

Article

Requirements for Project Managers—What Do Job Advertisements Say?

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Abstract: The growing number of projects and the key role of project managers in their implementation makes the competencies of managers a subject of many studies. An attempt can be made to determine the project manager competencies that employers appreciate the most through analyses of job advertisements. Due to a very large number of job advertisements, it may be difficult or even impossible to analyze their content manually. A solution may be to fetch and process job advertisements automatically. The main purpose of this paper was to identify the project manager competencies that are the most desired by employers. An analysis of job advertisements was performed to identify the project manager competencies required by employers. Job advertisements were automatically downloaded from online job boards. Fragments of job advertisements that described requirements were analyzed with text mining. The analysis included preprocessing, building of corpora of documents, construction of document-term matrices, application of traditional data mining methods, and Latent Dirichlet Allocation (LDA), which is a popular topic modeling algorithm. After the initial text processing (all characters except letters were removed, uppercase letters were converted to lowercase letters, words deemed useless were removed, and words were converted to their basic form), n-grams were built, and topics identified with LDA were generated. The most frequently used words and n-grams, along with the identified topics, were graphically represented. The meanings of the words and sentences were not analyzed in the text mining analysis of the job advertisements. The analysis did not take into account whether the words appeared side by side in the document—except for the intentional creation of n-grams (such as “communication skill”). The analysis, however, facilitated the identification of certain patterns and regularities in the occurrence of specific strings in the documents (fragments of advertisements describing the requirements). The interpretation of the results is based on the frequency of words and n-grams and frequency of words in topics identified by the LDA algorithm. This paper contributes to science by showing that text mining of job offers can, to some extent, help determine project manager competencies in demand. The method can be used by organizations training future project managers to modify and better adapt curricula to the needs of the labor market. It can be used to monitor the current trends in project manager requirements as well.



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1. Introduction

An unstable environment, aggressive competition, and changing customer expectations force companies to take unconventional actions, constantly modify their offer, and search for and test strategic moves. Traditional, rigid organizational structures do not allow companies to adapt to the environment quickly. Project management can solve this. It plays an important role in a changing business environment. Projects can help organizations implement strategic changes required in a dynamic marketplace. They make companies more flexible, empowering them to effectively and efficiently achieve their goals. Next to experience, project management is the most frequently sought competency required when recruiting employees [1,2]. The growing use of project management to realize organizations’

plans is a trend of the last decades. Important success factors of project implementation are the knowledge, skills, and attitude of the person who manages it. This means that there is increasing pressure on people holding this position [3].

Managers' competencies are crucial to the success of a project [4,5] and the main predictors of its performance [6,7]. Therefore, the development of competencies of project managers in organizations is an important contributor to improving project management performance and, consequently, organizational performance [8–10]. The competencies of project managers are intensely researched. Some of the studies are related to education. Researchers are trying to find out how to educate project managers to improve their competencies [11–18]. Research has focused on project manager competencies in managing projects in different areas like industry, finance, software development, and the translation market [19–26]. Some of the studies concerned different stages of the project life cycle, specific types of project managers' competencies, and their ability to manage the project team [27–33].

Project manager competencies can also be studied using data from job advertisements available online. Ahsan et al. developed a list of project manager job competencies by content analysis of job advertisements. The analysis was done by authors manually; no content analysis software was used [34]. Due to the huge number of job advertisements, it can be difficult or even impossible to analyze the content without a system that automatically processes text documents. The extraction of information and knowledge from unstructured text documents to detect lexical or linguistic patterns is generally referred to as text mining. Text mining is widely used to deeply dig information in job description texts to obtain the skills, technologies, or knowledge fields that the employee needs to master [35–37]. Zheng et al. analyzed big data of job advertisements to investigate the real-world demand for construction project manager competencies in China. Their results suggested eight major competency dimensions that recruiters expect from construction project managers [38].

The paper's objective was to identify the requirements and competencies of project manager candidates sought after by employers. To achieve it, the author conducted a text mining analysis of online job advertisements. The structure of the work has been subordinated to the goal. The first part of the research was a review of the literature to determine and group project manager competencies. This allowed the author to interpret the results obtained in the second part of the study, which was a text mining analysis of online job advertisements. The text mining analysis involved preprocessing, building of corpora of documents, construction of document-term matrices, application of traditional data mining methods, and Latent Dirichlet Allocation (LDA), which is a popular topic modeling algorithm. The results are shown in figures. The most popular words/n-grams and topics identified with LDA were presented. The text mining solution used by the author did not analyze word- or sentence-level semantics. Nevertheless, it detected certain principles and patterns of occurrence of specific words and n-grams in the documents (parts of job advertisements with requirements concerning project managers).

This paper contributes to the development of the project manager competencies literature by showing that job advertisements can be a valuable source of data and can be used to characterize project management requirements. The innovation of this paper is the automatic harvesting of recruitment information related to project managers for 44 countries/areas.

2. Project Managers' Competencies

Competency is a set of related knowledge, attitudes, skills, and other personal characteristics that influence a significant part of work. It correlates with job performance, can be measured against well-accepted standards, improved through training and development, and broken down into competency dimensions [39]. A person's competencies include personality traits, motivation, skills, self-esteem related to functioning in a group, as well as acquired and used knowledge [40]. They combine knowledge, skills, experience, demon-

stable performance, and personal competencies, including attitudes, motivation, behavior, and personality traits [41]. Competencies can be divided into two basic groups, i.e., hard and soft competencies. Hard ones relate to a specific job position. They are defined as professional, technical, substantive, and functional competencies. On the other hand, soft competencies are personality traits contributing to given professional roles (behavioral, social, interpersonal) [42]. Competency is the ability of a person, team, or company to mobilize and combine resources (i.e., knowledge, skills, and attitudes) to act in a given situation [43].

The growing popularity of project management is related to the growing requirements for project managers [44]. The number of competencies that project managers need to have is increasing [44,45]. The responsibilities and competencies of the project manager are closely related to the factors influencing the project's success [46]. The project manager should have professional knowledge of the subject-matter area of the project and be an expert in project management methods and techniques [47]. The characteristics of the project and its complexity require specific competencies from the project manager, while aspects of the project such as technology, direct managerial support, and project structure influence the appropriate competencies of the project manager for successful project completion [34]. Project managers' competencies are often presented as a set of knowledge, skills, personality traits, and experience [47]. Project manager competencies are the ability to use skills, knowledge, and personal characteristics that increase the effectiveness and efficiency of project managers in doing their job and thus increase the likelihood of project success [48].

Chipulu et al. divided project manager competencies into six dimensions: industry and general skills, knowledge and experience in project management, (senior) managerial skills, (positive) personality traits, experience in project management methodology, and professional qualifications and risk management over a project life cycle [49]. According to Wachowiak et al., the skills of a project manager can be divided into the following groups [50]:

- technical—they help understand the essence of the project and perform the tasks;
- interpersonal—this is the ability to establish and maintain contacts between people;
- conceptual—they facilitate creative problem solving;
- diagnostic and analytical—they facilitate problem diagnosis;
- political—they help with an effective impact on the environment of the project.

Among the most important competencies of project managers, Piwowski-Sulej included [51]:

- high professional qualifications, technical knowledge related to the subject and scope of the project, knowledge of management methodologies (traditional and modern methodologies),
- the ability to set goals and organize the work of a project team,
- independence in assessing facts,
- openness to non-standard working methods,
- well-developed social skills (including negotiation and diplomatic skills, tolerance for a different point of view of team members, and a marketing approach to the client).

The list of project manager competencies developed by Musioł-Urbańczyk includes 46 items divided into four groups, i.e., professional competencies (19 competencies), social competencies (9 competencies), personal competencies (14 competencies), and business competencies (4 competencies). The research on the impact of competencies on the effectiveness of the project manager's actions shows that the following competencies are fundamental: the ability to communicate, the ability to make decisions, leadership, the ability to motivate team members, the ability to build a team, the ability to manage communication in the project, teamwork, the ability to negotiate, loyalty, the ability to manage the scope of the project, and flexibility [52].

Ahsan et al. developed a list of project manager job competencies by content analysis of job advertisements covering different industries in Australia and New Zealand. The content analysis was done manually, and no content analysis software was used. The top 10 competencies identified by the researchers were communication, technical skills, stakeholder management, cost management, time management, educational background, planning, leadership, team building and management, and certification [34].

Project manager competencies are related to the use of a common professional language and project management concepts. Competency determines workplace behavior and can be measured using current standards [53]. There are several international models of project manager competencies [54,55]:

- Project management competency development framework, 3rd edition by the Project Management Institute [56]. This standard consists of three separate components: project management knowledge, performance competency, and personal competency [57].
- APM Body of Knowledge, 7th edition, developed by the Association for Project Management [58]. In this standard, competency components are defined within three domains: technical competency, behavioral competency, and contextual competency [55].
- AIPM Professional Competency Standards for Project Management, developed by the Australian Institute of Project Management. The standards are described in terms of project management units: scope, time, cost, quality, human resources, communication, risk, contract, and procurement management [59]. This standard was designed to cover most industries and most projects, from simple to complex ones [55].
- Individual Competence Baseline, Version 4 (ICB4), established by the International Project Management Association [60]. This standard is a set of 29 general competencies, which can be applied to project, program, and portfolio environments [61].

Expectations towards key competencies of a project manager may vary. They will depend on the type of project, its size, scope, the methodology adopted, or the size and type of the organization. There are also differences in identifying key competencies between experts composed of recruiters, project management lecturers, assessors, and project managers [62]. The research on developing and applying self-assessment instruments for evaluating project managers' competencies showed that it is difficult to define the universal competencies framework. It is caused by the diversity of business fields and specifics of the organizations. In general, competency sets that can be used for evaluation should be tailored to a particular organization [63].

3. Research Methodology

Job advertisements with the phrase “project manager” in the title were fetched from Indeed (Indeed was founded in 2004 with a simple mission: help people find jobs. Indeed is now the largest job site in the world, with 250 million monthly users and 10 new jobs added every second [64]). The advertisements were downloaded from 17 April 2021 to 22 April 2021 for all 63 available countries or areas. This process was completed in RStudio with such packages as *roest* [65], *downloader* [66], and *xml2* [67].

Next, advertisements in languages other than English were removed. The advertisement language was identified with packages *clld2* [68] and *clld3* [69]. In addition, advertisements classified as duplicates were removed as well. An advertisement was considered a duplicate when its content was identical to the content of another advertisement and was published by the same organization. The content was treated as a string of characters and compared in RStudio using the comparison operator “==”. The number of advertisements qualified for the analysis was 25,884 (44 countries or areas). The advertisements were posted to data frames of 25,884 rows and 4 columns. A single row stored data on a single advertisement in the following columns:

- “Adverts_ID”—the automatically generated unique advertisement number,
- “Adverts_title”—the title of the advertisement,

- “Adverts_content”—the entire content of the advertisement,
- “Country_area”—the name of the country/area for which the offer was retrieved, such as “Austria” for advertisements from the Indeed board at <https://at.indeed.com>.
- The preliminary analysis of the advertisements demonstrated that
- twenty thousand two hundred and eight (78.1%) offers had additional words apart from “project manager” in the title (examples of titles: “IT Project Manager—Tele communications (Permanent)”, “Senior Project Manager”, “Graduate Electronics Project Manager”). These advertisements were classified to set A;
- five thousand six hundred and seventy-six (21.9%) of the advertisements had only the phrase “project manager” in the title. They were classified to set B;
- the advertisements failed to use semantic HTML tags in accordance with JobPosting [70] or used them incorrectly. The tags label various sections of the HTML document, such as required educational background (“educationRequirements”), job description (responsibilities”), or financial terms (“baseSalary”);
- the order of the sections and their headings varied among advertisements (such as company introduction, job description, requirements);
- some advertisements lacked certain sections, such as requirements, job description, or company introduction.

The next step was to find: (1) the part describing requirements and (2) its heading. The identified data were put into two additional columns:

- Requirement—the part of the advertisement describing requirements,
- Requirement—heading—the heading of the description of requirements

The process was conducted manually for random advertisements because the structures of the advertisements differed, and no JobPosting HTML tags were used. First, twenty A set and five B set advertisements were randomly selected for each country/area. If the number of advertisements for a country was lower than twenty for set A and five for set B, all advertisements were selected. Only the selected advertisements were left in the data frame and then exported into an xlsx file. Then the content of columns *Requirement* and *Requirement—title* was created in the spreadsheet with “select, copy, paste”. The data were then imported into RStudio. At this point, the data frame consisted of 988 rows and 6 columns.

Table 1 presents the numbers of fetched and randomly selected advertisements by country/region and sets A and B. According to the table, 1650 advertisements were fetched for Australia; 75.5% (1246) were classified to set A and 24.5% to set B. Twenty-five advertisements were analyzed for this country (20 from set A and 5 from set B). Out of the 25,884 fetched advertisements, 988 were analyzed: 791 from set A and 197 from set B.

Table 1. The number of job advertisements downloaded and selected for analysis.

Country/Area	Downloaded Job Advertisements			Selected Job Advertisements		
	A	B	Total	A	B	Total
Argentina	32 (80%)	8 (20%)	40	20 (80%)	5 (20%)	25
Australia	1,246 (75.5%)	404 (24.5%)	1,650	20 (80%)	5 (20%)	25
Austria	94 (91.3%)	9 (8.7%)	103	20 (80%)	5 (20%)	25
Belgium	391 (85%)	69 (15%)	460	20 (80%)	5 (20%)	25
Brazil	30 (73.2%)	11 (26.8%)	41	20 (80%)	5 (20%)	25
Canada	1,087 (76%)	343 (24%)	1,430	20 (80%)	5 (20%)	25
Chile	13 (68.4%)	6 (31.6%)	19	13 (72.2%)	5 (27.8%)	18
China	462 (83.5%)	91 (16.5%)	553	20 (80%)	5 (20%)	25
Colombia	24 (85.7%)	4 (14.3%)	28	20 (83.3%)	4 (16.7%)	24

Table 1. Cont.

Country/Area	Downloaded Job Advertisements			Selected Job Advertisements		
	A	B	Total	A	B	Total
Costa Rica	35 (66%)	18 (34%)	53	20 (80%)	5 (20%)	25
Czech Republic	62 (92.5%)	5 (7.5%)	67	20 (80%)	5 (20%)	25
Ecuador	4 (100%)	0 (0%)	4	4 (100%)	0 (0%)	4
Germany	323 (92.6%)	26 (7.4%)	349	20 (80%)	5 (20%)	25
Hong Kong	187 (84.6%)	34 (15.4%)	221	20 (80%)	5 (20%)	25
Hungary	136 (82.9%)	28 (17.1%)	164	20 (80%)	5 (20%)	25
India	835 (66.5%)	420 (33.5%)	1,255	20 (80%)	5 (20%)	25
Italy	40 (90.9%)	4 (9.1%)	44	20 (83.3%)	4 (16.7%)	24
Kuwait	13 (65%)	7 (35%)	20	13 (72.2%)	5 (27.8%)	18
Luxembourg	47 (90.4%)	5 (9.6%)	52	20 (80%)	5 (20%)	25
Malaysia	199 (72.4%)	76 (27.6%)	275	20 (80%)	5 (20%)	25
Mexico	103 (73%)	38 (27%)	141	20 (80%)	5 (20%)	25
Morocco	12 (85.7%)	2 (14.3%)	14	12 (85.7%)	2 (14.3%)	14
Netherlands	76 (79.2%)	20 (20.8%)	96	20 (80%)	5 (20%)	25
New Zealand	228 (69.9%)	98 (30.1%)	326	20 (80%)	5 (20%)	25
Nigeria	48 (73.8%)	17 (26.2%)	65	20 (80%)	5 (20%)	25
Norway	30 (81.1%)	7 (18.9%)	37	20 (80%)	5 (20%)	25
Oman	14 (77.8%)	4 (22.2%)	18	14 (77.8%)	4 (22.2%)	18
Pakistan	29 (61.7%)	18 (38.3%)	47	20 (80%)	5 (20%)	25
Panama	4 (80%)	1 (20%)	5	4 (80%)	1 (20%)	5
Peru	5 (83.3%)	1 (16.7%)	6	5 (83.3%)	1 (16.7%)	6
Philippines	257 (68.7%)	117 (31.3%)	374	20 (80%)	5 (20%)	25
Poland	147 (84%)	28 (16%)	175	20 (80%)	5 (20%)	25
Singapore	907 (69.5%)	398 (30.5%)	1,305	20 (80%)	5 (20%)	25
South Africa	58 (81.7%)	13 (18.3%)	71	20 (80%)	5 (20%)	25
South Korea	31 (83.8%)	6 (16.2%)	37	20 (80%)	5 (20%)	25
Spain	127 (92%)	11 (8%)	138	20 (80%)	5 (20%)	25
Taiwan	82 (88.2%)	11 (11.8%)	93	20 (80%)	5 (20%)	25
Thailand	111 (69.4%)	49 (30.6%)	160	20 (80%)	5 (20%)	25
Turkey	30 (71.4%)	12 (28.6%)	42	20 (80%)	5 (20%)	25
Ukraine	91 (69.5%)	40 (30.5%)	131	20 (80%)	5 (20%)	25
United Kingdom	2921 (77%)	871 (23%)	3,792	20 (80%)	5 (20%)	25
United States	9,539 (80.5%)	2,307 (19.5%)	11,846	20 (80%)	5 (20%)	25
Uruguay	6 (85.7%)	1 (14.3%)	7	6 (85.7%)	1 (14.3%)	7
Vietnam	92 (70.8%)	38 (29.2%)	130	20 (80%)	5 (20%)	25
	20,208 (78.1%)	5,676 (21.9%)	25,884	791 (80.1%)	197 (19.9%)	988

The next stage was a text mining analysis of requirement sections stored in the Requirement column. The RStudio was used for this purpose. The analysis involved such steps as text preprocessing, building n-grams, creation of corpora, searching for the most

common words and n-grams, and generation of abstract topics using the Latent Dirichlet Allocation method (LDA). Some actions were repeated until the results were satisfactory.

Some of the preprocessing operations were:

- removal of all characters except letters;
- lowercasing;
- removal of words considered useless (such as conjunctions, prepositions, etc.) with an original list of stopwords;
- stemming.

The cleaned text was used to generate n-grams of two to five words. N-grams are sequences of characters or words extracted from a text [71]. N-grams were created separately for each piece of text with the End Of Line character (EOL) at the end. The resulting n-grams were put into additional columns: 2-g, 3-g, etc. Table 2 shows the results of pre-cleaning and generation of 2-g for two example pieces of text. The first piece of text initially consisted of seven words: “You”, “hold”, “a”, “master”, “degree”, “in”, and “Engineering”. After text cleaning, the words “You”, “a”, and “in” were removed. The word “Engineering” was reduced to its basic form, and its letters were changed to the lower case. The four words that remained (“hold”, “master”, “degree”, “engineer”) were used to generate three 2-g: “hold master”, “master degree”, and “degree engineer”.

Table 2. Text cleaning and n-gram creating—example.

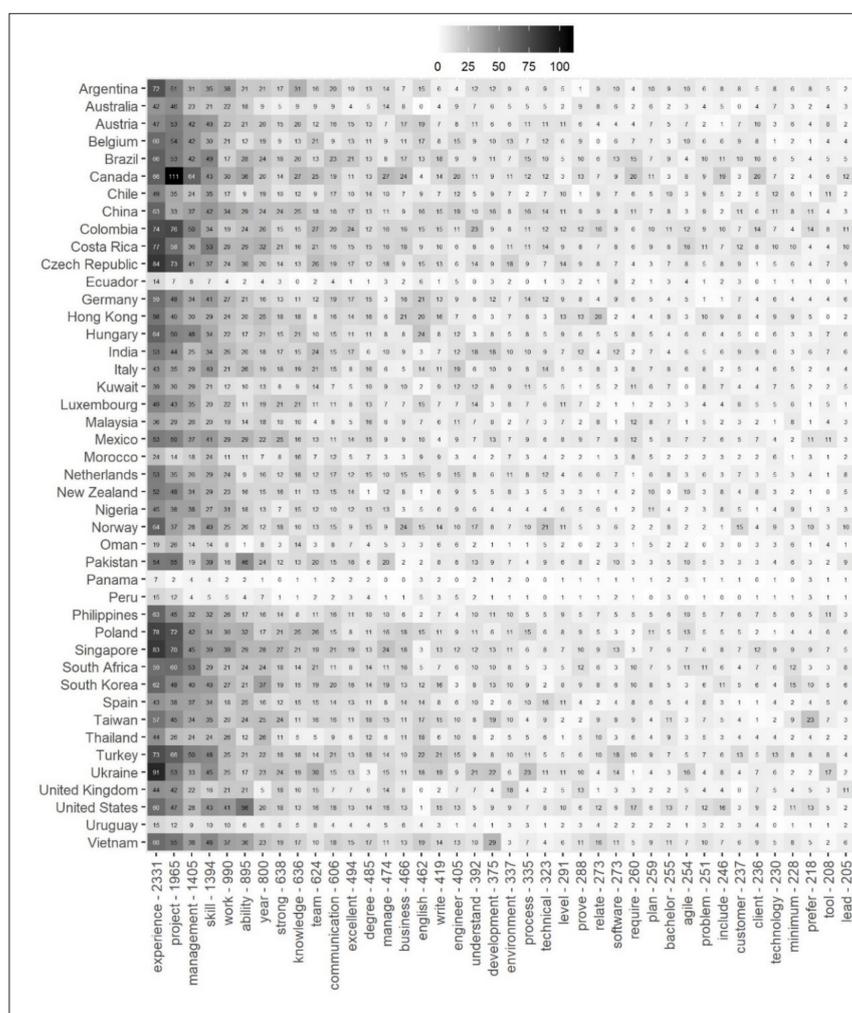
Original Text	Text after Cleaning	2-Grams
– You hold a master degree in Engineering	hold master degree engineer	“hold master”; “master degree”; “degree engineer”
– You have 10 years of experience working in an engineering environment for the development, design, and construction of solar and or wind farms	year experience work engineer environment development design construction solar wind farm	“year experience”; “experience work”; “work engineer”; “engineer environment”; “environment development”; “development design”; “design construction”; “construction solar”; “solar wind”; “wind farm”

The data in column Requirement were the first corpus. The content of each cell was treated as a separate document. The remaining corpora were generated from columns with the n-grams. A document-term matrix with the term frequency (TF) was created for each corpus. The next action was to find the most common words and n-grams and visualize them.

The last stage was the application of LDA, which is a popular topic modeling algorithm. The supposition for the algorithm is that each document is represented by a set of topics, and each topic is represented by words. The LDA method was described by Blei, Ng, and Jordan [72]. The study employed the implementation of the algorithm available in an R package, *topicmodels*. The topics were generated for the documents in column Requirement. The identified topics were intended to help determine desired project manager competencies and categorize them (such as competencies for agile projects).

4. Results

Figures 1 and 2 use a heat map to show the distribution occurrences of the most used word/n-gram by country/area. Black color indicates the maximum number of occurrences of word/n-gram for a given country/area. The white indicates zero occurrences. The y-axis shows the countries/areas in alphabetical order. The x-axis shows the most frequently used words/n-grams, together with the total number of their occurrences in the 988 documents analyzed. They are sorted in descending order of their occurrences.



tion skills ("communication skill", "write verbal", "write speak" etc.), organizational skills ("organizational skill"), and time management skills ("time management").

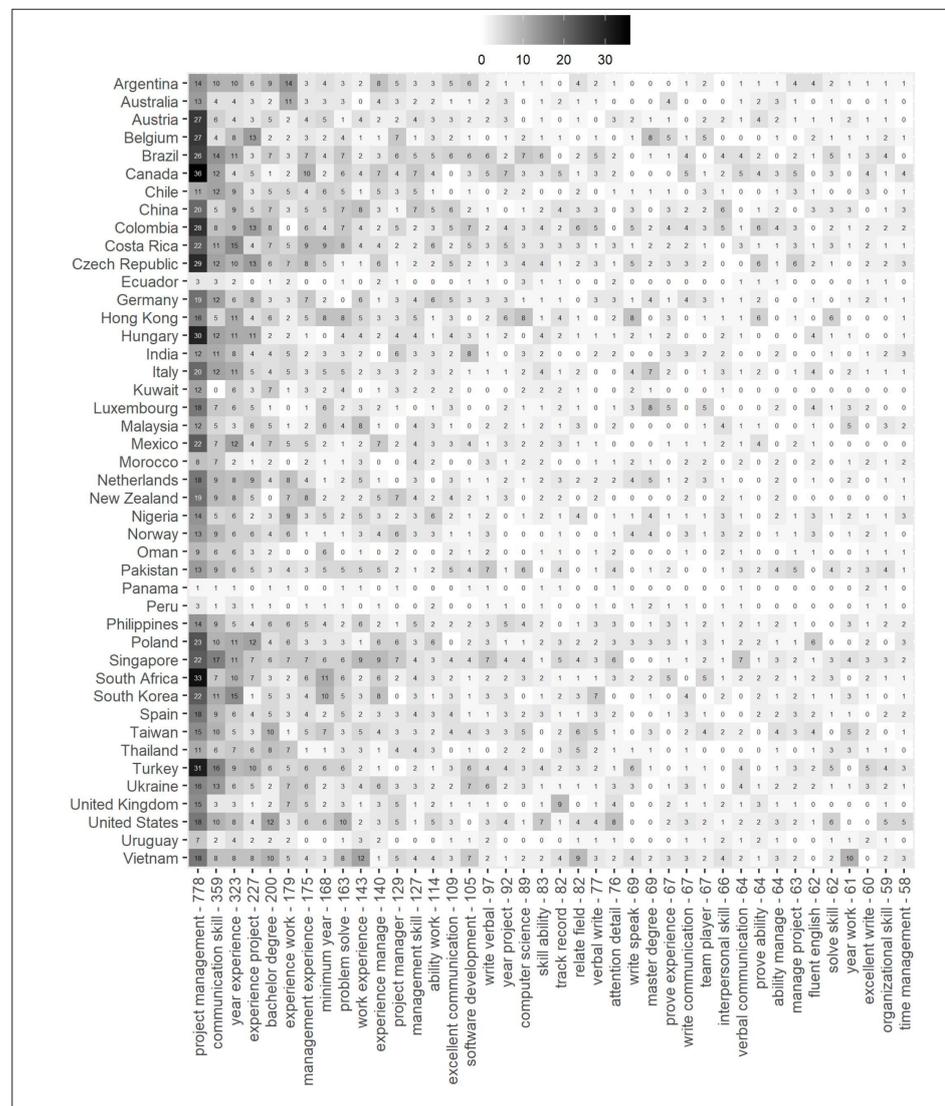


Figure 2. Forty most used 2-g.

project management experience (147); experience project management (145); year experience project (83); year project management (80); minimum year experience (66); problem solve skill (62); write verbal communication (61); excellent communication skill (56); write communication skill (54); verbal communication skill (53); year work experience (53); prove track record (48); verbal write communication (47); project management skill (43); degree computer science (40); experience project manager (40); project management tool (38); excellent write verbal (38); write speak english (35); communication skill english (32); excellent verbal write (31); fast pace environment (30); computer science engineer (30); knowledge project management (29); project management methodology (29); work experience project (28); experience software development (28); project management professional (27); analytic problem solve (27); year experience manage (27); strong communication skill (27); minimum year project (26); time management skill (26); write oral communication (25); project management certification (24); cross functional team (23); bachelor degree equivalent (23); bachelor degree computer (22); relevant work experience (22); communication skill ability (21)

Figure 3. Forty most used 3-g.

year project management experience (63); year experience project management (54); write verbal communication skill (52); verbal write communication skill (38); excellent write verbal communication (31); minimum year project management (25); excellent verbal write communication (25); project management professional pmp (19); bachelor degree computer science (19); work experience project management (19); analytic problem solve skill (19); write oral communication skill (18); skill include attention detail (17); organizational skill include attention (17); year relevant work experience (17); solid organizational skill include (16); face internal communication skill (15); client face internal communication (15); software development life cycle (15); degree computer science engineer (14); year experience project manager (14); oral write communication skill (13); minimum year experience project (12); strong write verbal communication (12); excellent client face internal (12); communication skill write verbal (11); strong project management skill (10); year work experience project (10); management professional pmp certification (10); excellent write oral communication (10); degree computer science information (10); prove work experience project (10); organizational time management skill (10); experience project management tool (10)

Figure 4. Thirty-four most used 4-g.

excellent write verbal communication skill (28); minimum year project management experience (20); excellent verbal write communication skill (20); organizational skill include attention detail (17); solid organizational skill include attention (16); client face internal communication skill (15); excellent client face internal communication (12); project management professional pmp certification (10); strong write verbal communication skill (10); write verbal communication skill english (8); excellent write oral communication skill (8); skill include attention detail multi (8); include attention detail multi task (8); minimum year experience project management (7); year work experience project management (7); write oral communication skill english (7); degree computer science information system (7); understand hand experience software development (7); technical background understand hand experience (7); prove work experience project management (7); background understand hand experience software (7); bachelor degree computer science engineer (6); skill include attention detail multitask (6); bachelor degree computer science information (6); verbal write communication skill ability (6); understand software development life cycle (6)

Figure 5. Twenty-six most used 5-g.

The frequency analysis presented in Figures 1 and 2 shows that in Ecuador, Panama, Peru, and Uruguay, the number of words uses is lower compared to other countries/areas (cells more often white or light grey). The primary cause is the lower number of analyzed documents for these countries (4, 5, 6, and 7 advertisements, respectively).

N-grams consisting of three to five words were not divided by country/area. They are presented in Figures 3–5. Apparently, the more words in an n-gram, the smaller the frequency. The most common 3-g “project management experience” occurred 147 times. The most frequent 4-g “year project management experience” was found 63 times. Only 28 instances of the most used 5-g “excellent write verbal communication skill” were identified. Note that the next most common 5-g “excellent verbal write communication skill” occurred 20 times, and the only difference from the first one was the order of two words. In this particular case, the n-grams could be merged, and their frequencies added.

Apart from the previously identified requirements, n-grams in Figures 3–5 additionally pointed to such requirements as problem solving, the ability to use methods and tools for project managing, and certificates (3-g: “problem solve skill”, “project management methodology”, “project management tool”, “project management certification”; 4-g: “analytic problem solve skill”, “project management professional pmp”). Five-grams indicated the requirement of communication skills in English (“write verbal communication skill english”, “write oral communication skill english”). The requirements concerning English most likely came from advertisements posted in countries where it is not an official language (such as Austria or Poland).

The number of topics to be generated was an important decision. Using the function *FindTopicsNumber* in the R package *ldatuning* [73], the four metrics reported in [74–77] were computed by training several LDA models with the number of topics ranging from 2 to 30.

The results displayed in Figure 6 suggest that the optimal number of topics with respect to these metrics is between 6 to 30 topics. The number of topics was also determined via manual inspection of a variety of topic sets trained using several different numbers of topics. The author set the final number of topics to 21.

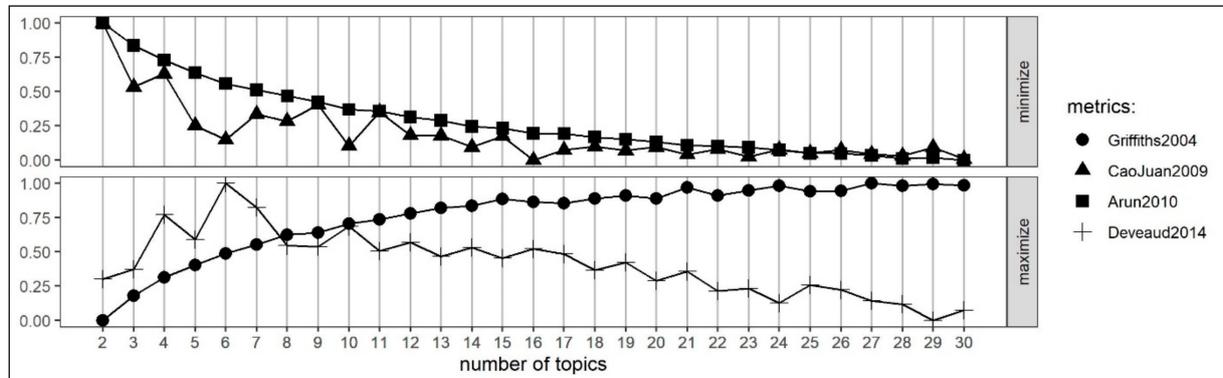


Figure 6. The selection of the number of topics in topic modeling using four metrics.

Figure 7 shows topics generated with the LDA algorithm. They were also intended to identify desired competencies of project managers. Five words with the highest beta value were presented for each topic. This value represents how likely topic i is to contain word j .

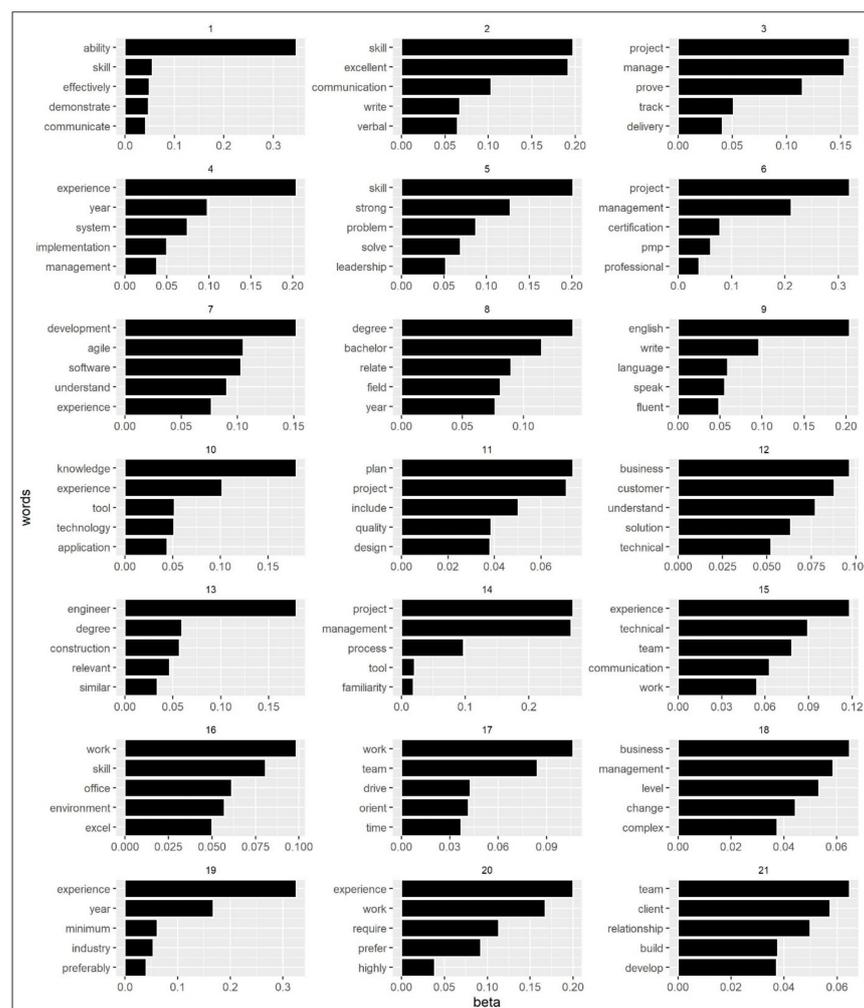


Figure 7. The topics generated with LDA.

An analysis of the generated topics can also determine the most popular requirements for future project managers. The previously identified requirements concerning experience (topics numbers 4, 7, 10, 15, 19, and 20) and proof of experience (topic number 3), communication skills (topics numbers 1, 2, 9, and 15), educational background (topics numbers: 8 and 13), certificates (topic number 6), problem-solving ability (topic number 5), software development project management (topic number 7), and managing project in other areas (topics numbers 12 and 19) that require knowledge of selected business processes and technical solutions were confirmed.

Other identified requirements were knowledge of tools for project management (topics numbers 14 and 16), project planning, and project quality management (topic number 11). Topic 17 suggest team-working and team-leading ability with time orientation.

In summary, based on the results presented in Figures 1–5 and topics generated with LDA (which are presented in Figure 7), the most popular requirements for future project managers are:

- proof (one year's or more) experience in:
 - general project management (project planning, project quality management etc.)
 - managing specific types of projects (for example software development)
 - working in a specific economic sector (for example industry, software development)
 - project management with specific methodology (for example agile methodology)
- communication skills (write and verbal, with special emphasis on the English language)
- university degree in specific areas (for example “computer science”)
- certificates proving knowledge in a specific area (for example Professional in Project Management (PPM))
- social skills (necessary when working with project team members, clients, project stakeholders)
- ability to:
 - problem-solving
 - team-working
 - team-leading
 - time managing
 - working under time pressure
 - use methods and tools for project managing (for example software like Excel, MS Project)

Some of the requirements are typical for most projects. For example, knowledge of the tools used in project management, knowledge of project management methodologies, soft skills, communication skills, cooperation with people and managing them, dealing with current problems, and time management. Some requirements are related to the specifics of the company's activity and the projects it carries out. If the project will be carried out in a specific branch of the economy, the candidate is expected to have knowledge related to it. This knowledge can be confirmed by a university degree. Since the job advertisements analyzed concerned projects implemented in all areas, the results do not show which field of knowledge was concerned—excepted for a computer science degree, which most often occurred in the analyzed documents. It can be said that there has been a certain generalization. We see that employers want project managers with a university degree, but in this particular study, we do not know which one.

5. Discussion, Conclusions, and Limitations

Project managers play a central role in all types of projects. To perform well, project managers need to develop several complementary competencies, including technical, contextual, and behavioral ones. This makes manager competencies critical for employers. Thus, they strive to win employees with the right skills. Competencies that are in demand can also be hints for current and future project managers and for organizations that teach and train them.

The results suggest that experience is among the fundamental requirements. Similar results were presented in [1,2]. The researchers found that, next to project management, the experience was the most frequently sought competency required in recruitment criteria. The n-grams and topics generated with LDA show that it is about the experience in general project management (for example, 3-g "project management experience"), experience with specific types of projects, such as software development (for example, 3-g "experience software development"), experience with specific industry (for example, 4-g "year relevant work experience" or topic 19 "experience year minimum industry preferably") and experience with specific methodology (for example agile methodology). It is in line with the finding by Pawlak that the project manager should have professional knowledge of the subject matter of the project [47].

Another frequent requirement was the ability to communicate, both in writing and speech (for example, 4-g "write verbal communication skill"), and human team activities, such as cooperation, team building, management, and leading ("team", topic 15 "experience technical, team, communication, work", topic 21 "team client relationship build develop"). These two were among the key competencies presented by Musioł-Urbańczyk (the ability to communicate, the ability to motivate team members, the ability to build a team, the ability to manage communication, leadership, and teamwork) [52] and among the key competencies presented by Ahsan et al. (communication, leadership, team building, and management) [34]. The three other requirements, time management, educational background, and certificates, were also identified by Ahsan et al. and counted among the top ten competencies [34].

According to Hussein et al., the set of competencies should be tailored to a particular organization [63]. As Soltysik et al. noted, expectations towards key competencies of a project manager may vary. They will depend on the type of project, its size, scope, the methodology adopted, size, and type of organization [62]. This is also evident in the present paper. The most frequent words, n-grams, and topics identified with LDA suggest that employers value higher education. However, it is not possible to identify the specific field. Undoubtedly, some advertisements contain words identifying certain educational backgrounds, such as finance and marketing, but they were not included in the results due to their low frequency. The only exception is 3-g "degree computer science", which occurred so often that the specific field of study could be pinpointed.

To conclude, the most common requirements for project managers included experience, communication skills, right education background, knowledge of methods of project managing and functioning of selected business processes, organizational abilities, problem-solving, time management, team management, and certificates for expert knowledge.

The present research has the following limitations. Only job advertisements written in English were analyzed. In the case of countries for which this language is not an official language, this contributed to a reduction in the number of advertisements. The postings were downloaded only for a period of 6 days. An attempt to automatically identify the requirements section did not yield the expected results. Therefore, it was carried out manually for a number of random advertisements, which reduced the number of analyzed documents. The content of the job advertisements was not analyzed by country/area, although the results showed in Figures 1 and 2 suggest that there are differences between them.

Future research can address the following issues:

- developing a tool/solution that automatically identifies a specific section in a job advertisement, e.g., requirements, job description, company description, which would make it possible to analyze all downloaded job advertisements
- comparison of project managers' competencies
 - by project type
 - by economic sector
 - between countries by continent, official language, country size, population sizes

- categorization of job advertisements using text clustering (for example with K-means text clustering)
- analysis of job advertisements written in a language other than English after they have been machine translated into English.

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