additionally user can download it as the set of pdf documents. Moreover, digital version in SKOS/RDF format is possible to download. The EuroVoc is based on dedicated ontology defined in SKOS and SKOS-XL standards. For programmers, set of SKOS/RDF files and supplemental XML files are provided together with simple ReST service with limited functionality.

Through the web interface, we can obtain semantic relations of selected term (concept). In the Figure 1 result for “public administration” concept is presented in the Polish language on the left side and English on the right side. A similar result can be obtained from pdf files.

<p><b>administracja publiczna</b>  <b>04 ŻYCIE POLITYCZNE</b>            MT 0436 władza wykonawcza i służba publiczna            NT1 administracja centralna                NT2 ministerstwo            NT1 administracja elektroniczna            NT1 administracja lokalna            NT1 administracja regionalna            NT1 analiza polityki [4.8]            NT1 instytucja publiczna            NT1 kształtowanie polityki            NT1 nadzór administracyjny            NT1 partnerstwo publiczno-prywatne            NT1 polityka władz publicznych            NT1 przedstawiciele samorządów lokalnych i regionalnych            NT1 siedziba organu            NT1 służba publiczna            NT1 stosunki administracja-obywatel                NT2 formalności administracyjne                NT2 jawność administracyjna                NT2 rzecznik praw obywatelskich                NT2 zażalenie administracyjne            RT budynek publiczny [ 2846 ] nauki administracyjne [ 3611 ] organy państwowe [ 0406 ] władza dyskrecyjna [ 0406 ]  <b>URI</b> <a href="http://eurovoc.europa.eu/77">http://eurovoc.europa.eu/77</a>  <b>Has Exact Match</b>  <i>Public administration (AGROVOC) administration (AGROVOC) Public administration (ECLAS) administration (GEMET) Public administration (STW Thesaurus for Economics) public administration (Unbis Thesaurus)</i></p>	<p><b>public administration</b>            UF <i>general government</i>  <b>04 POLITICS</b>            MT 0436 executive power and public service            NT1 administration headquarters            NT1 administrative supervision            NT1 central government                NT2 ministry            NT1 citizen-authority relations                NT2 administrative formalities                NT2 administrative transparency                NT2 appeal to an administrative authority                NT2 mediator            NT1 electronic government            NT1 local government            NT1 policy analysis [4.8]            NT1 policymaking            NT1 public institution            NT1 public policy            NT1 public-private partnership            NT1 public service            NT1 regional government            NT1 representative of local or regional authority            RT administrative science [ 3611 ] discretionary power [ 0406 ] public authorities [ 0406 ] public building [ 2846 ]  <b>URI</b> <a href="http://eurovoc.europa.eu/77">http://eurovoc.europa.eu/77</a>  <b>Has Exact Match</b>  <i>Public administration (AGROVOC) administration (AGROVOC) Public administration (ECLAS) administration (GEMET) Public administration (STW Thesaurus for Economics) public administration (Unbis Thesaurus)</i></p>
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**Figure 1.** Concept of “public administration”  
 Source: EuroVoc web page [10]



Terms are described according to ISO standard, NT1 means narrower term one level down, NT2 two levels down. UF denotes that public administration is preferred term for “general government”. Contrary “general government” has USE relation with “public administration”. We have to note that every concept has its own identifier; “public administration” has 77. Related concepts similarly have unique identifiers “administrative science” 3611, “discretionary power” – 0406, “public authorities” – 0406, “public building” - 2846. Additionally, we have some extensions: domain – 04 POLITICS, and subdomain - MT 0436 executive power and public service. Moreover, analogous terms in other dictionaries are presented in HasExactMatch section. We can easily obtain versions in other languages with the web interface or from files with parallel concepts listings. We can see in the Polish language we have no synonyms.

```

<rdf:Description rdf:about="http://eurovoc.europa.eu/77">
  ...
  <dc:identifier>77</dc:identifier>
  ...
  <skos:prefLabel xml:lang="nl">overheidsadministratie</skos:prefLabel>
  <skos:prefLabel xml:lang="en">public administration</skos:prefLabel>
  ...
  <skos:altLabel xml:lang="en">general government</skos:altLabel>
  <skos:altLabel xml:lang="de">Behörde</skos:altLabel>
  ...
  <skos:prefLabel xml:lang="pl">administracja publiczna</skos:prefLabel>
  <skos:altLabel xml:lang="cs">orgány státní správy</skos:altLabel>
  ...
  <skosxl:prefLabel rdf:resource="http://eurovoc.europa.eu/209582"/>
  ...
  <skos:narrower rdf:resource="http://eurovoc.europa.eu/6894"/>
  ...
  <skos:prefLabel xml:lang="fi">julkinen hallinto</skos:prefLabel>
  <skosxl:prefLabel rdf:resource="http://eurovoc.europa.eu/328377"/>
  ...
</rdf:Description>

```

**Figure 2.** Concept of “public administration”

*Source:* EuroVoc SKOS/RDF file [11]

In the Fig. 2 fragment of SKOS/RDF file for “public administration” concept is presented. As we can see all information is included in <rdf:Description rdf:about="http://eurovoc.europa.eu/77"> element with identifier 77. There are preference label for Polish term <skos:prefLabel xml:lang="pl"> administracja publiczna</skos:prefLabel> and for English term <skos:prefLabel xml:lang="en">public administration</skos:prefLabel>. We have to note that terms are defined separately in SKOS document and have its own identifiers (Fig. 3), in the Fig. 2 we have listed English preference label second time as <skosxl:prefLabel rdf:resource="http://eurovoc.europa.eu/209582"/>.

Preference label for term in Polish “administracja elektroniczna” is listed second time too: `<skosxl:prefLabel rdf:resource="http://eurovoc.europa.eu/328377"/>` (Fig. 3). Narrower or broader terms are pointed by their identifier for “electronic government” we have `<skos:narrower rdf:resource="http://eurovoc.europa.eu/6894"/>`.

```

<rdf:Description rdf:about=http://eurovoc.europa.eu/209582
  <rdf:type rdf:resource="http://www.w3.org/2008/05/skos-xl#Label"/
  <owl:versionInfo rdf:datatype="http://www.w3.org/2001/XMLSchema#string">n/a</owl:versionInfo>
  <skosxl:literalForm xml:lang="en">public administration</skosxl:literalForm>
  <dct:type rdf:resource="http://publications.europa.eu/resource/authority/label-type/STANDARDLABEL"/>
</rdf:Description>
...
<rdf:Description rdf:about="http://eurovoc.europa.eu/328377">
  <rdf:type rdf:resource="http://www.w3.org/2008/05/skos-xl#Label"/>
  <owl:versionInfo rdf:datatype="http://www.w3.org/2001/XMLSchema#string">n/a</owl:versionInfo>
  <skosxl:literalForm xml:lang="pl">administracja publiczna</skosxl:literalForm>
  <dct:type rdf:resource="http://publications.europa.eu/resource/authority/label-type/STANDARDLABEL"/>
</rdf:Description>

```

**Figure 3.** Terms “public administration” and “administracja publiczna”  
*Source:* EuroVoc SKOS/RDF file [11]

EuroVoc like ConceptNet is dedicated to the wide range of issues. EuroVoc is not only one example of SKOS implementation. There are many dictionaries dedicated to specific topics. Very well-known is AGROVOC [12], huge multilingual thesaurus in the agriculture domain. EuroVoc has fewer extensions to SKOS format than AGROVOC and allows for a simpler illustration of semantic relationships. More information about other multilingual dictionaries was presented in [8]. Applications of AGROVOC to indexing agricultural texts in Polish and English language were discussed by us in [8]. More examples of indexing tools are presented in [8] and [16].

### 3. ConceptNet

ConceptNet is a freely-available semantic network, designed to help computers understand the meanings of words that people use [1]. It started from the crowdsourcing project Open Mind Common Sense, which was launched in 1999 at the MIT Media Lab. At the beginning the facts were collected from people who came to the Open Mind Common Sense site. Today ConceptNet is a huge graph of general knowledge representing words and phrases and the relationships between them. The data is taken from a variety of resources. Big collection of facts is acquired from Open Mind Common Sense. Much information is extracted from parsing Wiktionary, in multiple languages. Wiktionary gives information about synonyms, antonyms, translations of concepts into hundreds of languages, and multiple

labeled word senses for many words. The next source of knowledge is games with a purpose (such as Verbosity and nadya.jp) designed to collect common knowledge. These games give knowledge about people’s intuitive word associations. Expert-created dictionary-style knowledge comes from WordNet, Open Multilingual WordNet and JMDict (Japanese-multilingual dictionary). Some knowledge comes from OpenCyc, a hierarchy of hypernyms provided by Cyc a system that represents common sense knowledge in predicate logic. Moreover, ConceptNet is connected to a subset of DBpedia, which extracts knowledge from Wikipedia articles. With the combination of these sources, ConceptNet contains over 21 million edges and over 8 million nodes. Its English vocabulary contains approximately 1,500,000 nodes, and there are 83 languages in which it contains at least 10,000 nodes. The largest source of input for ConceptNet is Wiktionary, which provides 18.1 million edges and is mostly responsible for its large multilingual vocabulary [13].

Terms and phrases are nodes in ConceptNet graph. Generally nodes (terms) are identified by URLs, for example, /c/en/vegetable/, and language code is a part of an identifier. Nodes are connected with edges. An edge, or assertion, is a unit of knowledge which describes a particular relation between two nodes - natural-language terms. Every assertion has a relation: start node and end node; it means that generally assertions are directed. Rich semantic is supported by 36 core relations. There are defined 7 symmetric relations: Antonym, DistinctFrom, EtymologicallyRelatedTo, LocatedNear, RelatedTo, SimilarTo, and Synonym. The directionality of symmetrical edges is not important; start node can be exchanged with end node. Moreover there are defined twenty nine asymmetric relations: AtLocation, CapableOf, Causes, CausesDesire, CreatedBy, DefinedAs, DerivedFrom, Desires, Entails, ExternalURL, FormOf, HasA, HasContext, HasSubevent, HasFirstSubevent, HasLastSubevent, HasPrerequisite, HasProperty, InstanceOf, IsA, MadeOf, MannerOf, MotivatedByGoal, ObstructedBy, PartOf, ReceivesAction, SenseOf, SymbolOf, and UsedFor. For example, IsA relation describes hierarchical relation and means that start node is a subtype or a specific instance of end node. We have to note that there is separate relation InstanceOf which means that start node is an example of end node. Some asymmetric relations are opposite to each other, for example PartOf is reverse to HasA. Synonym means that start node and end node have very similar meanings. It should be emphasized that Synonym may be term translation in a different language. Very important is FormOf relation it describes that start node is an inflected form of end node; end node is the root word of start node. We illustrate above remarks on examples, starting from “public administration”.

In the Fig. 4 a fragment of JSON file for “administracja publiczna” is presented. The file is relatively small; node /c/pl/administracja\_publiczna/ has only two edges. The first edge is relation r/ExternalURL/ which connects it with node

/http://pl.dbpedia.org/resource/Administracja\_publiczna/ (for short in Fig. 4 only id is presented). The second edge is relation r/Synonym/ and connects it with English translation node /c/en/public\_administration/. This edge is presented in its entirety in the Fig. 4 to show a full edge description. The edge details: start node, end node and sources of information are described.

```

{
  "@context": [ "http://api.conceptnet.io/ld/conceptnet5.6/context.ld.json" ],
  "@id": "/c/pl/administracja_publiczna",
  "edges": [
    { "@id": "/a[/r/ExternalURL/,/c/pl/administracja_publiczna/,http://pl.dbpedia.org/resource/Administracja_publiczna/]",... },
    { "@id": "/a[/r/Synonym/,/c/pl/administracja_publiczna/,/c/en/public_administration/]",
      "@type": "Edge",
      "dataset": "/d/dbpedia/en",
      "end": {
        "@id": "/c/en/public_administration",
        "@type": "Node",
        "label": "public administration",
        "language": "en",
        "term": "/c/en/public_administration"
      },
      "license": "cc:by-sa/4.0",
      "rel": {
        "@id": "/r/Synonym",
        "@type": "Relation",
        "label": "Synonym"
      },
      "sources": [
        {
          "@id": "/s/resource/dbpedia/2015/en",
          "@type": "Source",
          "contributor": "/s/resource/dbpedia/2015/en"
        }
      ],
      "start": {
        "@id": "/c/pl/administracja_publiczna",
        "@type": "Node",
        "label": "administracja publiczna",
        "language": "pl",
        "term": "/c/pl/administracja_publiczna"
      },
      "surfaceText": null,
      "weight": 0.5
    }
  ]
}

```

**Figure 4.** Term “administracja publiczna”.

*Source:* ConceptNet API [14]

In the Fig. 5 fragments of JSON file for “public administration” are presented. There are more than 70 edges. Most of them are edges with Synonym relation -

translation to other languages. It is interesting that some Synonyms, even it is symmetric relation, are present as two edges, for example for French translation we have `/a/[r/Synonym/,c/fr/administration_publique/, /c/en/public_administration/]` and `/a/[r/Synonym/,c/en/public_administration/n/, /c/fr/administration_publique/]`. For most languages, among them Polish, we have only one edge start node is in particular language, but end node is in English. For the Polish language we have `/a/[r/Synonym/,c/pl/administracja_publiczna/, /c/en/public_administration/]`. For the Japanese language we have three edges two edges `/a/[r/Synonym/,c/ja/行政学/n/,c/en/public_administration/]`, and one edge `/a/[r/Synonym/,c/en/public_administration/n/,c/ja/行政/]`. It is connected with source of information. It is Japanese-multilingual dictionary (jmdict/1.07), DBPedia (dbpedia/2015/en) and Wiktionary (wiktionary/en). For some languages, like French, there are two sources DBPedia (dbpedia/2015/en) and Wiktionary (wiktionary/en). For Polish, there is only one source DBPedia (dbpedia/2015/en).

```

{
  "@context": [ "http://api.conceptnet.io/ld/conceptnet5.6/context.ld.json" ],
  "@id": "/c/en/public_administration",
  "edges": [
    {"@id": "/a/[r/Synonym/,c/ja/行政学/n/,c/en/public_administration/]", ... },
    {"@id": "/a/[r/ExternalURL/,c/en/public_administration/,http://dbpedia.org/resource/Public_administration/]",...
    },
    {"@id": "/a/[r/ExternalURL/,c/en/public_administration/,http://wikidata.dbpedia.org/resource/Q31728/]", ... },
    {"@id": "/a/[r/RelatedTo/,c/en/public_administration/n/,c/en/administration/]", ... },
    ...
    {"@id": "/a/[r/Synonym/,c/en/public_administration/n/,c/de/öffentliche_verwaltung/]",... },
    {"@id": "/a/[r/Synonym/,c/en/public_administration/n/,c/fr/administration_publique/]",... },
    {"@id": "/a/[r/Synonym/,c/en/public_administration/n/,c/ja/行政/]",... },
    ...
    {"@id": "/a/[r/Synonym/,c/en/public_administration/n/,c/zh/公共行政/]",... },
    {"@id": "/a/[r/Synonym/,c/ar/إدارة_علمة/,c/en/public_administration/]",... },
    ...
    {"@id": "/a/[r/Synonym/,c/fr/administration_publique/,c/en/public_administration/]",... },
    ...
    {"@id": "/a/[r/Synonym/,c/ja/行政学/,c/en/public_administration/]",... },
    ...
    {"@id": "/a/[r/Synonym/,c/pl/administracja_publiczna/,c/en/public_administration/]",... },
    ...
    {"@id": "/a/[r/Synonym/,c/zh/公共行政学/,c/en/public_administration/]",... },
    {"@id": "/a/[r/ExternalURL/,c/en/public_administration/,http://en.wiktionary.org/wiki/public_administration/]",
    ... }
  ],
  ...
}

```

**Figure 5.** Term “public\_administration”  
*Source:* ConceptNet API [14]

From edges with relation FormOf we can obtain inflected forms. To illustrate this we can show edges for the term “administracja”. In the Fig. 6 fragment of JSON file for “administracja” is presented. We have inflected forms: *administracjach*, *administracją*, *administracjami*, *administracje*, *administrację*, *administracji*, *administracjo*, *administracjom*, *administracyj*. All forms (except the last) appear two times, the edges differ only by the noun designation (/n) and additionally we have edges with the same forms and RelatedTo relation. Sources of inflected forms are French and German Wiktionary. There are two additional edges with RelatedTo: */a[/r/RelatedTo/,c/pl/administracja/n/,c/fr/administration/]* and */a[/r/RelatedTo/,c/pl/administracja/n/,c/en/administration/]*. Moreover there are three edges with Polish Synonyms: *rząd*, *zarząd*, *zarządzać* and */a[/r/Synonym/,c/en/administration/n/,c/pl/administracja/]*.

```

{
  "@context": [ "http://api.conceptnet.io/ld/conceptnet5.6/context.ld.json" ],
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  ]
}

```

**Figure 6.** Term “administracja”  
 Source: ConceptNet API [14]

Summarizing, in ConceptNet we have much richer semantics than in EuroVoc, however, it is rather chaotic. Synonym relation is ambiguous; translation can be deduced only from the language code. There are no preferred terms. Relation IsA is analogous to broader term, but not the analogy to narrower term. The reason is that to describe narrower term ConceptNet uses the same relation IsA. For example in the description of the term cattle we have ingoing edge /a/[r/IsA/,c/en/cow/n/,c/en/cattle/n/] and in the description of the term cow we have exactly the same but outgoing edge /a/[r/IsA/,c/en/cow/n/,c/en/cattle/n/].

#### **4. Tests results, conclusions and future work**

The indexing tool was prepared in two symmetric versions, to index English text with Polish translation of main words, and to index Polish text with English translation of main words. The indexing algorithm, based on ConceptNet, consists of four steps: removing stopwords; finding the base form of a word by analyzing FormOf edges connected with the word; recognizing the part of speech (noun, verb or adjective); translating founded most frequent words into second language by Synonym edges. For testing English indexation with Polish translation we selected 8 texts published in English language in Agricultural Engineering Journal (vol. 153, 154, 155). We analyzed ten most frequent nouns and five most frequent verbs, because it allows recognizing the links among the texts [15]. Generally indexing in English based on ConceptNet worked quite good, all most important nouns were properly recognized likewise verbs. Finding basic form of word was almost perfect. Automatic translation into Polish was relatively good, even some translation had bad quality. Ten important nouns were translated in 85%, five verbs only in 67% of cases. For testing Polish indexation with translation into English we selected nineteen publications in Polish language from older volumes of the same journal as above (the same papers, particularly abstracts, were used in the analysis performed in [16] to evaluation Polish indexer based on AGROVOC and comparing it to other indexers). The first seven papers are connected with maize cultivation and production; the next twelve generally are connected with potatoes. Indexing in Polish based on ConceptNet worked relatively good, almost all most important nouns were properly recognized. Finding basic form of word was about 90% for nouns and 98% for verb. Unfortunately many verbs were unrecognized because they are absent in ConceptNet. Automatic ten important nouns translation into English was similar to English indexer - 81%. Five important verbs were properly translated in 77%.

To summarize we can conclude that ConceptNet allows finding the basic forms of nouns; however simple algorithm based on ForOf relation is not enough. Situation with parallel translation into second language is much complicated. ConceptNet contains much common knowledge, which in fact hinders the automatic

translation. For example the Polish word *kukurydza* has two English synonyms: corn and maize. On the other hand word corn has four synonyms in Polish: *kukurydza*, *nagniotek*, *odcisk*, *odgniotek*. Similarly the Polish word *krowa* has two English synonyms: cow and bag. Unfortunately relation is not symmetric because at the same time the English word cow has synonyms *klepa*, *krowa*, *prukwa*, *pułło*. Generally the biggest problem is chaotic semantics. Relation FormOf is not consequently used, sometimes it is replaced by RelatedTo. Similar situation is with Synonym relation. In conclusion, it can be pointed that ConceptNet is suitable rather as a helper tool. The base of indexers should be thesauri based on standards such as EuroVoc.

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## **OPTIMIZATION OF TRANSPORT POTENTIAL OF THE TRANSPORTATION COMPANY TAKING INTO ACCOUNT RANDOM DEMAND FOR TRANSPORT SERVICES**

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Is considered a transport company, which operates a uniform in the sense of destination, means of transport for example tankers, with random exploitation characteristics. The company's transport potential is measured by the number of transportable means of transport for a sufficiently long period of time. The company operates on the market of transport services, where the demand for transport services is also random. The problem of optimizing the transport potential of a transport company is being considered, taking into account the random demand for transport services.

Keywords: transport potential, demand, stochastic process.

### **1. Introduction**

One of the basic problems of transport company management is to ensure its continuous presence on the market of transport services. This is achieved mainly by ensuring the appropriate transport potential of the means of transport available, in line with the anticipated demand for transport services [8, 18].

The transport potential of a transport company is usually equated with the number of means of transport (ST) capable of providing transport services at a given time. Reducing the number of ST below a certain minimum (threshold value)

will reduce the company's transport potential, hence the loss of its competitiveness and, as a consequence, the company's falling out of the transport services market.

The maladjustment of the transportation company's transport potential to the demand for transport services, which will be shaped on the market of these services in the time horizon anticipated by the company, naturally leads to the following two situations:

- reduce the company's competitiveness in the transport services market, and even exit the market when transport capacity is lower than demand,
- incurring additional costs by the company due to not utilizing the transport potential exceeding the demand for transport services.

One of the measure of matching the transportation potential of a transport company to the demand for transport services may be the probability that in the forecast time horizon the transport potential will not be exceeded by demand - in the first situation or transport potential is exceeded by demand - in the second situation.

Usually, the first situation among the above-mentioned generates greater consequences for the transport company and will therefore be considered further, while the random nature of both the demand for transport services created by the market and the supply of transport services by the company will be taken into account [5].

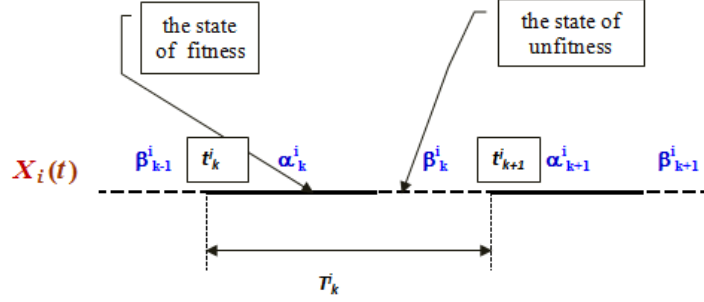
## 2. Transport potential – supply of transport services

Consider the transport company [5], which has  $I$  of means of transport (ST) for the same destiny (e.g. trucks) and used to meet the demand for homogeneous type of transport services (e.g. transport of bulk cargo). Let  $\mathbf{I} = \{I_1, I_2, \dots, I_n\}$  be the set of numbers of ST that do not need to be the same, i.e. they do not have to have the same design solutions.

It is assumed that from the point of view of the transport company the process of each ST can be considered as a succession over time of independent states:

- the state of fitness of the ST for the implementation of transport services,
- the state of unfitness of the ST for the implementation of transport services (e.g. ST repair).

Thus, the process of exploitation of each ST can be considered as a two-state stochastic process  $\mathbf{X}(t)$  (Fig. 1), which is a sequence of consecutive (not overlapping in time) states fitness (rectangular pulses), separated states of unfitness.



**Figure 1.** Example of a exploitation process of the  $i$ -th, ( $i \in I$ ) of ST.

Fig. 1 are symbolized  $\alpha_k^i, \alpha_{k+1}^i, \dots, (k = 1, 2, \dots)$  durations of states fitness of  $i$ -th ST, and symbols  $\beta_k^i, \beta_{k+1}^i, \dots, (k = 1, 2, \dots)$  - durations his of states unfitness.

Let that  $\alpha_k^i, (k = 1, 2, \dots)$  are realizations of continuous random variables,  $A_k^i$  respectively, with the same probability distributions. For simplify the notation, each of these random variables will be denoted by symbol  $A_i$ . Let that  $\beta_k^i, (k = 1, 2, \dots)$  are realizations of continuous random variables,  $B_k^i$  respectively, with the same probability distributions. For simplify the notation, each of these random variables will be denoted by symbol  $B_i$ . With the use of  $t_k^i$  and  $t_{k+1}^i$ , the moments of occurrence of two successive states of fitness,  $i$ -th ST, were determined, and with the help of  $T_k^i$  - the length of the time interval between occurrences of these states.

Using the designations shown in Fig. 1, exploitation process of  $i$ -th ST you can be represented as a stochastic process, in which the condition is satisfied:

$$T_k^i = t_{k+1}^i - t_k^i > \alpha_k^i. \quad (1)$$

It is assumed that the processes of exploitation of all ST are stochastic processes, which are independent and stationary in a broader sense. Thus, for the  $i$ -th ST can be determined the expected length of time between occurrences of two consecutive states of fitness, which is expressed in the following formula:

$$ET_i = \int_0^{\infty} T \cdot f_i(T) dT \quad (2)$$

where  $f_i(T)$  is the density function of the probability distribution of the random variable describing the length of time between occurrences of two consecutive states of fitness) the process of exploitation the  $i$ -th ST.

Is assumed that are known density functions  $f_i^\alpha(t)$  and  $f_i^\beta(t)$  of probability distributions of random variables  $A_i$  and  $B_i$  respectively. It is also assumed that the random variables  $A_i$  and  $B_i$  are independent from each other and that have finite variances and finite expected values  $Ea_i$  and  $Eb_i$  expressed by the following formulas:

$$\begin{aligned} Ea_i &= \int_0^{\infty} \alpha \cdot f_i^\alpha(\alpha) d\alpha, \\ Eb_i &= \int_0^{\infty} \beta \cdot f_i^\beta(\beta) d\beta. \end{aligned} \quad (3)$$

If the process exploitation of car is stationary, the probability that in randomly chosen time moment  $\xi$  there occurs the state of fitness is given by the formula:

$$p_i = \frac{Ea_i}{ET_i} = E\mu_i \cdot Ea_i \quad (4)$$

where  $E\mu_i$  - expected frequency of occurrence state of fitness, wherein

$$E\mu_i = \frac{1}{ET_i} = \frac{1}{Ea_i + Eb_i}. \quad (5)$$

It is assumed that the transport company will have the required potential of lading when in the required period of time in a state of fitness would be no less cars than the threshold number  $s$ , resulting from the estimated level of demand for transport services.

Due to the fact that the transport companies can include a different number of different transport means and to exploit them under different conditions of the threshold number of means of transport in those companies will also be different. The threshold number of ST should be set so that:

- was the smallest possible under the given conditions,
- took into account the process of shaping the demand for transport services in the area of the company's operations.

The independence of the process of ST exploitation, this means that it is possible that a randomly chosen moment in a state of alertness may also be more than one ST. Let  $X(t)$  is the resultant of a process exploitation of cars. It is a process binary (the state of fitness and the state of unfitness), in which the state of fitness, means

the state referred to as **TE** (*technical efficiency*), formed by superposition of states fitness any ST in number, at least equal to the threshold number of ST  $s$ , ( $s = 1, 2, \dots, I$ ). **TE** state will be taken as the desired state when its duration is not less than the established value  $\tau$ . In other cases, the status of **TE** will be treated as a state indicating the inability to satisfy the demand for transport services at the required level;  $\tau$  value is determined for each company separately.

It is important for the management of the transport company to know the expected value of the duration of the fitness period **TE**, when the company has only  $k$  fit ST from all existing  $I$ . Let  $Y_I(t)$  mean the stochastic process of the form [5, 7]:

$$Y_I(t) = \sum_{i=1}^I X_i(t). \quad (6)$$

For the assumptions regarding the exploitation processes of ST, an event that in the random moment  $\xi$  of ST from among cars owned by the company is able to fitness can be written as:

$$Y_I(\xi) = k, \quad k = 0, 1, 2, \dots, I. \quad (7)$$

The probability of this event is expressed by formula:

$$\gamma_{I,k} = \frac{I}{k!} \frac{d^k}{dx^k} \prod_{i=1}^I (q_i + xp_i) \Big|_{x=0}, \quad k = 0, 1, 2, \dots, I, \quad (8)$$

at the condition

$$\sum_{k=0}^I \gamma_{I,k} = 1, \quad (9)$$

where  $p_i$  is expressed by equation (4), and  $q_i = I - p_i$ .

In practice, the **TE** state will usually be treated as desirable, if its duration is not shorter than at least a fixed value of  $\tau$ , determined for each enterprise individually.

Taking into account the assumptions regarding the processes of ST exploitation, it is possible to determine the probability that the **TE** state obtained as a result of the  $k$  coincidence of means of transport from among  $I$  these means, owned by the company, will last no shorter than a certain value of  $\tau > 0$ . It is expressed as a dependence [5]:

$$\gamma_{I,k}(\tau) = \frac{I}{k!} \frac{d^k}{dx^k} \prod_{i=1}^I (Q_i(\tau) + xP_i(\tau)) \Big|_{x=0}, \quad k = 0, 1, 2, \dots, I, \quad (10)$$

where, taking into account (5)

$$P_i(\tau) = E\mu_i \int_{\tau}^{\infty} (x - \tau) f_i^{\alpha}(x) dx = E\mu_i \int_{\tau}^{\infty} dx \int_x^{\infty} f_i^{\alpha}(y) dy, \quad i = 1, 2, \dots, I,$$

$$Q_i(\tau) = E\mu_i \int_{\tau}^{\infty} (x - \tau) f_i^{\beta}(x) dx = E\mu_i \int_{\tau}^{\infty} dx \int_x^{\infty} f_i^{\beta}(y) dy, \quad i = 1, 2, \dots, I.$$

It is possible to determine the function of density of the probability distribution of the duration of the *TE* state created by coincidence of fitness states  $k$ , ( $k = 0, 1, 2, \dots, I$ ) of any among  $I$  means of transport, which will last no shorter than a certain amount  $\tau > 0$  [5, 7]:

$$f_{I,k}^{\alpha}(\tau) = \frac{I}{E\mu_{I,k}(\tau)} \frac{d^2}{d\tau^2} \gamma_{I,k}(\tau), \quad k = 0, 1, 2, \dots, I \quad (11)$$

where

$$E\mu_{I,k}(\tau) = -\frac{I}{k!} \frac{\partial^{k+1}}{\partial x^k \partial \tau} \prod_{i=1}^I (Q_i(\tau) + xP_i(\tau)) \Big|_{x=0}, \quad k = 0, 1, 2, \dots, I. \quad (12)$$

Let  $E\lambda_{I,k}$  denote the expected length (duration) of the *TE* state created by the coincidence of fitness  $k$ , ( $k = 0, 1, 2, \dots, I$ ) of any among  $I$  of the means of transport. It expresses the following relationship:

$$E\lambda_{I,k} = \int_0^{\infty} \tau f_{I,k}^{\alpha}(\tau) d\tau = \frac{\gamma_{I,k}}{E\mu_{I,k}(0)}, \quad k = 0, 1, 2, \dots, I. \quad (13)$$

If the company has means of transport, which exploitation processes have similar characteristics,  $E\lambda_{I,k}$  expresses the relationship:

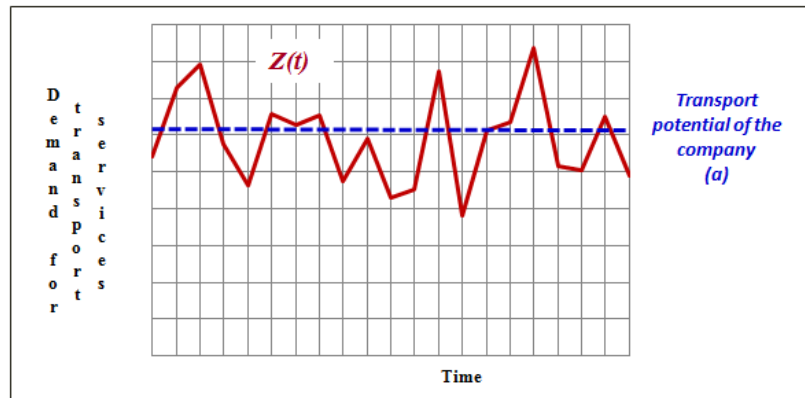
$$E\lambda_{I,k} = \frac{I}{E\mu} \frac{p(I-p)}{(I-k)p + k(I-p)}, \quad k = 0, 1, 2, \dots, I, \quad (14)$$

wherein  $p$  and  $E\mu$  express dependencies (4) and (5), respectively, and are the same for each mean of transport.

### 3. Demand for transport services

According [6] it is assumed that the further demand for transport services can be described by means of continuous stochastic process  $Z(t)$  class CC. It is assumed also that process  $Z(t)$  is stationary, ergodic and differentiable in the mean-square sense [1, 2, 3, 4, 9, 10, 11, 12, 13, 14, 15, 16, 17]. Let  $m_z$  be the expected value of this process and  $K_x(\tau) = \sigma_z^2 r(\tau)$  its correlation function, where  $r(\tau)$  defines a normalized correlation function.

Managing a transport company requires knowledge about the extent to which the supply of transport services that it can offer is matched to the forecasted demand for these services. The introduction states that one measure to match the transport capacity of a transport undertaking with the demand for transport services may be the probability that the transport potential will not be outweighed by demand over the foreseeable time horizon. Therefore, the problem considered here concerns is to determine the probability of exceedance by the demand for transport services (process  $Z(t)$ ) of the transport potential of transport company fixed at a level  $a$ . An exemplary implementation of demand for transport services as a function of time (exemplary implementation of the stochastic process  $Z(t)$ ) for the constant value of the transport potential is shown in Figure 2.



**Figure 2.** Exemplary implementation of the stochastic process  $Z(t)$  describing the demand for transport services in case of value of transport potential.

Calculation of this probability is difficult for the generally formulated process  $Z(t)$ . Practically useful calculation formulas can be obtained relatively easily only for normal stochastic processes. This problem was discussed in detail in [6], and a useful calculation formula for the probability of not exceeding the transport

potential of the transport company by the demand for transport services in the  $T$ -period was obtained for the normal stochastic process in the following form:

$$P_0(a, T) = \exp\left(-\frac{T}{2\pi} \cdot \sqrt{\frac{K_z''(0)}{K_z'(0)}} \cdot \exp\left(-\frac{(a-m_z)^2}{2\sigma_z^2}\right)\right). \quad (15)$$

In the case of difficulties related to the identification of the correlation function of the process  $Z(t)$ , you can use practically useful estimates of this probability:

- lower estimation

$$P_0(a, T) \geq P_0^{\min} = \Phi\left(\frac{a-m_z}{\sigma_z}\right) - n_0 \cdot T \cdot \exp\left(-\frac{(a-m_z)^2}{2 \cdot \sigma_z^2}\right), \quad (16)$$

- upper estimation

$$P_0(a, T) \leq P_0^{\max} = \Phi\left(\frac{a-m_z}{\sigma_z}\right) \cdot \exp\left(-n_0 \cdot T \cdot \exp\left(-\frac{(a-m_z)^2}{2 \cdot \sigma_z^2}\right)\right), \quad (17)$$

where the function  $\Phi(x)$  means the integral function of Laplace, and  $n_0$  - the expected number of additions by the process  $Z(t)$  of its expected value in a unit of time, which can be taken as equal [12]:

$$n_0 = \frac{I}{2\sqrt{\pi}}. \quad (18)$$

Formulas (15) - (17) can be used when the following inequality is met:

$$T \leq \frac{\Phi\left(\frac{a-m_z}{\sigma_z}\right)}{n_0} \cdot \exp\left(\frac{(a-m_z)^2}{2 \cdot \sigma_z^2}\right) \quad (19)$$

#### 4. Optimization problem

One of the practical optimization problems that can be formulated in the case under consideration is the problem of ensuring the maximum likelihood of not exceeding the transport company's transport potential by demand for transport services in the desired period of time. Verbally, such a problem can be formulated, for example, as follows:



specify a minimum number of usable means of transport from among the  $I$  possessed with known operational characteristics, which will ensure maximization of the probability of not exceeding the company's transport potential (supply of transport services), described by the linear function  $g$  of the number of usable means of transport in a given time horizon  $\delta$ .

Using the calculation formulas given above, the above-mentioned problem can be given the following formal form:

- decision variable:

$m$  - the number of means of transport usable,

- optimization goals:

$$m \rightarrow \min \quad (20)$$

$$P_0(g(m), \delta) = \exp\left(-\frac{\delta}{2\pi} \sqrt{-\frac{K_z''(0)}{K_z'(0)}} \exp\left(-\frac{(g(m) - m_z)^2}{2\sigma_z^2}\right)\right) \rightarrow \max \quad (21)$$

- restrictions:

$$E\lambda_{t,m} \geq \delta \quad (22)$$

$$\delta \leq 2\sqrt{\pi} \cdot \Phi\left(\frac{g(m) - m_z}{\sigma_z}\right) \cdot \exp\left(\frac{(g(m) - m_z)^2}{2 \cdot \sigma_z^2}\right) \quad (23)$$

- boundary conditions:

$$\delta, T \geq 0 \quad (24)$$

$$m \in \{1, 2, \dots, I\} \quad (25)$$

The formulated problem is a probabilistic non-linear task of a two-criteria optimization whose solution is a set of combinations of the number of means of transport and the probability of not exceeding the company's potential.

## 5. Conclusions

Point 4 of this article formulates an example of the optimization problem related to the basic problem of each transport company, which is the best match of the offered by her size of transport services to the forecasted demand for these

services on the market. A particular difficulty for the company is the identification of how the demand for transport services is shaped. This paper proposes a description of demand using a normal stationary continuous stochastic process. It allowed to obtain calculation formulas enabling to carry out approximate calculations regarding the level of matching supply of transport services to the expected demand for them. Of course, the problem formulated in point 4 is not the only one possible and should be treated as an example of a formalized approach to the problem, which is usually solved using experience and intuition and statistical relations between supply and demand for transport services in the past. In case the company would be interested in minimizing the expected duration of the demand exceeded by the supply volume, the previously formulated problem should include the function of the character's purpose:

$$E\tau = \pi \sqrt{-\frac{K'_z(0)}{K''_z(0)}} \cdot \exp\left(-\frac{(g(m)-m_z)^2}{2\sigma_z^2}\right) \cdot \left(1 - \Phi\left(\frac{g(m)-m_z}{\sigma_z}\right)\right) \quad (26)$$

with unchanged restrictions, where  $E\tau$  is the expected value of the duration of the excess of demand over the supply of  $g(m)$ .

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## **ICT IN MEETING THE TRANSPORT NEEDS OF SENIORS: AN OPPORTUNITY OR A THREAT?**

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The article addresses the problems related to the transport needs of seniors, including the potential role of ICT solutions in meeting these needs. It discusses the use of ICT by seniors, as well as their needs and expectations regarding the transport system. An attempt to assign the examples of ICT solutions, that might be helpful in more effective fulfilment of the seniors' expectations concerning the desired features of transport system was undertaken. The influence of the implementation of ICT in transport system on the transport needs of seniors was discussed with the indication of the areas that will require taking additional measures and conducting further research.

Keywords: ICT, seniors, transport services, social exclusion, digital exclusion

### **1. Introduction**

The ageing of the EU society presents numerous challenges both in social and economic terms. The needs, expectations and capacities of seniors are different from the expectations of other social groups [8]. Seniors are classified as a group that is particularly at risk of social and digital exclusion. Combating exclusion is an important task for different (public, private, EU, domestic and other) entities.

Proper fulfilment of the transport needs of elderly people reduces the risk of social exclusion and improves the perceived quality of life. At the same time, the increasing use of modern information and communications solutions (ICT) by entities providing transport services may cause an increased risk of digital exclusion.

The purpose of the article is to outline the problems of the influence of the increasing application of ICT in providing transport services on the fulfilment of the transport needs of elderly people. The article uses the analysis of literature and statistical data on the ageing of the society and the degree of ICT use by seniors in order to outline the problems of the transport needs of seniors and the potential influence of ICT application on their fulfilment in the further part of the paper.

The problems of old age in the context of economic, social and cultural changes are the effect of demographic processes which have been deepening over the years. The role of elderly people in the changing demography began to be considered more precisely in 2012, which was declared as the European Year of Active Ageing and Intergenerational Solidarity [16]. The ageing of society is regarded as a strategic problem faced by many countries, including Poland – the forecasted structure of Polish society has been presented in Table 1).

**Table 1.** Polish population forecast by biological age groups (in thousands and in per cent) for 2015-2050

Age	2015		2020		2030		2040		2050	
	thousand	%	thousand	%	thousand	%	thousand	%	thousand	%
Total	38,419	100.0	38,138	100.0	37,185	100.0	35,668	100.0	33,951	100.0
0-14	5,728	14.9	5,659	14.8	4,856	13.1	4,302	12.1	4,120	12.1
15-64	26,620	69.3	25,285	66.3	23,683	63.7	21,937	61.5	18,733	55.2
65+	6,071	15.8	7,194	18.9	8,646	23.3	9,429	26.4	11,097	32.7
80+	1,560	4.1	1,684	4.4	2,206	5.9	3,373	9.5	3,537	10.4

*Source:* own study based on GUS (Statistics Poland) data [5]

Initially, the problem of the ageing of the society concerned only the rural areas, which was connected with the migration of young individuals searching for better jobs and aiming to improve the quality of life. Nowadays, not only does it concern a majority of cities, but even the entire country, as shown by the data included in Table 2.

The presented forecasts indicate that a vast majority of people (almost twice as many) aged 65 or more will live in the cities rather than in the rural areas, both in the near future and in a longer perspective [5]. The transport needs of elderly people, regardless of the place of residence, are different than the needs of other age cohorts, and require taking appropriate measures in order to adjust the available transport needs and the entire broadly understood transport system, so as to include these needs.

**Table 2.** Polish population forecast of people aged 65 and more (in thousands and in per cent) in urban and rural areas for 2015-2050

Specification		2015		2020		2030		2040		2050	
		thousand	%	thousand	%	thousand	%	thousand	%	thousand	%
Cities	Total	23,129	100.0	22,716	100.0	21,618	100.0	20,234	100.0	18,826	100.0
	65+	3,936	17.0	4,719	20.8	5,477	25.3	5,691	28.1	6,533	34.7
	80+	966	4.2	1,076	4.7	1,482	6.9	2,207	10.9	2,143	11.4
Villages	Total	15,290	100.0	15,421	100.0	15,567	100.0	15,434	100.0	15,125	100.0
	65+	2,134	14.0	2,475	16.1	3,169	20.4	3,738	24.2	3,738	30.2
	80+	594	3.9	608	4.0	723	4.7	1,165	7.6	1,165	9.2

*Source:* own study based on GUS (Statistics Poland) data [5]

Seniors, or the group of people aged 65 or more (frequently described by age) is neither homogenous nor static. Firstly, there are big differences within the group due to features such as e.g. place of residence, family and material situation, education, health condition, gender, or even age itself. It is expected that a person who is about to turn 65 will have different expectations and needs than a person approaching the age of 80. Similarly, the other features will also translate to different capacities and expectations of seniors. Secondly, attention should be drawn to the changes occurring with reference to the entire group, resulting from the generation and life experiences, as well as work during social and technological transformations, such as the proliferation of computers and their use in various areas of life, Internet access or dissemination of mobile phones. Another important fact is the progress in medicine and general improvement of the quality of life, also in older age. The individuals who currently qualify for the age group 65+ begin to differ from the 'typical' image of a senior as a person who is not very active, uneducated or in a difficult financial situation. Such changes are increasingly noticeable and expected to increase further [6].

The transport needs of seniors and their expectations regarding a transport system will be described in the further part of the paper.

## **2. Transport needs and expectations of seniors regarding transport system**

The transport expectations and needs are different from the needs of other age groups. The most typical example is the discontinuation of mandatory daily commuting when a person retires, which does not, however, necessarily have to reduce the seniors' demand for transport services, especially that one of the consequences of stopping professional work is the surplus of free time which seniors may want to

use in different ways. Seniors are increasingly willing to participate in cultural and integration events, educate themselves, as well as take part in sports and leisure events [13]. This results from the fact that they want to maintain social and physical activity for as long as possible and be independent, which has a significant impact on the quality of life perceived by them, as well as reduces the risk related to the sense of loneliness and social exclusion [3].

It shall also be remembered that the group of seniors is not homogenous, and the transport needs within this group will also be different, depending on the characteristics of particular seniors. For example, gender, age or family situation may have an influence on a senior's transport expectations and behaviours [14; 7]. Another factor that shall be taken into consideration when analysing the issues connected with the transport needs of seniors is the specific transport system in which these needs will be fulfilled, as well as the role that the senior will perform in this system (e.g. driver, private vehicle passenger, public transport passenger, pedestrian, etc.). The possibility of fulfilling the transport needs of seniors within the framework of a particular transport system depends on many objective factors and on the system perception by seniors.

**Table 3.** Transport system features expected by seniors

Feature	Description
Affordable	Use of transport system should be possible within the financial resources available to seniors.
Available	Seniors should be able to fulfil their transport needs by using the existing transport system.
Barrier-free	Transport system (both infrastructure and means of transport) should be adjusted to individual use (without or with minimum support of third parties) by seniors, taking into consideration potential difficulties (physical, sensory or cognitive) that are usually experienced by elderly people.
Comfortable	Use of transport system should not cause a sense of (physical or mental) discomfort, stress or anxiety in elderly people.
Comprehensible	Information about the opportunities offered within the framework of the transport system should be reported through different channels, so as to help seniors understand the transport offer that is available to them.
Efficient	Journey to a particular destination should be possible within reasonable time, taking into consideration the distance and means of transport used.
Friendly	Employees taking part in the process of providing transport services should be aware of the needs and limitations experienced by elderly people and should be available in the most appropriate manner (whether personally, or by telephone, e-mail or chat).
Reliable	Transport needs within the framework of a particular transport system should be carried out in a predictable manner and in line with the adopted assumptions (e.g. timetable, expected journey time), with the exception of fortuitous events that are difficult to predict (e.g. road accidents or very bad weather conditions).
Safe	The risk of accident during the use of transport system by a senior should be minimised.
Secure	Seniors should feel safe when using transport system – any threat from other transport system users, whether real or only felt by seniors, should be minimised.
Transparent	Seniors should be aware of the existence and possibility to use the available transport services, as well as conditions of their availability.

*Source:* based on [9]

The seniors' expectations regarding transport system concern a number of features and attributes describing the ease of using particular services, as well as their suitability and adjustment to the transport needs of seniors [9]. The desired transport system features and their description were included in Table 3.

When analysing the presented seniors' expectations regarding transport system, we may pay attention to the fact that a part of these expectations is not only limited to this particular group. The features such as availability, efficiency, and reliability are desired by everyone using a transport system, regardless of age. However, a majority of other features are more significant from the point of view of seniors, especially if the transport system is to guarantee their independence and higher social activity by ensuring the fulfilment of their transport needs.

Taking into consideration the large significance attributed to ICT solutions as a factor having a potentially big impact on more complete fulfilment of seniors' needs (not only in terms of transport), the data on the use of selected tools and solutions by Polish seniors will be described further in the paper.

### 3. Use of ICT by seniors

When considering the use of ICT for the purpose of better fulfilment of seniors' transport needs, the question about the relevance of such activities should be posed. It is universally believed that computer and Internet access are tools which, especially in case of elderly and disabled people, may increase their ability to participate in social life, as well as improve the quality of life perceived by them [1]. Unfortunately, in reality, elderly people use both computers and Internet (also mobile) far less frequently than the other age groups (see Table 4).

**Table 4.** Use of computer and Internet by particular age groups (in per cent) in 2017 in Poland

Age	16-24	25-34	35-44	45-54	55-64	65-74	Total
Regular computer use	97.1	92.2	85.1	66.9	46.8	25.6	71.2
Regular Internet use	99.0	94.5	87.5	67.7	47.5	26.0	70.3
Individuals having smartphones	91.5	85.6	74.1	49.4	29.1	14.9	59.5
Internet connection via mobile phone or smartphone	80.6	60.3	45.2	24.3	11.8	5.0	37.8

*Source:* based on [15] p. 110, 125, 146, 165

The relatively low use of different Internet communication services by elderly people can be noticed (see Table 5), which is alarming if we assume the phenomenon of the substitution of transport needs by new communication opportunities, resulting from the universal Internet access. Based on the presented data, Internet



access is not universal among the group of seniors, and its use for maintaining (or establishing) contacts with other individuals is even less common.

**Table 5.** Individuals using Internet communication services during the last 3 months of 2017 (in per cent) in Poland

Age	16-24	25-34	35-44	45-54	55-64	65-74	Total
Instant messaging use	68.0	49.0	31.8	15.9	7.2	3.5	29.7
Telephone calls via Internet	57.2	41.7	35.1	25.5	17.0	11.9	31.7
Sending and receiving e-mails	87.4	85.1	73.2	49.3	33.2	17.6	59.8
Social network use	90.5	75.1	56.8	30.6	17.8	9.5	48.0

*Source:* based on [15] p. 134-135

The marginal significance of the use of Internet for organising transport or special apps can also be noticed in case of a group of people aged 65 and more (see Table 6). We should obviously not forget that the services available within the sharing economy (e.g. BlaBlaCar or Uber) are a relatively new phenomenon in the Polish market and their popularity among the other age groups is not high either. The question whether they will become more popular remains open due to a number of controversies, e.g. related to the legal regulation of such type of services, or problems with verification and trust required for their efficient and effective implementation. Carsharing or carpooling are examples of the Mobility-as-a-Service (MaaS) solutions that by combining different modes of transport aim at limiting the travel with the use of privately-owned vehicles [17].

**Table 6.** Use of websites or applications within the framework of sharing economy for the purpose of transport organisation in 2017 (in per cent) in Poland

Age		16-24	25-34	35-44	45-54	55-64	65-74	Total
Total		11.5	10.2	6.7	4.2	2.5	0.7	6.2
Users of	dedicated websites or apps	7.5	8.3	5.1	3.0	1.7	0.5	4.6
	other websites or apps	6.2	3.7	3.0	1.7	1.1	0.4	2.7

*Source:* based on [15] p. 134-135

The potentially low level of ICT use by seniors seems to confirm the concerns raised at various levels, related to the risk of digital exclusion of this social group. Digital exclusion in the literature on the subject is most frequently defined in two aspects: material and non-material. The material aspect concerns the availability of computer and the Internet for a particular person, whereas the non-material aspect is related to knowledge, motivation and needs fulfilled through such access [2].

The lack of equality in access to digital technologies results from the differences in distribution of material, time, intellectual, social and cultural resources [4].

The availability of a specific technology will not result in its regular use if a person does not feel the need to use it. The question arises whether despite such a small degree of the use of computer, mobile phones, the Internet and various communication services, ICT can still be used for better fulfilment of the transport needs of seniors, or the opposite: the increase of ICT use in the activity of providers of broadly defined transport services will have a negative impact on the possibility of fulfilment of the transport needs of seniors, and consequently increase their risk of both digital and social exclusion? An attempt to address this question will be made in the further part of this article.

#### **4. ICT use in transport**

The mutual connections between transport on the one hand, and communication and impact of implementation of different modern ICT solutions on the other hand, have been of interest for the scientists since their popularisation. The following phenomena may be indicated here [11, 12]:

- substitution (replacement or elimination), i.e. decreased demand for transport by transferring the fulfilment of a part of needs to a different medium (e.g. use of e-administration or e-banking, teleconferences),
- complementarity (stimulation or impetus), which may take two forms:
  - when higher access to information stimulates the demand for transport (e.g. possibility to use a cheaper offer from a travel agency in online shopping, or when the fulfilment of transport needs creates the willingness to establish contact with the individuals who stayed at home),
  - when ICT use has an impact on the increase of effectiveness in fulfilling transport needs both on the part of the travelling person (e.g. better travel planning thanks to the use of information obtained from the Internet), or entities providing transport services (e.g. better vehicle fleet management by the public transport organiser),
- lack of mutual impact between ICT implementation and transport system (e.g. resulting from the selection of an ineffective solution which was not approved by the users).

As in a majority of cases of ICT use in different sectors, both its direct and indirect influence can be noticed in transport as well [10]. There are many ways in which ICT may have an impact both on the transport of passengers and goods by different means of transport. It is not possible to list and describe (even shortly) all of them due to the limited volume of this paper, especially that the set of available solutions

is constantly expanding. However, the author took the attempt to assign examples of ICT solutions to selected transport system features that are expected by seniors (see Table 7).

**Table 7.** Examples of ICT solutions that can be used to fulfil senior’s expectations concerning the transport system features

Feature	Examples of ICT solutions that may fulfil the expectations of seniors
Affordable	- integrated fare collection systems, e-tickets, city cards, possibility to buy tickets online/through an app,
Available	- demand responsive transportation, dynamic ride-sharing, planning routes and frequency of connections based on the information obtained from ITS
Barrier-free	- MaaS, e.g.: carsharing, carpooling, autonomous/driverless cars, demand responsive paratransit
Comfortable	- MaaS, e.g. carsharing, carpooling, autonomous/driverless cars, demand responsive paratransit
Comprehensible	dynamic passenger information system in public transport vehicles and stops, online and mobile timetables, travel planning applications
Efficient	- any solutions related to broadly defined ITS that allow to address arising situations based on the information obtained in real time
Friendly	- any channels used for communicating with the user: web portals, mobile apps, hotlines, social media, etc.
Reliable	- any solutions related to broadly defined ITS that allow to address arising situations based on the information obtained in real time
Safe	- any V2V, V2I, I2V solutions that support driving vehicles, parking vehicles, etc.
Secure	- monitoring and quick response systems in public transport vehicles and stops
Transparent	- any channels used for communicating with the user: web portals, mobile apps, hotlines, social media, etc.

The ICT solutions listed in Table 7 do not cover all possibilities within the discussed scope. However, in the light of the data indicating a low use of such basic tools and solutions as a computer or social networks, the question about the actual impact of ICT on the fulfilment of transport needs of seniors is absolutely relevant. When analysing the list of examples of ICT solutions included in Table 7, attention may be drawn to the fact that some of them, applied by the entities that either provide transport services (e.g. public transport organiser) or make means of transport available (car manufacturers, carsharing companies) will influence the general effectiveness of the transport system without any action required on the part of seniors. For example, any solutions related to broadly defined ITS that allow addressing arising situations on the basis of information obtained in real time will improve the system reliability and effectiveness. The same is true for brake and parking support systems that will improve the safety of all traffic participants and enable seniors to use this means of transport longer and more comfortably. The situation is less obvious in case of ICT solutions that require seniors to take action -

certain activities will probably be simpler and carried out more frequently (e.g. obtaining a city card on a one-time basis, or using GPS devices while driving a vehicle) than others (e.g. the use of sharing economy solutions, such as carsharing or carpooling, as indicated by the data from Table 6).

## 5. Conclusion

The ageing of society and the attempts to meet seniors' needs presents numerous challenges on many levels: social, economic, administrative and political. This also concerns the broadly understood transport sector, which involves different entities (both public and commercial) providing transport services. To some extent, the transport needs of seniors overlap general transport needs reported by other age groups; however, certain significant differences may be indicated, such as e.g. different destinations, preferred hours of making journeys, or expectations in terms of comfort and safety, resulting from the age and health condition.

In considering how the increasingly popular implementation of modern ICT solutions by the entities providing transport services will influence the fulfilment of the transport needs of seniors, the first thing to be taken into account is how these needs and expectations differ from the needs and expectations of other age groups, as well as to what degree seniors use computers, mobile phones, and the Internet. These factors were to serve as the basis for considering whether ICT are a real opportunity to improve the transport needs of seniors, or contrary, whether they may be a reason for the deepening of social exclusion due to smaller availability of certain transport services.

Taking into account the role performed by seniors in the transport system, as well as how specific ICT solutions influence the transport system operation, two general groups of solutions that may be more or less efficient in fulfilling the transport needs of seniors were indicated. The first group includes the solutions implemented and existing regardless of the involvement and actions taken by seniors, such as e.g. Intelligent Transport Systems based on communication between particular elements of a transport system (e.g. V2V or I2V). These solutions influence both the improved fulfilment of the transport needs of other social groups (e.g. through more efficient management of the vehicle fleet owned by the public transport operator), as well as e.g. the improvement of seniors' safety (e.g. all systems based on vehicle communication with other vehicles, as well as braking or parking support infrastructure). The second group includes the solutions whose efficiency depends on the actions taken by seniors themselves (e.g. use of mobile timetables, sharing economy portals or taxi booking apps). This broadly defined type of ICT solutions may have limited efficiency and require taking additional promotional and educational measures. Such activities would be intended to moti-

vate seniors and let them gain competences necessary for the effective use of new opportunities offered by ICT.

To sum up, the progressive implementation of ICT may be both an opportunity and a threat for seniors, depending on the number of factors that require conducting further research in this respect. Additionally, the activities related to ICT used for better fulfilment of the transport needs of seniors require the involvement of institutions at different levels of public administration, companies providing services in the field of transport, non-governmental organisations and the seniors themselves.

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## **E-SHOPPING MODELS IN SELECTED EUROPEAN COUNTRIES**

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The paper presents e-shopping preferences in selected European countries. Research encompassed the period of 2007-2017. The source material includes foreign and domestic literature on the subject, numerical data provided by Eurostat and data from DPD report. The work was developed using the descriptive, tabular and graphic tools, as well as the Pearson linear correlation coefficient. The average Internet purchases by individuals in households in European Union increased from 30% in 2007 to 57% in 2017. E-shopping is very different in individual EU countries. They differ in terms of ordered goods online, frequency of purchases, important criteria of e-shopping to customers, devices used to order, preferred payment methods and places of parcels delivered. It was found very high level of correlation between the Internet purchases and the computer and Internet access.

Key words: e-commerce, e-shopping, European market

### **1. Introduction**

E-commerce (electronic commerce) is the buying and selling of goods and services, or the transmitting of funds or data, over an electronic network, primarily the internet [1]. Electronic commerce is a relatively new concept. The term electronic commerce is frequently used to denote different meanings, very often depending on the professional orientation and background, focal product or service, and type of information technology deployed [2, 3, 4]. E-commerce is the process of purchasing, selling and exchange of products, services and information via com-

puter networks. E-commerce is very important a part of e-business and e-economy. E-commerce only refers to the goods and services transaction between a seller and a consumer, whereas e-business refers to the complete process necessary to manage an online business[5, 6].

The increased pace of development of e-commerce was associated with shifting of financial and human resources to this field of activity. Enterprises, which were skeptical at first, were forced by the competition to invest in e-commerce [7]. After year 2005, e-business developed very quickly. This was aided by development of mobile applications and improvement of the electronic distribution and payment systems [8, 9].

Each business focuses on a type of client. As for entities participating in e-commerce, the following systems have been identified: business-to-business (B2B), business-to-consumer (B2C), consumer-to-consumer (C2C), consumer-to-business (C2B), business-to-public (B2P). In addition to these types of electronic commerce, there are other popular types such as G2C (Government-to-Consumer), C2G (Consumer-to-Government) or B2E (Business-to-Employer) [10, 11]. B2C relations are the most popular. In this system businesses sell their products or services directly to the consumer. This is the usual type and there are thousands of examples of clothes, shoes or electronics stores [12, 13].

E-shopping (electronic shopping, online shopping) is a form of e-commerce which allows consumers to directly buy goods or services from a seller over the Internet using a web browser. Consumers can find a product by visiting the website of the retailer directly or by searching among other vendors using a shopping search engine, which displays the same product's availability and pricing at different e-retailers. Customers can shop online using desktop computers, laptops, tablet computers and smartphones. Online stores are usually available 24 hours a day and many consumers have internet access both at work and at home. So it is very convenient for them to shop online. One of the great benefits of online shopping is the ability to read product reviews, written either by experts or fellow online shoppers [14, 15, 16].

## **2. Research methodology**

The main objective of the study was to assess the functioning e-shopping models in selected European countries. The detailed objectives included determining the importance of electronic sales in society, showing the most popular products sold electronically, defining parameters important for customers, fixing of correlations between e-shopping and access to a computer and the Internet. Research encompassed the period of 2017-2017. The source material includes foreign and domestic literature on the subject, numerical data provided by Eurostat and data from DPD report. The E-Shopper Barometer of DPD presents pan-



European shifts in shopping habits identified in a Kantar TNS survey between June 1st and July 3rd, 2017. Blind interviews were conducted online among 24,871 participants across 21 European countries and Russia. The article includes selected results from the five largest e-sales markets and Poland. 1643 interviews were conducted in Great Britain, 1544 in France, 1582 in Germany, 1539 in Spain, 1509 in Italy and 1509 in Poland. The work was developed using the descriptive, tabular and graphic tools, as well as the Pearson linear correlation coefficient.

### 3. The results

The average Internet purchases by individuals in households in European Union increased from 30% in 2007 to 57% in 2017 (Tab. 1). That mean the most of half society used Internet to purchase. For the most of countries this rate is slightly higher that 50%. In the top of European countries in terms of Internet purchase, it is interesting to see that almost all the most economically developed countries are represented. Data shows that more than 80% of British and Swedish Internet users used online shopping in 2017. Huge growth can be found in Estonia: 9% of Internet users shopped online in 2007, but this percentage will grow to 58% by 2017. In Slovakia, ecommerce adaption will also grow strong: from 16% in 2007 to 59% in 2017. Internet purchases are the least popular in the countries that joined the EU in the recent accession, but also in several of the most economically developed countries, such as Italy and Spain. Therefore, there were large disparities between EU countries. Overall, Internet shopping has become a fairly natural way to purchase goods.

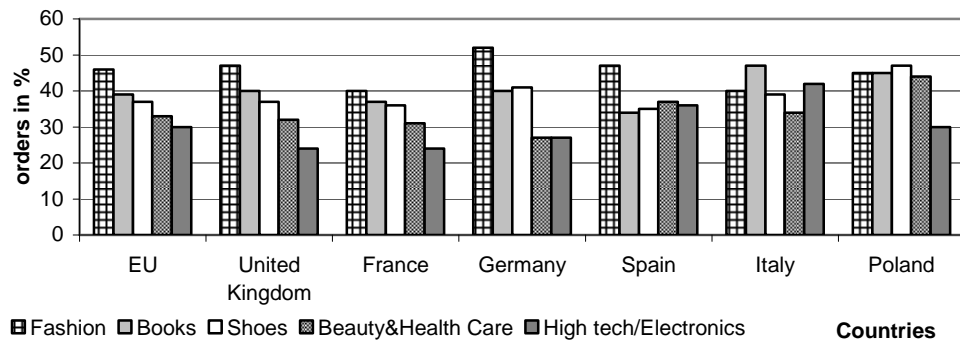
Based on data from the UK, Germany, France, Spain, Italy and Poland it found out that clothing, books and footwear are amongst the most popular product categories, just like beauty and health products and electronics (Fig. 1). This categories are well-established with little room to progress. Fashion remains the leading product category that e-shoppers order, because 20% of purchases were made online. Each category's degree of maturity varies according to country. Fashion products purchases was the most popular in Germany (52% people bought this product), books and electronics in Italy (47%), shoes, beauty and health products in Poland (respectively 47 and 44%). In terms of growth potential, books, high-tech/electronics show the best chances of attracting new online buyers.

Around 14 of all e-shoppers have ordered fresh food and beverages online (Fig. 2). Most of them (27%) bought from this product category regularly, at least once per month. The UK is a particularly active market in this respect, with 33% of e-shoppers having already made at least one purchase a week from the fresh food and beverage category. The UK is far ahead in % age of food purchases made online.

**Table 1.** Internet purchases by individuals in Households in years 2007-2017

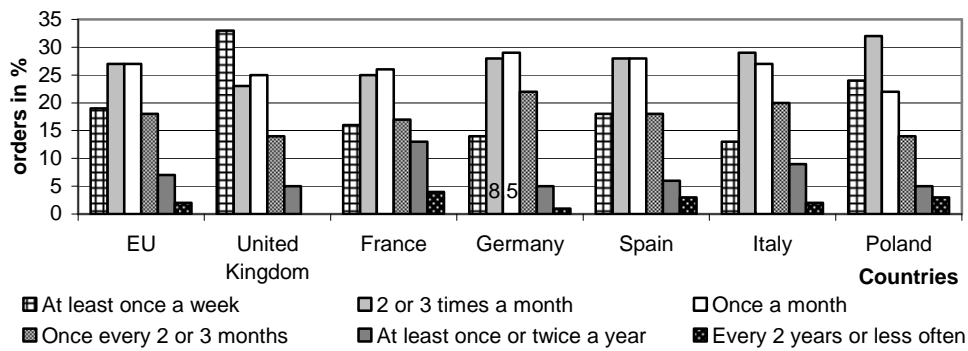
Countries	Internet purchases by individuals in years (% of individuals]										
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
United Kingdom	53	57	66	67	71	73	77	79	81	83	82
Sweden	53	53	63	66	71	74	73	75	71	76	81
Denmark	56	59	64	68	70	73	77	78	79	82	80
Luxembourg	47	49	58	60	65	68	70	74	78	78	80
Netherlands	55	56	63	67	69	65	69	71	71	74	79
Germany	52	53	56	60	64	65	69	70	73	74	75
Finland	48	51	54	59	62	65	65	68	69	67	71
France	34	40	44	54	53	57	59	62	65	66	67
Austria	36	37	41	42	44	48	54	53	58	58	62
Belgium	21	21	36	38	43	45	48	54	55	57	60
Slovakia	16	23	28	33	37	45	44	48	50	56	59
Estonia	9	10	17	17	20	23	23	49	59	56	58
Czech Republic	17	23	24	27	30	32	36	43	45	47	56
Ireland	33	36	37	36	43	46	46	50	51	59	53
Malta	20	22	34	38	45	44	46	47	51	48	52
Spain	18	19	22	24	27	30	32	37	42	44	50
Latvia	11	16	19	17	20	27	32	34	38	44	46
Slovenia	16	18	24	27	31	34	36	37	39	40	46
Poland	16	18	23	29	30	30	32	34	37	42	45
Hungary	11	14	16	18	22	25	29	33	36	39	39
Lithuania	6	6	8	11	16	20	26	26	32	33	38
Portugal	9	10	13	15	18	22	25	26	31	31	34
Greece	8	9	10	12	18	20	25	26	32	31	32
Italy	10	11	12	15	15	17	20	22	26	29	32
Cyprus	10	9	16	18	21	21	25	27	23	29	32
Croatia	7	7	10	14	17	23	26	28	31	33	29
Bulgaria	3	3	5	5	7	9	12	17	18	17	18
Romania	3	4	2	4	6	5	8	10	11	12	16
EU 28	30	32	36	40	42	44	47	50	53	55	57

Sources: Eurostat Database



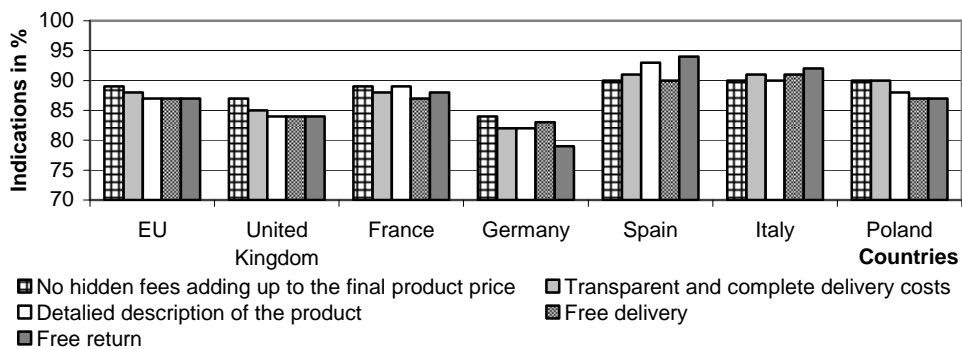
**Figure 1.** Types of goods ordered online

Sources: European E-shopper barometer report 2017, dpd group, dpdgroup.com.



**Figure 2.** Frequency of order Fresh Food & Beverage online

Sources: European E-shopper barometer report 2017, dpd group, dpdgroup.com.

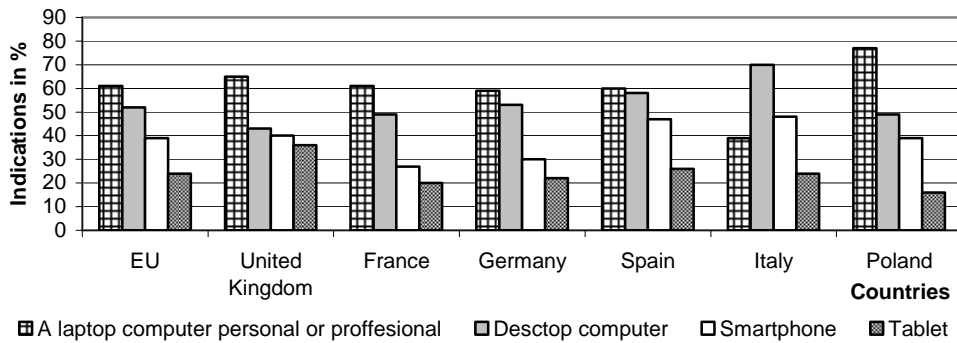


**Figure 3.** Important criteria of e-shopping to customers

Sources: European E-shopper barometer report 2017, dpd group, dpdgroup.com.

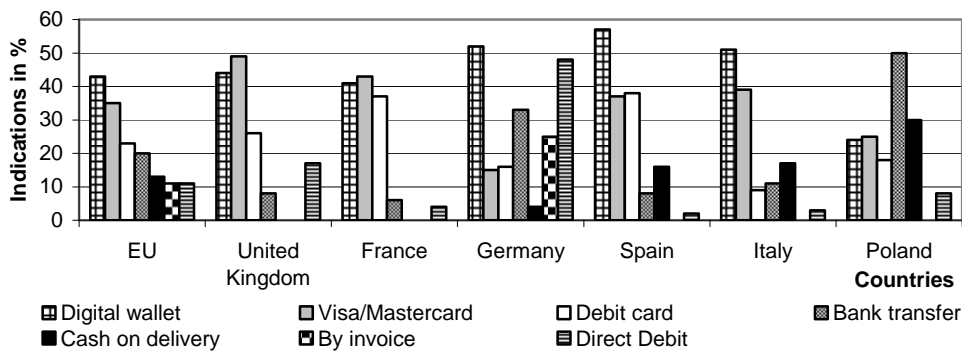
For customers of online stores the most important criterion in e-shopping was no hidden fees adding up to the final product price (Fig. 3). The highest demands were placed in countries from the South of Europe, in Italy and Spain, and the smallest in Germany. Needs were differentiated and dependent on many factors, such as culture, society profile, etc. In Spain and Italy the most important criterion was free return and in Poland was transparent and complete delivery costs.

Most online purchases were still made on a laptop or desktop computer (Fig. 4). E-shoppers buy from multiple devices, increasingly from smartphones. Smartphones are more used by the young generation. Nonetheless, laptop and desktop computers remain the primary devices used to purchase online (61% use laptop and 52% use desktop), meaning that an easy-to-navigate website is also critical. Of those surveyed, 43% said that they consider a mobile-friendly website to be an essential factor in making online purchases.



**Figure 4.** The devices used to order

Sources: European E-shopper barometer report 2017, dpd group, dpdgroup.com.

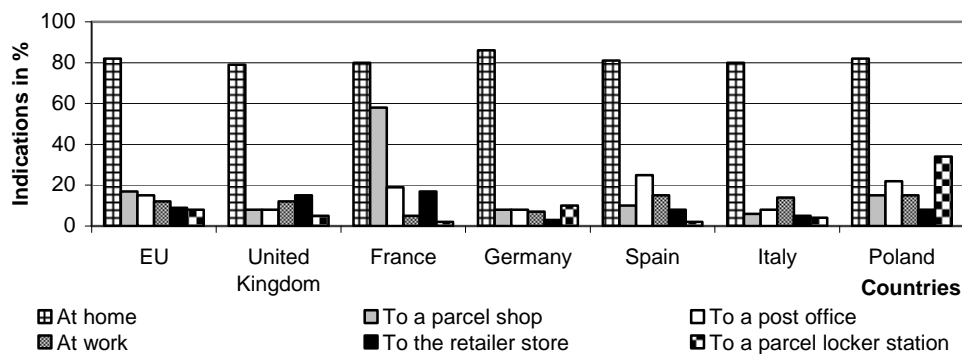


**Figure 5.** Preferred payment methods to pay online

Sources: European E-shopper barometer report 2017, dpd group, dpdgroup.com.

In EU, digital wallets like PayPal and AliPay are the preferred means of payment for online shopping, followed by Visa, Mastercard and other credit/debit cards (Fig. 5). However, each country has its own unique habits and preferences: Germany, Hungary, the Netherlands, and Portugal rarely use credit/debit cards; cash-on-delivery is a very important way to pay in Romania, Slovenia, and Slovakia; Austria and Switzerland prefer to pay by invoice. Certain countries opt for local payment methods, among them iDeal in the Netherlands, Mister Cash in Belgium, and Payu in Poland. E-shoppers tend to have well-established habits; half of them only have one preferred payment method. In Western Europe, paying by credit card for online purchasing is common. In Central and Eastern Europe, cash on delivery is the most popular way to payment.

Each European country has its own specific habits, with delivery and payment preferences varying widely from one place to the next. Therefore, in order to develop e-commerce and meet customer expectations, e-shops need to think local to maximize opportunities. Flexibility is also key: most e-shoppers say next-day delivery, real-time tracking, and the option to reschedule are likely to incite them to purchase. Home is the main delivery place used in EU and is still the most-have for e-tailers (Fig. 6). However, taking into account the countries specificities and large growth potential of all the alternative delivery palces, e-shops should consider expanding their delivery offer. The best solution is delivery parcels to where e-shoppers may be. As there are not always at home, especially during the week. Alternative options become more and more popular, for example at work, in parcel shop, or in parcel locker station. Delivery to a parcel shop is very common in France and parcel locker stations are very popular in Poland and the Baltics. Places of parcel delivery is very different in EU countries.



**Figure 6.** Places of parcels delivered

Sources: European E-shopper barometer report 2017, dpd group, dpdgroup.com.

Table 2 presents results of the Pearson correlation coefficient and p value. The limit value of significance level was assumed to be  $p = 0.05$ . Significant correla-

tions were marked by grey background of the text. Correlation coefficients were calculated for years 2007-2017 and for all countries in UE.

**Table 2.** Pearson correlation coefficients between the Internet purchases and levels of access to computers and Internet

Parameters	Pearson linear correlation coefficients											
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2007-2017
The coefficients of correlation between the percentage of Internet purchases and availability of computers in households												
correlation	0,906	0,910	0,928	0,928	0,952	0,945	0,928	0,952	0,931	0,934	0,945	0,922
p-vale	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
The coefficients of correlation between the percentage of Internet purchases and computer use in last 12 months												
correlation	0,909	0,895	0,928	0,911	0,920	0,933	0,924	0,961	0,960	0,955	0,948	0,929
p-vale	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
The coefficients of correlation between the percentage of Internet purchases and level of Internet access												
correlation	0,897	0,903	0,928	0,928	0,948	0,954	0,929	0,959	0,933	0,945	0,930	0,900
p-vale	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
The coefficients of correlation between the percentage of Internet purchases access to broadband Internet												
correlation	-0,10	-0,10	-0,01	0,472	0,402	0,477	0,347	0,416	0,330	0,314	0,178	0,461
p-vale	0,628	0,607	0,987	0,011	0,034	0,01	0,07	0,028	0,086	0,104	0,364	0,001

Source: own research

Very strong positive correlation values were found to exist between the percentage of Internet purchases and availability of computers in households, computer use in last 12 months and level of Internet access. These dependencies were stronger in subsequent years. Only in the case of broadband Internet in relation to Internet purchase, the relations were not obvious. The correlations were only in 2010-2014 and all period of research. The relations was weak. This means that the existence of high-speed Internet is not a determinant of the use of online stores.

#### 4. Summary

The most of half society of European Union used Internet to purchase. Data shows that more than 80% of British and Swedish Internet users used online shopping in 2017. Internet purchases are the least popular in the countries that joined the EU in the recent accession, but also in several of the most economically developed countries, such as Italy and Spain. Therefore, there were large disparities between EU countries.

Based on data from the UK, Germany, France, Spain, Italy and Poland it found out that clothing, books and footwear are amongst the most popular product categories, just like beauty and health products and electronics. These categories are well-established with little room to progress. Each category's degree of maturity varies according to country. In terms of growth potential, books, high-tech/electronics show the best chances of attracting new online buyers. Around 14 of all e-shoppers have ordered fresh food and beverages online. Most of them (27%) bought from this product category regularly, at least once per month. Laptop and desktop computers remain the primary devices used to purchase online. Smartphones are more used by the young generation. In EU, digital wallets are the preferred means of payment for online shopping, followed by Visa, Mastercard and other credit/debit cards. Each country has its own unique habits and preferences. Differences were also found in payment preferences. Delivery to a parcel shop is very common in France and parcel locker stations are very popular in Poland and the Baltics.

It was found very high level of correlation between the Internet purchases and the computer and Internet access. No correlation was found when comparing the Internet purchases and use of broadband Internet.

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## **MODELLING OF AGRICULTURAL COMMODITY PRICE EFFECTS ON THE FISCAL PERFORMANCE AND ECONOMIC GROWTH IN UKRAINE**

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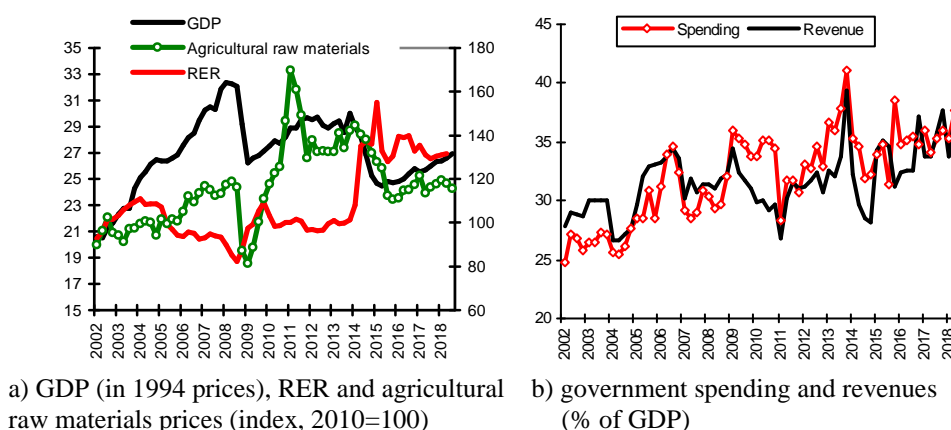
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named by Ivan Franko*

This paper analyses the effects of agricultural raw materials prices upon fiscal policy indicators and gross domestic product (GDP) output in Ukraine, on the basis of the VAR/VEC model using quarterly data for the period of 2002–2018. The results indicate a positive effect of agricultural commodity prices on GDP, with both government expenditure and revenue declining in the wake of favorable commodity price developments. As expected, higher agricultural commodity prices are associated with a real exchange rate (RER) appreciation, which in turn brings about an increase in government expenditure and revenue combined with an expansionary effect on GDP. Furthermore, agricultural commodity price and RER shocks are characterized by asymmetrical effects upon output. Among other results, there are positive output effects by both government expenditures and revenues, while the reverse causality suggests a decrease in fiscal variables following an increase in GDP. Several implications for stabilization policies are discussed.

**Keywords:** agricultural commodity prices, fiscal policy, GDP, real exchange rate, Ukraine

## 1. Introduction

Since the middle of 2000s, the share of agricultural commodities in Ukraine's exports has increased to 40 percent. However, it exposes the output and fiscal balance to the risk of commodity price shocks. A potential solution is anchoring fiscal policy framework in terms of rules that target the cyclically adjusted or structural (as opposed to actual) balance in an effort to overcome problems of procyclicality and fiscal volatility in the environment with large and persistent commodity shocks [6; 8]. It is assumed that the rule-based fiscal policies allow for budget surpluses in good times, thus creating pre-conditions for an expansionary fiscal stance during economic slowdown. Although several studies confirm an inverse relationship between fiscal rules and procyclicality for Latin American commodity 'republics' [9; 10; 12], opposite results are also obtained [6; 8; 13].



**Figure 1.** Ukraine: selected macroeconomic indicators, 2002–2018  
*Source:* Ukraine's State Statistical Committee ([www.ukrstat.gov.ua](http://www.ukrstat.gov.ua)),  
 Ukraine's Ministry of Finance ([www.minfin.gov.ua](http://www.minfin.gov.ua))

Changes in the Ukraine's GDP seem to follow closely the developments in the agricultural commodity prices (Fig. 1a). In 2008-2009 and 2014-2015, agricultural commodity price shocks coincided with sharp realignments of Ukrainian currency hryvna, but any relationships between both nominal variables could be obscured by simultaneity of currency crises that started that time. However, it is not ruled out that higher agricultural prices contributed to the RER appreciation in 2002-2008, while this kind of relationship is not likely to mark post-crisis period. Fiscal variables do not reveal any connections with agricultural raw material prices, with irregular oscillations around an upward trend being visible for both government spending and revenues (Fig. 1b).

The aim of this article is to provide an empirical assessment of agricultural raw materials prices upon the RER, output and fiscal variables in Ukraine. The remainder of this paper is organized as follows. The next section reviews the relevant literature on the relationship between commodity prices and fiscal performance. Section 3 presents data and econometric methodology. In Section 4 empirical results are discussed. The last section concludes.

## **2. Commodity prices and fiscal performance**

Assuming a high volatility of commodity prices, it is quite natural to perform an anti-cyclical fiscal policy, with the real (nominal) exchange rate serving as a shock absorber. During a period of high commodity prices, it is expedient to improve the budget balance thus creating a greater fiscal space, which gives more room for accommodating terms-of-trade (TOT) shocks. For example, such an approach is established for Chile and Peru [14]. Among Latin American countries, only Chile targets cyclically adjusted indicators although Colombia is going the “Chilean way” and the Mexican rule offers some stabilization properties. Argentina, Brazil and Peru apply numerical rules targeting the overall/primary public balance and/or the public spending [7]. Limited exchange rate flexibility, weak external position, and loose fiscal policy tend to amplify the negative effects of adverse TOT shocks on domestic output, especially if sharp drops in commodity prices are preceded by booms [1]. For Ukraine, it is of particular importance that financial dollarization is likely to act as a shock “amplifier.”

The optimal windfall allocation rule between spending today and asset accumulation for low-income countries with imperfect access to world capital markets and a variety of externalities associated with public infrastructure, as well as direct complementarity effect with private investment, and reduced distribution costs, are studied by Agenor [2]. It is established that an optimal response to commodity price shocks defined in terms of the volatility of private consumption and either the non-resource primary fiscal balance or a more general index of macroeconomic stability, which accounts for the volatility of the RER, implies a dynamic trade-off between spending now and spending later. Such a policy is considered to be better option for fiscal policy in comparison to an unconditional cash transfer policy.

Alternative fiscal rules imply targeting of a structural budget balance, in connection to commodity prices, as it is suggested by a successful experience of Chile [7]. Familiar arguments in favor of the structural balance rule are found for Mexico [3], Brazil [5] and Colombia [11], important commodity exporters. During the recent commodity boom of 2002-2012 the impact of increases in commodity prices tends to be higher for the Latin American countries with low fiscal procyclicality [4]. However, a procyclical fiscal policy pattern still dominates in

the region. For 20 countries of Latin America and the Caribbean over the period of 1990–2013 period, it is found that 1 percent increase in the output gap is associated with up to 0.66 percentage point deterioration in the structural primary balance, with the inverse relationship being stronger in countries that face large TOT shocks [6]. Analysing a dataset of 48 non-renewable commodity exporters for the period 1970–2014, it is stated that fiscal policy tends to have a procyclical bias (mainly via expenditures of the public sector), with no sign of declining in recent years despite adopting the fiscal rules [8]. Such an outcome can be explained by non-linearity of budget balance with respect to public debt stock. Based on a panel of developed and emerging economies over the period of 1990-2011, it is found that when the public debt-to-GDP ratio exceeds threshold of 86 percent, fiscal policy becomes rather procyclical [9].

As the procyclical fiscal policy promises larger gains in the short run, it can be difficult to implement prudent solutions because of political reasons. For example, it is established for Chile with a Dynamic Stochastic General Equilibrium (DSGE) model that if the government saves most of the extra revenues from the higher commodity price; an increase of a copper price by 10 percent leads to an expansion of output below 0.2 percent and a RER appreciation of 0.5 percent [13]. Although an expansionary fiscal stance is associated with a stronger output expansion above 0.5 percent and a RER appreciation of 0.8 percent, such a policy can create substantial difficulties in the intertemporal context. Argentina is a good example of such a case.

### 3. Empirical methodology

We use quarterly series of the following variables for the period of 2002Q1:2018Q2: agricultural raw materials prices,  $praw_t$  (index, 2010=100), real effective exchange rate,  $rer_t$  (index, 2010 = 100), government revenue and spending,  $rev_t$  and  $g_t$  respectively (percent of GDP), gross domestic product,  $y_t$  (in 1994 prices). Fiscal variables are taken from the National Bank of Ukraine ([www.bank.gov.ua](http://www.bank.gov.ua)), GDP from the Ukraine's State Statistical Office ([www.ukrstat.gov.ua](http://www.ukrstat.gov.ua)), while the time series for agricultural raw materials prices and RER are obtained from the IMF's databases ([www.imf.org](http://www.imf.org)). All variables enter in logs, with GDP, government revenue and spending series being seasonally adjusted.

Except for the government revenues, all other variables are integrated of order 1, or simply I(1), as indicated by the unit root tests (Table 1). However, it is possible to assume that weak stationarity of  $rev_t$  does not affect statistical properties of the relationship between our variables, especially when accounting for the fact that stationarity of  $rev_t$  is not confirmed for a shorter 2006-2018

sample. As suggested by the Johansen test (Table 2), there is at least one cointegrating equation between endogenous variables.

**Table 1.** Unit Root Tests for endogenous variables

	ADF		PP	
	L	FD	L	FD
$praw_t$	-2,88*	-6,34***	-2,39	-6,14***
$rer_t$	-1,23	-7,82***	-1,33	-7,81***
$rev_t$	-3,38**	-9,54***	-3,38**	-13,53***
$g_t$	-2,49	-10,78***	-2,29	-12,08***
$y_t$	-2,14	-5,51**	-2,04	-5,50*

Note: \*\*\*, \*\*, \* null hypothesis of a unit root can be rejected at 1, 5 and 10 percent level of confidence, respectively; L and FD stand for levels and first differences, respectively

**Table 2.** Johansen Test Statistics for  $praw_t$ ,  $rer_t$ ,  $rev_t$ ,  $g_t$ , and  $y_t$

Number of cointegrating equations		Trace statistic	0.05 Critical value	Prob.	Max-Eigen Statistic	0.05 Critical value	Prob.
$H_0: r = r_0$	$r = 0$	89,67***	76.97	0.0	36.30**	34.80	0.03
	$r = 1$	53.37*	54.07	0.06	25.55	28.58	0.11
	$r = 2$	27.81	35.19	0.24	16.57	22.29	0.25
	$r = 3$	11.24	20.26	0.51	7.78	15.89	0.57
	$r = 4$	3.46	9.16	0.4974	3.46	9.16	0.49

Assuming that endogenous variables are  $I(1)$  and cointegrated with rank  $r$  ( $0 < r < n$ ), the Vector Error-Correction Model (VECM) representation with structural restrictions presents as follows:

$$B(L)\Delta z_t = -\alpha\beta z_{t-1} + \xi_t, \quad (1)$$

where  $B(L)$  is the matrix polynomial with degree  $k$ ,  $\alpha$  and  $\beta$  are  $n \times r$  matrices of rank  $r$ ,  $z_t$  is the vector of endogenous variables,  $\Delta$  is the operator of first differences,  $\xi_t$  is the vector of stochastic innovations. Exact identification of  $\beta$  requires  $r$  restrictions on each of the  $r$  cointegrating vectors.

The vectors of endogenous variables and stochastic innovations are chosen as follows:  $z_t = (\Delta praw_t, \Delta rer_t, \Delta rev_t, \Delta g_t, \Delta y_t)$ ,  $\xi_t = (\xi_t^{praw}, \xi_t^{rer}, \xi_t^{rev}, \xi_t^g, \xi_t^y)$ , where  $\xi_t^{praw}$ ,  $\xi_t^{rer}$ ,  $\xi_t^{rev}$ ,  $\xi_t^g$  and  $\xi_t^y$  are stochastic innovations for respective endogenous variables. It is assumed that the agricultural raw materials prices affect RER, with fiscal variables and output in the third, fourth and fifth places, implying that innovations to government revenue and spending or output do not influence relative prices in the very same period they occur.

For computational purposes, EViews 6.1 program is used. We include two lags into the VECM, as suggested by the Akaike criterion for a VAR model with same endogenous variables.

#### 4. Empirical results and discussion

The selected impulse responses of endogenous variables are presented in Fig. 2. Table 3 reports the portion of the forecast error variance decomposition (FEVD) in the endogenous variable at different forecast horizons, which is attributable to innovations in other variables (the dominant shock is in bold type).

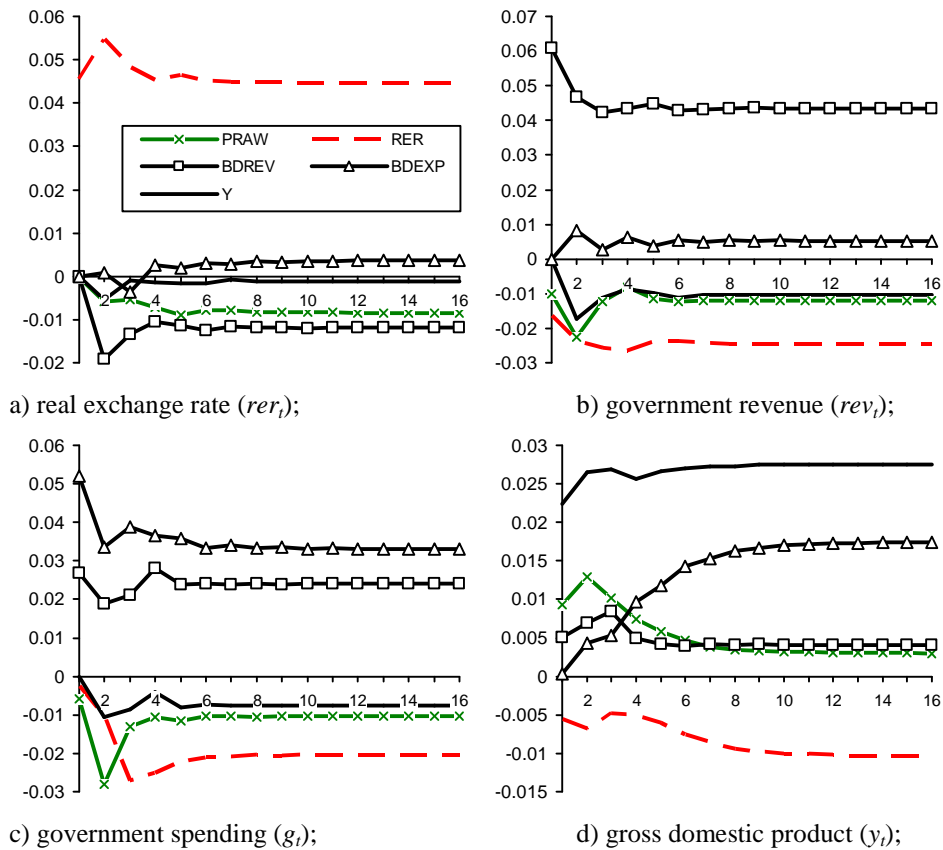
As expected, it is likely that higher prices of agricultural raw materials bring about appreciation of the RER, similar to the impact of an increase in the government revenue on the relative prices (Fig. 2a). Such similarity is observed for the expansionary effects of both variables upon output (Fig. 2d). Potentially an increase in agricultural raw materials prices can contribute to the RER appreciation through either strengthening of a nominal exchange rate or an increase in the domestic food prices. Higher government revenue is likely to bring about appreciation of the RER mainly through the mechanism of a nominal exchange rate appreciation, as any efforts to improve tax collection are associated with higher demand for money and downward pressure on domestic prices.

Following an increase in the agricultural raw materials prices, there is a decrease in either government revenue (Fig. 2b), or government spending (Fig. 2c). However, the fraction of  $praw_t$  in the FEVD of  $rer_t$  is marginal, meaning that prices of agricultural raw materials do not have a significant impact upon the RER (Table 1). For other endogenous variables, the fraction of  $praw_t$  in the FEVD is somewhat higher, but still below 10 percent (the only exception is a short-term impact of  $praw_t$  upon output with a horizon of 4 quarters). To the same extent, the RER is not affected significantly by any of the endogenous variables.

Both government revenue and spending do not react to output, which is bad news in the former case and good news in the latter case. Depreciation of the RER is associated with a decrease in both government revenue and spending, with both outcomes being consistent with a clear restrictionary effect upon output. The fraction of  $rer_t$  in the FEVD of fiscal variables gradually increases up to 20 percent, reflecting the importance of relative prices in shaping both government revenues and expenditures. Government revenues seem to be independent of spending decisions, but there is significant causality running from  $rev_t$  to  $g_t$ . The fraction of  $rev_t$  in the FEVD of  $g_t$  is between 20 and 24 percent.

There is no evidence for a standard textbook expansionary effect of exchange rate depreciation upon output. Just the opposite, any downward movements of the relative prices are likely to bring about a decrease in output, but the importance of this link should not be exaggerated. According to the FEVD analysis, changes in

$rer_t$  explain up to 7 percent of changes in output. Although both government revenues and expenditures are expansionary with respect to output, the impact of the latter seems to be much stronger, with the fraction of  $g_t$  in the FEVD of  $y_t$  gradually increasing from 4 to 20 percent.



**Figure 2.** Fiscal policy effects on exchange rates

Although changes in the agricultural raw material prices do not explain a significant portion of the FEVD of the other endogenous variables, nevertheless the impulse response functions imply a potential favourable impact of higher prices upon output, with a simultaneous appreciation of the RER. As the latter effect is also expansionary, it argues in favor of a discreet stabilization policy with fiscal instruments. For the case of a procyclical increase in prices of agricultural raw materials, our study suggests the implementation of government spending cuts, while an increase in the government revenue is recommended for the periods with lower prices. Such options are consistent with proposals by Agenor [2] of not using

cash transfers policy in response to a favourable TOT shock. Similar to other countries (Chile), it is desirable to implement a fiscal policy rule, in the way that accounts for an expansionary impact of both government revenue and spending (it runs counter to a conventional interpretation of fiscal policy with revenue and spending having asymmetric output effects).

**Table 4.** Forecast error variance decomposition

Impulses	Responses to	Forecast horizons			
		4	8	12	16
Real effective exchange rate ( $rer_t$ )	$praw_t$	1	2	2	3
	$rer_t$	<b>92</b>	<b>91</b>	<b>91</b>	<b>91</b>
	$rev_t$	6	6	6	6
	$g_t$	0	0	0	0
	$y_t$	0	0	0	0
Government revenue ( $rev_t$ )	$praw_t$	6	6	6	5
	$rer_t$	<b>17</b>	<b>19</b>	<b>20</b>	<b>20</b>
	$rev_t$	<b>73</b>	<b>71</b>	<b>70</b>	<b>70</b>
	$g_t$	1	1	1	1
	$y_t$	4	4	4	4
Government spending ( $g_t$ )	$praw_t$	9	7	7	6
	$rer_t$	<b>13</b>	<b>15</b>	<b>16</b>	<b>18</b>
	$rev_t$	<b>20</b>	<b>22</b>	<b>23</b>	<b>24</b>
	$g_t$	<b>57</b>	<b>54</b>	<b>52</b>	<b>51</b>
	$y_t$	2	2	2	2
Output ( $y_t$ )	$praw_t$	12	6	4	3
	$rer_t$	4	5	6	7
	$rev_t$	5	3	2	2
	$g_t$	<b>4</b>	<b>13</b>	<b>17</b>	<b>20</b>
	$y_t$	<b>75</b>	<b>72</b>	<b>69</b>	<b>68</b>

Note: results for a VAR model with variables in deviations from trend are given in brackets

## 6. Conclusions

Our results suggest that there is a positive effect of prices of agricultural raw materials on GDP, with both government expenditure and revenue declining in the period of a favourable price shock. However, the analysis of FEVD reveals that the importance of agricultural raw materials prices as a factor behind Ukraine's output and fiscal variables is rather low. As expected, higher agricultural raw materials prices are associated with the RER appreciation, reflecting an increase in the export receipts. On the other hand, the RER depreciation brings about a decrease in the



government expenditure and revenue combined with a strong downward pressure on output. It means that any attempts to achieve more 'competitive' RER are counterproductive in the Ukraine's economy. Also, it is worth noting that agricultural raw materials price and RER shocks are characterized by asymmetrical effects upon output. Among other results, there are positive output effects by both government expenditures and revenues, while the reverse causality suggests a decrease in both fiscal variables following an increase in GDP. For the purpose of stabilization policies, our study suggests implementation of government spending cuts in the case of an increase in the agricultural raw materials prices, while an increase in the government revenue is recommended for the periods of lower prices. Similar to other countries (Chile), it is desirable to implement the fiscal policy rule, in the way that accounts for an expansionary impact of both government revenue and spending.

Obviously, there is much room for further investigation of endogenous fiscal policy rules accounting for commodity price developments, and our results would be a useful tool for that purpose. It would seem important to recognize that volatility of commodity prices can bring about a downward pressure on the long-run growth path. Also, we did not consider the interaction between fiscal and monetary policy stances, as well as effects of large exchange rate devaluations in 2008 and 2014. Finally, structural shifts in the Ukraine's economy require consideration in the context of commodity prices.

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## THE USE OF MAAS SERVICES: AN EXAMPLE OF THE POLISH Y GENERATION

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Socio-economic changes and evolving IT environment led to the emergence of new mobility solutions, very popular in urban areas. New Mobility Services (NMS), including Mobility-as-a-Service (MaaS) are now an integral part of short- and long-distance transportation service portfolio in many countries and are offered both by companies (public or private) and individual bidders. The challenge for the service providers is now to adjust the business models of those solutions to the customers' needs. The particular layers of designing MaaS solutions are crucial to meet the requirements of users, especially young adults (Y generation), considered as the primary target group for MaaS offer. Therefore, the study aims to examine the level of awareness of the MaaS market offer and, in addition, a range of use of those solutions.

Keywords: Mobility-as-a-Service, MaaS, IT, public transport, mobility choices, y generation, software development, mobile applications

### 1. Introduction

Changes in the area of the terrestrial mobility (especially increasing number of travels) and good access to modern technologies create new challenges for mobility service providers, both private- and public-owned, but also a new, emerging ones – the individual bidders. Because of the sharing economy trend, the traditional model of ownership has changed. To address all the problems related to customer-oriented or customer-centred approach in the area of mobility services, Mobility-as-a-

Service solutions (MaaS) will play a huge role. They would probably solve the problems with congestion and a lack of parking space, especially in the city centre areas. In addition, MaaS can address some issues specified in sustainable urban mobility plans (SUMP) created for many cities around the world. What is more, most of the MaaS offers are related to car use, and compatible with so-called "car culture", presented by many societies, especially in Europe, Japan and USA.

The study aims to examine the level of awareness of the MaaS providers among young adults in Poland and in addition, a level of use of such solutions. After achieving this objective, some directions can be drawn for further research on the discussed topic and for the development of those solutions.

The best of the researcher's knowledge, this area has not been empirically studied for Y generation in Poland. In addition, the literature review carried out to prepare this paper did not address this issue. Therefore, there is a research gap to be filled in by examining the choices of the Polish young adults. Taking into consideration the above-mentioned arguments, the main research question in this paper is:

RQ1: Do the Polish young adults know and use the MaaS solutions?

The answer to this question addresses the problem of developing such solutions and can be helpful for MaaS providers to improve their offer.

The paper is organised as follows. The first section gives a review of the literature on the studied topic, according to the chosen literature review procedure, search engine and search criteria. The second part of the paper presents the methodology of the main research, namely survey. The third section contains research results divided into general ones and those for the specified respondents' group. The last one part concludes the paper, presents its limitations and specifies areas for future research.

## **2. Literature review**

### 2.1. Procedure

To obtain reliable results of the literature review, the chosen procedure for defining the publication base have been used. The analysis was aimed at identifying critical areas of knowledge on the use of MaaS, then to verify them among the group of respondents and compare with the results obtained by other researchers.

The procedure chosen for this study was based on the Denyer and Tranfield's approach [1], which is defined as proper for exploratory socio-economic research. This standardised research procedure makes research in this paper transparent, replicable, exclusive, aggregative and heuristic. It aims to identify trends and main characteristics of the studied subject to continue research work using other methods.

To objectify the process of building the literature database in the stage on determining primary literature, Boolean logic was used, in which the merit criterion was publication title ("mobility-as-a-service" or "MaaS" in title), and the technical one- full-text records. The time criterion was not specified, although naturally, due to the novelty of the main research topic, the selected articles were published from 2011 to 2018. The EBSCOhost search engine was used to carry out the search procedure.

## 2.2. Results

After the implementation of the literature review procedure, including removing duplicates and analysing the abstract and text of chosen literature, only 14 papers were identified as those strictly related to the studied subject and object.

Mobility services are a group of traditional and new solutions offered by individual bidders, public and private companies to customers to travel the route from the starting point to the destination point [2]. New Mobility Services (NMS) are a part of the market offer and emerged ca. 2010 as a result of last socio-economic trends. The mentioned trends include the sharing economy with its part - shared mobility. Within the group of NMS, a subgroup of Mobility-as-a-Service (MaaS) can be derived, delivered both by private car owners (C2C) and by fleet owners (B2C, B2B, B2A), with use of web portals or (in most cases) mobile applications.

The basic level of integration is the partial integration of MaaS, that makes it impossible to exploit the full benefits from the integration of different mobility solutions (for example a lack of tickets buying services on the MaaS platform), only checking and analysing the possible journey routes. Advanced integration is represented by most of MaaS solutions, and its core is aimed to integrate the public transport with car sharing, taxi systems, long-distance travel services and car rentals. Its more developed form is advanced integration with mobility packages, offering pre-purchasing of service packages, also for specific socio-economical groups like families and businesses.

MaaS systems consist hardware (especially important when offering semi-autonomous or in near future – fully autonomous cars), and software (mapping, identifying localisation, dynamic virtual bumper, booking system, planning and steering control, external communication, detecting objects and their path) [3]. The structure and nature of the elements that make up such a system should take into consideration environmental factors, human factors (intuitive user interface), law issues (safety, anti-vandalism), security (data privacy, hacking resistance) and scalability. Devices that operate in MaaS environment communicate with each other using the D2D communication (device-2-device) by building a communication network. Those systems contain a built-in complex analytical system that allows, for example, preparing routes map based on the user's profile, analysis of previous routes and declared goals that make up the person's mobility pattern [4].

MaaS can be developed in different variants in different countries. Well-known approaches in this area are market-driven scenario, public controlled development and public-private development. In public transport, many values are essential to be established and improved, such as competence structure, brand value, access to MaaS, business model [5].

Elements of MaaS IT solutions are, according to Bouwman et al. approach [6], divided into four groups: service design, technology design, organisation and finance design gathered from different sources and presented by Szmelter [2; see Table 1]. The service design is a part of the important in the value creation process.

MaaS is inspired by cloud computing in the field of transport. The complex structure of those systems, especially modelling and forecasting of data, is hidden by user-friendly interface [7]. Therefore, a good Business Intelligence tool should be developed to analyse big data from various sources in real time. Usually, they are administrated and owned by mobility operators (still called by most researchers and practitioners “transport operators”). The best way to create the mobility market is cooperation between those operators (federation of operators). In this way, they can attract the offer by allowing the use of their services jointly with those of the partner. This generates substantial synergy effects for both transaction parties. MaaS provide two kinds of functionalities: transport on demand, subscription service (kinds of buying the ticket, fixed or pay-as-you-go), and additionally – the potential to create new markets [8]. Two features describe them: technology and availability. They are intended to provide benefits for individual users, public and private sector.

MaaS services address the whole journey on short distances and the first and last mile of the journey in long distances by offering developed public transport services and other mobility services provided by private companies. The main characteristic of all MaaS is the possibility of using it by booking the means of transport with use of the mobile application. It can be short- or long-distance travel, but as it was said before, the main focus is made on short-distance travel. This, in turn, will result in lower private-own car number, and less traffic congestion and greenhouse gases. In turn, customers expect a short waiting time, travel time and great comfort, which is why the most popular solutions are car sharing and ridesharing. The challenges on the MaaS market are many and require the use of, among others: advanced forecasting and agent-based day-to-day adjustment process, advanced pricing models [9], MaaS development scenarios by use of interviews [5], trials with autonomous shared cars [3], building and testing tier-structured MaaS solutions [7], presenting device-level information-centric networking architecture [4], network modelling (simulation) according to price fragmentation approach [10], semi-structured interviews with users [8], capability-driven approach [11], or simulation of functioning such a system [4]. Adjusting the current state of the

transportation systems to the market needs can also be done by using the patterns from MaaS applications [2,12,13], implementations in cities [14], and new approaches to MaaS development like, for example, end-to-end virtual mobile networks [15]. Further, much more detailed analysis of all MaaS systems in 2017 was made by Jittrapirom et al. [16] and Johansson [17].

**Table 1.** Functionalities and elements of MaaS IT solutions

Area	Element/functionality
Service design	Journey searching (fastest, cleanest, cheapest)
	Trip planning
	Trip advising
	Trip comparison
	Traffic analysis
	Price analysis
	Journey booking, integrated booking
	Activating tickets/trips
	Checking trip history
	Customer service (24/7 service)
	Application and web solutions
	Detection of passive deviations (e.g. Weather) and active (e.g. driving too slowly)
	Navigation system
	Online information about delays
	Feedback messages system
	Integrating other city mobility services
	Travel diary and its analysis
Integration with planned meetings and mobility assistance	
Intermodal routing analysis, inter-solution routing analysis	
Technology design	Integration of real-time data including open data (e.g. timetables), social media data, sensor data and crowd data (e.g. user device data)
	Data safety
	RFID
	Real-time service
	Compatibility with iOS, Android and other operating systems
	Big data analysis
	Trip forecasts system
	Fleet management options
	Integration with Decision Support Systems
	Cohort analysis and forecasting
	Layout personalization possibilities
	Real-time connectivity between vehicles (V2V) and between vehicles and infrastructure (V2I)
	Integration with calendars (MS Outlook, Google Scholar)

**Table 1.** Functionalities and elements of MaaS IT solutions (cont.)

Organization design	Integration of service providers (including e-mobility providers and public transportation)
	Organizing a partnership model with other providers
	Project management issues
	Product lifecycle management
	Integration with partners
	Defining data sharing policy
	Revenue and cost-sharing agreement
	Defining geographical scope (regional, regional and urban, only urban)
	Defining a number of modes
Finance design	Payment
	Price models
	Checking balance
	Currency rates integration
	Charging
	Calculating fixed costs
	Payment possibilities
	Common payment tools and clearing procedure

### 3. Research method

The primary research method was the survey method, an online, anonymous survey. The main tool in this method - the questionnaire contained questions regarding attitudes, behaviours and opinions. Its part contained questions about MaaS use and opinions about these solutions. The questions were modelled on the available interview sheets, and questionnaires in current literature on the mobility of young adults, also called the Y generation, and if that was impossible to reach these questionnaires in the selected literature - based on the research results and conclusions described in these papers. After the pilot study and amendments in the questionnaire, a survey among representatives of the Y generation was preceded. The surveyed persons were recruited with use of a purposive strategy [18,19] based on the inclusion criteria that the participant should be born between 1981 and 1999 and be a Polish citizen (see Table 2). As an additional approach, a snowball sampling method was used [20] to increase the number of participants because random sampling procedure in the case of this study was hard to reach. The survey was held from March to November 2018. 437 people took part in the survey. The data collected while conducting the survey was mainly qualitative, two- or multi-level data. Variables were described on nominal and ordinal scales. For this reason, as the first, descriptive statistics and cardinality tables were used to characterise the surveyed group and present some general results for young adults as one group.



#### 4. Research results

First of all, the MaaS idea was familiar to the respondents. What is extraordinary, every surveyed person knew the MaaS solutions (see Table 3). As it turned out, the most popular MaaS services are provided by Uber, myTaxi and BlaBlaCar. What is surprising, the first and second of them appeared on the Polish market very recently (Uber in December 2013, myTaxi in February 2013), and not only in every big city at the same moment (most of those solutions were launched firstly in Warsaw, then in other Polish cities). This fact shows the dynamic growth in the number of clients using taxi and para-taxi services with the use of mobile applications. In general, the car-related MaaS are popular in Poland (except to 4Mobility, available only in Warsaw). On the other hand, the applications enabling the scooter rental (Blinkee, Scroot, JedenŚlad) were not popular in the surveyed group, however, if the study was repeated only among the residents of the Polish capital city, the results would undoubtedly be higher, because for this city usually the other residents' attitudes and choices can be presented than for other Polish cities.

**Table 2.** Characteristics of the research sample

Category	Result
Year of birth	1981-1990 19,22%; 1991-1999 81,78%
Sex	Female 56,50%; Male 43,50%
Student status	Bachelor students 53,3%; Master students 9,8%; Doctoral students 0,7%; Graduate 35,5%, Non-student 0,7%
Personal status	Single 41,4%, in a relationship; 51,9%; married 6,6%
Place of residence	City 500.000p or more 19,0%; City 200.000-500.000p 39,4%; City 100.000-200.000p 7,1%; City, 50.000-100.000p 8,5%; City less than 50.000p 15,6%; Countryside, suburban zone 6,2%; Countryside 4,3%
Housing status	Own flat/house (without mortgage) 23,1%, Own flat/house (mortgage) 4,3%, Flat/house owned by family 29,1%, Rented flat 38,7%, Dormitory 4,8%
Household size	One person 6,6%; Two persons 41,0%; Three, four or five persons 48,5%; More than 5 3,9%
Kids in the household (0-16 years old)	Yes 9,8%; No 90,2%
Monthly income per person	500 PLN or less 2,7%; 500-1000 PLN 8,7%; 1000-1500 PLN 18,1%; 1500-2000 PLN 20,8%; 2000-3000 PLN 20,8%; 3000-5000 PLN 15,3%; more than 5000 7,3%

The respondents in this survey use practically only taxis or parataxis, the most popular of which are Uber and myTaxi (short-distance), then BlaBlaCar (long-distance) and Traficar (short-distance). An unusual case of the free-floating car-sharing system in Poland is Traficar, currently operating in 6 locations (Tricity, Warsaw, Wrocław, Poznań, Cracow, Silesian agglomeration), launched in October

2016. The number of the Traficar users grow rapidly, what is confirmed by the data in this paper. 62,5% of respondents know this MaaS solution, and almost 10% use this for travelling within the city and suburban areas because those locations are the most popular among the Traficar users. This solution is based on the network of stations (usually the gas stations of one of the most popular gasoline supplier) and the free-floating car-sharing system (the user can leave the car wherever he wants), so the business model of this solutions is very new, and the services – flexible and individualised.

The potential for the development of MaaS services can also be considered through the prism of young people's opinion on these solutions because this will affect the future value of the market and the participation of individual service providers in the mobility sector. Due to the young age of economic activity in the sphere of mobility, such opinions should be taken into account. According to research, more than half of young people use mobile applications to order a taxi and more than 10% of respondents use MaaS services at least once a week (see Table 4). More than half of the respondents admitted that they use those solutions, although the frequency of using them is various. About 77,5% of respondents positively perceive the introduction of para-taxi (e.g. Uber) on the mobility market. 57,74% of respondents confirm that the concept of car sharing is well-known. About 20% present the opposite opinion, perhaps due to the fact that most of these people do not use MaaS services. Surprisingly, over 58% of young adults believe that the introduction of urban cars on demand, in the hourly rental system, would be beneficial for modern cities.

**Table 3.** The awareness of MaaS brands in Poland among young adults

Knowing the MaaS	No. of people	% of people	Use of MaaS	No. of people	% of people
Generally	437	100%	Generally	244	55,8%
Uber	431	98,6%	Uber	206	47,1%
BlaBlaCar	430	98,4%	BlaBlaCar	89	20,4%
Ecocar	268	61,3%	Ecocar	12	2,7%
iTaxi	240	54,9%	iTaxi	23	5,3%
myTaxi	385	88,1%	myTaxi	128	29,5%
Traficar	273	62,5%	Traficar	40	9,2%
Taxify	93	21,3%	Taxify	12	2,7%
Blinkee	73	16,7%	Blinkee	6	1,4%
Scroot	40	9,2%	Scroot	5	1,1%
JedenŚlad	51	11,4%	JedenŚlad	2	0,5%
4Mobility	50	11,4%	4Mobility	2	0,5%
Other	87	19,9%	Other	33	7,6%

All the above results indicate a positive perception of the mobility market offer in the field of MaaS services by young Poles, generation Y. The respondents declared both the use of these solutions at a high level and a high assessment of their suitability for society. The results of the study give the group some optimism when it comes to predicting the future of this services market. Certainly, with time, positive assessments of participants who do not use MaaS will result in the use of these solutions.

**Table 4.** The opinions of young Poles about launching the car-related MaaS on the market

Question	Result
Do you use the mobile application to call a taxi?	Yes (55,84%), No (44,16%)
I use the mobile application to call a taxi or para-taxi or shared vehicle.	Yes, every day (1,60%), Yes, couple times a week (4,12%), Yes, once a week (8,01%), Yes, less than once a week, more often then once a month (16,93%), Yes, once a month or less (23,80%), No (45,54%)
Launching the Uber and similar solutions is good, I like it	(1- I completely disagree; 5 - I definitely agree) 1 (1,60%); 2 (2,52%); 3 (18,31%), 4 (34,10%), 5 (43,48%)
I like the concept of the shared cars or renting cars on demand.	(1- I completely disagree; 5 - I definitely agree) 1 (2,97%); 2 (9,61%), 3 (19,68%), 4 (32,04%), 5 (35,70%)
Urban car (public, rented per hour) is a good solution for cities.	(1- I completely disagree; 5 - I definitely agree) 1 (4,58%); 2 (9,38%), 3 (27,69%), 4 (38,67%), 5 (19,68%)

## 5. Conclusions, research limitations, future research directions and plans

This research showed the attitudes of Polish young adults to use Mobility-as-a-Service solutions. The answers of the respondents enabled achieving the study goal. The travel behaviour of Polish young adults characteristics and tendency to present specific behaviours within the area of mobility can be the basic assumptions for mobility services development, including IT solutions. The strong tendency to use MaaS solutions is visible, taking into consideration the pace of growth in this market worldwide, but especially in Poland. Solutions launched to the market only a few years ago are definitely recognisable and used by a large percentage of the respondents, so can be a contribution to believe that similar results can be achieved for the entire population.

Though, the idea of MaaS is very promising regarding the level of its awareness on the Polish market. The next steps of the data analysis will be focused on the examination of the differences between the men and women, younger and older cohorts, urban, suburban and rural residents, and according to their marital and parental status, housing status and level of disposable income. The obtained results should be compared to those available for other societies.

Though, it should be noted that this research has few limitations. Firstly, the literature research method concerns only papers with particular search criteria. Therefore, there is a risk of omission of papers related to the studied topic. Secondly, no random sampling method was used to carry out the survey. Therefore, the presented research results can be less reliable. Consequently, the results of this survey cannot be extrapolated to the whole population of Polish young adults.

Despite those limitations, the described research results are promising and can serve as a basis for further research, comparisons, developing the software or verifying the existing one. Further research should be conducted to obtain more data on Y generation mobility choices, the use of mobile MaaS applications, and other dimensions of screening the mobility market. In addition, comparative analysis can be made not only for young adults in different countries but also for different age groups (generations) to provide the guidelines for the development of MaaS software dedicated to various user groups.

Technological considerations are one of the main issues related to smart city creation and its operations [21]. That is the reason for developing the research in the areas of real-time big data analysis, the creation of a communication network, for example, development of D2D network schemes [4]. These and many other issues in the area of generations' mobility should be addressed in future theoretical and empirical research.

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## CLUSTER ANALYSIS AS A PRELIMINARY PROBLEM IN NEURAL MODELLING OF THE POLISH POWER EXCHANGE

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The work focuses on cluster analysis as a preliminary problem in neural modelling based on the data quoted on the Day Ahead Market of the Polish Power Exchange as a subsystem of the system of Towarowa Giełda Energii S.A. [Polish Power Exchange]. The paper contains the results of literature research related to cluster analysis methods, description of possible applications of artificial neural networks SOM for mapping information on the volume of electrical power sold and prices obtained, description of possible applications of MATLAB and Simulink environment, and especially Neural Network Toolbox for mapping knowledge, and cluster analysis performed for selected data.

Keywords: artificial self-organizing neural networks, business intelligence, cluster analysis, neural modelling, Day Ahead Market, Polish Power Exchange.

### 1. Introduction

Due to immense increase in information and data towards the end of the 20<sup>th</sup> century, a need for the automated preliminary analysis and visualization of the obtained results arose. Among numerous tools for knowledge visualization, especially for cluster analysis, numerous environment tools such as MATLAB and Simulink, including Neural Network Toolbox were developed [2]. First works on the subject demonstrated that artificial neural networks, including SOM (Self-Organizing Map) played a significant role in the process of cluster analysis [11, 16-20, 22-23]. Due to

the fact that the number of transactions concluded on the Day Ahead Market (DAM) of the Polish Power Exchange Market (PPEM), and, consequently, the amount of data related to the volume of electrical power (ep) delivered and sold [MWh] and prices obtained for ep sold [PLN/MWh] is rising, the need for preliminary analysis of the data arises [12]. Relatively new, though reliable method used for analysis of large datasets is cluster analysis, thoroughly described in works by Wierzchoń S. and Kłopotek M. [24-25].

Therefore, the main objective of the conducted research was to conduct cluster analysis using the Neural Network Toolbox in the MA-TLAB and Simuink environment as a preliminary issue prior to the use of Artificial Neural Networks (SSN) to model the TGEE system, that is to model neural TGEE. The basic problem to solve was to highlight in the data set specific clusters of information with similar features and properties using the appropriate cluster analysis method. The obtained data presented in the cluster analysis are called classes that differ in terms of creating specific, more or less explicit clusters of data projected, for example, on a plane. Cluster analysis assumes the existence of a sequence of objects, which is described by an n-dimensional vector.

In order to identify similarities between pairs of objects, their similarity or dissimilarity measures are introduced. The two measures depend on each other, i.e. if the value of dissimilarity decreases, the value of similarity increases. Clustering algorithms are used for comparing objects, which algorithms are thoroughly described e.g. in works [1, 3-5, 8-10, 21]. The notion of cluster analysis is also referred to as data grouping or data clustering, and was borrowed from data exploration and machine learning as a specific non-pattern classification [1, 4-5, 7-9, 21]. Therefore, cluster analysis is a method of classification without supervisor (unsupervised learning), i.e. obtained by employing a method grouping elements into homogeneous classes or data clusters, with the rule of grouping being specific similarity between the elements, determined using probability function called metric, appropriate for the problem being analysed [3-5, 21].

## 2. Cluster analysis methods

Among cluster analysis methods based on artificial neural networks (ANN), the following methods may be distinguished, related to, i.a. [3-6]:

- classification, i.e. division of the measurements results being analysed by means of ANN into classes based on their specific features,
- regression, i.e. assigning data, input to the artificial neural network in the form of known features of the system to results of observation,
- clustering, i.e. cluster analysis involving grouping training pairs (so called samples) according to similarity between them,



- anomaly detection, i.e. detection of clusters similar to the pattern that is completely different from the expected pattern,
- association rules, i.e. rules related to determination of relations between the features and attributes in the matrix of values of training (here: input) pairs to the artificial neural network.

At present, the methods of data analysis, including preliminary analysis of data are more advanced (e.g. systems for classifying images by Microsoft), and have much lower error rate than those conducted by people classifying objects or elements.

In order to improve the quality of data being processed, in artificial intelligence algorithms, including artificial neural networks, input data undergo appropriate preparation. The process of preparation of the database (input matrices) comprises the following stages:

- preliminary transformation of data related, e.g. to scaling individual numeric data in order to obtain appropriate values, often combined with supplementing the missing values and characteristics construction involving formation of new characteristics, describing processes occurring in the system from the point of view of the research goal; such analyses are performed using e.g. automated algorithms, including methods that learn so called representation,
- preliminary transformation of data related e.g. to scaling selection of characteristics involving verification - whether they describe the phenomenon being analysed correctly and exhaustively from the point of view of selection of the most significant relations, including assignment of weights to them or use of other methods of classification (e.g. ranking, tournament, assigning ranks, etc.).

Classification can be defined as assignment of an object or an element to a specific input class of the sample, whose class is unknown. Assignment to the class is performed by a trained model called classifier, which acts based on the value of known characteristics or similarity of characteristics.

It is taught using sequence of samples e.g. in the form of vectors or matrices, for which both the class and the values of characteristics are known. In this case, supervised teaching is applied. There is also a possibility of using various classification algorithms. Therefore, it is necessary to select the best algorithm for the classification problem being solved in order to obtain the best efficiency and effectiveness. The most frequently used algorithms include logic regression, decision trees, random forests, support vector machine, etc. They are characterized by both low complexity and high efficiency and effectiveness of classification. Logic regression is one of many algorithms, which are used for classification when a sample is assigned to one of two classes. A significant problem to solve is then selection of the appropriate method for determination of coefficients such as the least square method, decomposition method, Cholesky factorization (decomposition), or gradient method, etc.

Decision tree is a classifier, usually represented by a binary tree, in which nodes describe individual pieces of data in terms of the values of a selected characteristic, and leaves describe individual samples that belong to a given class.

Another method is random forest as a set of classifiers (ensemble classifier) in which each single classifier is a decision tree trained continuously without halts until a leaf contains only samples belonging to the same class. Each classifier in the random forest is trained using a random data sample selected for that particular classifier. Such a technique of data generation is called bagging or bootstrap aggregating [21, 24-25].

Another algorithm used in classification is Support Vector Machine algorithm, which determines a hyperplane that separates samples from various classes with a maximum margin between them. In order to ensure maximum width of the margin between the samples from various classes, minimization of the module of the vector  $\|\mathbf{w}\|$  is performed, at the same time maintaining class welding. A separate problem is the assessment of classifier performance, conducted in order to establish its quality. For this purpose, two sets of data are required, the first one for training the classifier, i.e. so called training set, and the other one, used for testing the classifier. More detailed assessment of classifier may be obtained by  $k$ -fold testing, which is often performed as data validation. Various metrics such as permutation test are used for the assessment of the classifier. Clustering algorithms use different distance measures, the most important of which are presented in table 1. They include, i. a., the Minkowski distance, the Mahalanobis distance, the cosine distance, the power distance and the Bregman divergence. Measures and models corresponding to the above distances are presented in table 2. They are described in detail, i.a. in works [21-25].

In the literature on the subject, cluster analysis algorithms are divided into the following basic categories [3-5, 7-11, 19-21, 23-25]:

- hierarchical methods based on development of classification hierarchy for a set of objects, starting with such division in which each object constitutes a cluster, and finishing with a division, in which all objects belong to one cluster,
- grouping using k-means method – grouping that involves preliminary division of the population into a predefined number of clusters, followed by the improvement of the division by moving certain elements to other groups,
- fuzzy clustering method, including the best known c-means method, in which an element is assigned to more than one category, which allows for using fuzzy clustering algorithms in tasks involving classification of elements to one or more categories,
- methods that use Self-Organizing Maps, which allow for so called knowledge mapping and self-formation of clusters of data or information about data.

**Table 1.** List of distance measures

No and Name	Measure	Special cases	Application	Notes
1	2	3	4	5
1. Minkowski distance	Generalised measure of distance between points in Euclidean space.	P=1 city block (Mahnattan) distance P=2 Euclidean distance P=∞ Tchebychev distance is obtained.	Exact Sciences, Psychology, Design.	With the increase of dimensionality of the problem, the difference between close and far points dwindles The value of Minkowski distance is dominated by characteristics measured on a scale with the greatest span.
2. Mahalonobis distance	It is assumed that the characteristics are not correlated with one another.	When co-variance matrix is a diagonal matrix. The distance becomes weighted Euclidean distance.	When characteristics are not correlated For identification of outliers.	For $y_i = -\sum 1/2 x_i$ Is transformed to Euclidean distance
3. Cosine distance	Uses cosine of the angle, and is basic measure used in systems for finding information.	-	For measuring similarity between documents.	-
4. Power distance	Increase or decrease of increasing weight.	P = r distance is equal Minkowski distance.	Changing weight in the selected dimension	-
5. Bregman divergence	Considers more complex relations between the compared vectors.	-	In problems related to signal compression.	Is often transformed to other distances.

Source: own compilation on the basis of works [5, 21, 24-25]

**Table 2.** Mathematical models of distance measurement

No.	No	Mathematical model
1.	Minkowski distance	$d_p(x_i, x_j) = \left[ \sum_{l=1}^n  x_{il} - x_{jl} ^p \right]^{1/p}$
2.	Mahalonobis distance	$d_{\Sigma}(x_i, x_j) = \sqrt{(x_i - x_j)^T \Sigma^{-1} (x_i - x_j)}$
3.	Cosine distance	$d_{cos}(x_i, x_j) = 1 - \frac{\sum_{l=1}^n x_{il} x_{jl}}{\ x_i\  \ x_j\ }$
4.	Power distance	$(d_{p,r}(x_i, x_j) = \sum_{l=1}^n  x_{il} - x_{jl} ^p)^{1/r}$
5.	Bregman divergence	$d_{\varphi}(x, y) = \varphi(x) - \varphi(y) - (x - y)^T \nabla \varphi(y)$

Source: own compilation on the basis of works [5, 21, 24-25]

Moreover, three different techniques of fuzzy clustering can be distinguished: partitioning algorithms, which involve finding an optimum division of a set of examples into a specified number of clusters (groups), hierarchical algorithms, which involve hierarchical attempt at discovering cluster structure, density-based algorithms, which divide sets of examples using probabilistic model for base clusters.

### **3. Polish Power Exchange**

Towarowa Giełda Energii S.A. (TGE S.A.) [Polish Power Exchange, PPE] is a joint stock company established in 1999 [12, 16, 18]. PPE offers its participants access to uniform market data, which can be accessed through the Company's platform, the access is open, and rules for all commercial transactions are uniform.

PPE is a subsystem of PE with transactions quotation e.g. Day Ahead Market (DAM). The data allow for finding the best offer on the market and managing prices and volume of electrical power required by customers. The main areas of activity of the Exchange include commodity transactions on the following markets: the Day Ahead Market, the Commodity Forward Instruments Market with Physical Delivery, Property Rights Market, Emission Allowances Market, etc.

Polish Power Exchange initiated introduction of new solutions related to trade in electrical power. It runs markets in which the biggest companies in power industry participate. PPE is constantly developing and adding new markets. At present Polish Exchange Market conducts activity related to trade in electricity and liquid and gaseous fuel, limiting emission of pollution, limiting the volume of production, property rights, etc.

The Day Ahead Market is a spot market for electrical power. Its main goal is to create prices of power for contracts concluded on the power market in Poland. Another goal of the DAM is to balance contract positions, assessment of companies value, generation of investment signals related to development of new power capacities, etc. The DAM on the TGE S.A. consists of 24-hour day markets, where specific hour contracts are quoted. Moreover, the DAM offers three types of block contracts, i.e. BASE – delivery of 1 MWh of electrical power per hour, PEAK – delivery of 1 MWh of electrical power between hours 7:00 – 22:00, Offpeak – delivery of 1MWh of electrical power outside peak hours e.g. 0:00-7:00 and 22:00-24:00.

TGE S.A. also permits submission and settle over-the-counter transactions (OCT) based on standards contracts quoted on the DAM session, and the trading volume is calculated with the accuracy of 0.01 zł/MWh (minimum volume equals 0.1 MWh). Quotations on the exchange take place daily in electronic form, by means of a special platform developed for this purpose. Selection of a particular day takes place following the selection of this day in the calendar together with the information, which, due to public access may be used in scientific and research

experiments. Numeric data from PPE is available to anyone. The values used in the calculations cover the period of three months (01.07.2010 - 30.09.2010). The values present electrical power delivered and sold [MWh] and the average weighted by the volume of electrical power price obtained at a given hour of the 24-hour day [PLN/MWh]. Due to relatively big amount of data for an example research experiment, i.e. the dimension of 24 x 92 (24 hours of the 24-hour day, 92 samples from the above mentioned three months), only the data related to the volume of electrical power [MWh] will be shown. In order to show how the data increase and decrease in particular hours of the 24-hour day and in particular days, the visualisation was performed for particular volumes of sold and delivered electrical power for appropriate hours and days for the average price obtained for electrical power sold.

#### 4. Preliminary preparation of data for the experiment

Data was obtained in the form of two matrices 24 x 92 (for the period of 01.07.2010 - 30.09.2010) from PPE quoted on the DAM, i.e. matrix of ep volume and matrix of prices [12]. Therefore, the first matrix presents 24 inputs corresponding to the volume of electrical power delivered and sold [MWh] in particular hours of the 24-hour day, quoted on the DAM in the period of 3 months. The second matrix contains averages weighted by price volume obtained from power sold to customers [PLN/MWh] in particular hours of the 24-hour day in the above mentioned period. In order to improve the process of training artificial neural network, the data was normalized and the course was presented in fig. 1. In order to input data to Matlab Workspace two separate matrices were created, namely: **U** – matrix of ep volume **Y** – matrix of weighted averages of ep prices.

#### 5. Research experiment

In order to create Self-Organizing Maps, newsom function was used, which creates a self-organizing map with two inputs and a network of neurons on the hexagonal map with dimensions x by y, as follows: [2]:

$$\text{net} = \text{newom}([0 \ 1; 0 \ 2], [2 \ 4]) \quad (1)$$

To create plots of a generated map, a standard function, e.g. plot may be used:

$$\text{plot}(\text{net}, 'r') \quad (2)$$

The values of weights of a learning artificial neural network SOM, following initiation are further determined based on the winner takes all rule (WTA) [2, 6, 10, 13, 16, 22,26]:

$$\|u(k) - w_c(k)\| = \min\{\|u(k) - w_i(k)\|\}, \quad (3)$$

where:

- $u(k)$  – input vector,
- $w_c(k)$  – vector of winner neuron weights,
- $w_i(k)$  – weight vector of i-th neuron.

In comparison with competitive networks, Kohonen networks not only adapt their weights as weights related to the winner neuron but also weights of all their neighbours within specified neighbourhood radius according to the following rule [6, 10]:

$$w_i = \begin{cases} (1 - \alpha) w_i(k) + \alpha u_i(k), & \text{for } i \in \Omega \\ w_i(k), & \text{in other wise} \end{cases} \quad (4)$$

where:

- $\Omega$ - neighbourhood of the winner neuron,
- $\alpha$ - learning step.

At the beginning of learning, a neuron predisposed to be the winner, is selected based on minimization of the difference between the weights of neurons, while the components of the input vector are determined according to the dependence [6, 24-25]:

$$d(x, W_w) = \min_{1 < j < N} d(x, w_j) \quad (5)$$

where:  $d(x, W_w)$  – distance function between the input vector  $x$  and weights of the neuron.

The most common standard distance functions used include:

- scalar product

$$d(x, W_i) = \|x\| \|W_i\| \cos(x W_i), \quad (6)$$

- Euclidean distance

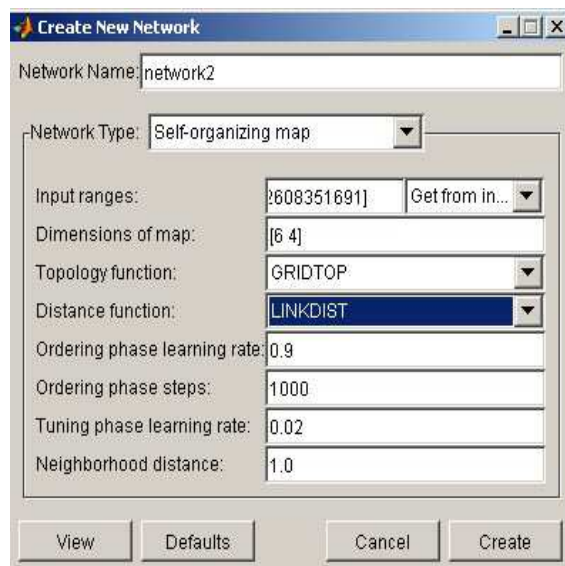
$$d(x, W_i) = \|x - W_i\| = \sqrt{\sum_{j=1}^N (x_j - W_j^{(i)})^2}, \quad (7)$$

- Manhattan norm

$$d(x, W_i) = \sqrt{\sum_{j=1}^N \|x_j - W_j^{(i)}\|}, \quad (8)$$

and many other methods, including those presented in table 1 and in table 2 [3-5, 21-25].

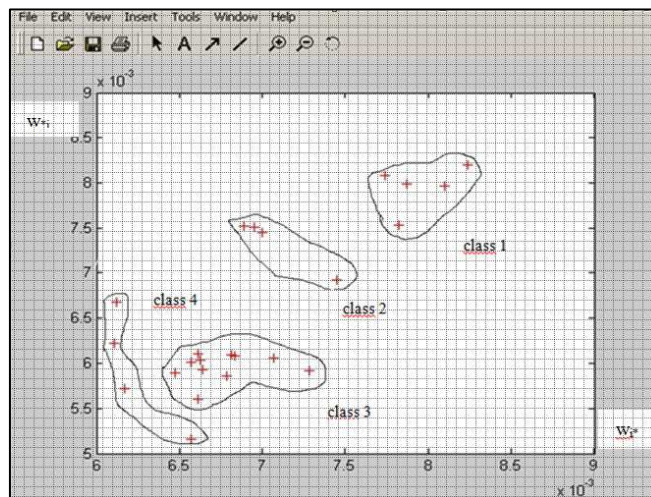
In order to perform cluster analysis, Artificial Neural Network (SOM) was used, which was designed using Neural Network Toolbox and SOM Toolbox. The experiment involved 24 input quantities related to the volume of electrical power sold in particular hours of the 24-hour day [MWh] and 24 output quantities related to the average price obtained in particular hours of the 24-hour day for electrical energy sold [PLN/MWh]. Therefore, the input matrix and the output matrix have the dimensions of 24 x 92. This allowed to define a system of MIMO type (Multi Input i Multi Output) as a real fragment of a system, which is PPE quoted on the DAM. A model of the PPE was designed in the form of Artificial Neural Network of SOM type with 24 inputs, which was used for mapping knowledge related to regularities found in the real system. Competitive learning method was used, which involves competition of neurons on a grid with the dimensions 6 x 4 as in figure 1, i.e. values of weights of 24 neurons are projected onto a plane in order to show data clusters that show self-organization – figure 2.



**Figure 1.** Designing ANN SOM. Denotations: LINKDIST – layer distance function, GRIDTOP – type of network topology, Get from Input – getting input data matrix.  
*Source:* elaboration using Neural Network Toolbox [5]

The figure shows four forming classes of neurons, i.e. four price categories set and quoted on the Day Ahead Market for electrical energy delivered and sold in the period being examined (in 24 hours of the 24-hour day). All the above mentioned classes are characterized by different strength of the relationship between the vol-

ume and the price of electrical energy, with the relationship being the strongest for class 1 and the weakest for class 4, respectively.



**Figure 2.** Mapping final values of 24 weights onto a plane using Artificial Neural Network SOM, available in SOM Toolbox. Denotations: x axis – values of weights related to neuron 1, i.e. weights  $w_{1*}$ , y axis – values of weights related to neuron 2, i.e. weights  $w_{2*}$ . Elaboration using SOM Toolbox [5]

## 6. Conclusion and further research

Cluster analysis was performed as a preliminary problem of neural modelling of Polish Power Exchange. This was related to, i.a., performing literature research on cluster analysis methods in order to examine possibility of projecting knowledge in relation to PPE quoted on the DAM, selection of the artificial neural network (SOM) and its use for mapping information about the volume of energy sold and prices obtained on PPE DAM.

Possibilities of MATLAB and Simulink environment, especially Neural Network Toolbox were examined in the scope of the research, data was prepared and cluster analysis was performed using the prepared data, with no predefined cluster analysis method, e.g. k-means. Instead, SOM (Self-Organizing Maps) were used. Four classes were obtained indicating the occurrence of four categories of prices on PPE quoted on the DAM.

Thus, the fundamental goal of the research was fulfilled as a result of designing and conducting preliminary analysis of real data concerning PPE listed on the DAM. It turned out that there is a possibility of separating four classes covering



points on the knowledge map (fig. 2), which can be further used to carry out in-depth research in assigning to individual neurons the numbers of hours and possible tracking of changes in their position in separate hours 24 hours a day for the entire examined period, which sets a new direction for research.

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