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Digital Maturity Models – a Bibliometric Exploration

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Abstract. *This paper aims to investigate literature on digital maturity modelling in order to build a better understanding of this field of research which is gaining increased attention from both public as well as private institutions. The objective of the study is to outline a clear vision of what the main areas of research related to digital maturity models are and ultimately map out particular research directions that could benefit from further academic attention in the future. For this purpose, a bibliometric analysis was employed, relying on academic publishing data obtained from the Scopus scientific database. After selection and filtering, 468 pieces of literature were deemed relevant and were subsequently mapped for analysis using co-occurrence and bibliographic coupling. Results show that there is an exponential increase in academic attention for digital maturity modelling in the last 3 years, with recent interest being focused towards the manufacturing sector and small and medium sized enterprises, while other expected sectors such as e-government have fallen behind. It has also been found that digital maturity modelling is in a divergent stage, producing a large amount of different models and only in the last year there are signs of attempts at converging existing knowledge into fewer models with a more rigorous, quantitative development. Consequently, this paper proposes that a key direction of research for digital maturity modelling should be the addition of quantitative based evaluation of digital maturity components and their effectiveness as part of a digital maturity model.*

Keywords: digitalization, digital maturity model, bibliometric analysis.

Introduction

The concept of digitalization has garnered a growing amount of attention over the last several years, particularly in terms of research, but also because of the policies that have been implemented by the government. The European Union (EU) states continue to fall behind the United States of America (US) in terms of digitalization, as shown in the recent reports published by the European Investment Bank (2022).

In 2020, the European Union (EU) announced the Digital Decade project, which outlined the vision and purpose of Europe's digital policy and strategy until 2030 (European Commission, 2022). According to Revoltella et al.'s research (2020), the purpose of this strategy is to benefit from the improved management practices that are found in digitalized organizations. Additionally, this policy seeks to capitalize on the rise in innovation that has been seen to be created as the digitalization of firms grows.

To this end, the European Commission has pushed forward financing programs for European Digital Innovation Hubs (EDIHs), which has culminated in establishing policy dictating the direct use of digital maturity models (DMMs) in the assessment of organizations looking to digitalize. This assessment is meant to help organizations set a target of complete integration of

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digital tools and processes into their business model, thus reaching an optimal state of digitalization for their company, this state being designated as having reached digital maturity (Aslanova & Kulichkina, 2020). Through a public webinar titled "Deep Dive into the DMA Tool" in February 2023 representatives of the Digital Transformation Accelerator (DTA), the European Commission's Directorate General for Communications Networks, Content and Technology, and the Joint Research Council (JRC) offered insights into the theoretical foundation and practical use of the digital maturity assessment (DMA) Tool. This comprehensive tool, which was subsequently released in March 2023, is considered an essential element of EDIH operations and required for assessing the digital maturity of their clients (small and medium-sized enterprises/public sector organizations) prior to any significant intervention by EDIHs (European Commission, 2023).

This has essentially turned digital maturity models into actual policy implementation tools, making it even more important to take a look at the current status of DMMs in academic literature in order to identify current developments trends and potential gaps that could indicate weaknesses in the basis for usage of such tool. This paper attempts to analyze these aspects through a bibliometric analysis of existing literature and potentially indicate future research directions in order to fill in any identified gaps.

Literature Review

With the advent of DMMs into policy, the European Commission has practically established a client-centric standard for what digital maturity assessments should be based on, especially in the case of smaller enterprises and public organizations. As such, maturity assessments, in the eyes of the EU, should evaluate the comprehensive level of digital advancement among clients of the European Digital Innovation Hubs (EDIH), including small and medium-sized enterprises (SMEs) and public service organizations (PSOs), across six distinct dimensions: Digital Strategy and Investments; Digital Preparedness; Human-Centered Digitalization; Data Governance and Security; Interoperability; Sustainable Digitalization (European Commission, 2023). SMEs represent a particularly important target for DMMs because the majority of available maturity models primarily target big organizations. Furthermore, SMEs intending to employ maturity models encounter problems, since various models exist, proposing differing maturity aspects (Motjolopane & Chanza, 2023).

Exploring academic literature, we can find that the approach of assessing dimension in organizations in order to has been well established during the past decade. In a recent review, more than one hundred maturity models have been produced in the field of information systems (Krol & Zdonek, 2020, as cited in Motjolopane & Chanza, 2023). They further claim that organizations continue to have challenges in adopting an appropriate maturity model to evaluate their level of maturity in the field of important data. Therefore, a significant obstacle for decision-makers to have is the choice of a relevant maturity model among the available options. In addition, the dimensions of analysis represent perhaps the most important factor producing analytical discrepancies between different maturity models. This is due to the absence of agreement over sub-criteria of organizational sizes, varying degrees of maturity which are confounded by industry a company is active in, and assessment criteria required to determine the precise maturity level (Ustaoglu, 2019, as cited in Motjolopane & Chanza, 2023). This of course stems from existing literature and well-developed analyses which indicate different versions of key analytical factors for success in different circumstances. For example, Păunescu and Argatu (2020) establish both internal conditions (people, resources, processes, and organizational culture) and external factors such as potential risks and threats in ensuring optimal business efficiency and organizational resiliency.

This is corroborated in the context of DMMs with evidence of maturity models needing to rely on the following dimensions in order to be effective: strategy, leadership and company culture, information communication infrastructure, big data analytics, data culture and governance. This is supplemented by additional business model transformation elements: products and services, processes and resources, and customer experience (Motjolopane & Chanza, 2023).

In an attempted consolidation of existing digital maturity models up to 2023, a more generally applicable model in the context of SMEs and other types of organizations was proposed independently from the European Union DMA introduced earlier that relies on seven dimensions to assess digital maturity, namely: Organization & Structure, Technology, Strategy, Customer, Employee, Culture and Transformation Process (Business Process) (Haryanti et. al, 2023). These dimensions (with their respective subdimensions) are the most commonly used in digital maturity assessments up to this point in time, and while the model does not offer a mathematical basis for relative importance of these various dimensions compared to each other, it does indicate that digital maturity models are heading towards a consolidated, more generally applicable format. This will reduce problems with digital maturity assessment, despite claims that the task of choosing an appropriate maturity model for small and medium firms is made more difficult (Motjolopane & Chanza, 2023).

This paper attempts to investigate whether there is indeed a focus on trying to develop more widely applicable DMMs, especially in the context of SMEs, given that officially, even the European Commission imposed model is more catered to public service organizations (European Commission, 2023). The paper is looking to find what the some of the most influential paper in DMM literature have been, or could be, and analyze them in conjunction with other literature database data for clues into potential gaps or weaknesses that exist in existing research, and which might need to be tackled by academics in the future.

Methodology

This study relies on conducting a bibliometric analysis of academic literature discussing digital maturity models. This analysis aims to cover 3 main research objectives:

O1: Establishing the current trend in terms of volume of publications on the subject of digital maturity models. This is aimed at assessing the perceived relevance of the subject in terms of academic attention.

O2: Establishing the most common general interests (key concepts/words) of existing literature on digital maturity models. This is aimed at assessing whether there are some expected or unexpected developments present in the scope of research conducted on DMMs.

O3: Establishing whether there are any particular trends in research interests. This is aimed at identifying potential current or future directions of research based on the existing literature.

The analysis was conducted using VOSviewer version 1.6.20 software, using a simplified manner derived from that described as suitable for bibliometric research by Donthu et. al. (2021). Thus, this paper only uses a selection of the tools presented in that research, namely key word co-occurrence and bibliographic coupling, as they are directly relevant to answering the research objectives listed above.

It should be noted that key words in the context of this paper represent single words or multiple word expressions that indicate the general subject matter which authors or journals have assigned to a particular piece of literature upon publication. As such, these key words are treated

as single "items" for the purpose of cluster analysis. The software mentioned was used because of its longstanding history and large volume of usage by academia over the last decade (with over 10000 citations) in conducting bibliometric analysis (Van Eck & Waltman, 2010).

Data selection

In order to conduct the bibliometric analysis, it is critical to undergo careful data selection and data processing in order to ensure relevance of results prior to engaging in the production of the analytical outputs. Initial data extraction was conducted according to the following methodological source, scope and period limitations:

Source: Scopus database;

The Scopus indexing database was selected as a basis for this analysis as it offers a selection of top-end academic publications across a large variety of publishers, while not being as restrictive as the other potential top-end source which is Clarivate Analytics (Web of Science) indexed publications. The choices were restricted to these two options mainly because they are the ones that ensure a minimum level of quality in the articles analyzed while also offering easy bibliometric data extraction.

Scope: literature pertaining to digital maturity models in economic publications;

The selection of literature for analysis was obtained by conducting a general search for "digital maturity model" in the Scopus database. The search was conducted to check not only the existence of the search terms in the title of published literature but also the abstract and key words of the papers indexed in the database.

Period: All relevant database literature indexed in the Scopus database up to January 10th 2024 (latest extraction);

The resulting list of the initial database search was populated by over 1900 of various types of publications, including 888 Articles and 770 Conference papers. While this number is impressive, it should be noted that most publications were categorized as pertaining to Computer Science and Engineering category publications and as such potentially too far outside the scope of this research without engaging in further data filtering.

Data Filtering

To facilitate analysis and eliminate the forementioned excess of articles outside the intended scope of this paper, several filters were applied to the search data in order to narrow down the valid data points for our analysis.

First of all, additional filters were applied to the indexing categories that papers to be counted towards analysis should be sourced from. As we are mainly interested in the development, treatment and application of digital maturity models in economic and organizational settings, only papers pertaining to the "Business, Management and Accounting", "Social Sciences", and "Economics, Econometrics and Finance" subject areas were taken into account. This first filter eliminated the vast majority of potentially irrelevant publications, producing a result of 653 pieces of literature to be considered. Unsurprisingly, the "Business, Management and Accounting" category was the most populated in this regard, having 390 publications on its list.

Additionally, the publications were further filtered to contain only English language papers categorized as Articles and Conference Papers. This was done due to the authors' inability to fairly investigate the content of other language publications while at the same time considering that

articles and conference papers in this language benefit from the largest, most diverse and at the same time most rigorous potential pool of reviewers.

It should also be noted that for the purpose of accurate co-occurrence analysis, which relies on building networks between key words that published papers are labeled with, there was additional filtering and replacement conducted. This involves the selection of groups of key words that have the same essential meaning and their replacement with a singularly recognizable key term for the entire group, a list of which is outlined in Table 1.

Table 1. Key term combination thesaurus

Key word	Congregated term
big data analytics	big data
building information model - bim	bim
business models	business model
capability maturity models	capability maturity model
critical success factor	critical success factors
cyber security	cybersecurity
design science research	design-science research
digital capabilities	digital capability
digital strategies	digital strategy
digital technologies	digital technology
digitalisation	digitalization
digitisation	digitization
information and communication technology	ict
information system	information systems
information technology	ict
internet of things	iot
internet of things (iot)	iot
life long learning	lifelong learning
literature reviews	literature review
manufacture	manufacturing
manufacturing companies	manufacturing
manufacturing industries	manufacturing
manufacturing organisations	manufacturing
manufacturing organizations	manufacturing
manufacturing sector	manufacturing
maturity indices	maturity index
maturity models	maturity model
small and medium-sized enterprise	sme
smes	sme
surveys	survey
questionnaire survey	survey
systematic literature review	literature review
systematic review	literature review

Key word	Congregated term
design-science researches	design-science research
digital innovations	digital innovation

Source: Authors' own research.

All terms used for congregating the data are also key words already existing among the papers used for analysis, The purpose of this thesaurus is to ensure that the software used for analysis does not artificially separate key word occurrences and links into multiple redundant options. This is also critical for purposes of replicability for any that would be interested in conducting their own analysis.

Results and discussions

The final list of publications to be taken into account for analysis resulted in 468 relevant pieces of literature, ranging in period of publication from 1998 to 2024. It should be noted the extensive filtering done upon the initial search data was not strictly exclusive besides the requirement to contain all the original search terms. This means that publications can have multiple designated categories in terms of subject area or even language. Table 2 contains the resulting distribution of publications per subject area, including the top three other categories possible besides the core economic ones.

Table 2. Subject distribution of filtered literature

Subject area	No of articles
Business,Management and Accounting	278
Social Sciences	203
Economics, Econometrics and Finance	52
Computer Science	*197*
Engineering	*145*
Decision Sciences	*109*

Source: Authors' own research.

The relevance of this distribution lies mainly in getting an idea of the scope of the journals that would potentially be most interested in publishing literature on DMMs. This denotes that journals and conferences dealing with economic subjects, in conjunction with Computer Science, Engineering or Decision Sciences are the most likely to accept papers on digital maturity models while at the same time also offering a potentially quicker resolution to publication status if they have previous history in publishing such papers.

Figure 1 moves forward and describes the distribution over time of filtered literature linked to digital maturity models, thus beginning our analysis into the progress of this area of research.

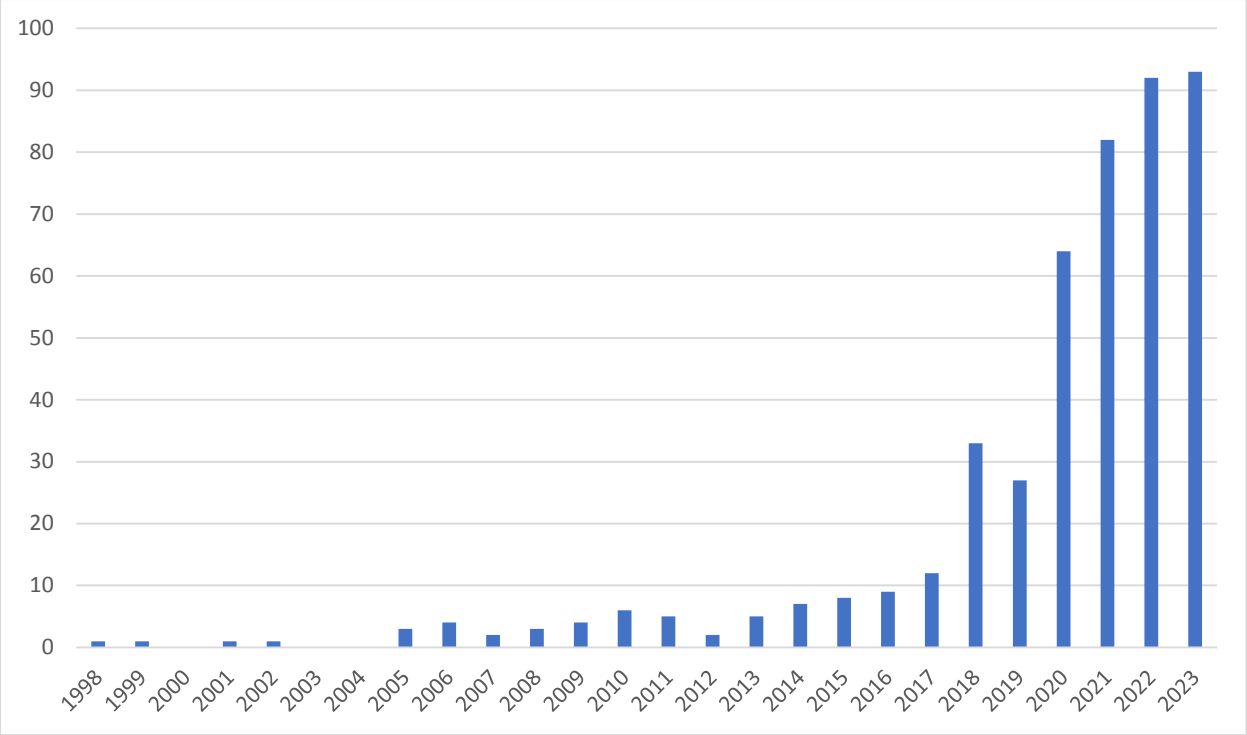

Figure 1. Number of relevant publications per year

Source: Authors' own research.

While on its own it may not seem that important to know the above, a mapping of the timeline of relevant economic publications on DMMs shows that this is a subject that has seen very rapid growth in volume in the past half decade.

The number of articles and conference papers published on the subject of digital maturity models has increased by over 8 times in 2023 compared to 2017, showing that this is an area of research in the immediate interest of the academic community focusing on economic, business and social sciences. However it does seem that the increase in interest has begun to taper off in the last two years which denotes that research in this field could be reaching a certain level of maturity within the next couple of years. These results could also mean that research into this subject is beginning to reorient itself into certain directions while consolidating knowledge built so far in order to enable these specific reorientations.

Co-occurrence analysis

The purpose of this analysis is to build a visualization of networks of key words used in the selected academic publications in the interest of discovering potential groups of subjects as well as the thematic evolution of research into our chosen subject. Figure 2 presents the graphical output based on co-occurrence between key words in the relevant literature, with clusterization applied.

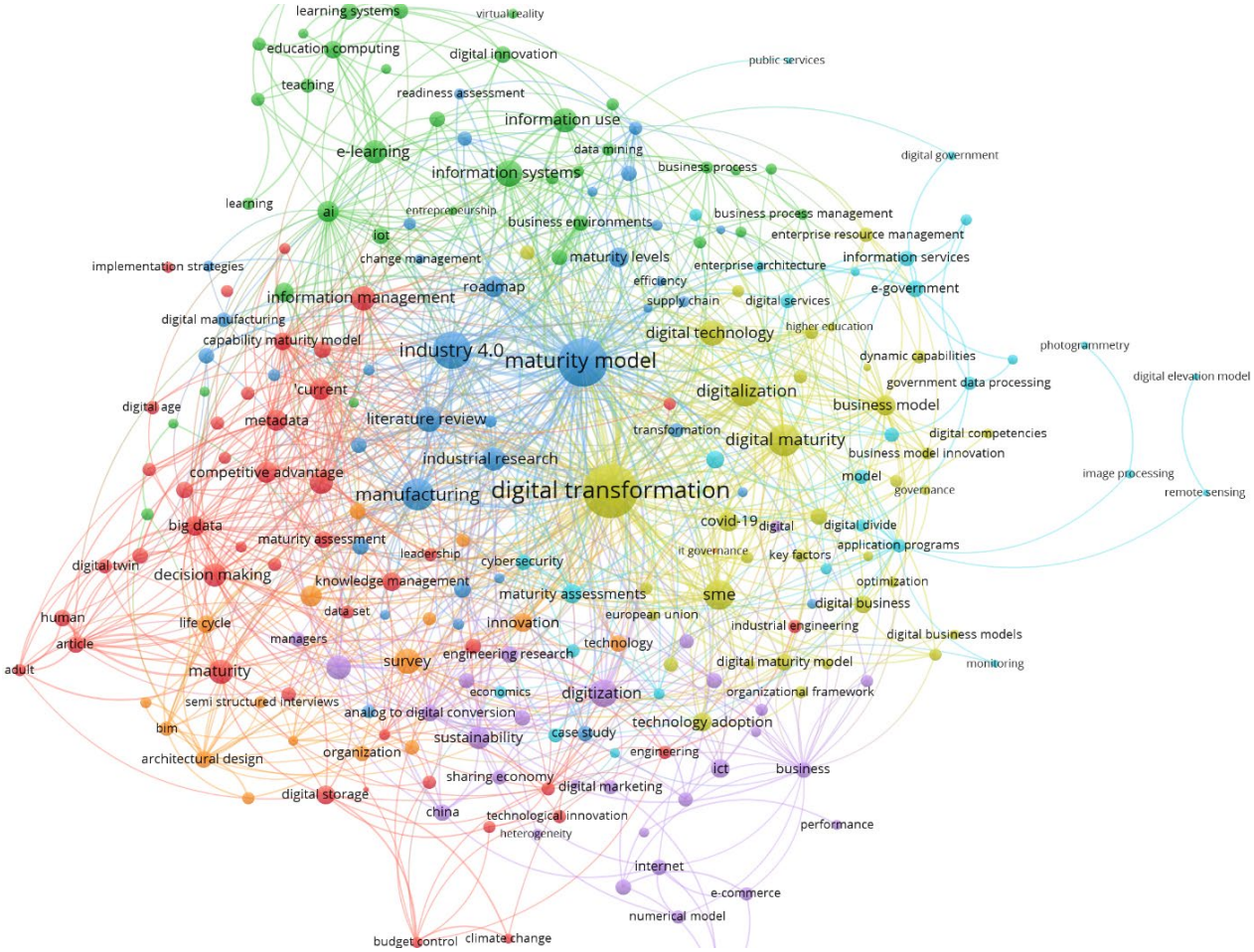

Figure 2. Key word co-occurrence with clustering

Source: Authors' own research.

The selection of key words from the database was conducted using complete full counting (the same wight is given to each key word occurrence and link regardless of whether it is an author defined key word or publication defined key word) which will naturally produce larger bubbles for more often occuring key words. The visualization has been produced to maintain number of occurences as the weights of each node in order to better illustrate which general subjects are of greater interest in DMM research. It should also be taken into account that the network would be much larget than what is presented, however, because we are interested in spotting areas of focus for research rather than identifying specific terms, a minimum number of three occurences was selected as a treshhold for a key word to be mapped. In addition, terms that despite meeting the minimum number of occurences did not have any co-occurrence connections were also eliminated from analysis.

In this case we can observe that besides general terms associated with the context in which digital maturity models are relevant, namely digital transformation, maturity models or industry 4.0, there are certain key nodes that seem to produce greater interest in terms of research and would perhaps indicate key focuses on behalf of those sponsoring this academic research. For example, it is clear that there is great interest in DMMs and related investigation targeted specifically at the

manufacturing sector, as well as small and medium sized enterprises. We can also notice a significant amount of interest being given to areas such as e-learning and e-government, but perhaps not as much as would be expected in comparison with private enterprises.

In order to facilitate more rigurous analysis in terms of identifying major themes of research, key words were grouped based on co-occurrence connections and relative strength of those connections, as denoted by the differentiated coloring of the nodes present. The grouping, or clustering was produced using a lin/log modularity approach as introduced by Van Eck and Waltman (2022), a method preferred by the authors both because of the clear layout produced, but also because of the reduced number of clusters assigned to valid key word nodes.

Analyzing the resulting clusters, we can identify several major thematic areas of interest among academic literature related to DMMs, as outlined in Table 3:

Table 3. Key word clustering with thematic identification

Cluster	Color	No. of items	Thematic description
1	red	44	Cluster containing research indicated by authors as "current". Seems to specialize thematically toward the manufacturing sector, with a more specific emphasis on strategic driven research including decision making, data analytics and risk management.
2	green	36	Cluster seems mainly focused on educational research, denoted by congregations of terms such as e-learning, teaching, or education engineering. There is also a secondary diverging theme of interest identified in the area of process management with the particular context of customer experience and sales.
3	blue	36	Cluster composed of general domain terms, common to a large variety of research directions, rather than specific research themes. This is also denoted graphically by the concentration of nodes in a central location of the network.
4	yellow	35	Cluster main research theme is identified as being mainly related to SMEs and their business models, especially in a Covid-19 context. This also seem to be the most European-centric research cluster, as indicated by authors.
5	purple	29	Cluster main theme is identified as related to sustainability and sustainable development aspects of DMMs, with a secondary focus on e-commerce and digital marketing.
6	cyan	29	Cluster main theme is related to e-government, public administration and digital services. There is also a particular targeting on the digital divide between levels of digitalization in different regions.
7	orange	17	Cluster main theme seems to be directed toward architectural design and building information modelling.

Source: Authors' own research

Through this clustering we have managed to identify six main directions of research on digital maturity models that seem to be most interesting for academics, with several secondary themes. We can notice this clustering becomes important by providing authors interested in digital maturity model with current research directions but is incomplete without the introduction of a timeline of sorts.

Figure 3 presents a visual timescale addition to the co-occurrence output which helps verify what key words are contained in the most recent pieces of literature.

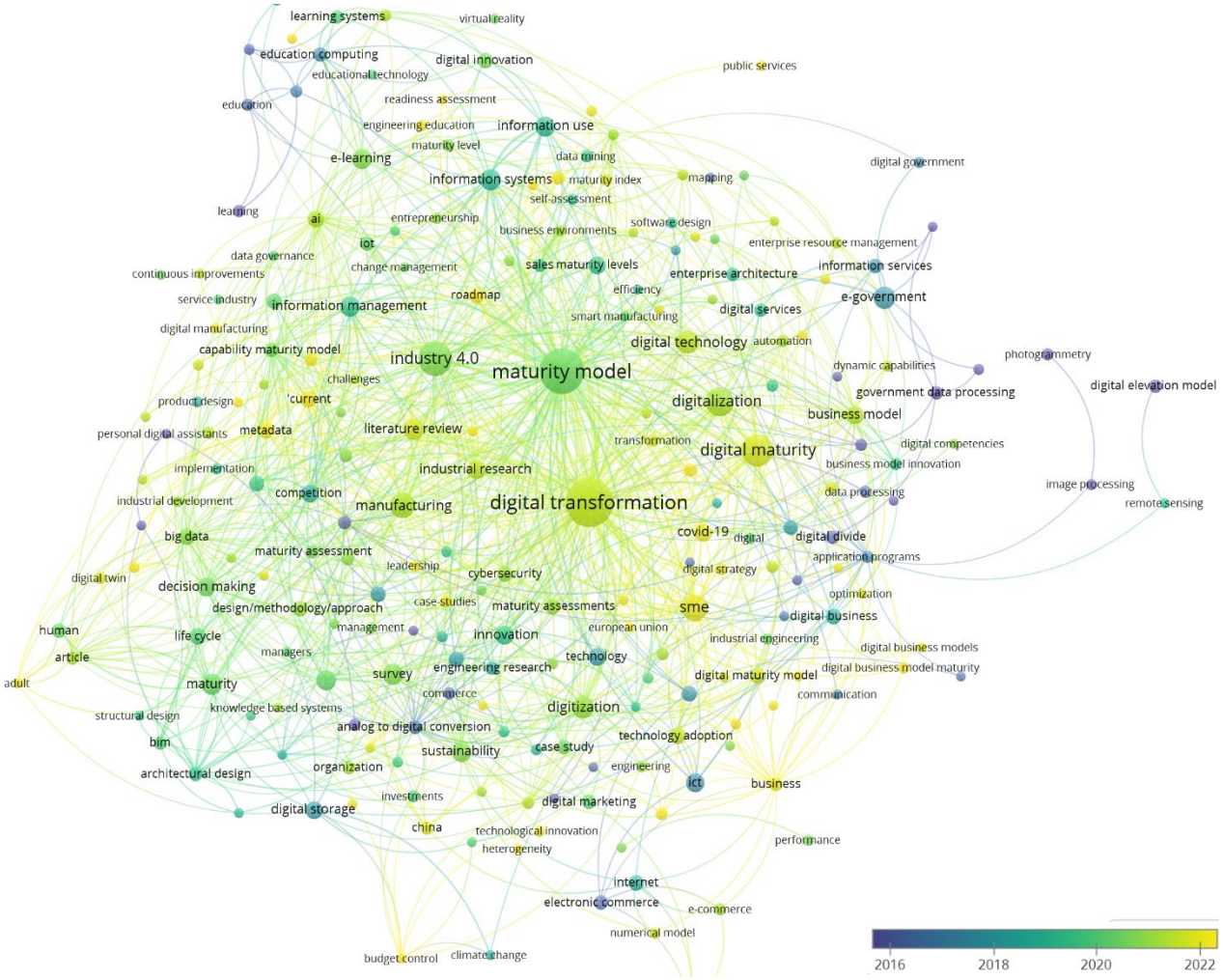

Figure 3. Key word co-occurence with timescale

Source: Authors' own research.

By inserting a time based heatmap we can further refine the results produced by the earlier clustering. The time scale involved represents a color coding of the average year of publication for pieces of literature related to the particular key word presented. From the visualization results obtained we can indeed judge that Cluster 1, identified initially as populated by "current" research does indeed have a large collection of very recently published paper, containing a significant amount of nodes with an average publication within the last two years. As such, it is safer to make a judgement that current research on digital maturity models has a significant focus on the manufacturing sector and managing digital transformation in that area. A particular interest is given to research into digital twins, decision making and data analytics with these areas thus being considered key to the development of DMMs as effective tools for digital transformation. This also indicates that these are the areas currently considered by authors as having insufficient development and could benefit from more focus in future research. This attention on the manufacturing sector is also supported by existing research which is attempting to build understanding of the future outlook of manufacturing companies in the context of industry 4.0 (Bootz, et. al., 2022).

Based on the resulting graphics we can also notice that Cluster 3 can be judged as also being at the forefront of current research, especially when it comes to its main theme, namely SMEs. This supports the initialy literature, that there is a deficit of proper understanding of poper digital maturity modelling targeted at small and medium sized enterprises, with plenty of authors targeting this area in the last two years (Motjolopane & Chanza, 2023).

Of particular interest as a result of this part of the results, we can notice a distinct lack of identification or direct treatment of weaknesses in DMMs. Within the key word network we can distinctly identify the existence of the precursor of DMMs, namely "capability maturity models", which were themselves derived from stages of growth model which established both the idea of maturity and the concept of stages of development (Nolan, 1979). However, other than seeing further specialization development of DMMs for specific areas such as those identified in the cluster themes, we do not see any particular presence of research in identifying and addressing more fundamental DMM weaknesses, even though capability maturity models before them have already been noted to produce specific knowledge or information gaps (Finkelstein, 1992). It seems that the validity of the DMM framework is taken on the basis of effective historical usage of its precursors in the field of software development, relying on quantitatively evaluating digital capabilities, but not in itself quantitatively derived or evaluated.

Bibliographic coupling analysis

The purpose of this analysis is to identify potentially significant single pieces of literature for the development of digital maturity models, as can be seen in Figure 4, which would prove useful in making more targeted analyses should authors decide to focus on particular models. It should be noted that over 40 different maturity models have been identified in use, and selecting the proper one, in conjunction with the current themes of interest for research can help develop different applications and specificities of these instruments (Haryanti, et. al., 2023).

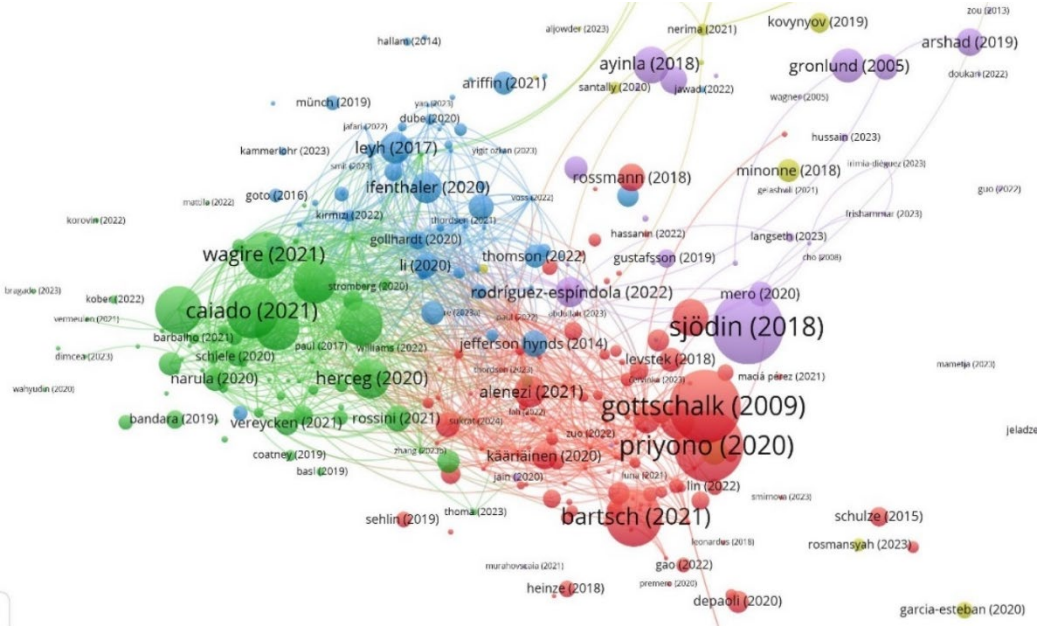

Figure 4. Bibliographic coupling with citation weights

Source: Authors' own research.

For the purposes of our analysis, clustering becomes less important that the weights given to each paper in the visualization. In this case, in order to identify the most influential papers relevant for DMM research, weights were given to each node based on the number of subsequent citations that paper has received. As such, a quick selection of the most impactful papers to be taken into account when building upon DMM literature is the following:

Table 4. Top selection of influential paper on DMMs by citation weights

Author(s)	Subject of the paper	Year
Gottschalk	Maturity levels for interoperability of digital government	2009
Priyono et. al.	Identifying Digital Transformation Paths in the Business Model of SMEs during the COVID-19 Pandemic	2020
Sjodin et. al.	Smart Factory Implementation and Process Innovation. A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing - Moving to smart factories presents specific challenges that can be addressed through a structured approach focused on people, processes, and technologies.	2018
Bartsch et.al.	Leadership matters in crisis-induced digital transformation: how to lead service employees effectively during the COVID-19 pandemic	2021
Caiado et. al.	A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management	2021
Santos and Martinho	An Industry 4.0 maturity model proposal	2020

Source: Authors' own research.

The paper selection in Table 4 contains top examples of impactful literature out of our database and is deemed sufficient to add credence to the earlier analysis. This is due to the fact that, perhaps unsurprisingly, we can notice some of the themes identified in the previous cluster analysis in each of these papers. The citation based weights given illustrate in Figure 4 that these papers are very important to the maping of development of digital maturity models and are thus necessary to take into account for any future research. This is especially true as all of these papers actually fit into the key topics of interest identified in our previous cluster analysis despite being earlier than the majority of paper dealing with those topics. As such, these papers can also present a potential basis for quickly spotting any preexisting gaps in current or future research derived from them.

We should take into account however that four of the six listed papers have been published within the last 3-4 years, which makes it apparent that digital maturity models overall are actually in their infancy, and gives support to the idea that the previously identified rise in publications on DMMs after 2020 may continue. Given this aspect however, it also becomes important to conduct a different bibliographic map, based not on citation weights, but rather on total link strength, which is illustrated in Figure 5.

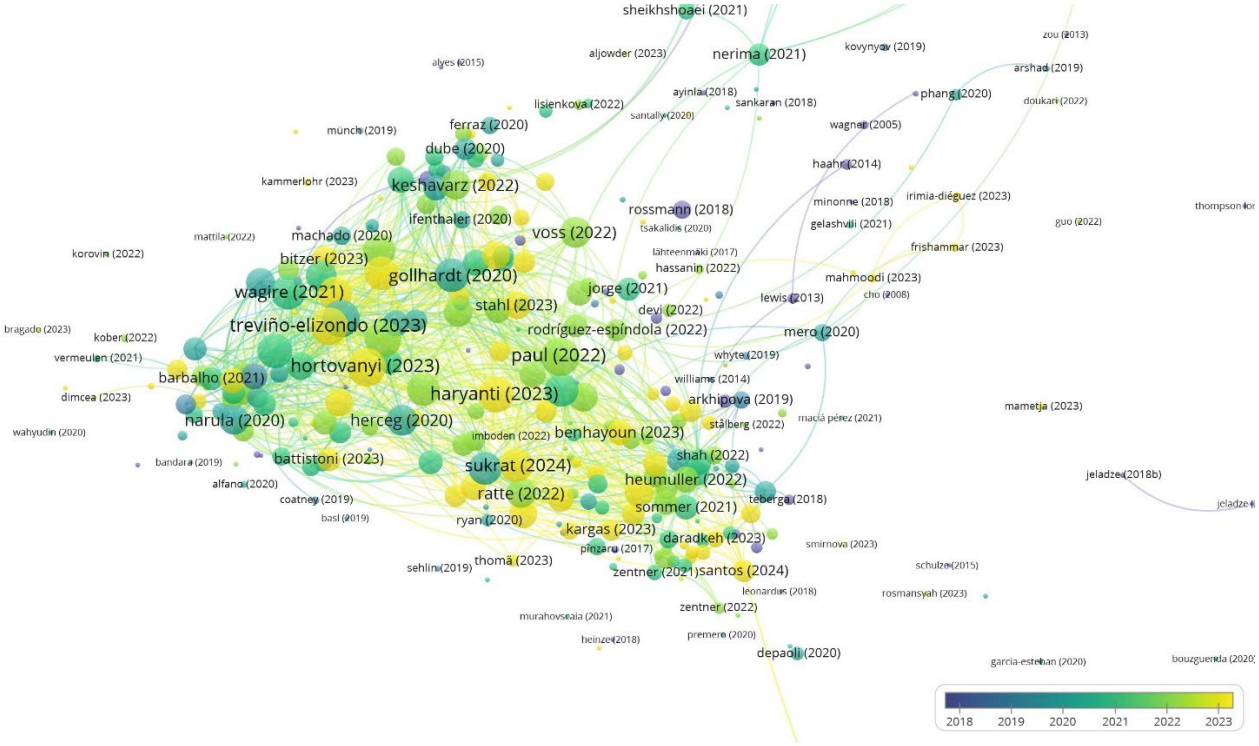

Figure 5. Bibliographic coupling of paper with Total Link strength weights over time

Source: Authors' own research.

This output becomes very important in terms of identifying key pieces of relevant research that may not have yet had the time to get enough traction in the academic community in order to be cited but can be identified as influential to the subject. This is indicated by their relative positioning in terms citations and co-citations involving both their own cited sources, as well as co-citations in terms of weights which adds strength to their link to other pieces of literature with which they have been grouped by authors. Visually these aspects are expressed in the size of the corresponding bubbles and their location within the spread of data points.

Thus, we can identify relatively obscure pieces of literature in terms of citations, but which carry significant weight in terms of further development of the research field on DMMs. We can thus extract as example the Haryanti et. al. (2023) Extended Digital Maturity Model, which is pushed as a consolidation of previously existing models into a more flexible format that is aimed at being more readily applicable regardless of enterprise size. We can also identify the Trevino-Elizondo and Garcia-Reyes (2023) proposal for a maturity model focusing particularly on employee development and readiness for industry 4.0 adoption and digital transformation. Given that the aforementioned Extended Digital Maturity Model, like others before it, has identified human resources as a key dimension of digital maturity it becomes apparent that researchers are now focusing on detailing and refining the characteristics of the components of DMMs, which thus have entered a stage of consolidation in terms of overall composition.

The introduction of new models while focusing on more narrow fields of study that have been identified in the cluster analysis shows that academic research on digital maturity models is still in an accumulation stage, building up knowledge and identifying narrower areas of interest for

which DMMs could be useful. To give an additional example, rather than tackle specific problems in existing DMMs, Sukrat & Leeraphong (2024) have introduced yet another digital maturity model, further simplified to make it more flexible and specifically targeted at microenterprises and small enterprises. As such, even in the latest publications on DMMs authors chose to produce further divergent modelling rather than converging towards adapting specific models to new situations and reducing their weaknesses. This indicates that research subjects identified by our analysis as having the largest amount of recent interest have indeed only begun to be explored and will likely represent a focus of research for the next few years.

Conclusion

Overall, this research has found that digital maturity models represent a major focus of development in academia, having garnered increasing interest over time and grown exponentially in the past three years in terms of volume of publications.

While our bibliographic analysis has identified six main directions that academics are taking with their research, and a plethora of secondary subjects of interest as outlined in Table 3, the areas of interest that stand out most are manufacturing and small and medium sized enterprises. The two subject areas concomitantly display both high number of occurrences (per Figure 2), as well as a high number of recent publishing done in their particular field (per Figure 3) which verifies to some extent the interest of academia to develop models that plug the gaps in digitalization that institutions withing the European Union especially considers of great concern to its economy (Ficarra, et. al., 2021). As such, these two areas can be considered the main foci of research and academic knowledge building related to digital maturity models for the foreseeable future.

However, our analysis also indicates a lack of focus by academics on analyzing the basis of digital maturity models. While capability maturity models, from which DMMs are sourced, do have a distinct presence in the analyzed literature, the entire area of research on digital maturity models seems currently focused on positive research, with no real analysis on potential weaknesses of DMMs. Despite the increasing number of available DMMs, authors seem to be able to afford to introduce new models because even in the most recent ones there is no significant quantitative research gone into verifying the effectiveness of DMMs (Haryanti,et. al., 2023). This means that there is currently no real evaluation on which digital maturity models are potentially better and can serve as points of concentration for research. This is also supported by the fact that most models introduced only carry out qualitative investigations of the implementation of DMMs. Further investigation should probably be carried out, at the very least in analyzing the extracted influential papers presented in Table 4, in order to see whether there are some fundamental factors that push DMM development research to be of a qualitative nature.

However, we can consider of key interest a less noticeable gap, which is related to the fact that current DMMs rely on previous ones for their composition, but no attempt has been made to mathematically verify and quantify the relative importance of DMM components to the functioning of the models that contain them. The closest literature appears to have come so far is simply measuring their occurrences in previous models as weights for dimension importance (Haryanti, et. al., 2023). This research has only been able to find two attempts at providing mathematical rigor to DMMs. However, these attempts are far away from serving their full potential in achieving their

purpose, firstly because of the limited scope of the analysis which is restricted to the narrower field of supply-chain management in most advanced example in the case of Caiado, et al. (2021). Secondly, because of not employing a clear method for ranking components in the model produced by Kljajić Borštnar and Pucihar (2021).

Upon closer look we can notice that both limited attempts at introducing a better basis for evaluation of the impact of DMMs components on the utility of the models pertain to using decision science tools on DMM composition. As such, this paper proposes that perhaps the most fertile direction of research in the area of DMMs is that of applying decision making instruments which have a mathematical basis such as multiple-criteria decision analysis with analytical networks or fuzzy logic algorithms. This type of future research could aid in the consolidation and focusing of research on DMMs by not only allowing a more rigorous approach to building DMMs, but also permitting potential verification of the effectiveness of those produced DMMs by comparing predicted impact results with real impact and then adjusting accordingly to a better iteration of the model.

Overall, it should also be taken into account that this research, despite clarifying the immediate horizon of interest for research on digital maturity models, does contain some limitations. First of all, despite using the Scopus database, which is fairly inclusive in terms of high-quality research, it is by no means a guarantee that all relevant and potentially impactful pieces of literature have indeed been considered for analysis, especially if these are sources in the private sector rather than academia. As such, we cannot judge whether the public interest in DMMs actually matches the areas highlighted by our analysis of the main themes approached by academics. Therefore, a more detailed and rigorous bibliometric research on this subject would benefit from including additional pieces of literature from decentralized databases that may not have reached Scopus indexing.

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References

Aslanova, I., & Kulichkina, A. (2020). Digital Maturity: definition and model. *2nd International Scientific and Practical Conference on Modern Management Trends and the Digital Economy - from Regional Development to Global Economic Growth (MTDE)*, 443-449. Atlantis Press SARL. https://doi.org/10.2991/aebmr.k.200502.073

Bartsch, S., Weber, E., Buttgen, M., & Huber, A. (2021). Leadership matters in crisis-induced digital transformation: how to lead service employees effectively during the COVID-19 pandemic. *Journal of Service Management, 31*(1), 71-85. https://doi.org/10.1108/JOSM-05-2020-0160

Bootz, J., Michel, S., Pallud, J., & Monti, R. (2022). Possible changes of Industry 4.0 in 2030 in the face of uberization: Results of a participatory and systemic foresight study. *Technological Forecasting and Social Change, 184*, 121962. https://doi.org/10.1016/j.techfore.2022.121962

Caiado, R., Scavarda, L., Gaviao, L., Ivson, P., Nascimento, D., & Garza-Reyes, J. (2021). A fuzzy rule-based industry 4.0 maturity model for operations and supply chain management. *International Journal of Production Economics, 231*, 107883. https://doi.org/10.1016/j.ijpe.2020.107883

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

European Commission. (2022). *Europe's digital Decade*. Shaping Europe's Digital Future. https://digital-strategy.ec.europa.eu/en/policies/europes-digital-decade

European Commission. (2023, February). *A deep dive into the DMA Tool.* European Digital Innovation Hubs Network. https://european-digital-innovation-hubs.ec.europa.eu/events/deep-dive-dma-tool

European Investment Bank. (2022). *Digitalisation in Europe 2021-2022 : evidence from the EIB Investment Survey,* https://data.europa.eu/doi/10.2867/76258

Ficarra, M., Rückert, D., Weiss, A., & Weiss, C. (2021). *Digitalisation in Europe 2020-2021.* European Investment Bank. https://doi.org/10.2867/1363

Finkelstein, A. (1992). A software process immaturity model. *SIGSOFT Software Engineering Notes, 17*(5), 22-23. https://openaccess.city.ac.uk/id/eprint/26452/

Gottschalk, P. (2009). Maturity levels for interoperability of digital government. *Government information quarterly, 26*(1), 75-81. https://doi.org/10.1016/j.giq.2008.03.003

Haryanti, T., Rakhmawati, N., & Subriadi, A. (2023). The Extended Digital maturity model. *Big Data and Cognitive Computing, 7*(1), 17. https://doi.org/10.3390/bdcc7010017

Kljajić Borštnar, M., & Pucihar, A. (2021). Multi-Attribute Assessment of Digital maturity of SMEs. *Electronics, 10*(8), 885. https://doi.org/10.3390/electronics10080885

Motjolopane, I., & Chanza, M. (2023). Digital transformation dimensions for evaluating SMEs' readiness for big data analytics and artificial intelligence: A review. *INTERNATIONAL JOURNAL OF RESEARCH IN BUSINESS AND SOCIAL SCIENCE, 12*(7), 583-595. https://doi.org/10.20525/ijrbs.v12i7.2837

Nolan, R. (1979). Managing the Crises in Data Processing. *Harvard Business Review, 57*(2), 115-126. https://hbr.org/1979/03/managing-the-crises-in-data-processing

Paunescu, C., & Argatu, R. (2020). Critical functions in ensuring effective business continuity management. Evidence from Romanian companies. *Journal of Business Economics and Management*, 497-520. http://dx.doi.org/10.3846/jbem.2020.12205

Priyono, A., Moin, A., & Putri, V. (2020). Identifying Digital Transformation Paths in the Business Model of SMEs during the COVID-19 Pandemic. *Journal of Open Innovation: Technology, Market, and Complexity, 6*(4), 104. https://doi.org/10.3390/joitmc6040104

Revoltella, D., Ruckert, D., & Weiss, C. (2020, March). *Adoption of digital technologies by firms in Europe and the US*. VoxEU. https://voxeu.org/article/adoption-digital-technologies-firms-europe-and-us

Santos, R., & Martinho, J. (2020). An Industry 4.0 maturity model proposal. *Journal of Manufacturing Technology Management, 31*(5), 1023-1043. https://doi.org/10.1108/JMTM-09-2018-0284

Sjodin, D., Parida, V., Leksell, M., & Petrovic, A. (2018). Smart Factory Implementation and Process Innovation. *Research-Technology Management, 61*(5), 22-31. https://doi.org/10.1080/08956308.2018.1471277

Sukrat, S., & Leeraphong, A. (2024). A Digital Business Transformation Maturity Model for Micro Enterprises in Developing Countries. *Global Business and Organizational Excellence, 43*(2), 149–175. https://doi.org/10.1002/joe.22230

Trevino-Elizondo, B., & Garcia-Reyes, H. (Sustainability). An Employee Competency Development Maturity Model for Industry 4.0 Adoption. *15*, 11371. https://doi.org/10.3390/su151411371

Van Eck, N., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics, 84*, 523-538. https://doi.org/10.1007/s11192-009-0146-3

Van Eck, N., & Waltman, L. (2022). *VOSviewer Manual*. CWTS, University of Leiden. https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.18.pdf