Original Research Article

RESEARCH TRENDS IN TECHNOLOGY CHANGE

Abstract

The publicationaimtoexaminethe main trends and tendencies related to technological development with the help of the keyword search method. Afteran overview of relatedliterature, a "mind-map"modelwaspresented, each part of itwasusedasthefocussubject of thekeywordsearch. Based on a detailed review and evaluation of each keyword area, the paper attempts to explore key features and characteristics, using qualitative cluster analysis. Based on the conclusions and the results of the study, the framework of a comprehensive literature review research can be defined, in order to further examine the connections and correlations of technological development trends.

Keywords

technology development, technology trends, technology forecast, research trends

Introduction

The word "technology" already has a complex meaning in common usage, it is not narrowed down to just the manufacturing process. The conceptwascomprehensivelyelaboratedby Pataki in hisbook, whichstates: *"Technology is a system of expertise and tools to meet needs."*Everydayknowledgecan be consideredasthebasiclevel of realknowledge, throughwhichwe orient ourselves in the world. In addition, profession-likeknowledge (expertise) isa higher level of real knowledge, which is additive to everyday knowledge. Technologytypicallyreliesonscience, butexperimentalknowledgeis alsopart of it. Sometimes, thescientificexplanation of experimentalknowledge is notknown, but stillwe useit,asitworks in practice. (Pataki, 2005)

The topic of new technologiesistouchedbymanyareas,theresearch of Gopalakrishnan and Damanpour (1997) examined the different perspectives of economists, technical developers, and social scientists. The different perspectives generally agreed that the key areas for new technologies were: product and process, the radical or incremental nature of the new technology, and the focus of the technological change (like only technical or wider meaning).
Manyresearchdealwithtechnologyevaluationmethodsfrom the side of a company, whichusuallyapproachestheinternaltechnologyevaluationprocessfromthepoint of view of management objectives. Gerdsri and Kocaoglu (2007) identified a three-phase process called

“Technology Development Envelope- TDE”: (1) gathering strategic information about the new technology, (2) evaluating the technology in light of the organizational goals, and (3) creating the technology development strategy.

The publication by Phaal et. al (2001) provides a good overview of the management frameworks related to the introduction of technological innovations. In addition to several possible models, relevant aspects and processes, they highlight the main elements of the general technological roadmap, which are: business and market, product and service, capability and systems, and also skills, competencies, resources as important areas related to the introduction of new technology.

The management approach to the research and development process is also highly dependent on cultural and corporate specificities. A study by Zedtwitz and Gassmann (2002) pointed out which factors influence the local or international nature of research and development. The spectrum from the local technical base to a global R&D center can also be the result of a development process.

The book of Roper et. al (2011) Forecasting and Managing of Technology provides a thorough overview of the topic. Its compilation covers the following topics in detail in connection with the evaluation of new technologies: technology forecasting, understanding the context of the technology, technology information, analysis methods and scenario analysis, economic and market analysis, impact analysis, cost and risk assessment, technology implementation process.

The methodology of technology forecasting is very broad, however, it is not an easy task to make a clear forecast for a specific technology in a dynamically changing environment. The method of Yang and Zhu (2015) presents a semantically based study, but a number of other qualitative and quantitative approaches are alsoavailable in relatedinternationalresearch.

If we approach the topic from the side of innovation systems, many further known approaches can be founded as well. Berhout et.al (2006) placedtechnologicalresearchamongscientificdiscoveries, market transactions, and product development.

Technology can also be seen as one of the drivers of innovation, which is exactly what Berman and Hagan (2006) present in their publication. They drew the conclusions by examining the examples of several companies. From their point of view, the main features of a technology-driven strategy are: it is based on scientific discoveries, it builds on some uncertainty, iterative, market-oriented, future-oriented.

The book of Deutsch et. al (2019) on Strategic Techno Management links technology and strategy-making and the implementation as well as with organizational governance issues. Relevant issues in the framework of strategic technology management are the technological environment (external and internal), driving forces and mechanisms (capabilities), technological aspects, and pulling mechanisms (technological requirements).

Research goals and method

The aim of the current research was to examine the trends related to the research of new technologies, with the purpose to outline which topic areasare more strongly researched, and which other topics may be related. Based on these contexts, conclusions are tried to be drawn about the focal points of research on new technologies, which mayidentifykeyareasforfurtherresearch.

In order to define the topic areas to be examined, the so-called “mind-mapping” method was uses to define seven main areas as relevant aspects of technological developments:

1. technological trends,
2. technology forecasting,
3. new market needs,
4. new technologies,
5. new technological capabilities,
6. technological change management,
7. technology based service.

The seven areas were further subdivided, resulting in chart of Figure 1, which provides an overview of the thematic area, and which illustrates the possible relevant topics of market-oriented technological developments. The above mentioned 7 key areas have been selected as subject of the current research, with the context as it be seen in Figure 1.

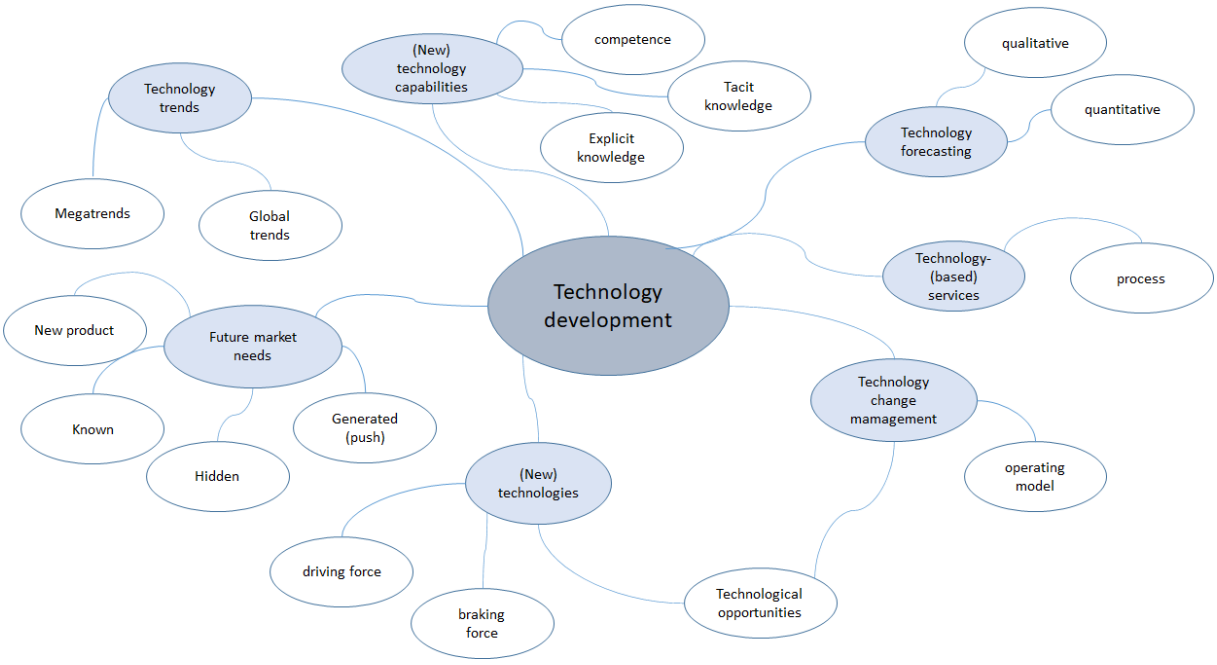

Figure 1 *Mind-map of selected relevant fields of thechnology development*

During the research, VOSviewer software was used to examine and visualize the correlations of keywords related to the selected research topics. The VOS viewer is suitable for visualizing the network relationships of keywords. The basis of the analysis is the range of keywords found in the paper titles and paper abstracts of published scientific publications from a previously queried scientific database. In the course of the research, a thousand publications published in the last ten years have been analysed by VOSviewer.The search results were presented via contact maps as the software creates different clusters of keywords, this is illustrated with different colors. Major keywords founding resulted in a larger "bubble," which means that the word has appeared more times in publications throughout the set of studies. Based on the software setup, we worked with a minimum frequency of ten times of appearance. The figure also illustrates the relationship strength between the keywords, with thickening bubbles indicating a more common correlation. The results were interpreted based on a qualitative cluster analysis of the contact maps of the found keywords.

Examination and analysis

(1) Keyword: Technological trends

Based on Figure 2, four clusters can be distinguished, from which the main topic area can be highlighted. Clusters were defined based on keyword evaluations, which developed as follows:

- green color: application and challenge topic area,
- red color: data and methods subject area,
- yellow: change, pattern, evaluation - concrete effects, consequences,
- blue color: theory, network, architecture, service - conclusions and areas.

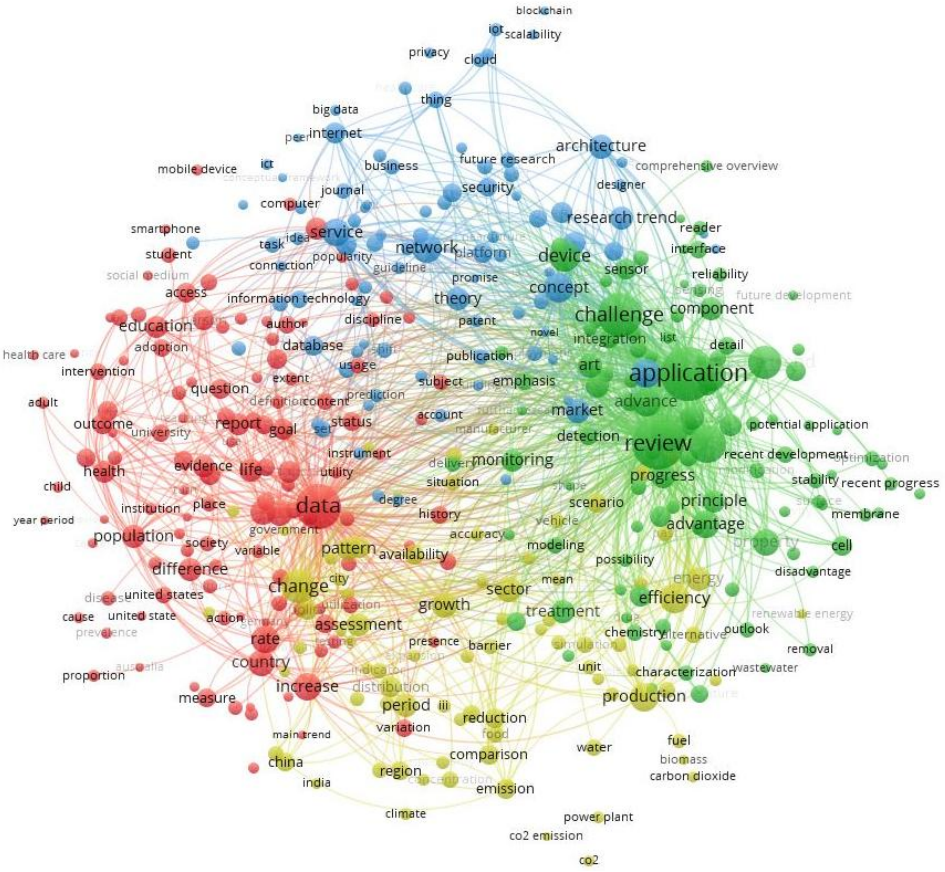

Figure 2. *Keywords found in technology trend research*

The analysis shows the outstanding relationship and extent of the green and red clusters. The research topic area of technological trends is well characterized by the “data” (red cluster) that industrial part-takers need to have, research, examine and process them with the help of methods. In addition, the other major cluster area is “application” and “challenge” (green cluster), which is also an understandable result, as the available technological data need to be able to put in practice. However, the application is in many cases a challenge for industry.

The areas of the two larger clusters are connected by the effects of the data and application of technological trends and their result, as well as the conclusions on, for example, future research trends, service changes, etc.

Overall, the four cluster areas are closely related and the four areas are logically formed. The orientation of the smaller keywords towards the two larger clusters also makes sense.

In addition, further studies may outline relevant issues in the research topic area. To do this, some keywords need to be paired by matching the keywords from the smaller cluster that are close to the two larger clusters (green and red clusters), as shown in Figure 3. as an example in connection with this section.

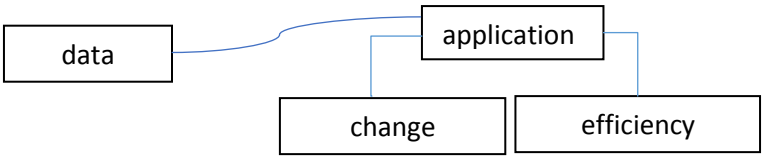

Figure 3. *Main keywords of characteristic clusters - example*

By the figure, it can be said that in addition to the research of data from technological trends, the scope of research on the application of technologies is intensive. However, it is difficult to predict how efficient this will be and whether there is a clear scenario for the technology application.

Based on the examination of the research topic area, it was established that the emergence of technological trends should be addressed and its field of application should be determined. Based on these, the question arises as to where and how to apply and use the given technological trend.

(2) Keyword: Technology forecast

The emergence of technological trends can be projected over time using forecasts, both qualitatively and quantitatively. Since, the term itself is closely related to the technological trends observed previously, we also defined the characteristic clusters here with the help of keyword analysis.

Based on the analysis, four clusters can be distinguished, but here it cannot be singled out a dominant cluster that is clearly differs from the others. The groups of clusters are founded as follows:

- green color: forecast, algorithm, prediction, performance (forecast, algorythm, prediction, performance) - methods topic area,
- red color: change, knowledge, future, trend, innovation (change, knowledge, future, trend, innovation) - change and impact area,
- yellow color: scenario, potential, price, adoption - the role of connecting the other three clusters,
- blue color: assessment, monitoring, measurement - area of assessment and examples.

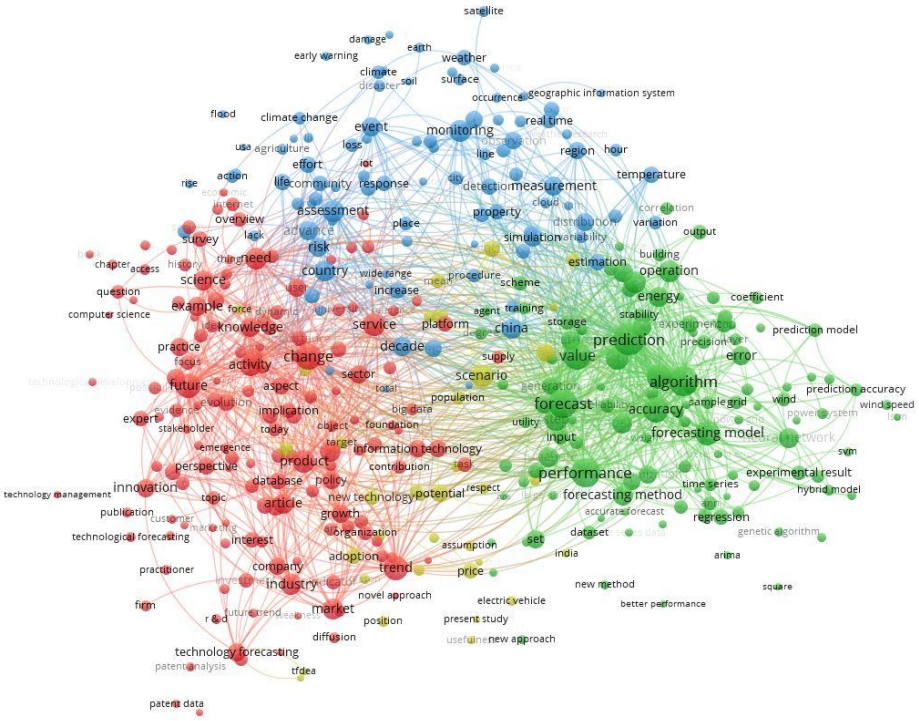

Figure 4. *Keywords found in technology forecasting research*

In the figure, it can be seen that the red and green clusters are where the most keywords are found, and it is grouped better. These two clusters are dominatly connected by the blue cluster, and only scattered by a few yellow keywords. Based on this, it can be said that the methodology of technology forecasting (green cluster) is a more mature area, so there are a number of tools that can be used to predict technological changes and trends. The cluster of evaluations and examples (blue) forms a link with the change / impact cluster area (red). This relationship also proves to be logical, as the technology that emerges always generates some effect that needs to be put in consideration. At the same time, the impact of a given technology must be assessed not only economically but also in technical terms, as the new technology may have an impact on existing ones. Last but not least, the forecasting methodology can also be qualified.

The green and red clusters are to a lesser connected by the yellow cluster. Nevertheless, it covers keywords such as adaptation, purpose, and scenario that are relevant to the research topic, since, the predicted technology, and its application or adaptation aspects, need to be addressed. However, based on the figure, this is a less researched area, as it contains significantly fewer keywords than the other three clusters.

(3) Keyword: New technologies

Following the technology forecast, the keyword “new technologies” itself have been examined in row. Based on the study, clusters were formed as follows:

- green color: world, service, innovation, activity, practice - world, service, innovation, activity, practice - main focuses, definition of (global) directions,
- red color: device, performance, network - definition of comprehensive professional directions (technology),
- blue color: treatment, disease, accuracy - identification of the main areas involved (social point of view).

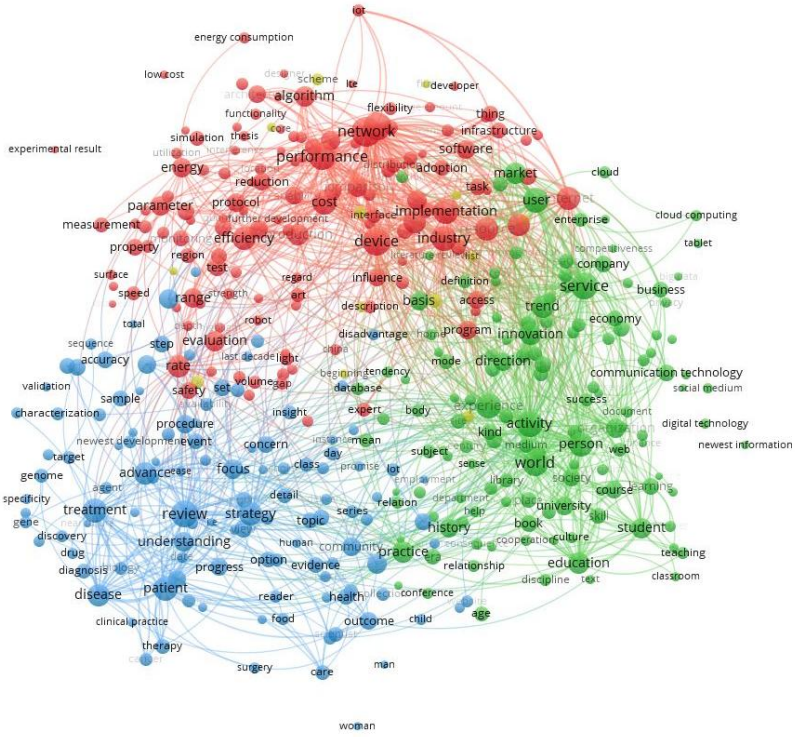

Figure 5. *Keywords found in new technology research*

Dominantly prominent keywords appear in less extent in this figure. Three clusters have formed, which are slightly divisive, but at the same time closely related. This phenomenon may be explained by the fact that the emergence of a new technology affects the world in many forms, or a new and unknown thing affects the technology. Examining the social cluster (blue color), the conclusion can be made that the emergence of a disease (such as COVID-19) calls for new technological solutions in different areas and has a serious impact on society. It is also possible to further examine these factors around the world (green), where the keywords service, education, and innovation also appear. A less visible keyword also appears, which is experience, that is still relevant. The decisive factor in the utilization of the new technology is the possession of experience itself, an aspect which has also been raised in previous studies. The third area is the area of overall directions (red), that is, the range of keywords specific to the technology itself.

In summary, the study does not stand out as a dominant area in relation to new technologies. Thus, it is mainly the relationship between the clusters and the relationship between the

keywords that appear there. For further analysis, it is necessary to specify the field of technologies to be investigated (e.g. industrial technologies).

(4) Keyword: New market needs

The emergence of technologies and innovations is driven by the formation of different market demands. However, its reverse is also true, according to the fact, that the market may have a need for the technology that has already appeared. At this point, the question of the application of the technology rises again.

The keyword search returned the following results:

- green color: application - application cluster
- purple color: education, institutions - society cluster
- blue color: companies, enterprises, surveys, customers - market method cluster
- yellow color: program, participation, economic growth - economy cluster
- red color: production - production or delivery, potention, price) - market advantage cluster

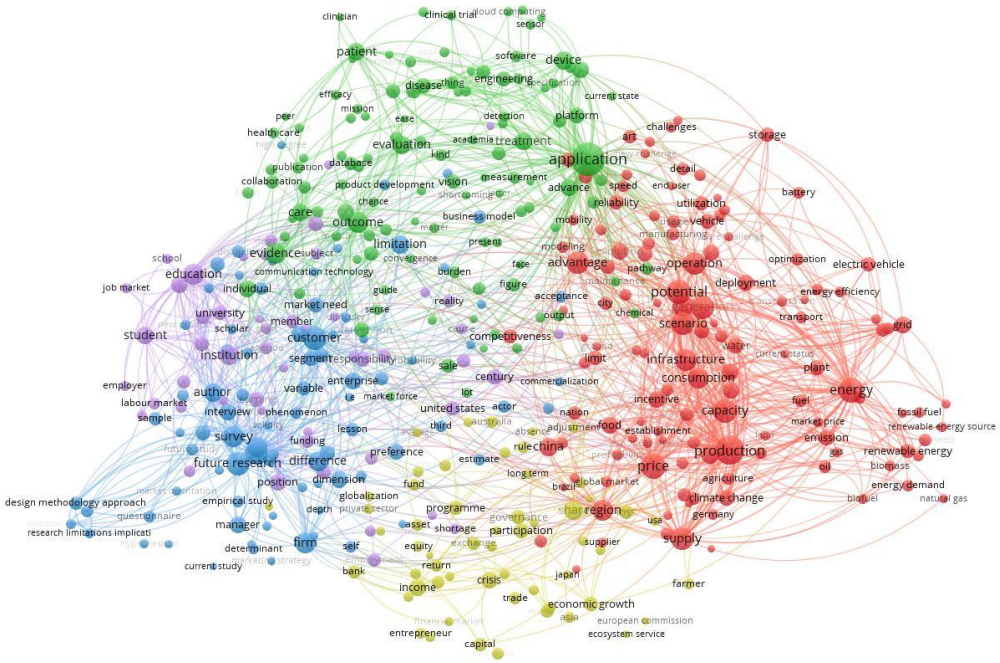

Figure 6. *Keywords found in new market demand research*

Two larger clusters can be highlighted based on the studies, these are application (green) and market advantage (red) clusters. Based on all this, it can be said that whoever can apply the technologies gains a market advantage. In addition, the keywords of the five clusters are scattered and only smaller groupings can be observed within the cluster or between each other. In the market advantage cluster (red), a smaller grouping appears with keywords related

to ’energy’. In the background of it, additional terms can be seen, such as renewable energy and emissions. Thus, a relationship can be assumed between energy technologies and market advantage.

The relationship between themarket approach (blue) and society (purple) clusters is apparently closer. This may be due to the fact that the participants in society are the ones who developed and use related methods, or, society is the one that generates new market demands.

(5) Keyword: New technological capabilities

Applying the technology trends discussed earlier and gaining a market advantage requires a kind of skill. Therefore, we also performed a keyword study of new technological capabilities. The search resulted in the following result:

- yellow: device, communication, network, service - infrastructure cluster,
- red color: technique, field, structure, efficiency - area cluster,
- green: study, management, IT, resource, impact, framework - practice, implementation cluster,
- blue color: user, group, daily user - human cluster.

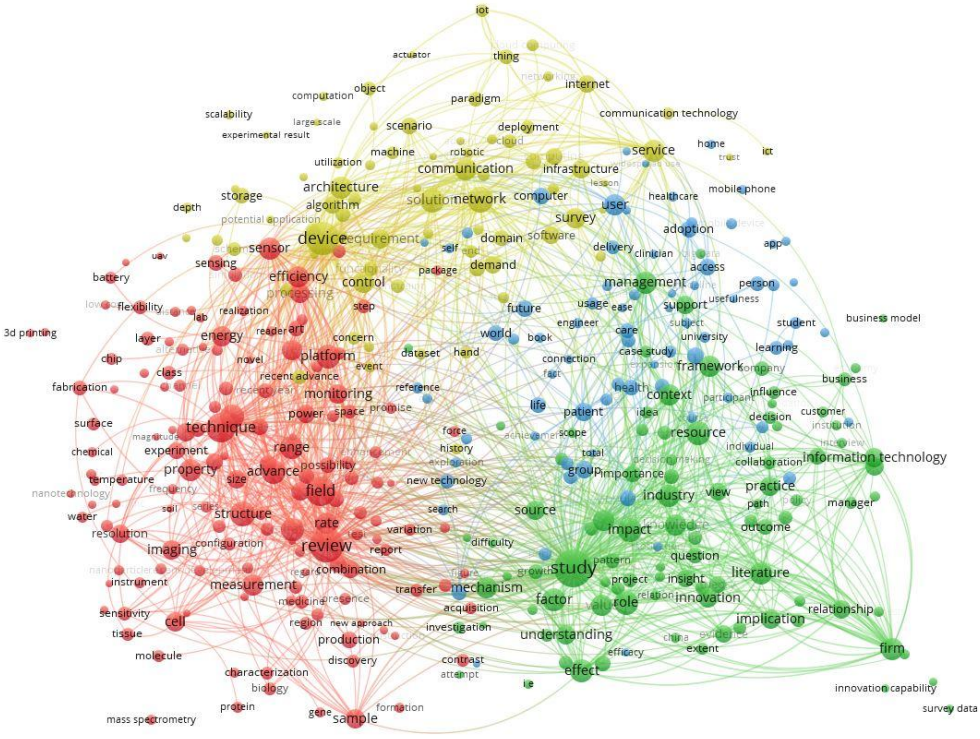

Figure 7. *Keywords found in research on new technological capabilities*

Based on the figure, it can be said that the clusters are relatively loosely connected to each other. The two major clusters are the range of skills (red), which refers to the area of application of technologies, and the practice (green), which is grouped around learning. So,

most probably it is the learning that can create skills related to new technologies. At the same time, the human background (blue) cluster, which supports carrying out the learning, being more closely related to this cluster. However, there is no strong relationship between the two larger clusters.Based on these, there is no close relationship between the learning of technological skills and their market use, by which a market benefit can be obtained.

(6) Keyword: Technology change management

Another keyword related to technology is technology change management. In the course of the study, the answer was seeked for to what technology-based change management emerges with the advent of a new technology. In such a case, some change occurs, whichtypicallyrequires management methodologies. Based on the keyword search, the following well-separated clusters appear:

- blue color: innovation, environment, industry - ecosystem cluster,
- green: politics, climate change, environment - directions / areas of influence cluster,
- red color: outcome, intervention, quality - practice / implementation cluster.

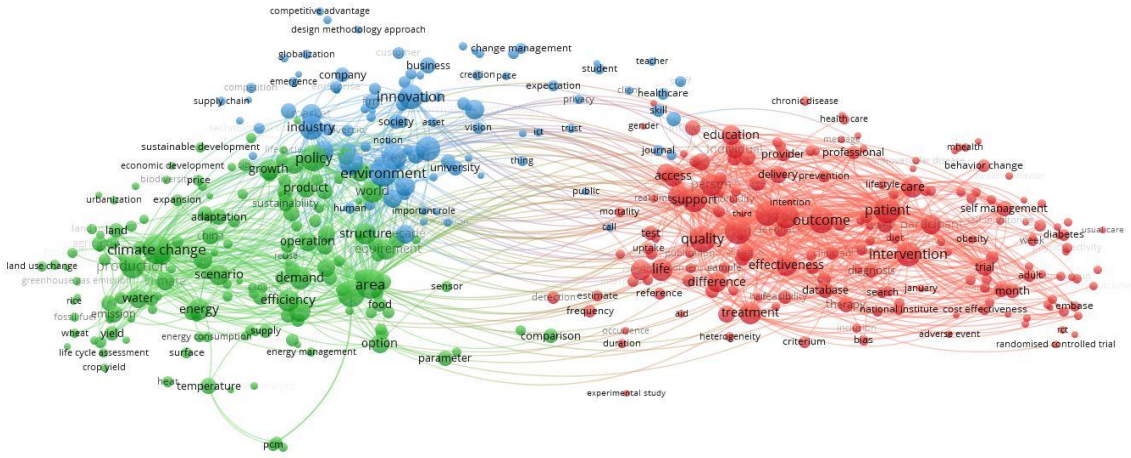

Figure 8. *Keywords found in research on technological change*

Based on the figure, three cluster areas can be distinguished. Of these, the impacted areas (green) and the environment (blue) cluster are more closely related. This phenomenon can be explained by the fact that technology-induced change appears in several areas and thus shapes environments. An environment like that can even be an innovation ecosystem. In contrast, the implementation / practice cluster is much further away, suggesting a weaker relationship with the other two clusters.

(7) Keyword: Technology based services

Finally, it was examined what cluster areas arise in relation to technology-based services. The research topic also has great importance, as the efficiency of their service is decisive for the

market participants.Based on the results of the keyword search, three clusters can be distinguished:

- blue color: study, factor, consequence - theoretical background cluster,
- green color: condition, practice, evidence, risk, outcome - impact area cluster,
- red color: challenge, network, architecture - service structure cluster.

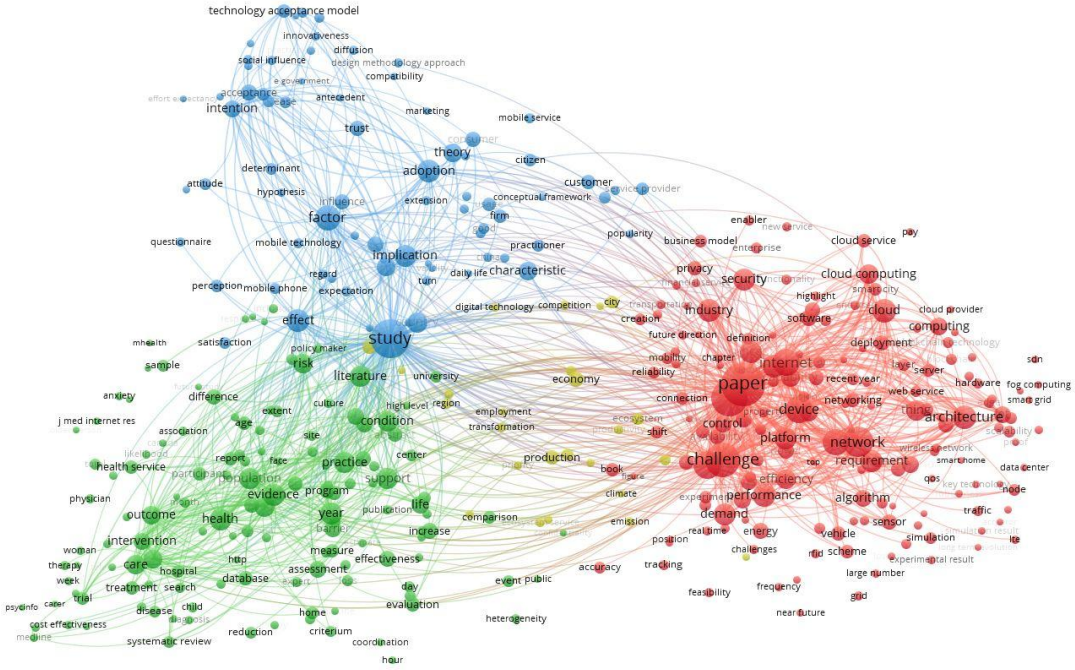

Figure 9. *Keywords found in technology services research*

Thethreeclusters, whicharecloselyrelated in terms of theirtheoreticalbackground (indicated in blue) and area of impact, areclearlydistinct.Withinthetheoreticalbackgroundcluster(blue), thekeywordsarequitespread out. Amongthese, thedefiningkeywordis”study”, whichnotonlyrefers back totheacquisition of technologycapabilitybutcanalsopointforwardto service development as a learning process. The impactareacluster(green) is thefieldswheretechnology-basedservicesmanifestandincludesthecharacteristicsassociatedwith the use of any new technology. The redcluster, whilemarkedlydistinct, is primarilya broadcollection of keywords.

Summary of findings

The findings presented above are summarized in Figure 10, which contains the main consequences of the whole study in a comprehensive overview.

Field	Technology trends			
Search word	Technology trends			
Cluster characteristics	Not separating			
Clusters	Technological challanges	Methodological bases	The effects of trends, and its consequences	Conclusions and areas
Keyword - highlighted	**application**	**data**	-	-
Keyword - others	challange tool	meaning formation	change pattern evaluation efficiency növekedés	service network theory concept architecture
Color	(green)	(red)	(yellow)	(blue)

Field	Technology forecasting			
Search word	Technology forecasting			
Cluster characteristics	Not separating			
Clusters	Forecast methods	Areas of change	Evaluation and examples	Case characteristics
Keyword - highlighted	-	-	-	**scenario**
Keyword - others	forecast algorithm prediction performance	change knowledge future trend innovation	assessment monitoring mesurement	potential price adoption
Color	(green)	(red)	(blue)	(yellow)

Field	New technologies		
Search word	Newest technologies		
Cluster characteristics	Not separating		
Clusters	Main focuses	Professional directions	Social aspescts
Keyword - highlighted	-	-	-
Keyword - others	world service innovation activity practice	device performance network	treatment disease accuracy
Color	(green)	(red)	(blue)

Field	New market needs				
Search word	Future market				
Cluster characteristics	Partly separating				
Clusters	Application in the market	Social aspescts	Market approach	Economic point of view	Market advantages
Keyword - highlighted	**application**	-	-	-	**production**
Keyword - others	output device evaluation limits	education institutions	companies enterprises surveys customers	program participation economic growth	potention delivery price
Color	(green)	(purple)	(blue)	(yellow)	(red)

Field	Technology capabilities			
Search word	Technology capabilities			
Cluster characteristics	Separating			
Clusters	Technological infrastructure	Range of skills	Technologies in practise	Human background
Keyword - highlighted	**device**	**-**	**-**	**-**
Keyword - others	communication network service	technique field structure efficiency	management IT resource impact framework	user group daily user
Color	(yellow)	(red)	(green)	(blue)

Field	Technology change management		
Search word	Technology change management		
Cluster characteristics	Separating		
Clusters	Ecosystem environment	Directions and impacted areas	Implementation and practice
Keyword - highlighted	**innovation, environment**	**climate change, politics, environment**	**-**
Keyword - others	industry	product efficiency energy	outcome intervention quality
Color	(blue)	(green)	(red)

Field	Technology based services		
Search word	Technology services		
Cluster characteristics	Significantly separating		
Clusters	Theoretical background	Technological impact area	Service structure
Keyword - highlighted	**factors, consequences**	**-**	**challange, arhitechture**
Keyword - others	adaptation therory intention	condition condition evidence risk outcome	network device security
Color	(blue)	(green)	(red)

Figure 10. *Conclusions of the keyword analysis*

Conclusions

Basedontheseconclusions, theoriginal“mind-map”thatprovides anoverview of researchrelatedtotechnologicaldevelopmentcan be modified. Itnowshowssubjectsthatare in thefocus of researchasidentifiedthroughtargetedliteraturekeywordresearch (Figure 11).Thus, keywordanalysisprovesto be a feasibletooltoupdatinga holisticresearch map aligningit more closelywithstate-of-the-art research.

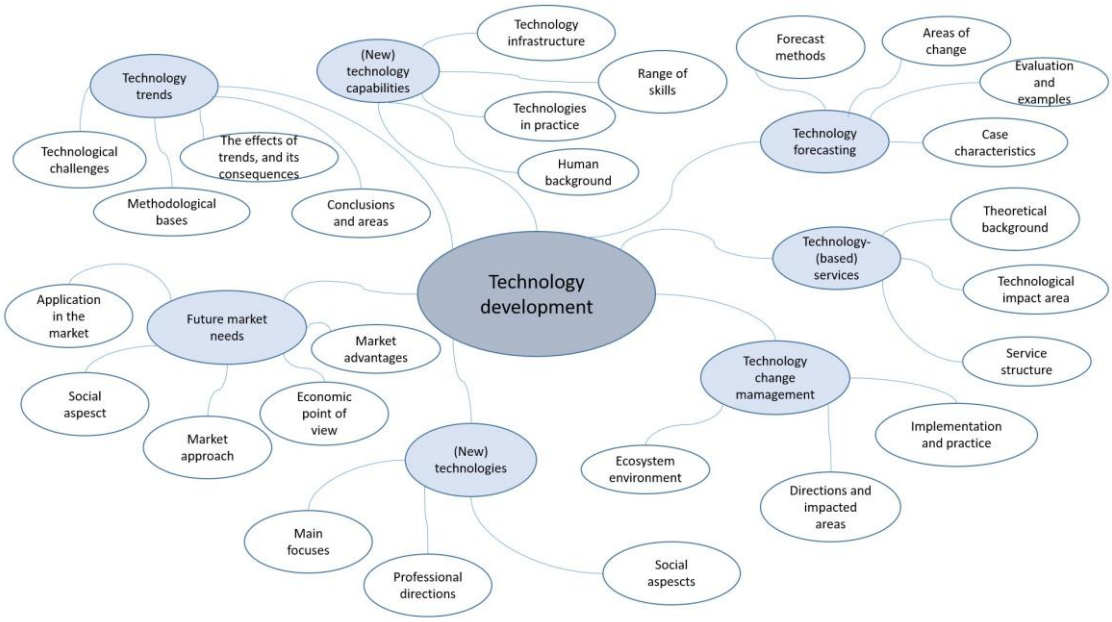

Figure 11 *Modified "mind-map"reflectingstate-of-the-art research*

Accordingtothefindings, eachsearchareacan be categorizedbasedonkeyword concentration and markedkeywordprominence (Figure 12). Itis observablethatthefields of technologicaltrends and technologyforecasting, whicharerelated in terms of content, thecoherence of keywords is stronger. Thismakesit more challengingtoseparatesub-areas; however, someprominentkeywordsdoemerge. Therefore, thesefieldsseemto be suitablefor further research.

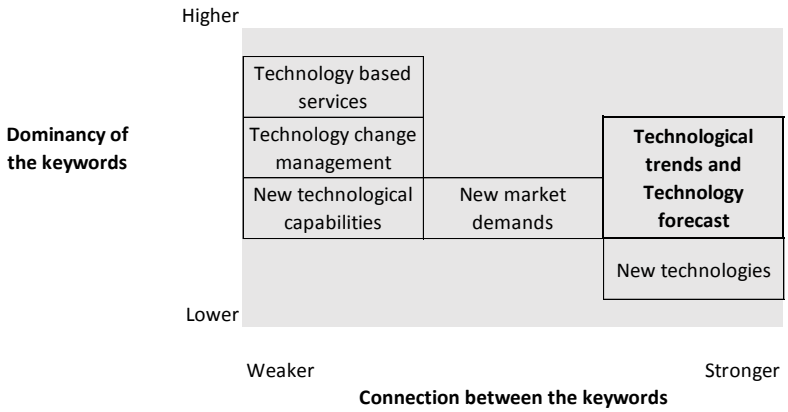

Figure 12. *Summary of the characteristics of each examined area*

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