MIS Quarterly Executive

Volume 23 | Issue 3 Article 9

September 2024

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Overly detailed and technical descriptions for IT positions, together with inconsistent occupation identifiers, cause companies to pass on qualified candidates who do not match every requirement, while job seekers fail to identify roles matching their skill sets. To address this matching problem, we analyzed 15,000+ IT job postings to create a list of 41 IT occupations, called ITOcc List. Leveraging this list will enable companies to attract a wider range of qualified candidates, and job seekers to more easily identify relevant openings.

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The Need for a Master List of IT Occupations

Companies struggle to find talent to fill IT positions. In a recent study, 64% of senior IT executives reported that the lack of qualified talent represents the largest barrier to implementing emerging technologies, such as generative AI or low-code/no-code development tools, when transitioning to a data-driven or digital organization.[1]

Meanwhile, qualified candidates are struggling to find IT jobs. Some blame overly detailed job postings.[2] By casting a wide net, employers may end up confusing potential candidates who find it difficult to determine whether they are qualified for a position.[3] In their attempt to find the ideal candidate, employers frequently create what appears to be almost non-sensical job postings—for example 60% of "entry-level" software and IT services jobs on LinkedIn requiring 3+ years of experience.[4] Moreover, 88% of employers believe that qualified high-skill candidates are filtered out of the selection pool, often by automated AI-driven filters,

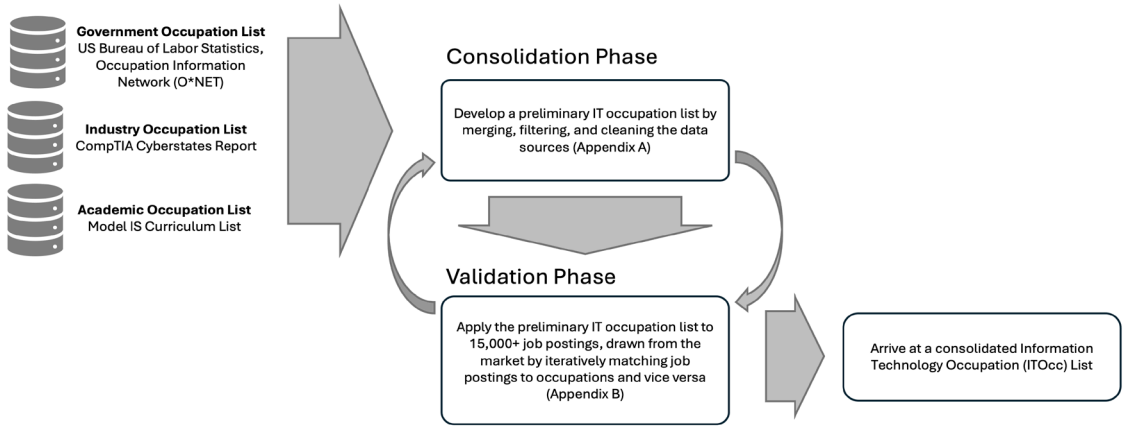
1 *Gartner Survey Reveals Talent Shortages as Biggest Barrier to Emerging Technologies Adoption*, Gartner Press Release, September 13, 2021, available at https://www.gartner.com/en/newsroom/press-releases/2021-09-13-gartner-survey-reveals-talent-shortages-as-biggest-barrier-to-emerging-technologies-adoption#:~:text=IT%20Executives%20Cited%20Lack%20of,new%20survey%20from%20Gartner%2C%20Inc.

2 Craig, R. *Employers Are Seeking 'Purple Squirrels.' Here's What We Can Do About It*, Forbes.com, February 14. 2020, available at https://www.forbes.com/sites/ryancraig/2020/02/14/employers-are-seeking-purple-squirrels-heres-what-we-can-do-about-it/.

3 Fink, B. *Overcoming the Impossible Job Description*, LinkedIn, April 19, 2016, available at https://www.linkedin.com/pulse/overcoming-impossible-job-description-brian-fink-ecre/.

4 Anders, G. *Hiring's new red line: why newcomers can't land 35% of "entry-level" jobs*, LinkedIn Workforce Insights, August 18, 2021, available at https://www.linkedin.com/pulse/hirings-new-red-line-why-newcomers-cant-land-35-jobs-george-anders/.

Figure 1: Developing the ITOcc List



due to over-specified or over-detailed job descriptions. One study found 94% of organizations admitting that they often fail to identify qualified mid-level candidates.[5]

Thus, on the one hand, highly specified job postings fail to identify and hire IT talent because such postings do not produce a sufficiently large pool of appropriate applicants. On the other hand, candidates fail to self-identify with the posted positions. To remedy these failings, we set out to create a master list of IT occupations, that both employers and job seekers can use to describe and identify IT jobs. Such a list will streamline the hiring process by enabling a greater focus on essential qualifications. Employers can use firm-specific requirements to differentiate between candidates in the applicant pool and identify the most qualified applicant.[6] IT job seekers will also benefit, because the list allows them to identify relevant openings by mapping their skills to the core IT categories while helping them to shape their applications. Moreover, they can also use the occupation descriptions to create their strategies for acquiring the skills necessary for specific IT occupations.

Two Phase Development of the ITOcc List

Developing the ITOcc List included two phases—consolidation and validation (see Figure 1, which also shows the sources used to create the list). In this article, we use the term "job" to denote an organization's employment of an individual to perform a defined set of tasks, whereas the term "occupation" represents similar jobs that make up an occupation. With a labeling scheme for occupations, organizations, such as the U.S. Bureau of Labor Statistics, can measure the availability, renumeration, etc. for each occupation.

Consolidation Phase

In the consolidation phase, we identified four occupation lists, two issued by the U.S. government,[7,8] one from industry[9] and the last

5 Fuller, J. B., Raman, M., Sage-Gavin, E. and Hines, K. *Hidden Workers: Untapped Talent*, Harvard Business School Project on Managing the Future of Work and Accenture, October 4, 2021, available at https://www.hbs.edu/managing-the-future-of-work/Documents/research/hiddenworkers09032021.pdf.

6 Lazear, E. P. *Firm-Specific Human Capital: A Skill-Weights Approach*, National Bureau of Economic Research Working Paper Series, No. 9679, May 2003, available at https://doi.org/10.3386/w9679.

7 *Standard Occupational Classification*, U.S. Department of Labor, available at https://www.bls.gov/soc/#:~:text=All%20workers%20are%20classified%20into,groups%2C%20and%2023%20major%20groups.

8 O*NET® 28.2 *Database*, National Center for O*NET Development, available at https://www.onetcenter.org/database.html#overview.

9 *State of the Tech Workforce 2023*, The Computing Technology Industry Association (CompTIA), October 2023, available at https://www.comptia.org/content/research/state-of-the-tech-workforce-2023.

from academic[10] sources. Each list had been developed for various uses and with various goals in mind and often included more than just IT occupations. The Bureau of Labor Statistics (BLS) occupation list, for example, provides detailed information about 867 occupations and is intended for a variety of users, ranging from government program administrators to those responsible for industrial and labor relations. The O*NET database classifies 1,016 occupations across the entire US economy and was developed to help people identify, among other things, the training necessary to make them competitive in the workforce. The Computing Technology Industry Association (CompTIA) list quantifies the size and scope of the U.S. technology industry and workforce, and gathers metrics, such as wages, business establishments, job postings and gender ratios. And the academic list has, for 14 years, been guiding universities in IT curriculum development. Because the Bureau of Labor Statistics and O*Net lists covered far more than just IT occupations, and because there were considerable overlaps across all four lists, we first eliminated duplicates and filtered out non-IT occupations. This preliminary list of 62 IT occupations served as our starting point for developing the ITOcc List. (The consolidation phase is described in detail in Appendix A.)

Validation Phase

During the validation phase, we accessed a sample of 15,529 job postings from online sites[11] between the years 2015 and 2023, using the search term "information technology."[12] The postings were proportionally pulled for each U.S. state based on that state's population. We then set about matching each posting to an occupation in the preliminary list. Job postings were either matched to an IT occupation in the list, classified as an IT occupation not in the list, identified as a job whose title was "too vague" (e.g., IT specialist) or identified as a "non-IT" job (e.g., art director).

Next, we reviewed and amended the list of IT occupations to ensure it would support the stated purpose of enabling both employers and job seekers to describe and identify IT jobs. This stated purpose has competing goals. First, the occupation list must be generic enough so that occupations can be "easily" found in the list; it would be ineffective if it was excessively long or overly specialized. Second, the list must be sufficiently comprehensive and include most IT occupations. This review resulted in the removal of some occupations that were overly specific for purposes of providing a comprehensive, yet generic, list of IT occupations.

Outcome of the Validation Phase

We found there was an 86% rate of matching more than 15,000 job postings to the preliminary occupation list—i.e., 54 of the 62 occupations on the preliminary list had at least one job posting match. We eliminated the eight unmatched occupations (Cartographers and Photogrammetrists, Credit Analysts, e-Business Managers, Electrical and Electronic Equipment Assemblers, Human Factors Engineers and Ergonomists, Industrial Engineers, Intelligence Analysts and Statisticians) from the list. These removals do not imply that these occupations do not exist, but that they occur so infrequently in the IT jobs market that they would add little utility to the ITOcc List.

We added five occupations to the preliminary list when they surfaced in the job postings (Business Continuity Specialists, Procurement Clerks, Human Resources Specialists, Sales Representatives and Technical Writers). These occupations were originally excluded from the preliminary list because their descriptions were broad and did not indicate that they were IT occupations. However, the job postings suggested that there are jobs in these IT specialization occupations. For example, within the Procurement Clerk occupation there is a set of jobs focused on the acquisition of IT products and services. These five additional occupations were included in the ITOcc List using their original occupation titles, but with an "IT Specialization" label.

10 Topi, H., Valacich, J. S., Wright, R. T., Kaiser, K. M., Nunamaker Jr., J. F., Sipior, J. C. and de Vreede, G. J. *IS 2010: Curriculum Guidelines for Undergraduate Degree Programs in Information Systems*, Association for Computing Machinery and Association for Information Systems, 2010, available at https://www.acm.org/binaries/content/assets/education/curricula-recommendations/is-2010-acm-final.pdf.

11 Sites accessed included CareerBuilder, Dice, Indeed, LinkedIn and Monster.

12 The search term was chosen to be broad enough to capture all IT jobs but narrow enough to exclude non-IT jobs. The resulting sample included a small percentage (2%) of non-IT jobs.

The validation process also added a final occupation—Deployment Specialist—that was not included in the preliminary list, nor in any of the original source lists. However, there were 47 job postings for this occupation.

The validation phase found that 91% of the job postings matched to an occupation. Some of the postings (7%) had job titles that were too vague to match to an occupation (e.g., information technology technician, field technician, IT specialist, etc.). Additionally, 2% of the job postings were unmatched because they were for non-IT jobs (e.g., art director, mechanical designer, lab technician, registered nurse, HVAC systems specialist, etc.).

In the last step of the validation phase, we reviewed and validated the occupation list to ensure we achieved our stated purpose, which provided us with insights into the domains within which IT occupations appear. We identified 19 domain-specific occupations, representing about 2% of the job postings, that were too narrow in their occupation definition and skill specification. As a result, these 19 occupations were excluded from the ITOcc List, leaving a total of 41 IT occupations. (The validation stage is described in detail in Appendix B.)

The ITOcc List of 41 IT Occupations

Table 1 lists the final 41 occupations, ordered by market demand as determined by job posting counts. The occupation codes and descriptions are taken from O*NET OnLine.[13] For occupations without a code, we developed the descriptions based on searches of professional or job posting websites, or from the job postings assigned to the occupation. The occupations identified with the label "IT Specialization" are occupations in O*NET that are broader than the IT domain, but our analysis of job postings indicated an IT specialization subgroup. The ITOcc List covers about 89% of the IT labor market. It can be used by employers to manage the pool of job candidates, by job seekers to identify appropriate positions, and by scholars to study and understand the IT labor market.

13 https://www.onetonline.org/; details about an occupation can be found by entering the code from the table.

Recommendations for Leveraging the ITOcc List of IT Occupations

We provide the following four recommendations (three for employers and one for job candidates) for getting the most value from the ITOcc List of IT occupations.

1. Employers Should Use Recognizable Job Titles

We recommend that employers use recognizable job titles that are easier for job candidates to identify with. Our review of more than 15,000 job postings highlights the need to do this. Though our analysis showed that job titles are somewhat descriptive of jobs, they often appear to be firm-specific in terminology and may not easily indicate the occupation. For example, on close inspection, a posting for an "OS and App Integration Administrator" seemed to align with the "Deployment Specialist" IT occupation.

2. Employers Should Embed Occupation Labels within Job Descriptions

To reduce a job candidate's confusion, we recommend that employers include the appropriate occupation from the ITOcc List in job postings. This could be accomplished by including a searchable field in the job posting called "Occupation," followed by the appropriate occupation name as well as the job title. This would allow candidates to search for job postings based on occupation names (e.g., Software Developer) in addition to keywords, skills and job titles.

3. Employers Should Avoid Multi-Occupation Job Descriptions

Employers should be aware of the pitfalls of posting compound jobs that cross multiple occupations. Such postings may prevent candidates from recognizing the opportunity, resulting in an exceptionally small candidate pool. For example, analysis of a posting for a "Digital Strategist" revealed a broad span of duties, including applying conceptual strategy, articulating marketing to the C-suite, implementing procedures, applying service packs, creating new products, reporting extract, transform and load (ETL) performance,

Table 1: Our Comprehensive ITOcc List of 41 IT Occupations

IT Occupation and Code	Occupation Description	Job Posting Count	Sample %
Computer User Support Specialists (15-1232.00)	Provide technical assistance to computer users. Answer questions or resolve computer problems for clients in person, via telephone or electronically. May provide assistance concerning the use of computer hardware and software, including printing, installation, word processing, electronic mail and operating systems.	3,585	23.09%
Computer and Information Systems Managers (11-3021.00)	Plan, direct or coordinate activities in such fields as electronic data processing, information systems, systems analysis and computer programming.	1,862	11.99%
Software Developers (15-1252.00)	Research, design and develop computer and network software or specialized utility programs. Analyze user needs and develop software solutions, applying principles and techniques of computer science, engineering and mathematical analysis. Update software or enhance existing software capabilities. May work with computer hardware engineers to integrate hardware and software systems, and develop specifications and performance requirements. May maintain databases within an application area, working individually or coordinating database development as part of a team.	1,542	9.93%
Network and Computer Systems Administrators (15-1244.00)	Install, configure and maintain an organization's local area network (LAN), wide area network (WAN), data communications network, operating systems, and physical and virtual servers. Perform system monitoring and verify the integrity and availability of hardware, network, and server resources and systems. Review system and application logs and verify completion of scheduled jobs, including system backups. Analyze network and server resource consumption and control user access. Install and upgrade software and maintain software licenses. May assist in network modeling, analysis, planning, and coordination between network and data communications hardware and software.	1,297	8.35%
Computer Systems Analysts/Business Analysts (15-1211.00)	Analyze science, engineering, business and other data processing problems to develop and implement solutions to complex applications problems, system administration issues or network concerns. Perform systems management and integration functions, improve existing computer systems, and review computer system capabilities, workflow and schedule limitations. May analyze or recommend commercially available software.	900	5.80%
Information Technology Project Managers (15-1299.09)	Plan, initiate and manage information technology (IT) projects. Lead and guide the work of technical staff. Serve as liaison between business and technical aspects of projects. Plan project stages and assess business implications for each stage. Monitor progress to assure deadlines, standards and cost targets are met.	477	3.07%
Security Management Specialists (13-1199.07)	Conduct security assessments for organizations, and design security systems and processes. May specialize in areas such as physical security or the safety of employees and facilities.	458	2.95%
Computer Systems Engineers and Architects (15-1299.08)	Design and develop solutions to complex applications problems, system administration issues or network concerns. Perform systems management and integration functions.	455	2.93%

Table 1: Our Comprehensive ITOcc List of 41 IT Occupations (Continuation)

IT Occupation and Code	Occupation Description	Job Posting Count	Sample %
Computer Network Architects (15-1241.00)	Design and implement computer and information networks, such as local area networks (LAN), wide area networks (WAN), intranets, extranets, and other data communications networks. Perform network modeling, analysis and planning, including analysis of capacity needs for network infrastructures. May also design network and computer security measures. May research and recommend network and data communications hardware and software.	447	2.88%
Information Security Analysts (15-1212.00)	Plan, implement, upgrade or monitor security measures for the protection of computer networks and information. Assess system vulnerabilities for security risks and propose and implement risk mitigation strategies. May ensure appropriate security controls are in place that will safeguard digital files and vital electronic infrastructure. May respond to computer security breaches and viruses.	345	2.22%
Computer Network Support Specialists (15-1231.00)	Analyze, test, troubleshoot and evaluate existing network systems, such as local area networks (LAN), wide area networks (WAN), cloud networks, servers and other data communications networks. Perform network maintenance to ensure networks operate correctly with minimal interruption.	316	2.03%
IT Consultants	Provide organizations with advice, guidelines and a road map for sourcing, using and managing IT assets and resources, and with best practices for using IT solutions and services for their business objectives and in solving their problems. Help implement websites, software, network infrastructure, cloud environments, software packages and other IT business solutions. Typically, an IT consultant specializes in one key area or domain.[14]	312	2.01%
Information Security Engineers (15-1299.05)	Develop and oversee the implementation of information security procedures and policies. Build, maintain and upgrade security technology, such as firewalls, for the safe use of computer networks and the transmission and retrieval of information. Design and implement appropriate security controls to identify vulnerabilities and protect digital files and electronic infrastructures. Monitor and respond to computer security breaches, viruses and intrusions, and perform forensic investigation. May oversee the assessment of information security systems.	209	1.35%
Business Intelligence Analysts/Data Analysts (15-2051.01)	Produce financial and market intelligence by querying data repositories and generating periodic reports. Devise methods for identifying data patterns and trends in available information sources.	196	1.26%

14 This description is based on Rouse, M. *Information Technology Consultant*, Techopedia, October 12, 2015, available at https://www.techopedia.com/definition/628/information-technology-consultant-it-consultant.

Table 1: Our Comprehensive ITOcc List of 41 IT Occupations (Continuation)

IT Occupation and Code	Occupation Description	Job Posting Count	Sample %
Database Analysts/ Data Modelers	Database analysts are a subgroup of database administration staff. They typically maintain data storage and assess database design. One aspect of this job involves determining how keys and other tools or markers are used to identify and retrieve individual records. Often, a database analyst works with a team that physically supports servers and other parts of the system in order to keep it working well. Beyond that, a database analyst is concerned with studying how a database is organized and how the data in it is used by the corporation.[15]	155	1.00%
Software Quality Assurance Analysts and Testers (15-1253.00)	Develop and execute software tests to identify software problems and their causes. Test system modifications to prepare for implementation. Document software and application defects using a bug tracking system and report defects to software or web developers. Create and maintain databases of known defects. May participate in software design reviews to provide input on functional requirements, operational characteristics, product designs and schedules.	153	0.99%
Computer Hardware Engineers (17-2061.00)	Research, design, develop or test computer or computer-related equipment for commercial, industrial, military or scientific use. May supervise the manufacturing and installation of computer or computer-related equipment and components.	132	0.85%
Regulatory Affairs Specialists (IT Specialization) (13-1041.07)	Coordinate and document internal regulatory processes, such as internal audits, inspections, license renewals or registrations. May compile and prepare materials for submission to regulatory agencies.	105	0.68%
Computer Programmers (15-1251.00)	Create, modify and test the code and scripts that allow computer applications to run. Work from specifications drawn up by software and web developers or other individuals. May develop and write computer programs to store, locate and retrieve specific documents, data and information.	89	0.57%
Web and Digital Interface Designers (15-1255.00)	Design digital user interfaces or websites. Develop and test layouts, interfaces, functionality and navigation menus to ensure compatibility and usability across browsers or devices. May use web framework applications as well as client-side code and processes. May evaluate web design following web and accessibility standards, and may analyze web use metrics and optimize websites for marketability and search engine ranking. May design and test interfaces that facilitate human-computer interaction and maximize the usability of digital devices, websites, and software with a focus on aesthetics and design. May create graphics used in websites and manage website content and links.	89	0.57%

15 This description is based on Rouse, M. *Database Analyst*, Techopedia, September 30, 2014, available at https://www.techopedia.com/definition/18680/database-analyst.

Table 1: Our Comprehensive ITOcc List of 41 IT Occupations (Continuation)

IT Occupation and Code	Occupation Description	Job Posting Count	Sample %
Software Package Specialists	Analyze, integrate, configure, test, deploy and support purchased software packages in organizations. This role focuses on purchased packages and how they are integrated, deployed and supported within the enterprise's IT architecture.[16]	87	0.56%
Database Administrators (15-1242.00)	Administer test, and implement computer databases, applying knowledge of database management systems. Coordinate changes to computer databases. Identify, investigate and resolve database performance issues, database capacity and database scalability. May plan, coordinate, and implement security measures to safeguard computer databases.	81	0.52%
Data Warehousing Specialists (15-1243.01)	Design, model, or implement corporate data warehousing activities. Program and configure warehouses of database information and provide support to warehouse users.	69	0.44%
Sales Representatives (IT Specialization) (41-4011.00)	Sell goods for wholesalers or manufacturers where technical or scientific knowledge is required in such areas as biology, engineering, chemistry and electronics, normally obtained from at least two years of post-secondary education.	62	0.40%
Database Architects (15-1243.00)	Design strategies for enterprise databases, data warehouse systems and multidimensional networks. Set standards for database operations, programming, query processes and security. Model, design and construct large relational databases or data warehouses. Create and optimize data models for warehouse infrastructure and workflow. Integrate new systems with existing warehouse structure and refine system performance and functionality.	54	0.35%
Deployment Specialists	Implement and verify software releases as required for new system deployments, system upgrade or version deployment, and system migrations. Deployment specialists are particularly skilled in software configuration management and the use of multiple progressive software environments.[17]	47	0.30%
Web Developers (15-1254.00)	Develop and implement websites, web applications, application databases and interactive web interfaces. Evaluate code to ensure that it is properly structured, meets industry standards, and is compatible with browsers and devices. Optimize website performance, scalability and server-side code and processes. May develop website infrastructure and integrate websites with other computer applications.	46	0.30%

16 This description is based on the job posting descriptions associated with it.

17 This description is based on the job posting descriptions associated with it.

Table 1: Our Comprehensive ITOcc List of 41 IT Occupations (Continuation)

IT Occupation and Code	Occupation Description	Job Posting Count	Sample %
Data Scientists (15-2051.00)	Develop and implement a set of techniques or analytics applications to transform raw data into meaningful information using data-oriented programming languages and visualization software. Apply data mining, data modeling, natural language processing and machine learning to extract and analyze information from large structured and unstructured datasets. Visualize, interpret and report data findings. May create dynamic data reports.	45	0.29%
Web Administrators (15-1299.01)	Manage web environment design, deployment, development and maintenance activities. Perform testing and quality assurance of websites and web applications.	24	0.15%
Loss Prevention Managers (IT Specialization) (11-9199.08)	Plan and direct policies, procedures or systems to prevent the loss of assets. Determine risk exposure or potential liability, and develop risk control measures.	23	0.15%
Procurement Clerks (IT Specialization) (43-3061.00)	Compile information and records to draw up purchase orders for procurement of materials and services.	22	0.14%
Computer and Information Research Scientists (15-1221.00)	Conduct research into fundamental computer and information science as theorists, designers or inventors. Develop solutions to problems in the field of computer hardware and software.	21	0.14%
Technical Writers (IT Specialization) (27-3042.00)	Write technical materials, such as equipment manuals, appendices, or operating and maintenance instructions. May assist in layout work.	19	0.12%
Digital Forensics Analysts (15-1299.06)	Conduct investigations on computer-based crimes to establish documentary or physical evidence, such as digital media and logs associated with cyber intrusion incidents. Analyze digital evidence and investigate computer security incidents to derive information in support of system and network vulnerability mitigation. Preserve and present computer-related evidence in support of criminal, fraud, counter-intelligence or law-enforcement investigations.	11	0.07%
Human Resources Specialists (IT Specialization) (13-1071.00)	Recruit, screen, interview or place individuals within an organization. May perform other activities in multiple HR areas.	11	0.07%
Computer, Automated Teller and Office Machine Repairers (49-2011.00)	Repair, maintain or install computers, word processing systems, automated teller machines and electronic office machines, such as duplicating and fax machines.	10	0.06%
Document Management Specialists (15-1299.03)	Implement and administer enterprise-wide document management systems and related procedures that allow organizations to capture, store, retrieve, share and destroy electronic records and documents.	10	0.06%

Table 1: Our Comprehensive ITOcc List of 41 IT Occupations (Continuation)

IT Occupation and Code	Occupation Description	Job Posting Count	Sample %
Penetration Testers (15-1299.04)	Evaluate network system security by conducting simulated internal and external cyberattacks using adversary tools and techniques. Attempt to breach and exploit critical systems and gain access to sensitive information to assess system security.	10	0.06%
Business Continuity Specialist (IT Specialization) (13-1199.04)	Develop, maintain or implement business continuity and disaster recovery strategies and solutions, including risk assessments, business impact analyses, strategy selection, and documentation of business continuity and disaster recovery procedures. Plan, conduct and debrief regular mock-disaster exercises to test the adequacy of existing plans and strategies, updating procedures and plans regularly. Act as a coordinator for continuity efforts after a disruption event.	4	0.03%
Blockchain Engineers (15-1299.07)	Maintain and support distributed and decentralized blockchain-based networks or blockchain applications such as cryptocurrency exchange, payment processing, document sharing and digital voting. Design and deploy secure blockchain design patterns and solutions over geographically distributed networks using advanced technologies. May assist with infrastructure setup and testing for application transparency and security.	3	0.02%
Video Game Designers (15-1199.11)	Design core features of video games. Specify innovative game and role-play mechanics, story lines and character biographies. Create and maintain design documentation. Guide and collaborate with production staff to produce games as designed.	2	0.01%
	Total Matched Jobs	**13,785**	**88.77%**
	Non-IT	**339**	**2.18%**
	Vague (e.g., information technology technician, field technician, IT specialist, etc.)	**1,155**	**7.44%**
	Domain-specific IT occupation jobs (e.g., aerospace, healthcare, finance, etc.) (See Domain-Specific Exclusions table in Appendix B for details.)	**250**	**1.61%**
	Total Jobs in Sample	**15,529**	**100%**

debugging infrastructure, and more. This abbreviated list of duties spans at least seven occupations. Though it may not always be possible to avoid posting compound job descriptions, employers need to recognize the issues that this practice creates.

4. Job Candidates Should Know their Occupation

By implementing the first three recommendations, employers will enable job candidates to accurately identify available positions that align with their occupation(s). Candidates should review the ITOcc List and use the occupation descriptions in Table 1 to identify one or more occupations that apply to them and then use those occupations to aid in their search for relevant job postings. Moreover, candidates can use their identified occupation to aid their skills acquisition strategy.

Future Development and Other Uses of the ITOcc List

The ITOcc List is an important first step in understanding the IT job market. A key next step

is to review IT job postings to identify the skills required for each occupation in the ITOcc List. Once the skills are identified, it will be possible to categorize the major specializations within each occupation.

Identifying the skills required in a job posting (for example medical billing or JavaScript programming) would enable skills to be aggregated into skill types (e.g., healthcare industry expertise or Java technology profile). Such aggregation will increase understanding of how skill profiles (i.e., sets of skill types that appear together in job postings such as the combination of Java technology skill and healthcare industry expertise) change across occupations. For a specific occupation, it will then be possible to identify the requirements for the following, not-exhaustive, list of skill types:

- Industry expertise (e.g., healthcare, manufacturing, retail, insurance, etc.)
- Business functions (e.g., accounting, marketing, supply chain, HR, sales, etc.)
- Software development process steps (e.g., initiation, analysis, design, implementation, etc.),
- Technology profiles (e.g., Java software development environment, C#, Python)
- Soft skill profile (e.g., written communication, oral communication, team player, etc.)

The combination of skill types and skill profiles can then be used to further improve IT jobs market supply and demand matching. Candidates could then define their "profile" in terms of industry, business function, software development process steps, technology profile, soft skill profile, etc.). For example, a candidate could define his or her skill profile as "a Java software developer in insurance payer systems with team leadership background in the healthcare industry." Companies would likewise define job postings in terms of a profile using the same skill types. Assuming both candidate profiles and job profiles were available to a job search engine, candidates could receive a ranked list of potential jobs and employers could receive a ranked list of candidates.

However, the ITOcc List of IT occupations will change over time, as will the skills, skill types, and skill profiles, and the number of job postings for a particular occupation (e.g., Blockchain Engineer is a relatively new occupation). Thus, the ITOcc List will allow the evolution of the IT jobs market to be tracked over time. There will be a need for ongoing research to identify and report the changing trends.

The ITOcc List could also be used by academics or accreditation agencies to define or assess areas of study or avoid curricular overlaps across programs or neighboring institutions. Textbooks might also be designed around the SIM occupations, particularly as the skills are further articulated. Researchers studying the impact of AI on jobs might also find the classification and job market data useful as it evolves over time.

In conclusion, we believe the ITOcc List has considerable potential to better match the HR requirements of industry to the candidates emerging from, or continuing to participate, in educational programs. Moreover, educational providers could benefit from the richer understanding of employers' HR needs provided by the ITOcc List.

Appendix A: Consolidation Phase

The consolidation phase comprised four steps: 1) identify source lists; 2) merge source lists; 3); filter merged list; and 4) clean merge list, which resulted in a preliminary IT occupation list. The outcome of each step was independently reviewed and analyzed by two researchers, with any inconsistencies being reconciled. Consistency between the different researchers, as measured by Cohen's Kappa,[18] was found to be greater than 0.90, indicating excellent consistency.

Step 1: Identify Source Lists

During the first step, we identified four occupation list sources to use as the basis for developing the ITOcc List.

18 Cohen's Kappa is a statistical measure used to quantify the level of agreement between two raters who each classify items into categories. Its value ranges from 0 (poor) to 1 (perfect). For more information, see *Cohen's Kappa*, DATAtab, available at https://datatab.net/tutorial/cohens-kappa.

The first list, drawn from the Bureau of Labor Statistics[19] Standard Occupation Codes 2018 list, contained 867 occupations that are used to facilitate the collection, calculation, and dissemination of data about the U.S. labor market, U.S. working conditions, pricing and economic productivity measures. Users of the list range from government program administrators to those responsible for industrial and labor relations.

The second list, the Occupation Information Network (O*NET)[20] list, contained the most detailed and comprehensive description of occupations. The list was initially derived using the Bureau of Labor Statistics list and is primarily used by employers to define and develop workers' skills. At the time we accessed the O*NET list, it included details of 1,016 U.S. occupations.

The third list used in our study was the Computing Technology Industry Association (CompTIA) list.[21] This list is the basis for the annual CompTIA report that quantifies the size and scope of the U.S. technology industry and workforce, using metrics such as wages, business establishments, job postings and gender ratios. The CompTIA list uses 19 Bureau of Labor Statistics codes to define the IT workforce.

The fourth list, drawn from the academic literature, was the Model IS Curriculum (MISC) List.[22] It included 17 career tracks, or occupations. The MISC List has been used for developing university curricula intended to prepare students for IT employment and career advancement.

Step 2: Merge Source Lists

The next step was to merge the four occupation lists into a single list. The goal was to create a single non-redundant list of IT occupations. The O*NET list, as the most inclusive list of occupations, provided the basis for the merged list. Occupations from the other lists were mapped into the O*NET list and, when mappings were unsuccessful, the occupation was added.

The merge process identified three issues that affected how many occupations from the CompTIA and MISC lists were represented on the preliminary list. First, the CompTIA list included the Bureau of Labor Statistics code for "Computer Occupations, All Other" (code 15-1299). However, the O*NET list had expanded this code into nine specific occupations, and the codes for these nine occupations on the preliminary list replaced the single 15-1299 code from the CompTIA list. Second, the O*NET list had expanded the 15-1243 code (Database Architects) into two specific occupations and the codes for these two occupations on the preliminary replaced the single 15-1243 code from the CompTIA list. These two changes meant that the preliminary list included a total of 28 occupations from the CompTIA list instead of the original 19.

Lastly, two occupations on the MISC list, Business Analyst and Business Process Analyst, were deemed to be significantly overlapping and were thus merged into a single occupation "Computer Systems Analysts/Business Analysts." Thus, the preliminary list included 16 occupations from the MISC list instead of the original 17.

The merged list included occupation descriptions that were mostly taken from the O*NET list. The exceptions were four occupations in the MISC list that were not included in the other source lists. Unlike the Bureau of Labor Statistics and O*NET lists, the MISC list does not provide descriptions. We therefore developed the descriptions for these four occupations based on searches in professional or job posting websites. With these four additional occupations, the merged list contained 1,020 occupations. Note that this large number of occupations is a result of O*Net and the Bureau of Labor Statistics defining occupations for the entire U.S. economy, not just IT occupations.

Step 3: Filter Merged List

After compiling descriptions for all 1,020 occupations in the merged list, we eliminated non-IT occupations by searching for descriptions that included the terms "computer," "information"

19 *About the U.S. Bureau of Labor Statistics*, United States Department of Labor, April 2024, available at https://www.bls.gov/bls/about-bls.htm#:~:text=BLS%20collects%2C%20calculates%2C%20analyzes%2C,%2C%20researchers%2C%20and%20government%20organizations.&text=The%20Bureau%20of%20Labor%20Statistics%20measures%20labor%20market%20activity%2C%20working,public%20and%20private%20decision%20making.

20 O*NET® 28.2 Database, op. cit.

21 State of the Tech Workforce 2023, op. cit., October 2023.

22 Topi, H., Valacich, J. S., Wright, R. T., Kaiser, K., Nunamaker Jr., J. F., Sipior, J. C., & de Vreede, G., op. cit., 2010.

The Preliminary List of 62 IT Occupations and their Sources

BLS	O*NET	CompTIA	MISC	O*NET Code	Occupation Title Sample
X	X			17-3021.00	Aerospace Engineering and Operations Technologists and Technicians
	X			19-1029.01	Bioinformatics Scientists
	X			15-2099.01	Bioinformatics Technicians
X	X			17-2031.00	Bioengineers and Biomedical Engineers
	X	X		15-1299.07	Blockchain Engineers
	X			15-2051.01	Business Intelligence Analysts/Data Analyst
X	X			17-1021.00	Cartographers and Photogrammetrists
X	X	X		15-1221.00	Computer and Information Research Scientists
X	X	X	X	11-3021.00	Computer and Information Systems Managers
X	X	X		17-2061.00	Computer Hardware Engineers
X	X	X		15-1241.00	Computer Network Architects
X	X	X		15-1231.00	Computer Network Support Specialists
X	X	X		15-1251.00	Computer Programmers
X	X	X		15-1211.00	Computer Systems Analysts/Business Analysts
	X	X	X	15-1299.08	Computer Systems Engineers/Architects
X	X	X		15-1232.00	Computer User Support Specialists
	X	X		49-2011.00	Computer, Automated Teller and Office Machine Repairers
X	X			13-2041.00	Credit Analysts
X	X	X		15-2051.00	Data Scientists
	X	X		15-1243.01	Data Warehousing Specialists
X	X	X	X	15-1242.00	Database Administrators
			X	_	Database Analyst/Data Modeler 15
X	X	X		15-1243.00	Database Architects
	X	X		15-1299.06	Digital Forensics Analysts
	X	X		15-1299.03	Document Management Specialists
			X	_	e-Business Manager
	X			51-2022.00	Electrical and Electronic Equipment Assemblers
X	X			17-3023.00	Electrical and Electronic Engineering Technologists and Technicians
X	X			43-6011.00	Executive Secretaries and Executive Administrative Assistants
X	X			13-2051.00	Financial and Investment Analysts
	X	X		15-1299.02	Geographic Information Systems Technologists and Technicians

The Preliminary List of 62 IT Occupations and their Sources

BLS	O*NET	CompTIA	MISC	O*NET Code	Occupation Title Sample
	X			15-1211.01	Health Informatics Specialists
	X			29-9021.00	Health Information Technologists and Medical Registrars
	X			17-2112.01	Human Factors Engineers and Ergonomists
X	X			17-3026.00	Industrial Engineering Technologists and Technicians
X	X			17-2112.00	Industrial Engineers
X	X	X	X	15-1212.00	Information Security Analysts
	X	X		15-1299.05	Information Security Engineers
	X	X	X	15-1299.09	Information Technology Project Managers
	X			33-3021.06	Intelligence Analysts
			X	_	IT Consultant
	X			13-1081.01	Logistics Engineers
	X		X	11-9199.08	Loss Prevention Managers
X	X			13-1161.00	Market Research Analysts and Marketing Specialists
X	X			29-2072.00	Medical Records Specialists
X	X	X	X	15-1244.00	Network and Computer Systems Administrators
X	X			15-2031.00	Operations Research Analysts
	X	X		15-1299.04	Penetration Testers
X	X			49-2021.00	Radio, Cellular, and Tower Equipment Installers and Repairers
X	X		X	13-1041.07	Regulatory Affairs Specialists
	X			13-1161.01	Search Marketing Strategists
	X			13-1199.07	Security Management Specialists
X	X	X	X	15-1252.00	Software Developers
			X	_	Software Package Specialists
X	X	X		15-1253.00	Software Quality Assurance Analysts and Testers
X	X			15-2041.00	Statisticians
	X			15-1241.01	Telecommunications Engineering Specialists
X	X			49-2022.00	Telecommunications Equipment Installers and Repairers, Except Line Installers
	X			15-1199.11	Video Game Designers
	X	X	X	15-1299.01	Web Administrators
X	X	X	X	15-1255.00	Web and Digital Interface Designers
X	X	X		15-1254.00	Web Developers

and "technology,"[23] If the occupation description contained any of the three search terms or was an occupation with a SOC Code prefix of "15-1…" indicating[24] "Computer Occupations," or was in the CompTIA or MISC lists, then it was identified as a potentially relevant occupation. This filtering reduced the merged list to 175 potential IT occupations.

Step 4: Clean Merged List

In Step 4, we analyzed the 175 potential IT occupations to remove occupations outside the scope of this study (i.e., the IT jobs market). Three classes of occupations were removed in this cleaning process: 1) computer numerically controlled (CNC) tool occupations; 2) teaching occupations; and 3) military occupations. Additionally, some occupations were removed based on descriptions that revealed the occupation simply "used" IT (e.g., "use computers," "use computerized," "record transaction," etc.). Others were removed because the descriptions used the words "information," "technology" or "computer" in a context unrelated to an IT occupation (e.g., "provide information," "using computer-assisted design technology," "work with informational," "process technologies," "engineering technology," etc.). The cleaning process also removed occupations that were not specific enough (e.g., "All Computer Occupations Not Listed Separately").

At the end of the cleaning step the preliminary list of potential IT occupations had been reduced to 62 (see table below, which lists the occupations alphabetically). The table includes the O*NET occupation codes. Additional information about a specific occupation can be obtained by entering the code from the table into the website https://www.onetonline.org/. Occupations without a code are those from the academic MISC List that did not reconcile to an O*NET-listed occupation.

23 Unlike job postings, the occupation descriptions don't always use current terminology. A review of obvious "information technology" occupations revealed that the descriptions often included the less frequently used, term "computer." Because of this, we added "computer" to the occupation filter.

24 "15-1xxx" is the Standard Occupation Code (SOC) prefix that identifies Computer Occupations within the Bureau of Labor Statistics and O*NET hierarchy of occupations.

Appendix B: Validation Phase

The validation phase, during which we created the final ITOcc List of 41 IT occupations, comprised three steps: 1) identifying occupation-driven matches; 2) assigning unmatched clusters of job postings to occupations; and 3) reviewing the suitability of the results of steps 1 and 2 for inclusion in the final list. We used the sample of 15,529 job postings pulled from online job posting websites in the validation matching steps, and the outcomes of each step was independently reviewed by two researchers. The reviews and analyses were then compared and reconciled where needed. Again, consistency between the different researchers, measured by Cohen's Kappa, was found to be excellent.

Step 1: Identifying Occupation-Driven Matches

To identify occupation-driven matches, we looked for job postings that matched an occupation on our preliminary list. To do this, we reviewed the occupation's title and description and searched job posting titles using keywords that would help identify jobs that matched the occupation. For example, words used in job titles for the "Computer and Information Systems Managers" occupation (code 11-3021.00) included: manager, mgr, director, dir, vice president, VP, CIO, CTO, executive, etc. Jobs that matched were marked with the occupation identifier.

Sometimes, the job titles contained words that needed further examination; and whenever specific products were identified in job titles, we generalized to achieve a match. For example, the "Database Administrators" occupation (code 15-1141.00) was matched to job titles for specific products, such as Oracle RAC administrator, Cassandra administrator, DB2 administrator, Postgres administrator, etc. An occupation was validated when we found job postings that matched the occupation.

Interestingly, there were eight occupations in the preliminary list (identified in the table below) for which no job postings were found, so we did not include these in the ITOcc List. This is not to say that these occupations do not exist; rather, jobs in these occupations occur so infrequently that they would not add utility to the ITOcc List.

Occupations Excluded Because No Job Postings Found

Code	Occupation
17-1021.00	Cartographers and Photogrammetrists
13-2041.00	Credit Analysts
_	e-Business Manager
51-2022.00	Electrical and Electronic Equipment Assemblers
17-2112.01	Human Factors Engineers and Ergonomists
17-2112.00	Industrial Engineers
33-3021.06	Intelligence Analysts
15-2041.00	Statisticians

Six IT Occupations Identified from Clusters of Unmatched Job Postings

Code	IT Occupation	Cluster Description	Job Title Examples
13-1199.04	Business Continuity Specialists (IT Specialization)	Job titles that appear to be associated with disaster recovery and business continuity	IT business continuity lead, technology professional disaster recovery, etc.
_	Deployment Specialists	Job titles that appear to be associated with deployment of IT applications and systems	Release engineer, build and release engineer, etc.
43-3061.00	Procurement Clerks (IT Specialization)	Job titles that appear to be associated with the IT purchasing process	Procurement specialist, IT vendor management specialist, etc.
13-1071.00	HR Specialists (IT Specialization)	Job titles that appear to be associated with the acquisition of IT talent	IT staffing, IT recruiter, Senior recruiter, recruiter, etc.
41-4011.00	Sales Representatives, Wholesale and Manufacturing, Technical and Scientific Products	Job titles that appear to be associated with technology sales	Account manager, sales professional, sales engineer, etc.
27-3042.00	Technical Writers (IT Specialization)	Job titles that appear to be associated with technical writing	Copywriter, technical writer, senior technical writer, content writer, etc.

Step 2: Assigning Unmatched Clusters of Job Postings to Occupations

After identifying all the occupation-driven matches, the remaining unmatched job postings were reviewed and clustered, with the clusters being assigned to occupations where possible. The clusters of unmatched job postings were created by looking for common words (e.g., engineer, specialist, accounting, etc.) or phrases (e.g., technology lead, customer service, digital transformation, etc.) in their titles. Each cluster was then reviewed and, wherever possible, matched to an occupation in the preliminary list. However, not all job clusters could be matched to an occupation, and these clusters were labeled in one of eight ways.

Domain-Specific Occupations Excluded from the ITOcc List

Code	Occupation	No. of Job Postings	Sample %
17-3021.00	Aerospace Engineering and Operations Technologists/Technicians	3	0.02%
17-2031.00	Bioengineers and Biomedical Engineers	3	0.02%
15-2099.01	Bioinformatics Scientists	9	0.06%
43-9111.01	Bioinformatics Technicians	10	0.07%
17-3023.00	Electrical and Electronic Engineering Technologists and Technicians	11	0.08%
43-6011.00	Executive Secretaries and Executive Administrative Assistants	46	0.33%
13-2051.00	Financial and Investment Analysts	14	0.10%
15-1299.02	Geographic Information Systems Technologists and Technicians	41	0.29%
15-1211.01	Health Informatics Specialists	6	0.04%
29-9021.00	Health Information Technologists and Medical Registrars	7	0.05%
17-3026.00	Industrial Engineering Technologists and Technicians	32	0.23%
13-1081.01	Logistics Engineers	4	0.03%
13-1161.00	Market Research Analysts and Marketing Specialists	24	0.17%
29-2072.00	Medical Records Specialists	1	0.01%
15-2031.00	Operations Research Analysts	1	0.01%
49-2021.00	Radio, Cellular, and Tower Equipment Installers and Repairers	4	0.03%
13-1161.01	Search Marketing Strategists	1	0.01%
15-1241.01	Telecommunications Engineering Specialists	23	0.16%
49-2022.00	Telecommunications Equipment Installers and Repairers, Except Line Installers	10	0.07%
	Totals	**250**	**1.61%**

First, some of the unmatched job clusters had titles that were too vague to identify an occupation (e.g., Information Technology Technician, Field Technician, IT Specialist, etc.). These unmatched job clusters accounted for about 7% of the sample (i.e., 1,155 job postings), which we labeled as "vague."

The second group of unmatched job clusters were identified as "erroneous" and were assigned a "Non-IT" label. Examples of job titles in these clusters were: art director, mechanical designer, lab technician, registered nurse, HVAC systems specialist, military and teaching. These unmatched job clusters accounted for about 2% of the sample (339 job postings).

The remaining unmatched job clusters were assigned to six IT occupations not on the preliminary list but that were deemed relevant for the ITOcc List. We checked if any of these six occupations were included in the original four source lists and found that five of them were on the O*Net list. These five occupations had been excluded from the preliminary list because their descriptions and titles did not indicate they were IT occupations. We added these occupations to the ITOcc List with a note that an IT specialization exists for that occupation. The sixth occupation, labeled as "Deployment Specialists," was not found on any of the original lists. However, because the job postings in

this cluster clearly suggests a Deployment Specialist occupation, it was added to the ITOcc List. The six new occupations identified from clusters unmatched with IT occupations on the provisional list are shown in table below, together with examples of the job descriptions.

Step 3: Reviewing and Validating the Results for Inclusion in the Final ITOcc List

After completing the occupation-driven matching and assigning unmatched clusters of job postings to occupations, the results were reviewed and validated for inclusion in the final list of IT occupations. The purpose of the ITOcc List is to enable both employers and job seekers to describe and identify IT jobs. But this purpose has competing goals. First, the occupation list must be generic enough so that occupations can be "easily" found; the list would be ineffective if it was excessively long or overly specialized. Second, the list must be comprehensive enough to include most IT occupations.

The final review and validation identified 19 occupations whose descriptions were domain-specific. IT occupations in some domains, such as healthcare, aerospace, finance and geographic information systems, require a high level of domain-specific knowledge. For example, Bioinformatics Scientist is a domain specialization of Data Scientist. In addition, we found that some domains have occupations that, while requiring IT skills, are not truly IT positions (e.g., Aerospace Engineering and Operations Technologists/Technicians, Financial and Investment Analysts, Market Research Analysts and Marketing Specialists, etc.). These 19 domain-specific occupations, which accounted for less than 2% of the job postings, were excluded from the ITOcc List since they were either overly specialized for the intended purpose of the list or were incomplete because not all domains that could have been identified were identified. The 19 excluded domain-specific occupations are listed in the table below.

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