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The Development and Evaluation of a New O*NET® Related Occupations Matrix

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Executive Summary

The Occupational Information Network (O*NET®) is a comprehensive system for exploring information about jobs. Users exploring O*NET OnLine will find descriptions of many aspects of occupations, such as the tools and abilities required to perform the job tasks. One component of these descriptions is the "related occupations" feature, which matches 1 to 10 "related" occupations to each target occupation. However, researchers developed the original related occupations matrix (ROM) over 10 years ago, suggesting it should be updated to incorporate new occupations and new data. There is also a need to establish a methodology for updating the ROM more regularly when new data becomes available. In the present effort, we accomplish these objectives by (a) reviewing current O*NET user needs, (b) developing a framework for the ROM that best meets those needs, (c) developing and testing multiple matching algorithms, and (d) evaluating the new ROM in terms of other descriptors.

To determine user needs, we reviewed resources both internal (e.g., O*NET's Office of Management and Budget [OMB] clearance package) and external (e.g., internet keyword searches) to O*NET. From these resources, we identified two main categories of users that may benefit from the related occupations feature:

1. *Career Changers* – This includes individuals looking for jobs that transfer from their previous job and experience. In other words, occupations that are matched to a target occupation using the Change algorithm answer the question "Is this a job I can pursue with minimal additional preparation?"

2. *Career Starters* – This includes individuals looking for jobs that capture similar general capabilities and interests to the target job. In other words, occupations that are matched to the target occupation using the Starter algorithm answer the question "Is this a job I would want to pursue?"

These two categories provided the framework for developing the new related occupations matrices.

We evaluated multiple iterations of the Change and Starter ROM algorithms by manipulating two components: (a) the O*NET descriptor domains included in each algorithm and (b) the matching metric used in each algorithm. Nine O*NET descriptor domains were considered for the algorithms—Knowledge, Skills, Abilities, Interests, Work Styles, Work Values, Generalized Work Activities (GWAs), Work Context, and Job Zone. We also considered four matching metrics—Raw Euclidean Distance, Mahalanobis' D, Standardized Euclidean Distance, and Pearson Correlation. By manipulating the descriptor domains and matching metrics, we created multiple versions of the Starter and Change ROMs and evaluated each qualitatively (e.g., evaluating whether occupations matched with the Change algorithm could transfer to that occupation from the target occupation) and quantitatively (e.g., the extent to which the matched Starter and Change occupations overlap with one another and the original ROM).

The final Starter algorithm included cross-occupation worker-oriented descriptor domains (Abilities, Interests, Work Styles, and Work Values), while the final Change algorithm included job-specific descriptor domains (Knowledge, Skills, Work Activities, Work Context, and Job Zone). Occupations resulting from both algorithms were matched using the Euclidean Distance metric, with each domain unit-weighted except for Job Zone in the Change algorithm, which received a weight of 1.3.

We further evaluated the Starter and Change related occupations in two ways: (a) through a rational review task and (b) through statistical analysis. Four independent analysts with experience in

workforce analysis completed the rational review task. The analysts reviewed the Change related occupations to remove any inappropriately matched occupations and the Starter occupations to reduce redundancy between the matched Starter and Change occupations. The analysts had the opportunity to replace dropped occupations with alternatives. For the Change metric, the analysts dropped 15.2% (*n* = 1,306 out of 8,580) of the matched occupations but replaced 82.2% (*n* = 1,074) of those drops with alternative occupations. Similarly, for the Starter metric, the analysts dropped 15.2% (*n* = 1,302 out of 8,580) of the matched occupations. All of the dropped Starter occupations were replaced with alternative occupations. We submitted the post-review Starter and Change ROMs to further statistical analysis.

We completed the statistical evaluation of the Starter and Change ROMs through relative comparisons on relevant referent variables, including Job Family, Salary, Classification of Instruction Program (CIP) Family Codes, Education, Experience, and Training. Our hypothesis was that related occupations matched to target occupations using the Change algorithm will be more similar to one another on these key referent measures than occupations matched using the Starter algorithm. Our hypothesis was supported for all of the referent variables examined, though the magnitude of the differences was weaker for the Salary and Work Experience. The overall pattern of results suggests the Change ROM is more closely aligned to the target occupations on key referent measures than the Starter ROM, supporting the use of the new Starter and Change related occupations for job transfer and career exploration, respectively.

We believe the revised ROMs are an advancement to the related occupations available in the O*NET system because the new related occupations (a) are tailored to specific user needs and (b) use new data (e.g., Job Zone) that were not available when the original ROMs were developed. The present report also establishes a procedure for updating the related occupations in the future as new data become available.

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THE DEVELOPMENT AND EVALUATION OF A NEW O*NET® RELATED OCCUPATIONS MATRIX

I. Overview

The Occupational Information Network (O*NET®) is a comprehensive system for exploring information about jobs. Users exploring O*NET OnLine (www.onetonline.org, a U.S. Department of Labor sponsored website) will find descriptions of many aspects of occupations, such as the tools and abilities required to perform the job tasks. One component of these descriptions is the "related occupations" feature, which matches 1 to 10 "related" occupations to each target occupation. However, researchers developed the original related occupations matrix (ROM) over 10 years ago (Drewes, Tarantino, Atkins, & Paige, 1999), suggesting it should be updated to incorporate new occupations and new data. There is also a need to establish a methodology for updating the ROM more regularly when new data become available. In the present effort, we accomplish these objectives by (a) reviewing current O*NET user needs, (b) developing a framework for the ROM that best meets those needs, (c) developing and testing multiple matching algorithms, and (d) evaluating the new ROM in terms of other descriptors.

II. Background

Related occupations have their roots in the initial O*NET development work, when data collected on job descriptors were used to create job clusters (Baughman, Norris, Cooke, Peterson, & Mumford, 1999). Developing clusters of occupations requires standardized measures of job and worker characteristics that are detailed enough to distinguish occupations. O*NET was developed with the express purpose of making these types of comparisons. Using the first version of the O*NET database (O*NET 98), the authors concluded that data on individual O*NET descriptors were at the appropriate level of detail to make meaningful comparisons of individual occupations. Following on this work, researchers developed the first ROM to determine the potential for using O*NET for "computer-assisted career field matching capability" (Drewes et al., 1999). The core purpose for this initial matrix was to serve "displaced workers"—individuals that leave or lose their job can use the related occupations to identify other occupations with similar requirements. In the case of this initial ROM, occupations were matched on independent analyst ratings of worker abilities, skills, and knowledge, as well as general work activities and work context. This initial matrix is still maintained as part of the O*NET's database and web application.

Since this initial work, the O*NET database has changed in a number of ways. First, developers condensed the original list of jobs in the database from 1,122 Occupational Units to 974 occupations under the O*NET Standard Occupational Classification (SOC) system (Levine, Nottingham, Paige, & Lewis, 2000). The O*NET-SOC occupational taxonomy has been updated 3 times, with the most recent occurring in February 2011 (National Center for O*NET Development, 2010). Starting in 2000, the O*NET database was updated annually so complete information could be gathered on all O*NET-SOC jobs. Under database version 16 (specifically O*NET 16.0, the most recent version at the time of this writing), 858 occupations had complete data on the descriptor domains of interest.[1] The database also relied more heavily on incumbent versus analyst data for particular descriptor domains (Rivkin, Lewis, Cox, & Koritko, 2001). Previous work comparing analyst and incumbent data suggests that the patterns of ratings are similar for the two populations, but the means are different (Childs, Peterson, & Mumford, 1999; Tsacoumis & Van Iddekinge, 2006), which may have an impact on the how jobs are matched, depending on the type of similarity metric used. Finally, the number and nature of descriptor domains has changed from the original

[1] See http://www.onetcenter.org/database.html for more details.

database to the more current versions. For example, Job Zone, which codifies the educational and experience requirements of different occupations, was not part of O*NET 98 (National Center for O*NET Development, 2008). In addition to these structural changes to the O*NET database, the uses of the O*NET database have expanded dramatically in recent years (Tippins & Hilton, 2010).

The present study builds on previous work by recognizing these changes and accounting for them in the development of a revised ROM. This was done by (a) researching the uses of O*NET from a user perspective, (b) mapping the relevant O*NET descriptor domains to those users, and (c) selecting the appropriate similarity metric for matching occupations on these descriptor domains.

*Identifying O*NET ROM Users*

During the early stages of developing the new ROM, the National Academy of Sciences (NAS) released a comprehensive review of O*NET's core elements and potential users (Tippins & Hilton, 2010). The panel's review included a comprehensive description of O*NET's current users, which include workforce development specialists, career development professionals, and human resources professionals. Not all of the users in these fields have use for related occupations, but the diversity of users does suggest the potential need for more than one ROM. After a detailed review of the NAS report, internal O*NET documents (e.g., O*NET's Office of Management and Budget [OMB] clearance package [U.S. Department of Labor Employment and Training Administration, 2008], O*NET's "Products at Work" [National Center for O*NET Development, 2011]), and additional internet keyword searching about the uses of O*NET, the researchers identified two main categories of users that may benefit from the related occupations feature:

1. *Career Changers* – This category includes individuals looking for jobs that directly transfer from their previous job and experience. In other words, occupations that are matched to a target occupation using the Change algorithm answer the question "Is this a job I can *immediately* pursue?" This algorithm would be used by an individual who lost her job and wants to find an occupation where her skills might transfer. That is, an individual would need minimal additional preparation (training, education, or experience) before starting the new job.

2. *Career Starters* – This category includes individuals looking for jobs that capture similar general capabilities and interests to the target job. In other words, occupations that are matched to the target occupation using the Starter algorithm answer the question "Is this a job I would *want* to pursue?" This algorithm might be used by an individual seeking a career change or a student transitioning into the workforce. That is, an individual would need significant additional preparation (training, education, or experience) before starting the new job.

These two categories provided the framework for developing the new related occupations matrices. Once these categories were identified, we considered which O*NET descriptor domains should be included as components of the Starter and Change categories.

*O*NET Descriptor Domains*

The O*NET content model comprises a number of "descriptor domains." In order to be considered for use in the development of the revised ROMs, the descriptor domains had to be standardized across occupations. For example, descriptor domains that are measured by ratings of importance, such as the Knowledge and Skill domains, were considered for use in the ROMs, while unstandardized domains, such

as the Tasks and Detailed Work Activity domains, were not considered. With these criteria in mind, the following descriptor domains were considered:

1. *Knowledge* – The O*NET developers defined occupational knowledge as "a collection of discrete but related and original facts, information, and principles about a certain domain" that is acquired through education, training, or experience (Fleishman, Costanza, Wetrogan, Uhlman, & Marshall-Mies, 1995; p. 4-1). The Knowledge domain comprises 33 elements, such as "Administration and Management" and "Design." To determine the Knowledge requirements for a particular occupation, job incumbents[2] rate the importance of each Knowledge element on a 1 (Not Important) to 5 (Extremely Important) scale. For each element, they also rate the level of Knowledge required using a 1 to 7 scale. Several of the scale points use specific work activities (Peterson et al., 2001) as anchors. These same rating scales are used for multiple descriptor domains described below.

2. *Skills* – In the O*NET framework, Skills are capabilities of individuals that are acquired through experience and practice, and are used to facilitate knowledge acquisition (Mumford, Peterson, & Childs, 1999). The O*NET Skills contain both basic (e.g., active learning, mathematics) and cross-functional elements, and the cross functional elements can be further described by five categories: (a) complex problem solving, (b) resource management, (c) social, (d) systems, and (e) technical. Within these categories, there are a total of 35 elements, rated on importance and level by trained independent O*NET analysts (Tsacoumis & Willison, 2010; Tsacoumis, Willison, & Wasko, 2010), rather than job incumbents.

3. *Abilities* – Unlike Skills, which are acquired through experience and practice, Abilities can be thought of as relatively stable characteristics of an individual (Fleishman, Wetrogan, Uhlman, & Marshall-Mies, 1995). The O*NET Abilities descriptor domain contains 52 elements subsumed under four categories: (a) cognitive abilities, (b) physical abilities, (c) psychomotor abilities, and (d) sensory abilities. Trained O*NET analysts rate each element on importance and level (Donsbach, Tsacoumis, Sager, & Updegraff, 2003).

4. *Interests* – The O*NET Interests descriptor domain relies on Holland's RIASEC taxonomy of occupational preferences (Dawis, 1991). It has six elements: Realistic (R), Investigative (I), Artistic (A), Social (S), Enterprising (E), and Conventional (C). The Interest ratings currently in the O*NET database were determined by trained analysts (Rounds, Armstrong, Liao, Lewis, & Rivkin, 2008a; Rounds, Smith, Hubert, Lewis, & Rivkin, 1999).

5. *Work Styles* – The O*NET Work Styles descriptor domain contains elements of individual personality, temperament, and cognitive styles (Borman, McKee, & Schneider, 1995). It comprises 16 elements subsumed under seven categories: (a) achievement orientation, (b) social influence, (c) interpersonal orientation, (d) adjustment, (e) conscientiousness, (f) independence, and (g) practical intelligence. Job incumbents provide ratings of importance on each element.

6. *Work Values* – The work values framework is based on the Minnesota Theory of Work Adjustment (Dawis & Lofquist, 1984; cf. Hubbard et al., 2000), and comprises six elements: (a) Achievement,

[2] For more details on the job incumbent rating process, see the most recent justification for the O*NET Data Collection Program in the Office of Management and Budget (OMB) clearance package (U.S. Department of Labor Employment and Training Administration, 2012).

(b) Independence, (c) Recognition, (d) Relationships, (e) Support, and (f) Working Conditions. Ratings of the work values supported by each occupation were determined by trained analysts (McCloy, Waugh, Medsker, Wall, Rivkin, & Lewis, 1999; Rounds, Armstrong, Liao, Lewis, & Rivkin, 2008b).

7. *Generalized Work Activities (GWAs)* – The original developers of O*NET defined a GWA as "an aggregation of similar job activities/behaviors that underlie the accomplishment of major work functions" (Jeanneret, Borman, Kubisiak, & Hanson, 1999; p. 106). This descriptor domain has 41 elements subsumed under four categories: (a) information input, (b) interacting with others, (c) mental processes, and (d) work output. GWAs are currently rated on importance and level by job incumbents.

8. *Work Context* – The Work Context descriptor domain contains interpersonal, physical, and structural elements of the work environment that represent the conditions under which work is performed (Peterson et al., 2001). There are a total of 57 elements, 55 of which are rated on 5-point rating scales with varying anchors depending on the nature of the item. For example, one item asks "How responsible are you for the health and safety of other workers on your current job?" and the scale ranges from 1=No responsibility to 5=Very high responsibility while another item asks "How often are conflict situations a part of your current job?" and the scale ranges from 1=Never to 5=Every day. The remaining two elements are rated on a 3-point scale. Ratings are made by job incumbents.

9. *Job Zone* – Trained analysts assign each O*NET occupation to one of five Job Zones (National Center for O*NET Development, 2008). Each job zone represents the level of education and experience required for the position, though more weight is given to the amount of education required. Job Zone ranges from 1 ("Little or no preparation needed") to 5 ("Extensive preparation needed").

A complete list of the elements that comprise these descriptor domains can be found in Appendix A. These descriptor domains vary along two dimensions: (a) job-oriented versus worker-oriented and (b) cross-occupation versus occupation-specific. Because the Change algorithm concerns job transfer, this algorithm will emphasize more occupation-specific descriptor domains such as Knowledge, Skills, and Job Zone. The Starter algorithm, with its heavier emphasis on career exploration, will emphasize worker-oriented cross-occupation descriptor domains, such as Interests and Work Styles.

Similarity Metrics

A third consideration in developing a new ROM is how to measure the degree of similarity between two occupations when matching them to one another. According to Cronbach and Gleser's (1953) seminal work on the topic, the determination of similarity can be described along three dimensions: (a) elevation, or the *mean* similarity/differences between the profiles, (b) scatter, or the *variance* similarity/differences between the profiles, and (c) shape, or the similarity/differences between profiles after controlling for elevation and scatter. Figure 1 illustrates these concepts.

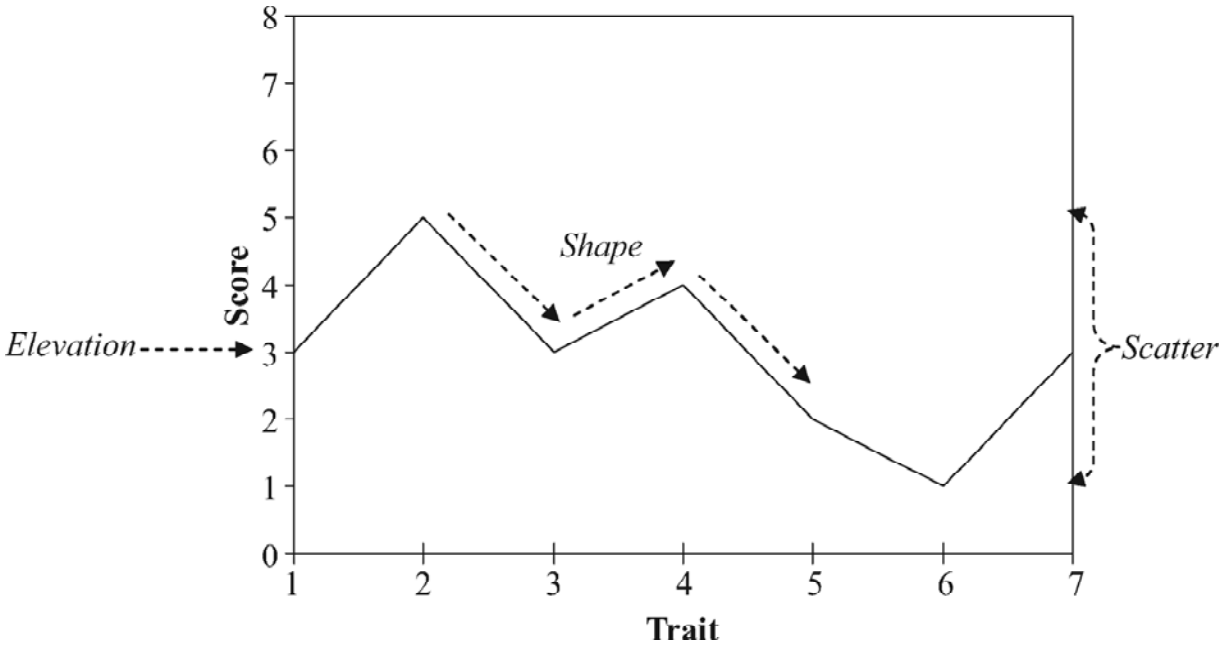

Figure 1. Illustration of Similarity Metric Components

Specific profile similarity algorithms tend to come in one of two classes (Edwards, 1993): (a) sum of the difference between profile elements, and (b) correlations between profiles. The choice of which algorithm class to use depends in large part on whether "elevation" is important to the match. For example, career exploration tools such as the Strong Interest Inventory (Hansen & Campbell, 1985) are often ipsatively scored. In other words, the scores are provided in terms of each dimension's importance for the test-taker relative to all other dimensions, rather than relative to other people who have taken the test. The reason for this type of scoring is, in choosing a field of endeavor, the user is most interested in determining their preferences for certain fields against others. The level or "elevation" information matters little in this context, but the "shape" information is important (see Figure 1). By contrast, if a user were interested in determining whether she meets the qualifications for a new occupation, elevation information matters greatly, because the "distance" (i.e., mean difference) between the user's level on a construct and the occupation's level would have a dramatic impact on her suitability for the occupation (Drewes et al., 1999; McCloy, Campbell, Oswald, Lewis, & Rivkin, 1999).

Thus, the choice of similarity metric should be driven at least in part by the theoretical reason for matching the profiles. Because the Change algorithm is more concerned with immediate job transfer, we believe elevation information is more conceptually important to the Change algorithm than the Starter algorithm. However, because the Starter algorithm is more concerned with career exploration, the first matching algorithms that we tested emphasized shape while controlling for elevation and scatter. However, even within these two classes of metrics (sum of the mean differences and correlations), there are multiple potential algorithms. The choice of which specific algorithm to use was driven by initial evaluations of matched related occupations. The following two "sum of the differences between profile elements" metrics were tested (the descriptions and formulas are derived primarily from Edwards, 1993):

1. *Raw Euclidian Distance* (D_{Raw}) – Provides an index of profile similarity using the sum of squared mean differences across profiles. The squaring of the differences means that (a) the metric is non-directional (i.e., it doesn't matter if the mean is higher or lower, just that it's different at a certain magnitude) and (b) larger differences are weighted more heavily. This metric takes into account all three components of similarity: elevation, scatter, and shape. This metric can be expressed using the following formula:

$$D_{Raw} = \sqrt{\Sigma(X_i - Y_i)^2} \quad (1)$$

where i represents the individual profile elements.

2. *Mahalanobis' D* (D_{Mah}) – This metric also uses the mean differences, but weights each difference by the pooled within-entity variance-covariance matrix. This has the effect of giving even greater weight to outlying differences. It also has the advantage of yielding a standardized metric. This metric can be expressed using the following formula:

$$D_{Mah} = \sqrt{(X_i - Y_i)' S^{-1} (X_i - Y_i)} \quad (2)$$

where S^{-1} is the pooled within-entity variance-covariance matrix.

The next two "correlations between profiles" metrics were also considered:

3. *Standardized Euclidean Distances* (D_{Std}) – The formula for this metric is the same as D^2_{RAW} above. However, rather than using raw scores as the input for the formula, the data are first standardized before the distance is calculated. This has the effect of eliminating elevation and scatter differences from the metric, so all that is left is shape.

4. *Pearson Correlation* (r) – Provides an index of profile similarity using a Pearson product-moment correlation coefficient. It can be represented by the following formula:

$$r = \frac{\Sigma(z_X z_Y)}{N} \quad (3)$$

where z_X and z_Y are z-scores for variables X and Y.

Summary

The related occupations work has its roots in the initial effort to develop and validate uses of the O*NET system. The original related occupations algorithm used the O*NET 98 data to identify related occupations for 1,122 Occupational Units (OUs). The present study seeks to build off that initial research by (a) focusing on specific end-users and (b) using new data available in the system, and (c) considering alternative matching metrics. Two sets of target users were identified: Career Changers and Career Starters. Subsequent development activities were framed around these two sets of users. Two components of the related occupations algorithm can be manipulated to maximize utility for users: (a) the O*NET descriptor domains included in the matrices and (b) the similarity metric used. Each component impacts the ROM in unique ways.

III. Matching Algorithm Development

Methodological Overview

As described in more detail below, a number of different algorithms were developed and tested before finalizing the Starter and Change related occupations. However, all of these algorithms were developed using the same basic steps (described graphically in Figure 2):

1. *Create descriptor domain-specific files*. Using the data available on O*NET Resource Center,[3] we transformed each database so that there was one row per occupation for each descriptor domain.[4] For descriptor domains with element ratings of both importance and level (e.g., Knowledge and Skills), we combined the component ratings using unit-weighted means. We used this approach based on previous work showing that adding level to ratings of importance adds to the interpretability of matching procedures (Allen, Tsacoumis, & McCloy, 2011). In cases where matching was being performed using the D_{Std} metric, the elements within the target descriptor domain were also standardized (i.e., z-scored).

2. *Create complete similarity matrices for each descriptor domain*. Using the files from Step 1, we generated similarity matrices for each O*NET descriptor under consideration. This resulted in an 858 by 858 (corresponding to the number of occupations with complete data in the O*NET 16.0 database) matrix for each descriptor domain. Each cell within these matrices represented the similarity metric calculated between two jobs across elements within the descriptor domain. Two occupations that were very similar to one another had a similarity index value near zero when D_{Raw} or D_{Std} were used, and near 1.0 if *r* or D_{Mah} were used.

3. *Standardize the similarity matrices (if necessary)*. The raw Euclidean distance algorithm (D_{Raw}) does not result in standardized scores. This means that the same similarity value computed using one descriptor domain versus another will differ in interpretation as a function of the number of elements in the domain and the scaling of those elements. Therefore, we standardized the matrices themselves by converting all of the values in the matrix to z-scores. That is, we standardized separately across all values within the Work Context similarity matrix, the Abilities similarity matrix, and so forth.

4. *Combine the matrices into an overall Related Occupations Matrix*. After the matrix for each O*NET descriptor was computed and standardized, an arithmetic average of the corresponding cell values from each component matrix was taken to form an overall matrix. The most "similar" occupations (closest to zero for the Euclidean matrices, closest to 1.0 for D_{Mah} and *r*) for each target occupation constituted the "related occupations."

[3] http://www.onetcenter.org/database.html

[4] All of the analyses were initially conducted on O*NET Databases 14.0 and 15.0; however, the final ROMs were created using O*NET Database 16.0. Unless otherwise noted, all of the results reported here are from Database 16.0.

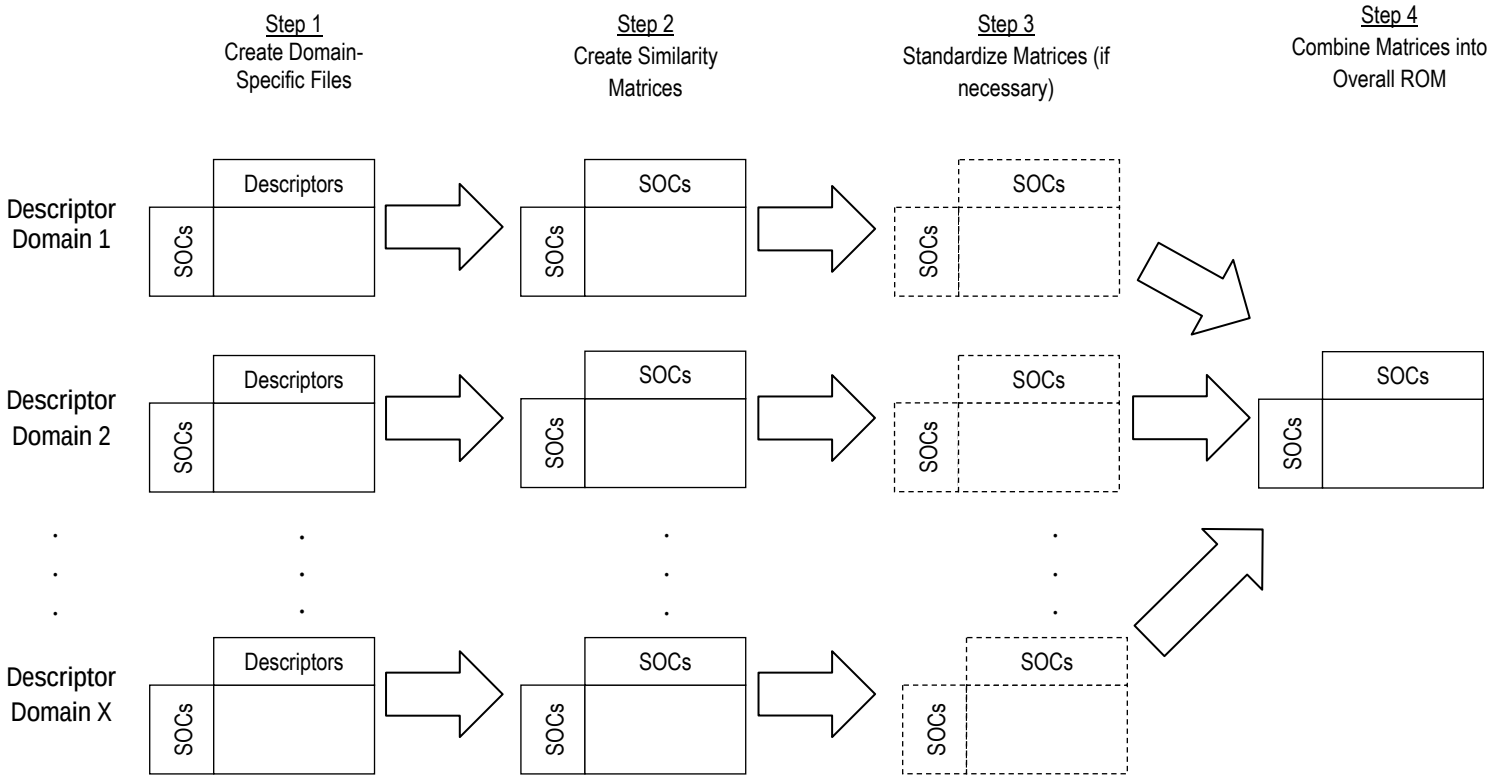

Figure 2. Graphical Representation of Related Occupations Matrix (ROM) Construction Process. SOC = Standard Occupational Classification code.

For the purpose of evaluating the metrics, the top 10 most similar occupations for each target occupation were considered the "related occupations." By computing the matrices separately for each descriptor domain, transforming the values to z-scores, and combining them, we ensure that the individual domains are each receiving close to equal weight.[5] Had each of the individual elements been included in the same algorithm, certain descriptor domains would have carried little or no weight. For example, if the individual elements in the Interests domain (6 elements) and the Abilities domain (52 elements) been included in a similarity algorithm, the Abilities elements would have masked the effect of Interests. This procedure ensures that each component descriptor domain is represented in the scoring algorithms.

Initial Algorithms

We chose the descriptor domains and similarity metrics for the Starter and Change algorithms based on previous research and a theoretical understanding of the descriptor domains. Specifically, consistent with a career exploration focus, the initial Starter algorithms comprised cross-occupation, worker-oriented descriptor domains (e.g., Interests, Work Values), and matched occupations using pattern-oriented similarity metrics (i.e., D_{Std}, r). Reliance on descriptor domains that do not focus on job content should lead to a more heterogeneous list of related occupations, which is desirable for career exploration purposes. Consistent with its job-transfer focus, the initial Change algorithms comprised work-oriented (e.g., GWAs) and job-specific worker-oriented (e.g., Knowledge, Skills) descriptor domains, and matched occupations using mean difference metrics (i.e., D_{Mah} , D_{Raw}). In contrast with the Starter algorithm, the focus on content-specific descriptor domains should lead to homogeneous sets of related occupations, which is more desirable for job transfer purposes. The specific components of the initial algorithms can be found in Table 1. Note that Work Context, despite being a work-oriented descriptor domain, was not included in the initial Change algorithm due to concerns about variability in the interpretation and scaling of the individual elements. All of the descriptor domains within each algorithm were unit-weighted, and the Change algorithm results in the first iteration were output by Job Zone.

To evaluate these initial algorithms, we selected the top 10 matches for 50 occupations, spread across job families. We evaluated these initial results and considered the following questions in our evaluation:

- For the Change algorithm, could someone in one job reasonably transfer to another job on the related occupation list in a relatively short amount of time?
- Do the related occupations computed with the Starter algorithm seem reasonable in terms of shared interests or underlying capabilities but also show variability?
- To what degree does the new list overlap with the current related occupations list? While we expect our list to demonstrate differences with the previous list given the new methodology and data, we nonetheless would expect the new related occupations, and the Change ROM in particular, to overlap with the original matrix to some degree.

[5] Though, as described in the "Job Zone Inclusion in Change Algorithm" section later, the domains are not perfectly equally weighted.

*Table 1. List of Similarity Metrics and O*NET Descriptors by Starter and Change Algorithms*

	Descriptor Domain	No. Elements	Type of Rating	Scale	D_{Raw}	D_{Mah}	r	D_{Std}
Change Algorithm	Knowledge	33	- Level - Importance	0 – 7 1 – 5	X	X		
	Skills	35	- Level - Importance	0 – 7 1 – 5	X	X		
	Work Activities	41	- Level - Importance	0 – 7 1 – 5	X	X		
Start Algorithm	Abilities	52	- Level - Importance	1 – 5			X	X
	Interests	6	- Interest	1 – 7			X	X
	Work Styles	16	- Importance	1 – 5			X	X
	Work Values	6	- Extent	1 – 7			X	X

Note. The Career Change results were output by Job Zone.

After reviewing these initial results, we concluded that the more commonly used similarity metrics (r; D_{Raw}) were more face valid than the less commonly used metrics. For example, with the Starter algorithm, the top three occupations matched to Mental Health Counselors were Genetic Counselors, Midwives, and Low Vision Therapists when linked using the D_{Std} metric, and Secondary School Special Education Teachers, Substance Abuse/Behavioral Disorder Counselors, and Marriage/Family Therapists when using r. The same was true for the Change algorithm, where the bottom three (8 through 10) of the top 10 occupations linked to Tellers using the D_{Mah} metric included Bartenders, Welding/Soldering Machine Setters, and Mail Clerks/Mail Machine Operators. When using D_{Raw} the occupations in the same position were License Clerks, Customer Service Reps, and Parts Salespersons. While these initial results were promising, they suggested that even minor changes to the matching algorithms can have a dramatic effect on the related occupations. Thus, various adjustments were made to the matching algorithms and evaluated by the research team.

Refinement of Initial Matching Algorithms

We tested a number of adjustments to determine the final Starter and Change algorithms. These adjustments included (a) adjusting the similarity metric used to compute each algorithm, (b) adjusting the role of job zone in the computation of the Change algorithm, and (c) examining the descriptor domains contributing to each algorithm.

Matching Algorithm Adjustment

We judged that the D_{Raw} and r statistics were more interpretable than the counterpart statistics in the initial matching algorithms. Hence, the D_{Std} and D_{Mah} were not considered for further evaluation. After the first initial algorithms were created, we recognized that it may also be appropriate to use D_{Raw} for the Starter algorithm in addition to the Change. Though career exploration tools often match individuals to jobs using "correlation between profiles" metrics (see, for example, O*NET's Ability Profiler; Allen et al., 2011; McCloy, Campbell et al., 1999), the O*NET descriptor data included in the Starter algorithm computation takes into account elevation information, suggesting a "sum of the differences between profile elements" may also be appropriate. In other words, the O*NET descriptor domains don't just compare occupations to each other on an absolute scale, such as a 1 to 5 rating of Importance. For this reason, later iterations of the Starter algorithm, we matched occupations using D_{Raw} rather than r; and found the matched occupations to be more interpretable. Hence, the final algorithms used D_{Raw} to match occupations for both the Starter and the Change algorithms.

Job Zone Inclusion in Change Algorithm

From the early stages, we recognized that Job Zone was a critical component of the Change algorithm, given the algorithm's emphasis on matching jobs that an individual can pursue with minimal additional preparation. For example, if a target occupation in Zone 2 ("Some preparation needed") was matched to another occupation in Zone 4 ("Considerable preparation needed"), we could argue that this was not a realistic match because it is clear from the descriptions that a substantial amount of additional preparation would be needed to pursue the matched job. For this reason, in the initial computations, we sorted the occupations matched by Change algorithm into Job Zones so that individuals could decide how much preparation they were willing to take on in order to pursue a matched occupation. However, this procedure led to a number of unusual linkages, particularly in Job Zones 1 and 5, where there are fewer O*NET occupations than in Job Zones 2 through 4. For example, many occupations were linked to cooks or kitchen preparation jobs, even if the target occupation had nothing to do with food because those jobs make up a large percentage of Zone 1 occupations. To adjust for this, we added Job Zone to the Change algorithm as a separate descriptor domain, equally weighted with the other descriptor domains. Though this addressed the issue of having unusual linkages, it raised an additional concern with regard to the weighting of Job Zone in the algorithm.

As described earlier, we wanted each descriptor domain contributing to each algorithm to be equally weighted—that is, we wanted each domain, on average across all occupations for a particular algorithm, to contribute equally to the final score. We accomplished this by unit-weighting each descriptor domain contributing to the Starter and Change algorithms. However, the concern is that while each descriptor domain may be *unit-weighted* in computation, the *effective weight* for Job Zone on average might be lower than the other descriptor domains.

Effective weights recognize that a composite score (i.e., the Starter and Change algorithms) is a function of the variances and covariances of the elements that contribute to that score (Wang & Stanley, 1970). For the Starter and Change algorithms, in the instances where one descriptor domain (e.g., Knowledge) has greater variance or covariance than another (e.g., Job Zone), that domain would be weighted more heavily in a composite. This is of particular concern for Job Zone because there is only one element (the 5-point Job Zone scale) contributing to the algorithm, as opposed to 6 or more scales for the

other domains (see Table 1). Thus, even if the elements in the Change algorithm are unit-weighted, Job Zone could be underrepresented in the algorithm compared to other domains if the effective weight is much smaller.

To test whether differential effective weights were an issue for the Change algorithm, we first calculated the effective weights for each O*NET descriptor domain for all occupations. Second, we computed the average effective weight for each descriptor domain across all occupations. The results of this procedure suggest that the effective weight of Job Zone in the Change algorithm was between 20% and 30% lower than that of other descriptor domains, on average. To account for this, the D_{Raw} statistic for Job Zone was multiplied by 1.3 before being aggregated into the over Change algorithm. All of the other descriptor domains in the Change algorithm received a weight of 1.0.

Other Descriptor Domain Refinements

In addition to Job Zone, we also tried adding Work Context as an additional descriptor domain to the Change algorithm. Work Context had been included in the original related occupations algorithm (Drewes et al., 1999), and additional iterations found that it contributed to the interpretability of the Change algorithm. Hence, Work Context was included in the final Change algorithm. We also considered adding the Knowledge and Skills descriptor domains into the Starter algorithm. This was tested in response to reactions to earlier versions of the Starter ROM that showed a high degree of variability in the job domains matched to each target occupation. While the Knowledge and Skill descriptor domains did make the Starter matches more interpretable, it also increased the overlap between the Starter and Change algorithms to as high as 49%. The researchers decided that the high degree of overlap between the two algorithms was not desirable from the end-user perspective; hence, the Knowledge and Skill domains were excluded from the final Starter algorithm.

Final Algorithm

The final components of the Starter and Change algorithms are summarized in Table 2. As shown in Figure 2, both algorithms were computed by (a) constructing a matrix of D_{Raw} for each descriptor domain, (b) standardizing the matrix for each descriptor domain, and (c) aggregating the descriptor domains using the weights in Table 2. Using these procedures, we identified the Starter and Change related occupations. If an O*NET occupation was missing data from one of the component descriptor domains, it was excluded from consideration in both the Starter and Change computations. In the context of the ROMs, the D_{Raw} computation for one target by related occupation cell can be expressed by the following formula (see Appendix B for more complete information on computing the Starter and Change related occupations by hand):

$$D_{Raw} = \sqrt{(X_a - Y_a)^2 + (X_b - Y_b)^2 + \cdots + (X_z - Y_z)^2} \quad (4)$$

where X represents the target and Y represents the related occupation, and a, b, and z represent the individual elements for a descriptor domain (e.g., Arithmetic Reasoning in the Abilities domain).

The D_{Raw} statistics are then standardized and combined into the final Starter and Change algorithms computed for each target by related occupation pair. These algorithms can be expressed with the following formulae:

$$RO_{Starter} = Z(D_{Abilities}) + Z(D_{Interests}) + Z(D_{Styles}) + Z(D_{Work\ Values}) \quad (5)$$

$$RO_{Change} = 1.3 * Z(D_{Job\ Zone}) + Z(D_{Knowledge}) + Z(D_{Skills}) + Z(D_{GWAs}) + Z(D_{Context}) \quad (6)$$

*Table 2. Matrix of O*NET Descriptor Domains Included in the Starter and Change Algorithms*

				ROM Components	
Descriptor Domain	Type of Rating	Scale	Weight	Starter	Change
Abilities [52]	- Level - Importance	0 – 7 1 – 5	1.0	X	
Interests [6]	- Interest	1 – 7	1.0	X	
Work Styles [16]	- Importance	1 – 5	1.0	X	
Work Values [6]	- Extent	1 – 7	1.0	X	
Knowledge [33]	- Level - Importance	0 – 7 1 – 5	1.0		X
Skills [35]	- Level - Importance	0 – 7 1 – 5	1.0		X
Work Activities [41]	- Level - Importance	0 – 7 1 – 5	1.0		X
Work Context [57]	- Frequency - Importance	1 – 5	1.0		X
Job Zone [1]	-Zone	1 – 5	1.3		X

Note. Both metrics were matched using the Raw Euclidean Distance formula described in Formulas 1 and 4. Numbers in brackets represent the number of component elements for that descriptor domain. Job Zone received a slightly higher weight than the other domains because its average effective weight (weight based on variability in the scale; Wang & Stanley, 1970) was lower than that of the other descriptor domains.

The 10 related occupations with the closest matches (i.e., the smallest $RO_{Starter}$ and RO_{Change} values) to each target occupation constituted the Starter and Change ROMs. We further refined the Change ROM by excluding any related occupation that was more than one Job Zone different from the target occupation. This was done to improve the interpretability of the Change metric. For example, individuals may be working in a job in Job Zone 2, but have acquired enough experiences and training to be eligible for a Zone 3 job or could acquire a Zone 3 job with little additional training. On the other hand, it is unlikely that the same individual could easily "Change" into a Zone 4 job. Hence, related occupations within one Job Zone (higher or lower) of the target occupation were included in the final Change ROM. Matches more than one Job Zone higher or lower than the target occupation were automatically excluded.

Using the final algorithm, only 12 of the 8,580 (858 occupation * 10 matches; or 0.1%) related Change occupations were more than one Job Zone different from the target occupation.

IV. Evaluation of Related Occupation Matrices

We evaluated the Starter and Change related occupations in two ways: (a) through a rational review task and (b) through statistical analysis. The review task evaluated the related occupations at the individual user level. For example, users examining the related occupations for a particular target occupation will expect that all of the occupations matched with the Change algorithm will be jobs they can transfer to with minimal additional preparation. If this is not the case for one or more related occupations, it will damage the credibility of the ROMs. The job of the analysts was to ensure that each related occupation was an appropriate match from the user perspective. After incorporating the results of the rational review into the ROM, we evaluated the metrics statistically. The statistical analyses were based on the assumption that occupations matched with the Change metric would be more closely related to one another than occupations matched with the Starter metrics on a number of referent measures. Once we completed these evaluation activities, we finalized the ROMs.

Rational Review Task

Four independent analysts with experience in workforce analysis completed a review of the Change and Starter related occupations. The analysts reviewed the Change related occupations to remove any inappropriately matched occupations. To accomplish this, the analysts reviewed the 10 matched occupations, taking into consideration the target and related occupation's field similarity[6] (e.g., architecture, education, legal), occupational similarity (e.g., supervisory, technical), and the expected amount of time and additional training/experience that would be needed to transition from the target occupation to the related occupation. The analysts removed occupations that were not sufficiently similar to one another, as defined by the Change ROM objective, from the related occupations list. If a related occupation was removed from the initial list of 10 related occupations for a target occupation, the analyst had the opportunity to select another occupation to add to the ROM from the next 15 best Change algorithm matches.

Analysts reviewed the Starter related occupations to reduce redundancy between the Starter and Change occupations. Unlike for the Change related occupations, analysts did not consider the similarity of the two occupations in their review. In instances where there was substantial overlap between the Starter and Change related occupations for a particular target occupation, alternate Starter occupations were chosen from the next 15 best matches. As a general rule for both the Starter and Change related occupations, the analysts were instructed to attempt to maintain 10 Change and 10 Starter matches, though in some cases, this was not possible.

To prepare for this task, O*NET first trained the analysts by having them complete the Starter and Change reviews for 20 target occupations. The analysts then shared their review results and discussed any discrepancies in a group setting. Once these discrepancies were resolved and the analysts shared a common frame of reference for the task, they began their reviews of the Starter and Change related occupations. These training procedures were similar to those used in previous O*NET research (e.g., Rounds et al., 2008a; 2008b). The analysts completed the task independently for each set of related occupations (i.e., they first reviewed all of their assigned Change related occupations, then all of the Starter

[6] As defined by each occupation's Classification of Instruction Programs (CIP) codes, described in more detail later.

related occupations). Each analyst reviewed between 210 and 219 target occupations for a total of 2,100 to 2,190 judgments for *each* ROM. Given the resource-intensive nature of this review task, each analyst evaluated an independent set of occupations.

For the Change algorithm, the analysts dropped a total 15.2% (*n* = 1,306 out of 8,580) of the matched occupations but replaced 82.2% (*n* = 1,074) of those drops with alternative occupations. For each individual analyst, the percentage of drops ranged from a low of 3.1% (*n* = 65 out of 2,110) to a high of 34.7% (*n* = 761 out of 2,190), while the rates of replacement for the dropped occupations ranged from 71.5% (544 replacements out of 761 drops) to 100.0% (65 replacements out of 65 drops). Similarly, for the Starter metric, the analysts dropped 15.2% (*n* = 1,302 out of 8,580) of the matched occupations. Individual analysts' review results dropped between 4.8% (*n* = 100 out of 2,100) and 22.4% (*n* = 491 out of 2,190) of the matched occupations. All of the dropped occupations were replaced with alternative occupations for the Starter metric. There are a number of potential explanations for the variations among individual analysts, including low interrater reliability or systematic differences in the target occupation domains being reviewed. However, these possibilities could not be explored further given there was no overlap among the target reviews.

The outcome of the review task can be summarized in Table 3. As expected, the Change ROM was more closely aligned with the originally-developed ROM (Drewes et al., 1999), both before and after the review task. The average overlap percentage between the Starter and Change ROMs was 31.3% prior to the review task, and about 16% after the review task was complete. We used the post-review Starter and Change ROMs in the evaluation analyses described next.

Table 3. Overlap Rates between the Original, Starter, and Change ROMs

Description	Average % Overlap – Pre-Review	Average % Overlap – Post-Review
1. Overall Overlap between Starter and Change ROMs	31.3	--
2. Overlap between Starter and Change ROMs with Change ROM as denominator	--	16.0
3. Overlap between Starter and Change ROMs with Starter ROM as denominator	--	15.9
4. Overlap between Original and Starter ROMs with Starter ROM as denominator	12.4	10.9
5. Overlap between Original and Change ROM with Change ROM as denominator	16.3	17.1
6. Overlap between Original and Starter ROM with Original ROM as denominator	17.8	15.7
7. Overlap between Original and Change ROM with Original ROM as denominator	23.1	23.7

Note. "Average % Overlap" was calculated by taking the percent matching for each target occupation, then averaging across all target occupations. Overlap rates for each target occupation were computed by taking the number of occupations matched to a target occupation by both ROMs, and dividing by the total number of possible matches (i.e., the "denominator"). The number of possible matches changed depending on the ROM—for example, the number of related occupations linked to each target occupation using the Original ROM ranged from 1 to 10, while the number of related occupations linked to each target occupation using the Starter ROM was always 10.

Evaluation Analyses

Approach

The challenge to empirically evaluating the Starter and Change ROMs is that the computations are done using a relative rather than absolute metric. In other words, one occupation is "more similar" than

another, but there is no absolute cutoff value (for D_{Raw} at least) for interpreting whether a match is "strong" or "weak" in an absolute sense. In absence of an absolute method for evaluating the new related occupations, we relied on relative comparisons between the Starter and Change ROMs on relevant external (to the O*NET databases) and internal referent variables. Our hypothesis is that ROMs matched to target occupations using the Change algorithm will be more similar to one another on these key referent measures than occupations matched using the Starter algorithm. The following referent data were used to complete these evaluation analyses:

1. Job Family – Job Family is the highest-order level in the O*NET-SOC taxonomy; with all occupations being sorted into one of 22 categories.[7] According to O*NET OnLine, Job Families are "groups of occupations based upon work performed, skills, education, training, and credentials" (http://www.onetonline.org/find/family).These groups generally correspond to the industry of the occupation (e.g., Legal Occupations, Production Occupations).

2. Salary – The Bureau of Labor Statistics (BLS) maintains employment and wage data by occupation using a number of different organizing frameworks, including O*NET-SOC.[8]

3. Classification of Instruction Program (CIP) Family Codes – According to the National Center for Education Statistics (NCES) website, the purpose of CIP is to "provide a taxonomic scheme that will support the accurate tracking, assessment, and reporting of fields of study and program completions activity."[9] Similar to Job Family, the highest-order level in the CIP taxonomy is 2-digit "Family" level. There are 50 CIP families and codes for numerous individual occupations, most of which are crosswalked to the O*NET-SOC occupations.

4. Education, Experience, and Training Categories – O*NET collects education, experience, and training requirements for occupations from job incumbents and occupational experts. The frequencies for selecting each education, experience, and training level is maintained in the databases. There are numerous levels for each of these variables. For example, the education variable has 12 levels, ranging from "Less than a High School Diploma" to "Post-Doctoral Training."[10] The median level of education for each target and related occupation was computed from this data and used in the analyses.

After selecting these referent measures, we next selected statistical approaches for determining the degree of similarity between the ROMs and target occupations on these variables. Depending on the structure of the referent data, we used one of the following three statistics:

1. p(Overlap) and Corrected p(Overlap) – The p(Overlap) statistic is the proportion of target/related occupation combinations in which the target occupation and related occupation are from the same referent variable category. However, the target and related occupation can also be from the same occupation due to chance. Therefore, we also computed a Corrected p(Overlap) statistic that corrects for the amount of matches expected by chance based on the total number of occupations

[7] There are actually 23 Job Families, with the 23rd being Military-Specific Occupations. O*NET information is not collected for these occupations; hence, they were not included in any analyses in this report.
[8] See http://www.bls.gov/oes/current/oes_nat.htm. Data retrieved 12/15/2011.
[9] See more information about the CIP taxonomy at http://nces.ed.gov/pubs2002/cip2000/
[10] Experience ranged from 1 (None) to 11 (Over 10 Years) and On-Site Training ranged from 1 (None) to 9 (Over 10 Years).

in the target occupation's referent variable category. This correction can be represented by the following formula (Cohen's kappa):

$$pCorrected = (pObserved - pRandom) \,/\, (1 - pRandom) \quad (7)$$

We computed the p(Overlap) and Corrected p(Overlap) statistics for nominally-scaled referent variables (i.e., Job Family, CIP Family).

2. $\underline{M_{Diff}}$ – M_{Diff} is the mean (within target occupation) difference in the referent variable between the target and related occupation. The M_{Diff} statistic is determined by computing (a) the difference (absolute value) between the target occupation's level on the referent variable and the related occupation's level on the same variable, (b) the mean of the referent variable differences within each target occupation, and (c) the average across all occupations or within a particular subgroup (e.g., Job Family). We computed the M_{Diff} statistic for normally-distributed ordinal-scaled referent variables (i.e., education, experience, and training).

3. $\underline{Mdn_{diff}}$ – Mdn_{diff} is the median absolute difference between a target occupation's referent score and the same score for the related occupation. We computed Mdn_{diff} for the Salary referent variable. Mdn_{diff} is conceptually similar to M_{Diff} above, but relies on the median due to the positively skewed nature of Salary data. The statistic was computed by (a) computing the absolute difference between the target occupation's salary and the related occupation's salary for both the Starter and Change ROMs, and (b) computing the median difference across related occupations within overall or by Job Zone. We also computed the standard deviation of the differences (absolute difference between the target occupation's salary and the related occupation's salary) within each target occupation.

Once the computation of the above statistics for the Starter and Change ROMs was complete, we then determined whether the two ROMs were significantly different in their degree of overlap with the target occupation using non-parametric test statistics appropriate to the data under investigation. The results are reported below. We also conducted the same analyses on the pre-review Starter and Change ROMs. These are reported in Appendix C. The results for the pre-review ROMs reported in Appendix C are similar to the post-review ROMs reported below, though the results presented in the text are a bit more supportive of our hypotheses than the pre-review tables. Interested readers can consult Appendix C as these results are not discussed further in the body of this report.

Results

The results for the Job Family referent variable are consistent with our expectations, as reported in Table 4. We conducted the analyses for the full sample of 858 occupations and by Job Zone. Overall and across most Job Zones, the Change ROMs show more Job Family overlap with the target occupations than the Starter ROMs. Using a z-test of the difference in proportions,[11] this difference is statistically significant ($p < .05$) and in the correct direction for the overall sample of jobs and for four of the five job zones. For Job Zone 5 (Extensive Preparation Needed), the difference was statistically significant, but in the opposite direction of expectations (i.e., the overlap was higher for the Starter ROMs than the Change ROMs). A

[11] Degrees of freedom = the number of target occupations minus 1.

potential explanation for this finding is that the range of occupations is narrower in Zone 5, which may reduce the differentiating effect of the descriptors included in Change metric.

Table 4. Variability in Job Family Overall and by Job Zone

		p(Overlap)		Corrected p(Overlap)			
Occupation family in Target Occupation	*N*	Starter	Change	Starter	Change	Diff	*p(z)*
Overall	858	.44	.52	.41	.49	.08	<.001
1 – Little or No Preparation Needed	53	.29	.39	.26	.37	.11	<.001
2 – Some Preparation Needed	260	.44	.60	.41	.58	.17	<.001
3 – Medium Preparation Needed	240	.40	.49	.37	.46	.09	<.001
4 – Considerable Preparation Needed	176	.43	.51	.40	.49	.09	<.001
5 – Extensive Preparation Needed	129	.59	.47	.57	.44	-.13	<.001

Note. p(Overlap) = the proportion of related occupations whose O*NET Job Family is the same as the target occupation's O*NET Family. Corrected p(Overlap) is equivalent to Cohen's Kappa which corrects for the overlap that would occur randomly. The correction assumes that each occupation has an equal chance of being randomly selected. Target and related occupations without a job zone were excluded. Diff. = Starter corrected p(overlap) – Change corrected p(overlap). Coefficients in bold are significant ($p < .05$) using $p(z)$, where $p(z)$ = z-test comparing the difference in proportions between the Starter and Change overlap proportions.

Table 5 shows the results for the Salary referent variable, showing partial support for our hypothesis. For the overall sample of occupations, the Mdn_{diff} in Salary for the Change ROMs was significantly lower than the Mdn_{diff} in Salary for the Starter ROMs using a Wilcoxon signed rank test. However, the magnitude of the difference was quite small. When categorized by Job Zone, there were four statistically significant differences, but one of those four was opposite the theoretically expected direction (i.e., the difference was higher for the Change ROM than the Starter ROM). The largest differences were for the lower Job Zones. In all cases, the magnitude of the differences (as determined using a Cohen's d) was quite small, suggesting that salary may be affected by too many other factors to be consistently captured by the job and worker-oriented characteristics in the ROMs.

Table 5. Variability in Salary Overall and by Job Zone

	Starter			Change				
Job Zone	Mdn_{diff}	Mdn_{SD}	% ≥ .5 *SD*	Mdn_{diff}	Mdn_{SD}	% ≥ .5 *SD*	*d*	*p*
Overall	8,190	10,067	56.5	7,440	9,750	52.6	.05	<.001
1 – Little or No Preparation	3,810	5,130	54.0	2,750	3,260	40.0	.15	<.001
2 – Some Preparation	5,780	7,183	60.0	4,910	5,775	54.6	.10	<.001
3 – Medium Preparation	9,290	10,433	59.7	8,760	10,615	57.4	.04	.375
4 – Considerable Preparation	12,590	14,232	59.6	11,540	13,618	55.3	.01	.013
5 – Extensive Preparation	12,920	13,262	36.1	13,505	15,361	38.3	-.02	.014

Note. Medians rather than means (of absolute differences and standard deviations) were computed because of the highly-skewed nature of salary data. Mdn_{diff} = the median of the absolute differences between the target salary and its related occupation. Mdn_{SD} = the median, across target occupations, of the standard deviation (of Starter or Change salary minus target salary) across related occupations within a target occupation. % ≥ .5 *SD* = the percentage of times that a related occupation's salary is at least one-half a standard deviation (among target occupations within the job zone) different from the target occupation's salary. *d* = Cohen's *d*, or the standardized (using the standard deviation among target occupations within the job zone) mean difference in $|Mdn_{diff}|$ between the Starter and Change metrics; coefficients in bold were found to be statistically significant using the Wilcoxon signed rank test.

The results for the CIP Family referent variable overall and by Job Family are reported in Table 6. The results are consistent with expectations, with the Change ROMs yielding consistently higher p(Overlap) and Corrected p(Overlap) statistics than the Starter ROMs. This is true for the overall sample and for all but a few Job Families. Furthermore, the differences between the Starter and Change Corrected p(Overlap)

statistics was statistically significant ($p < .001$) in 45.5% of the Job Families (10 out of 22), using a z-test. This was despite low sample sizes in many of the individual Job Families. Across Job Families, the degree of p(Overlap) difference was much larger for some families (e.g., Construction and Extraction) than others. Perhaps very specific technical skills or knowledge required by some occupations are transferable to only a few occupations. In general, the occupation families with high Diff values appear to involve more specific technical skills and knowledge than occupation families with low or negative Diff values (e.g., Management, Office and Administrative Support).

Table 6. Variability in CIP Family Overall and by Job Family

		p(Overlap)		Corrected p(Overlap)			
Occupation family in Target Occupation	*N*	Starter	Change	Starter	Change	Diff	*p(z)*
Overall	803	.34	.46	.30	.43	.13	<.001
35 - Food Preparation and Serving Related	16	.45	.77	.40	.77	.37	<.001
23 - Legal	8	.00	.30	-.01	.29	.31	<.001
51 - Production	83	.26	.48	.19	.48	.28	<.001
47 - Construction and Extraction	54	.37	.63	.32	.59	.28	<.001
15 - Computer and Mathematical	23	.38	.63	.36	.62	.26	<.001
53 - Transportation and Material Moving	42	.24	.43	.20	.40	.20	<.001
33 - Protective Services	26	.34	.52	.30	.49	.20	<.001
37 - Building and Grounds Cleaning and Maintenance	6	.07	.22	.05	.20	.15	.018
19 - Life, Physical, and Social Science	53	.11	.25	.09	.23	.15	<.001
17 - Architecture and Engineering	52	.43	.55	.40	.53	.13	<.001
45 - Farming, Fishing, and Forestry	16	.14	.25	.09	.20	.11	.016
49 - Installation, Maintenance, and Repair	49	.32	.40	.27	.37	.10	.005
13 - Business and Financial Operations	41	.43	.51	.38	.47	.09	.012
25 - Education, Training, and Library	56	.26	.34	.22	.30	.08	.006
27 - Arts, Design, Entertainment, Sports, and Media	43	.16	.24	.14	.21	.07	.006
29 - Healthcare Practitioners and Technical	68	.56	.63	.54	.58	.05	.004
39 - Personal Care and Service	24	.24	.29	.22	.25	.04	.135
11 - Management	37	.31	.34	.27	.30	.03	.174
43 - Office and Administrative Support	58	.57	.58	.50	.52	.03	.332
41 - Sales and Related	21	.55	.54	.48	.47	-.01	.379
21 - Community and Social Services	13	.21	.21	.18	.16	-.02	.500
31 - Healthcare Support	14	.67	.60	.60	.56	-.04	.150

Note. p(Overlap) = the proportion of related occupations whose CIP family is the same as the target occupation's CIP family. Corrected p(Overlap) is equivalent to Cohen's Kappa which corrects for the overlap that would occur randomly. The correction assumes that each occupation has an equal chance of being randomly selected. Target and related occupations without a CIP or with a CIP of *Other* were excluded from analysis. Diff. = Starter corrected p(overlap) – Change corrected p(overlap Coefficients in bold are significant ($p < .05$) using $p(z)$, where $p(z)$ = z-test comparing the difference in proportions between the Starter and Change overlap proportions. The table is sorted in descending order of *Diff*.

Finally, we examined the Education, Experience, and On-Site Training referent variables in Table 7. The results for all three variables generally support our hypothesis that there will be larger differences between the target and related occupations when computed using the Starter algorithm than the Change algorithm. For the overall sample and by Job Family, there were consistently larger differences in the Starter ROM than the Change ROM, and the differences were often statistically significant using a dependent samples t-test. This was particularly true for the Education Level variable, which is not surprising given the role of Job Zone in the algorithm. Our hypothesis was not as strongly supported for the Work Experience and On-Site Training variables. Though the Starter ROM had a higher M_{Diff} values than the Change metric in the overall sample for both variables, the magnitude of this difference was fairly small (< .10). Additionally, the differences between the Starter and Change ROMs was statistically significant for

only 5 of the 22 Job Families for both variables, though this is higher than the number of significant differences we would expect by chance with a p-value of .05 (23% versus 5%), providing support for our hypothesis.

Taken with the qualitative review completed by independent analysts, these results support the use of the new Starter and Change ROMs for job transfer and career exploration, respectively. The overall pattern of results strongly suggests the Change ROMs are more closely aligned to the target occupations on key referent measures than the Starter ROMs. Though not definitive, this pattern of results suggests that the Starter and Change algorithms are matching occupations in a manner consistent with theoretical expectations.

V. Conclusions

In the present study, we updated O*NET's Related Occupations Matrix (ROM). We started by identifying the users of O*NET that would most benefit from a related occupations feature. This led to the development of two matrices: (a) a Change ROM, designed to assist users in locating jobs they can pursue with minimal additional preparation and (b) a Starter ROM, designed to assist users in locating jobs that would suit their interests, values, and capabilities. Different O*NET descriptor domains were used to create each set of related occupations. The Change related occupations relied on requirements-based and occupation-specific domains, including Job Zone, Knowledge, Skills, GWAs, and Work Context. The Starter related occupations relied more heavily on worker-oriented, occupation-invariant domains, including Abilities, Interests, Work Styles, and Work Values. We also tested a number of different similarity metrics before developing the final algorithms to create the ROMs. We then subjected the initial related occupations to a review task that further refined the ROM algorithms. Finally, we conducted a series of evaluation analyses to support the use of the ROMs in the O*NET system. The final set of related occupations can be found in Appendix D (separate volume).

We believe these new related occupations are an advancement of the related occupations currently in the O*NET system because the new related occupations (a) are tailored to specific user needs and (b) use new data (e.g., Job Zone) that were not available when the original related occupations were developed. The present report also establishes a procedure for updating the related occupations in the future as new data become available. Beyond the immediate task of updating the ROMs, we believe this research could be beneficial in other ways. For example, it demonstrates how O*NET information can be used by professionals to assist individuals with job transfer or career exploration. Because the data are publically available, the procedures described in this research could be used to create tailored related occupations for specific populations, such as the military, or for more specific purposes, such as career awareness (Drewes et al., 1999). This research could also inform professionals looking to use O*NET to help conducting synthetic validity or job clustering research.

Table 7. Variability in Education, Experience, and Training Levels Overall and by Job Family

		Education Level M_{Diff}				Experience Level M_{Diff}				On-Site Training M_{Diff}			
Occupation family	*N*	Sta.	Chg.	Diff.	*p*(*t*)	Sta.	Chg.	Diff.	*p*(*t*)	Sta.	Chg.	Diff.	*p*(*t*)
Overall	852	0.92	0.70	0.22	<.001	1.43	1.36	0.07	.001	1.08	0.99	0.09	<.001
11 - Management	37	1.04	0.72	0.32	<.001	1.22	1.01	0.21	.012	1.19	1.08	0.11	.078
13 - Business and Financial Operations	41	0.94	0.58	0.37	<.001	1.02	0.96	0.07	.417	0.99	0.99	0.00	.984
15 - Computer and Mathematical	22	0.83	0.65	0.18	.148	1.13	1.02	0.11	.142	1.25	1.15	0.10	.223
17 - Architecture and Engineering	52	0.83	0.53	0.29	<.001	1.15	1.08	0.07	.342	1.05	1.07	-0.02	.734
19 - Life, Physical, and Social Science	53	1.68	1.27	0.40	<.001	1.07	1.01	0.06	.253	1.17	1.18	0.00	.987
21 - Community and Social Services	13	1.58	1.50	0.08	.760	1.39	1.04	0.35	.036	1.07	1.06	0.01	.920
23 - Legal	7	2.65	1.99	0.65	.034	1.22	1.50	-0.27	.180	1.21	1.24	-0.03	.836
25 - Education, Training, and Library	56	1.26	1.26	0.00	.990	1.22	1.17	0.05	.486	1.00	0.95	0.06	.371
27 - Arts, Design, Entertainment, Sports, and Media	43	1.36	0.89	0.46	<.001	1.30	1.40	-0.11	.413	1.24	1.10	0.14	.099
29 - Healthcare Practitioners and Technical	68	1.28	0.99	0.29	.019	1.33	1.32	0.01	.936	1.06	0.91	0.16	.007
31 - Healthcare Support	15	1.02	0.98	0.05	.744	1.87	1.88	-0.01	.829	0.77	0.63	0.13	.195
33 - Protective Services	27	1.14	0.95	0.19	.047	1.97	2.00	-0.03	.809	1.02	0.97	0.06	.496
35 - Food Preparation and Serving Related	16	0.60	0.50	0.10	.149	1.20	1.41	-0.21	.317	0.56	0.31	0.25	.005
37 - Building and Grounds Cleaning and Maintenance	8	0.50	0.46	0.04	.588	2.11	2.22	-0.11	.686	0.92	0.87	0.05	.764
39 - Personal Care and Service	31	1.03	0.64	0.39	<.001	1.35	1.52	-0.17	.102	0.90	0.69	0.21	.001
41 - Sales and Related	21	0.81	0.55	0.26	.006	2.18	1.84	0.34	.105	0.75	0.80	-0.05	.551
43 - Office and Administrative Support	61	0.76	0.53	0.23	.001	1.59	1.44	0.15	.125	0.75	0.71	0.04	.207
45 - Farming, Fishing, and Forestry	17	0.93	0.73	0.20	.124	1.52	1.66	-0.14	.317	1.17	0.99	0.18	.080
47 - Construction and Extraction	57	0.40	0.35	0.05	.072	1.50	1.51	-0.01	.907	1.42	1.34	0.08	.167
49 - Installation, Maintenance, and Repair	51	0.63	0.50	0.14	.005	1.12	0.98	0.14	.043	1.40	1.39	0.01	.851
51 - Production	104	0.42	0.30	0.12	<.001	1.77	1.59	0.18	.009	1.06	0.89	0.17	<.001
53 - Transportation and Material Moving	52	0.65	0.42	0.23	<.001	1.80	1.59	0.22	.030	1.10	0.92	0.18	.003

Note. *Sta.* = Starter, *Chg.* = Change. M_{Diff} = The mean of the difference (within target occupation) in Education, Experience, and On-Site Training between the target and related occupation. Diff. = Starter M_{Diff} – Change M_{Diff}. *p*(*t*) = dependent t-test that the Starter and Change M_{Diff} values are the same; values less than $p < .05$ and in the theoretically expected direction are shaded in gray.

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Appendix A: O*NET Content Model Descriptors

*Table A.1. O*NET Abilities*

Ability	Definition
Cognitive Abilities	
Oral Comprehension	The ability to listen to and understand information and ideas presented through spoken words and sentences.
Written Comprehension	The ability to read and understand information and ideas presented in writing.
Oral Expression	The ability to communicate information and ideas in speaking so others will understand.
Written Expression	The ability to communicate information and ideas in writing so others will understand.
Fluency of Ideas	The ability to come up with a number of ideas about a topic (the number of ideas is important, not their quality, correctness, or creativity).
Originality	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem.
Problem Sensitivity	The ability to tell when something is wrong or is likely to go wrong. It does not involve solving the problem, only recognizing there is a problem.
Deductive Reasoning	The ability to apply general rules to specific problems to produce answers that make sense.
Inductive Reasoning	The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).
Information Ordering	The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations).
Category Flexibility	The ability to generate or use different sets of rules for combining or grouping things in different ways.
Mathematical Reasoning	The ability to choose the right mathematical methods or formulas to solve a problem.
Number Facility	The ability to add, subtract, multiply, or divide quickly and correctly.
Memorization	The ability to remember information such as words, numbers, pictures, and procedures.
Speed of Closure	The ability to quickly make sense of, combine, and organize information into meaningful patterns.
Flexibility of Closure	The ability to identify or detect a known pattern (a figure, object, word, or sound) that is hidden in other distracting material.
Perceptual Speed	The ability to quickly and accurately compare similarities and differences among sets of letters, numbers, objects, pictures, or patterns. The things to be compared may be presented at the same time or one after the other. This ability also includes comparing a presented object with a remembered object.
Spatial Orientation	The ability to know your location in relation to the environment or to know where other objects are in relation to you.
Visualization	The ability to imagine how something will look after it is moved around or when its parts are moved or rearranged.
Selective Attention	The ability to concentrate on a task over a period of time without being distracted.
Time Sharing	The ability to shift back and forth between two or more activities or sources of information (such as speech, sounds, touch, or other sources).
Psychomotor Abilities	
Arm-Hand Steadiness	The ability to keep your hand and arm steady while moving your arm or while holding your arm and hand in one position.

Table A.1. (Continued)

Ability	Definition
Manual Dexterity	The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.
Finger Dexterity	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects.
Control Precision	The ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions.
Multilimb Coordination	The ability to coordinate two or more limbs (for example, two arms, two legs, or one leg and one arm) while sitting, standing, or lying down. It does not involve performing the activities while the whole body is in motion.
Response Orientation	The ability to choose quickly between two or more movements in response to two or more different signals (lights, sounds, pictures). It includes the speed with which the correct response is started with the hand, foot, or other body part.
Rate Control	The ability to time your movements or the movement of a piece of equipment in anticipation of changes in the speed and/or direction of a moving object or scene.
Reaction Time	The ability to quickly respond (with the hand, finger, or foot) to a signal (sound, light, picture) when it appears.
Wrist-Finger Speed	The ability to make fast, simple, repeated movements of the fingers, hands, and wrists.
Speed of Limb Movement	The ability to quickly move the arms and legs.
Physical Abilities	
Static Strength	The ability to exert maximum muscle force to lift, push, pull, or carry objects.
Explosive Strength	The ability to use short bursts of muscle force to propel oneself (as in jumping or sprinting), or to throw an object.
Dynamic Strength	The ability to exert muscle force repeatedly or continuously over time. This involves muscular endurance and resistance to muscle fatigue.
Trunk Strength	The ability to use your abdominal and lower back muscles to support part of the body repeatedly or continuously over time without 'giving out' or fatiguing.
Stamina	The ability to exert yourself physically over long periods of time without getting winded or out of breath.
Extent Flexibility	The ability to bend, stretch, twist, or reach with your body, arms, and/or legs.
Dynamic Flexibility	The ability to quickly and repeatedly bend, stretch, twist, or reach out with your body, arms, and/or legs.
Gross Body Coordination	The ability to coordinate the movement of your arms, legs, and torso together when the whole body is in motion.
Gross Body Equilibrium	The ability to keep or regain your body balance or stay upright when in an unstable position.
Sensory Abilities	
Near Vision	The ability to see details at close range (within a few feet of the observer).
Far Vision	The ability to see details at a distance.
Visual Color Discrimination	The ability to match or detect differences between colors, including shades of color and brightness.
Night Vision	The ability to see under low light conditions.

Table A.1. (Continued)

Ability	Definition
Peripheral Vision	The ability to see objects or movement of objects to one's side when the eyes are looking ahead.
Depth Perception	The ability to judge which of several objects is closer or farther away from you, or to judge the distance between you and an object.
Glare Sensitivity	The ability to see objects in the presence of glare or bright lighting.
Hearing Sensitivity	The ability to detect or tell the differences between sounds that vary in pitch and loudness.
Auditory Attention	The ability to focus on a single source of sound in the presence of other distracting sounds.
Sound Localization	The ability to tell the direction from which a sound originated.
Speech Recognition	The ability to identify and understand the speech of another person.
Speech Clarity	The ability to speak clearly so others can understand you.

*Table A.2. O*NET Vocational Interests*

Interest	Definition
Realistic	Realistic occupations frequently involve work activities that include practical, hands-on problems and solutions. They often deal with plants, animals, and real-world materials like wood, tools, and machinery. Many of the occupations require working outside, and do not involve a lot of paperwork or working closely with others.
Investigative	Investigative occupations frequently involve working with ideas, and require an extensive amount of thinking. These occupations can involve searching for facts and figuring out problems mentally.
Artistic	Artistic occupations frequently involve working with forms, designs and patterns. They often require self-expression and the work can be done without following a clear set of rules.
Social	Social occupations frequently involve working with, communicating with, and teaching people. These occupations often involve helping or providing service to others.
Enterprising	Enterprising occupations frequently involve starting up and carrying out projects. These occupations can involve leading people and making many decisions. Sometimes they require risk taking and often deal with business.
Conventional	Conventional occupations frequently involve following set procedures and routines. These occupations can include working with data and details more than with ideas. Usually there is a clear line of authority to follow.

*Table A.3. O*NET Work Styles*

Work Style	Definition
Achievement Orientation	*Job requires personal goal setting, trying to succeed at those goals, and striving to be competent in own work*
Achievement/Effort	Job requires establishing and maintaining personally challenging achievement goals and exerting effort toward mastering tasks.
Persistence	Job requires persistence in the face of obstacles.
Initiative	Job requires a willingness to take on responsibilities and challenges.
Social Influence	*Job requires having an impact on others in the organization, and displaying energy and leadership*
Leadership	Job requires a willingness to lead, take charge, and offer opinions and direction.
Interpersonal Orientation	*Job requires being pleasant, cooperative, sensitive to others, easy to get along with, and having a preference for associating with other organization members*
Cooperation	Job requires being pleasant with others on the job and displaying a good-natured, cooperative attitude.
Concern for Others	Job requires being sensitive to others' needs and feelings and being understanding and helpful on the job.
Social Orientation	Job requires preferring to work with others rather than alone, and being personally connected with others on the job.
Adjustment	*Job requires maturity, poise, flexibility, and restraint to cope with pressure, stress, criticism, setbacks, personal and work-related problems, etc.*
Self Control	Job requires maintaining composure, keeping emotions in check, controlling anger, and avoiding aggressive behavior, even in very difficult situations.
Stress Tolerance	Job requires accepting criticism and dealing calmly and effectively with high stress situations.
Adaptability/Flexibility	Job requires being open to change (positive or negative) and to considerable variety in the workplace.
Conscientiousness	*Job requires dependability, commitment to doing the job correctly and carefully, and being trustworthy, accountable, and attentive to details*
Dependability	Job requires being reliable, responsible, and dependable, and fulfilling obligations.
Attention to Detail	Job requires being careful about detail and thorough in completing work tasks.
Integrity	Job requires being honest and ethical.
Independence	*Job requires developing one's own ways of doing things, guiding oneself with little or no supervision, and depending on oneself to get things done.*
Practical Intelligence	*Job requires generating useful ideas and thinking things through logically*
Innovation	Job requires creativity and alternative thinking to develop new ideas for and answers to work-related problems.
Analytical Thinking	Job requires analyzing information and using logic to address work-related issues and problems.

*Table A.4. O*NET Basic and Cross-Functional Skills*

Skill	Definition
Basic Skills	
Content	Background structures needed to work with and acquire more specific skills in a variety of different domains
Reading Comprehension	Understanding written sentences and paragraphs in work related documents.
Active Listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.
Writing	Communicating effectively in writing as appropriate for the needs of the audience.
Speaking	Talking to others to convey information effectively.
Mathematics	Using mathematics to solve problems.
Science	Using scientific rules and methods to solve problems.
Process	Procedures that contribute to the more rapid acquisition of knowledge and skill across a variety of domains
Critical Thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
Active Learning	Understanding the implications of new information for both current and future problem-solving and decision-making.
Learning Strategies	Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.
Monitoring	Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.
Cross-Functional Skills	
Social Skills	
Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
Coordination	Adjusting actions in relation to others' actions.
Persuasion	Persuading others to change their minds or behavior.
Negotiation	Bringing others together and trying to reconcile differences.
Instructing	Teaching others how to do something.
Service Orientation	Actively looking for ways to help people.
Complex Problem Solving Skills	
Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
Technical Skills	
Operations Analysis	Analyzing needs and product requirements to create a design.
Technology Design	Generating or adapting equipment and technology to serve user needs.
Equipment Selection	Determining the kind of tools and equipment needed to do a job.
Installation	Installing equipment, machines, wiring, or programs to meet specifications.
Programming	Writing computer programs for various purposes.

Table A.4. (Continued)

Skill	Definition
Operation Monitoring	Watching gauges, dials, or other indicators to make sure a machine is working properly.
Operation and Control	Controlling operations of equipment or systems.
Equipment Maintenance	Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
Troubleshooting	Determining causes of operating errors and deciding what to do about it.
Repairing	Repairing machines or systems using the needed tools.
Quality Control Analysis	Conducting tests and inspections of products, services, or processes to evaluate quality or performance.
Systems Skills	
Judgment and Decision Making	Considering the relative costs and benefits of potential actions to choose the most appropriate one.
Systems Analysis	Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.
Systems Evaluation	Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.
Resource Management Skills	
Time Management	Managing one's own time and the time of others.
Management of Financial Resources	Determining how money will be spent to get the work done, and accounting for these expenditures.
Management of Material Resources	Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work.
Management of Personnel Resources	Motivating, developing, and directing people as they work, identifying the best people for the job.

*Table A.5. O*NET Knowledges*

Knowledge	Definition
Business and Management	Knowledge of principles and facts related to business administration and accounting, human and material resource management in organizations, sales and marketing, economics, and office information and organizing systems
Administration and Management	Knowledge of business and management principles involved in strategic planning, resource allocation, human resources modeling, leadership technique, production methods, and coordination of people and resources.
Clerical	Knowledge of administrative and clerical procedures and systems such as word processing, managing files and records, stenography and transcription, designing forms, and other office procedures and terminology.
Economics and Accounting	Knowledge of economic and accounting principles and practices, the financial markets, banking and the analysis and reporting of financial data.
Sales and Marketing	Knowledge of principles and methods for showing, promoting, and selling products or services. This includes marketing strategy and tactics, product demonstration, sales techniques, and sales control systems.
Customer and Personal Service	Knowledge of principles and processes for providing customer and personal services. This includes customer needs assessment, meeting quality standards for services, and evaluation of customer satisfaction.
Personnel and Human Resources	Knowledge of principles and procedures for personnel recruitment, selection, training, compensation and benefits, labor relations and negotiation, and personnel information systems.
Manufacturing and Production	Knowledge of principles and facts related to the production, processing, storage, and distribution of manufactured and agricultural goods
Production and Processing	Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.
Food Production	Knowledge of techniques and equipment for planting, growing, and harvesting food products (both plant and animal) for consumption, including storage/handling techniques.
Engineering and Technology	Knowledge of the design, development, and application of technology for specific purposes.
Computers and Electronics	Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.
Engineering and Technology	Knowledge of the practical application of engineering science and technology. This includes applying principles, techniques, procedures, and equipment to the design and production of various goods and services.
Design	Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.
Building and Construction	Knowledge of materials, methods, and the tools involved in the construction or repair of houses, buildings, or other structures such as highways and roads.
Mechanical	Knowledge of machines and tools, including their designs, uses, repair, and maintenance.
Mathematics and Science	Knowledge of the history, theories, methods, and applications of the physical, biological, social, mathematical, and geography
Mathematics	Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.
Physics	Knowledge and prediction of physical principles, laws, their interrelationships, and applications to understanding fluid, material, and atmospheric dynamics, and mechanical, electrical, atomic and sub- atomic structures and processes.

Table A.5. (Continued)

Knowledge	Definition
Chemistry	Knowledge of the chemical composition, structure, and properties of substances and of the chemical processes and transformations that they undergo. This includes uses of chemicals and their interactions, danger signs, production techniques, and disposal methods.
Biology	Knowledge of plant and animal organisms, their tissues, cells, functions, interdependencies, and interactions with each other and the environment.
Psychology	Knowledge of human behavior and performance; individual differences in ability, personality, and interests; learning and motivation; psychological research methods; and the assessment and treatment of behavioral and affective disorders.
Sociology and Anthropology	Knowledge of group behavior and dynamics, societal trends and influences, human migrations, ethnicity, cultures and their history and origins.
Geography	Knowledge of principles and methods for describing the features of land, sea, and air masses, including their physical characteristics, locations, interrelationships, and distribution of plant, animal, and human life.
Health Services	Knowledge of principles and facts regarding diagnosing, curing, and preventing disease, and improving and preserving physical and mental health and well-being
Medicine and Dentistry	Knowledge of the information and techniques needed to diagnose and treat human injuries, diseases, and deformities. This includes symptoms, treatment alternatives, drug properties and interactions, and preventive health-care measures.
Therapy and Counseling	Knowledge of principles, methods, and procedures for diagnosis, treatment, and rehabilitation of physical and mental dysfunctions, and for career counseling and guidance.
Education and Training	Knowledge of principles and methods for curriculum and training design, teaching and instruction for individuals and groups, and the measurement of training effects.
Arts and Humanities	Knowledge of facts and principles related to the branches of learning concerned with human thought, language, and the arts.
English Language	Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.
Foreign Language	Knowledge of the structure and content of a foreign (non-English) language including the meaning and spelling of words, rules of composition and grammar, and pronunciation.
Fine Arts	Knowledge of the theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama, and sculpture.
History and Archeology	Knowledge of historical events and their causes, indicators, and effects on civilizations and cultures.
Philosophy and Theology	Knowledge of different philosophical systems and religions. This includes their basic principles, values, ethics, ways of thinking, customs, practices, and their impact on human culture.
Law and Public Safety	Knowledge of regulations and methods for maintaining people and property free from danger, injury, or damage; the rules of public conduct established and enforced by legislation, and the political process establishing such rules.
Public Safety and Security	Knowledge of relevant equipment, policies, procedures, and strategies to promote effective local, state, or national security operations for the protection of people, data, property, and institutions.
Law and Government	Knowledge of laws, legal codes, court procedures, precedents, government regulations, executive orders, agency rules, and the democratic political process.

Table A.5. (Continued)

Knowledge	Definition
Communications	Knowledge of the science and art of delivering information
Telecommunications	Knowledge of transmission, broadcasting, switching, control, and operation of telecommunications systems.
Communications and Media	Knowledge of media production, communication, and dissemination techniques and methods. This includes alternative ways to inform and entertain via written, oral, and visual media.
Transportation	Knowledge of principles and methods for moving people or goods by air, rail, sea, or road, including the relative costs and benefits.

Table A.6. Generalized Work Activities (GWAs)

GWA	Definition
Information Input	
Getting Information	Observing, receiving, and otherwise obtaining information from all relevant sources.
Monitor Processes, Materials, or Surroundings	Monitoring and reviewing information from materials, events, or the environment, to detect or assess problems.
Identifying Objects, Actions, and Events	Identifying information by categorizing, estimating, recognizing differences or similarities, and detecting changes in circumstances or events.
Inspecting Equipment, Structures, or Material	Inspecting equipment, structures, or materials to identify the cause of errors or other problems or defects.
Estimating the Quantifiable Characteristics of Products, Events, or Information	Estimating sizes, distances, and quantities; or determining time, costs, resources, or materials needed to perform a work activity.
Mental Processes	
Judging the Qualities of Things, Services, or People	Assessing the value, importance, or quality of things or people.
Processing Information	Compiling, coding, categorizing, calculating, tabulating, auditing, or verifying information or data.
Evaluating Information to Determine Compliance with Standards	Using relevant information and individual judgment to determine whether events or processes comply with laws, regulations, or standards.
Analyzing Data or Information	Identifying the underlying principles, reasons, or facts of information by breaking down information or data into separate parts.
Making Decisions and Solving Problems	Analyzing information and evaluating results to choose the best solution and solve problems.
Thinking Creatively	Developing, designing, or creating new applications, ideas, relationships, systems, or products, including artistic contributions.
Updating and Using Relevant Knowledge	Keeping up-to-date technically and applying new knowledge to your job.
Developing Objectives and Strategies	Establishing long-range objectives and specifying the strategies and actions to achieve them.
Scheduling Work and Activities	Scheduling events, programs, and activities, as well as the work of others.
Organizing, Planning, and Prioritizing Work	Developing specific goals and plans to prioritize, organize, and accomplish your work.
Work Output	
Performing General Physical Activities	Performing physical activities that require considerable use of your arms and legs and moving your whole body, such as climbing, lifting, balancing, walking, stooping, and handling of materials.
Handling and Moving Objects	Using hands and arms in handling, installing, positioning, and moving materials, and manipulating things.
Controlling Machines and Processes	Using either control mechanisms or direct physical activity to operate machines or processes (not including computers or vehicles).
Operating Vehicles, Mechanized Devices, or Equipment	Running, maneuvering, navigating, or driving vehicles or mechanized equipment, such as forklifts, passenger vehicles, aircraft, or water craft.

Table A.6. (Continued)

GWA	Definition
Interacting With Computers	Using computers and computer systems (including hardware and software) to program, write software, set up functions, enter data, or process information.
Drafting, Laying Out, and Specifying Technical Devices, Parts, and Equipment	Providing documentation, detailed instructions, drawings, or specifications to tell others about how devices, parts, equipment, or structures are to be fabricated, constructed, assembled, modified, maintained, or used.
Repairing and Maintaining Mechanical Equipment	Servicing, repairing, adjusting, and testing machines, devices, moving parts, and equipment that operate primarily on the basis of mechanical (not electronic) principles.
Repairing and Maintaining Electronic Equipment	Servicing, repairing, calibrating, regulating, fine-tuning, or testing machines, devices, and equipment that operate primarily on the basis of electrical or electronic (not mechanical) principles.
Documenting/Recording Information	Entering, transcribing, recording, storing, or maintaining information in written or electronic/magnetic form.
Interacting With Others	
Interpreting the Meaning of Information for Others	Translating or explaining what information means and how it can be used.
Communicating with Supervisors, Peers, or Subordinates	Providing information to supervisors, co-workers, and subordinates by telephone, in written form, e-mail, or in person.
Communicating with Persons Outside Organization	Communicating with people outside the organization, representing the organization to customers, the public, government, and other external sources. This information can be exchanged in person, in writing, or by telephone or e-mail.
Establishing and Maintaining Interpersonal Relationships	Developing constructive and cooperative working relationships with others, and maintaining them over time.
Assisting and Caring for Others	Providing personal assistance, medical attention, emotional support, or other personal care to others such as coworkers, customers, or patients.
Selling or Influencing Others	Convincing others to buy merchandise/goods or to otherwise change their minds or actions.
Resolving Conflicts and Negotiating with Others	Handling complaints, settling disputes, and resolving grievances and conflicts, or otherwise negotiating with others.
Performing for or Working Directly with the Public	Performing for people or dealing directly with the public. This includes serving customers in restaurants and stores, and receiving clients or guests.
Coordinating the Work and Activities of Others	Getting members of a group to work together to accomplish tasks.
Developing and Building Teams	Encouraging and building mutual trust, respect, and cooperation among team members.
Training and Teaching Others	Identifying the educational needs of others, developing formal educational or training programs or classes, and teaching or instructing others.
Guiding, Directing, and Motivating Subordinates	Providing guidance and direction to subordinates, including setting performance standards and monitoring performance.
Coaching and Developing Others	Identifying the developmental needs of others and coaching, mentoring, or otherwise helping others to improve their knowledge or skills.
Provide Consultation and Advice to Others	Providing guidance and expert advice to management or other groups on technical, systems-, or process-related topics.

Table A.6. (Continued)

GWA	Definition
Performing Administrative Activities	Performing day-to-day administrative tasks such as maintaining information files and processing paperwork.
Staffing Organizational Units	Recruiting, interviewing, selecting, hiring, and promoting employees in an organization.
Monitoring and Controlling Resources	Monitoring and controlling resources and overseeing the spending of money.

*Table A.7. O*NET Work Values*

Work Value	Definition
Achievement	Occupations that satisfy this work value are results oriented and allow employees to use their strongest abilities, giving them a feeling of accomplishment. Corresponding needs are Ability Utilization and Achievement.
Working Conditions	Occupations that satisfy this work value offer job security and good working conditions. Corresponding needs are Activity, Compensation, Independence, Security, Variety and Working Conditions.
Recognition	Occupations that satisfy this work value offer advancement, potential for leadership, and are often considered prestigious. Corresponding needs are Advancement, Authority, Recognition and Social Status.
Relationships	Occupations that satisfy this work value allow employees to provide service to others and work with co-workers in a friendly non-competitive environment. Corresponding needs are Co-workers, Moral Values and Social Service.
Support	Occupations that satisfy this work value offer supportive management that stands behind employees. Corresponding needs are Company Policies, Supervision: Human Relations and Supervision: Technical.
Independence	Occupations that satisfy this work value allow employees to work on their own and make decisions. Corresponding needs are Creativity, Responsibility and Autonomy.

*Table A.8. O*NET Work Context*

Work Context	Definition
Public Speaking	How often do you have to perform public speaking in this job?
Telephone	How often do you have telephone conversations in this job?
Electronic Mail	How often do you use electronic mail in this job?
Letters and Memos	How often does the job require written letters and memos?
Face-to-Face Discussions	How often do you have to have face-to-face discussions with individuals or teams in this job?
Contact With Others	How much does this job require the worker to be in contact with others (face-to-face, by telephone, or otherwise) in order to perform it?
Work With Work Group or Team	How important is it to work with others in a group or team in this job?
Deal With External Customers	How important is it to work with external customers or the public in this job?
Coordinate or Lead Others	How important is it to coordinate or lead others in accomplishing work activities in this job?
Responsible for Others' Health and Safety	How much responsibility is there for the health and safety of others in this job?
Responsibility for Outcomes and Results	How responsible is the worker for work outcomes and results of other workers?
Frequency of Conflict Situations	How often are there conflict situations the employee has to face in this job?
Deal With Unpleasant or Angry People	How frequently does the worker have to deal with unpleasant, angry, or discourteous individuals as part of the job requirements?
Deal With Physically Aggressive People	How frequently does this job require the worker to deal with physical aggression of violent individuals?
Indoors, Environmentally Controlled	How often does this job require working indoors in environmentally controlled conditions?
Indoors, Not Environmentally Controlled	How often does this job require working indoors in non-controlled environmental conditions (e.g., warehouse without heat)?
Outdoors, Exposed to Weather	How often does this job require working outdoors, exposed to all weather conditions?
Outdoors, Under Cover	How often does this job require working outdoors, under cover (e.g., structure with roof but no walls)?
In an Open Vehicle or Equipment	How often does this job require working in an open vehicle or equipment (e.g., tractor)?
In an Enclosed Vehicle or Equipment	How often does this job require working in a closed vehicle or equipment (e.g., car)?
Physical Proximity	To what extent does this job require the worker to perform job tasks in close physical proximity to other people?
Sounds, Noise Levels Are Distracting or Uncomfortable	How often does this job require working exposed to sounds and noise levels that are distracting or uncomfortable?
Very Hot or Cold Temperatures	How often does this job require working in very hot (above 90 F degrees) or very cold (below 32 F degrees) temperatures?
Extremely Bright or Inadequate Lighting	How often does this job require working in extremely bright or inadequate lighting conditions?

Table A.8. (Continued)

Work Context	Definition
Exposed to Contaminants	How often does this job require working exposed to contaminants (such as pollutants, gases, dust or odors)?
Cramped Work Space, Awkward Positions	How often does this job require working in cramped work spaces that requires getting into awkward positions?
Exposed to Whole Body Vibration	How often does this job require exposure to whole body vibration (e.g., operate a jackhammer)?
Exposed to Radiation	How often does this job require exposure to radiation?
Exposed to High Places	How often does this job require exposure to high places?
Exposed to Hazardous Conditions	How often does this job require exposure to hazardous conditions?
Exposed to Hazardous Equipment	How often does this job require exposure to hazardous equipment?
Exposed to Minor Burns, Cuts, Bites, or Stings	How often does this job require exposure to minor burns, cuts, bites, or stings?
Spend Time Sitting	How much does this job require sitting?
Spend Time Standing	How much does this job require standing?
Spend Time Climbing Ladders, Scaffolds, or Poles	How much does this job require climbing ladders, scaffolds, or poles?
Spend Time Walking and Running	How much does this job require walking and running?
Spend Time Keeping or Regaining Balance	How much does this job require keeping or regaining your balance?
Spend Time Using Your Hands to Handle, Control, or Feel Objects, Tools, or Controls	How much does this job require using your hands to handle, control, or feel objects, tools or controls?
Spend Time Bending or Twisting the Body	How much does this job require bending or twisting your body?
Spend Time Making Repetitive Motions	How much does this job require making repetitive motions?
Wear Common Protective or Safety Equipment such as Safety Shoes, Glasses, Gloves, Hearing Protection, Hard Hats, or Life Jackets	How much does this job require wearing common protective or safety equipment such as safety shoes, glasses, gloves, hard hats or life jackets?
Wear Specialized Protective or Safety Equipment such as Breathing Apparatus, Safety Harness, Full Protection Suits, or Radiation Protection	How much does this job require wearing specialized protective or safety equipment such as breathing apparatus, safety harness, full protection suits, or radiation protection?
Consequence of Error	How serious would the result usually be if the worker made a mistake that was not readily correctable?
Impact of Decisions on Co-workers or Company Results	How do the decisions an employee makes impact the results of co-workers, clients or the company?
Frequency of Decision Making	How frequently is the worker required to make decisions that affect other people, the financial resources, and/or the image and reputation of the organization?
Freedom to Make Decisions	How much decision making freedom, without supervision, does the job offer?
Degree of Automation	How automated is the job?
Importance of Being Exact or Accurate	How important is being very exact or highly accurate in performing this job?

Table A.8. (Continued)

Work Context	Definition
Importance of Repeating Same Tasks	How important is repeating the same physical activities (e.g., key entry) or mental activities (e.g., checking entries in a ledger) over and over, without stopping, to performing this job?
Structured versus Unstructured Work	To what extent is this job structured for the worker, rather than allowing the worker to determine tasks, priorities, and goals?
Level of Competition	To what extent does this job require the worker to compete or to be aware of competitive pressures?
Time Pressure	How often does this job require the worker to meet strict deadlines?
Pace Determined by Speed of Equipment	How important is it to this job that the pace is determined by the speed of equipment or machinery? (This does not refer to keeping busy at all times on this job.)

Appendix B: Detailed Computation of Starter and Change ROM Algorithms

The first step in conducting the analyses is to construct ratings tables for the O*NET descriptor domains included in the algorithms and create a separate table for each.[12] The Starter algorithm relies on different descriptor domains than the Change algorithm—there is no overlap between the two. Table B.1 below shows which descriptor domains and scales to include in computing each ROM.

Table B.1. Scales and Abbreviations Used for the Starter and Change Analyses

Descriptor Domain	Starter	Change
Abilities	Importance (IM) Level (LV)	
Work Context		Context (CX)
Interests	Interest (OI)	
Knowledge		IM, LV
Skills		IM, LV
Work Styles	IM	
Work Values	Value (EX)	
GWAs		IM, LV
Job Zone		Job Zone (JZ)

Note. If an occupation was missing data for any of the above descriptor domains, it was excluded from the Starter and Change ROM computations.

Once the tables have been obtained, the Starter and Change ROMs can be computed with the following steps:

Step 1. Obtain the values for the descriptors within each domain (e.g., Abilities). These are the average ratings (among incumbents, analysts, or occupational experts depending on the descriptor domain). In the O*NET datafiles, this field is typically called "Data Value." Illustrative examples for three Work Context elements and three Skill elements for 15 fictional occupations are reported in Table B.2.[13]

Step 2. For the four descriptor domains that include both Importance and Level ratings, compute the average of the two scores to create one score per descriptor (as shown in Table B.1 above). Take the average value of Importance and Level to arrive at a single rating. For the 15 fictional occupations in Table B.2, the average of the Skill Importance and Level ratings are illustrated in Table B.3.

Step 3. Create ratings tables for each descriptor domain where the rows are occupations and the columns are individual descriptors (which are called *elements* in the O*NET data files). These tables should look something like Table B.3, but include *all* of the elements for that domain and *all* of the target occupations.

[12] Data can be obtained from the O*NET Resource Center Production Database page; http://www.onetcenter.org/database.html. The O*NET data files have one record (i.e., row) per element. The data should be rearranged so that each element is in a separate field (i.e., column), similar to Table B.2.

[13] For simplicity in computation, we have made all of the elements whole numbers.

Table B.2. Illustrative Work Context and Skill Ratings

	Work Context			Skill - Importance Rating			Skill - Level Rating		
Occupation	Public Speaking	Outdoors Exposed	Electronic Mail	Reading Compreh.	Math-ematics	Instructing	Reading Compreh.	Math-ematics	Instructing
Occ01	1	3	6	3	5	2	7	0	4
Occ02	3	5	1	5	5	2	5	2	7
Occ03	5	6	6	4	4	1	3	4	3
Occ04	4	1	1	1	1	4	5	2	5
Occ05	3	2	1	1	5	4	4	2	4
Occ06	6	6	1	1	5	5	6	6	1
Occ07	5	2	4	4	1	3	1	7	0
Occ08	5	5	3	3	3	1	1	4	7
Occ09	2	3	4	3	2	2	7	4	6
Occ10	6	5	1	5	2	4	3	3	1
Occ11	3	4	6	3	1	2	1	7	5
Occ12	1	5	6	5	3	4	1	2	4
Occ13	4	3	2	1	3	2	1	2	3
Occ14	2	6	6	1	5	3	1	6	4
Occ15	1	2	2	3	2	3	3	3	0

Table B.3. Illustrative Averaged Skill Ratings

	Skill - Averaged		
Occupation	Public Speaking	Outdoors Exposed	Electronic Mail
Occ01	5.0	2.5	3.0
Occ02	5.0	3.5	4.5
Occ03	3.5	4.0	2.0
Occ04	3.0	1.5	4.5
Occ05	2.5	3.5	4.0
Occ06	3.5	5.5	3.0
Occ07	2.5	4.0	1.5
Occ08	2.0	3.5	4.0
Occ09	5.0	3.0	4.0
Occ10	4.0	2.5	2.5
Occ11	2.0	4.0	3.5
Occ12	3.0	2.5	4.0
Occ13	1.0	2.5	2.5
Occ14	1.0	5.5	3.5
Occ15	3.0	2.5	1.5

Step 4. Compute the Euclidean distance between each pair of occupations. In the formula for Euclidean distance shown below, *d* = Euclidean distance, *i* = the characteristic (e.g., Reading Comprehension, Mathematics, Instructing), *k* = the number of descriptors, *x* and *y* are the two occupations. Though the expression is slightly different for illustrative purposes, this is the same formula as Formula 1 in the body of the report.

$$d(x,y) = \sqrt{\sum_{i=1}^{k}(x_i - y_i)^2} \tag{8}$$

In the example below, using just the numbers for Occupations 1 and 3 in Table B.3, the Euclidean distance between the two occupations is:

$$d = \sqrt{(5.0 - 3.5)^2 + (2.5 - 4.0)^2 + (3.0 - 2.0)^2} = 2.35 \tag{9}$$

When *d* is computed for all possible pairs of occupations, the result is an $n \times n$ distance table, where n = the number of occupations. In other words, the rows and columns are occupations, and the value in each cell is the Euclidean distance between the pair of occupations. For the 15 fictional occupations described above, these matrices are illustrated in Table B.4.

Table B.4. Illustrative Work Context and Skill Distance Table

	Occ01	Occ02	Occ03	Occ04	Occ05	Occ06	Occ07	Occ08	Occ09	Occ10	Occ11	Occ12	Occ13	Occ14	Occ15
Occ01	-	1.80	2.35	2.69	2.87	3.35	3.28	3.32	1.12	1.12	3.39	2.24	4.03	5.02	2.50
Occ02	5.74	-	2.96	2.83	2.55	2.92	3.94	3.04	0.71	2.45	3.20	2.29	4.58	4.58	3.74
Occ03	5.00	5.48	-	3.57	2.29	1.80	1.12	2.55	2.69	1.66	2.12	2.55	2.96	3.28	1.66
Occ04	6.16	4.12	7.14	-	2.12	4.30	3.94	2.29	2.55	2.45	2.87	1.12	3.00	4.58	3.16
Occ05	5.48	3.00	6.71	1.41	-	2.45	2.55	0.50	2.55	2.35	0.87	1.12	2.35	2.55	2.74
Occ06	7.68	3.16	5.10	5.39	5.00	-	2.35	2.69	3.08	3.08	2.18	3.20	3.94	2.55	3.39
Occ07	4.58	4.69	4.47	3.32	3.61	5.10	-	2.60	3.67	2.35	2.06	2.96	2.35	2.92	1.58
Occ08	5.39	2.83	3.16	4.58	4.12	2.45	3.16	-	3.04	2.69	0.71	1.41	2.06	2.29	2.87
Occ09	2.24	3.74	4.69	4.12	3.32	5.83	3.16	3.74	-	1.87	3.20	2.06	4.30	4.74	3.24
Occ10	7.35	3.00	5.20	4.47	4.24	1.00	4.36	2.24	5.39	-	2.69	1.80	3.00	4.36	1.41
Occ11	2.24	5.10	2.83	5.92	5.39	6.16	3.46	3.74	2.45	5.92	-	1.87	2.06	1.80	2.69
Occ12	2.00	5.39	4.12	7.07	6.16	7.14	5.39	5.00	3.00	7.07	2.24	-	2.50	3.64	2.50
Occ13	5.00	2.45	5.10	2.24	1.73	3.74	2.45	2.45	2.83	3.00	4.24	5.39	-	3.16	2.24
Occ14	3.16	5.20	3.00	7.35	6.48	6.40	5.39	4.36	3.61	6.48	2.24	1.41	5.39	-	4.12
Occ15	4.12	3.74	6.93	3.32	2.24	6.48	4.47	5.10	2.45	5.92	4.90	5.00	3.16	5.74	-

Note. To conserve space, both the Work Context and Skill results are presented in the same table. The Work Context results are below the diagonal and the Skill results are above the diagonal. The computation for the shaded cell is illustrated in Formula 9.

Step 5. Convert each distance table into standard scores (i.e., z-scores). Because different scales are used for different O*NET descriptor domains, each must be set to a common scale in preparation for combining distance results in Step 6.

To accomplish this, compute the mean and standard deviation (*SD*) across all values within the descriptor domain's distance table. In Table B.4, the lower triangle represents the Work Context distance results and upper triangle represents the Skill distance results. In the example above, compute the mean and *SD* for the lower triangle, then the upper triangle. For Work Context, the mean of the elements in Table B.4 is 4.37 and the SD is 1.57, while for Skills, the mean is 2.67 and the SD is 0.93.[14] Once this is complete, each distance value can be converted into a *z*-score using the formula below:

$$z = (d - Mean) / SD \quad (10)$$

The results of this procedure for the 15 fictional occupations are reported in Table B.5. In Formula 11, we standardize the *d* reported in Formula 9.

$$z = (2.35 - 2.67) / 0.93 = 0.40 \quad (11)$$

[14] Due to rounding error, computing the numbers by hand using Table B.4 will not yield the same SD for the Skills distance results.

Note that Job Zone has a weight of 1.3 while the other characteristics have a weight of 1.0. Therefore, when trying to replicate the Change algorithm described in the body of the report, multiply the values in the Job Zone *z*-scores table by 1.3.

Table B.5. Illustrative Work Context and Skill Standardized Distance Table

	Occ01	Occ02	Occ03	Occ04	Occ05	Occ06	Occ07	Occ08	Occ09	Occ10	Occ11	Occ12	Occ13	Occ14	Occ15
Occ01	-	-0.94	-0.35	0.02	0.21	0.73	0.65	0.69	-1.67	-1.67	0.77	-0.47	1.46	2.53	-0.19
Occ02	0.88	-	0.30	0.17	-0.13	0.26	1.36	0.39	-2.11	-0.24	0.57	-0.41	2.05	2.05	1.15
Occ03	0.40	0.71	-	0.96	-0.41	-0.94	-1.67	-0.13	0.02	-1.09	-0.59	-0.13	0.30	0.65	-1.09
Occ04	1.14	-0.15	1.76	-	-0.59	1.75	1.36	-0.41	-0.13	-0.24	0.21	-1.67	0.35	2.05	0.52
Occ05	0.71	-0.87	1.49	-1.88	-	-0.24	-0.13	-2.34	-0.13	-0.35	-1.94	-1.67	-0.35	-0.13	0.07
Occ06	2.11	-0.77	0.47	0.65	0.40	-	-0.35	0.02	0.44	0.44	-0.53	0.57	1.36	-0.13	0.77
Occ07	0.14	0.21	0.07	-0.67	-0.48	0.47	-	-0.08	1.07	-0.35	-0.66	0.30	-0.35	0.26	-1.18
Occ08	0.65	-0.98	-0.77	0.14	-0.15	-1.22	-0.77	-	0.39	0.02	-2.11	-1.35	-0.66	-0.41	0.21
Occ09	-1.35	-0.40	0.21	-0.15	-0.67	0.93	-0.77	-0.40	-	-0.86	0.57	-0.66	1.75	2.22	0.61
Occ10	1.89	-0.87	0.53	0.07	-0.08	-2.14	-0.01	-1.35	0.65	-	0.02	-0.94	0.35	1.81	-1.35
Occ11	-1.35	0.47	-0.98	0.98	0.65	1.14	-0.57	-0.40	-1.22	0.98	-	-0.86	-0.66	-0.94	0.02
Occ12	-1.50	0.65	-0.15	1.72	1.14	1.76	0.65	0.40	-0.87	1.72	-1.35	-	-0.19	1.04	-0.19
Occ13	0.40	-1.22	0.47	-1.35	-1.67	-0.40	-1.22	-1.22	-0.98	-0.87	-0.08	0.65	-	0.52	-0.47
Occ14	-0.77	0.53	-0.87	1.89	1.34	1.29	0.65	-0.01	-0.48	1.34	-1.35	-1.88	0.65	-	1.56
Occ15	-0.15	-0.40	1.63	-0.67	-1.35	1.34	0.07	0.47	-1.22	0.98	0.34	0.40	-0.77	0.88	-

Note. These are standardized values. Thus, a value of zero does not represent a distance of zero. Large negative values represent small distances, large positive values represent large distances, and values near zero represent intermediate distances. To conserve space, both the Work Context and Skill results are presented in the same table. The Work Context results are below the diagonal and the Skill results are above the diagonal. The computation for the shaded cell is illustrated in Formula 11.

Step 6. *Average the distance tables across O*NET descriptor domains*. Do this cell-by-cell. For example, compute the value for cell (2,1) in the average table by computing the average of the (2,1) values in all the z-score tables. The result is still an $n \times n$ table. If replicating the Change algorithm, average the following distance elements: Work Context, Knowledges, Skills, GWA, and Job Zone (with the elements multiplied by 1.3). If replicating the Starter algorithm, average only the following distance elements: Ability, Interests, Work Styles, and Work Values. For the 15 fictional occupations, the results of this combination are reported in Table B.6.

Step 7. *Compute rank order of the related occupations*. The lower the cell's value, the more closely related the two occupations. For the first row (i.e., first target occupation), find the lowest value in the row. That cell represents a rank of 1. The corresponding occupation in the column is the target occupation's most-closely related occupation. The occupation with the lowest value in each row is shaded in Table B.6.

Step 8. *List the top 10 related occupations for each target occupation*. To record the related occupations, create a table with 10 rows for each target occupation. Output the 10 related occupations with the smallest average distance values (computed in Step 6) to each row.

Complete Steps 1 through 8 for the full O*NET descriptor domains described in Table B.1 to replicate the initial set of Starter and Change related occupations. This list was modified based on a rational review.

Table B.6. Average of Work Context and Skill Distance Tables

	Occ01	Occ02	Occ03	Occ04	Occ05	Occ06	Occ07	Occ08	Occ09	Occ10	Occ11	Occ12	Occ13	Occ14	Occ15
Occ01	-	-0.94	-0.35	0.02	0.21	0.73	0.65	0.69	-1.67	-1.67	0.77	-0.47	1.46	2.53	-0.19
Occ02	-0.94	-	0.30	0.17	-0.13	0.26	1.36	0.39	-2.11	-0.24	0.57	-0.41	2.05	2.05	1.15
Occ03	-0.35	0.30	-	0.96	-0.41	-0.94	-1.67	-0.13	0.02	-1.09	-0.59	-0.13	0.30	0.65	-1.09
Occ04	0.02	0.17	0.96	-	-0.59	1.75	1.36	-0.41	-0.13	-0.24	0.21	-1.67	0.35	2.05	0.52
Occ05	0.21	-0.13	-0.41	-0.59	-	-0.24	-0.13	-2.34	-0.13	-0.35	-1.94	-1.67	-0.35	-0.13	0.07
Occ06	0.73	0.26	-0.94	1.75	-0.24	-	-0.35	0.02	0.44	0.44	-0.53	0.57	1.36	-0.13	0.77
Occ07	0.65	1.36	-1.67	1.36	-0.13	-0.35	-	-0.08	1.07	-0.35	-0.66	0.30	-0.35	0.26	-1.18
Occ08	0.69	0.39	-0.13	-0.41	-2.34	0.02	-0.08	-	0.39	0.02	-2.11	-1.35	-0.66	-0.41	0.21
Occ09	-1.67	-2.11	0.02	-0.13	-0.13	0.44	1.07	0.39	-	-0.86	0.57	-0.66	1.75	2.22	0.61
Occ10	-1.67	-0.24	-1.09	-0.24	-0.35	0.44	-0.35	0.02	-0.86	-	0.02	-0.94	0.35	1.81	-1.35
Occ11	0.77	0.57	-0.59	0.21	-1.94	-0.53	-0.66	-2.11	0.57	0.02	-	-0.86	-0.66	-0.94	0.02
Occ12	-0.47	-0.41	-0.13	-1.67	-1.67	0.57	0.30	-1.35	-0.66	-0.94	-0.86	-	-0.19	1.04	-0.19
Occ13	1.46	2.05	0.30	0.35	-0.35	1.36	-0.35	-0.66	1.75	0.35	-0.66	-0.19	-	0.52	-0.47
Occ14	2.53	2.05	0.65	2.05	-0.13	-0.13	0.26	-0.41	2.22	1.81	-0.94	1.04	0.52	-	1.56
Occ15	-0.19	1.15	-1.09	0.52	0.07	0.77	-1.18	0.21	0.61	-1.35	0.02	-0.19	-0.47	1.56	-

Note. These are standardized values. Thus, a value of zero does not represent a distance of zero. Large negative values represent small distances, large positive values represent large distances, and values near zero represent intermediate distances. The lowest value in each row is shaded. Note that three occupations have two occupations tied for the lowest value.

Appendix C: Pre-Rational Review Evaluation Results

Table C.1. Variability in Job Family Overall and by Job Zone (Pre-Analyst Task)

Occupation family in Target Occupation	*N*	p(Overlap) Sta.	p(Overlap) Chg.	Corrected p(Overlap) Sta.	Corrected p(Overlap) Chg.	Corrected p(Overlap) Diff	*p(z)* Diff.
Overall	858	.47	.54	.45	.52	.08	<.001
1 – Little or No Preparation Needed	53	.30	.37	.28	.35	.07	.008
2 – Some Preparation Needed	260	.46	.59	.44	.57	.14	<.001
3 – Medium Preparation Needed	240	.42	.49	.40	.46	.07	<.001
4 – Considerable Preparation Needed	176	.49	.52	.46	.50	.04	.013
5 – Extensive Preparation Needed	129	.64	.66	.62	.64	.02	.194

Note. Sta. = Starter; Chg. = Change. p(Overlap) = the proportion of related occupations whose O*NET Job Family is the same as the target occupation's O*NET Family. Corrected p(Overlap) is equivalent to Cohen's Kappa which corrects for the overlap that would occur randomly. The correction assumes that each occupation has an equal chance of being randomly selected. Target and related occupations without a job zone were excluded. Diff. = Starter corrected p(overlap) – Change corrected p(overlap). Coefficients in bold are significant ($p < .05$) using $p(z)$, where $p(z)$ = z-test comparing the difference in proportions between the Starter and Change overlap proportions.

Table C.2. Variability in Salary Overall and by Job Zone (Pre-Analyst Task)

Job Zone	Starter Mdn_{diff}	Starter Mdn_{SD}	Starter % ≥ .5 *SD*	Change Mdn_{diff}	Change Mdn_{SD}	Change % ≥ .5 *SD*	*d*	*p*
Overall	7,860	9,708	54.3	7,510	9,705	53.0	0.01	<.001
1 – Little or No Preparation	3,740	5,088	53.3	2,730	2,575	39.6	0.14	<.001
2 – Some Preparation	5,600	7,143	58.9	4,920	5,775	54.8	0.08	<.001
3 – Medium Preparation	8,920	10,322	57.7	8,875	10,509	57.6	-0.02	.288
4 – Considerable Preparation	11,575	13,256	55.7	11,775	13,243	55.3	-0.01	.725
5 – Extensive Preparation	11,610	13,084	33.8	14,500	17,781	40.2	-0.08	<.001

Note. Medians rather than means (of absolute differences and standard deviations) were computed because of the highly-skewed nature of salary data. Mdn_{diff} = the median of the absolute differences between the target salary and its related occupation. Mdn_{SD} = the median, across target occupations, of the standard deviation (of Starter or Change salary minus target salary) across related occupations within a target occupation. % ≥ .5 *SD* = the percentage of times that a related occupation's salary is at least one-half a standard deviation (among target occupations within the job zone) different from the target occupation's salary. *d* = Cohen's *d*, or the standardized (using the standard deviation among target occupations within the job zone) mean difference in $|Mdn_{diff}|$ between the Starter and Change metrics; coefficients in bold were found to be statistically significant using the Wilcoxon signed rank test.

Table C.3. Variability in CIP Family Overall and by Job Family (Pre-Analyst Task)

Occupation family in Target Occupation	*N*	p(Overlap) Start.	p(Overlap) Chng.	Corrected p(Overlap) Start.	Corrected p(Overlap) Chng.	Corrected p(Overlap) Diff	*p(z)*
Overall	802	.36	.43	.32	.40	.08	<.001
47 – Construction and Extraction	54	.36	.62	.31	.58	.27	<.001
35 – Food Preparation and Serving Related	16	.44	.65	.41	.66	.25	.001
33 – Protective Services	26	.33	.53	.28	.49	.21	<.001
15 – Computer and Mathematical	23	.44	.62	.42	.61	.18	<.001
51 – Production	82	.31	.42	.25	.40	.15	<.001
53 – Transportation and Material Moving	42	.27	.40	.23	.36	.13	<.001
49 – Installation, Maintenance, and Repair	49	.31	.38	.26	.34	.09	.011
23 – Legal	8	.11	.20	.10	.19	.09	.064
19 – Life, Physical, and Social Science	53	.13	.22	.11	.20	.09	<.001
17 – Architecture and Engineering	52	.47	.55	.45	.53	.08	.008
45 – Farming, Fishing, and Forestry	16	.16	.22	.11	.18	.07	.123
29 – Healthcare Practitioners and Technical	68	.57	.63	.54	.61	.07	.013
37 – Building and Grounds Cleaning Maintenance	6	.10	.14	.06	.12	.06	.269
43 – Office and Administrative Support	58	.54	.56	.47	.49	.03	.333
13 – Business and Financial Operations	41	.43	.46	.38	.41	.03	.263
25 – Education, Training, and Library	56	.31	.31	.28	.29	.01	.373
11 – Management	37	.30	.31	.26	.26	.00	.436
27 – Arts, Design, Entertainment, Sports, and Media	43	.22	.21	.20	.19	-.01	.433
39 – Personal Care and Service	24	.25	.26	.23	.21	-.01	.456
21 – Community and Social Services	13	.23	.21	.18	.17	-.02	.381
31 – Healthcare Support	14	.68	.59	.61	.55	-.07	.078
41 – Sales and Related	21	.61	.53	.55	.46	-.09	.061

Note. p(Overlap) = the proportion of related occupations whose CIP family is the same as the target occupation's CIP family. Corrected p(Overlap) is equivalent to Cohen's Kappa which corrects for the overlap that would occur randomly. The correction assumes that each occupation has an equal chance of being randomly selected. Target and related occupations without a CIP or with a CIP of *Other* were excluded from analysis. Diff. = Starter corrected p(overlap) – Change corrected p(overlap Coefficients in bold are significant ($p < .05$) using *p*(*z*), where *p*(*z)* = z-test comparing the difference in proportions between the Starter and Change overlap proportions. The table is sorted in descending order of *Diff*.

Table C.4. Variability in Education, Experience, and Training Levels Overall and by Job Family (Pre-Analyst Task)

		Education Level M_{Diff}				Experience Level M_{Diff}				On-Site Training M_{Diff}			
Occupation family	*N*	Sta.	Chg.	Diff.	*p*(*t*)	Sta.	Chg.	Diff.	*p*(*t*)	Sta.	Chg.	Diff.	*p*(*t*)
Overall	852	0.86	0.69	0.18	<.001	1.40	1.36	0.04	.023	1.06	0.98	0.08	<.001
11 - Management	37	0.97	0.78	0.19	.057	1.10	1.03	0.08	.343	1.09	1.07	0.02	.735
13 - Business and Financial Operations	41	0.85	0.54	0.30	.003	0.99	0.91	0.08	.252	0.95	0.98	-0.04	.481
15 - Computer and Mathematical	22	0.74	0.61	0.13	.193	1.03	1.03	0.00	.994	1.27	1.13	0.14	.048
17 - Architecture and Engineering	52	0.76	0.53	0.23	.001	1.20	1.10	0.10	.093	1.08	1.04	0.04	.413
19 - Life, Physical, and Social Science	53	1.60	1.16	0.44	<.001	1.07	1.02	0.06	.280	1.19	1.10	0.09	.192
21 - Community and Social Services	13	1.59	1.33	0.26	.307	1.21	1.02	0.19	.074	1.04	1.00	0.05	.586
23 - Legal	7	2.34	1.95	0.39	.172	1.23	1.65	-0.42	.120	1.24	1.03	0.21	.041
25 - Education, Training, and Library	56	1.16	1.09	0.07	.401	1.17	1.13	0.04	.429	1.00	0.89	0.11	.007
27 - Arts, Design, Entertainment, Sports, and Media	43	1.26	0.88	0.39	<.001	1.24	1.38	-0.14	.224	1.18	1.11	0.07	.381
29 - Healthcare Practitioners and Technical	68	1.12	1.15	-0.03	.699	1.31	1.31	0.00	.958	0.98	0.89	0.09	.023
31 - Healthcare Support	15	1.01	0.99	0.02	.877	1.87	1.90	-0.03	.829	0.76	0.63	0.13	.216
33 - Protective Services	27	1.14	0.95	0.19	.047	1.97	2.00	-0.03	.809	1.02	0.97	0.06	.496
35 - Food Preparation and Serving Related	16	0.56	0.48	0.09	.208	1.22	1.35	-0.13	.538	0.58	0.40	0.18	.051
37 - Building and Grounds Cleaning and Maintenance	8	0.56	0.34	0.22	.083	2.10	2.25	-0.15	.584	0.89	0.90	0.00	.994
39 - Personal Care and Service	31	1.00	0.65	0.35	<.001	1.44	1.53	-0.09	.247	0.88	0.70	0.18	.004
41 - Sales and Related	21	0.74	0.54	0.20	.006	2.06	1.84	0.22	.134	0.74	0.81	-0.07	.257
43 - Office and Administrative Support	61	0.72	0.53	0.19	.003	1.54	1.47	0.08	.402	0.74	0.71	0.03	.296
45 - Farming, Fishing, and Forestry	17	0.89	0.72	0.17	.138	1.49	1.66	-0.17	.207	1.18	1.02	0.15	.126
47 - Construction and Extraction	57	0.41	0.34	0.07	.048	1.49	1.53	-0.04	.649	1.41	1.33	0.08	.216
49 - Installation, Maintenance, and Repair	51	0.65	0.48	0.17	<.001	1.12	0.97	0.15	.017	1.41	1.37	0.03	.464
51 - Production	104	0.39	0.29	0.09	.004	1.74	1.60	0.14	.029	1.03	0.89	0.14	<.001
53 - Transportation and Material Moving	52	0.61	0.43	0.18	.001	1.77	1.62	0.15	.087	1.05	0.92	0.13	.029

Note. *Sta.* = Starter, *Chg.* = Change. M_{Diff} = The mean of the difference (within target occupation) in Education, Experience, and On-Site Training between the target and related occupation. Diff. = Starter M_{Diff} – Change M_{Diff}. *p*(*t*) = dependent t-test that the Starter and Change M_{Diff} values are the same; values less than $p < .05$ and in the theoretically expected direction are shaded in gray.