Fall 2019

Identifying and Quantifying Personnel Skills Gaps

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IDENTIFYING AND QUANTIFYING PERSONNEL SKILLS GAPS

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A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

ENGINEERING MANAGEMENT

OLD DOMINION UNIVERSITY
December 2019

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ABSTRACT

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One of the issues organizations face is identifying the required skills needed for a position and then evaluating whether their personnel have these skills or if there is a "skills gap". The skills gap is the distance between the position requirements and the skills currently possessed by the worker in that position. While multiple models have been created over the years to address facets of the problem, none of them provide a comprehensive framework to clearly identify the required skills and worker qualifications and then evaluate the degree of similarity. A composite skills gap model has been developed using the Design Science Research Method to combine elements of previous models and to ensure that the resulting model met a set of established criteria. The Skills Gap Analysis Model (SGAM) was evaluated using demonstration data to ensure that it provided a single taxonomy for both position requirements and the worker qualifications, the resulting descriptions were quantifiable and comparable, the data was accurate and actionable, the model framework is adaptable to any domain, and that it is easy to use and not time consuming. The framework provided by the model establishes a theoretical foundation for skills gap analyses that allows for more analytical research in this area. By utilizing the SGAM to identify position requirements and worker qualifications, organizations can move personnel to better suited positions or utilize needed training in the specific areas identified. As technology moves towards increasing automation, robotics and artificial intelligence, this type of model can identify what skills are necessary for "re-tooling" the workforce to meet the needs to support these systems.

NOMENCLATURE

Abilities	Possession of the means to perform an activity or task. (Wilson et al. 2012).
Aptitudes	The capacity to learn or understand a particular task or subject. (Wilson et al. 2012).
Disconnect	A misunderstanding or unclear direction between a person in a position and the organization’s requirements and expectations for that position
Human Capital Object (HCO)	Multifaceted collection of work and workplace data content requirements in a specific environment or set of environments that will be used to support manpower, training and HIS analysis. An HCO is comprised of SkillObjects ™.
JASS	Job Assessment Selection Software. A program developed by the Army in the 1980s to classify and compare jobs.
Knowledge	Information and facts acquired by a person through experience or education. A thorough understanding of a particular subject (Wilson et al. 2012).
KSAOs	Knowledge, Skill, Abilities, and Others
KSAs	Knowledge, Skill, and Abilities.
MOS	Military Occupational Specialty. The grouping that the Army uses to classify jobs.
Reliability	The ability of a test to dependably produce the same results when given repeatedly to the same person.
Skill Gap	A requirement for a skill not currently possessed by the person in that position.
Skills	The manual, verbal, or mental ability to do something well. (Wilson et al. 2012).
SkillObjects ™	Observable occupational skill containing unique knowledge, skills, abilities, tools, tasks, and resources (KSATTR) at the job level and context work elements.
SME	Subject Matter Expert. A person that through experience or education is an authority in a particular area.
Task	Detailed pieces of work
Transferrable Skills	Skills acquired while working in one area or job that are also valid for another area or job.
Validated Test	The test is an adequate tool to measure for its intended purpose.
Validity	How well the test measures the intended attributes.
Work	The mental or physical effort done to achieve a result.

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1. INTRODUCTION

1.1 Background of the Problem

Whether enterprises are growing, restructuring, downsizing, having to fill jobs vacated by retiring professionals, having to deal with a technology shift, or just filling positions created by workers pursuing other opportunities, organizations are quickly realizing that one of their most valuable assets is their people (Pfeffer & Veiga, 1999; Fulmer & Ployhart, 2014). Positions require people with the correct skills to accomplish the work.

Enterprises need to identify skills gaps between their current workforce and their future capabilities in order to address their workforce planning needs. Enterprises strive to align their systems, technologies and workforce with current and future business objectives. A "skills gap" is the differential between the requirements of a job position and the skills that a worker possesses. Before an organization can train existing personnel, move personnel to better matched positions, or hire new personnel, these gaps need to be identified.

There is some controversy about the cause of current gaps in worker skills. One theory states that the modern-day skills requirements are outpacing the education system (Olson, 2015; Galagan 2010), i.e., schools and universities are not preparing the workforce to meet new job requirements. This viewpoint is supported by the 2013 Georgetown University Center on Education and the Workforce Recovery: Job Growth and Education Requirements Through 2020 report which explains that 60% workers need some postsecondary education for today's jobs, compared to 1 in 3 in the 1970s and that this number will increase to 65% by 2020. Another theory purports that organizations are unwilling to train their existing workers, not willing to pay fair wages for the skills they need, need to move to position themselves in a better area to obtain a proper workforce, or are just not effective at identifying requirements and matching personnel skills sets (Cappelli, 2015). Other studies cite lack of motivation, poor attitude and dependability as issues, not technical ability (Pearce, 2006). Regardless of the causes of the "skills gap", the need to quantitatively identify it exists.

One of the potential reasons for the large debate about the skills gap is that it has been difficult for enterprises to measure and quantify it. Abraham (2015) and Cappelli (2015) cite that while there has been an increase in employer complaints, current data did not support these claims, and they note the poor quality of the information presented to support the complaints. Olson (2015) agreed with the skills gap claims and discussed potential solutions to “bridge” the gap. He suggests identifying the talent requirements, but no methodology is provided for accomplishing this task. Manpower Group (2013) indicates that 35% of employers have concerns over filling positions and provides several possible causes. The 2011 Manufacturing Institute and Deloitte Report states that 67% of manufacturers have a moderate to severe shortage of available, qualified workers. Neither of these reports discuss how to evaluate or quantify the gap. While every organization is different, each with its own unique set of issues, a prescriptive “engineering approach” to provide and evaluate skill gap data does not exist.

The literature agrees that organizations need to identify their own skills gaps to address their workforce planning needs. Having a method to identify and quantify these needs would give organizations the information they need to address the gap. At issue is that before organizations can train existing personnel, move personnel to better matched positions, or hire new personnel, they need to understand exactly what these gaps are.

This research summarizes the relevant literature and current models that exist in this domain and presents a more robust model to identify, quantify and address the skills gap between positions and personnel. While the application of the work for organizations is compelling, this research also establishes the theoretical foundation for skills gap analyses, allowing more analytical research in this area, and proposes a model framework based on combining existing models and developing an accompanying algorithm to quantify the skills gap. As shown in Figure 1, the need to identify and quantify skills gaps in an enterprise occurs in several areas.

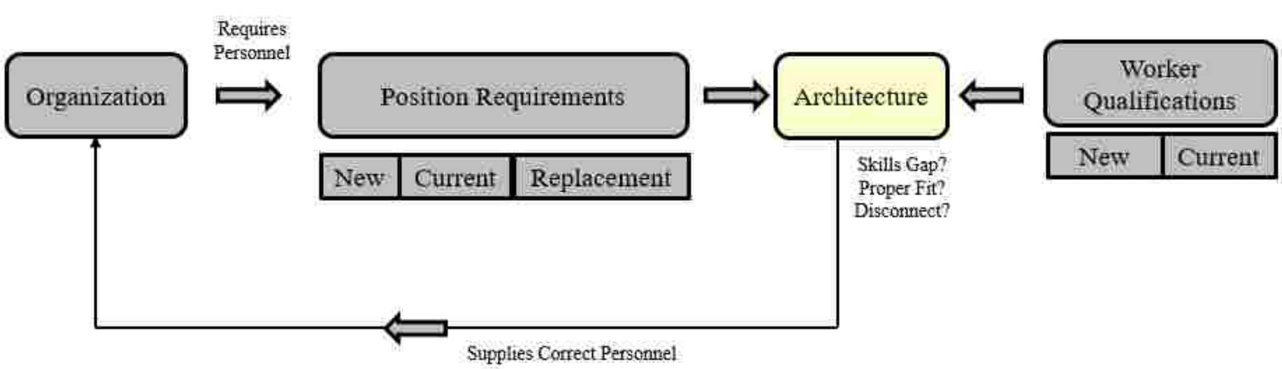


Figure 1. Potential Skills Gaps in Enterprises

The first area is the identification of a skills gap between the existing worker and the current job position. It is critical that personnel meet the job requirements, as this gap is costly for organizations (Watkins, et al., 2016). The gap can result in a loss of productivity, reduced morale, and the overworking of the existing workforce. Overworking the existing workforce and having operators perform tasks that they are not qualified for can create quality and safety concerns (Caruso, et al., 2004; Spurgon, et al., 1997; Goldenhar, et al., 2003; Kawada & Ooya, 2005).

The second area is when new or changing technology causes existing positions requirements to change or even be phased out. The remaining personnel may not be able to successfully adapt to the new job requirements; these people need training to be able to perform the required functions, but it is critical that the gaps are properly identified so that the proper training can be utilized. Training in the wrong areas is costly from a time and monetary perspective and is not beneficial for the organization.

The third area is to determine if existing personnel skills can be used in other areas of the organization. Evaluating the skill gap between the worker and the other available jobs can identify the degree of training required, which correlates to cost, to enable the candidate to fill the position. After a skill gap has been identified, the worker needs to be trained, but the issue still remains in identifying what to train and how much to train. According to the American Society for Training & Development (2013) State of Industry Report, US organizations spent over $164 billion dollars on training. Being able to identify and quantify skills gaps can help organizations ensure that they are training in the correct areas and that they are maximizing the effectiveness of the training.

Lastly, Figure 1 identifies the impact on new hires. The issue is how to describe available positions to hire appropriate personnel; it is important that the potential new hires are matched against up-to-date requirements for the position. Placing the wrong person in a critical position could result in loss of productivity, loss of revenue, low morale, and customer relation issues.

Several issues are important to defining a skills gap model: identifying the descriptors needed to identify position requirements and worker skills, ensuring the position requirements and the worker's qualifications use the same taxonomy, what evaluation metrics are applicable, and finally how to make the comparison.

Different organizations have different titles for similar positions and personnel skills are described in a variety of ways. In order to make an accurate worker-to-position comparison, the position requirements and the worker's qualifications need to be in the same language with quantitative ratings. Many of the current methods do not provide a method for an “apples-to-apples” comparison, meaning the data for each perspective can be reasonably compared. Once both the worker skills set and position requirements are in the same language, the skills gap can be calculated (see Figure 2).

Figure 2. Skills Gaps Calculation

1.2 Why is this Problem Compelling?

The ability to find the right workers and being able to identify skills gaps for an existing workforce has become increasingly more important. Skills gaps are costly and negatively affect productivity. The need exists to identify and quantify roles and responsibilities for positions that can be clearly identified and articulated to the worker. The 2018 U.S Department of Labor statistics cite that there are 6.7 million U.S. job openings with 6.3 million unemployed. Evaluating the numbers, there should be more than enough jobs for everyone. Are these people not qualified or are organizations not able to match these people with the correct positions?

Additionally, the skills gap problem is complex. The diagram in Figure 3 identifies some of the factors needed to identify a skills gap. These factors include the descriptors for the position requirements and worker skills, the underlying taxonomy, appropriate metrics to weight and rank the descriptors, and how to evaluate the outcomes. The fundamental concept is that in order to make an accurate comparison both the position requirements and the worker qualifications need to use the same taxonomy. This is shown in the diagram by the apples next to each area. This ensures the “apples-to-apples” comparison can be made.

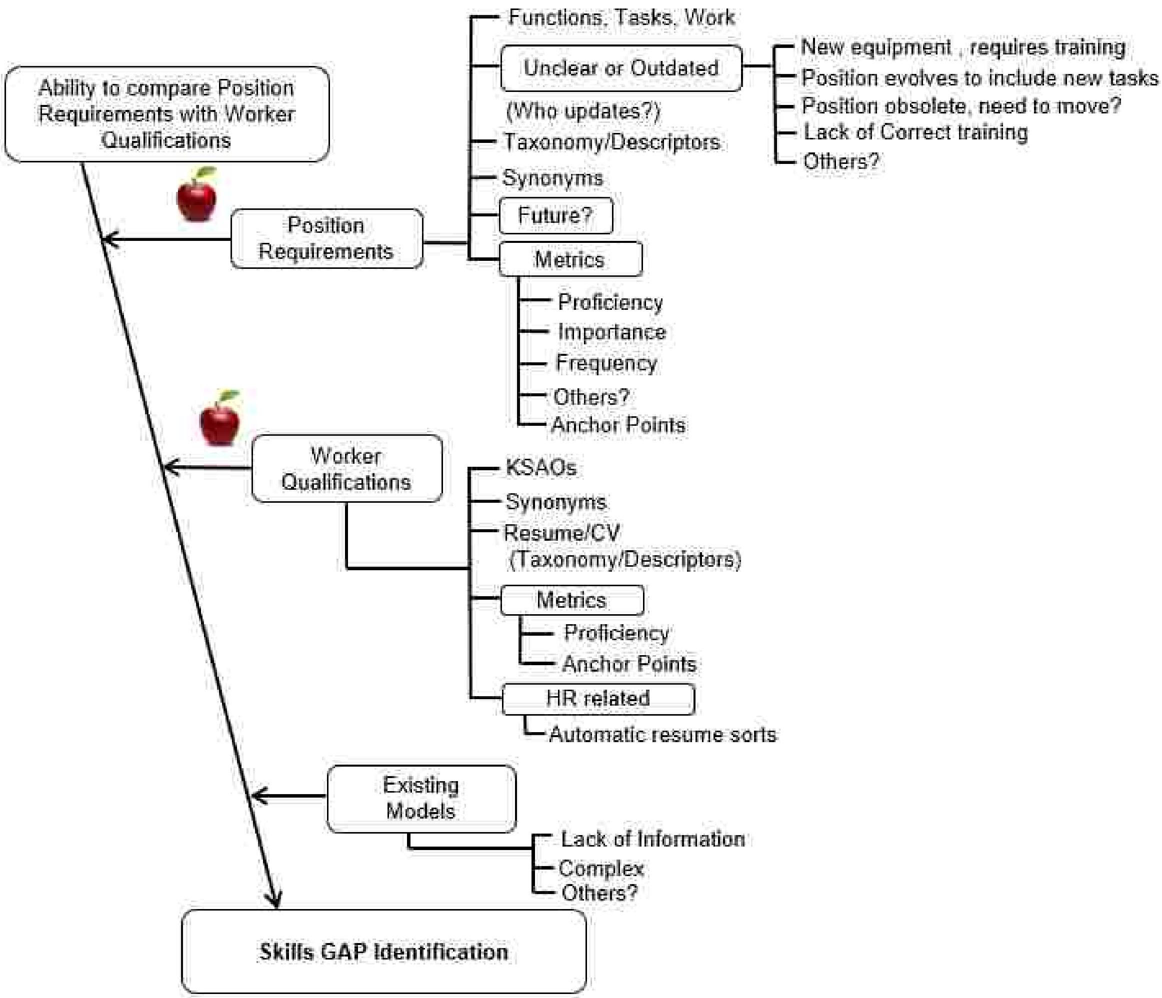


Figure 3. Skills Gap Identification

Positions within an organization require specific skills sets. These skill sets typically detail activities that the person needs to be able to successfully perform the requirements of the position. When comparing personnel to positions, three scenarios are possible:

Scenario 1: The worker's skills set is balanced with what the organization needs. The position should be adequately filled, and the organization should not have any issues.

Scenario 2: The worker skills set is greater than the position requirements. This is inefficient use of the available human resource. In this case the worker may not be challenged and may seek employment elsewhere. With a positive gap, matching the worker with a different, more suitable position could benefit both the organization and the worker.

Scenario 3: When the position requirements are greater than the worker's skills, this creates a negative gap. Negative gaps are costly for organizations and as such, closing or eliminating the gap is desired, usually through training or selecting alternative personnel.

With technology moving towards automation, robotics and artificial intelligence, i.e., Industry 4.0, being able to identify the skills gaps will be necessary for “re-tooling” the workforce to meet the needs to support these systems. Before organizations can train existing personnel, move personnel to better matched positions, or hire new personnel, they need to understand exactly what the skills gaps are. By clearly identifying the skills gap, manpower and personnel decisions can be made about hiring, training and shifting personnel to meet the enterprise needs.

1.3 Research Strategy

This research goal is to develop a model that allows a skills gap to be identified based on a common representation of a job position and personnel skills. The main challenge is how to identify the position requirements and worker skills in a manner that the two can be used for comparison. The details include developing a model using the proper descriptors that can be used to quantify the job requirements, developing a scale to rate the importance of each descriptor, capturing the existing personnel qualifications using the same descriptors, and developing a corresponding method to compare the job requirements to the personnel’s skills. The model will have to be easy to use, be able to parse data effectively to minimize effort, and yield actionable data that would be useful for the minimizing the gap. The research will employ a Design Science research strategy to create a new artifact, the Skills Gap Analysis Model.

1.4 Contribution to the Body of Knowledge

This work directly addresses the need for a robust model to identify, quantify, and address the “skills gap” between positions and personnel. This research is timely for both system and organizational design as increasing levels of system autonomy has changed the way that positions are defined and shifting the role of workers. A model framework based on combining existing models identified in the literature review and developing the accompanying algorithm to quantify the skills gap provides the basis for the Skills Gap Analysis Model (SGAM). This model provides a theoretical foundation for analysis that allows for more analytical research in this area.

1.5 Alignment with System Engineering Research

The skills gap problem, while widely recognized, has not received much attention in the academic literature. The problem has been viewed as largely an organizational one, and often "workarounds", such as additional training, adding extra personnel, and overtime hours are used to address the gap. While the immediate application of the work has been articulated from an organizational manpower perspective, the need for a formal model for the use of human resources from a systems point of view has been identified in the systems architecting practice. Bruseberg (2007) identified an architecture approach to identify individual attributes as part of system roles in order to identify gaps in task assignments that would impact system performance. Handley (2017) discusses the need to define the human capabilities that result from matching qualified soldiers to technology tasks in order to better define trade-offs between soldier assignments. In this sense, a capability is the opposite of a "gap". Human interactions with both systems and other humans have become a key concern of system engineers as systems continue to grow in scale and complexity, and as humans continue to become key components of the system and impact its performance (Orellana and Madni, 2014). Thus, systems engineering is concerned with the total view of the system and must necessarily relate to the enterprise or organization for whom the system is being built, including its people and processes (Sage & Lynch, 1998). System support for enterprise architectures defines the structure and operation of an organization to determine how an organization can most effectively achieve its current and future objectives. A model to evaluate the capability and gaps of its personnel is a necessary part of this assessment.

1.6 Dissertation Outline

This research follows the Design Science Research framework laid out by Hevner (2007). The ensuing chapters are aligned with this methodology. Specifically, this chapter has identified the problem and the motivation for the research. Chapter 2 provides a literature review of the current methods and models to identify position requirements and worker requirements. It identifies the gap in the body of knowledge on the determination of a skills gap. Based on the shortcomings of the existing models, the solution requirements are defined. Chapter 3 discussed Design Science Research as an methodology to address this problem, and articulates the research objectives and methods to achieve this goal. Chapter 4 provides the composite model development and the algorithm design. Chapter 5 discusses the demonstration to elicit user feedback on the utility of the model and algorithm to identify the skills gap from both a position and worker perspective. Chapter 6 evaluates the data collected at the demonstration based on the established criteria to determine if the composite model and algorithm achieve the research goal. Finally, Chapter 7 offers an outline of strengths, limitations, and implications of the proposed framework to the body of knowledge and practice of systems modeling and architecture. It provides the communication plan to different stakeholders to conclude the Design Science Research method.

2. LITERATURE REVIEW

This chapter provides a review of the literature in this domain, including the terminology used as well as the definition of the "skills gap" problem. It reviews and compares existing worker-to-job fit models and other methods used to match personnel to positions. It discusses the difficulties of identifying and quantifying worker qualifications as well as position descriptors. It also provides the criteria to evaluate the existing models in order to identify the gap in the body of knowledge that this research will address.

2.1 Domain Terminology and Skills Gap Problem

The skills-gap problem can be considered an equation. The objective is to ensure that the requirements of the positions on the left side of the equation correspond to the worker qualifications on the right side. If there is an imbalance, the differential is the "skills gap." Part of the difficulty with this research domain is the differences in terminology that is used to describe both the position and the worker, along with their corresponding attributes. This section will describe the terminology used in this field and identify the basic skills gap model that will guide this research and be used to evaluate existing models.

2.1.1 Terminology

A job position is typically described by the roles and responsibilities that detail the functions, tasks, and work that a worker in the position needs to be able to perform. A function is an activity that a worker is required to complete. The activity can then be broken done into tasks and subtasks which are detailed pieces of work. Work is defined as the mental or physical effort done to achieve a result. Using these three components, position requirements can be articulated.

In the System Engineering domain, human functions are determined from overall system functions and decomposed to the task level. These tasks are then grouped into roles, and roles are grouped into a position that can be assigned to a single individual (Bruseberg, 2008). Position requirements are determined based on the competencies required for each constituent role and its associated tasks. Note that from the job position perspective, the requirements are derived from the human function requirements in part of a larger system context; thus, the language of the job position is grounded in the overall system components and goals.

The Human Role Strategy, developed during the system requirements analysis phase, articulates the plan for human involvement in a system that will be used to guide further function allocation, and thereby define the worker roles in the system. (DD 21 ONR, 1998). The tasks, roles and requirements comprise definitions that mutually depend on each other. For example:

- Tasks determine required skills and knowledge
- Existing role definitions may influence position descriptions
- New roles may be defined based on new human function allocations

On the position side of the equation, the system is reviewed to determine roles and responsibilities of the position. All the work that this position is required to complete is analyzed and all the related functions, tasks, and sub-tasks needed are detailed to ensure all the requirements of the position are identified.

On the worker side of the equation resides the qualifications that the worker possesses that should meet the requirements to perform all the required functions, tasks, and work of the position. In the combined work by Wilson, et al. in 2012, knowledge is defined as information and facts acquired by a person through experience or education; knowledge represents the body of information applied directly to the performance of a task. Skills are defined as the manual, verbal, or mental ability to do something well; skills are the result of a learned task. Abilities are defined as possession of the means to perform an activity or task; abilities are the observable behavior to perform a task. “Others” typically refers to all the other attributes that are not easily categorized into the knowledge, skills, and abilities grouping. This could include items such as being able to perform specific work activities or tasks. The combination of knowledge, skills, abilities, and other are typically referred to as KSAOs and are the worker’s qualifications.

2.1.2 Skills Gap Model

In order to be successful in the position, the worker’s qualifications have to meet the position requirements. Note that from a worker’s perspective, qualifications are determined from past training that can be codified as KSAOs and applied to other jobs. From the position perspective, the job descriptions are determined from roles and responsibilities based on the work or system that is being operated. The difference between the two sides of the equation is the "skills gap." The worker to position model can be generalized as shown in Figure 4. This model can be used to evaluate existing models and identify the gap in the body of knowledge that this work will address.

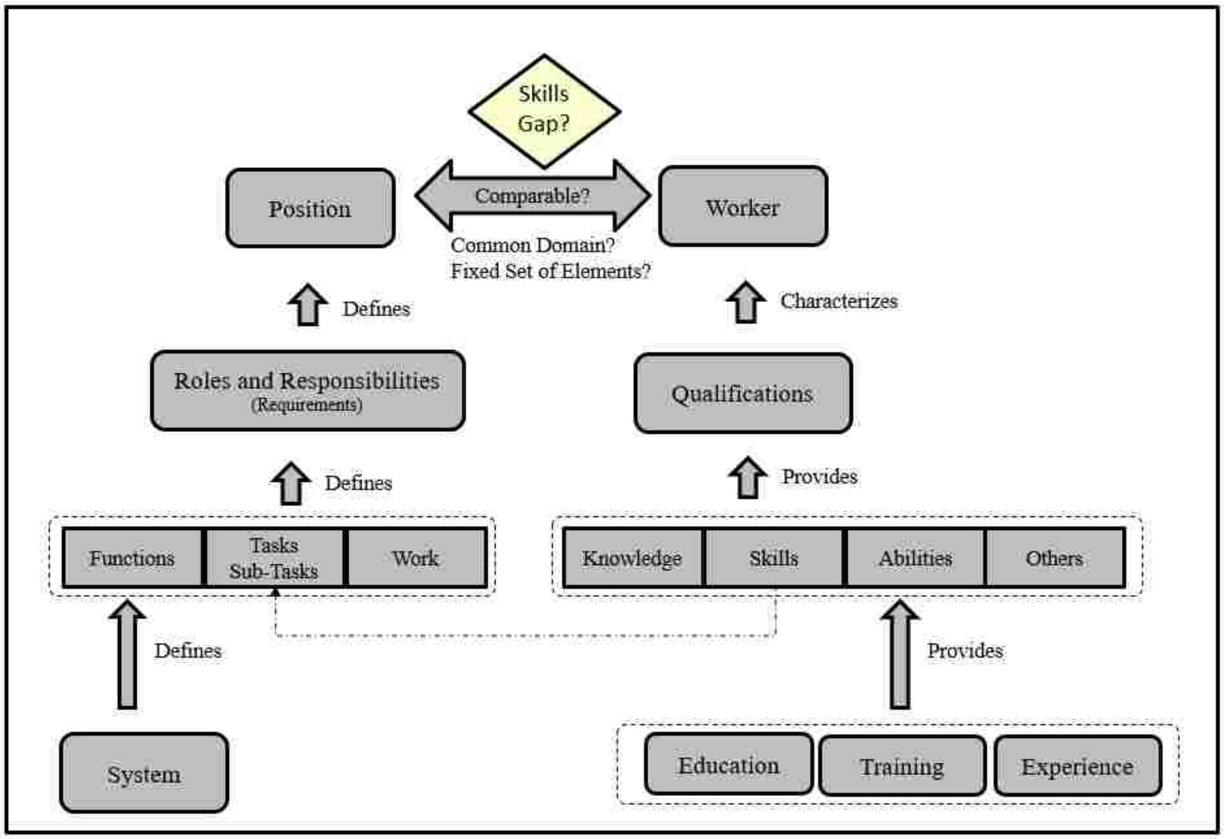


Figure 4. Domain Terminology

For a model to be able to identify and quantify a skills gap, the first and main requirement is that it has to be able to compare the position requirements and the worker qualifications. To do this it must be able to compare the position functions, tasks, and work to the worker's KSAOs. To make this comparison these descriptors need to use the same language. Then, to make the skills gap calculation the two sides can be compared using the equation shown in Figure 2.

2.1.3 Criteria to Evaluate Existing Models

To evaluate existing skills gap models a consistent set of criteria is needed. Some of the most current and popular worker-to-position models will be evaluated to review their purpose and to determine if they detail the worker requirements, position requirements, or both. The data collected will be reviewed to see if it is comparable. To ensure it is comparable it must be quantifiable. How the information is collected and how frequently it is updated will also be reviewed. The robustness, if the data is actionable, and the "ease of use" for each model will also be reviewed. All of these criteria are summarized in Table 1.

Table 1. Model Evaluation Criteria

	Criteria		Description	Acceptable (A) / Needs Improvement (NI)
1	Taxonomy/ Same Language	Position Requirements	How are these defined?	TBD
		Worker Qualifications	How are these defined?	TBD
2	Comparable	Data comparison	Can the data be compared? Is there consistent terminology?	TBD
		Quantifiable data	Is the data quantifiable and is there a rating system. Are variables weighted?	TBD
3	Adaptable	Information updated	Is the information up to date? How often is it updated?	TBD
		Robustness	Does it have a strong adaptable framework?	TBD
4	Actionable	Provide accurate and actionable data	Able to identify and quantify skills gaps?	TBD
5	Usability	Ease of use	Time consuming? Able to parse data?	TBD

To be beneficial, a new model would have to be generalizable, it would have to provide both the position requirements and the worker qualifications (both perspectives) in the same language, would have to be adaptable to any domain, allow for comparison (quantifiable data), be quick and easy to use (usability/burden), and provide accurate and actionable data (robust). These aspects should ensure that the model facilitates quick and easy identification of position requirements, as well as being able to quantify the level of a particular skill that is needed.

Each area will be evaluated to determine if it is acceptable (A) and would meet the needs of this research of it would need improvement (NI). After each of the models is evaluated, the combined results will be reviewed.

2.2 Existing Worker to Job Fit Models

Several comprehensive, worker to job fit models have been identified. Four of the most predominant ones are discussed in this section. The first model was developed by the Office of Personnel Management to classify its Human Resources workforce. The next two models were developed by Department of Defense organizations, as the military has a strong need to quantify both its positions and its personnel in order to manage its manpower effectively. The most comprehensive model has been developed by the Department of Labor. This model has been widely validated and has been used extensively in research applications. This section reviews these four models and evaluates their strengths and weaknesses based on the criteria identified in Table 1.

2.1.1 Office of Personnel Management MOSAIC model

One of the early drivers of the use of KSAOs was the US Office of Personnel Management (OPM). OPM conducted government wide occupational studies to collect information on human resource management functions. The OPM Delegated Examining Operations Handbook (2007) described the measured KSAOs, behaviors, and other characteristics identified for a worker to be successful in a position. This set of information was identified as a competency. The OPM's goal was to define a set of common tasks and competencies used to describe all occupations included in the study in order to structure human resources functions and to provide workers information on the factors on which they are selected, trained, and evaluated. KSAOs for a position were identified, and based on the applicant written responses, the level of their ability was graded to determine if the applicant was able to demonstrate the requirements and a decision was made whether or not to move the applicant to the next step of the application process. According to the OPM Handbook, a score above 70 out of 100 was required to move on in the process.

However, criticisms of this approach led to a decreased use of KSAOs in the application process. The method of determining applicants' appropriate KSAOs was a long process and led to discouraging individuals to apply for positions. Because of this, there was a Federal initiative to phase out the KSAO essays (Kay, 2011). Additionally, some well qualified applicants were not identified based on the KSAO system. While the set of KSAOs had been determined for each position, it was up to the applicant to provide a narrative that could be rated to determine the applicant's alignment with the requirements.

The government wide study, Multipurpose Occupational Systems Analysis – Close Ended (MOSAIC) was an attempt to document the competencies needed for almost 200 Federal positions. This system was based on studies performed over several years and represents the position requirements. The position information is based on these closed studies while the worker qualifications would have to be determined through the KSAO essay method previously described, which has a Federal initiative to phase out this process. The OPM Handbook does describe an extensive job analysis methodology. The methodology states for a SME to detail the important competencies and to rate them, but there is not a consistent comparison method based on common terminology. While there is a lot of good information related to identifying the position requirements, making the position-to-worker comparison is difficult using this model. The model evaluation summary is shown in Table 2.

Table 2. MOSIAC Model Evaluation

	Criteria		Details	Acceptable (A) / Needs Improvement (NI)
1	Taxonomy/ Same Language	Position Requirements	Details competencies almost 200 Federal positions. Only Federal, adaptable to private sector?	NI
		Worker Qualifications	OPM Job analysis methodology, generic	NI
2	Comparable	Data comparison	OPM Job analysis methodology, generic, not apples-to-apples	NI
		Quantifiable data	Does apply metrics, but not weighted and no rating scales.	NI
3	Adaptable	Information updated	No; based on previous studies.	NI
		Robustness	May be solid for current positions, does not adapt to changing positions.	NI
4	Actionable	Provide accurate and actionable data	No method to determine skills gaps.	NI
5	Usability	Ease of use	Difficult. Time consuming process involving multiple personnel.	NI

2.2.2 Navy's Human Capital Object (HCO) Model

The HCO (Human Capital Object) Conceptual and Logical Data Model, shown in Figure 5, is a worker to job model developed for the US Navy. It captures the requirements and status of both Navy work and individual Sailor career activities and plans (Ross et al., n.d.). This model was an attempt to match individual sailor profiles (HCOi), the right side of Figure 5, with known position requirements (HCOr), the left side of Figure 5, to help sailors manage their careers.

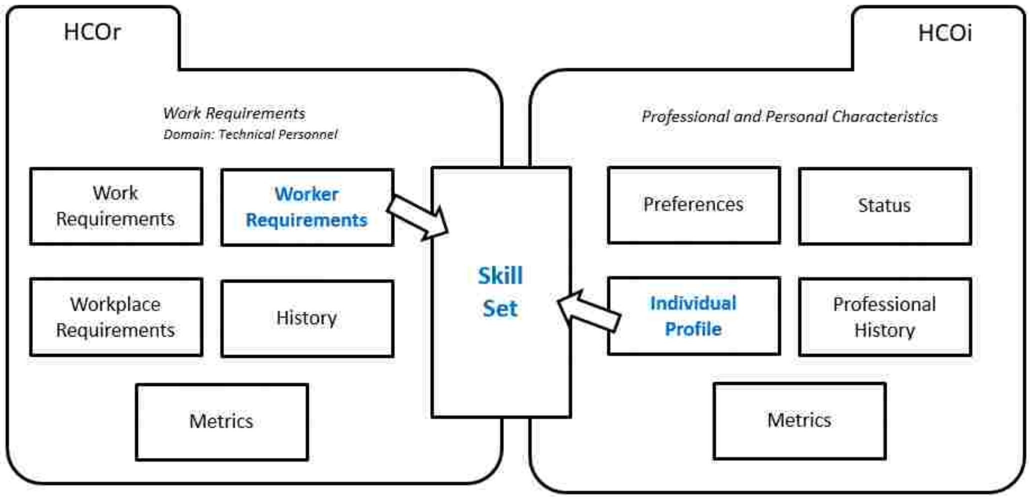


Figure 5. Navy's Human Capital Object (HCO) Model

The HCO model is extensive and accounts for a wide variety of variables. On the position side, this model captures work requirements, workplace requirements, worker requirements, and history. On the worker side, the model captures preferences, the individual profile, professional history, and status. Additionally, for both the work requirements and the professional/personal characteristics there is a set of metrics.

The HCO model provides a framework for matching personnel skills and work requirements. It also has good start in identifying KSAOs using the SkillObjects™ based taxonomy. SkillObjects™ uses detailed descriptions of occupational tasks. The skills contain unique Knowledge, Skills, Abilities, Tools, Tasks, and Resources KSATTR) to describe the position requirements (Ross et al., n.d.). These are similar but not the same as the descriptions used by OPM in their MOSAIC project. Enterprises recognize the need to identify needed KSAOs but there is not common database and the focus is typically on the position requirements. There is a need to detail the worker qualifications using the same database so that comparisons can be made.

The shortcomings for the HCO model are that it is complex and collects data in many areas making it time consuming and cumbersome to use. Some of the data collection areas are shown in Figure 6. To be useful, the methodology and system would have to be simpler and quicker to use.

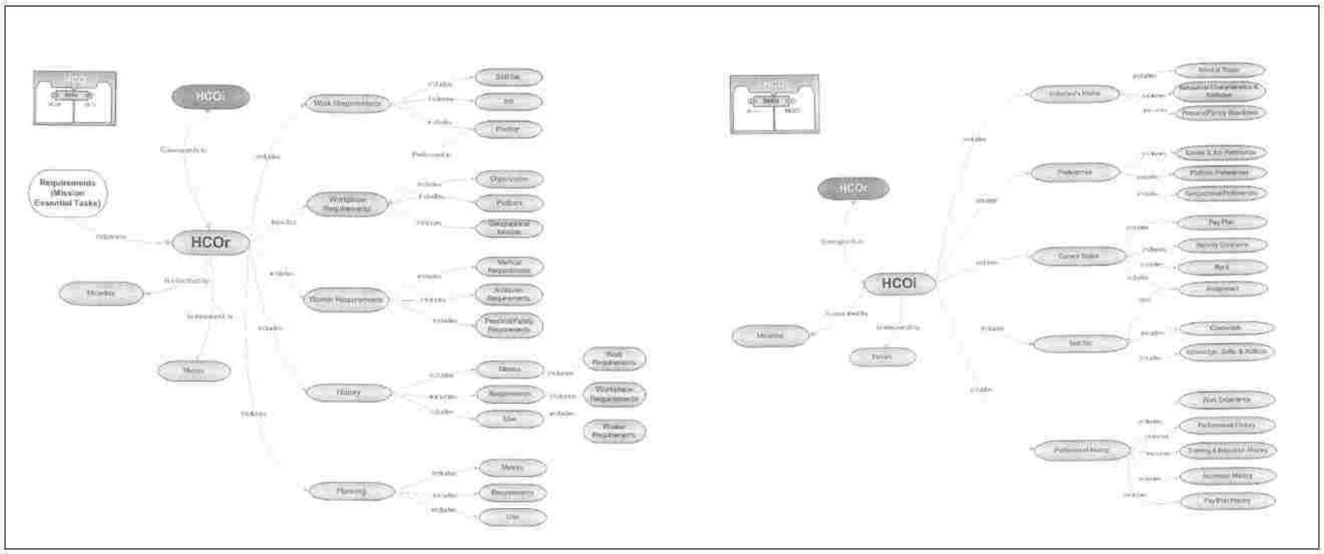


Figure 6. Human Capital Object (HCO) Data Collection Areas

For the HCO model evaluation, Ross et al. note the need to align work requirements to position (billets) and match these with the correct personnel. While the HCO model does provide a strong framework for a worker-to-position comparison, there are several areas that would need to be improved. The HCO model evaluation is shown in Table 3.

Table 3. HCO Model Evaluation

	Criteria		Details	Acceptable (A) / Needs Improvement (NI)
1	Taxonomy/ Same Language	Position Requirements	Uses SkillObjects to identify KSAOs	NI
		Worker Qualifications	Not much information available	NI
2	Comparable	Data comparison	Not much information available	NI
		Quantifiable data	Not much information available	NI
3	Adaptable	Information updated	Not much information available	NI
		Robustness	Solid framework, sets basis for comparison	A
4	Actionable	Provide accurate and actionable data	No method to determine skills gaps.	NI
5	Usability	Ease of use	A lot of data/extensive, cumbersome information not readily available	NI

2.2.3 Job Assessment Software System (JASS)

In 1983, an Army project developed a program that was easy to use and could quickly specify the requirements for a position. The result of the project was the Job Assessment Software System (JASS). Fleishman and Quaintance (1984) added to the existing JASS work by improving the taxonomy of aptitudes and started to develop relationships between them. The program allows the user to define and add metrics for the human aptitudes required to do a job (Knapp and Tillman 1998). The program also allows the user to identify the aptitudes required for a job and scale the amount of the aptitude that is required (Garneau, n.d.). The program allows subject matter experts (SMEs) to break the aptitude down to the taxonomy of skills and abilities identified by Fleishman in Table 4 to define what is needed for a position. This approach provides a consistent terminology domain on the position side to identify and quantify the requirements of a job or position.

Table 4. Taxonomy of skills and abilities (Knapp and Tillman, 1998).

Cognitive skill and experience		**Perceptual-motor ability**	
Communication • Oral comprehension • Written comprehension • Oral expression • Written expression	*Conceptual* • Memorization • Problem sensitivity • Originality • Fluency of ideas • Flexibility of closure • Selective attention • Spatial orientation • Visualization	*Vision* • Near vision • Far vision • Night vision • Visual color discrimination • Peripheral vision • Depth perception • Glare sensitivity	*Audition* • General hearing • Auditory attention • Sound localization
Reasoning • Inductive reasoning • Category flexibility • Deductive reasoning • Information ordering • Mathematical reasoning • Number facility	*Speed-loaded* • Time sharing • Speed of closure • Perceptual speed and accuracy • Reaction time • Choice reaction time	*Psychomotor* • Control precision • Rate control • Wrist-finger speed • Finger dexterity • Manual dexterity • Arm-hand steadiness • Multi-limb coordination	*Gross motor* • Extent flexibility • Dynamic flexibility • Speed of limb movement • Gross body equilibrium • Gross body coordination • Static strength • Explosive strength • Dynamic strength • Trunk strength • Stamina

This work is a good start towards developing a quantifying solution to identify skills gaps. By using Likert scale slide rules with logical anchor points, easy to understand metrics are applied as shown in Figure 7.

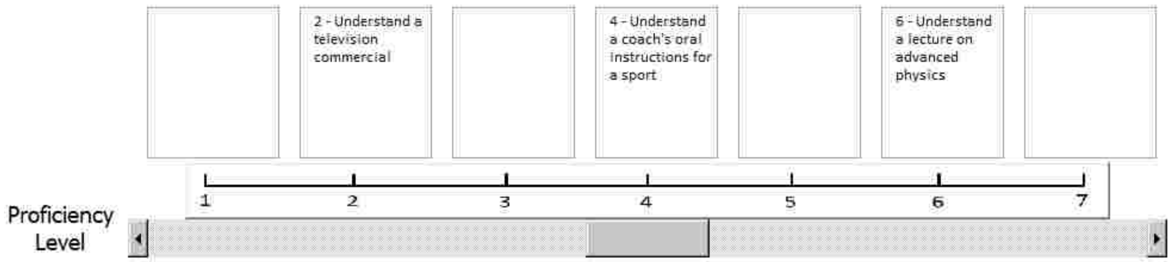


Figure 7. JASS Logical Anchor Points

This program can be used to identify job requirements for positions categorized as military occupational specialties (MOSs). This program also allows the requirements between two MOS categories to be compared to determine if personnel from one classification might be able to perform in another classification. The other benefit of this program is it also permits visualization of the results and allows the data to be easily exported into other programs.

The underlying decision model provided by the program allows the user to identify the aptitudes required for a job and the amount of the aptitude that is required based on a seven-point scale. The questions and scale criteria are also shown in Appendix A. JASS details every aspect of an activity. The JASS method breaks each job into an assignment. The analysis time needed for a single job assignment can take up to 26 minutes, as shown in Figure 8.

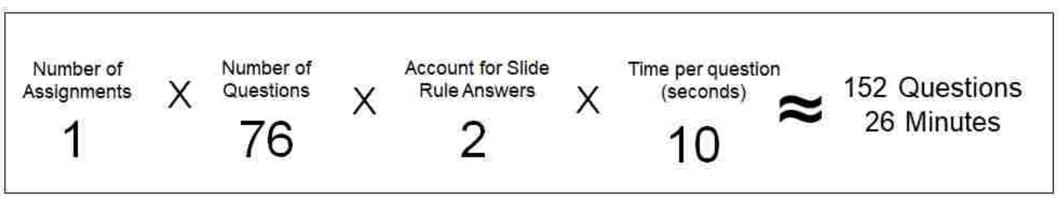


Figure 8. JASS Time Required

The problem is that it is not unusual for a position to have at least 100-200 assignments when described at this level of detail. This would require over 40 hours to use JASS to identify the types and weights for the different abilities for the position. With the current version of JASS it would be possible to have SMEs use the program to detail all the requirements of the position and also detail the abilities of the worker in an attempt to determine the gap, but this effort would be extremely time consuming and the current taxonomy is heavily weight towards physical attributes as shown in Figure 9.

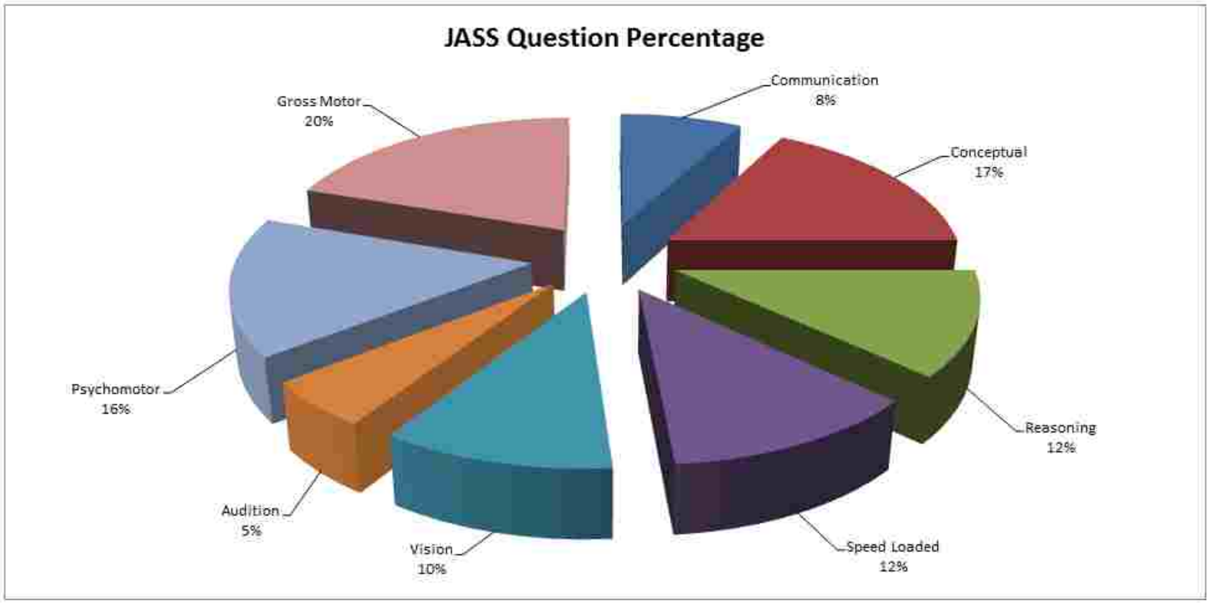


Figure 9. JASS Question Percentage

JASS does provide an updated method for making the skill/work requirement comparison that many organizations would be interested in using. The logic used to detail assignment requirements does allow the evaluator to skip irrelevant questions, but there are several concerns with using JASS. First, to detail every assignment makes the process very time consuming. Second, because it was first introduced in 1983 (over 30 years ago), it is heavily weighted towards accessing job positions that are more physical. As the work environment is changing and jobs are requiring more logic and reasoning over physical strength, better methods are needed to access more technology focused job requirements. Thirdly, using the existing taxonomy, it would be difficult to identify a skills gaps for many current positions. Finally, it is important that any skills model yield reasonable results with a reasonable amount of effort in order to be beneficial. The JASS model evaluation is shown in Table 5.

Table 5. JASS Model Evaluation

	Criteria		Details	Acceptable (A) / Needs Improvement (NI)
1	Taxonomy/ Same Language	Position Requirements	Uses Fleishman's taxonomy for evaluation of assignments	NI
		Worker Qualifications	Can use Fleishman's taxonomy	NI
2	Comparable	Data comparison	Ability to compare	A
		Quantifiable data	Uses slide scales to add metrics	A
3	Adaptable	Information updated	Not updated	NI
		Robustness	Based more on physical attributes, dated Needs improved taxonomy	NI
4	Actionable	Provide accurate and actionable data	Method to compare, but better descriptors and metrics required.	NI
5	Usability	Ease of use	Easy to use with good method to skip non-relevant questions, computer based	A

2.2.4 Occupational Information Network (O*NET)

The Dictionary of Occupational Titles (DOT) was developed in the 1930s to match skill supply with skill demand to help with the economic crisis of the times (Peterson et al., 2001). This system was used for about 60 years and typically consisted of trained occupational analysts traveling to the work site. At the worksite they would observe the work, conduct interviews, document the aspects the position, and rate the occupation specific details. This was a very resource intensive process. The job analysis activity is tedious work and needs to be updated periodically to capture changes that have occurred over time (Clifford, 1994). Many organizations have used the DOT information over the years to set up job descriptions and training requirements. In the 1990, the Secretary of Labor started the Advisory Panel for the Dictionary of Occupational Titles (APDOT). After reviewing the pros and cons of the existing DOT system, the improved Occupational Information Network (O*NET) was developed. O*NET is an online resource developed by the Department of Labor to serve "as a national benchmark that provides a common language for all users of occupational information" (U.S. Department of Labor, 1993). The information in O*Net is an accumulation and synthesis of job analysis research for multiple jobs across multiple organizations (Campion, M. A. et al., 1999). This system contains a wealth of information, with over 70 years of combined job analysis research. The foundation for this system is the content model shown in Figure 10.

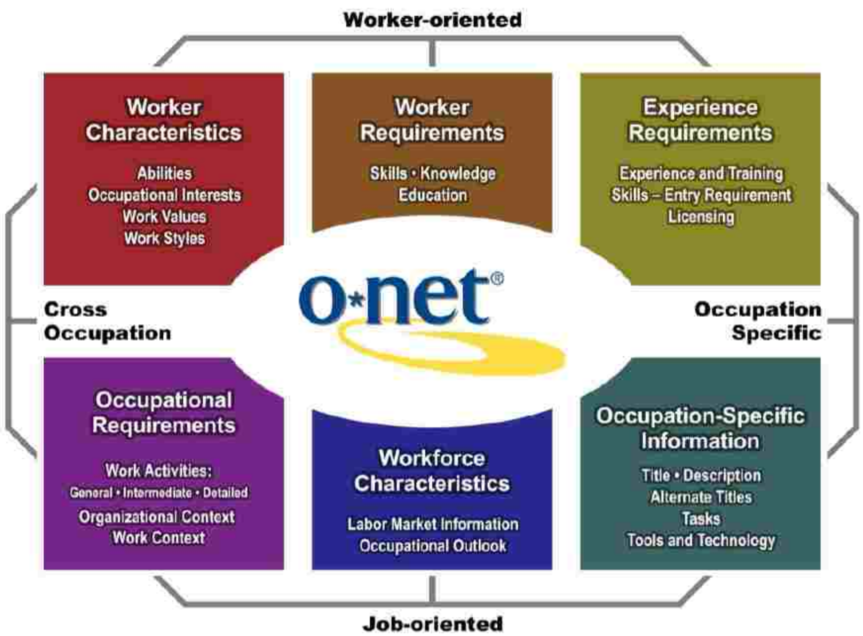


Figure 10. O*NET Content Model
Retrieved February 28, 2018 from https://www.onetcenter.org/content.html

The goal of the O*NET content model is to define the key features of an occupation as a standardized, measurable set of variables called "descriptors" (Retrieved August 17, 2018 from https://www.onetcenter.org/overview.html). The descriptors capture the knowledge, skills, and abilities to perform specific tasks and activities. The O*Net model is divided into six domains to organize this information. The information contained in each of the sub-modules is as follows:

<u>Worker Characteristics</u>
This module lists the worker attributes and abilities needed to perform the work. It also contains details about occupational interests, work values, and work styles. These can affect the worker's interest level, satisfaction level, engagement, and how they approach tasks.

<u>Worker Requirements</u>
This module contains attributes about basic skills, cross-functional skills, knowledge, and education.

<u>Experience Requirements</u>
This module contains attributes about experience and training, basic skills – entry requirement, cross-functional skills – entry requirement, and licensing.

<u>Occupational-Specific Information</u>
This module contains information such as title, description, alternate titles, tasks, and tools and technology related to an occupation.

Workforce Characteristics
This module contains labor market information and reviews the occupational outlook.

Occupational Requirements
This module contains a list of the generalized work activities.

The combination of these six modules, gives a good overall summary about what is needed for a particular occupation. Much of the information collected could fall into multiple modules, but the established framework organizes the information into an easy to understand model. O*NET collects data from three primary sources: job incumbents, occupational experts, and occupational analysts. The data is collected from questionnaire responses, interviews, and surveys. The O*NET database is sponsored by the U.S. Department of Labor and is continually updated so that it remains valid, reliable, and current. The descriptors used provide more detailed and encompassing information than both the HCO and JASS models, and the framework provides a logical method to sort through the data.

There have been many studies about the pros and cons of the new O*NET system. The new raw data collection method for the O*NET system uses surveys and a simplified rating scale for a self-job analysis technique. Peterson et al. (2001) described O*NET as “a highly useable and inexpensive methodology for analyzing jobs”. The new system allows for quicker updates and due to the use of new technology, the internet, the information is readily accessible for organizations and academia. The potential cons have been cited as a potential job inaccuracy due to low response rates or respondents basing responses on what they think management wants. Despite the potential cons, most of the literature cites O*NET to be a great source of information. The O*NET model is well defined and is still actively updated, and it provides broader information beyond just skills. O*NET provides important job and occupational information that can be used to detail job requirements and worker attributes, as well as descriptions of different types of generalized workers.

The downside to O*NET is that a method is needed to parse this information down to an acceptable level. Converse et al. (2004) stated that any application would have to work through conceptual, methodological, and practical issues. Peterson et al. (2001) noted that for O*NET to be a success, applications will have to be developed to use the data. O*NET is generic, pulling from several job positions for an all-encompassing position description (see Figure 11).

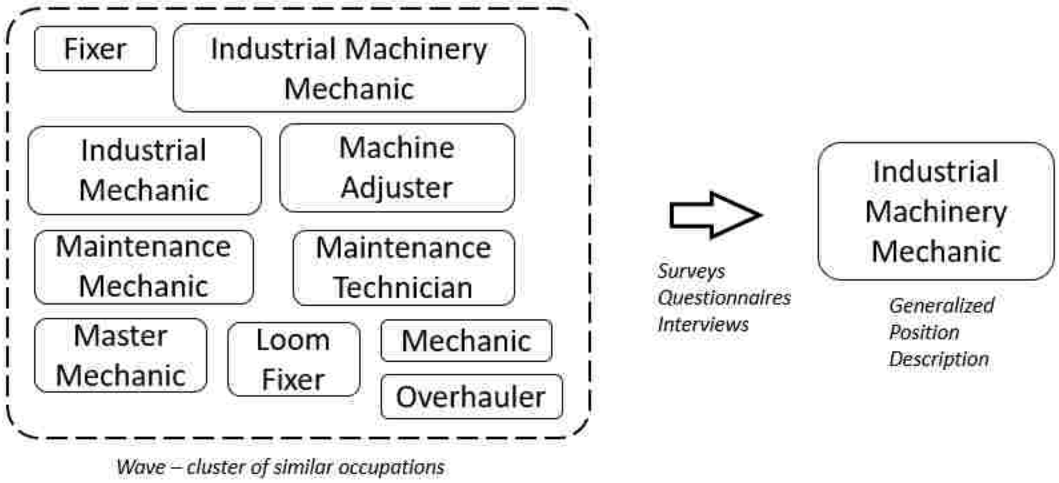
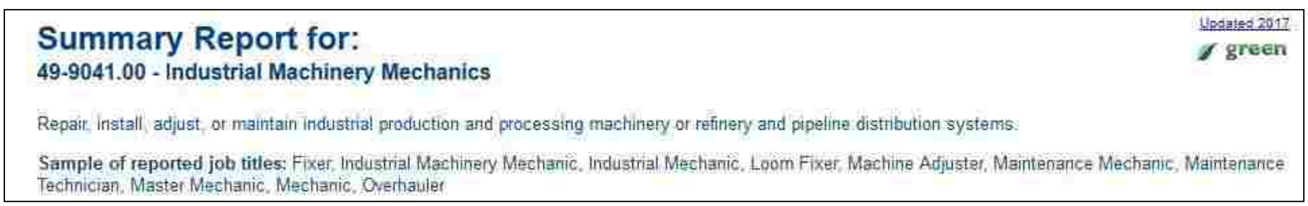


Figure 11. O*NET Position Description for Industrial Machinery Mechanics

The O*NET data collection occurs in what the O*NET program describes as waves. A "wave" is a cluster of similar occupations. Figure 12 shows the grouping used for Industrial Machinery Mechanics.



Summary Report for:
49-9041.00 - Industrial Machinery Mechanics

Updated 2017
green

Repair, install, adjust, or maintain industrial production and processing machinery or refinery and pipeline distribution systems.

Sample of reported job titles: Fixer, Industrial Machinery Mechanic, Industrial Mechanic, Loom Fixer, Machine Adjuster, Maintenance Mechanic, Maintenance Technician, Master Mechanic, Mechanic, Overhauler

Figure 12. Industrial Machinery Mechanics
Retrieved February 28, 2018 from https://www.onetonline.org/link/summary/17-3029.09

This O*NET job description is a combination of 10 different related positions making it a very generalized description, and the information for this combined job description also comes from several different sources as shown in Figure 13.

Data Collection Information for:

49-9041.00 - Industrial Machinery Mechanics Green

The data in O*NET OnLine is regularly updated as part of an ongoing data collection program. For more information, visit the O*NET Resource Center. The table below lists the date and source for data provided for this occupation.

Abilities	Analyst (2013)
Alternate Titles	Multiple sources (2016)
Detailed Work Activities	Analyst (2014)
Education	Incumbent (2013)
Interests	Analyst (2008)
Job Zone	Analyst (2013)
Knowledge	Incumbent (2013)
Sample of Reported Titles	Incumbent (2013)
Skills	Analyst (2013)
Tasks	Incumbent (2013)
Tools & Technology	Analyst (2017)
Work Activities	Incumbent (2013)
Work Context	Incumbent (2013)
Work Needs	Legacy Analyst
Work Styles	Incumbent (2013)
Work Values	Analyst (2008)

Figure 13. Industrial Machinery Mechanics Data Collection
Retrieved February 28, 2018 from https://www.onetonline.org/link/summary/17-3029.09

While this method is great for collecting lots of relevant information it would be difficult to compare an existing organization profile to the O*NET database. There are too many variables on both sides, the information is not in the same language, and the database is too generic for a good comparison to identify skills gaps. Even the O*NET toolkit recommends using the extensive database as a starting point to develop a thorough job description. In their example, the hiring authority selected the key factors they felt were needed and then worked with existing personnel to add in others they felt were important. The O*NET model evaluation is shown in Table 6.

Table 6. O*NET Model Evaluation

	Criteria		Details	Acceptable (A) / Needs Improvement (NI)
1	Taxonomy/ Same Language	Position Requirements	Uses O*NET descriptors	A
		Worker Qualifications	Uses O*NET descriptors	A
2	Comparable	Data comparison	Ability to add comparison methods	NI
		Quantifiable data	Ability to add metrics and ratings	NI
3	Adaptable	Information updated	Data is updated to remain current, online resources	A
		Robustness	Descriptors updated but comparison method needs work Method needed to parse and compare	NI
4	Actionable	Provide accurate and actionable data	No method to determine skills gaps.	NI
5	Usability	Ease of use	Wealth of occupational information, need method to make useful and actionable	NI

2.2.5 Other Initiatives

The literature mentions several other skills matching and training initiatives such as Navy Knowledge Online (KNO), Improved Performance Research Integration Tool (IMPRINT), and Secretary's Commission on Achieving Necessary Skills (SCANS). The KNO system was used to allow NAVY personnel to access training content. This was set up to be a central self-educating and learning portal. This system has shifted to "My Navy Portal" as of April 14th, 2017 due to complaints of poor support, broken links, and unpopular interface. IMPRINT was developed by the Army Research lab (ARL) and is a human performance modeling software and allows for discrete event simulation. The software is being used to evaluate workload and overwork load conditions. Future research with IMPRINT may include operator performance predictions and fatigue in complex systems. SCANS was a government initiative that took place in the early 1990s to determine what skills would be needed to have a successful high-performance, high-skill, future economy. This report identified the need to classify and organize skills, "a new language" (Kane et al., 1990), so that needed skills could be identified and proper training could be established, but no clear path forward was identified.

2.2.6 Model Summary and Comparison

The models reviewed in the previous sections are summarized in Table 7. The review criteria classify the strengths and weaknesses of each model and identify where the discrepancies are in the overall model catalog to identify skills gaps at a reasonable level of rigor balanced with ease of use.

Table 7. Model Comparison

			Model			
	Criteria		MOSAIC	HCO	JASS	ONET
1	Taxonomy/ Same Language	Position Requirements	NI	NI	NI	A
		Worker Qualifications	NI	NI	NI	A
2	Comparible	Data comparison	NI	NI	A	NI
		Quantifiable data	NI	NI	A	NI
3	Adaptable	Information updated	NI	NI	NI	A
		Robustness	NI	A	NI	NI
4	Actionable	Provide accurate and actionable data	NI	NI	NI	NI
5	Usability	Ease of use	NI	NI	A	NI

*Acceptable (A) /Needs Improvement (NI)

While each of the models have strengths, none of the individual models would be able to provide the desired quantifiable skills gap analysis results alone. Reviewing the models, O*NET does an excellent job of describing position requirements in term of descriptors and has methods to ensure these job descriptions are updated. These descriptors could also be used to define the worker qualifications. JASS has started a good method for data comparison and by using the slide rules with logical anchor points so that metrics and a rating method can be added. The MOSAIC project through OPM also discusses the adding metrics and using proficiency and frequency fields but the JASS program has advanced this concept past the worksheets suggested by OPM. The HCO model developed a strong framework for a comparison but has weaknesses with the taxonomy and the application of metrics. The missing component is a model that can bring all these features together and provide accurate and actionable data.

2.3 Methodologies to define Position Requirements and Worker Qualifications

In order to define a skills gap, both the position descriptors and the worker qualifications need to be clearly articulated in a manner that is both comparable (are they the same?) and quantifiable (is the degree of fit sufficient?). As shown in the model evaluation, models usually support only one side of the equation, i.e. defining the job position requirements or defining the worker qualifications. A skills gap model needs to be able to address both sides of the skills gap equation shown in Figure 2 in order to determine the degree of fit.

Position requirements need to adequately define what is required to perform the work and the worker qualifications need to adequately capture the KSAOs of the person; these two sides need to be comparable. In order to accomplish this, they need to use the same taxonomy. The descriptors used to identify what the position needs must also be used to identify the worker's KSAOs. This section will review some of the other KSAO identification methods currently being used.

2.3.1 Identifying KSAOs

In the work by Ross et al. (n.d), the group reviewed the use of SkillObjects™ in order to compare tasks and the KSAOs required. From the Navy ILE Learning Objective Statements Specifications and Guidance (MPT&ECIPSWIT-ILE-SPEC-1), SkillObjects™ are defined, measurable, and detailed descriptions used to define the job requirements for position. These are the knowledge, skills, tools, abilities and resources (KSATTR) that are used to detail the work requirements. Their research stated that this information, with further development, could provide a foundation for a capability-based model. The research shows the need for a strong taxonomy for the KSATTR identification and comparison.

There have been several projects started with the intent of identifying KSAOs for a position. In 2006, SkillsNET received a $35 million-dollar contract to provide operation, maintenance, analysis, training, technical services, and a commercial-off-the-shelf Skills Management System software application suite (“US Navy Spends $35M”, 2006, para. 1), (Moore, 2006). The goal of the program was to define skills necessary for a particular position and identify training and career development opportunities. Finding information about the results of this activity has proven difficult. Another research project references the use of SkillsNET in other areas. Reiter-Palmon et al. (2006) researched developing a web-based tool using the job analysis process adapted from SkillsNet (see Figure 14). For this job analysis process, there are several steps requiring multiple personnel. This activity would be time consuming, and the organization and evaluation of data collected is complex.

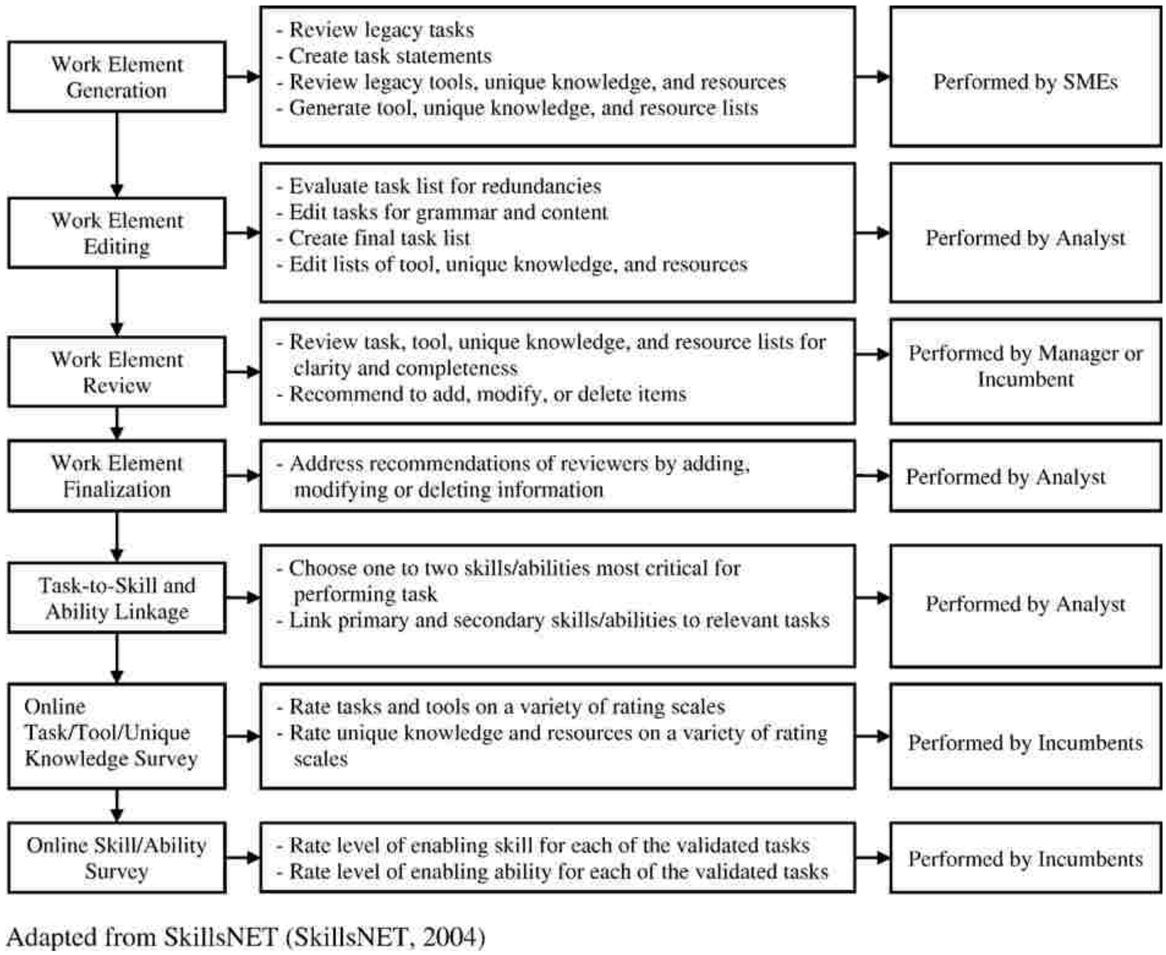


Figure 14. SkillsNET web-based job analysis process (Reiter-Palmon et al., 2006)

2.3.2 Military Occupation Specialties

The military's use of Military Occupational Specialties (MOS) provides a consistent method to identify specific position requirements. Individuals assigned to a position category must pass all required training to become qualified in the MOS. The use of MOS or (ratings for the US Navy) provides the basis for detailing and training, as well as some alignment with civilian employers. A worker will have to have all the required KSAOs to fill the MOS position. As the military has evolved so has the need to improve the MOS system. Shipman and Finley (1989), collected information to address the following three questions:

1. Does a new MOS need to be created to support a new system?
2. Should new requirements be merged with an existing MOS?

3. Does the family of branch MOS and career management fields (CMFs) need to be restructured?

These are the same questions that are being asked 30 years later. A better system that can easily identify the required KSAOs needed for a position and the ability to compare positions is needed.

Another issue facing military personnel is the transition to the civilian workforce. Because the military MOS system uses yet another taxonomy to define position requirements, matching these to any of the several methods used by private industry is difficult ("Get", 2012). There is a strong need to recognize and translate military skills to civilian positions, especially in advanced manufacturing.

2.3.3 Generating New Position Descriptions with Key Words

When a new position is created, work goes into identifying why the position is needed and the job requirements are detailed; it is important to detail the work requirements (KSAOs) to ensure the person selected will meet the objectives of the position. Existing position requirements may have changed due to new technology or a shift in the organization's focus. For a "good" worker-to-position fit, it is critical to be able to specifically and quantitatively identify what is needed for these positions. In industry, in contrast to the military, positions are usually described using keywords or phrases that identify the main aspects of the position. Each organization often has its own position descriptors.

Position requirements are usually generated when a new position is created and a worker needs to be assigned. By reviewing a typical hiring process (Figure 15), it can be seen that the first part of the process defines the position requirements (the worker requirements) and the second part identifies the worker skills (the individual profile). This is similar to the Navy HCO model detailed in section 2.2.2.

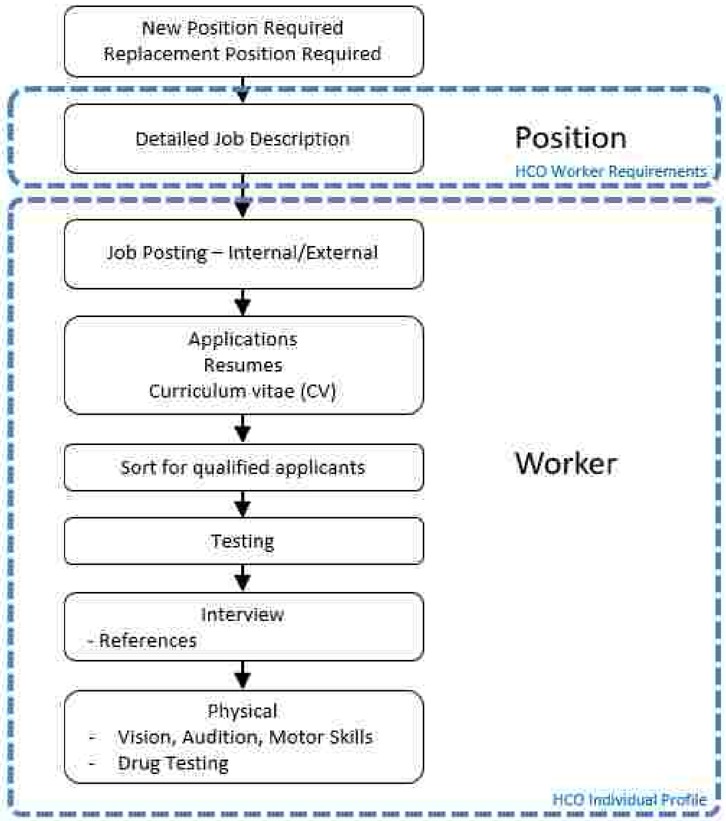


Figure 15. Typical Hiring Process

Typically, the first step in the process is to sort through potential candidates to compare the position description to resumes, applications or curriculum vitaes (CV) to identify the applicants that would appear to be the best fit. With the increased use of technology, many organizations are utilizing online job applications such as USAJOBS.gov, NASA STARS (STaffing And Recruiting System) w/Resumix, Monster.com, and Indeed.com that automate this selection process. Because of the large volume of applicants for certain jobs, programs with specific algorithms are being used to search online resumes. These systems are often referred to as applicant tracking systems (ATS). The ATS systems use algorithms that search for keywords and the number of occurrences of these words to determine which applicants can move to the next stage of the process. i.e., having the resume reviewed by the hiring official. This reduces the amount of work that is required and allows the hiring group to focus on the most qualified applicants.

The use of keywords for position descriptions can be problematic. Table 8 shows some technical keywords that are very similar. If the selection software is programmed to look for specific words, it will miss the others and may exclude qualified applicants. Some of the more advanced algorithms are linking the different keywords to be more accurate with their analysis.

Table 8. Examples of Technical Keyword Synonyms

Keyword	Related Synonyms
Pneumatics	Air operated, air controlled
3D Design	CAD, computer aided design, Creo, Solidworks, Catia, AutoCAD
Safety	OSHA
PM	Preventive maintenance, Overall equipment effectiveness, OEE (Overall Equipment Effectiveness)
Microsoft Office	Excel, Word, Office Products, MS Products
PLC	Programmable Logic Controls, CNC, Computer Numeric Controls, Robotic Programming, CAM, Computer Aided Machining
Quality Assurance	QA, QC, Quality Control, SPC, Statistical Process Control, Auditor
Sensors	Detection system, instrumentation

Another issue is that different organizations with the same job title could need completely different personnel. For example, an organization with a lot of injection molding machines would want a mechanic with a great deal of hydraulics experience whereas an organization that has small air operated (pneumatic) machines does not need a mechanic with any hydraulic experience. Although both have the same job title of mechanic, the job requirements can be completely different. Because organizations can have a large difference in needs for the same job title, they need to be able to quickly and easily identify a position. To further define the position the organization should be able to quantify how much of a particular aptitude is needed. Referencing the prior example, an organization does not need a hydraulics expert if there are no hydraulic machines. They may want some hydraulic knowledge, but they would weigh pneumatic knowledge a great deal higher. It is important to focus on the requirements of the position rather than the title of the job.

Similarly, the practice of keeping job descriptions very generic or vague with the intent of shifting employee responsibilities is also problematic. Adding “other position duties as required” as a catchall phrase results in a very generic position description. Without clear definition of what is needed, it will be difficult to identify any skills gaps between the position description and the potential personnel.

2.3.4 Extracting Worker KSAOs from Resumes

Resumes are where workers capture their work experience using keywords and phrases based on their background. As mentioned, the keyword synonym issue may inadvertently exclude a qualified applicant, or an applicant may not have included enough information to be considered, even if they were qualified. An issue is that as applicants learn how the system works, they can cater the applications to jump past the initial “keyword search” hurdle. By using the same keywords found in the job description and using multiple instances of the keywords, the application will be automatically moved to the next stage. To prevent this practice, organizations are starting to put warnings on their job postings. The following warning was included in a USAJOBS posting (2018) for a NASA engineer position: “Deliberate attempts to falsify your application information, such as copying portions of this job announcement into your resume, may result in you being removed from consideration for this position.” As noted by online articles covered by LinkedIn (Peggs, 2015) and Forbes (Steinfield, 2016), many applicants are aware of how these search engines function and there is a concern that resumes will become copies of the job description just to overcome the Applicant Tracking Systems (ATS).

2.3.5 Job Analysis

In manufacturing, when a new machine is needed, the machine specifications and details are thoroughly thought out and planned, e.g., what the machine has to do, what it makes, how much it needs to make, how fast it needs to make it, etc. are clearly defined. When looking at job positions a similar approach should be taken. Many organizations use an activity called a “job analysis” to determine what is needed for a position. A job analysis is the process of defining the work, activities, task, products, services, or processes performed or produced by a worker (Clifford, 1994). To perform a proper job analysis, workers that are currently in that position are typically interviewed to help define the job requirements. Managers and subject matter experts are often also consulted for their input. All three groups will use their own terminology and phrases when detailing a position which may create discrepancies when trying to compare what is required to potential workers.

2.3.6 Summary of Methodologies

Currently, positions are usually described using keywords or phrases that identify the main responsibilities of the job. Each organization develops its own job description identifying the KSAOs that it feels are important. The challenges of identifying job requirements include determining what to select, distinguishing different terms for the same attributes, rating the importance of each requirement, and the frequency that the skill is needed. In much of the literature it states that the hiring organization will be trained to discern the requirements from the resume; however, there is no mention of how this is done (Galagan, 2010). This is an important step in hiring personnel and for determining training requirements, but the details for performing this activity are not clear.

Reviewing the current methods, position descriptions and MOSs detail what is required for a position. They have some similarities as they both attempt to define the position requirements and may use some of the same taxonomy. The resume and KSAO essay are also similar and may use some of the same taxonomy. The main issue is that although some of the descriptors may be the same, in order to perform a consistent comparison between the position and the worker, both the position and KSAO descriptors also need to be from the same taxonomy. There are several methods to detail the position and worker requirements but there is not a consistent terminology that can tie them all together. An encompassing taxonomy is needed to describe both the position requirements and the worker qualifications so that matching and comparisons can be conducted effectively. The Venn diagram shown in Figure 16 describes this partition.

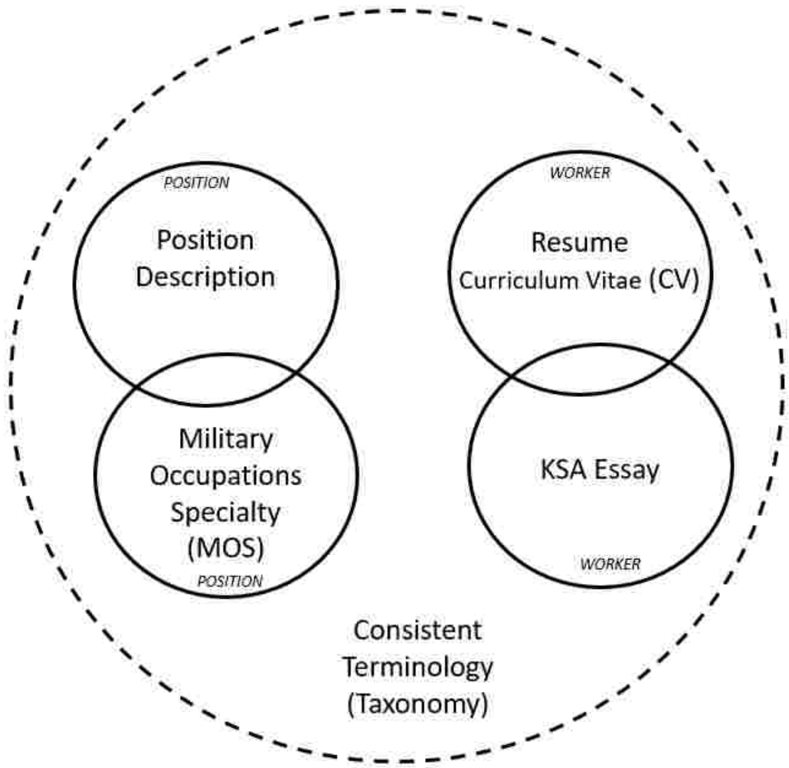


Figure 16. Terminology Issue

Additionally, the position requirements need to be captured in a common format that allows the organization to add metrics that can be used for evaluation. By allowing organizations to apply metrics as they identify what is needed for a position, they can ensure that they get the right worker or can train in the correct area when a gap is identified. The same issue applies to the position requirements for identifying the worker KSAOs. Both need to be in the same language for any type of comparison to be successful.

2.3.7 Gap in the Body of Knowledge and Requirements for a Skills Gap Model

The following criteria were identified in section 2.1.3 for a successful skill gap model: the ability to detail the position requirements, the ability to detail the worker qualifications, and the ability to quantifiably compare the two using metrics. The model would also need to have up-to-date information, be robust enough to be generalizable to any domain, and easy to use so that it would provide actionable results within an acceptable amount of effort.

Table 9. Model/Initiative Summary

	Criteria						
Models/Initiatives	**Taxonomy**	**Comparable**	**Adaptable**	**Actionable**	**Usability**	**Key Points**	**References**
MOSAIC (Multipurpose Occupational Systems Analysis – Close Ended)	X					KSAOs	OPM Delegated Examining Operations Handbook (2007) , Kay (2011), Ross et al, (n.d.), Kane et al (1990), DD 21 ONR (1998)
HCO (Human Capital Object)		X			X	Framework	Ross et al, (n.d.), HCO Conceptual and Logical Data Model (Sea Warrior)
JASS (Job Assessment Software System)		X			X	Parser, Decision path	Fleishman and Quaintance (1984), Knapp and Tillman (1998), Garneau (n.d.),
O*NET (Occupational Information Network)	X		X			Descriptors (KSAOs)	Peterson et al (2001), Clifford (1994), U.S. Department of Labor (1993), Campion, M. A. et al (1999), Converse et al. (2004), Dictionary of Occupational Titles (DOT), Secretary of Labor started the Advisory Panel for the Dictionary of Occupational Titles (APDOT)
KNO (Navy Knowledge Online)						Self-learning	System has shifted to "My Navy Portal
IMPRINT (Improved Performance Research Integration Tool)						Human Performance Modeling	Army Research lab (ARL)
SCANS (Secretary's Commission on Achieving Necessary Skills)						Skill organization	Kane et al (1990),
SkillsNET	X					KSAOs	Moore (2006), Reiter-Palmon et al. (2006)
MOS (Military Occupational Specialties)	X					KSAOs	Shipman and Finley (1989), "Get" (2012)
Resumes/CV	X					KSAOs	Peggs (2015), Steinfield (2016),
Job Analysis	X					KSAOs	Clifford (1994), Galagan (2010)

The summary tables shown in tables 7 and 9 indicate that while some of the models have many capabilities, none of the existing models meet all criteria. The gap in the body of knowledge is the ability to identify a skills gap and the model features that must be in place to support this. This is shown in Figure 17.

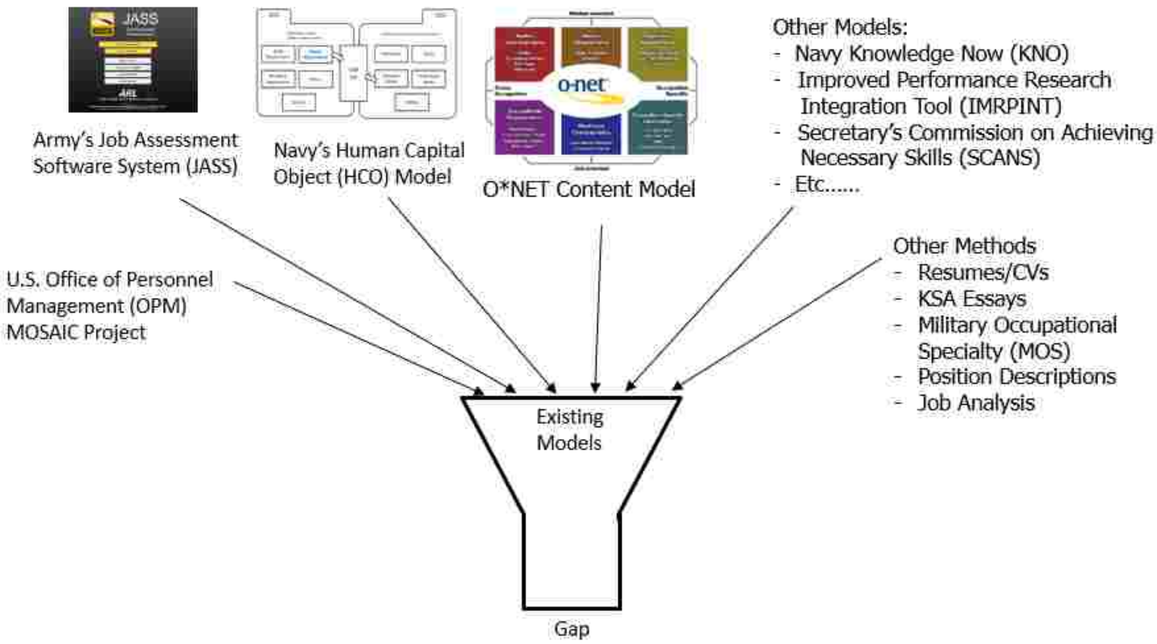


Figure 17. Literature Gap

The gap in the body of knowledge identifies the need for a generalizable model that provides both the position requirements and the worker qualifications (both perspectives) in the same language, is adaptable to any domain, allows for comparison (quantifiable data), is quick and easy to use (usability/burden), and provides accurate and actionable data (robust). None of the existing models provide a clear path for skills matching or provide an easy method to quantitatively identify skills gaps.

The focus of this research is on developing the underlying model and algorithm to quantify the "skills gap" that describes the distance between the position requirements and the worker's qualifications in a consistent, efficient and usable manner and to provide accurate and actionable data.

3. METHODOLOGY

This chapter begins by reiterating the gap in the body of knowledge identified at the end of Chapter 2 and provides a research methodology to create a model that addresses the identified gap. The research gap can be described using a diagram to show the strengths of existing models that can be leveraged in the skills gap model. The next section describes Design Science, a research methodology often used in the information sciences and elsewhere with the explicit purpose of improving existing models and methodologies. The steps for this research, aligned with the Design Science Research Methodology, are then articulated.

3.1 Addressing the Research Gap

The results of the literature review revealed a gap in the body of knowledge regarding worker-to-position fit models that support the identification of a skills gap, i.e., the mismatch in position requirements and worker competencies provided as actionable data. However, the review in Chapter 2 indicates that some existing models partially meet the requirements for such a model, and a solution model can leverage these modeling frameworks; i.e. the solution model is a composite model of the previous models with an improved algorithm. This approach satisfies the requirements, as shown in Table 10.

Table 10. New Composite Model

	Criteria		Model				Composite Model
			MOSAIC	HCO	JASS	ONET	
1	Taxonomy/ Same Language	Position Requirements	NI	NI	NI	A	A
		Worker Qualifications	NI	NI	NI	A	A
2	Comparible	Data comparison	NI	NI	A	NI	A
		Quantifiable data	NI	NI	A	NI	A
3	Adaptable	Information updated	NI	NI	NI	A	A
		Robustness	NI	A	NI	NI	A
4	Actionable	Provide accurate and actionable data	NI	NI	NI	NI	NEW
5	Usability	Ease of use	NI	NI	A	NI	A

*Acceptable (A) /Needs Improvement (NI)

As shown in the table, using the strengths of each model, it is possible to design a new all-encompassing model. The architecture of the composite model is based on the structure of the existing HCO model to compare position requirements and worker qualifications. The improved algorithm is based on the decision path logic from the JASS program augmented with specific scaled KSAO constructs; this will provide a framework that allows a "skills gap" to be quantitatively identified. The position requirements and the worker qualifications will both be in terms of O*NET descriptors. Figure 18 shows how the composite model aligns and supports the skills gap model.

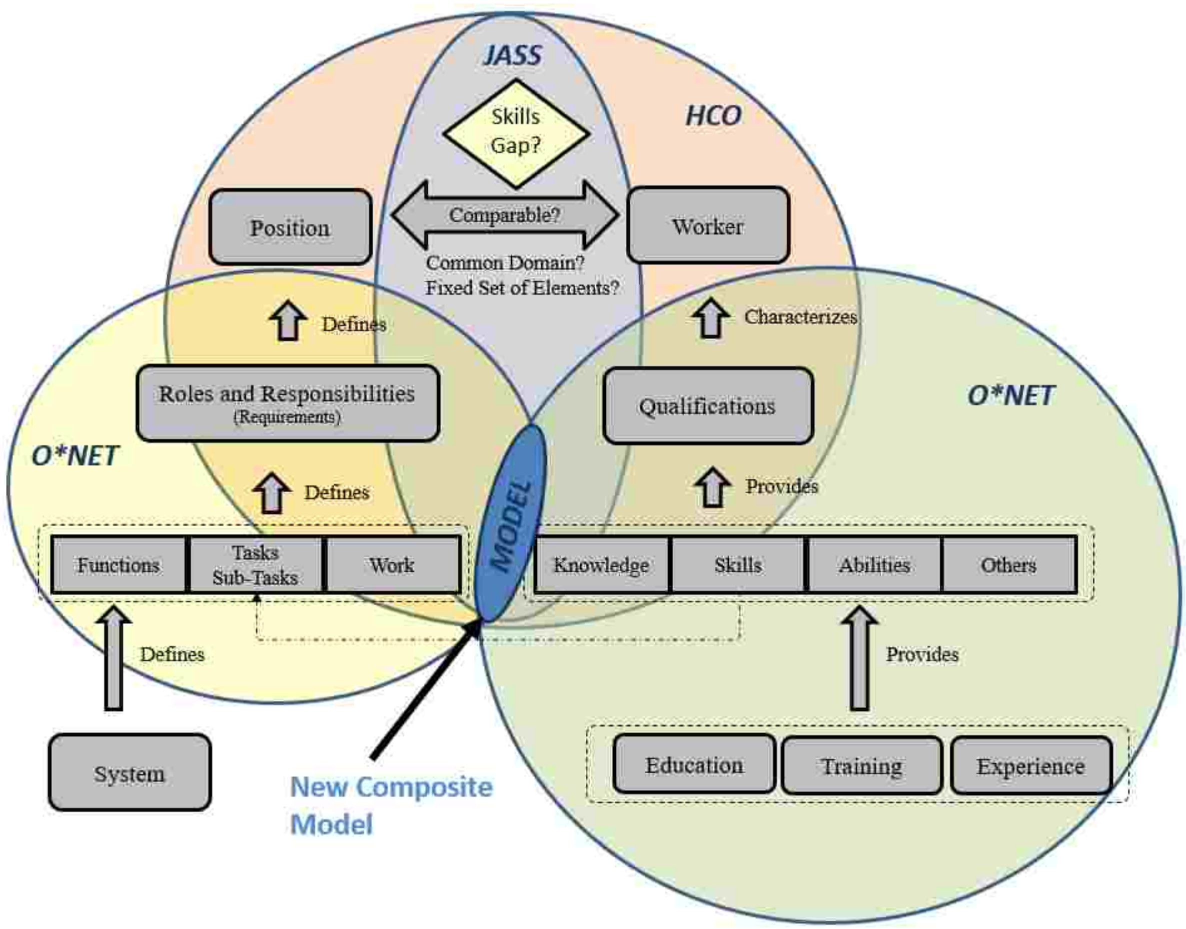


Figure 18. Architecture of the Composite Model

The O*NET database used on the position requirements side is shown in light yellow, and the O*NET database used on the worker qualifications side is shown in light green, the HCO model is shown in orange, and the JASS program is shown in light blue. Using the strengths of all these together, the overlap in this Venn diagram is shown in dark blue. This dark blue section is the new composite model, the Skills Gap Analysis Model (SGAM). The benefit of combining the HCO model, the JASS program method, and O*NET is that the focus will be on the specific “position requirements” needed (from the organization side) and the “individual profile” (from the worker side) and how these can be compared to identify the gap. The key factor for success will be developing a model that can identify the specific KSAOs, a rating process, and calculating the distance that represents the skills gap. O*NET utilizes descriptors to identify knowledge, skills, abilities, and others (KSAOs) required for a position. These descriptors use words and phrases that can identify the position requirements and can also be used to detail the worker qualifications. By basing the model on the O*NET descriptors and having existing personnel use the same descriptors to detail their positions, the model can make a consistent comparison.

As described in Chapter 2, there is much variability in the use of KSAOs. In order to have a consistent methodology and because of the availability, wealth of information, and research already invested, the O*NET database with its descriptor method will be used to describe both job positions and worker qualifications. O*NET collects data from three primary sources: job incumbents, occupational experts, and occupational analysts. The O*NET database is continually updated so that it remains valid, reliable, and current. However, at issue is the ability of the data to be parsed in different ways so that it can be used to efficiently determine the requirements for different positions and compared to workers to identify skills gaps. This will require an updated algorithm to support the data identified in the model in order to calculate the skills gap.

The rating process will determine the best way to apply metrics to these descriptors for quantitative analysis. Using scaling metrics to include proficiency, importance, and frequency the algorithm will generate the detailed job requirements. The model will provide a quantifiable comparison of the fit of existing personnel to the position. The skills gap can then be represented as a distance between the two sets of parameters.

3.2 Research Approach

The research method adopted is based on the design science approach. Design science is a research methodology typically associated with information systems that uses existing knowledge-based models, referred to as artifacts, with the intent of improving these artifacts (Hevner et al., 2004). The result is an improved artifact that increases the understanding of a problem domain. The improved artifact should increase the effectiveness and efficiency of an organization. In this case the problem domain is the ability to efficiently and quantitatively identify skills gaps. The starting artifact is a database of position descriptions (O*NET database). This research process will result in a new model that improves efficiency, uses common terminology, and allows a quantitative analysis of the skills gap. The general design science research process is shown in Table 11.

Table 11. Design Science Research Methodology (DSRM) (Geerts, 2011)

DSRM activities	Activity description	Knowledge base
Problem identification and motivation	*What is the problem?* Define the research problem and justify the value of a solution.	Understand the problem's relevance and its current solutions and their weaknesses.
Define the objectives of a solution	*How should the problem be solved?* In addition to general objectives such as feasibility and performance, what are the specific criteria that a solution for the problen defined in step one should meet?	Kowledge of what is possible and what is feasible. Knowledge of methods, technologies, and theories that can help with defining the objectives.
Design and development	*Create an artifact that solves the problem.* Create constructs, models, methods, or instantiations in which a research contribution is embedded.	Application of methods, technologies, and theories to create an artifact that solves the problem.
Demonstration	*Demonstrate the use of the artifact.* Prove that the artifact works by solving one or more instances of the problem.	Knowledge of how to use the artifact to solve the problem.
Evaluation	*How well does the artifact work?* Observe and measure how well the artifact supports a solution to the problem by comparing the objectives with observed results.	Knowledge of relevant metrics and evaluation techniques.
Communication	Communicate the problem, its solution, and the utility, novelty,and effectiveness of the solution to researchers and other relevant audiences.	Knowledge of the disciplinary culture.

Design Science varies from many typical research activities as it is not describing or explaining an existing phenomenon but searching for ways to improve one. This shift from traditional research offers a great deal of potential to many research areas as it can provide solutions for known problems. Design Science can be applied to this work to address the ability to identify and quantify the "skills gap". Using the format developed by Geert (2011), a similar table for this research is shown in Table 12.

Table 12. DSRM – Identifying and Quantifying Skills Gaps

DSRM activities	Activity description	Knowledge base	Chapter Addressed
Problem identification and motivation	*What is the problem?* Organizational issues identifying skills gaps and position requirements. Being able to specifically identify needs organizations could target training programs, improve position placements, and improve their hiring process. Other potential benefits could be improved morale, less overtime, fewer quality issues, adn less employee turnover.	Literature review of current methods and models used to identify position requirements and worker qualifications.	1,2
Define the objectives of a solution	*How should the problem be solved?* Design of work requirement information systems that captures detailed information about a postion, is easily and constantly updated so that all information is up-to-date and relevant. System shuld be able to detail both the postion and worker rquriements and allow for comparisons.	Take the best of reviewed models (HCO, JASS, O*NET) and the lessons learned from other activities.	3
Design and development	*Create an artifact that solves the problem.* Design a generalizable model that can be applied to any domain that defines the postion requirements and the worker qualifications in the same language and applies metrics so that comparisons can be made to turn the information into actionable data.	O*NET to be used as a database, the use of parsed decision methods, application of metrics and weighting strategies, and logical comparison methods.	4
Demonstration	*Demonstrate the use of the artifact.* Proof of concept study involving technical personnel.	Excel based program using a parsed decision model to capture SME and worker inputs.	5
Evaluation	*How well does the artifact work?* Review proof of concept results and the SME and worker feedback about the new model.	Sorting criteria, comparison methods, and evaluation techniques.	6
Communication	Communicate the problem, its solution, and the utility, novelty,and effectiveness of the solution to researchers and other relevant audiences.	Dissertation submittal Article submittals	7

3.3 Research Examples

The Design Science Research Method (DSRM) varies from typical research, but as technology and issues have evolved, the need to address them also has evolved. Several researchers note that even before the DRSM was named it was being used in the information technology (IT) field to improve computer systems and software (Hevner et al., 2004), (Vaishnavi et al., 2017). These researchers also note that the method is not limited to the IT field. The DSRM allows researchers to investigate a relevant issue – what has been, what works, what doesn’t – and evaluate this information so that it can be used to create a new artifact that solves the problem. In recent years there has been increased interest in this method. Based on a Google Scholar search, the graph of the number of DSRM journal articles shows the increase over the last 14 years.

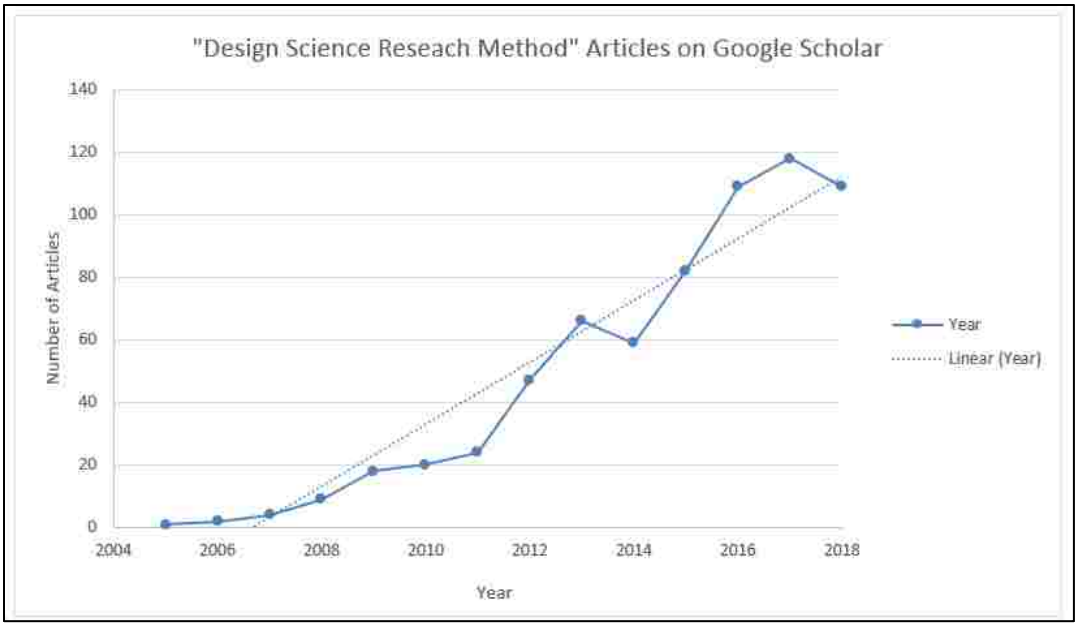


Figure 19. Design Science Research Method Usage

A recent example is the work by Amissah (2018). Amissah's research evaluated the existing System Modeling Language (SysML) and identified the system engineering need to improve the support of time-based simulation models. The artifact was a new model and framework that served as a testbed and guide for future work. This research follows a similar path. Instead of various computer languages there are various position descriptions and personnel qualification methods being used. There is the same need to develop a testbed and guide to properly identify both sides of the equation shown in Figure 2 and create a new model that allows for a quantitative comparison to identify a skills gap.

Other examples of the DSRM use include improving decision support systems (DSS) development in organizations (Arnott, 2005), improving construction purchasing (Bemelmans, 2014), and improving work-flow ergonomics (Valentin, 2015). All three of these examples follow the Design Science Research Method to design a practical solution to real world issues.

3.4 Application of Design Science Research Method

Throughout the model development, an example will be used to illustrate the development process in context. The example will focus on Manufacturing Production Technicians (see Figure 20). The manufacturing technician position was chosen because of the detailed information available in O*NET, the access to personnel in those positions; with the push for more US manufacturing, this is a critical area. While the new artifact will be developed using the manufacturing production technician's example, the resulting skills gap analysis model is generalizable to other domains.

Figure 20. O*NET Summary for Manufacturing Technician
Retrieved February 28, 2018 from https://www.onetonline.org/link/summary/17-3029.09

3.4.1 DSRM Step 1 – Problem Identification and Motivation

The introduction section to this thesis identified the motivation for this problem. In summary there is a need to identify skills gaps in personnel in an efficient and quantifiable method. Much of the literature states this is an important step in hiring personnel and for determining training requirements, but the details for performing this activity are not clear. Skills gaps are costly for organizations; with a better model to identify position requirements and worker qualifications, organizations can move personnel to better suited positions or utilize needed training in the specific areas identified.

3.4.2 DSRM Step 2 – Define the Objectives of a Solution

The literature review concluded with the requirements for a model to address the skills gap issue, namely the model must specifically quantify the difference between the position description and the personnel qualifications. In order to do this, the model needs to be able to detail both the position side and personnel side in the same language and allow for a detailed comparison. The resulting artifact must be adaptable to any occupation and give quantitative results to help determine person to job fit and help identify gaps.

3.4.3 DSRM Step 3 – Design and Development of the Artifact

This step of the Design Science Research Methodology develops the new artifact based on the problem identified in Chapter 1 and the model requirements articulated in Chapter 2. This step of the research will develop a Skills Gap Analysis Model based on the HCO model, the O*NET model, and a modified version of JASS as shown in the architecture of Figure 18. The HCO and O*NET models provide the framework for the comparison. The original JASS model was developed to identify position requirements. JASS is based on an underlying model of skills and abilities and utilizes a decision tree to select and pass over non-relevant questions and allows the evaluator to apply weight to position aptitudes. By using weighting levels, quantitative analyses can be applied. Some of the functionality of the JASS model is relevant in the development of an improved algorithm to parse the O*NET data.

By combining the HCO and O*NET models and some of the aspects of JASS, the resulting model can be used to evaluate the position requirements, the worker qualifications, and the fit of a worker to the position. O*NET utilizes descriptors to identify knowledge, skills, abilities, and others (KSAOs) required for a position. By applying metrics and scales to these descriptors, the position can be quantitatively evaluated. The proposed model will include a quantitative fit/rating and allow for the comparison of the “worker requirements” and the “individual profile” to help identify skills gaps and training opportunities. The research challenge of the model development will be to develop a methodology to determine how to parse and apply the O*NET data in a way that is conducive to describing a position and designing an algorithm that can compare this output to the existing individual profiles using quantitative O*NET database descriptors. The development of the new artifact, the skills gap analysis model, will be detailed in Chapter 4.

3.4.4 DSRM Step 4 – Demonstration

The model will be implemented in an Excel spreadsheet so that organization personnel can evaluate the utility of the model, i.e., does the model efficiently provide a quantitative skills gap? Additionally, the results can be used to confirm the internal validity of the model; that is, to ensure that there is consistency in the model results and that the outcomes are warranted from the data selected. Because this step involves consulting with human subjects, an application was filed with the Old Dominion University Institutional Review Board. This exempt research was approved, and the letter was received January 2, 2019 with IRB # 1310084-2.

The demonstration for this research involves using the model to characterize a specific position from both the position side and the worker side. A minimum of three subject matter experts (SMEs) will use the interface to detail a specific position within the technical domain case study. Using the same tool, at least five existing workers, industrial maintenance technicians (Technicians) from a local manufacturing facility will detail their positions. The quantity three was chosen for SMEs to make sure responses are anonymous. The quantity of five was chosen for the technicians because of the wider variation in worker capabilities and perceptions. Based on the research by Nielsen (2000), five users yield good results identifying greater than 75% of the usability issues.

The SMEs will use the model and algorithm to quantitatively detail the position requirements in terms of the O*NET descriptors. The SMEs will be chosen based on their experience and reputation for being an expert in their field. The SMEs all had greater than 20 years of experience in the manufacturing field and are currently supervisors of technical teams. Likewise, current personnel in these positions will also quantitatively detail their qualifications. Because current position descriptions may be outdated or incorrect it is important to get a more accurate overview of the current position, and the best source would be for the existing personnel to detail the position. This also ensures that both sets of data are in O*NET descriptor terms which will allow for a consistent comparison.

The new model provides a common representation of skills from both the position side and the personnel side. The algorithm will compare the two sets of data. The comparison will determine if there are any gaps between what the SMEs feel the position requires and the skills of the existing personnel. By applying metrics, the worker-to-position fit can also be quantitatively determined. After completing the demonstration activity, the SMEs and current personnel will complete an opinion survey regarding the suitability and relevance of the model to meet its stated goals. The survey will provide additional results for the evaluation of the model criteria of robustness and usability in the next DSRM step. The demonstration will be detailed in Chapter 5.

3.4.5 DSRM Step 5 – Evaluation

The results of demonstration activity will be used to evaluate the degree to which the skills gap analysis model meets the requirements outlined in Chapter 2. By using SMEs to specifically identify what is needed for the position and having existing employees in that position, Technicians, identify their qualifications, the new Skills Gap Analysis Model will quantitatively identify the distance between the two, the skills gap. The demonstration results will be used to evaluate the new artifact on the five identified criteria: Single Taxonomy, Comparable, Adaptable, Actionable, Usable.

Additionally, the data collected for both the SMEs and Technicians will be evaluated to determine the model reliability. The qualitative data collected from the opinion survey will be used to determine if the model meets the user’s needs. Any issues or areas for improvement will be identified. The evaluation will be completed and described in Chapter 6.

3.4.6 DSRM Step 6 – Communication

The communication plan will be described in Chapter 6. The communication plan will include various stakeholders in this research: researchers, system engineers, Human System Integration professionals, and human resources professionals. The conclusion along with the overall findings from this study will be captured in this thesis and journal article submissions;

detailed requirements are critical to determine a proper fit of a worker to a position. The detailed position description also lets candidates know specifically what is being required for the position. Likewise, accurate position descriptions are needed that use the same “language” as the worker qualifications so that comparisons can be made. By comparing the accurate position requirements directly to worker skill sets, current workers can be evaluated directly to determine the fit with the position. In addition, the results will be discussed with the organizations that participated in the demonstration

3.5 Summary

This research will develop a new artifact following the DSRM paradigm. The new generalizable model will be developed to reduce the large O*NET job analysis database into a condensed list of requirements for a position that can be used to provide a profile for a position description. The model also uses this database to detail the worker qualifications using the same methodology. The accompanying algorithm will provide a quantifiable comparison of the fit of existing personnel to the position. In this chapter, the methodology to develop the artifact has been described and the planned research aligned with the steps: Problem Identification, Solution Objectives, Artifact Development, Demonstration, Evaluation, and Communication. Additionally, the chapters of this thesis have been aligned with the Design Science stages, as indicated in Table 11.

4. MODEL DEVELOPMENT

4.1 Introduction

A synthesis of the HCO, JASS, and O*NET models augmented with domain specific skills and metrics was developed for use in evaluating the gap between personnel and positions. The strength of this new model is that it identifies specific knowledge, skill, ability, and others (KSAOs), including scaling metrics, using the same descriptors for both the position requirements and worker qualifications. This then allows a distance measure to be computed to quantify a "gap" between the position and the assigned personnel. The resulting model provides a better method for organizations to identify gaps to determine if existing personnel meet the position requirements. This type of model addresses the shortcomings identified in previous models by providing the worker and position information in the same language for comparison, ensuring the required data is readily available, and making the approach easy to use and understand.

Using the extensive O*NET database, a decision model (DM) was developed to parse the relevant information. Scaling metrics were used to include proficiency, importance, and frequency in the algorithm to generate the detailed position requirements or identify the worker's qualifications. The goal was to provide a model that can be used to determine specifically what is needed for a position and can also be utilized by existing workers to describe the skills that they have. The model, using the algorithm with metrics, should also calculate the difference in the two. This difference is the skills gap. The process to go from O*NET to a detailed position description is shown in Figure 21.

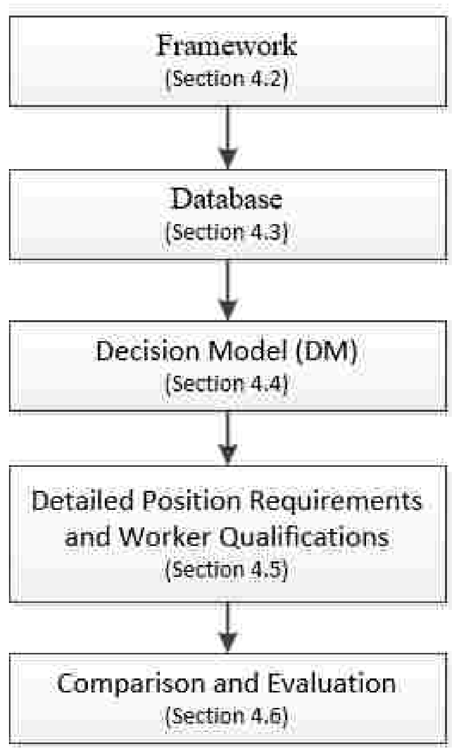


Figure 21. Framework to Skills Gap Identification Process

The model results in both the position description and worker qualifications in the same language so that they can be compared (see Figure 22).

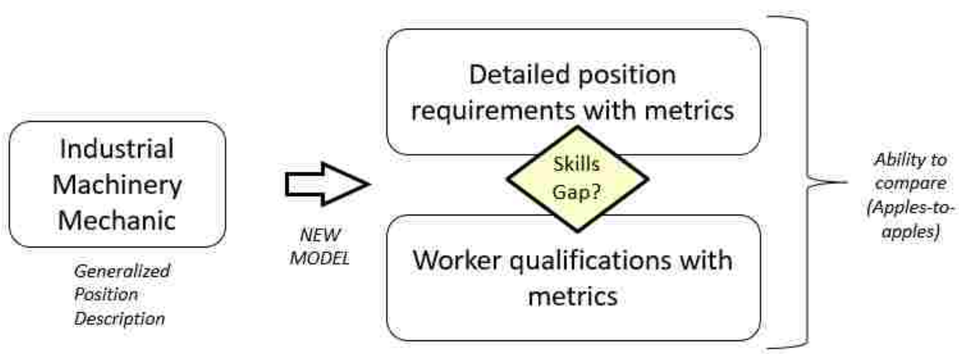


Figure 22. Generalized Details to Specifics

4. 2 Skills Gap Analysis Model Framework

The combined model framework is shown in Figure 23. The framework from the Navy's Human Capital Object (HCO) model was used to compare worker requirements and individual profile. The decision path logic from the Army's Job Assessment Software Selection (JASS) program augmented with specific scaled KSAO constructs from O*NET provides the comparison method that allows a "skills gap" to be quantitatively identified. This approach addresses the shortcomings identified in previous models by providing the worker and position information in the same language for comparisons.

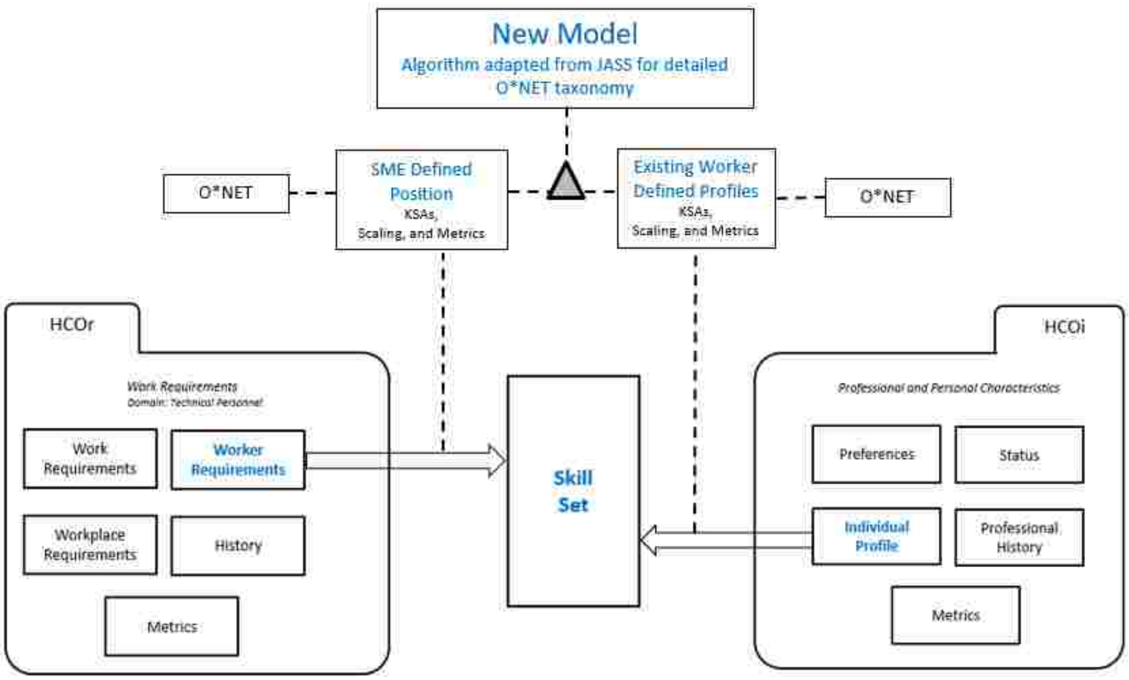


Figure 23. HCO/JASS/O*NET Combined

The benefit of combining the HCO framework, the JASS program method, and O*NET database is that the focus is on the specific "worker requirements" needed (from the organization side) and the "individual profile" (from the potential worker side) resulting in data sets that can be compared to identify the skills gap. The key factor when combining these systems was developing a model to identify the specific KSAOs on both sides, the rating process, and calculating the "gap" distance.

4.3 O*NET Database

The SGAM will leverage the extensive O*NET database. The O*NET data is organized into six major domains: worker characteristics, worker requirements, experience requirements, occupational-specific information, workforce characteristics, and occupational requirements. These descriptors also include softer skills to fully detail position requirements. Each of these domains can be subdivided into further categories with multiple job-oriented and worker-oriented descriptors in each. The categories and subcategories for the example technician position are shown in Figure 24. The numbers shown are the potential requirements for the manufacturing production technician position, in each area.

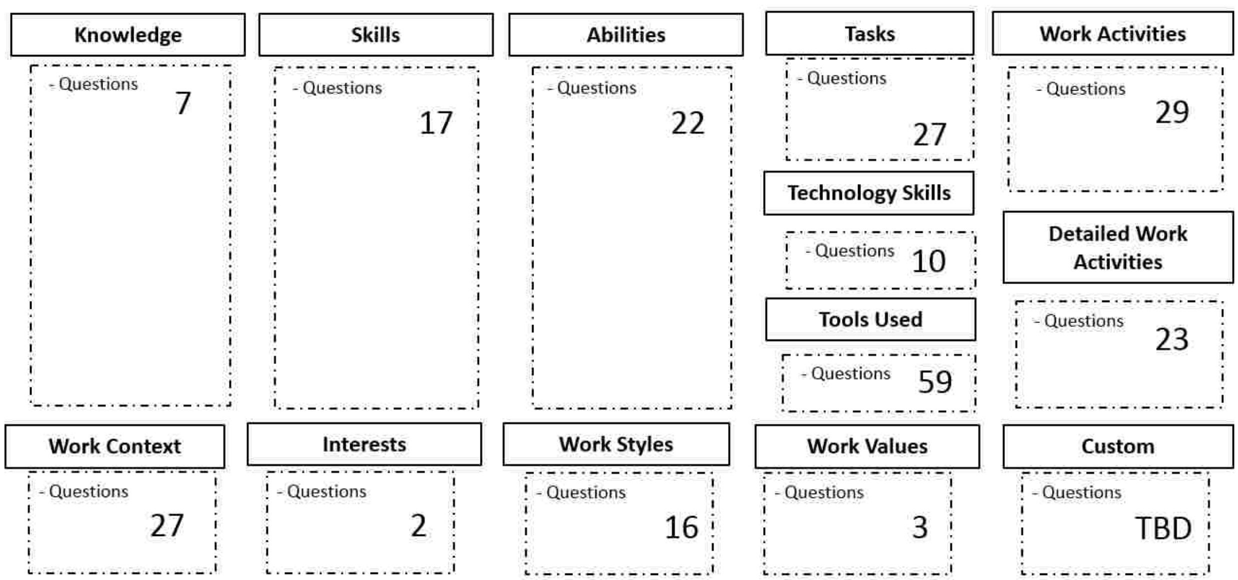


Figure 24. O*NET Categories

The O*NET model is very detailed, and the logical listing of all potential requirements is necessary to start identifying position requirements and personnel skills. Starting with a well-defined list helps with a phenomenon called “recall” (Reiter-Palmon et al., 2006). Recall prompts memory and enables users of the information to quickly and accurately identify the relevant items. This is analogous to having a shopping list before going to the grocery store. The O*NET model framework will ensure that the descriptions are complete and no items are forgotten.

Some O*NET profiles identify level of proficiency needed, importance, or frequency while some areas do not. See Table 13 below for O*NET Job position 49-9041.00 - Industrial Machinery

Mechanics. To ensure consistent data for comparison all relevant descriptors are captured and measured quantitatively in the new model.

Table 13. Proposed Skills gap analysis Method.

		Current: O*NET and JASS				Proposed - Composite Method			
Area	Module	Importance	Level	Frequency	Yes/No	Importance	Level	Frequency	Yes/No[1]
Worker Characteristics	Abilities	x	x			X	X	X	X
	Interests					X	X	X	X
	Work Styles	x				X	X	X	X
	Work Values					X	X	X	X
Worker Requirements	Knowledge	x	x			X	X	X	X
	Skills	x	x			X	X	X	X
Experience Requirements	Experience and Training					X	X	X	X
Occupational Requirements	Work Activities	x	x			X	X	X	X
	Detailed Work Activities					X	X	X	X
	Work Context					X	X	X	X
Occupation-Specific Information	Tasks	x	x	x		X	X	X	X
	Tools and Technology								
Custom	Custom					X	X	X	X

1. YES/No used for decisional questions only.

Questions are typically used for the job analysis activity to collect information. Breaking a task down into every detail would result in an overwhelming amount of questions. In the work by Clifford (1994), he discusses how to address details related to common activities. The example used is “drive a car”. Explicit details about opening the door, using the key or fob, and changing gears are not needed. The important aspect is the ability to use the combined KSAOs to complete a common activity. The O*NET descriptors make use of this method. This reduces the time is takes to complete a job analysis and makes comparisons more efficient.

4.4 Parsing the Model Data

The JASS program is not being used explicitly in the model, but aspects of it will be adapted to work with the new model. The ability to sort through the questions and only present what is relevant is critical. Figure 25 show potential results of running through the JASS for a particular activity. There can be up to a 59% reduction in the number of questions that need to be answered.

	Total Questions	Potential Skipped	New Amount	% Reduction
Communication	6	5	1	83.3%
Conceptual	13	5	8	38.5%
Reasoning	9	6	3	66.7%
Speed Loaded	9	4	5	44.4%
Vision	8	7	1	87.5%
Audition	4	1	3	25.0%
Psychomotor	12	8	4	66.7%
Gross Motor	15	9	6	60.0%
Totals:	**76**	**45**	**31**	**59.2%**

Figure 25. JASS Question Reduction

Within O*NET there is a large amount of data; the downside of a large detailed list is the amount of information can cause information overload. To demonstrate this point, all the potential descriptors for the manufacturing technician position are shown in Appendix D. Because O*NET is a large, comprehensive job analysis database, there is a great deal of information that needs to be sorted and analyzed. The skills gap analysis model includes a decision model to parse the O*Net data to make it usable for identifying skills gaps. The first step is to determine if there are dependencies between the requirements. To reduce the amount of data, the decision model will assess each section to determine if there are dependencies. Based on these dependencies, some of the descriptors can be logically removed saving time and effort and parse out only the relevant information. The process is shown in Figure 26.

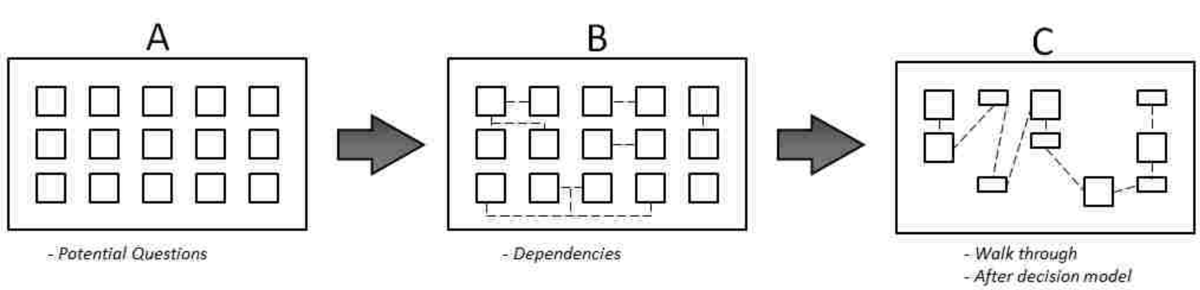


Figure 26. Dependency Evaluation

Using question dependencies, non-relevant questions are removed. Determining the dependencies is critical for reducing the amount of data. Some O*NET categories or descriptors can be eliminated because they are not appropriate to the idea of creating or detailing a position. Examples of these categories would include job zone, related occupations, wage & employment trends, and current job openings on the web. This is good overall information about the position but is not relevant for detailing what is needed for a position. The other O*NET categories and related descriptors can be used to detail the position. Additionally, many of these categories can be grouped into knowledge sections. Then within each knowledge section the skills, abilities, work activities, tasks, tools, and technology can be identified. This process would be repeated for all knowledge sections. Figure 27 shows the research process to be used for sorting through the categories and descriptors.

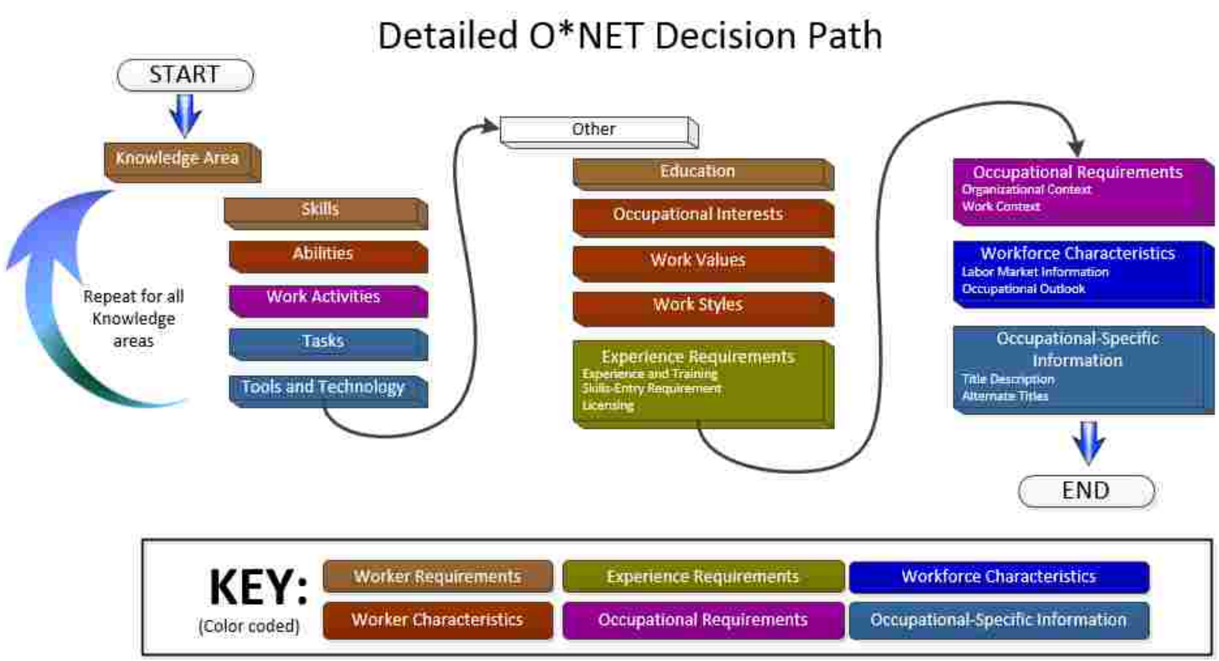


Figure 27. O*NET Decision Path

The key is for the decision path to provide a guide to logically and systematically navigate the large volume of questions and reduce the amount of time and effort required to provide an accurate and detailed position description. Figure 27 shows each section starting with the knowledge area. Similar to the JASS decision path model shown in Appendix B, many knowledge areas can start with a simple YES/NO decision. For example, if no computer knowledge is needed, then there are no computer skills needed, no specific computer abilities needed, no computer related work activities or detailed work activities are needed, and no computer related tools or technology are needed. A simple "NO" will by-pass all the related dependent questions. In a similar fashion within the sub-categories, YES/NO questions can also be used to skip non-relevant questions. The decision tree for this process along with these decision points is shown in Figure 28 below.

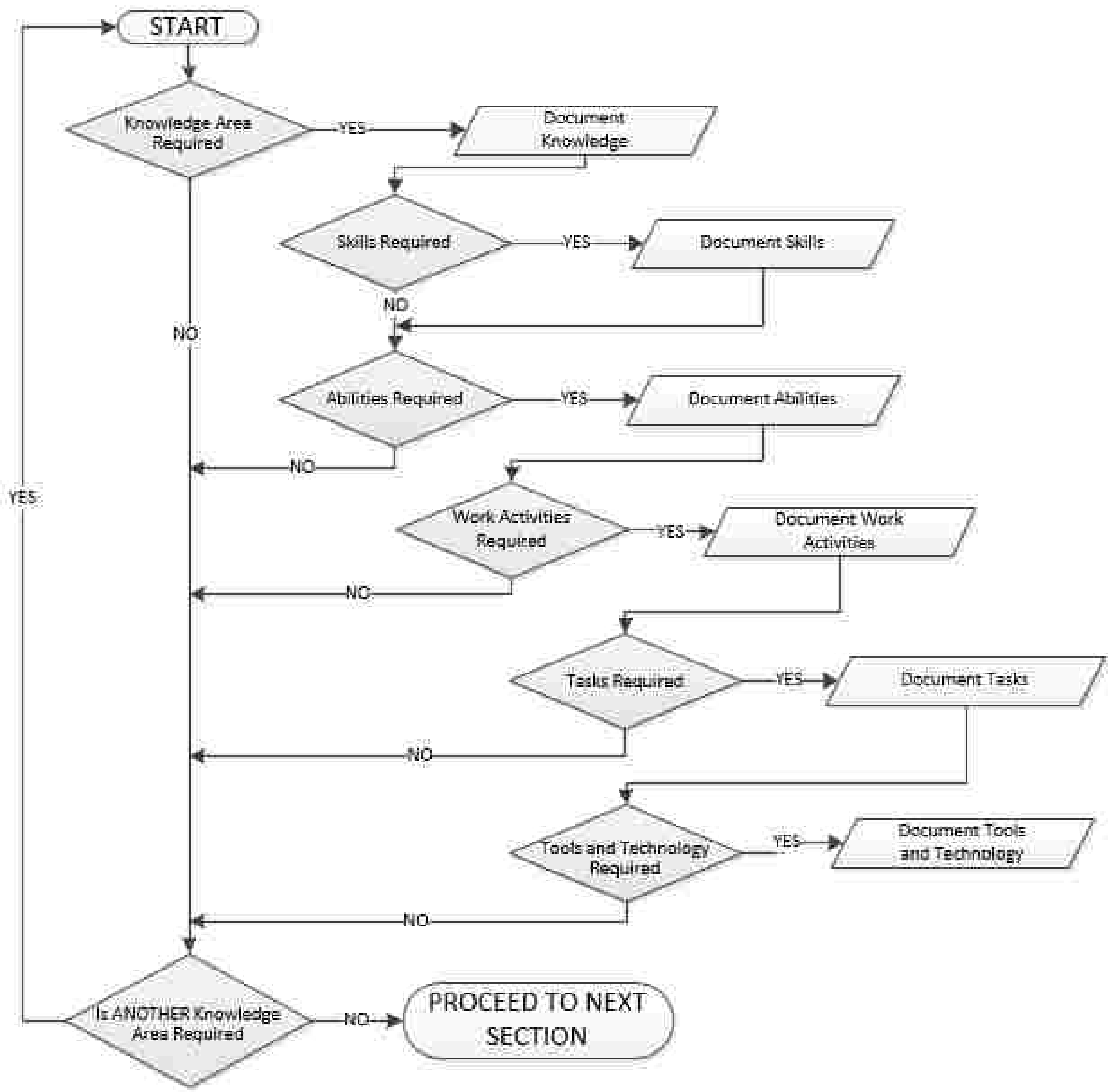


Figure 28. Skills Gap Analysis Model Knowledge Decision Tree

Using the logic tree shown along with the descriptor dependencies the model makes effective use of the evaluator's time.

4.5 Scaling Metrics

The decision path model results in a detailed and accurate position description. However, the missing components are the proficiency level, importance, and frequency. Several articles and the Delegated Examining Operations Handbook (2007) identified these as important components, but a clear method of use was not described. Adding in these criteria with scaling metrics allows the position to be better defined. Proficiency is used to describe the skill level needed for the position, Importance indicates how much the skill is needed for the position, and Frequency is how many times the skill will be needed for the position. The combination of these three metrics allows the SMEs to use the model to better define what is needed for the position and allows the technicians to better define their skill levels.

The issue of not including scaling metrics can be explained using the hydraulic and pneumatic mechanics example from before. They both have the same general requirements but very different positions. There could be a lot of variability in the position and one position could actually morph into the other, but with current methods this change would not be detected and the importance change of the requirements would not be captured. The biggest issue, in this example, is that the existing personnel may be able to perform the requirements of this new morphed position even though the position description has not changed. This research will produce a new algorithm to focus on the descriptors and include the proficiency level, importance, and frequency. Using the new method would also be able to track how positions have changed over time. Even if just the importance of a position requirement changes, that will affect the decision about who is the best fit for the position.

The model includes scaling metrics for proficiency, importance, and percentage of position. The level of proficiency will be scaled on a Likert scale from 1 to 7 as shown in Table 14. The use of logical anchor points helps to better identify the correct proficiency level. One person's definition of average may vary greatly from another person. The level of importance will use the Likert scales based on Table 15. Finally, the percentage of the position will use the Likert scales based on Table 16.

Table 14. Proficiency Scale

Likert Scale	Proficiency	Acceptable Percentage	General Description	Logical Anchor Points (Example from Figure 7.)
1	Novice	1-10	- Minimal to no experience/knowledge. - Would need very close supervision. - No troubleshooting ability.	
2	Beginner	10-25	- Minimal experience/knowledge. - Would need supervision. - Some troubleshooting ability.	Understand a television commercial
3	Less than average	25-40	- Minimal experience/knowledge. - Would need some supervision. - Some troubleshooting ability.	
4	Average	40-60	- Good experience with a strong knowledge base. - Minimal supervision required. - Average troubleshooting ability	Understand a coach's oral instruction for a sport
5	Better than average	60-75	- Good experience with a strong knowledge base. - Minimal to no supervision required. Able to assist others. - Above average troubleshooting ability	
6	Proficient	75-90	- Good experience with a strong knowledge base. - Minimal to no supervision required. Able to assist others. - Good troubleshooting ability	Understand a lecture on advanced physics
7	Expert	90-100	- Strong experience with a huge knowledge base. - No supervision required. Able to assist others. - Strong troubleshooting ability	

Table 15. Importance Scale

Likert Scale	Importance	Description
1	Not Important	- Has no effect on the ability to perform the job
2	Somewhat Important	- Needed but not critical - Could potentially learn on the job or be trained
3	Important	- Needed, would like the person to have - Would need training
4	Important	- Required to have for the position - Could potentially be trained, but position would suffer until training completed.
5	Very Important	- Critical for person to be successful in the position

Table 16. Frequency Scale

Likert Scale	Description
1	Once per year
2	More than once per year
3	More than once per month
4	More than once per week
5	Daily
6	Several times per day
7	Hourly or more often

The Likert scales allow the model to convert the responses into more descriptive quantitative data. The model weights descriptors using the scale and logical anchor points. Each descriptor has values for all three areas. The model, based on the percent of relevance for each of the three areas, then calculates a single value. The percent relevance may vary based on organization, but for this example, proficiency will be 80%, importance 15%, and frequency 5%. Because proficiency is critical it has the largest percentage. To help further differentiate between descriptors, the importance is set at 15% and frequency is the last 5%. The descriptor rating can be fine-tuned but can also be fixed for a certain position or organization. To make the data easier to evaluate, these values will be normalized so that a perfect value for each descriptor would be 100. The normalization equation is shown in Figure 29.

$$Normalized[Value] = \frac{(Value - Value_{min})(b-a)}{Value_{max} - Value_{min}}, \quad \text{where b is 100 and a is 0.}$$

Figure 29. Normalized Value

This equation will convert the program outputs to values between 0 and 100. Using this method, data for each descriptor is condensed to a single value. An example of the weighting and normalized values is shown in Table 17.

Table 17. Weighting and Normalized Values

	Proficiency	Importance	Frequency	Normalized
Relevance	80%	15%	5%	100%
Equation	=.8(7-1)*(100-0)/(7-1)	=.15(5-1)*(100-0)/(5-1)	=.05(7-1)*(100-0)/(7-1)	
MAX (7,5,7)	80	15	5	100
MIN (1,1,1)	0	0	0	0
MID (4,3,4)	40	7.5	2.5	50

Each descriptor is rated for importance, frequency, and percentage of the position, and using all three of these values with the identified relevance, the descriptor is quantitatively defined by a single number. An example is shown in the table below.

Table 18. Descriptor Value Example

Question:	Ability to read blueprints?	Percentage	Normalized
Proficiency (1-7)	5	80	53.33
Importance (1-5)	4	15	11.25
Frequency (1-7)	3	5	1.67
		Descriptor value:	66.25

The descriptor is normalized, and the percentage weights are applied to generate a number for each metric. The three numbers are then added together to get a final value for that descriptor. By having all descriptors with quantitative values, analysis and comparison can be performed. Using this method, data for each descriptor is condensed to a single value which can be averaged with the other descriptor vales to determine an exact position-to-worker fit measurement.

4.6 Comparison and Evaluation

To this point, using the decision model, the large O*NET database has been parsed based on the information entered by the user (see Figure 30). Additionally, using scaling metrics that include proficiency, importance, and frequency, the creation algorithm generates the detailed job requirements. The last stage in the model is calculating the difference in the two, the skills gap.

	Number of Questions
Tasks	27
Technology Skills	10
Tools Used	59
Knowledge	7
Skills	17
Abilities	22
Work Activities	29
Detailed Work Activities	23
Work Context	27
Interests	2
Work Styles	16
Work Values	3
Custom	-
Total:	242

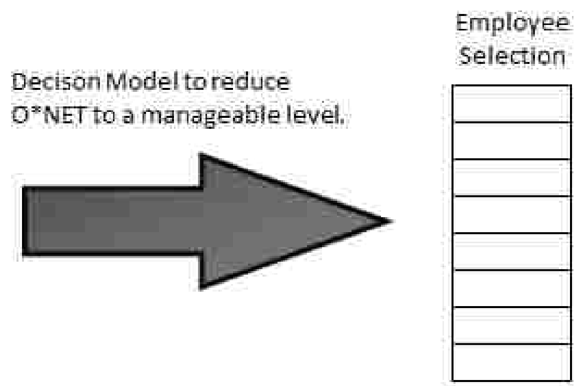


Figure 30. Model Reduction of O*NET

The position and worker requirements for each descriptor can be compared and the difference identified. This is shown graphically in Figure 31.

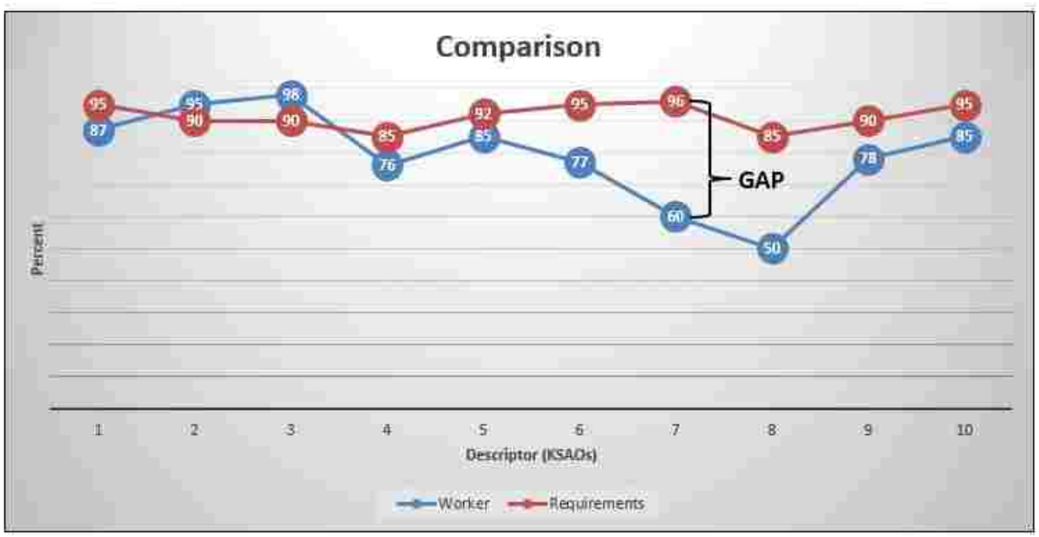


Figure 31. GAP Analysis

As shown on the graph, for each descriptor there is a difference between the requirements and the worker skills. This difference is the "gap". The gap can be quantitatively identified, as shown in Table 19. Note that the gap can be positive (over qualified), negative (under qualified), or neutral (meets requirements).

Table 19. Gap Analysis Example

Descriptor	Worker	Requirements	GAP	
1	87	95	-8	
2	95	90	5	
3	98	90	8	
4	76	85	-9	
5	85	92	-7	
6	77	95	-18	
7	60	96	-36	<<< Largest GAP
8	50	85	-35	
9	78	90	-12	
10	85	95	-10	
Average:	79.1	91.3	-12.2	

Along with an individual descriptor comparison, an overall worker-to-position fit coefficient can be determined by calculating the average of the summation of the differences between the position requirements and the worker qualifications using the equation in Figure 32. The overall fit value can be used to compare across a set of workers to evaluate who has the best fit to a position description.

$$Worker - to - Position\ Fit\ Coefficient = \frac{\left(\dfrac{\sum_{k=1}^{n} (Descriptor_{Required} - Descriptor_{Worker})}{n} \right)}{SME_{Average}}$$

Fit Coefficient < 1 : *Training needed*
Fit Coefficient $=1$: *Averaged exact fit*
Fit Coefficient >1 : *Over qualified*

Figure 32. Worker-to-Position Fit Coefficient

An average of the distance between the two values gives an overall rating of the worker to the skill set of the position. The comparison is made using the average of all descriptor “gaps”, so a worker could be strong in some areas and weak in others but still be an overall fit. The data collected will also show the areas that need improvement. Once the organization has the quantitative information, it can determine if a particular descriptor is critical, and set its own specific limits of acceptability. The chance of a perfect worker-to-position match will be slim, so each organization will have to determine its own acceptable fit limits. If an organization has a good training program, it may be willing to take a worker with more skills gaps and train them. If the organization needs the worker to perform immediately, it might want to make sure the person meets all the requirements

The skills gap analysis model provides improved identification of worker qualifications, enables a method for consistent comparison between the position and worker, and provides a method for organizations to identify gaps to determine if existing personnel can fill the position or if training is needed. Because of the comparison method, the specific areas needed for training can be identified. The quanitative analysis also allows the candidates to be compared and ranked in relation to the position.

4.7 Model Implementation

The model algorithms were implemented using Microsoft Excel. All the responses for the Decision Model and rating values for the Creation Algorithm are stored in Excel in a log sheet. This information will be used for the Comparison Algorithm and overall evaluations.

As an example, the mechanical technician position has 183 potential ONET descriptors. Using the parsed decision model, only 111 out of the 183 descriptors fall into one of the knowledge categories. Items such as education and training are to be considered “checkbox” requirements. That is, they either have it or they don’t. For example, some organizations require a 4-year college degree for a position. Others may require specific licensing. These “set in stone” non-negotiable requirements will not be included in the quantitative analysis of the position. There were also several items from the skills, abilities, work styles, and work context lists that were independent of knowledge. These items could still be grouped and still had dependencies on each other. Accounting for the independent items, the new flow diagram is shown below.

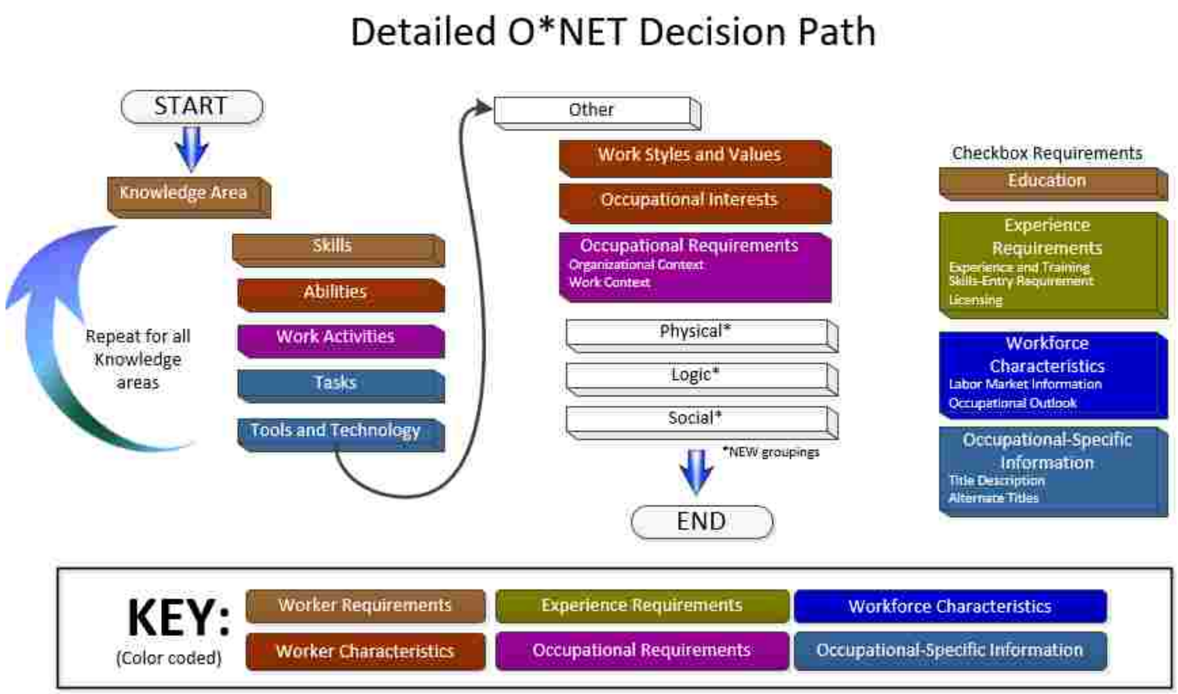


Figure 33. New Decision Path

Once all the descriptors are grouped with the associated dependent descriptors the next step is to turn these into questions (both decisional and rating) that will guide the evaluator through only the relevant areas and questions. An example of how this works is shown in Figure 34 for the knowledge area, English language. If this area is not needed, it will skip all the questions. If reading is not needed but speaking is, it will identify that, and the evaluator will provide input to indicate what levels are required. This method greatly reduces the numbers of questions needed to quantitatively detail a position.

Knowledge	English Language — Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.
Skills	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.
Skills	Reading Comprehension — Understanding written sentences and paragraphs in work related documents.
Skills	Speaking — Talking to others to convey information effectively.
Abilities	Speech Clarity — The ability to speak clearly so others can understand you.
Abilities	Speech Recognition — The ability to identify and understand the speech of another person.
Abilities	Oral Comprehension — The ability to listen to and understand information and ideas presented through spoken words and sentences.
Abilities	Oral Expression — The ability to communicate information and ideas in speaking so others will understand.
Work Context	Telephone — 52% responded "Every day."
Skills	Writing — Communicating effectively in writing as appropriate for the needs of the audience.
Abilities	Written Comprehension — The ability to read and understand information and ideas presented in writing.
Abilities	Written Expression — The ability to communicate information and ideas in writing so others will understand.
Work Context	Letters and Memos — 41% responded "Once a week or more but not every day."
Work Activities	Communicating with Supervisors, Peers, or Subordinates — Providing information to supervisors, co-workers, and subordinates by telephone, in written form, e-mail, or in person.

Figure 34. Knowledge Area Example

While sorting and organizing the descriptors, some of them have the same basic meaning such as “Responsible for Equipment Maintenance” and “Responsible for repairing and maintaining equipment”. These descriptors will be combined to reduce the number of questions needed. Starting with 183 descriptors, the number was reduced to 158. Out of the 158, 145 have the potential to have associated metrics. The other 13 are YES/NO decision questions to assist with the parsing. After all the knowledge areas and other areas are organized into a proper flow and converted into decision (yes/no) and rating questions based independent and dependent relationships, the model is ready for the demonstration.

The Excel file is set up to flow through all the questions in a logical format and only requires the participant to answer relevant questions. The participant only sees a clean user interface, but all the possible information is laid out in Excel and the VBA program will step through the information effectively. The main Excel sheet is shown in Figure 35.

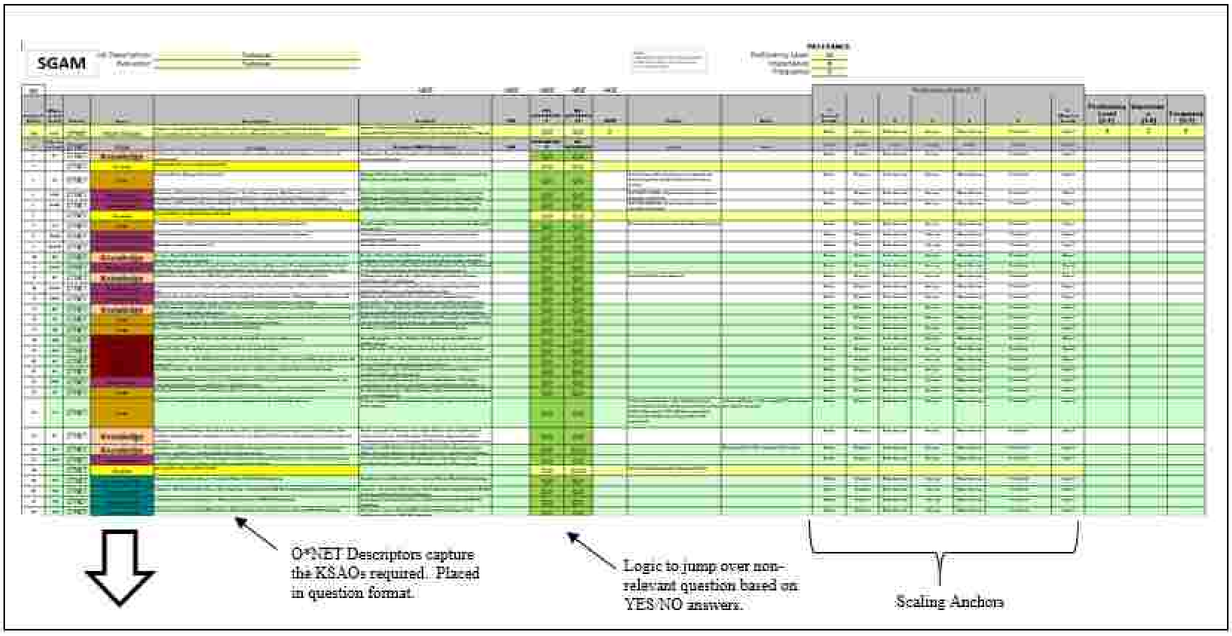


Figure 35. SGAM Excel Sheet

4.8 Summary

This chapter demonstrated how taking the best features from the HCO model, JASS, and O*NET could be combined to design the SGAM. Using structured and grouped O*NET descriptors with a parsed decision model, the JASS logic along with the described metrics, and the comparison algorithm, postions can be fully and quantitatively detailed from the organization position side and the worker side to allow for comparison.

5. DEMONSTRATION

The purpose of this DSRM stage is to demonstrate the use of the artifact to establish that the artifact addresses one or more instances of the problem domain. The skills gap analysis model (SGAM) was implemented in an Excel spreadsheet so that the model could use inputs from subject matter experts (SMEs) to characterize a specific position from both the position and the worker perspectives using the O*NET descriptors. This ensures that both sets of data are comparable terms which will allow the algorithm to equate two sets of data. After completing the activity, the SMEs and Technicians completed an opinion survey regarding the suitability and relevance of the SGAM. The outcomes of the demonstration, along with the survey data, will be used to evaluate the new artifact in Chapter 6.

5.1 Demonstration Protocol

The SGAM was implemented using Microsoft's Excel program to develop an executable version of the model that can accept user inputs in order to characterize a position. Excel provides an easily portable model that is standard for most organizations. Using the Visual Basic for Applications (VBA) functionality, it has the capabilities needed to parse the data and allows user inputs to drive the outcomes of the model. A simple interface steps the user through the model framework and applies the metrics for the comparison algorithm. The Excel file was emailed to leads within two local manufacturing organizations. These leads identified potential candidates to test the model. It was requested to get as many willing participants as possible. The target for both organizations was five for each group.

The participants were SMEs and Technicians within a specific operation area: Manufacturing Technology. It is important to note that all technicians who participated in the demonstration had the exact same job title. Because participants had the same job title, there was also a desire to compare position requirements and worker qualifications from different organizations.

The Excel file included all required informed consent questions, and the only information collected about participants was to determine if they were Subject Matter Experts (SME) or Technicians. Table 20 indicates the number of personnel who participated in the demonstration.

Table 20. Demonstration Participants

	SMEs	Technicians	Total
Company A	3	5	8
Company B	-	3	3
Total:	**3**	**8**	**11**

Both the SMEs and Technicians used the model to detail a specific position, Manufacturing Technician. The completed position descriptions (SME) or worker requirements (Technician), along with the user survey were emailed back to the researcher. Once received, the file was downloaded by the researcher and the message deleted. No identifiable information was retained.

5.2 Demonstration Model

The SGAM model (Excel file Version 021319), distributed to the SMEs and Technicians was an implementation of the model described in Chapter 3 using the features of an Excel workbook. By clicking one button the program starts.

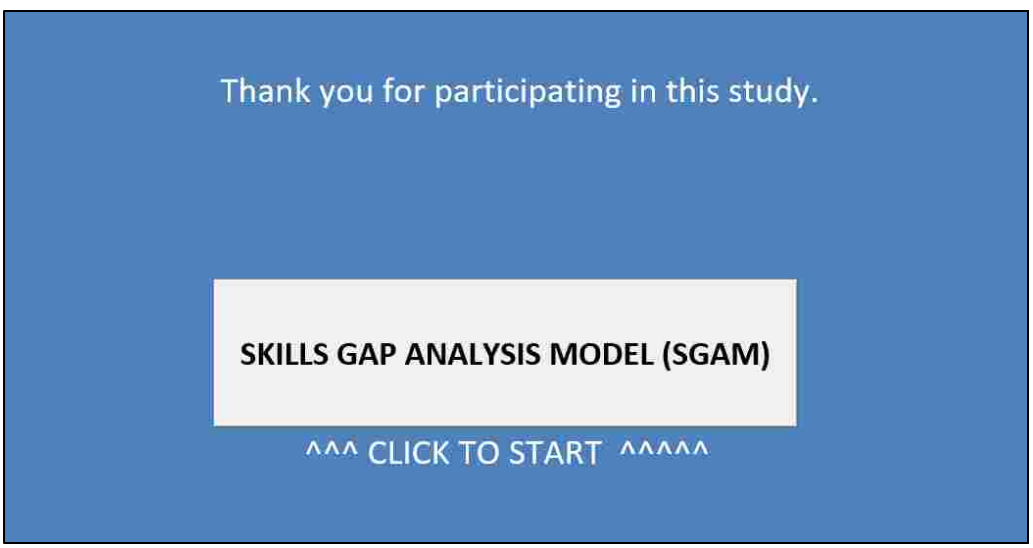
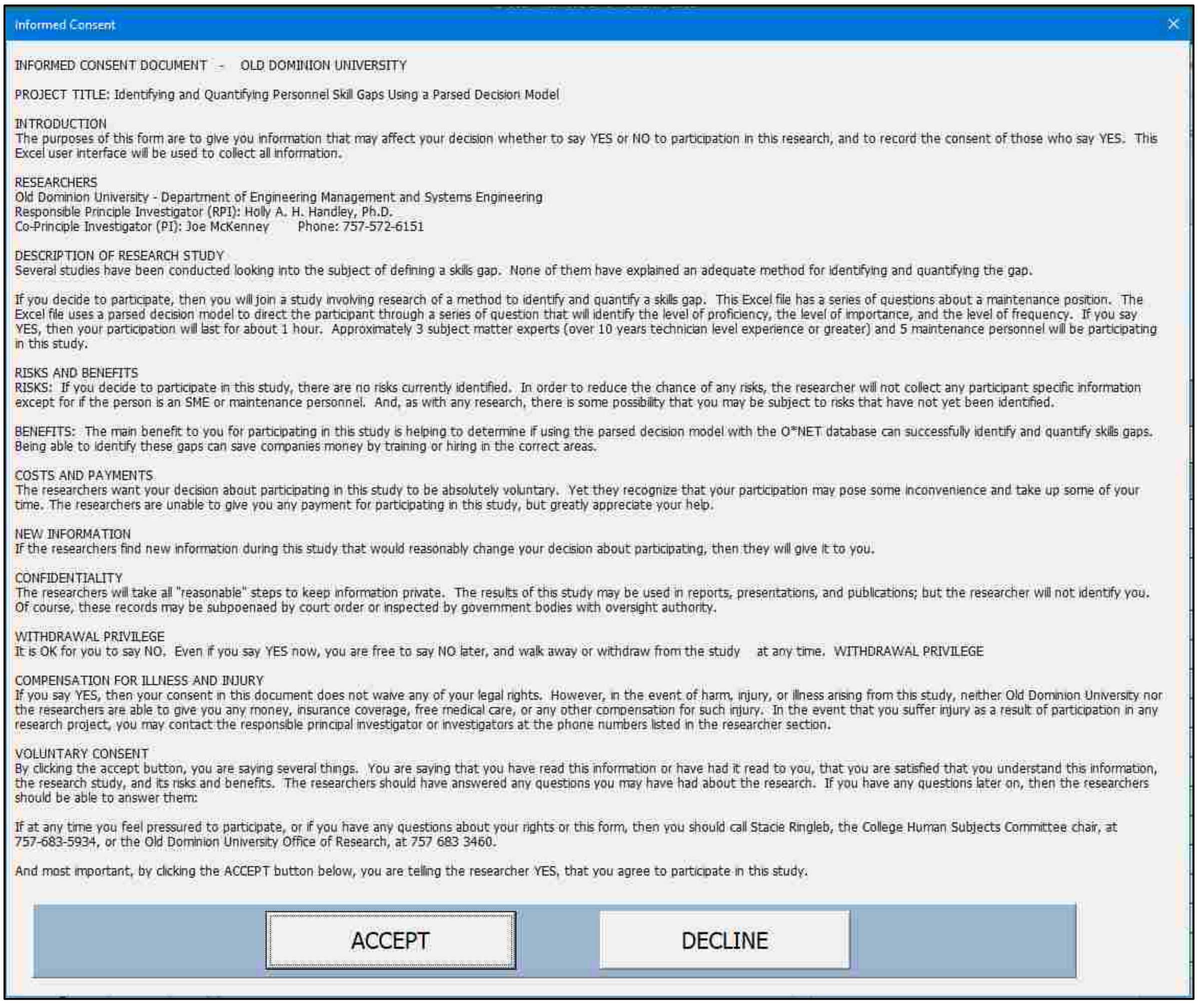


Figure 36. User Interface

When starting the demonstration, the user is prompted with a Consent Form (see Figure 37) containing all relevant information about the study. If the user selects the DECLINE button the program will close, and the user will be directed to close the file. No information will be collected.


Informed Consent

INFORMED CONSENT DOCUMENT - OLD DOMINION UNIVERSITY

PROJECT TITLE: Identifying and Quantifying Personnel Skill Gaps Using a Parsed Decision Model

INTRODUCTION
The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. This Excel user interface will be used to collect all information.

RESEARCHERS
Old Dominion University - Department of Engineering Management and Systems Engineering
Responsible Principle Investigator (RPI): Holly A. H. Handley, Ph.D.
Co-Principle Investigator (PI): Joe McKenney Phone: 757-572-6151

DESCRIPTION OF RESEARCH STUDY
Several studies have been conducted looking into the subject of defining a skills gap. None of them have explained an adequate method for identifying and quantifying the gap.

If you decide to participate, then you will join a study involving research of a method to identify and quantify a skills gap. This Excel file has a series of questions about a maintenance position. The Excel file uses a parsed decision model to direct the participant through a series of question that will identify the level of proficiency, the level of importance, and the level of frequency. If you say YES, then your participation will last for about 1 hour. Approximately 3 subject matter experts (over 10 years technician level experience or greater) and 5 maintenance personnel will be participating in this study.

RISKS AND BENEFITS
RISKS: If you decide to participate in this study, there are no risks currently identified. In order to reduce the chance of any risks, the researcher will not collect any participant specific information except for if the person is an SME or maintenance personnel. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS: The main benefit to you for participating in this study is helping to determine if using the parsed decision model with the O*NET database can successfully identify and quantify skills gaps. Being able to identify these gaps can save companies money by training or hiring in the correct areas.

COSTS AND PAYMENTS
The researchers want your decision about participating in this study to be absolutely voluntary. Yet they recognize that your participation may pose some inconvenience and take up some of your time. The researchers are unable to give you any payment for participating in this study, but greatly appreciate your help.

NEW INFORMATION
If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY
The researchers will take all "reasonable" steps to keep information private. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you. Of course, these records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE
It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study at any time. WITHDRAWAL PRIVILEGE

COMPENSATION FOR ILLNESS AND INJURY
If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of harm, injury, or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participation in any research project, you may contact the responsible principal investigator or investigators at the phone numbers listed in the researcher section.

VOLUNTARY CONSENT
By clicking the accept button, you are saying several things. You are saying that you have read this information or have had it read to you, that you are satisfied that you understand this information, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Stacie Ringleb, the College Human Subjects Committee chair, at 757-683-5934, or the Old Dominion University Office of Research, at 757 683 3460.

And most important, by clicking the ACCEPT button below, you are telling the researcher YES, that you agree to participate in this study.

ACCEPT DECLINE

Figure 37. Consent Form

If the user selects the ACCEPT button, the demonstration will start. The participant selects whether they are a SME or a Technician. For the SGAM, it is not only the proficiency level that is evaluated, it is also the importance and the frequency of the descriptor. The evaluator is asked to rate all three of these. Figure 38 shows the user screen for the participant to provide inputs.

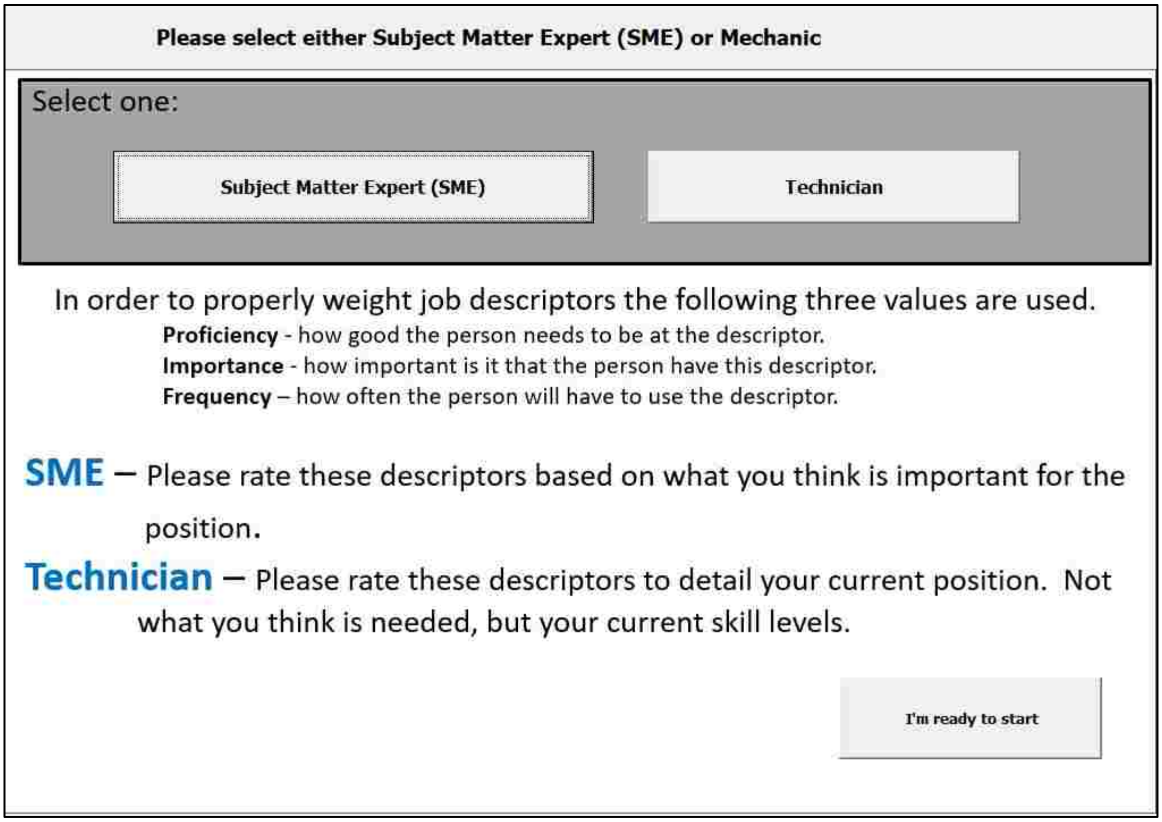


Figure 38. Participant Selection Form

The SGAM logically steps the user through all the questions based on the O*NET Knowledge areas for this domain using the parsed decision logic, i.e., skipping over any dependent questions that are not relevant based on previous question responses. Decision screens are used to determine if an area is relevant and consist of YES/NO questions (see Figure 39). If the item presented is not relevant to the position being described, the rating scale is hidden. Once an item is selected as relevant, the scale is provided. Additionally, items that can be identified as not relevant based on previous responses will be skipped; hence, the data parsing ability of the model's algorithm reduces the burden on the user. The percentage complete is displayed at the bottom, and the participant has the option to stop and exit at any time without saving any of the data.

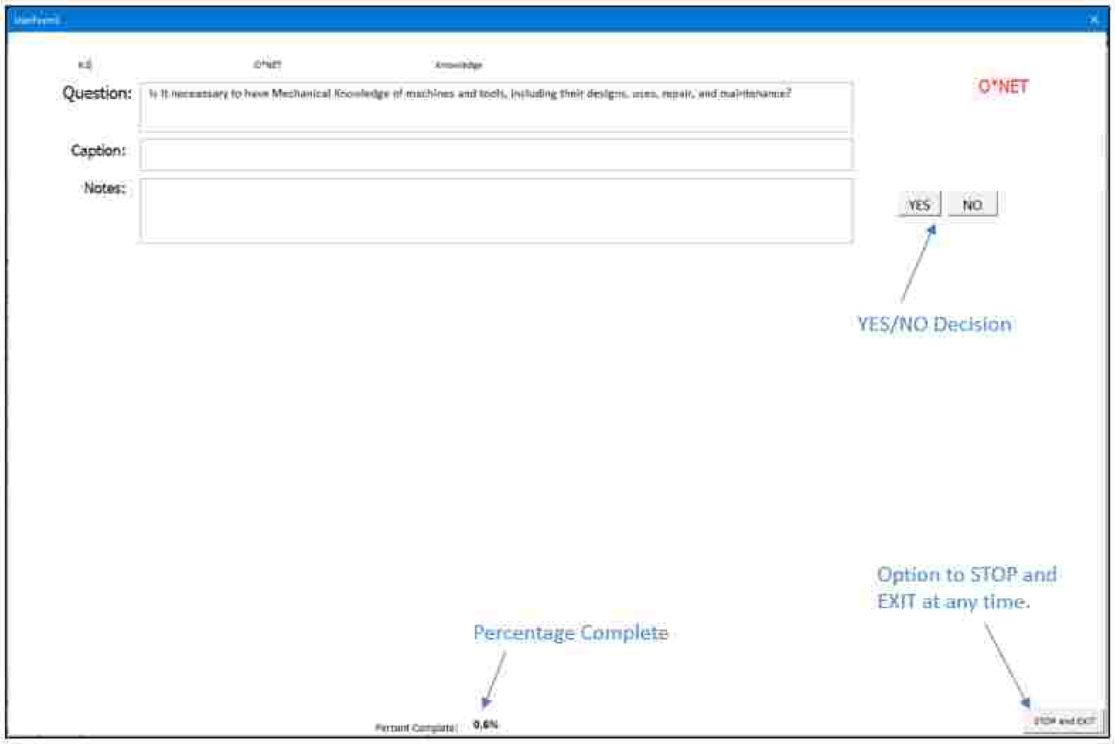


Figure 39. Decision Form

Using a slide scale, the proficiency of the descriptor (with anchor points), the importance of the descriptor, and the frequency that the descriptor is needed for the position are identified. The ratings form uses logical anchor points to make user selection easier and more accurate. These anchor points help prevent the typical concern about the self-evaluation being exaggerated by giving the user specific examples of the proficiency levels so they can choose appropriately. The slide scale enables the participant to quickly answer the questions.

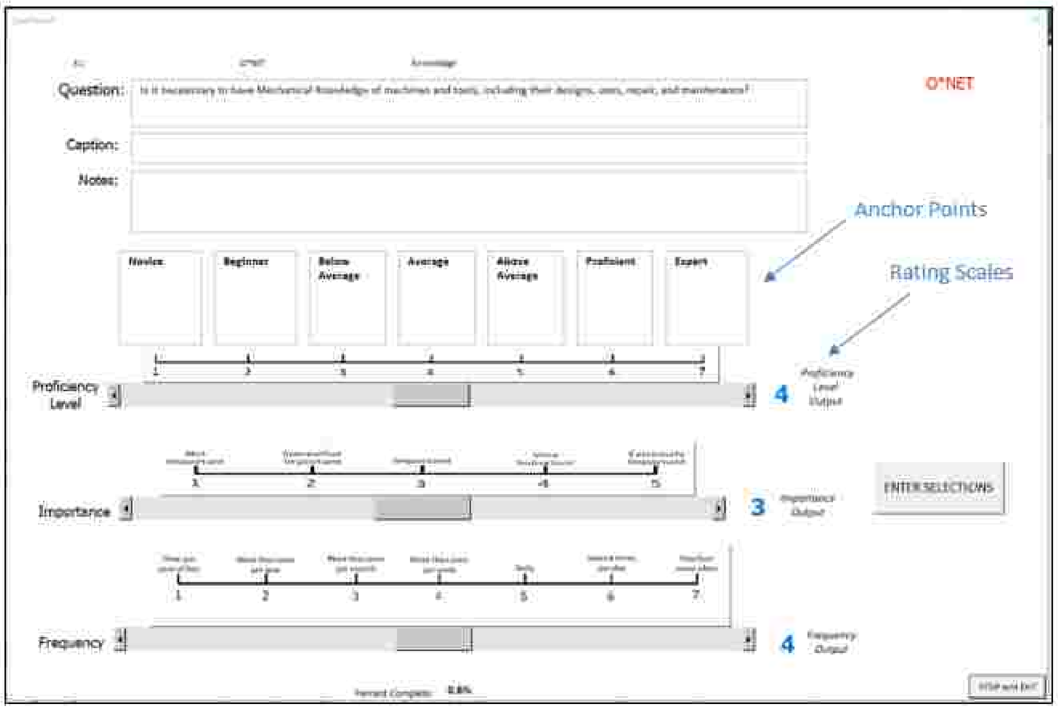


Figure 40. Ratings Form

After all the questions have been answered, the participant is informed that the data is saved.

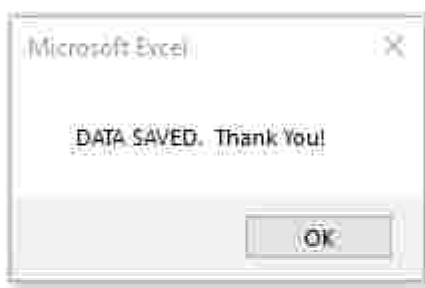


Figure 41. Model Data Saved Screen

All the data is temporarily stored until the end of the demonstration, and then it is automatically transferred to a log sheet (see Figure 42). During the transfer process, the scales for proficiency level, importance, and frequency are used to determine a rating factor for the relevance of each descriptor. The average of all the relevance factors results in a single number that can be used for an overall comparison. At the completion of the participant's rating of the position or worker requirements, the data is automatically stored within the Excel spreadsheet. The log sheet also tracks how many questions were answered and skipped using the parsing algorithm. The results from the SMEs detailing the position can then be compared to evaluate the inter-rater reliability of the model for detailing a common position. Likewise, the worker profiles will be compared to determine the internal consistency of the model for determining the required KSAOs. Finally, the model will be tested to quantitatively determine the skills gap, between the two sets of data.

Job Description	Technician				Technician				Technician			
Evaluator	Technician				Technician				Technician			
Date	2/18/19 4:22 PM				2/18/19 4:22 PM				2/18/19 4:22 PM			
Proficiency Level Used	30				30				30			
Importance Used	15				15				15			
Frequency Used	5				5				5			
Question	Proficiency Level (1-7)	Importance (1-5)	Frequency (1-7)	Rating	Proficiency Level (1-7)	Importance (1-5)	Frequency (1-7)	Rating	Proficiency Level (1-7)	Importance (1-5)	Frequency (1-7)	Rating
1	6	4	6	82.08	6	4	6	82.08	6	4	6	82.08
2												
3	6	4	5	81.25	6	4	5	81.25	6	4	5	81.25
4	6	4	5	81.25	6	4	5	81.25	6	4	5	81.25
5	6	4	6	82.08	6	4	6	82.08	6	4	6	82.08
6												
7	6	4	5	81.25	6	4	5	81.25	6	4	5	81.25
8	6	4	6	82.08	6	4	6	82.08	6	4	6	82.08
9	6	4	5	81.25	6	4	5	81.25	6	4	5	81.25
10	5	4	5	67.92	5	4	5	67.92	5	4	5	67.92
11	5	3	4	63.33	5	3	4	63.33	5	3	4	63.33
12	5	3	4	63.33	5	3	4	63.33	5	3	4	63.33
13	5	4	5	67.92	5	4	5	67.92	5	4	5	67.92
14	4	3	4	50.00	4	3	4	50.00	4	3	4	50.00
15	5	4	5	67.92	5	4	5	67.92	5	4	5	67.92
16	5	4	6	68.75	5	4	6	68.75	5	4	6	68.75
17	5	4	6	68.75	5	4	6	68.75	5	4	6	68.75
18	5	4	6	68.75	5	4	6	68.75	5	4	6	68.75
19	5	4	6	68.75	5	4	6	68.75	5	4	6	68.75
20	5	4	5	67.92	5	4	5	67.92	5	4	5	67.92
21	5	4	5	67.92	5	4	5	67.92	5	4	5	67.92
22	5	4	5	67.92	5	4	5	67.92	5	4	5	67.92
23	5	4	6	68.75	5	4	6	68.75	5	4	6	68.75
24	5	4	5	67.92	5	4	5	67.92	5	4	5	67.92

:

:

Total Questions	158	62.02	158	61.27	158	65.84	158
Questions answered	158		158		158		92
Questions skipped	0		7		0		66
Savings	0.00%		4.43%		0.00%		41.77%

Figure 42. Model Log Sheet

By comparing the SME values to the worker values, a quantitative worker-to-position fit measurement is obtained. By drilling down into the individual values for each descriptor specific details about what is driving the skills gap can be identified. Another benefit of implementing the model in Excel, with all the data stored in the log sheet, the basic graphing capabilities of Excel, can be used to visually identify the differences.

5.3 Survey to assess Model Suitability and Relevance

After the participant has completed the model demonstration, the program prompts the participant to complete a survey (see Figure 43).

Figure 43. Model Completion/Survey Screen

The survey is an adaptation of the System Usability Scale (SUS). The SUS (Brooke, 1986) consists of a 10-item questionnaire and provides a reliable tool for measuring usability. The SUS has become an industry standard and is reliable for small sample sizes and is has proven validity to identify unusable systems. For the Model Suitability and Relevance Survey (MSRS), each of the five model evaluation criteria will have two questions, one positive and one negative, as shown in Table 21. These questions are also listed in Appendix C.

Table 21. Model Suitability and Relevance Survey (MSRS) Questions

Question Number	Question	Criteria Number
1	I think this model will capture the main aspects of the position requirements and worker qualifications.	1 - postive
2	I feel this model is too complex to use.	5 - negative
3	Given the position requirements and personnel qualifications are in the same language, I feel this would provide a good model to identify skill gaps and training needs.	2 - positive
4	I feel this model would be better than the current method for identifying skills gaps	4 - positive
5	I think the requirements are organized in a logical manner.	3 - postive
6	I feel this model does not provide enough detail.	3 - negative
7	Given the output, I feel this model is easy to use.	5 - positive
8	I do not think proficiency, importance, and frequency are good metrics to use for weighting.	2 - negative
9	I do not think this model for identifying requirements would be better than the current method.	4 - negative
10	I feel the model does not capture all the position requirements and worker qualifications.	1 - negative

The survey questions are built into the Excel program and use a five-item Likert scale (see Figure 44) to capture the participant response. Participants also can provide open ended comments.

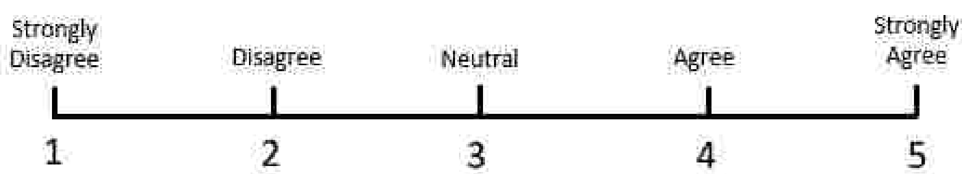


Figure 44. Survey Likert Scale

The participant is guided through all 10 questions using the Excel interface shown in Figure 45.

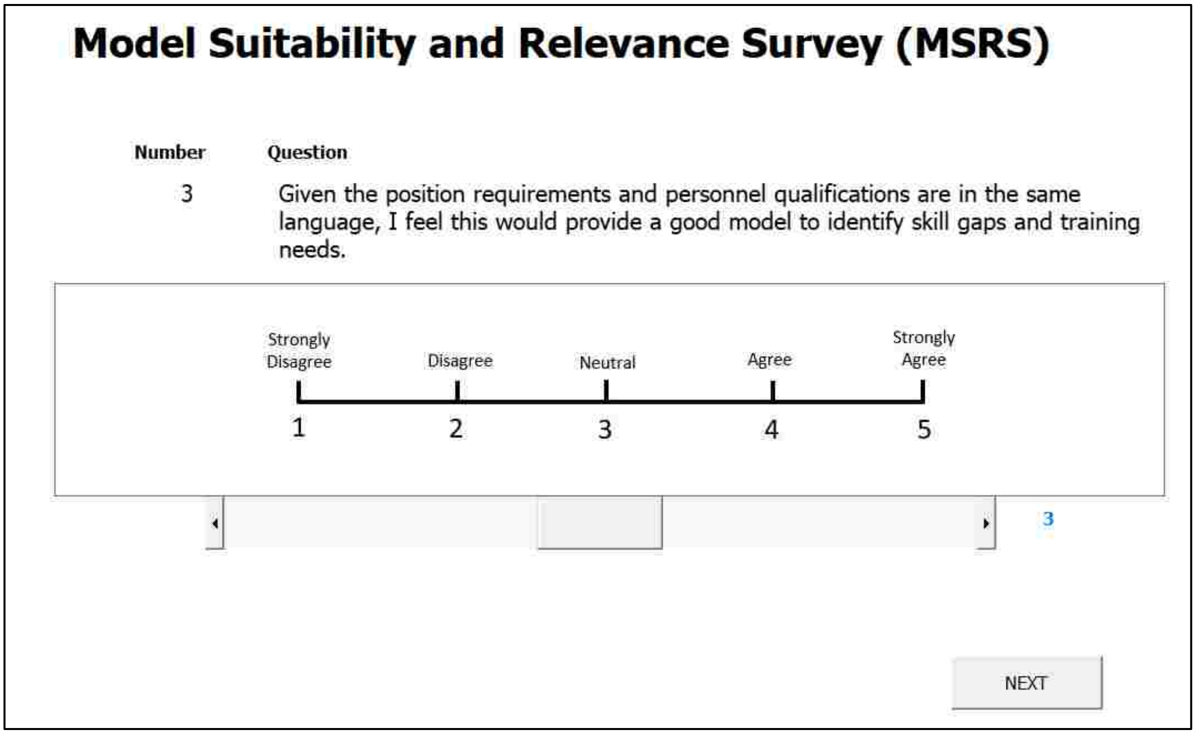


Figure 45. Survey Interface

Once all 10 questions have been completed the participant is thanked (see Figure 47) and the survey data is transferred to a worksheet in Excel where the data is collected and can be used for analysis. A sample log sheet is shown in Figure 46 below.

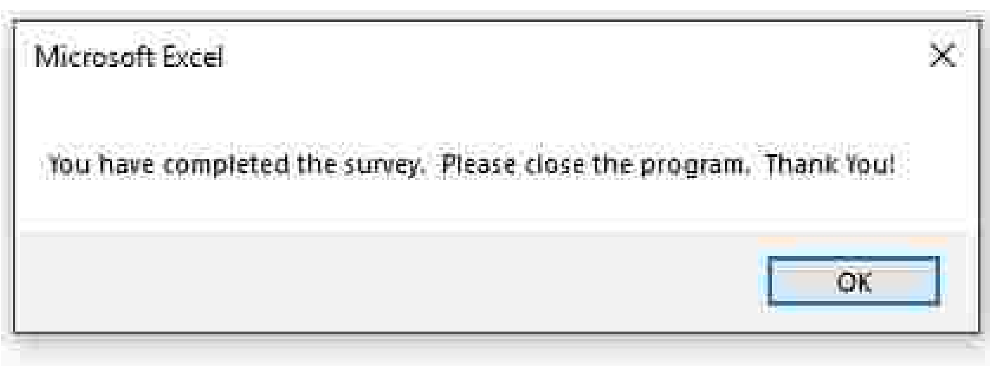


Figure 46. Survey Completion

	Job Description	Technician	Technician	Technician
	Evaluator	Technician	Technician	SME
	Date:	2/18/19 2:03 PM	2/18/19 2:23 PM	2/18/19 2:41 PM
Survey Questions	1	5	5	5
	2	5	5	5
	3	4	4	4
	4	4	4	4
	5	5	5	5
	6	4	4	4
	7	2	2	2
	8	2	2	2
	9	4	4	4
	10			

Figure 47. Survey Log Sheet

5.4 Summary

This section described the demonstration step of the Design Science Research Methodology. All the data collected from the demonstration participants was saved in the Excel program. No participant identifiers were retained. After all the data has been collected, the demonstration step is complete, and the data will be used for the evaluation step detailed in Chapter 6.

6. EVALUATION

The purpose of the evaluation stage of the DSRM is to ensure that the new artifact meets the requirements set out at the beginning of the development (as articulated in Chapter 2) and can address the problem identified at the beginning of the research (in Chapter 1). The data collected from the demonstration phase, reported in Chapter 5, can be used to complete the evaluation.

6.1 Criteria for the Skills Gap Analysis Model

The problem identified for this research was to improve existing skill models by combining them in such a way that the skills gap, based on a common representation of a job position and personnel skills, can be identified. The challenge was to identify the position requirements and worker skills using a common framework so that the comparison could be made. Additionally, the model needed to be easy to use, able to parse data effectively, and able to yield actionable data that would be useful for evaluation. The explicit criteria to evaluate the success of the new model were identified in section 2.1.3:

Criteria 1 - Single Taxonomy for both position requirements and the worker qualifications

Criteria 2 - Comparable (quantifiable data)

Criteria 3 - Adaptable to any domain (robust)

Criteria 4 - Actionable: Provide accurate and actionable data

Criteria 5 - Usability: Would be quick and easy to use

These criteria will be used in conjunction with the review of the data collected during the demonstration to evaluate the resulting SGAM model.

6.2 Evaluation of the Demonstration Data

6.2.1 Gap Analysis

The data collected during the demonstration use of the SGAM model by both SMEs and Technicians can be analyzed to evaluate the success criteria of the SGAM model and the response of the users to the new artifact. Each O*Net descriptor, which describes a KSAO needed, was converted to a question for the model. Participants provided proficiency, importance, and frequency responses for each descriptor question. In Figure 48, the vertical axis is quantitative numerical average determined from these responses. The first analysis provides a graph of the average of the SME results vs. the average of the Technician results. From these results, it can be seen the SME average is greater than the technician average. It also shows the ability of the model to represent both sets of data using the same taxonomy (Criteria 1).

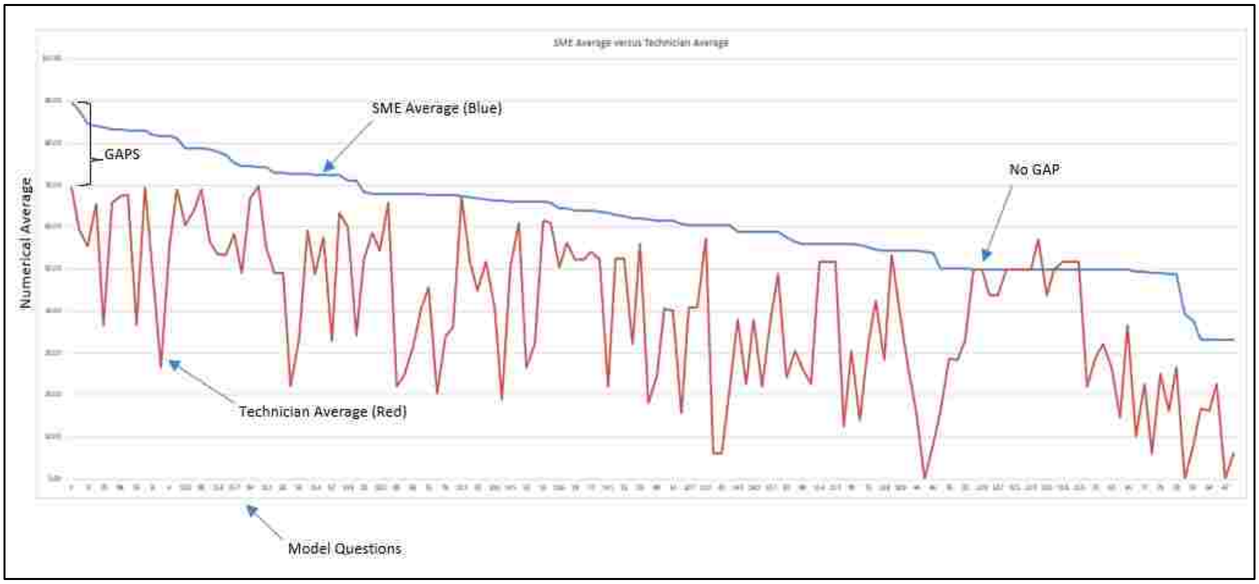


Figure 48. Demonstration Results – SME Average vs Technician Average

The average gap for each descriptor, based on the results above, can be graphed from high to low. This supports the ability to identify a quantifiable skills gap from the model data (Criteria 2). It also shows where the Technician average agrees with the SME average, where the gap equals zero, and the cases where the Technician average exceeds the SME average or where the gap is less than zero.

Having the data available, it is also possible to identify the skills gaps for a single individual as shown in the graph below.

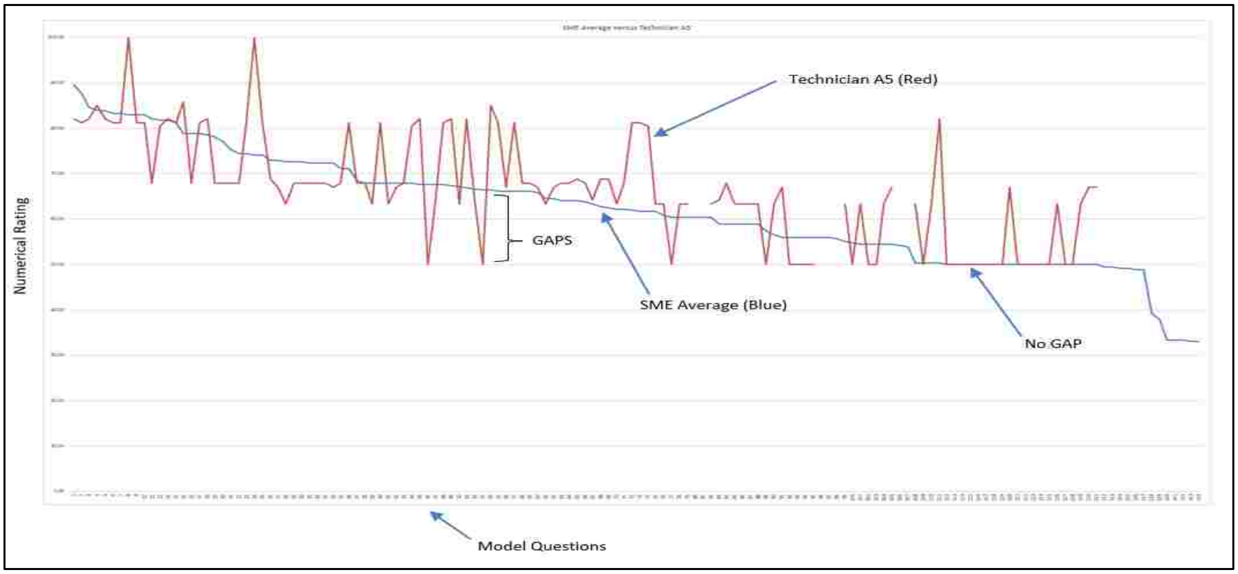


Figure 49. Demonstration Results – SME Average vs Technician A5

Technician A5 was the highest rated and will be discussed in more detail in section 6.2.5 Position "Fit" Evaluation. The graph shows specific areas that need improvement, skills gaps, and areas where this technician exceeds the SME average. The graph shows even the best fit technician would benefit from training in certain areas.

A graph of the gap averages from high to low as compared to the SME average is shown below.

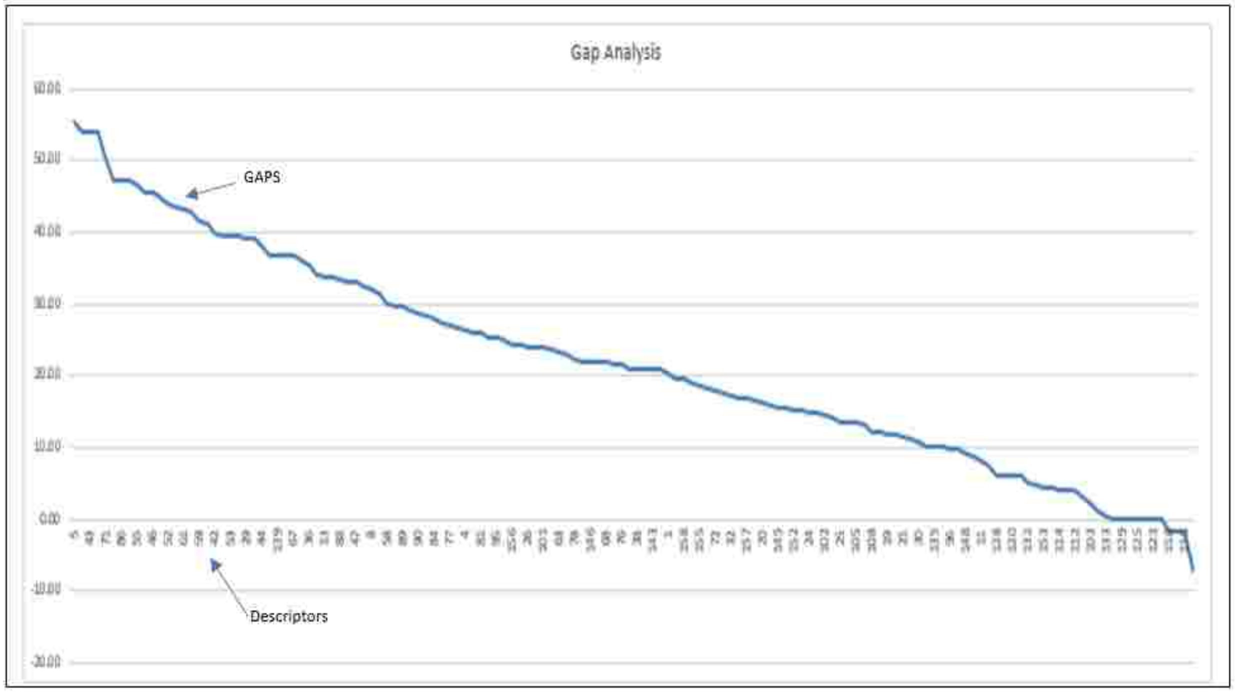


Figure 50. Demonstration Results – Identified Skills Gaps

The top ten identified gaps based on this data are shown in Table 22. These gaps are identified by both question and descriptor and provide actionable data for the model user (Criteria 4). The number in the "Gap" column represents the numerical average of the proficiency, importance, and frequency responses from the technician participants as compared to the SME average.

Table 22. Skills Gaps identified in the Demonstration Data

	QUESTION	GAPS	Descriptor
1	5	55.24	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.
2	49	54.17	Provide production, progress, or changeover reports to shift supervisors.
3	43	54.17	Scheduling Work and Activities — Scheduling events, programs, and activities, as well as the work of others.
4	48	54.17	Prepare production documents, such as standard operating procedures, manufacturing batch records, inventory reports, or productivity reports.
5	71	50.56	Provide advice or training to other technicians.
6	66	47.38	Set up and verify the functionality of safety equipment.
7	86	47.22	Identifying Objects, Actions, and Events — Identifying information by categorizing, estimating, recognizing differences or similarities, and detecting changes in circumstances or events.
8	70	47.17	Troubleshoot problems with equipment, devices, or products.
9	55	46.44	Making Decisions and Solving Problems — Analyzing information and evaluating results to choose the best solution and solve problems.
10	85	45.73	Analyzing Data or Information — Identifying the underlying principles, reasons, or facts of information by breaking down information or data into separate parts.

As shown in the table, the largest gap identified in the demonstration data is Repairing and Maintaining Electronic Equipment. As technology has improved, manufacturing equipment has moved from the mechanical dial assembly, cam driven, machines and contact gages to electronic servo-drives and vision systems. As these systems continue to evolve, the need for Technicians to gain these skills is becoming more important. The model correctly identifies this disconnect between the existing workforce (the Technicians) and the evolving needs of the organization (the SMEs). The other major gaps identify the need for better troubleshooting ability, organization skills, and communication.

In contrast, the four areas where the Technician average exceeded the SME average are shown in Table 23. While the adaptability criterion references the capability to tune the SAGM model domains, the ability to view the demonstration data from different user viewpoints also supports the adaptability of the model (Criteria 4).

Table 23. Items where Technician Requirements Exceeded SME Expectations

QUESTION	GAPS	Descriptor
118	-1.67	Reaction Time — The ability to quickly respond (with the hand, finger, or foot) to a signal (sound, light, picture) when it appears.
116	-1.67	Handling and Moving Objects — Using hands and arms in handling, installing, positioning, and moving materials, and manipulating
115	-1.67	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.
121	-7.14	Selective Attention — The ability to concentrate on a task over a period of time without being distracted.

As described in the table, questions 118, 116, and 115 all relate to traditional mechanic skills. The SGAM correctly identifies that the Technicians who participated in the demonstration excel in this area and, as such, are better than the SME identified requirements, i.e. as technology improves the importance and frequency of these skills will be reduced.

The robustness of the model allows each descriptor to be further analyzed. As an example, for question 121, "Selective Attention", a comparison can be made between the detail data provided by both the SMEs and the Technicians, as shown in Table 24. This level of detail provides additional support for Criteria 4 – Actionable Data.

Table 24. Details for Question 121 "Selective Attention"

	Proficiency Level (1-7)	Importance (1-5)	Frequency (1-7)
SME Average	4	3	4
Technician Average	4.5	3	4

For this question, the SMEs and Technicians agreed on the importance and frequency, but the Technicians rated it at a higher proficiency level. These parameters are all important when evaluating an existing workforce and may indicate a miscommunication with the workforce about the requirements of a task. For example, the frequency metric would be useful for organizations to see where employees are spending their time. Maintenance activities are typically hard to track because they do not have regular production metrics, such as number of parts produced. The SAGM model can identify these types of disconnects and can be used to communicate more directly with employees as well as identify training needs.

While Table 24 identifies the details for one particular question, the SME and Technician averages for the three evaluation metrics: proficiency, importance, and frequency, can be graphed across all questions, as shown in Figures 51, 52 and 53. The vertical axis for all three graphs is the numerical average based on the participant's responses. Note that the questions are sorted by the SME average, resulting in the smooth average line for the SME, as compared to the choppy line for the Technicians.

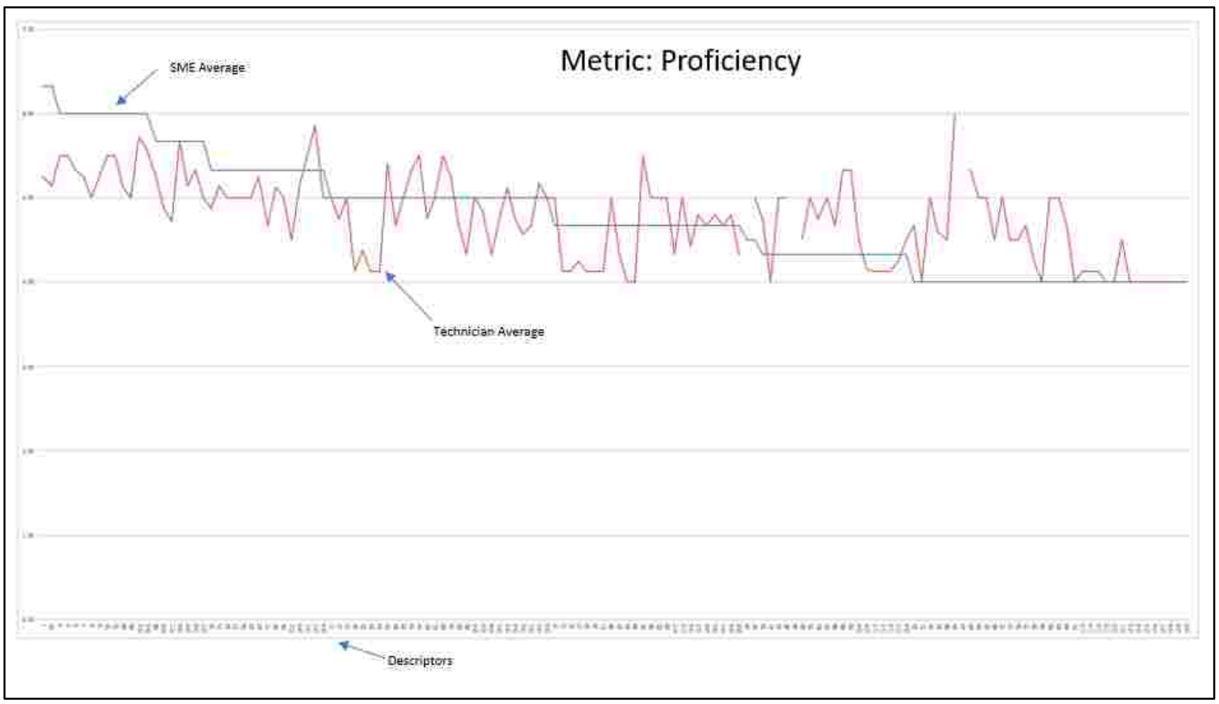


Figure 51. SME and Technician Average Metric Results - Proficiency

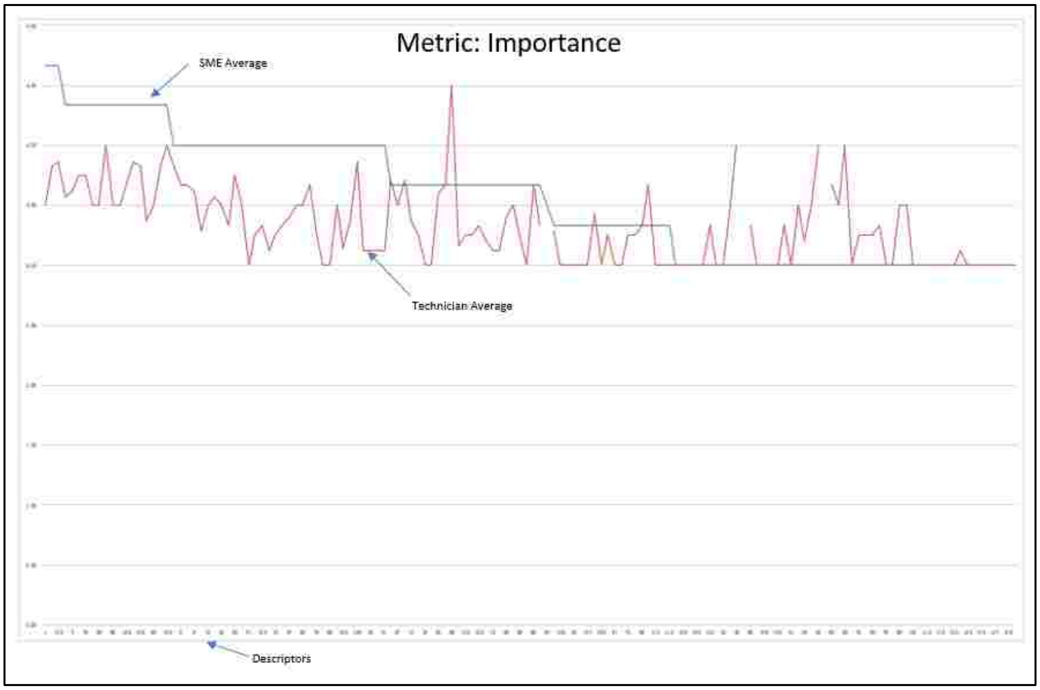


Figure 52. SME and Technician Average Metric Results – Importance

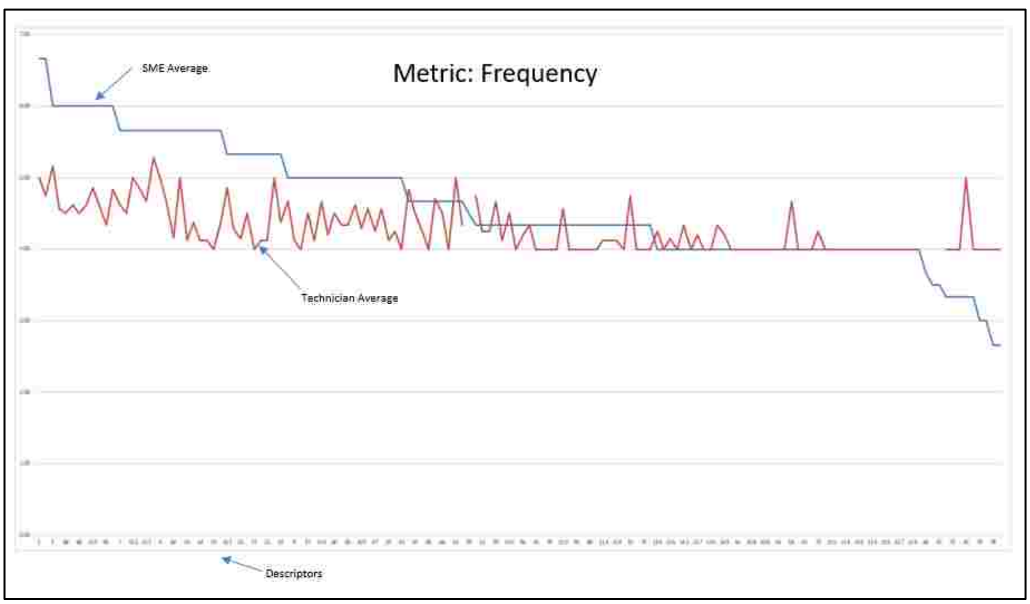


Figure 53. SME and Technician Average Metric Results - Frequency

These data can be reviewed for trends across the organization. For example, consistent disconnects in any one of the metrics can be used to review, perhaps incorrect, assumptions about specific skill requirements. For example, low frequency requirements, coupled with low importance, might indicate that this skill set can be contracted outside of the organization instead of maintaining that expertise in-house.

6.2.2 Participant Survey

After using the SGAM model, the SMEs and Technicians who participated in the demonstration were asked to complete the Model Suitability and Relevance Survey (MSRS). The outcomes of this survey support the usability (Criteria 5) of the new artifact, the SGAM model. The survey questions were identified in Table 21 of the previous chapter and are repeated here in 25 with the data collected from the MSRS survey.

Table 25. Survey Responses

	Question		SME Responses			Technician Responses								Variance	STD DEV	Average
+	1	I think this model will capture the main aspects of the position requirements and worker qualifications.	5	4	4	4	4	4	4	5	3	4	4	0.264	0.514	4.091
-	2	I feel this model is too complex to use.	4	3	4	4	3	3	3	3	3	3	4	0.231	0.481	3.364
+	3	Given the position requirements and personnel qualifications are in the same language, I feel this would provide a good model to identify skill gaps and training needs.	4	4	4	4	4	3	4	4	3	4	4	0.149	0.386	3.818
+	4	I feel this model would be better than the current method for identifying skills gaps.	4	4	4	4	4	4	5	4	4	5	4	0.149	0.386	4.182
+	5	I think the requirements are organized in a logical manner.	4	4	4	4	3	4	4	4	3	4	4	0.149	0.386	3.818
-	6	I feel this model does not provide enough detail.	5	4	4	5	3	3	5	5	4	4	4	0.512	0.716	4.182
+	7	Given the output, I feel this model is easy to use.	4	4	4	4	3	3	3	3	3	3	4	0.248	0.498	3.455
-	8	I do not think proficiency, importance, and frequency are good metrics to use for weighting.	4	4	4	4	4	5	4	4	3	4	4	0.182	0.426	4.000
-	9	I do not think this model for identifying requirements would be better than the current method.	4	4	4	4	4	3	4	4	3	4	4	0.149	0.386	3.818
-	10	I feel the model does not capture all the position requirements and worker qualifications.	4	4	4	4	4	4	3	4	3	3	4	0.198	0.445	3.727
	Notes		long			none								0.223	0.462	3.845

To analyze the results, the negative values are converted to positive values by reverse scoring the items. In this case the Likert scale is reversed for the negative items and the new values used. The data shows that most of those surveyed agreed with the positive questions and disagreed with the negative questions. This allows all the items to be included in an overall average, as shown in Figure 54.

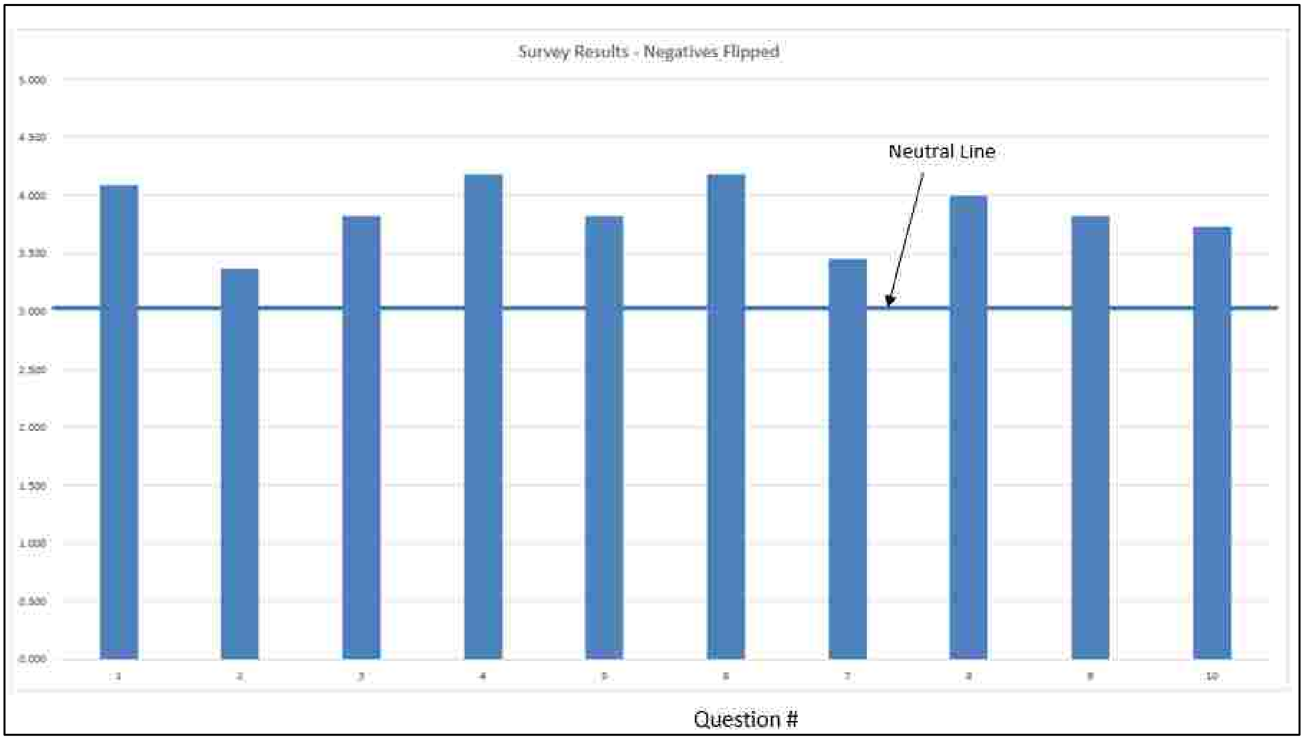


Figure 54. Survey Final Model Rating

As shown in Figure 54, the average of all the survey results is 3.845. The neutral line is at 3, so for the overall average all the responses are positive. The survey results show that the model is suitable and relevant. These results confirm Criteria 5 – Usability.

6.2.3 Data Parser Utility

As previously noted in model development (Chapter 4), the model allows the user to skip questions that they identify as not needed. This makes the most efficient use of the evaluator's time and reduces the effort needed. Table 26 summarizes the results.

Table 26. Participant "Skipped" Questions

	Skipped	% Reduction
SME 1	0	0.00%
SME 2	7	4.43%
SME 3	0	0.00%
Technician A1	92	58.23%
Technician A2	64	40.51%
Technician A3	22	13.92%
Technician A4	62	39.24%
Technician A5	15	9.49%
Technician B1	67	42.41%
Technician B2	11	6.96%
Technician B3	61	38.61%
Average:	36.45	23.07%

Reviewing the data from Table 26, the SME average is 2.33 skipped questions for a 1.48% reduction. In contrast, the Technician skipped question average was 49.35 questions for a 31.17% reduction. The technicians skipped 21 times more questions than the SMEs. These results are summarized in Table 27.

Table 27. Skipped Questions

	Skipped	% Reduction
SME Average	2.33	1.48%
Technician Average	49.25	31.17%

From this data, technicians put value on almost all the KSAOs identified for the position, whereas, the technicians did not identify that they had skills in many of those areas. These are areas that may require training. It is also possible that the technicians felt these areas were not part of their job so they felt they could be skipped, identifying a disconnect between what the organization identifies as a position requirement and what the worker feels is their responsibility.

The data parser helps reduce the amount of questions that need to be answered. However, even with the data parser, some of the survey comments mentioned that completing the model was lengthy. To further reduce the effort needed to complete the model, the questions can be further refined by only focusing on the high value descriptors.

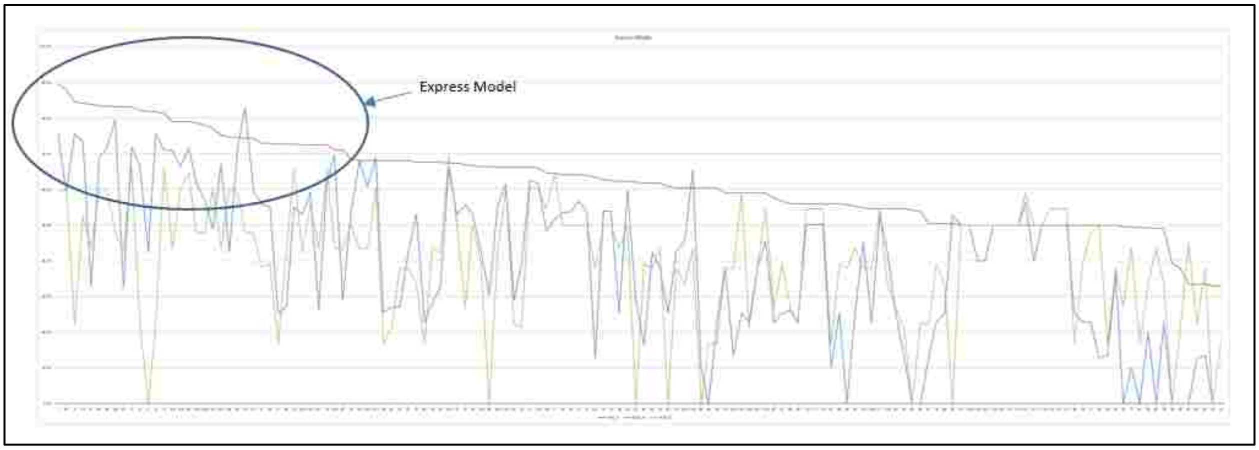


Figure 55. Express Model

Descriptors that required a low proficiency, low importance, or were needed very infrequently can be removed. By removing the lower value descriptors, the amount of data can be reduced. Once the SME baseline is established, it can be stored and used for future evaluations. Having this information stored, only the worker side of the model would have to performed. This one-sided approach saves time and effort. Although it should be noted that periodic SME evaluation of the position should be performed to make sure the requirements stay up to date.

6.2.4 Model Reliability

An important facet of any model development is an evaluation of the reliability of the model, i.e., does the model produce consistent results? The internal consistency of the model can be evaluated by comparing the results of the different sets of users who participated in the demonstration. The more reliable the model, the more likely it is to draw correct conclusions from the data collected. A model with high reliability is more likely to be used and trusted, supporting Criteria 5.

The demonstration allowed a group of SMEs to use the SGAM to identify the requirements for a position and also allowed a group of Technicians currently in that position to detail their qualifications. The results of the different groups of participants can be compared to evaluate the reliability of the SGAM model.

Table 28 indicates the variance among the SME data. The standard deviation (SD) is used to describe the distribution relative to the mean for the SME. In this case the SD for the complete set of data collected for all the SME responses is 3.77. The SD of the comparison table is 0.07 with a variance of 0.01. These values indicate the use of the SGAM by the SMEs resulted in close agreement on what is required for the position.

Table 28. SME Data Variation

	SME1	SME2	SME3
SME1	1.000	0.940	1.062
SME2	1.064	1.000	1.129
SME3	0.942	0.885	1.000

There were two groups of technicians from two organizations that participated in the demonstration. In the first set, five technicians from Organization A used the SGAM to rate their current skill skills sets. The results are shown in Table 29.

Table 29. Technician (Organization A) Data Variation

	TECH_A1	TECH_A2	TECH_A3	TECH_A4	TECH_A5
TECH_A1	1.000	1.760	2.904	1.971	3.220
TECH_A2	0.568	1.000	1.650	1.120	1.830
TECH_A3	0.344	0.606	1.000	0.679	1.109
TECH_A4	0.507	0.893	1.473	1.000	1.634
TECH_A5	0.311	0.547	0.902	0.612	1.000

The SD of the complete data set collected for the technician A responses is 16.60, the SD of the comparison table is 0.72 with a variance of 0.52. Additionally, the variance for the three technicians from organization B are shown below:

Table 30. Technician (Organization B) Data Variation

	TECH_B1	TECH_B2	TECH_B3
TECH_B1	1.000	1.976	1.106
TECH_B2	0.506	1.000	0.560
TECH_B3	0.904	1.787	1.000

The SD of the complete data set collected for the technician B responses is 15.67, and the SD of the comparison is 0.47 with a variance of 0.21. The SD and variance for the technician skill sets in both organizations are similar. The larger SD shows that within the organization here are differences in the available skill sets among technicians, even though they may be assigned to the same position. A summary of the data set averages, data set deviations, and variances is shown in Table 31.

Table 31. Data Variation Summary

	Data Set Average	Data Standard Deviation	Standard Deviation of Comparison Table	Data Variance of Comparison Table
SMEs	62.05	3.77	0.07	0.01
Technicians (Company A)	40.18	16.60	0.72	0.52
Technicians (Company B)	39.82	15.67	0.47	0.22

Comparing the SME average with the technician average, Table 32 shows that there is a big difference between SME average and the Technician averages.

Table 32. Data Average Comparisons

	SME_AVG	TECH_A_AVG	TECH_B_AVG
SME_AVG	1.000	0.648	0.642
TECH_A_AVG	1.544	1.000	0.991
TECH_B_AVG	1.558	1.009	1.000

The SME average for the position requirements was a great deal higher than what the technicians rated themselves showing a gap between what the employees possess versus what is needed. On average the SME identified the position needed 22% skills than technicians identified having. The SMEs expected more from the personnel in the technician position. This comparison also shows that the average of the skills sets for technicians with both organizations is similar, confirming consistency that is reflected in the model.

6.2.5 Position "Fit" Evaluation

The initial impetus for this work was the desire to compare a position description and a worker skill set and determine "fit". Using the fit coefficient equation from Figure 33 and the data collected from the demonstration, an example of the use of the SGAM model for a position "fit" evaluation can be performed. Table 33 describes the fit of the eight technicians who participated in the demonstration to the SME average position description.

Table 33. Data Average Comparisons

	Fit Coefficient	Ranking
Technician A1	0.30	8
Technician A2	0.52	5
Technician A3	0.87	3
Technician A4	0.59	4
Technician A5	0.96	1
Technician B1	0.47	7
Technician B2	0.93	2
Technician B3	0.52	6

Comparing the individual technician averages with the normalized SME requirement average, the technician fit is ranked from one to eight in the second column of Table 30. This information can be used for making hiring and promotion decisions or identifying the best person to move into a position based on the position requirements. Technician A5 has the smallest skills gap and thus ranks first in the fit column. Alternatively, Technician A1 has the largest gap, and ranks last in the fit column. From this perspective, Technician A1 would be the top candidate to receive training in order to better fit the current position. The SGAM data can be further examined to understand where Technician A1 skills gaps are. The SGAM data for Technician A1 was sorted from high to low and compared to the SME average (See Figure 56). The difference between the two identifies the gaps. This information can be used to identify training required or to identify a position that Technician A1 may be better suited to fill.

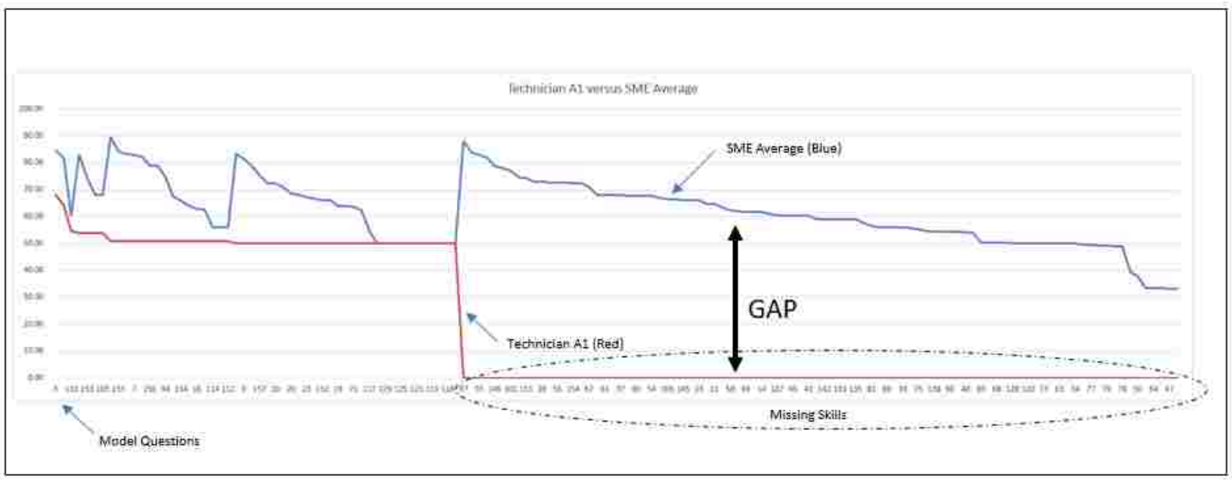


Figure 56. GAP Identification

6.2 Assessment of Skills Gap Analysis Model

The results of the user demonstration can be used to assess the SGAM artifact and evaluate if it meets the design criteria that were established at the onset of the Design Science Research Methodology. As noted in the sections above, different aspects of the demonstration lend evidence to the assessment of the model – these are detailed in Table 34.

Table 34. SGAM Assessment

Section	Data Evaluation	Success Criteria: Single Taxonomy	Comparable	Adaptable	Actionable	Usable
6.2.1	Gap Analysis	X (Figure 18)	X (Figure 48 & 49)		X (Table 22)	
6.2.2	Participant Survey					X (Figures 53 & 54)
6.2.3	Data Parser Utility					X (Table 26 & 27)
6.2.4	Model Reliability					X (Table 28, 29, & 31)
6.2.5	Position Fit Evaluation		X (Table 33)			
6.3	Adaptability			X (Figure 61)		

6.2.1 Taxonomy

To allow for quantitative comparison, both the position requirements and the worker qualifications need to be presented in a way that they can be reasonably compared. The information needs to use the same language. The use of the O*NET descriptors is effective in capturing this information for both sides and provides a classification of descriptors that can be used for both perspectives. This criterion was demonstrated by having both SMEs and Technicians use the same descriptors to identify what was required for a position and what the worker skills are.

6.2.2 Comparable

By adding the metrics for proficiency, importance, and frequency the descriptors can be weighted to provide the basis for a quantifiable comparison. Using this quantitative data, worker qualifications can be compared to position requirements to identify skills gaps. This criterion was demonstrated by using both the SME and Technician data to establish the differences between the two sets of descriptors.

6.2.3 Adaptable

The O*NET database is extensive and is constantly being updated so that it remains relevant. Using this database along with the described model, this method is adaptable to any domain. This criterion was not elicited during the demonstration. See section 6.3 below.

6.2.4 Actionable

This model generates better position descriptions that will provide clear direction about what is needed, provides improved identification of worker qualifications, enables a method for comparison between the position and worker, and provides a method for organizations to identify gaps to determine if existing personnel can fill the position or if training is needed. This criterion was demonstrated by identifying specific descriptors that could benefit from additional training, as well as identifying specific technicians who would be candidates for the training.

6.2.5 Usability

To be useful, the model would have to make effective use of the evaluator's time. Systems that are difficult and time intensive are not likely to be used. By using the O*NET descriptors and parsing the data to only ask the user relevant questions, the user's time is being used effectively. This criterion was demonstrated by asking the participants to complete a usability survey at the completion of the demonstration event and provide feedback on their perspective of using the tool.

Additionally, the results from the SME participants were compared to evaluate the inter-rater reliability of the model for detailing a common position. These results showed a high agreement. Likewise, the worker profiles were compared to determine the internal consistency of the model for determining the required KSAOs. Both results are shown in Figure 57.

	Data Set Average	Data Standard Deviation
SMEs	62.05	3.77
Technicians	40.00	16.14

Figure 57. Inter-rater Reliability

The worker results showed more variability. This result makes sense and supports the theory of the skills gap. The SMEs agreed on the position requirements, but the qualifications of the workers in the positions varied a great deal and were on average lower than what the position required.

6. 3. Example of Adaptability

To demonstrate the adaptability of the model, another job position will be evaluated, and the model steps will be reviewed. JASS uses a Barista position as an example, so for this exercise we will use the same position. Searching the O*NET database for "Barista", the position requirements are identified (See Figure 58).

Figure 58. O*NET Barista Details
Retrieved July 13, 2019 from https://www.onetonline.org/link/summary/35-3022.01

The framework and process were detailed in Chapter 4 and diagrammed in Figure 21, but they are shown again here in Figure 59.

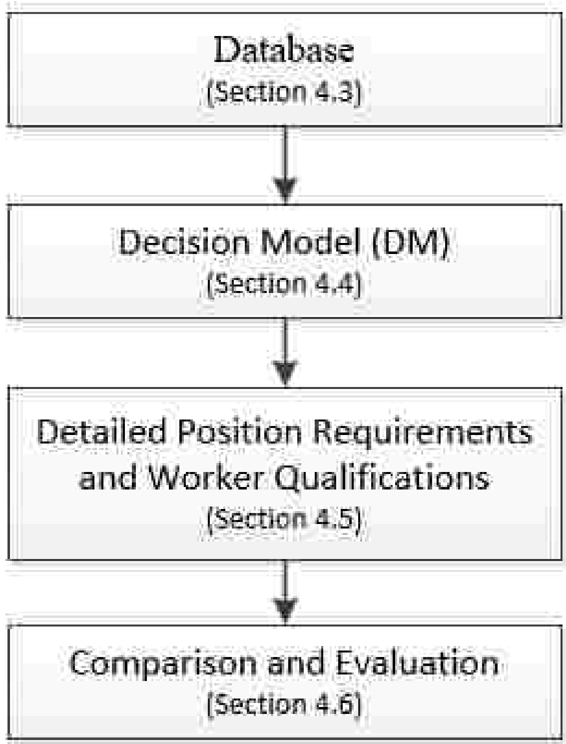


Figure 59. Adaptability Example

The O*NET position description identifies all the KSAOs required for the position using descriptors. These descriptors are organized in a logical manner for the Decision Model which allows participants to parse out non-relevant questions. The decision path is shown in Figure 60.

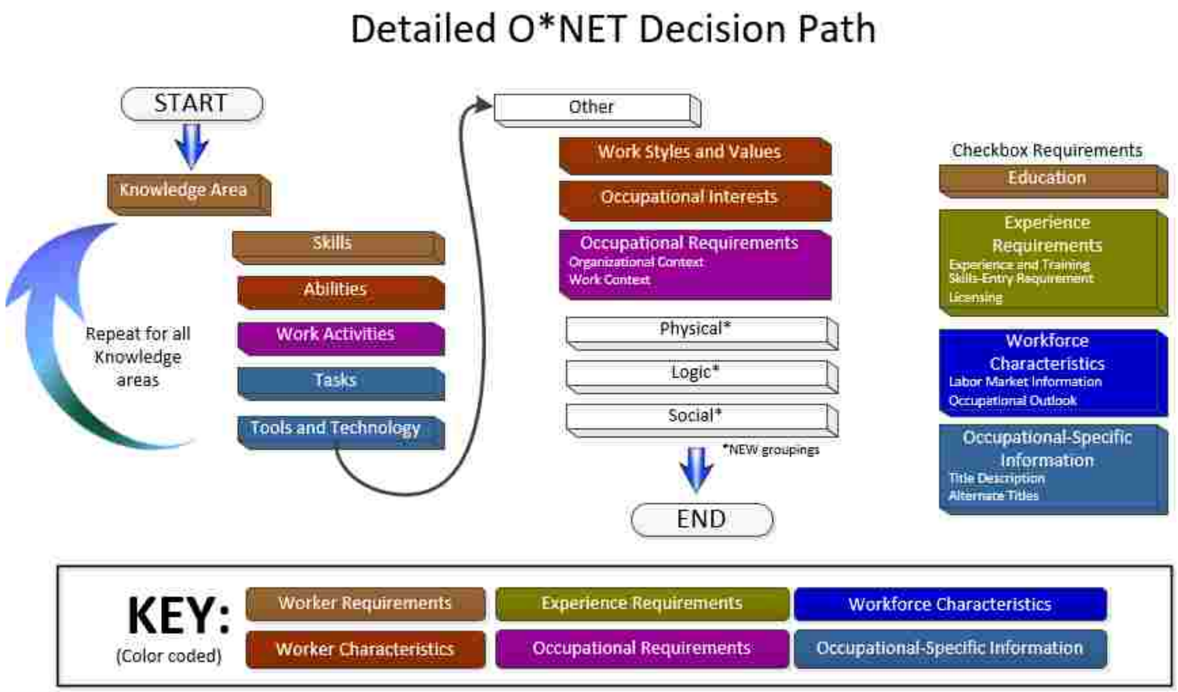


Figure 60. Decision Path

The descriptors are converted into questions, following the path above. An example is shown below.

Area	Description	Original ONET Descriptors
Knowledge	Is it neceassary to have 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.	
Skills	Able to Give 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.	Active Listening
Skills	Able to actively look for ways to help people.	Service Orientation
Skills	Able to talk to others to convey information effectively.	Speaking
Skills	Aware of others' reactions and understanding why they react as they do.	Social Perceptiveness
Skills	Adjusting actions in relation to others' actions.	Coordination
Skills	Able to Monitor/Assess performance of yourself, other individuals, or organizations to make improvements or take corrective action.	Monitoring
Skills	Able to understand written sentences and paragraphs in work related documents.	Reading Comprehension
Knowledge	Is it neceassary to have Sales and Marketing Knowledge. 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.	

Figure 61. Barista Example

By allowing SMEs and current workers to use the new model, the detailed position requirements and the worker qualifications can be determined. Through comparison and evaluation, the skills gaps and other areas of concern can be identified. The model presented is adaptable to any position description and satisfies criterion 3.

6.4 Overall Evaluation

In summary, the SGAM artifact meets all the evaluation criteria provided in Table 1 and shown completed in Table 35. The skills gap analysis model acceptably addresses all the identified criteria.

Table 35. Model Criteria (SGAM)

	Criteria		Details	Acceptable (A) / Needs Improvement (NI)
1	Taxonomy/ Same Language	Position Requirements	Uses O*NET descriptors	A
		Worker Qualifications	Uses O*NET descriptors	A
2	Comparible	Data comparison	Ability to compare	A
		Quantifiable data	Uses slide scales to add metrics	A
3	Adaptable	Information updated	Data is updated to remain current, online resources	A
		Robustness	Solid framework,sets basis for comparison	A
4	Actionable	Provide accurate and actionable data	The combination of the other models with metrics, parsing, and comparison algorithm provides accurate and actionable data	A
5	Usability	Ease of use	Easy to use with good method to skip non-relevant questions, computer based	A

7. COMMUNICATION PLAN AND CONCLUSIONS

The final step of the Design Science Research Methodology is to discuss plans to disseminate the research from the problem identification, the solution artifact, and its effectiveness to other researchers and potential users. This chapter also summarizes the research and presents the conclusions and recommendations of the dissertation.

7.1 Communication Plan

The communication plan identifies the means and audiences to disseminate the research and resulting artifact to relevant stakeholders.

7.1.1. Researchers

Researchers across many fields may be interested in these results for research involving human factors, personnel, manning and training. The appropriate mechanism to reach other researchers is peer reviewed publications. For research publications, the design science research methodology is most often used to structure the paper. For this work a paper has been accepted to be presented at the 63rd International Annual Meeting of the Human Factors and Ergonomics Society in Seattle, WA.

7.1.2 System Engineer

System engineers are often involved in developing human role strategies as part of the requirements analysis stage of system design. The human role strategy indicates what functions and decisions are performed by humans within the system, as well as those that are performed by humans with the assistance of other system components. These human system allocation decisions determine personnel types required for operation of the system. A journal paper is in preparation for the IEEE Systems Journal, sponsored by the IEEE Systems Council. An alternative journal will be the Systems Journal sponsored by INCOSE.

7.1.3 Human System Integration Practitioners

HSI is a system engineering discipline that applies knowledge of human capabilities and limitations throughout the design, implementation, and operation of hardware and software. (Citation: NASA/SP–2015-3709, Human Systems Integration (HSI) Practitioner's Guide, November 2015). The original JASS tool is part of a tool set developed for HSI Practitioners at the US Army Research Laboratory Human Research and Engineering Directorate (HRED) in Aberdeen, MD. The JASS developer, Dr. Christopher Garneau, has been consulted through the development of the SGAM. The final artifact, the SGAM excel spreadsheet program, will be provided to the ARL Tools Library, joining JASS, C3TRACE and IMPRINT as modeling and simulation tools for HSI Practitioners to use during system development to assess the HSI domains of Manpower, Personnel, Training and Human Factors.

7.1.4 Human Resource Professionals

The SGAM development was targeted for use in industry. Using this model, the worker qualifications are detailed and can be compared to the requirements. Once the up-to-date current job description is developed using this model with metrics, then existing personnel can be evaluated. If hiring, the clear concise job description helps ensure the correct person is selected. The established SME baseline can be used to compare potential applicants against. After the model is used to evaluate a worker, the worker could be compared against existing positions with baselines to determine the best fit.

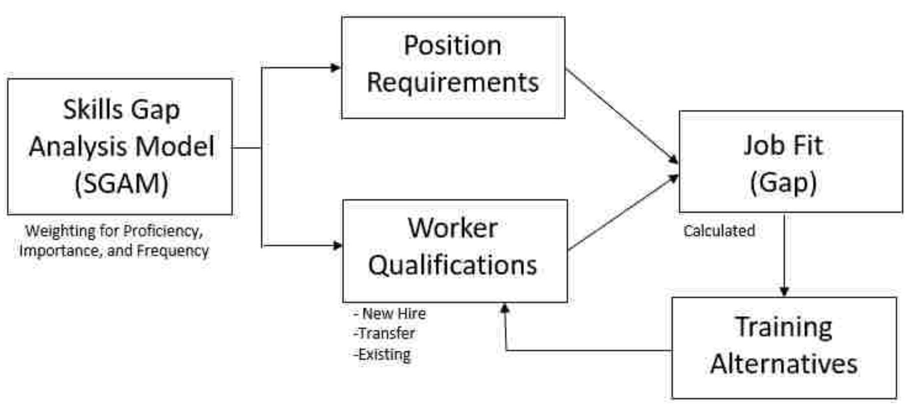


Figure 62. Model Flow

The data that can be obtained using this model would allow an organization to access its current skills levels and the skills gaps. Having this detailed information would allow the organization to develop a detailed training program.

This model and its use can be communicated through industry organizations such as the Commonwealth Center for Advanced Manufacturing, (CCAM) of which Old Dominion University is a member. Recently, ODU partnered with CCAM on a proposal for the Advanced Robotics for Manufacturing (ARM) which the SGAM model uses as the basis for re-training transitioning military veterans. The proposal specifically requested a "model that will translate the skills and competencies military personnel acquire to the skills and competencies required in manufacturing facilities" Citation: Advanced Robotics for Manufacturing, PROJECT CALL # ARM-EWD-18-01 for Education and Workforce Development Projects, October 17, 2018.

7.2 Conclusion

7.2.1 Exit Criteria

The Skills Gap Analysis Model (SGAM) identified five critical criteria that needed to be met to successfully identify and quantify gaps. Through the demonstration it was shown that these criteria were met using the new model. The criteria are shown again in Table 36 below.

Table 36. Model Exit Criteria (SGAM)

	Criteria		Details	Acceptable (A) / Needs Improvement (NI)
1	Taxonomy/ Same Language	Position Requirements	Uses O*NET descriptors	A
		Worker Qualifications	Uses O*NET descriptors	A
2	Comparible	Data comparison	Ability to compare	A
		Quantifiable data	Uses slide scales to add metrics	A
3	Adaptable	Information updated	Data is updated to remain current, online resources	A
		Robustness	Solid framework,sets basis for comparison	A
4	Actionable	Provide accurate and actionable data	The combination of the other models with metrics, parsing, and comparison algorithm provides accurate and actionable data	A
5	Usability	Ease of use	Easy to use with good method to skip non-relevant questions, computer based	A

The resulting artifact from this research, the SGAM model, is generalizable and can be applied to any position or domain. The resulting data, after analysis, provides actionable data that can be beneficial to organizations to understand their personnel resources.

7.2.2 Benefits of the Skills Gap Analysis Model

7.2.2.1 Training and Hiring

This model can be used to identify additional training for existing personnel, identify training needs when position requirements change, and identify specific requirements when new positions are created. Having the ability to identify and detail the exact skills gaps will allow the organization to target its training efforts. Also, being able to identify personnel that exceed the skills required in certain areas and pairing them with those that need help will also help with training. The use of this model will also help organizations track how positions have changed over time. The model can be applied to address labor shortages from a variety of perspectives.

7.2.2.2 Employee Disconnects

The model can also identify disconnects between the organization and the worker. A disconnect may be caused by personnel not being aware they are responsible for certain position functions. This can occur when responsibilities change or new ones are added and the change is not effectively communicated. This often occurs with organizations that run multiple shifts and weekend operations. By quickly identifying the disconnects, they can be addressed before they become an issue.

7.2.2.3 Applicant Pool Versus Requirements

The model can customize the descriptor selection and weighting criteria based on specific organizational needs. Trying to use the complete O*NET position description as a basis for what organizations should focus on for hiring and identifying skills gaps would be problematic. Figure 63A shows the selection of personnel based on the full O*NET description would be costly based on the time required to find the personnel and the money it would take to attract this highly qualified person. Also, the amount of personnel that could fill the position would be limited. Figure 63B shows a person could potentially fill the position effectively and only need a small portion of the wedge identified. To be cost effective, an organization would have to sort through the details for specifically what they need. This increases the chance of finding the correct person while saving time and money. The ability to parse out the relevant data and identify the smaller wedges from the extensive O*Net data would be beneficial to an organization.

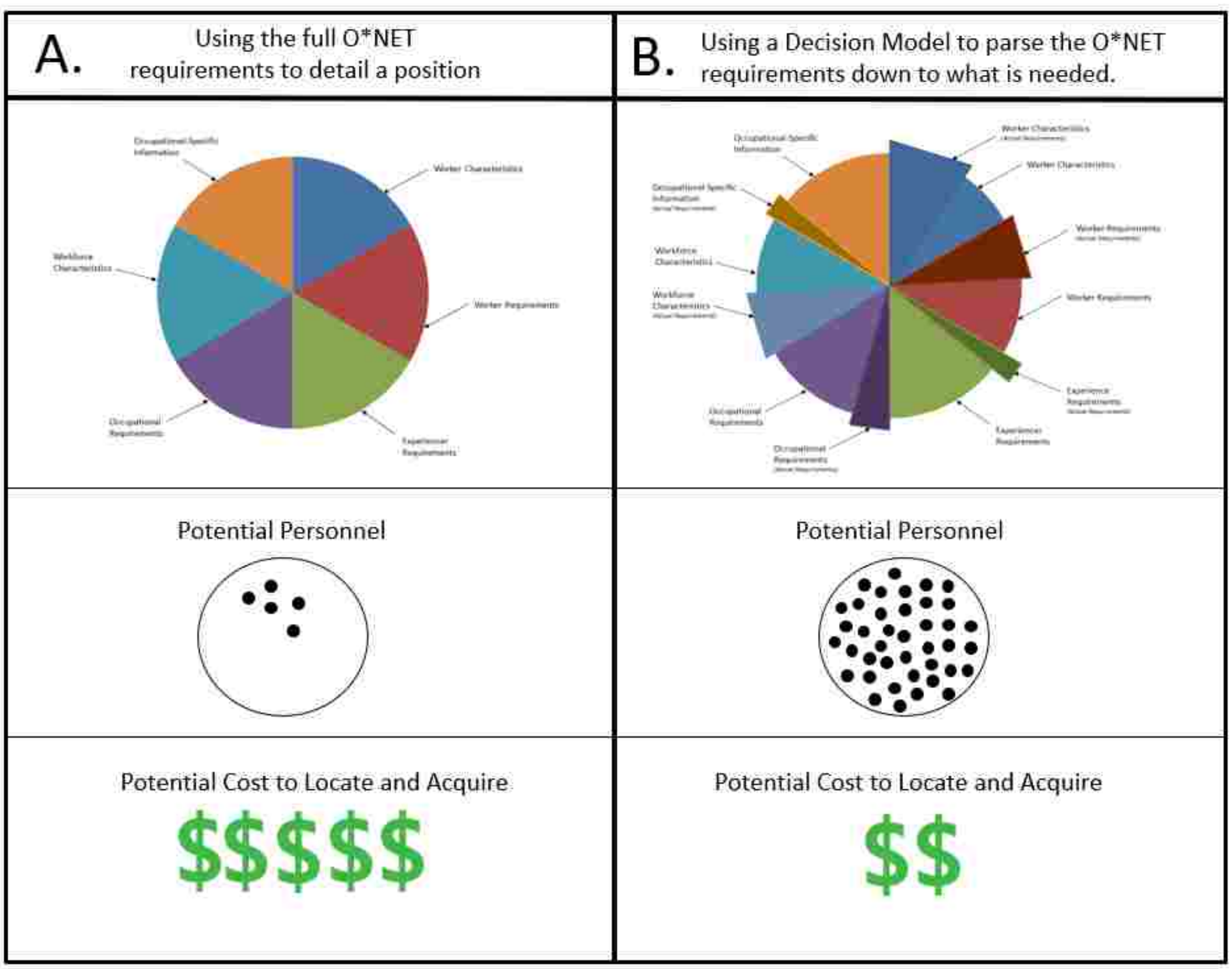


Figure 63. Full O*NET Requirements versus using Skills Gap Analysis Model

7.2.2.4 Legal Concerns

An organization may have to deal with a bad hiring decision for years, and corrective action can lead to legal issues and be very expensive. Based on the information from Cliffford (1994) for legal reasons there should be a clear audit trail from the job analysis to the decision. In the event there is legal action, with the new model it will be easy to demonstrate the employment decision was valid. The level of detail the new model provides will also help with performance evaluations to determine if the worker met all requirements of the position.

7.3 Opportunities for Future Research and Limitations

Using the same process, the SMEs used to identify what is needed, the model could be adjusted to allow interviewers to rate prospective applicants in the needed areas to come up with a quantitative score for decision making. Additionally, because the model identifies and quantifies the required descriptors, the prospective applicants could be tested in appropriate areas before the interview. The areas with the level of importance in each will have been identified, and test questions in these areas could be developed and weighted to ensure a proper fit. Testing before the interview ensures only the most qualified applicants are selected and that time spent by personnel within the organization is used effectively. This saves time, resources, and can lead to a better organizational fit. Also, if applicants are willing to test on their time, it shows commitment. Being able to test and screen applicants for the basic technical skills required would also be a good method to help organizations sort through large volumes of applicants.

Another potential application of this model is its use with Artificial Intelligence (AI). Using AI with Machine Learning (ML) it may be possible to have gaps automatically identified, have custom training programs automatically developed, provide detailed information to school systems about what classes are needed, and possibly suggest automation options to fill the gaps. Having all the information available would allow an intelligent system to make these calculations and decisions.

The only limitation to note is that a larger study population was desired. The overall results of the model were positive, but a larger sample size was targeted. Due to company size and production issues and even though the study was volunteer and anonymous, there were concerns from some technicians that the information collected would reflect negatively, so the response was less than expected. Future research could utilize a larger industry population for additional verification.

7.4 Summary and Recommendations

This research used the Design Science Research Method (DRSM) to develop a generalizable model that provides both the position requirements and the worker qualifications (both perspectives) in the same language, is adaptable to any domain, allows for comparison (quantifiable data), is quick and easy to use (usability/burden), and provides accurate and actionable data (robust). This model enables the articulation of the "skills gap" to describe the distance between the position requirements and the worker's qualifications. The consistency of the subject matter expert (SME) evaluations and the worker evaluations can also be evaluated.

The main contribution of this research is developing a model to clearly identify the needed skills to match existing personnel to existing or new job positions. This addresses a gap in the body of knowledge and details how this can be specifically accomplished. Much of the literature states this is an important step in hiring personnel and for determining training requirements, but the details for performing this activity are not clear. The model leverages the extensive O*NET data and allows end users to easily create a very detailed job description and add metrics to ensure a proper fit and will also help in identifying skills gaps. To evaluate the robustness and usability of the model, a small demonstration focusing on manufacturing technical personnel was conducted.

The model can be adapted to any occupation and give quantitative results to help determine person to job fit and help identify gaps. There have been a lot of programs that have attempted to detail job requirements and to identify worker KSAOs. This model leverages the best of the existing models and adds quantitative metrics, a scaling feature, and a method to parse the information down to an acceptable level so that it is useful for organizations.

Using this model, organizations can quantitatively determine the "skills gaps" with their existing personnel. By applying the model to identify position requirements and worker qualifications, organizations can also move personnel to better suited positions or utilize needed training in the specific areas identified. This type of model addresses the shortcomings identified in previous models by getting the worker and position information into the same language for comparisons; the required data is readily available, and the approach is easy to use and understand.

This research addresses a complex industry problem that affects multiple enterprise systems. The resulting SGAM model is a combination of several methods, taking the best of each and creating a new, generalizable, easy to adapt and use model that can be applied to any domain. The result is a generalizable model that parses data and quantifiably identifies what is needed for a position so that analyses and comparisons can be made.

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APPENDIX A

JASS QUESTIONS – ORIGINAL MODEL

			Yes	No	Caption	Notes	SCALE (1 to 7)			RATING
Communication	1	To perform the task, is it necessary that the person know and use language?								
	2	Is it necessary to listen to and understand spoken words and sentences?			Oral Comprehension	The ability to listen to and understand words and sentences.	1 Understand a McDonald's hamburger commercial	3 Understand instructions for a sport	6 Understand a lecture on navigating in space	
	3	Is it necessary to read and understand written words, sentences, and paragraphs?			Written Comprehension	The ability to understand written words, sentences, and paragraphs.	1 read the words on a road map	4.2 understand an apartment lease	6.5 understand an instruction book on repairing a missile instrument system	
	4	Assuming that the person is knowledgable about a subject or topic, must he communicate that knowledge to others?								
	5	Must he communicate through speaking so that others will understand his information?			Oral Expression	The ability to use words or sentences in speaking so that others will understand.	1 cancel newspaper delivery by phone	3.5 give directions to a motorist so that he can reach his destination	6.2 give a technical talk, using new concepts, on a technical subject before a professional society	
	6	Must he communicate through writing so that others will understand his information?			Written Expression	The ability to use words or sentences in writing so that others will understand.	1 write a note to remind someone to take something out of the freezer	3.5 write a job recommendation for a subordinate	6.5 write an instruction book for computer systems	
	7	Must the person be able to remember or memorize words, numbers, pictures, procedures, or other things?			Memorization	The ability to memorize and remember information, such as words, numbers, pictures, and procedures. Pieces of information can be remembered by themselves or with other pieces of information.	1 remember the number on your bus so that you get back on the right one	2.5 memorize the pledge to the flag	6 memorize the Gettysburg address after studying it for 15 minutes	
	8	Can problems, mistakes, or malfunctions occur in this task or as a part of the task? (e.g., machine isn't operating correctly)								
	9	Is it important that these problems are recognized by the person performing the task? (e.g., seamstress notices machine stitches are too tight; teacher recognizes child has a hearing problem; proofreader finds typing errors)			Problem sensitivity	The ability to tell when something is wrong or is likely to go wrong. It includes being able to identify the whole problem as well as the elements of the problem.	1 recognize that an unplugged lamp won't work	3.5 recognize from the mood of prisoners that a riot is about to occur	5.5 recognize an illness at an early stage when there are only a few symptoms	
	10	Does the task require the person to be creative? (e.g., develop new procedures where standard procedures are not applicable or not working well; produce unusual and clever ideas on a topic or situation; create novel solutions to problems)			Originality	The ability to produce unusual or clever ideas about a given topic or situation. It is the ability to invent creative solutions to problems or develop new procedures for situations in which standard procedures do not apply or are not working.	2 use a credit card to open a locked door	4.5 make jobs more interesting for subordinates	6.2 invent a new synthetic fiber	
	11	Is it necessary for the person to produce a number of ideas about a given topic, regardless or quality, to perform the task satisfactorily? (e.g., name four brands of toothpaste; think of as many names as possible for a new organization; name all the possible problems which might occur with a space launch)			Fluency of ideas	The ability to produce a number of ideas about a given topic.	1.6 name four brands of toothpaste	3.2 think of as many ideas as possible for the name of a new organization	6.5 name all possible problems that might occur with a space launch	
Conceptual	12	Are distracting stimuli present along with information relevant to the task?								
	13	Does the person know what he is looking for? (e.g., find a steak knife in a utensil drawer; look for a golf ball in the rough; receive Morse code in the presence of background noise)			Flexibility of closure	The ability to identify or detect a known pattern (like a figure, word, or object) that is hidden in other material. The task is to pick out the disguised pattern from the background material. (Pattern Recognition)	1.5 find a steak knife in a utensil drawer	4 look for a golf ball in the rough	6 receive high speed Morse code in presence of similar background signals	
	14	Must the person ignore distractions which are not part of the actual task? (e.g., study for an exam in a house of noisy children; listen to the news while a dinner conversation is taking place)			Selective attention	The ability to concentrate on a task one is doing. This ability includes concentrating while performing a boring task and not being distracted.	2.5 have a conversation with a friend at a noisy cocktail party	4.2 listen to a news broadcast during a dinner conversation	5.5 study for a math exam in a house of noisy, young children	
	15	Is it necessary that the person concentrate on a boring task?			Selective attention	The ability to concentrate on a task one is doing. This ability includes concentrating while performing a boring task and not being distracted.	2.5 have a conversation with a friend at a noisy cocktail party	4.2 listen to a news broadcast during a dinner conversation	5.5 study for a math exam in a house of noisy, young children	
	16	Is information about location important in the performance of the task?								
	17	Should the person know his location in relation to the location of objects? (e.g., locate his position on a road map)			Spatial Orientation	The ability to tell where you are in relation to the location of some object or to tell where the object is in relation to you.	2.5 Find your way through a familiar room when lights are out without bumping into anything	4 while lost in a rural area, locate your position on a road map	5.5 be aware of your orientation upon awakening in a gravity-free environment, like a spacecraft	
	18	Should the person know the location of objects in relation to his own location? (e.g., find his way through a dark room without bumping into anything)			Spatial Orientation	The ability to tell where you are in relation to the location of some object or to tell where the object is in relation to you.	2.5 Find your way through a familiar room when lights are out without bumping into anything	4 while lost in a rural area, locate your position on a road map	5.5 be aware of your orientation upon awakening in a gravity-free environment, like a spacecraft	
	19	Does the task require that the person be able to form mental images of how something will look after it is moved around or its parts have been re-arranged? (e.g., imagine how to put paper in a typewriter so letterhead comes out on top; imagine how to cut and fold a piece of paper to make a cube; imagine how a chess board would look after possible future moves)			Visualization	The ability to imagine how something will look when it is moved around or when its parts are moved or rearranged. It requires the forming of mental images of how patterns or objects would look after certain changes, such as unfolding or rotation. One has to predict how an object, set of objects, or pattern will appear after the changes are carried out.	1 imagine how to put paper in the typewriter so the letterhead comes out at the top	4 know how to cut and fold a piece of paper to make a cube	6 imagine your opponent's as well as your own moves in a chess game	

Reasoning	20	To perform the task, must the person generate rules or principles?								
	21	Must these rules explain diverse pieces of information? (e.g., diagnose a disease using results from many lab tests, decide which student characteristics are related to future success, decide on the best way to organize the office filing system)			Inductive Reasoning	The ability to combine separate pieces of information, or specific answers to problems, to form general rules or conclusions. It involves the ability to think of possible reasons for why things go	2 order a seafood platter at a restaurant to determine whether or not you like seafood	3.5 interpret a weather chart	5 diagnose a disease utilizing knowledge from many lab tests	
	22	Must these rules tell how to group a set of things in different ways? (e.g., generate a number of ways to sort nails—length, metal, etc.; invent rules for classifying flowers--size, color, scent, uses, etc.; construct classification systems for synthetic fibers—cost, strength, elasticity,			Category Flexibility	The ability to produce many rules so that each rule tells how to group a set of things in a different way. Each different group must contain at least two things from the original set of things.	1.7 generate a number of ways to sort nails (length, metal, size, etc.)	3.2 invent rules for classifying flowers (size, color, odor, uses, etc.)	6 construct classification systems for synthetic fibers (strength, cost, elasticity, etc.)	
	23	Must the person apply existing rules or principles?								
	24	Are the rules applied to specific cases to arrive at logical answers? (e.g., know you can coast down a hill due to gravity when you've run out of gas, use laws of economics in selecting stocks, design an aircraft wing using the principles of			Deductive Reasoning	The ability to apply general rules to specific problems to come up with logical answers. It involves deciding if an answer makes sense.	1.6 know that you can coast down a hill due to the law of gravity when you've run out of gas	5 use laws of economics in selecting stocks	6.4 design an aircraft wing using principles of aerodynamics	
	25	Are the rules used to order or arrange things in a specified way? (e.g., put invoices in numerical order, arrange sentences into a paragraph that makes sense, order sequence or check-out procedures for the space shuttle so that the least amount of time is expended)			Information Ordering	The ability to follow correctly a rule or set of rules to arrange things or actions in a certain order. The rule or set of rules used must be given. The things or actions to be put in order can include numbers, letters, words, pictures, procedures, sentences, and mathematical or	1.5 put things in numerical order	3 arrange five sentences into a paragraph that makes sense	6.5 determine the appropriate sequence of checkout procedures for the Challenger space shuttle	
	26	Does the task involve any mathematical or numerical concepts?								
	27	Must the person understand or organize a problem using mathematical concepts? Actual calculations and computations are not required. (e.g., set up a problem to determine how much 10 oranges will cost when they are 2 for 29 cents; decide how to calculate profits to determine size of Christmas bonuses; determine mathematics for simulating a lunar approach and landing)			Mathematical Reasoning	The ability to understand and organize a problem and then select a mathematical method or formula to solve the problem. It encompasses reasoning through mathematical problems to determine appropriate operations that can be performed to solve problems. It also includes the understanding or structuring of mathematical problems. The actual manipulation of numbers is not	1.5 decide how to compute what 10 oranges will cost when they are 2 for $0.29	4.2 decide how to calculate profits to determine size of Christmas bonuses	6.8 determine mathematics for simulating a lunar approach and landing	
	28	Does the task require that the person perform mathematical calculations, such as adding, subtracting, multiplying, or dividing? (e.g., add 2 and 7, balance checking account with monthly statement, compute interest payment			Number Facility	Involves the degree to which adding, subtracting, multiplying, and dividing can be done quickly and correctly. These can be steps in other operations like finding percentages and taking square	1 add 2 and 7	2.6 reconcile checking account monthly statement	5 compute interest payments that should be generated from investments	

Speed-Loaded	29	Does the information which must be used in the task come from two or more sources? (examples of two or more sources are drive a car, play an instrument in a conducted orchestra; examples of one source are read a newspaper, talk on the phone, watch television)								
	30	Must the person switch back and forth between the two or more sources of information relevant to the task? (e.g., listen to 2 conversations at once; watch street signs and the road while driving 30 mph; monitor several TV channels at the same time; monitor inbound and outbound planes on a radar scope during a period of			Time Sharing	The ability to shift back and forth between two or more sources of information.	3 watch street signs and the road while driving 30 mph	4.5 monitor several TV channels at the same time	6 keep track of all inbound and outbound planes during a period of heavy traffic	
	31	Must the person quickly structure information into a meaningful pattern? (e.g., recognize and old song after hearing only the first few notes; recognize weather patterns on a radar scope)								
	32	Is the pattern unpredictable?			Speed of Closure	Involves the degree to which different pieces of information can be combined and organized into one meaningful pattern quickly. It is not known beforehand what the pattern will be. The material may be visual or	2.2 while listening to the radio, recognize and start to hum an old song after hearing only the first few lines	4.2 find five camouflaged birds in a picture	5.2 interpret patterns on weather radar to decide if weather is changing	
	33	Must things, present or remembered, be compared with other things? (e.g., scan list of batting records to see who scored the most runs; read 5 temperature gauges in 30 seconds to insure safe operation; inspect electrical components for defects; recognize a lost glove)								
	34	Must the comparisons be made quickly and accurately?			Perceptual Speed and Accuracy	Involves the degree to which one can compare letters, numbers, objects, pictures, or patterns, quickly and accurately. 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	2.2 quickly scan list of batting records in Sunday sports section to see who scored the most runs	4 read 5 temperature gauges in 30 seconds to insure temperature is within safe limits	5.2 inspect assembled electrical components for defects as they flow by on a fastmoving line	
	35	Is it necessary for the person to initiate one response very quickly? (e.g., apply the brakes when light turns red; return the ball in a ping pong game; duck to miss being hit by a snowball)								
	36	Does the task involve only one response initiated to one signal?			Reaction Time	The ability to give one fast response to one signal (sound, light, picture) when it appears. This ability is concerned with the speed with which the movement can be started with the hand, foot, or other parts of the	2 start to apply brakes on your car 1 second after the light turns red	3.2 duck to miss being hit by a snowball thrown from across the street	5.2 hit back the ball which has been slammed at you in a ping-pong game	
	37	Must the person quickly choose between actions in response to two or more signals? (e.g., when doorbell and phone ring, select one to answer first; in and out-of-control spacecraft, pick 1 of 5 possible fixes)			Choice Reaction Time	The ability to choose between two or more movements quickly and accurately when two or more different signals (lights, sounds, pictures) are given. The ability is concerned with the speed with which the right response can be started with the hand, foot, or other parts of	2.2 when a doorbell and telephone ring simultaneously, select one to answer first in one second	4 operate a busy switchboard where you must switch calls in and out quickly and accurately every few seconds	6.2 in a spacecraft out of control, choose one of 5 possible corrections in 0.7 seconds	

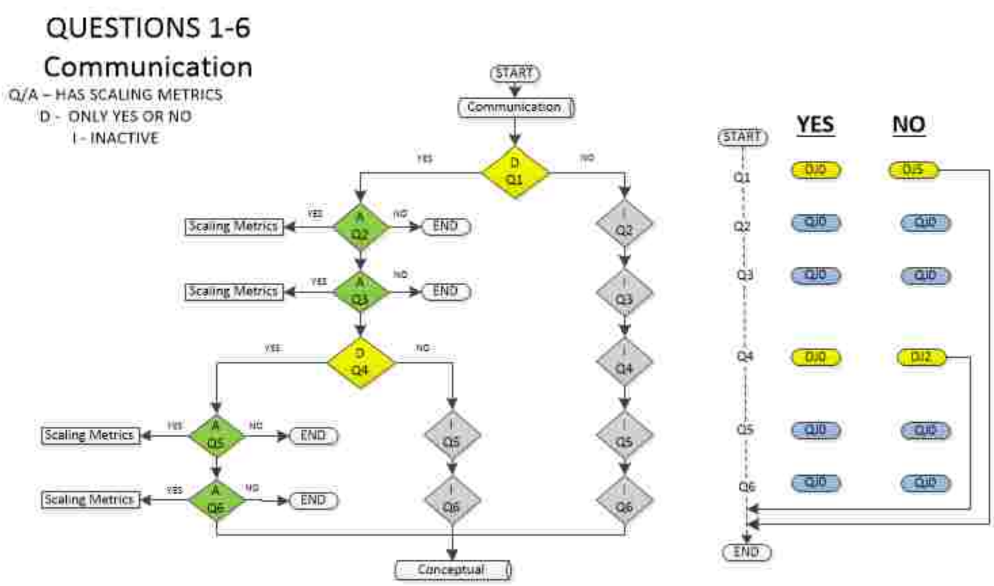
Vision	38	To perform the task, is it necessary to be able to see things in the environmental surroundings?								
Vision	39	Are the things that must be seen nearby?			Near Vision	The capacity to see close environmental surroundings.	1.5 plug in a TV set	4.5 cut and mount color film transparencies	6 read the fine print of legal journals	
Vision	40	Are the things that must be seen at a distance?			Far Vision	The capacity to see distant environmental surroundings.	1.5 point out a mountain range in the distance	4.5 drive a moving van across the country	6.5 detect differences in ocean vehicles on the horizon	
Vision	41	Must things be seen under low light conditions?			Night Vision	The ability to see under low light conditions.	1.5 find and turn on a light in a dim room	4.2 take notes during a slide presentation	5.5 catch lightning bugs on a summer evening	
Vision	42	Does the task require the capacity to match colors or to discriminate between colors?			Visual Color Discrimination	The capacity to match or discriminate between colors. This capacity also includes detecting differences in color purity (saturations) and brightness	1.5 sort soiled sheets and linens before washing	3.5 match wood grains in a lumber yard	6 paint a portrait from a living subject	
Vision	43	Is it necessary to perceive objects or movement toward the edge of the visual field? (e.g., monitor an opponent's position while returning a tennis serve; monitor the instrument panel of a jet plane)			Peripheral Vision	The ability to perceive objects or movements towards the edges of the visual field.	1.8 while driving, see cars approaching from left or right	3.6 monitor opponent's position while returning tennis serve	4.5 monitor the instrument panel of a jet aircraft	
Vision	44	Is it necessary to be able to tell which of several objects is farther away, or to judge how far an object is from the observer? (e.g., judge which of two distant buildings is closer; thread a needle)			Depth Perception	The ability to distinguish which of several objects is more distant from or nearer to the observer, or to judge the distance of an object from the observer.	2.8 judge which of two distant buildings is closer	4.2 operate a construction crane	5.5 thread a needle	
Vision	45	Is it necessary to see objects in the presence of glare or bright ambient lighting? (e.g., see boats on the horizon when sailing; snow ski in bright sunlight)			Glare Sensitivity	The ability to see objects in the presence of glare or bright ambient lighting.	1.5 view pictures printed on high gloss paper	4.5 see boats on the horizon while sailing	6 snow ski in bright sunlight	
Audition	46	Is it necessary to detect and to discriminate among sounds that vary over broad ranges of pitch and/or loudness? (e.g., notice the carriage return bell while typing; monitor electronic equipment at a			General Hearing	The ability to detect and to discriminate among sounds that vary over broad ranges of pitch and/or loudness.	1.8 notice the carriage return bell while typing	3.8 monitor audio alarms on electronic equipment at a nurse's station	6 identify a bird species by its call	
Audition	47	Is it necessary to focus on a single source of auditory information?								
Audition	48	Are other distractions or irrelevant auditory stimuli present?			Auditory Attention	The ability to focus on a single source of auditory information in the presence of other distracting and irrelevant auditory stimuli.	1.4 locate someone calling you from across a city street	4.5 listen for a flight announcement at an airport	5.8 receive Morse code in a noisy radio room	
Audition	49	Must the direction from which auditory stimuli originate be identified? (e.g., find a ringing telephone in an unfamiliar apartment; locate someone calling your name in the midst of a crowd)			Sound Localization	The ability to identify the direction from which an auditory stimulus originated relative to the observer.	1.5 find your ringing alarm clock	3.2 find a ringing telephone in an unfamiliar apartment	5 locate someone calling your name in the midst of a crowd	
Psychomotor	50	Does the task require the adjustment of controls of a machine or vehicle?								
Psychomotor	51	Must the controls be adjusted quickly and repeatedly to exact positions? (e.g., manipulate farm tractor controls; work sound equipment for a band; drill a tooth)			Control Precision	The ability to move controls of a machine or vehicle. This involves the degree to which these controls can be moved quickly and repeatedly to exact positions.	1.5 throw a light switch	3.5 manipulate farm tractor controls	6 drill a tooth	
Psychomotor	52	Must the controls be adjusted to changes in speed or direction of a continuously moving object or scene? (e.g., ride a bike along side a runner; shoot a duck in flight; operate controls to land a jet on an aircraft carrier in turbulent water)								
Psychomotor	53	Are the speed and direction of the object or scene unpredictable?			Rate Control	The ability to adjust an equipment control in response to changes in the speed and/or direction of a continuously moving object or scene. The ability does not extend to situations in which the speed and direction of the object are perfectly predictable.	1.8 ride a bicycle alongside a runner	3.4 keep up with the car ahead where its speed may vary	6.5 operate aircraft controls to land a jet on an aircraft carrier in turbulent weather	
Psychomotor	54	Must the person make repeated hand, finger, or wrist movements?								
Psychomotor	55	Is it important that these movements be fast? (e.g., use a pencil sharpener; scramble eggs; send Morse code using a telegraph key)			Wrist-Finger Speed	The ability to make fast, simple, repeated movements of the fingers, hands, and wrists. It involves little, if any, accuracy or eye-hand	1.8 use a pencil sharpener	3 scramble eggs with a fork	5 key a telegraph at 25 words per minute.	
Psychomotor	56	Do these movements require skillful or coordinated action?								
Psychomotor	57	Using the fingers? (e.g., untie a knot on a package; play a guitar; knit)			Finger Dexterity	The ability to make skillful, coordinated movements of the fingers of one or both hands and to grasp, place, or move small objects. This ability involves the degree to which these finger movements can be carried	1.5 put coins in a parking meter	3.4 untie a knot in a long-awaited package	5.5 play a classical flamenco piece on the guitar	
Psychomotor	58	Using one or both hands together? (e.g., fold laundry; crate oranges; juggle 3 balls)			Manual Dexterity	The ability to make skillful coordinated movements of one hand, a hand together with its arm, or two hands to grasp, place, move, or assemble objects like hand tools or blocks. This ability involves the degree to which these arm-hand movements can be carried out quickly. It does not involve moving machine or equipment controls like levers.	2.5 tie a necktie	4 package oranges in crates as rapidly as possible	6.8 perform open-heart surgery	
Psychomotor	59	Using one hand in conjunction with its arm? (e.g., toss a basketball; use a hammer)			Manual Dexterity	The ability to make skillful coordinated movements of one hand, a hand together with its arm, or two hands to grasp, place, move, or assemble objects like hand tools or blocks. This ability involves the degree to which these arm-hand movements can be carried out quickly. It does not involve moving machine or equipment controls like levers.	2.5 tie a necktie	4 package oranges in crates as rapidly as possible	6.8 perform open-heart surgery	
Psychomotor	60	Is it important that the arm and hand be steady? (e.g., light a cigarette; thread a needle; aim a bow and arrow)			Arm-Hand Steadiness	The ability to keep the hand and arm steady. It includes steadiness while making an arm movement as well as while holding the arm and hand in one position. This ability does not involve strength or speed.	1.8 light a cigarette	4.5 thread a needle	6.4 cut facets in diamonds	
Psychomotor	61	Does the task require the movement of 2 or more limbs together in a coordinated action while the body doesn't move because the person is sitting, standing, or lying down? (e.g., operate sewing machine with a foot treadle; operate a forklift truck in a warehouse; play drum set in a jazz band)			Multi-limb Coordination	The ability to coordinate movements of two or more limbs (for example, two legs or one leg and one arm), such as in moving equipment controls. Two or more limbs are in motion while the individual is sitting, standing, or lying down.	2.5 operate a sewing machine with a foot treadle	4 operate a fork lift in a warehouse	5.8 play drums in a jazz band	

Gross Motor	62	Does the task require the person to be flexible--i.e., able to bend, stretch, twist, or reach out with the body, arms, or legs? (e.g., reach for a soda in the back of the refrigerator; touch toes; do splits; win a limbo championship)			Extent Flexibility	The ability to bend, stretch, twist, or reach out with the body, arms, or legs.	1.8 reach for a soda in the back of the refrigerator	3.4 reach out for something on the top shelf	6 win a limbo championship	
	63	Must the flexible movements be made quickly and repeatedly? (e.g., fill a bag with shells at the seashore; shovel coal into a furnace; swim the butterfly stroke for 200 yards)			Dynamic Flexibility	The ability to bend, stretch, twist, or reach out with the body, arms, and/or legs, both quickly and repeatedly.	2 fill a bag with shells at the seashore	4 shovel coal in a furnace	5.6 do the butterfly stroke in a championship swim competition at the Olympics	
	64	To perform the task, is it necessary for the person to move their arms or legs?								
	65	Is the speed of the movement important? (e.g., swat a fly; play bongo drums)			Speed of Limb Movement	Involves the speed with which a single movement of the arms or legs can be made and/or repeated. This ability does not include accuracy, careful control, or coordination of movement.	2.5 saw through a thin piece of wood	4.5 swat a fly with a fly swatter	5.6 play the bongo drums in a band	
	66	Is it necessary that the person be able to keep or regain his balance to perform the task? (e.g., stand on a ladder; walk across a frozen pond; ride a surf board)			Gross Body Equilibrium	The ability to keep or regain one's body balance or to stay upright when in an unstable position. This ability includes maintaining one's balance when changing direction while moving or standing motionless.	2 stand on a ladder	4.2 walk on ice across a 25-foot pond	6 ride a surfboard when waves average 10 feet	
	67	Does the task require the whole body to be in motion?								
	68	Is it necessary and important to coordinate the movement of arms, legs, and torso together? (e.g., move around an obstacle course with no time limit; jump rope without tripping; perform a skilled ballet dance)			Gross Body Coordination	The ability to coordinate the movement of the arms, legs, and torso together in activities in which the whole body is in motion.	2.4 get around an obstacle course with no time limit	4.5 jump rope for 5 minutes without tripping or stopping	6.4 perform a skilled ballet such as Swan Lake	
	69	Does the task require the person to use a significant amount of physical/muscle strength? (e.g., push, pull, throw, or move an object or one's own body)								
	70	Is sustained force or muscle strength needed? (e.g., lift a dining room chair; push open a stuck door; lift front end of a V.W.)			Static Strength	The ability to use muscle force to lift, push, pull, or carry objects. It is the maximum force that one can exert for a brief period of time.	1.5 lift a dining room chair	3.2 push open a stuck door	6.4 lift up the front end of a V.W.	
	71	Are short bursts of muscle strength needed? (e.g., dive into a pool; drive a golf ball 200 yards; win the Olympic shot-put event; shoot a marble)			Explosive Strength	The ability to use short bursts of muscle force to propel oneself or an object. It requires gathering energy for bursts of muscle effort over a very short time period	1 shoot a marble	4 drive a golf ball 200 yards	6.4 win the shot-put event in the Olympics	
	72	Is this muscle strength used to support the person's body weight?								
	73	All of his body weight?								
	74	Using the arms and/or shoulder muscles? (e.g., do 25 push-ups; perform on the rings)			Dynamic Strength	The ability of the muscles to exert force repeatedly or continuously over a long time period. This is the ability to support, hold up, or move the body's own weight and/or objects repeatedly over time. It represents muscular endurance and emphasizes the resistance of the muscles to	1.4 squeeze fresh oranges to make orange juice	4.5 do 25 push-ups	6.8 win the rings events in the U.S. gymnastic finals	
	75	Is the support provided by the stomach and/or lower back muscles? (e.g., sit up in a reclining chair; do 100 sit-ups; lie on back and raise legs off the ground)			Trunk Strength	Involves the degree to which one's stomach and lower back muscles can support part of the body repeatedly or continuously over time. The ability involves the degree to which these trunk muscles do not fatigue when they are put under repeated or continuous strain.	2.2 sit up in a reclining chair	5.4 while lying on one's back, raise the legs off the floor for 5 seconds and repeat 10 times	6.5 do 100 sit-ups	
	76	Does the task require the person to exert himself physically over a long period of time without getting winded? (e.g., mow a small yard; swim 100 yards; jog 3 miles; bicycle 20 miles; walk around the block)			Stamina	The ability of the lungs and circulatory systems of the body to perform efficiently over long time periods. This is the ability to exert oneself physically without getting out of breath.	1.2 walk around the block	2.5 mow a small yard	6.2 bicycle 20 miles to work	

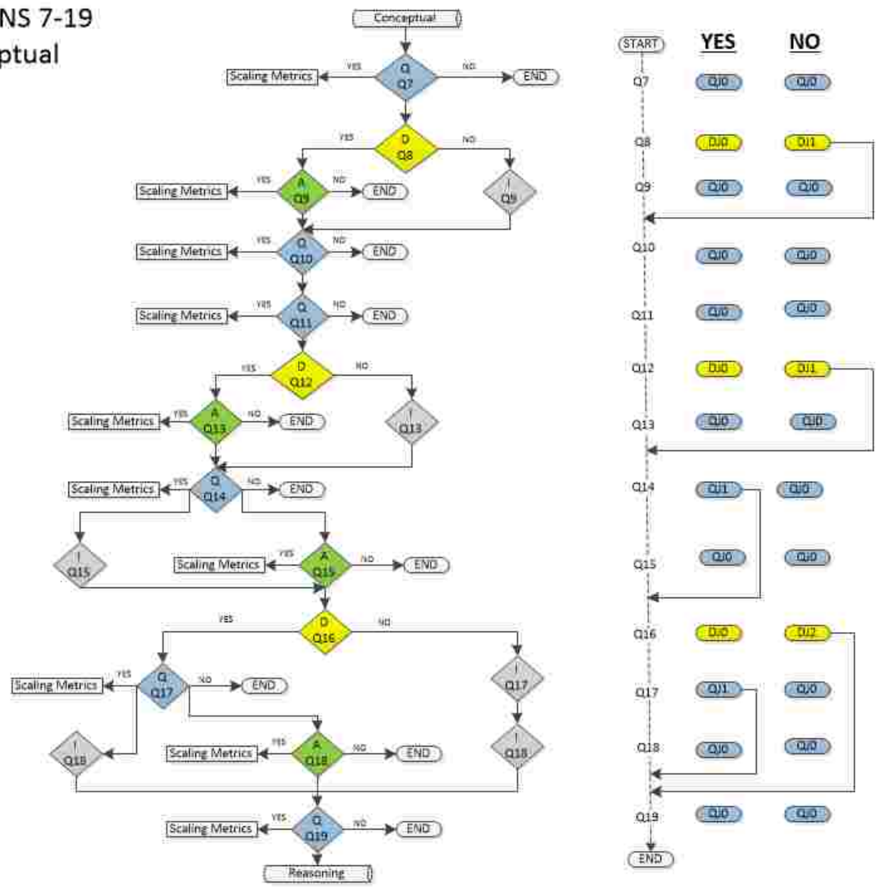
APPENDIX B

JASS LOGIC

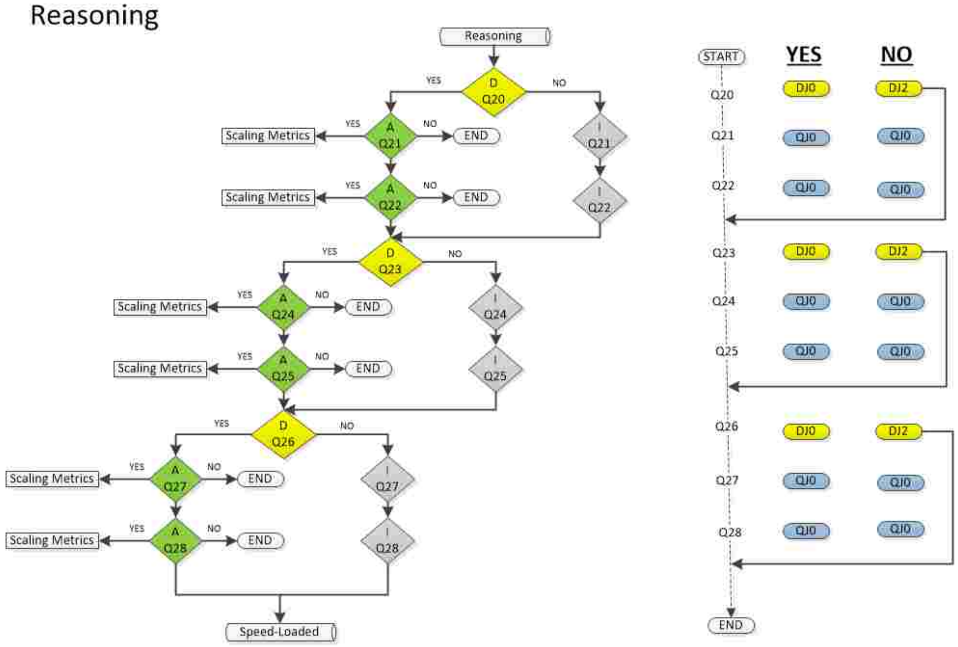
LOGIC FLOWCHART	DECISION PATH
D – Decision (no scaling) I – Inactive question A – Active question (w/scaling) Dependent Q – Question independent (w/scaling)	D – Decision (no scaling) Q – Question independent (w/scaling) Also if Answer in NO, no metrics option D – Decision no scaling metrics Q – Question with scaling metrics If YES then the question is active and relevant If NO then the question is inactive and not relevant J# - jumps over inactive questions and marks them not relevant # state how many to jump



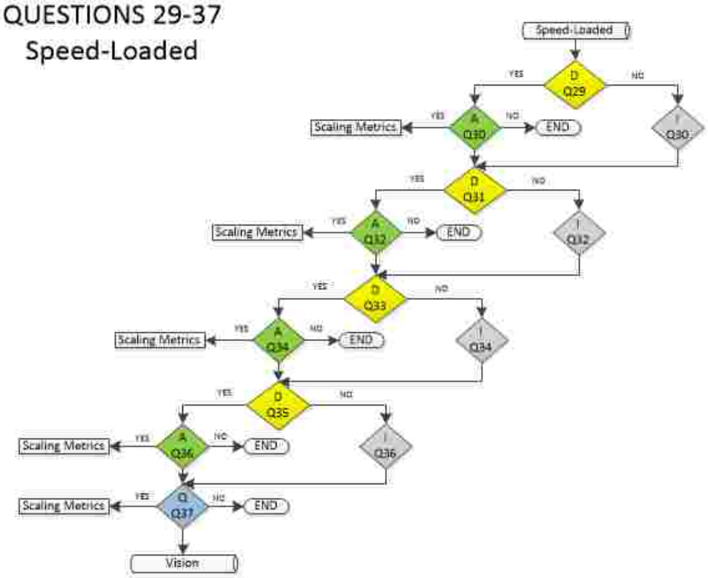
QUESTIONS 7-19
Conceptual

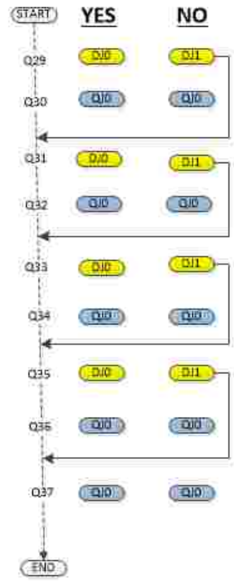


QUESTIONS 20-28
Reasoning

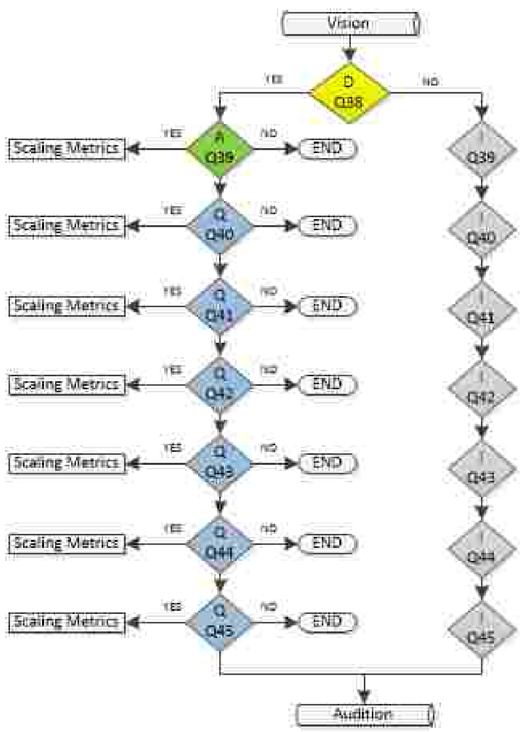


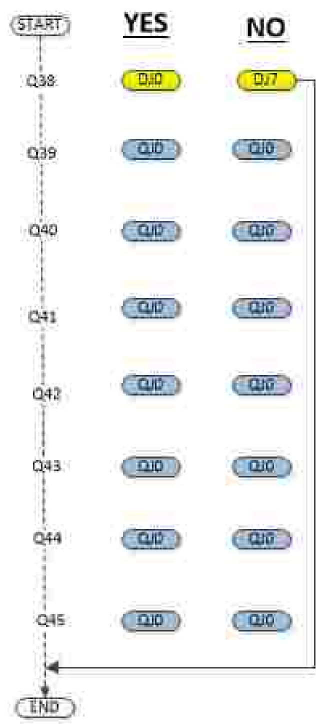
QUESTIONS 29-37
Speed-Loaded



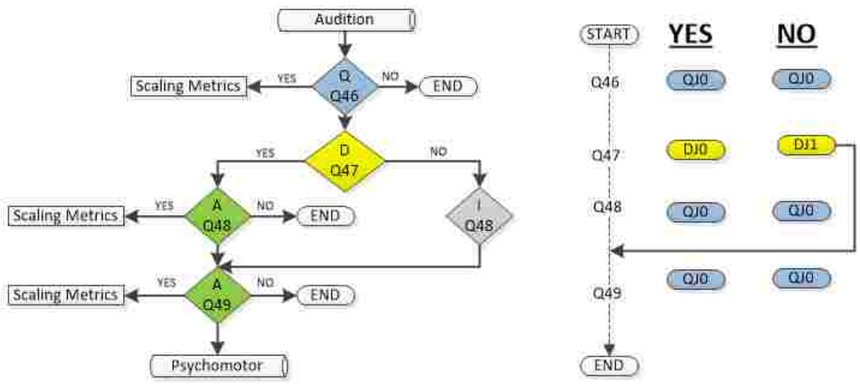


QUESTIONS 38-45
Vision

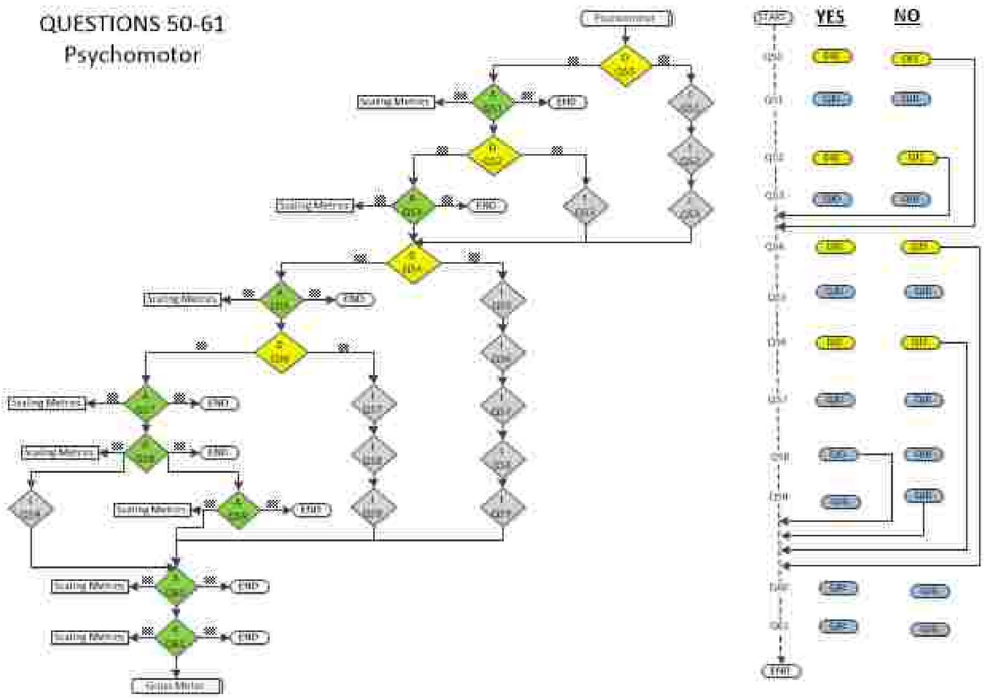




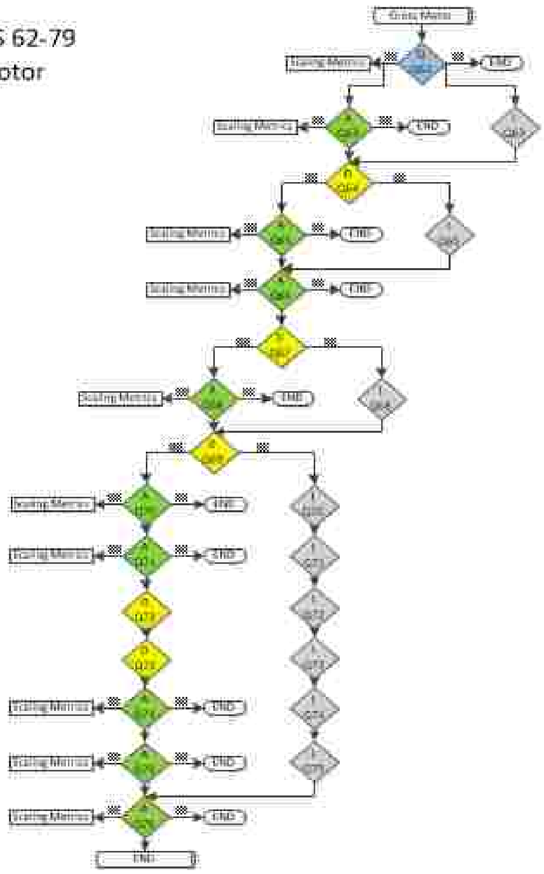
QUESTIONS 46-49
Audition

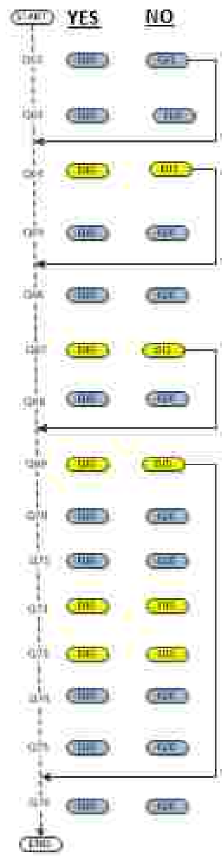


QUESTIONS 50-61
Psychomotor



QUESTIONS 62-79
Gross Motor



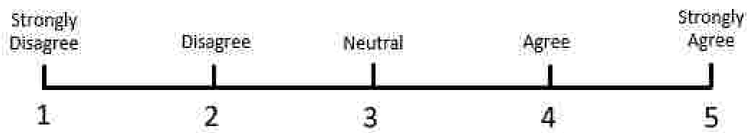


APPENDIX C

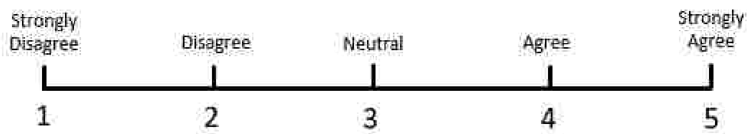
MODEL SUITABILITY AND RELEVANCE SURVEY (MSRS)

To gain a rough numerical idea on your views on the ease of use of this model. For each of the following questions, please mark the answer that most closely matches your opinion of the model.

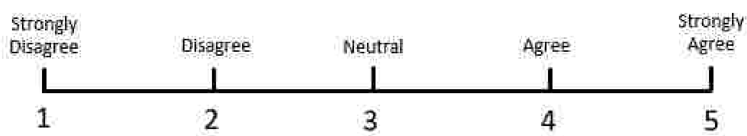
1. I think this model will capture the main aspects of the position requirements and worker qualifications.



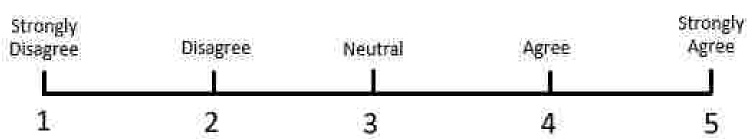
2. I feel this model is too complex to use.



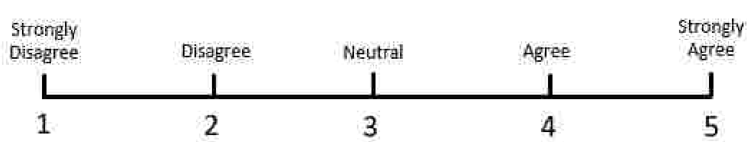
3. Given the position requirements and personnel qualifications are in the same language, I feel this would provide a good model to identify skills gaps and training needs.



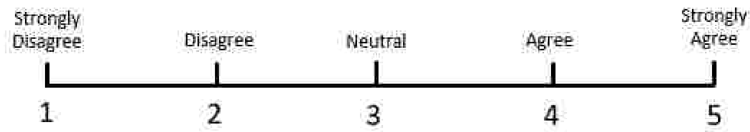
4. I feel this model would be better than the current method for identifying skills gaps.



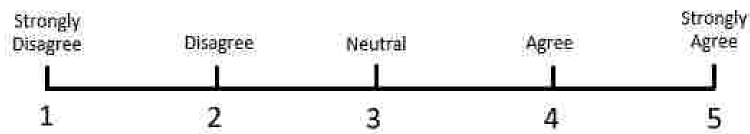
5. I think the requirements are organized in a logical manner.



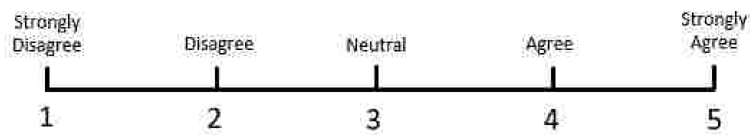
6. I feel this model does not provide enough detail.



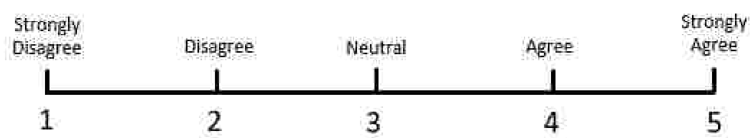
7. I feel this model is easy to use.



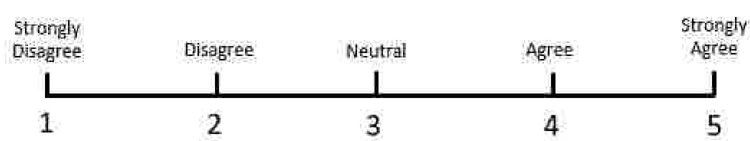
8. I do not think proficiency, importance, and frequency are good metrics to use for weighting.



9. I do not think this model for identifying requirements would be better than the current method.



10. I feel the model does not capture all the position requirements and worker qualifications.



APPENDIX D

O*NET DESCRIPTORS MANUFACTURING TECHNICIAN

In the process of developing the existing O*NET descriptors, job elements that were scored to be <50% important during surveys were not included.

Source	Area	Description
O*NET	Task	Set up and verify the functionality of safety equipment.
O*NET	Task	Adhere to all applicable regulations, policies, and procedures for health, safety, and environmental compliance.
O*NET	Task	Calibrate or adjust equipment to ensure quality production, using tools such as calipers, micrometers, height gauges, protractors, or ring gauges.
O*NET	Task	Inspect finished products for quality and adherence to customer specifications.
O*NET	Task	Monitor and adjust production processes or equipment for quality and productivity.
O*NET	Task	Troubleshoot problems with equipment, devices, or products.
O*NET	Task	Test products or subassemblies for functionality or quality.
O*NET	Task	Provide advice or training to other technicians.
O*NET	Task	Select cleaning materials, tools, or equipment.
O*NET	Task	Set up and operate production equipment in accordance with current good manufacturing practices and standard operating procedures.
O*NET	Task	Plan and lay out work to meet production and schedule requirements.
O*NET	Task	Install new manufacturing equipment.
O*NET	Task	Assist engineers in developing, building, or testing prototypes or new products, processes, or procedures.
O*NET	Task	Start up and shut down processing equipment.
O*NET	Task	Prepare and assemble materials.
O*NET	Task	Keep manufacturing production logs.
O*NET	Task	Measure and record data associated with operating equipment.
O*NET	Task	Build product subassemblies or final assemblies.
O*NET	Task	Prepare production documents, such as standard operating procedures, manufacturing batch records, inventory reports, or productivity reports.
O*NET	Task	Provide production, progress, or changeover reports to shift supervisors.
O*NET	Task	Maintain inventory of job materials.
O*NET	Task	Clean production equipment or work areas.
O*NET	Task	Conduct environmental safety inspections in accordance with standard protocols to ensure that production activities comply with environmental regulations or standards. Green Task Statement
O*NET	Task	Transfer hazardous or nonhazardous waste materials to collection areas for disposal, recycling, or reuse. Green Task Statement
O*NET	Task	Clean scrap materials for recycling or reuse, such as preparing aluminum scrap for cold-bonding processes or preparing paper for pulping or ink removal processes. Green Task Statement
O*NET	Task	Collect hazardous or nonhazardous waste or scrap materials in correctly labeled barrels or other containers. Green Task Statement
O*NET	Task	Package finished products.

Source	Area	Description
O*NET	Technology Skills	Analytical or scientific software— Cadence PSpice; Minitab Hot technology
O*NET	Technology Skills	Computer aided design CAD software Hot technology— Autodesk AutoCAD Hot technology; National Instruments Multisim
O*NET	Technology Skills	Development environment software — National Instruments LabVIEW Hot technology
O*NET	Technology Skills	Enterprise resource planning ERP software Hot technology— Plant maintenance software; SAP Hot technology
O*NET	Technology Skills	Industrial control software — Computer numerical control CNC software
O*NET	Technology Skills	Label making software — Labeling software
O*NET	Technology Skills	Office suite software — Microsoft Office
O*NET	Technology Skills	Presentation software — Microsoft PowerPoint Hot technology
O*NET	Technology Skills	Spreadsheet software — Microsoft Excel Hot technology
O*NET	Technology Skills	Word processing software — Microsoft Word

Source	Area	Description
O*NET	Knowledge	Mechanical — Knowledge of machines and tools, including their designs, uses, repair, and maintenance.
O*NET	Knowledge	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
O*NET	Knowledge	Production and Processing — Knowledge of raw materials, production processes, quality control, costs, and other techniques for maximizing the effective manufacture and distribution of goods.
O*NET	Knowledge	Design — Knowledge of design techniques, tools, and principles involved in production of precision technical plans, blueprints, drawings, and models.
O*NET	Knowledge	Mathematics — Knowledge of arithmetic, algebra, geometry, calculus, statistics, and their applications.
O*NET	Knowledge	English Language — Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition, and grammar.
O*NET	Knowledge	Computers and Electronics — Knowledge of circuit boards, processors, chips, electronic equipment, and computer hardware and software, including applications and programming.

Source	Area	Description
O*NET	Skills	Operation Monitoring — Watching gauges, dials, or other indicators to make sure a machine is working properly.
O*NET	Skills	Critical Thinking — Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
O*NET	Skills	Monitoring — Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.
O*NET	Skills	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.
O*NET	Skills	Equipment Maintenance — Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
O*NET	Skills	Reading Comprehension — Understanding written sentences and paragraphs in work related documents.
O*NET	Skills	Operation and Control — Controlling operations of equipment or systems.
O*NET	Skills	Quality Control Analysis — Conducting tests and inspections of products, services, or processes to evaluate quality or performance.
O*NET	Skills	Complex Problem Solving — Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.
O*NET	Skills	Judgment and Decision Making — Considering the relative costs and benefits of potential actions to choose the most appropriate one.
O*NET	Skills	Repairing — Repairing machines or systems using the needed tools.
O*NET	Skills	Troubleshooting — Determining causes of operating errors and deciding what to do about it.
O*NET	Skills	Time Management — Managing one's own time and the time of others.
O*NET	Skills	Active Learning — Understanding the implications of new information for both current and future problem-solving and decision-making.
O*NET	Skills	Coordination — Adjusting actions in relation to others' actions.
O*NET	Skills	Speaking — Talking to others to convey information effectively.
O*NET	Skills	Writing — Communicating effectively in writing as appropriate for the needs of the audience.

Source	Area	Description
O*NET	Abilities	Oral Comprehension — The ability to listen to and understand information and ideas presented through spoken words and sentences.
O*NET	Abilities	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.
O*NET	Abilities	Visualization — The ability to imagine how something will look after it is moved around or when its parts are moved or rearranged.
O*NET	Abilities	Oral Expression — The ability to communicate information and ideas in speaking so others will understand.
O*NET	Abilities	Deductive Reasoning — The ability to apply general rules to specific problems to produce answers that make sense.
O*NET	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.
O*NET	Abilities	Inductive Reasoning — The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events).
O*NET	Abilities	Near Vision — The ability to see details at close range (within a few feet of the observer).
O*NET	Abilities	Written Comprehension — The ability to read and understand information and ideas presented in writing.
O*NET	Abilities	Written Expression — The ability to communicate information and ideas in writing so others will understand.
O*NET	Abilities	Control Precision — The ability to quickly and repeatedly adjust the controls of a machine or a vehicle to exact positions.
O*NET	Abilities	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.
O*NET	Abilities	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.
O*NET	Abilities	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).
O*NET	Abilities	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.
O*NET	Abilities	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.
O*NET	Abilities	Speech Clarity — The ability to speak clearly so others can understand you.
O*NET	Abilities	Speech Recognition — The ability to identify and understand the speech of another person.
O*NET	Abilities	Category Flexibility — The ability to generate or use different sets of rules for combining or grouping things in different ways.
O*NET	Abilities	Reaction Time — The ability to quickly respond (with the hand, finger, or foot) to a signal (sound, light, picture) when it appears.
O*NET	Abilities	Selective Attention — The ability to concentrate on a task over a period of time without being distracted.
O*NET	Abilities	Visual Color Discrimination — The ability to match or detect differences between colors, including shades of color and brightness.

Source	Area	Description
O*NET	Work Activities	Inspecting Equipment, Structures, or Material — Inspecting equipment, structures, or materials to identify the cause of errors or other problems or defects.
O*NET	Work Activities	Making Decisions and Solving Problems — Analyzing information and evaluating results to choose the best solution and solve problems.
O*NET	Work Activities	Getting Information — Observing, receiving, and otherwise obtaining information from all relevant sources.
O*NET	Work Activities	Interacting With Computers — Using computers and computer systems (including hardware and software) to program, write software, set up functions, enter data, or process information.
O*NET	Work Activities	Communicating with Supervisors, Peers, or Subordinates — Providing information to supervisors, co-workers, and subordinates by telephone, in written form, e-mail, or in person.
O*NET	Work Activities	Controlling Machines and Processes — Using either control mechanisms or direct physical activity to operate machines or processes (not including computers or vehicles).
O*NET	Work Activities	Monitor Processes, Materials, or Surroundings — Monitoring and reviewing information from materials, events, or the environment, to detect or assess problems.
O*NET	Work Activities	Documenting/Recording Information — Entering, transcribing, recording, storing, or maintaining information in written or electronic/magnetic form.
O*NET	Work Activities	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.
O*NET	Work Activities	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.
O*NET	Work Activities	Thinking Creatively — Developing, designing, or creating new applications, ideas, relationships, systems, or products, including artistic contributions.
O*NET	Work Activities	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.
O*NET	Work Activities	Processing Information — Compiling, coding, categorizing, calculating, tabulating, auditing, or verifying information or data.
O*NET	Work Activities	Updating and Using Relevant Knowledge — Keeping up-to-date technically and applying new knowledge to your job.
O*NET	Work Activities	Identifying Objects, Actions, and Events — Identifying information by categorizing, estimating, recognizing differences or similarities, and detecting changes in circumstances or events.
O*NET	Work Activities	Analyzing Data or Information — Identifying the underlying principles, reasons, or facts of information by breaking down information or data into separate parts.
O*NET	Work Activities	Organizing, Planning, and Prioritizing Work — Developing specific goals and plans to prioritize, organize, and accomplish your work.
O*NET	Work Activities	Scheduling Work and Activities — Scheduling events, programs, and activities, as well as the work of others.
O*NET	Work Activities	Provide Consultation and Advice to Others — Providing guidance and expert advice to management or other groups on technical, systems-, or process-related topics.
O*NET	Work Activities	Training and Teaching Others — Identifying the educational needs of others, developing formal educational or training programs or classes, and teaching or instructing others.
O*NET	Work Activities	Coaching and Developing Others — Identifying the developmental needs of others and coaching, mentoring, or otherwise helping others to improve their knowledge or skills.
O*NET	Work Activities	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.
O*NET	Work Activities	Handling and Moving Objects — Using hands and arms in handling, installing, positioning, and moving materials, and manipulating things.
O*NET	Work Activities	Interpreting the Meaning of Information for Others — Translating or explaining what information means and how it can be used.
O*NET	Work Activities	Establishing and Maintaining Interpersonal Relationships — Developing constructive and cooperative working relationships with others, and maintaining them over time.
O*NET	Work Activities	Guiding, Directing, and Motivating Subordinates — Providing guidance and direction to subordinates, including setting performance standards and monitoring performance.
O*NET	Work Activities	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.
O*NET	Work Activities	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.
O*NET	Work Activities	Developing Objectives and Strategies — Establishing long-range objectives and specifying the strategies and actions to achieve them.

Source	Area	Description
O*NET	Detailed Work Activities	Test performance of electrical, electronic, mechanical, or integrated systems or equipment.
O*NET	Detailed Work Activities	Monitor activities affecting environmental quality.
O*NET	Detailed Work Activities	Calibrate scientific or technical equipment.
O*NET	Detailed Work Activities	Inspect finished products to locate flaws.
O*NET	Detailed Work Activities	Monitor the productivity or efficiency of industrial operations.
O*NET	Detailed Work Activities	Determine causes of operational problems or failures.
O*NET	Detailed Work Activities	Train personnel on proper operational procedures.
O*NET	Detailed Work Activities	Operate industrial equipment.
O*NET	Detailed Work Activities	Select project materials.
O*NET	Detailed Work Activities	Prepare detailed work plans.
O*NET	Detailed Work Activities	Create physical models or prototypes.
O*NET	Detailed Work Activities	Develop technical methods or processes.
O*NET	Detailed Work Activities	Install production equipment or systems.
O*NET	Detailed Work Activities	Prepare operational reports.
O*NET	Detailed Work Activities	Prepare materials for processing.
O*NET	Detailed Work Activities	Maintain operational records or records systems.
O*NET	Detailed Work Activities	Measure physical or chemical properties of materials or objects.
O*NET	Detailed Work Activities	Assemble equipment or components.
O*NET	Detailed Work Activities	Maintain clean work areas.
O*NET	Detailed Work Activities	Maintain inventories of materials, equipment, or products.
O*NET	Detailed Work Activities	Inspect equipment or systems.
O*NET	Detailed Work Activities	Dispose of hazardous materials.
O*NET	Detailed Work Activities	Package materials for transport.

Source	Area	Description
O*NET	Work Context	Wear Common Protective or Safety Equipment such as Safety Shoes, Glasses, Gloves, Hearing Protection, Hard Hats, or Life Jackets — 91% responded "Every day."
O*NET	Work Context	Electronic Mail — 87% responded "Every day."
O*NET	Work Context	Face-to-Face Discussions — 77% responded "Every day."
O*NET	Work Context	Sounds, Noise Levels Are Distracting or Uncomfortable — 53% responded "Every day."
O*NET	Work Context	Freedom to Make Decisions — 43% responded "A lot of freedom."
O*NET	Work Context	Duration of Typical Work Week — 59% responded "More than 40 hours."
O*NET	Work Context	Contact With Others — 52% responded "Contact with others most of the time."
O*NET	Work Context	Indoors, Environmentally Controlled — 70% responded "Every day."
O*NET	Work Context	Importance of Being Exact or Accurate — 35% responded "Extremely important."
O*NET	Work Context	Time Pressure — 70% responded "Once a week or more but not every day."
O*NET	Work Context	Work With Work Group or Team — 57% responded "Very important."
O*NET	Work Context	Telephone — 52% responded "Every day."
O*NET	Work Context	Structured versus Unstructured Work — 35% responded "Some freedom."
O*NET	Work Context	Frequency of Decision Making — 35% responded "Every day."
O*NET	Work Context	Responsible for Others' Health and Safety — 48% responded "High responsibility."
O*NET	Work Context	Exposed to Contaminants — 30% responded "Every day."
O*NET	Work Context	Spend Time Using Your Hands to Handle, Control, or Feel Objects, Tools, or Controls — 39% responded "Continually or almost continually."
O*NET	Work Context	Responsibility for Outcomes and Results — 30% responded "Limited responsibility."
O*NET	Work Context	Exposed to Hazardous Equipment — 30% responded "Every day."
O*NET	Work Context	Impact of Decisions on Co-workers or Company Results — 43% responded "Important results."
O*NET	Work Context	Spend Time Standing — 48% responded "About half the time."
O*NET	Work Context	Indoors, Not Environmentally Controlled — 39% responded "Every day."
O*NET	Work Context	Physical Proximity — 61% responded "Slightly close (e.g., shared office)."
O*NET	Work Context	Consequence of Error — 35% responded "Fairly serious."
O*NET	Work Context	Coordinate or Lead Others — 38% responded "Very important."
O*NET	Work Context	Importance of Repeating Same Tasks — 35% responded "Very important."
O*NET	Work Context	Letters and Memos — 41% responded "Once a week or more but not every day."

Source	Area	Description
O*NET	Interests	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.
O*NET	Interests	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.

Source	Area	Description
O*NET	Work Styles	Attention to Detail — Job requires being careful about detail and thorough in completing work tasks.
O*NET	Work Styles	Analytical Thinking — Job requires analyzing information and using logic to address work-related issues and problems.
O*NET	Work Styles	Dependability — Job requires being reliable, responsible, and dependable, and fulfilling obligations.
O*NET	Work Styles	Integrity — Job requires being honest and ethical.
O*NET	Work Styles	Adaptability/Flexibility — Job requires being open to change (positive or negative) and to considerable variety in the workplace.
O*NET	Work Styles	Initiative — Job requires a willingness to take on responsibilities and challenges.
O*NET	Work Styles	Cooperation — Job requires being pleasant with others on the job and displaying a good-natured, cooperative attitude.
O*NET	Work Styles	Stress Tolerance — Job requires accepting criticism and dealing calmly and effectively with high stress situations.
O*NET	Work Styles	Self Control — Job requires maintaining composure, keeping emotions in check, controlling anger, and avoiding aggressive behavior, even in very difficult situations.
O*NET	Work Styles	Achievement/Effort — Job requires establishing and maintaining personally challenging achievement goals and exerting effort toward mastering tasks.
O*NET	Work Styles	Persistence — Job requires persistence in the face of obstacles.
O*NET	Work Styles	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.
O*NET	Work Styles	Innovation — Job requires creativity and alternative thinking to develop new ideas for and answers to work-related problems.
O*NET	Work Styles	Leadership — Job requires a willingness to lead, take charge, and offer opinions and direction.
O*NET	Work Styles	Concern for Others — Job requires being sensitive to others' needs and feelings and being understanding and helpful on the job.
O*NET	Work Styles	Social Orientation — Job requires preferring to work with others rather than alone, and being personally connected with others on the job.

Source	Area	Description
O*NET	Work Values	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.
O*NET	Work Values	Independence — Occupations that satisfy this work value allow employees to work on their own and make decisions. Corresponding needs are Creativity, Responsibility and Autonomy.
O*NET	Work Values	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.

VITA

Martin Joseph McKenney is currently pursuing a PhD in Engineer Management and System Engineering from Old Dominion University in Norfolk, VA. He obtained a Bachelor of Science in Mechanical Engineering from Old Dominion University in 1993 and a Masters in Mechanical and Aerospace Engineering from the University of Virginia in 1999. He has worked for several large manufacturing companies including Siemens, Stihl, Johnson Controls, Coopervision, ATK, and AMA (Analytical Mechanics Associates, Inc). Areas of expertise include: mechanical design, manufacturing, automation, industrial controls, training, and documentation. He is currently working civil service as an aerospace engineer for NASA Langley specializing in manufacturing.