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Project Management in Nanotechnology: A Systematic Literature Review

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ABSTRACT

This paper provides a systematic review on the subject of project management in nanotechnology to analyze existing body of literature and identify subject areas for further research. The literature review has been performed using two academic databases – Scopus and Web of Science. Despite the growing importance of high-tech industries, there are few studies dedicated to managerial issues of nanotechnology projects. Study was conducted by adopting three-step methodology combining both quantitative and qualitative research methods. As a result, eight knowledge areas were identified covering risk management issues, role of nanotechnology in economic development, link with other industries, safety issues, implementation of PM tools in the field of nanotechnology and others. Paper also provides an overview of top journals related to the topic, the most active scientists, institutions and relevant publications. Findings of detailed citation analysis shows that the most cited papers are far from PM practice. Nevertheless, study has both academic and practical relevance, discussing scientifically grounded PM knowledge that is applicable to the management of nanotechnology projects.

INTRODUCTION

Nanotechnology is recognized by the European Commission as one of its six ''Key Enabling Technologies'' that contribute to sustainable competitiveness and growth in several fields of industrial application (EC, 2012). Organizations have made significant investments in cutting-edge technologies, hoping to gain competitive advantages in today's rapidly changing markets (Gomes and Romao, 2016). One of such most promised technologies that shape world market are nanotechnologies (Meshalkin, 2012). Nanotechnology is widely applied in our everyday life and is changing the entire society (He et al, 2018). A recent estimate of the global economic impact of nanotechnology is projected to be at least $3 trillion by 2020, which may employ 6 million workers in the rising nanotechnology industries worldwide (Roco et al, 2011). Nano materials are considered the building materials for the twenty first century and its basic element, nanotechnology, is considered to be benchmark for progress and civilization of nations and an indication for its renaissance (Abdin et al, 2018). These facts have driven many organizations into the development of nanotechnology, because such projects are a powerful tool for creating economic value, foster competitive advantage and generate business benefits for the organizations (Howsawi et al, 2014). Such trends increase the importance of project management in the nanotechnology industry.

Nanotechnology projects differ from other projects in terms of knowledge intensity, uniqueness, complexity of determining the final goals and directions of development, heterogeneity of the project implementation stages, etc. (Stoyanova, 2013). This advocates the idea that such projects should be managed with adequate PM tools and techniques. The main goal of this study is to provide an overview of the current literature on project management in nanotechnology, identify the most active scientists, institutions and relevant publications. Moreover, the authors aim to extract relevant and scientifically grounded PM knowledge that is applicable to the management of nanotechnology projects. Thus, two research questions guide our study: What challenges in management of nanotechnology projects can be identified through literature review? What kind of PM knowledge for managing nanotechnology projects is available in the scientific literature?

The study consists of six sections, where first section describes the research relevance, research problem and goal of the study. Section 2 focuses on the detailed literature review. Section 3 describes the three-step methodology adopted. Section 4 explains the results and includes the discussion part. Section 5 concludes the paper.

1. LITERATURE REVIEW

Nanotechnologies have the potential to solve basic social problems, increase competitiveness, create jobs and promote economic growth (Aschhoff et al, 2010; European Commission, 2009). Therefore, the nanotechnology industry started to attract global attention and the amount of projects in this industry are rising (Meshalkin, 2012). Many countries began to pay special attention to the development of nanotechnologies; over 60 have invested public funds in their nanotechnology development programs over the past couple of decades (Roco et al, 2011). Such interest pushes researches from all over the world to investigate how to manage projects in the nanotechnology industry.

The literature review reveals lack of studies dedicated to exploratory review of nanotechnology project management. There are few studies consisting literature analysis on the topic of nanotechnology and project management separately. For example, Shea (2005) conducted exploratory review and assumed that innovation management literature can be used to guide further research aimed at predicting the scale and nature of the impact of specific nanotechnology-based innovations (Shea, 2005). Further, Brocke and Lippe (2015) conducted a systematic literature review and analyzed the set of scientific knowledge of PM. He assessed the degree of understanding and solving specific problems of joint research projects, including Nano technological projects. (Brocke and Lippe, 2015).

From the literature analysis, it is clear that nanotechnology projects play vital role in modern markets and require a lot of close attention for their successful completion.

Very few scientists carry out research on the problems of implementing projects in nanotechnology, in particular, based on a managerial and economic approach. As far as we know, recently there is no in-depth review of the literature related to nanotechnology project management.

2. RESEARCH METHODOLOGY

The study consists of a systematic review of the literature, which aims to establish the level of knowledge in the field of project management in the nanotechnology industry. The authors identified, integrated and summarized existing research results that can provide relevant solutions to the problems of managing nanotechnology projects. The literature review focuses on scientific studies that Kloppenborg and Opfer (2002) define as "published works based on data (primary or secondary)", which make general conclusions drawn from data, where data and conclusions are concentrated either on the context of project management, or on management activities. Many scholars with different research topics (J.Brocke et al, 2009; Webster and Watson, 2002; Mukhtarova et al, 2016) use this method. The research methodology includes quantitative and qualitative analysis. The quantitative analysis consists of three levels. The first level dedicated to choosing a database for the data collection.

There are four basic tools that can provide significant bibliometric resources: Web of Science (Clarivate Analytics), Scopus (Elsevier), Google Scholar (GS) and ResearchGate (RG). We use Scopus and Web of Science databases in this study, because they have the largest reference and quoted databases of peer-reviewed literature (scientific journals, books and conference materials); also, there are books, conference proceedings, journals, more than 71 million papers, about 1,7 billion citations, 3,7 terabyte data from total 330 subjects in Scopus. In a multi-parameter analysis, only articles created by authors of the groups retained a significant difference in the number of citations in the databases and were associated with a significantly smaller number of links in Google Scholar. The accuracy of citation in Google Scholar was slightly lower than in Scopus or Web of Science (Kulkarni et al, 2009). Scopus offers about 20% more coverage than the Web of Science for citation analysis. Scopus covers a wider range of journals that help in both keyword searches and citation analysis, but is currently limited to recent articles (published after 1995) compared with the Web of Science (Falagas et al, 2008). Thus, we decided to use both databases.

The study includes resources from Scopus and Web of science gathered in 2019. Table 1 shows the number and content of studies that were chosen for the research from the two databases. According to Table 1, few studies cover nanotechnology project management completely. Further, we will explain the content and quality of the selected papers through quantitative and qualitative analysis.

Table 1. Investigated sample size

№		"Project Management"	"Nanotechnologies"	"Nanotechnology projects"	"Management of nanotechnology projects"
1	Total number of publications in Scopus	292,237	855	11	8
2	Selected as relevant for the study	125	43	4	2
3	Total number of publications in WOS	119,048	86	12	11
4	Selected as relevant for the study	132	31	5	3

Source: based on own research

At the second level of analysis, the authors made a search in the "Article title, abstract, keywords" fields using the keyword "project management". As a result, 292,237 documents in Scopus and 119,048 documents in Web of Science were identified. Then we used the keyword "nanotechnologies" and searched it among the previous set of results. There were 855 publications in Scopus and 86 documents in WOS labeled as "general". Then we searched for "nanotechnology projects", "management of nanotechnology projects" and thus narrowed searching. The extracted publication types from Scopus include journals, conference materials, books, and others presented in Figure 1.

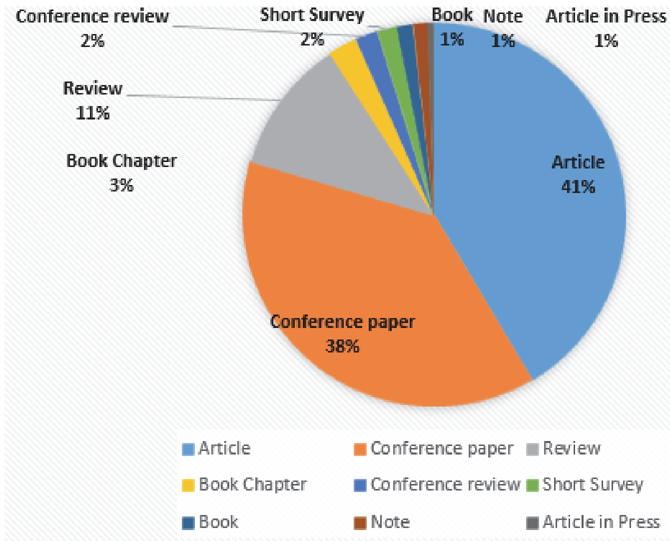

Figure 1. Segmentation of general category of publications by types in Scopus

Source: based on own research

As apparent in Figure 1, most documents found are articles and conference papers. Figure 2 presents the segmentation of publications in the WOS database. Figure 2 shows that most scholars choose journals and conferences in WOS for publishing their studies.

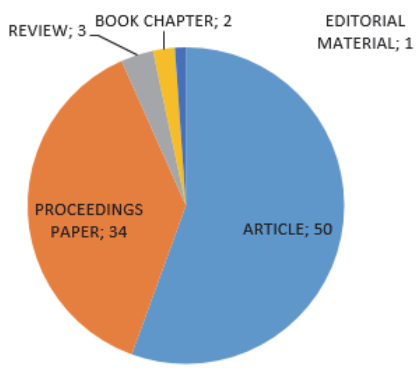

Figure 2. Segmentation of general category of publications by types in WOS

Source: based on own research

The next stage narrowed and deepen the analysis on a specific topic: "Business, management and accounting" (further BMA). As a result, the documents depicted in Figure 3 were found. The publications were analyzed using the bibliographic information of the authors, the years of publication, the content structure, the countries, the titles of journals and the frequency of quotations. The search met with serious problems in determining suitable selection criteria, as many of the “search keywords” used yielded a large number of results, and the nature of the topic did not allow for further restriction of search words. Therefore, we defined a list of criteria to be used to identify the records that would be saved and analyzed. At the third level of our analysis, we identified the most active journals containing at least 10 articles related to the management of nanotechnology projects, in general, and 3 articles for the BMA category. This methodology is adapted by Schiederig et al (2012) and used by Mukhtarova et al (2016). Further qualitative analysis summarizes the quantitative research and contains deeper consideration of literature in the field of investigated topic.

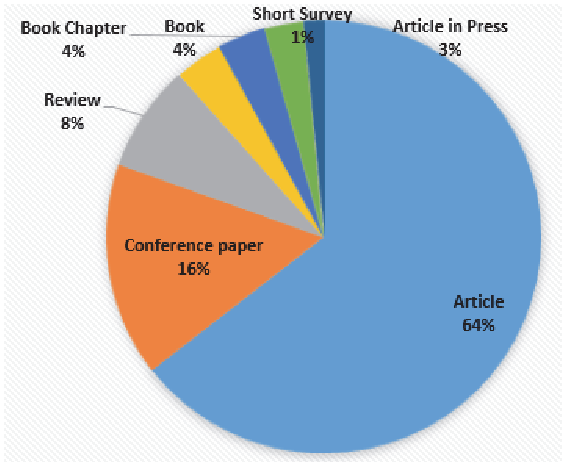

Figure 3. Segmentation of BMA category of publications by types in Scopus

Source: based on own research

3. RESULTS AND DISCUSSION

3.1 Quantitative analysis

The first level of our analysis is focused on the cumulative number of publications. Figure 4 shows the chronological development of publications using the BMA category: 855 in total and 138 in the BMA according to Scopus database. Figure 4 shows that the first paper related to a project in nanotechnology was published in 1992. The study is connected with the creation of the AIST institute called the Interdisciplinary Research Institute for Industrial Sciences (IRIS) (Tanaka et al, 1992). There are no published studies from 1993 to 1995. There were few publications, to be exact, a maximum of 2 publications per year in "general" in the period from 1996 to 2001. However, there were no publications in the "BMA" over the years. The figures show a steady growth in general (from 12 to 70, respectively) in the period from 2002 to 2018. Research in BMA began to be actively published since 2004. This is connected with the development of science parks in the USA and in the countries of Europe and Asia which focused on conducting a policy of analyzing R&D portfolios and attracting investments. A greater number of publications in “general” category reached 70 in 2016. Similarly, there are 17 publications in the BMA for this year.

Figure 4 shows the growth of studies in BMA area that may explained by high interest of scholars in investigated topic. Further, we compare dynamic of “BMA papers” with other spheres in WOS (Figure 5). Figure 5 shows lack of studies related to investigated topic in WOS (only single papers last two year). Publications in this direction in the Web of Science are combined in 25 subject areas (Figure 6).

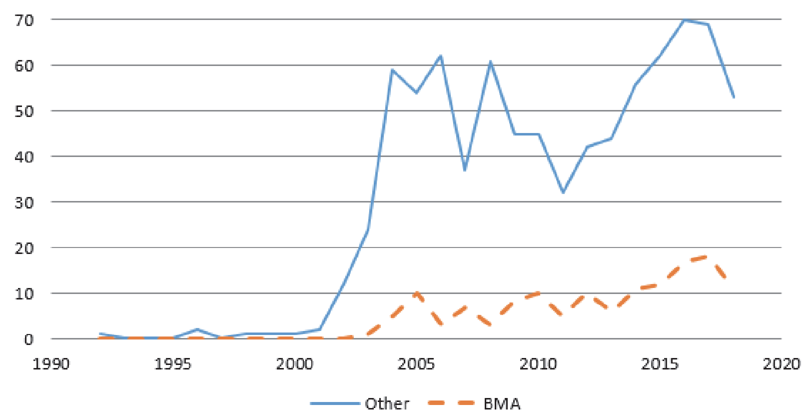

Figure 4. Development of annual publications in Scopus

Source: based on own research

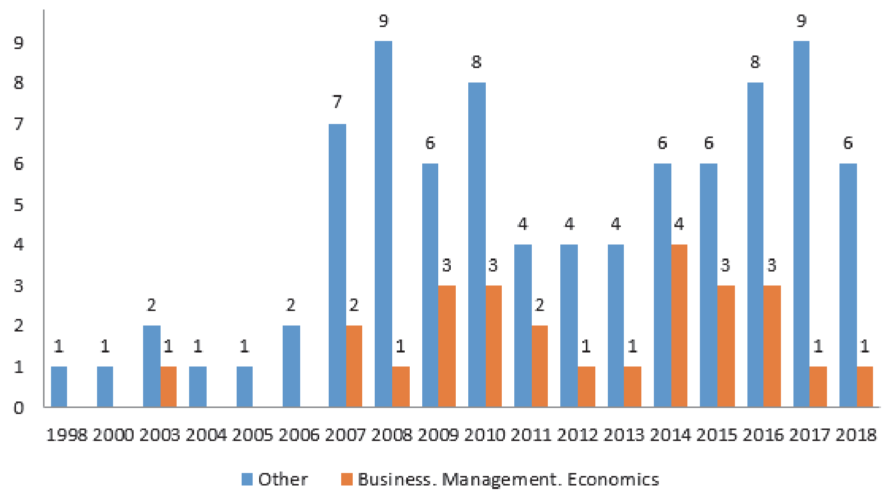

Figure 5. Development of annual publications in WOS

Source: based on own research.

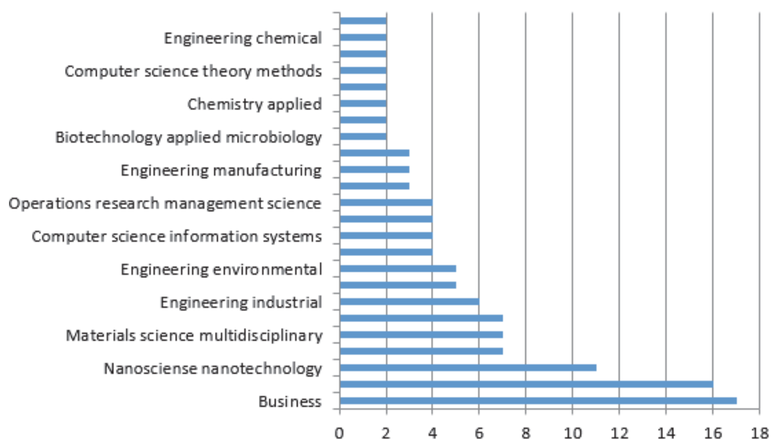

Figure 6. Share of publications by subject areas in WOS

Source: based on own research.

As depicted in Figure 6, most of the publications in our data set (17) are in the "Business" area, 16 of them Management publications, 11 linked to Nano science nanotechnology, 7 from Environmental sciences. However, the content analysis identified only 3 publications that explore the methods and tools of project management in the field of nanotechnology. This confirms our assumption that research related to the use of project management in the field of nanotechnology is not well developed. Scopus combines publications in 11 subject areas according to the key words "project management" in the results "nanotechnology". We reduced it to 18 subject areas with a minimum of 50 publications (Figure 7). Thus, the majority of publications in our data set (398) are in the field of "Engineering". 138 publications were related to BMA, 133 from Computer Science, 128 from Material Science, 96 from Social Science, 95 from Environmental Science, 93 from Physics and Astronomy and 79 about Chemical Engineering "Respectively. Other areas, such as Medicine (73), Chemistry (53) and Mathematics (52) have fewer publications than the above.

Figure 7. Share of publications by subject areas in Scopus

Source: based on own research

As we can see in Figure 7, most of the publications are in "Engineering". This is due to the development of nanotechnology projects in engineering, to be precise, computer technologies and electronics (the most significant results like creation of transistors on nanotubes have been obtained in this field). At the next level of our analysis, we tried to identify the countries with the highest amount of papers related to the research topic (Figure 8).

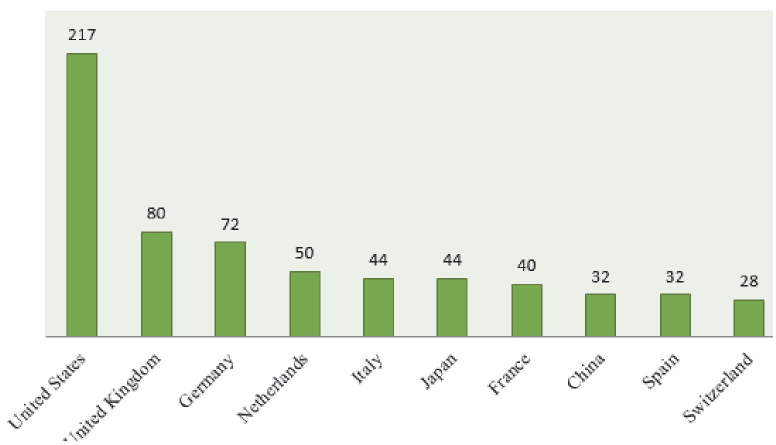

Figure 8. "General" articles sorted by countries in Scopus

Source: based on own research

As depicted in Figure 8, the overwhelming majority of publications in the “general” category originate from the United States, United Kingdom, and Germany. Meanwhile, the model is slightly different for BMA (Figure 9).

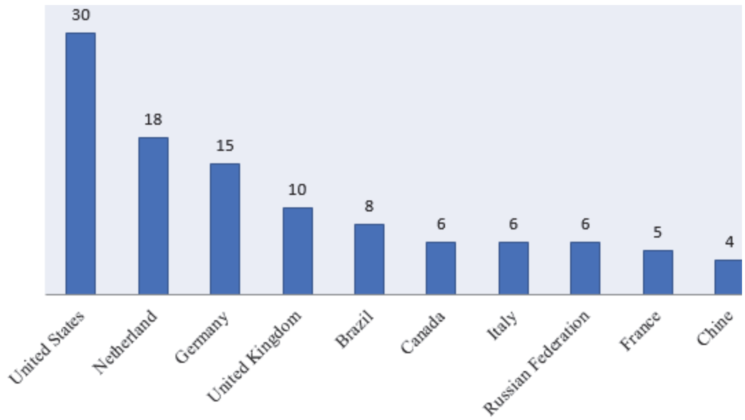

Figure 9. “BMA” articles sorted by countries in Scopus
Source: based on own research

As Figure 9 shows, “BMA leaders” are United States, Netherlands and Germany. These findings led us to state that countries from all continents are making efforts to study project management issues in nanotechnology. Interesting finding is above-mentioned list of countries are much differ in WOS (Table 2).

Table 2. “General” articles sorted by countries in WOS

Countries	Number of records	Percent share
USA	15	17.442 %
France	11	12.791 %
Italy	10	11.628 %
Switzerland	10	11.628 %
Netherlands	9	10.465 %
Spain	7	8.140 %
England	6	6.977 %
Greece	5	5.814 %
Brazil	4	4.651 %
Germany	4	4.651 %
Japan	4	4.651 %
Poland	4	4.651 %
Russia	4	4.651 %

Table 2 shows that USA is a leader according to two databases. American scholars published 15 articles in general. France, Italy and Switzerland also have at least 10 studies. Further, we limited the type of document “general” category to “articles”. There were 354 papers among 855 documents. We identified the most cited articles with no less than 50 citations. These results are reported in Table 3.

Table 3. Detailed citation analysis in Scopus

Rank	*Cites*	*Pub year*	*Author (s)*	*Title*	*Journal name*
1	634	2006	Li, X.-Q., Elliott, D.W., Zhang, W.-X.	Zero-valent iron nanoparticles for abatement of environmental pollutants: Materials and engineering aspects	Critical Reviews in Solid State and Materials Sciences
2	318	2008	Harward, V.J., Del Alamo, J.A., Lerman, S.R.	The iLab shared architecture: A web services infrastructure to build communities of internet accessible laboratories	Proceedings of the IEEE
3	215	2010	Stone, V., Nowack, B., Baun, A.	Nanomaterials for environmental studies: Classification, reference material issues, and strategies for physico-chemical characterisation	Science of the Total Environment
4	178	2014	Chen, M., Wan, J., Gonzalez, S.	A survey of recent developments in home M2M networks	IEEE Communications Surveys and Tutorials
5	131	2008	Paik, S.Y., Zalk, D.M., Swuste, P.	Application of a pilot control banding tool for risk level assessment and control of nanoparticle exposures	Annals of Occupational Hygiene
6	128	2009	Edwards-Jones, V.	The benefits of silver in hygiene, personal care and healthcare	Letters in Applied Microbiology
7	111	2006	Nataraj, S.K., Hosamani, K.M., Aminabhavi, T.M.	Distillery wastewater treatment by the membrane-based nanofiltration and reverse osmosis processes	Water Research
8	95	2006	Kuruvilla, S., Mays, N., Pleasant, A., Walt, G.	Describing the impact of health research: A Research Impact Framework	BMC Health Services Research
9	92	2010	Anders, S., Blamire, M.G., Buchholz, F.-Im. and	European roadmap on superconductive electronics - Status and perspectives	Physica C: Superconductivity and its Applications
10	90	2004	Zhu, W., Bartos, P.J.M., Porro, A.	Application of nanotechnology in construction Summary of a state-of-the-art report	Materials and Structures/Materiaux et Constructions
11	81	2009	Pease III, L.F., Lipin, D.I., Tsai, D.-H.	Quantitative characterization of virus-like particles by asymmetrical flow field flow fractionation, electrospray differential mobility analysis, and transmission electron microscopy	Biotechnology and Bioengineering
12	75	2012	Cleveland, D., Long, S.E., Pennington, P.L. and	Pilot estuarine mesocosm study on the environmental fate of Silver nanomaterials leached from consumer products	Science of the Total Environment
13	67	2012	Galamboš, M., Suchánek, P., Rosskopfová, O.	Sorption of anthropogenic radionuclides on natural and synthetic inorganic sorbents	Journal of Radioanalytical and Nuclear Chemistry
14	67	2008	Wardak, A., Gorman, M.E., Swami, N., Deshpande, S.	Identification of risks in the life cycle of nanotechnology-based products	Journal of Industrial Ecology
15	67	2005	Fisher, E.	Lessons learned from the Ethical, Legal and Social Implications program (ELSI): Planning societal implications research for the National Nanotechnology Program	Technology in Society

16	63	2013	Auger, J.	Speculative design: Crafting the speculation	Digital Creativity
17	58	2008	Tahara, Y., Honda, S., Kamiya, N.	A solid-in-oil nanodispersion for transcutaneous protein delivery	Journal of Controlled Release
18	57	2011	Brundiers, K., Wiek, A.	Educating Students in Real-world Sustainability Research: Vision and Implementation	Innovative Higher Education
19	57	2009	Fenwick, D., Daim, T.U., Gerdsri, N.	Value Driven Technology Road Mapping (VTRM) process integrating decision making and marketing tools: Case of Internet security technologies	Technological Forecasting and Social Change
20	54	2009	Kunnari, E., Valkama, J., Keskinen, M., Mansikkamäki, P.	Environmental evaluation of new technology: printed electronics case study	Journal of Cleaner Production
21	50	2010	Oliveira, M.G., Rozenfeld, H.	Integrating technology roadmapping and portfolio management at the front-end of new product development	Technological Forecasting and Social Change

Source: based on own research

Table 3 shows that the most cited paper published by Lee et al, (2006) in the journal Critical Reviews in Solid State and Materials Sciences was cited 634 times. Zhu (2004) published the earliest cited article in 2004 in Materials and Structures / Materiaux et Constructions journal. Three articles among these 21 papers contain more than 100 references. An analysis of the abstracts of 21 papers showed that only 3 of them are devoted to the implementation of nanotechnology projects. These papers were published in the following journals: "Journal of Industrial Ecology", "Technological Forecasting and Social Changes", "Technology in Society". The rest are in the field of health, chemistry and physics. In addition, we calculated annual links for each paper, which showed that some of them with a large total number of links have low annual links. The same analysis was done for the second group - "BMA" (Table 4).

Table 4. Detailed citation analysis for "BMA" in Scopus

№	Cites	Pub year	Author (s)	Title	Journal
1	67	2008	Wardak, A., Gorman, M.E., Swami, N., Deshpande, S.	Identification of risks in the life cycle of nanotechnology-based products	Journal of Industrial Ecology
2	67	2005	Fisher, E.	Lessons learned from the Ethical, Legal and Social Implications program (ELSI): Planning societal implications research for the National Nanotechnology Program	Technology in Society
3	57	2009	Fenwick, D., Daim, T.U., Gerdsri, N.	Value Driven Technology Road Mapping (VTRM) process integrating decision making and marketing tools: Case of Internet security technologies	Technological Forecasting and Social Change
4	54	2009	Kunnari, E., Valkama, J., Keskinen, M., Mansikkamäki, P.	Environmental evaluation of new technology: printed electronics case study	Journal of Cleaner Production

5	50	2010	Oliveira, M.G., Rozenfeld, H.	Integrating technology roadmapping and portfolio management at the front-end of new product development	Technological Forecasting and Social Change
6	42	2004	Tassey, G.	Underinvestment in public good technologies	Journal of Technology Transfer
7	30	2016	Granqvist, N., Gustafsson, R.	Temporal institutional work	Academy of Management Journal
8	30	2012	Raesfeld, A.V., Geurts, P., Jansen, M., Boshuizen, J., Luttge, R.	Influence of partner diversity on collaborative public R&D project outcomes: A study of application and commercialization of nanotechnologies in the Netherlands	Technovation
9	30	2009	Piotrowicz, W., Cuthbertson, R.	Sustainability – a new dimension in information systems evaluation	Journal of Enterprise Information Management

Source: based on own research

We extracted 96 papers by limiting the document type. Total 9 articles were selected with at least 30 total quotes. The paper of Wardak et al, (2008) published in the Journal of Industrial Ecology has 67 total references and heads the list. The main research areas of these journals are related to issues of management and technology development. The number of total and annual citations is significantly low in comparison to the previous results (Table 4). Further, we analyzed citations level in WOS database (Table 5).

Table 5. Articles with the highest number of citations in "general" category

№	Title	Author (s)	Journal	Pub year	Cites	Cites/ year
1	Identification of risks in the life cycle of nanotechnology-based products	Wardak, Ahson; Gorman, Michael E.; Swami, Nathan; Deshpande, Shilpa	Journal of Industrial Ecology	2008	61	5,08
2	Acceleration and extension of opportunity recognition for nanotechnologies and other emerging technologies	Linton, Jonathan D.; Walsh, Steven T.	International Small Business Journal	2008	40	3,33
3	Integrating technology roadmapping and portfolio management at the front-end of new product development	Oliveira, Maicon G.; Rozenfeld, Henrique	Technological Forecasting and Social Change	2010	38	3,8
4	ESTEEM: Managing societal acceptance in new energy projects A toolbox method for project managers	Raven, Rob P. J. M.; Jolivet, Eric; Mourik, Ruth M.; Feenstra, Ynke C. F. J.	Technological Forecasting and Social Change	2009	23	2,09
5	Is There Room at the Bottom for CSR? Corporate Social Responsibility and Nanotechnology in the UK	Groves, Chris; Frater, Lori; Lee, Robert; Stokes, Elen	Journal of Business Ethics	2011	22	2,44

6	Drivers of technology adoption - the case of nanomaterials in building construction	Arora, Sanjay K.; Foley, Rider W.; Youtie, Jan; Shapira, Philip; Wiek, Arnim	Technological Forecasting and Social Change	2014	19	3,17
7	Management principles for evaluating and introducing disruptive technologies: the case of nanotechnology in Switzerland	Bucher, P; Birkenmeier, B; Brodbeck, H; Escher, JP	R & D Management	2003	14	0,82
8	International Efforts in Nanoinformatics Research Applied to Nanomedicine	de la Iglesia, D.; Maojo, V.; Chiesa, S.; Martin-Sanchez, F.; Kern, J.; Potamias, G.; Crespo, J.; Garcia-Remesal, M.; Keuchkerian, S.; Kulikowski, C.; Mitchell, J. A.	Methods of Information In Medicine	2011	13	1,44
9	The eNanoMapper database for nanomaterial safety information	Jeliazkova, Nina; Chomenidis, Charalampos; Doganis, Philip; Fadeel, Bengt; Grafstrom, Roland; Hardy, Barry; Hastings, Janna; Hegi, Markus; Jeliazkov, Vedrin; Kochev, Nikolay; Kohonen, Pekka; Munteanu, Cristian R.; Sarimveis, Haralambos; Smeets, Bart; Sopasakis, Pantelis; Tsiliki, Georgia; Vorgrimmler, David; Willighagen, Egon	Beilstein Journal of Nanotechnology	2015	12	2,4
10	Improving industrial R&D practices with social and ethical aspects: Aligning key performance indicators with social and ethical aspects in food technology R&D	Flipse, Steven M.; van der Sanden, Maarten C. A.; Osseweijer, Patricia	Technological Forecasting and Social Change	2014	12	2

According to Table 5, the most cited paper related to nanotechnology management published in “Journal of Industrial Ecology” in 2008. Another one from “BMA” scope and published in “International small business journal”. One of the newest most cited papers related to nanotechnology published in specific nanotechnology journal in 2015. These findings let us to assume that there are lack of studies devoted to management of nanotechnology projects in WOS database.

3.2 Qualitative analysis

According to the quantitative analysis, the majority of publications in our data set (398) are in the field of "Engineering". The second place is taken by those in BMA. There are 138 publications related to BMA in Scopus database and more in WOS database. Such amount of papers let us assume that the topic of managing projects in nanotechnology industry is relevant and interesting for world`s scholars and scientist. Further findings of the detailed citation analysis shows that the most cited papers are far from PM practice. Papers from “BMA” category do not cover all aspects of nanotechnology project management. For example, paper of Wardak et al, (2008) published in the Journal of Industrial Ecology has a highest number of references and heads the list of most cited papers. However, the content of his research is far from PM. The main research areas of journals where published investigated papers relate to issues of management and technology development.

The qualitative analysis is based on the quantitative one and covers studies from Scopus and WOS too. The body of literature used for the qualitative analysis is presented in Table 6.

Table 6. The body of qualitative analysis

№	*Found knowledge areas*	*Number*	*Application area*	*Common research method*	*Sources*	*Results*
1	Risk management of nanotechnology projects	100	Economics and business Nanotechnology	Case study Qualitative analysis Quantitative analysis	Wang et al, 2010; Collyer et al, 2010; Lenfle, 2008; Procca, 2008; Barnes et al, 2006	Tool and technique, guidelines, methodological suggestions
2	The role of nanotechnology in economic development	9	Engineering Management	Qualitative data analysis	Shapira et al, 2015; Moller et al, 2012	Tools and techniques
3	The essence of nanotechnology project management	12	Physics	Mixed methods	Rose et al, 2019; Meshalkin et al, 2012; Sarkisov, 2013	Guidelines for managing nanotech. projects
4	Resources of nanotechnology projects	11	Information technology	Quantitative analysis	Fadel et al, (2018); Pillai, Bezbaruah (2017); Harsh et al, (2017)	Guidelines
5	Safety issues in nanotechnology	8	Physics Aerospace Engineering Pharmaceutical	Mixed methods	Kuhnel et al, (2016); Pillai and Bezbaruah (2017); Parikhani et al, (2018)	Conceptual results
6	Nanotechnologies link with other industries	11	Physics Biotechnology Chemical engineering	Empirical study Case study	Parisi et al, 2014; King et al, 2018); Mukhtarova et al, (2019); Kishi (2004).	Conceptual results Tools and techniques
7	Nanotechnology projects as a component of high-tech industry	10	Nanotechnology Engineering	Panel study Quantitative analysis	Fleischer et al, 2005; Cobb and Macoubri, 2004; Lee et al, 2005; Macoubrie, 2006; Wiek et al, 2009	New approaches
8	Implementation of PM tools in the field of nanotechnology	5	Business and management	Survey Mixed methods	Rolt et al, 2017; Pavlov et al, 2017; Micheletti et al, 2017.	List of practical suggestions

As depicted in Table 6, there are few number of publications selected for the qualitative analysis from Scopus and WOS due to the fact that most of them are far from the investigated topic. Despite of this, we tried to cover wide range of studies for conducting a deeper research.

Knowledge areas. In this point, we selected the main 8 areas which are mentioned more frequently than others. The most studied area is a risk management of nanotechnologies. Study found more than 100 papers in this subject. Least studied field is implementation of PM tools in the field of nanotechnology (5). It is important to note that only two of them are related to nanotechnology projects.

Application area. According to results of this point, only two areas are published in Economics and Business scope: risk management of nanotechnology projects and implementation of PM tools in the field of nanotechnology. Most of studies are published in Technical sciences like engineering and physics.

Common research methods. The study reveals the most used research methods like quantitative and qualitative analysis, mixed methods and case study. Scientists from all application areas use them.

Results. This point includes the main findings of the studies from the chosen areas. Most of the considered studies include guidelines, tools and techniques, conceptual results and practical suggestions. Further analysis provide the deeper consideration of these selected areas. The qualitative analysis of existing literature reveals the absence of common definition of nanotechnology project that complicate the research problem solving. The authors found a few scholars, who investigated and tried to explain the characteristics of nanotechnology projects and their management features (Rose et al, 2019; Meshalkin et al, 2012). Their studies highlighted the features of project management problems in the field of nanotechnology. They show advantages and disadvantages of the most common project management methods and the possibilities of using them during nanotechnology project implementation. For example, Meshalkin et al, (2012) investigated the characteristics of projects in the nanotechnology industry from the viewpoint of resource provision and conditions of realization. They show the specifics of project management problems in the nanotechnology industry. The authors suggest project simulation approach based on the use of temporal logic tools and substantiate the advisability of developing branching point-interval time methods for the simulation of nanotechnology projects.

It is very important to understand that Nano technological projects differ from other projects because they involve the manipulations with very small pieces of molecules and atoms (and have large embedded risks even for rather small-scale projects). At each of the stages of their implementation should be used specific managerial tasks and suitable methods. Accordingly, the implementation of project management involves ensuring the consistency of solving these problems by creating a single management loop (Sarkisov, 2013). This makes their management very complex and costly as explained in the literature reviewed. In order for a project to be successful, it is necessary to use project management tools. The amount of financial investment required to manage such projects is also huge, because a lot needs to be done in order to avoid health problems, the environment and other general design problems. There are many principles that project managers must take into account when performing their duties in the field of nanotechnology. These principles help streamline the work of managing nanotechnology projects.

A group of scholars lead by Fadel et al, (2018) claim that nanotechnology projects are technically complex. Management of such projects should take care about security measures because such projects often run by using sophisticated tools and equipment. Pillai and Bezbaruah (2017) support the idea of previous scholars and state that project managers have to spend more resources for providing security measures during project implementation, which may increase project costs. Moreover, Harsh et al, (2017) confirm that the management of the entire nanotechnology project depends on the amount of resources allocated to the tasks. Material and financial resources are very important for such projects. For this reason, substantial financial investment is needed to contribute to the success of the project. Kuhnel et al, (2016) also touch on safety issues, they state that beneficial effects of new technologies are often confronted by concerns regarding the safety of novel substances or materials and great effort has been put into research on potential hazards of Nano materials towards environmental organisms. But Kuhnel et al, (2016) also claim that the use of nanotechnology and advanced materials promises to revolutionize many areas of technology and improve our daily life. As they state, many positive effects on the environment are expected, either directly, by developing new technologies, techniques or energy generation due to lower consumption of raw materials. On the other hand, Shapira et al, (2015) argue that despite the fact that nanotechnology projects imply high costs this can be justified by the economic benefits that will be received later after implementing a project.

Parikhani et al, (2018) found other positive consequences related to nanotechnology project implementation. They conducted research on the environmental impact of nanotechnology. The authors found that environmental projects and health projects linked with nanotechnologies positively affect economic growth of countries that implement these projects. Moreover, Mukhtarova et al, (2019) investigate nanotechnology projects as a component of high-tech entrepreneurship and state that successful implementation of such projects may support the economic development of entire country. Many scholars link rapid development of nanotechnology industry with the current challenges of sustainability, food security, climate change and agricultural sector (Parisi et al, 2014; King et al, 2018). Their developments are engaging researchers in exploring the field of nanotechnology as new source of key improvements for the mentioned above sectors.

About 100 publications are devoted to the study of risks in the management of nanotechnology projects (Wang et al, 2010; Collyer et al, 2010; Lenfle, 2008; Procca, 2008; Barnes et al, 2006). Most of these scholars assume that high level of risk is one of major disadvantages of nanotechnology projects and present different risk management technologies (Collyer et al, 2010; Fadel et al, 2015). These technologies are usually determined by uncertainties, not risks, while standard risk assessment methods are often not fully applicable (Rose and Gazgo, 2019). For example, Fadel et al. (2015) proposes to apply objective-oriented approaches so-called "Top-down methods" that can improve and speed up the risk assessment process by combining technical information and expert assessment of emerging technology with human perception of value. J.Brocke et al, (2015) proposes another approach for risk management of nanotechnology project through investigation of uncertainty from risks and manage them, respectively, separately.

Another group of authors assume that nanotechnology projects should be managed according to the rules of high-tech project management (Fleischer et al, 2005; Cobb and Macoubrie, 2004; Lee et al, 2005; Macoubrie, 2006; Wiek et al, 2009). For example, Wiek et al, (2009) used an empirical quality system to analyze many possibilities and special software to create and filter scenarios according to pre-established criteria in terms of consistency, consistency and diversity. They presented a study scenario of possible future nanotechnology developments in Switzerland for the base year 2020. Their conceptual framework has created five possible scenarios for the development of nanotechnology in Switzerland for five different market conditions, where concentrated different kind of high technologies. On the other hand, scholars that investigates high-tech projects claim that there is lack of established PM practices and methodological recommendations for managing such projects (Karmarkar, 2004; Power and Cormican, 2015; Mukhtarova and Kozhakhmetova, 2017). Thus, it may be not so easy to rely on high-tech project management practice. For example, Mukhtarova and Kozhakhmetova (2017) assume that management of projects should be organized differently for different industries like nanotechnology, communications, green energy etc.

Another author who links nanotechnology projects with different industries is Kishi (2004). As he states, in the nanoscale world where physics, chemistry, and biology meet with one another, interdisciplinary research is inevitable. Besides, inter-organizational and international encounters should be increased because this world is the ultimate area of natural science. Kishi (2004) mentions the role of government in such project implementation and claims that one of the most important roles of the national government is the creation of researcher network for the promotion of the collaboration of researchers from different fields. He assumes that project management in the field of nanotechnology should involve different scientists from different areas.

Understanding and addressing complexities involved in integrating nanomaterial and non-nanomaterial data resources to enable and advance scientific research is a key focus of Nano informatics (Thomas et al, 2011a). This article discusses the integration of data resources across nanotechnology, including non-nanotechnology resources. It is one in a series of papers focusing on important aspects of Nano informatics produced by the Nano materials Data Curation Initiative (NDCI), which is part of the National Cancer Institute (NCI) Nanotechnology Working Group (Hendren et al, 2015).

Other papers in this series discuss data curation workflows (Powers et al,, 2015) and data completeness and quality (Marchese-Robinson et al,, 2016).

Qualitative analysis led us to claim that there is a lack of deeper studies on the topic of managing nanotechnology projects, which examine in detail the used tools of PM in nanotechnology industry.

CONCLUSION

The study let us to assume that nanotechnology projects are most promised technologies that shape world market and they are widely applied in our everyday life. The three level of quantitative analysis showed that the majority of publications in our data set (398) are in the field of "Engineering" followed by those in BMA with 138 publications in Scopus, such amount of papers led us to assume that the topic of managing projects in nanotechnology industry is relevant and interesting for world`s scholars and scientist. Further findings of detailed citation analysis shows that the most cited papers are far from PM practice. Papers from “BMA” do not cover all aspects of nanotechnology project management. For example, paper of Wardak et al, (2008) published in the Journal of Industrial Ecology has a highest number of references and heads the list of most cited papers but the content of his research is far from PM application. The main research areas of journals where the investigated papers are published relate to issues of management and technology development.

The first level of analysis focused on the cumulative number of publications shows the chronological development of publications using the BMA category are 138 from 855 in Scopus and total 17 in WOS. The next finding related to identifying the countries with the highest amount of papers related to the research topic. Thus, “BMA leaders” are United States, Netherlands and Germany in Scopus and USA, France, Italy are leaders in WOS. These findings let us to state that countries from all continents are making efforts to study project management issues in nanotechnology.

At the third level of our analysis, we identified the most active journals containing at least 10 articles related to the management of nanotechnology projects, in general, and 3 articles for the BMA category. Results show detailed citation analysis according to which the most cited papers are far from PM practice. Papers from “BMA” category do not cover entire aspects of nanotechnology project management. Moreover, results of qualitative analysis confirm this statement. Qualitative analysis reveals different groups of authors with different approaches of topic investigations. One group of them dedicate their studies for exploring positive effects of nanotechnology projects, others examine negative aspects of such projects. In addition, about 100 publications are devoted to the study of risks in the management of nanotechnology projects. The third group links management of nanotechnology projects with PM practice of projects from another industry. Finally, there are few amount of studies dedicated to real practice of nanotechnology project management.

Limitation of the study is consideration of a narrow topic. The authors consider PM practice only on the field of nanotechnology. Further researches may cover other projects from different industries like service, trade, production etc. Another limitation is that the authors consider only Scopus and WOS databases. Scholars who are interested in this field of research may use also other additional databases.

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