Technical Annex and Methodology

Humans Wanted: The future of work and how it's not what you think

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1. Examining the skills economy

RBC's research objective was to develop a robust, data-supported means of examining and understanding the Canadian "skills economy." We examined the workforce skills that will likely be in greatest demand in the Canadian labour market over the next several years, relative to the supply of those skills.

Our research findings relate to working Canadians generally, though we target our insights to young adults who seek guidance as they move into and between occupations in the early stages of their careers. The findings are also aimed at their mentors, educators and policymakers responsible for education, social development and employment.

We undertook our examination of skills on the basis of two initial premises:

First, in order to anchor our research in a clear definition and taxonomy of skills, we determined that in the absence of Canada-specific definitions, the U.S. Department of Labor's Occupational Information Network (O*NET) program provides a clear delineation of the key concepts, as indicated below.

Second, we identified occupations across functional areas and industries that relate to each other based on their skills content. The next step was to assess whether possessing or improving certain skills could enable more "horizontal" career paths, including mobility between occupations that appear unrelated at first glance.

To that end, our methodology leverages the occupational data that is made publicly available by Employment and Social Development Canada (ESDC) and the O*NET program.

	DEFINITIONS	EXAMPLES
Skills	Developed capacities that facilitate learning or the more rapid acquisition of knowledge.	See page 6.
Knowledge	Organized sets of principles and facts applying in general domains.	Building and construction, medicine and dentistry, sales and marketing, etc.
Abilities	Enduring attributes of the individual that influence performance.	Inductive reasoning, manual dexterity, perceptual speed, static strength, etc.
Interests	Preferences for work environments and outcomes.	Artistic, conventional, enterprising, etc.

2. Forecasting job openings in Canada

The Canadian Occupational Projection System (COPS) — a 10-year labour market forecast that ESDC produces biennially — was used to identify trends in the level, composition and sources of labour demand and supply. These projections take into account expected employment growth and the replacement of workers due to retirement, deaths and emigration.

We chose to concentrate our analysis on the shorter-term (2018-2021) projections, in which we have a higher degree of confidence, and also align more directly with the scope of our research focused on youth entering or transitioning within the job market in the next several years. The COPS projects job openings for 292 occupational groupings (hereafter simply referred to as "occupations"), drawn from the 2011 National Occupational Classifications (NOC). These occupations are further classified into managerial positions and nine skill-type groupings.

3. Assessing the skills needed for occupations

*O*NET classifies 35 cross-occupational skills, arranged into Basic Skills and Cross-Functional Skills categories, with seven distinct sub-categories as follows:*

BASIC SKILLS	
CONTENT SKILLS	
Reading Comprehension	Understanding written sentences and paragraphs in work related documents.
Active Listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.
Writing	Communicating effectively in writing as appropriate for the needs of the audience.
Speaking	Talking to others to convey information effectively.
Mathematics	Using mathematics to solve problems.
Science	Using scientific rules and methods to solve problems.
PROCESS SKILLS	
Critical Thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.
Active Learning	Understanding the implications of new information for both current and future problem-solving and decision-making.
Learning Strategies	Selecting and using training / instructional methods and procedures appropriate for the situation when learning or teaching new things.
Monitoring	Monitoring / assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.

	TECHNICAL SKILLS
Operations Analysis	Analyzing needs and product requirements to create a design.
Technology Design	Generating or adapting equipment and technology to serve user needs.
Equipment Selection	Determining the kind of tools and equipment needed to do a job.
Installation	Installing equipment, machines, wiring, or programs to meet specifications.
Programming	Writing computer programs for various purposes.
Operation Monitoring	Watching gauges, dials, or other indicators to make sure a machine is working properly.
Operation & Control	Controlling operations of equipment or systems.
Equipment Maintenance	Performing routine maintenance on equipment and determining when and what kind of maintenance is needed.
Troubleshooting	Determining causes of operating errors and deciding what to do about it.
Repairing	Repairing machines or systems using the needed tools.
Quality Control Analysis	Conducting tests and inspections of products, services, or processes to evaluate quality or performance.

CROSS-FUNCTIONAL SKILLS	
	SYSTEMS SKILLS
Judgment and Decision Making	Considering the relative costs and benefits of potential actions in order to choose the most appropriate one.
Systems Analysis	Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.
Systems Evaluation	Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.

	SOCIAL SKILLS
Social Perceptiveness	Being aware of others' reactions and understanding why they react as they do.
Co-ordination	Adjusting actions in relation to others' actions.
Persuasion	Persuading others to change their minds or behaviour.
Negotiation	Bringing others together and trying to reconcile differences.
Instructing	Teaching others how to do something.
Service Orientation	Actively looking for ways to help people.

	COMPLEX PROBLEM SOLVING SKILLS
Complex Problem Solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.

	RESOURCE MANAGEMENT SKILLS
Time Management	Managing one's own time and the time of others.
Management of Financial Resources	Determining how money will be spent to get the work done, and accounting for these expenditures.
Management of Material Resources	Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work.
Management of Personnel Resources	Motivating, developing, and directing people as they work; identifying the best people for the job.

Each occupation has two ratings, which identify how important each skill is for an occupation and the required proficiency level for each skill. The O*NET program rates skills by importance on a scale from 1 to 5 to determine how much a given skill descriptor matters to an occupation. The level rating, on a scale from 0 to 7, determines how proficient one must be with respect to a given skill descriptor in order to perform an occupation.

With the skills rating profiles by occupation for the United States and by job opening projections for Canada, we sought to build a crosswalk between the two to establish a projected outlook of skills for the Canadian labour market between 2018 and 2021.

To accomplish this, we matched each of the 292 Canadian occupations as classified by the COPS (NOC-11) to their corresponding code under the International Standard Classification of Occupations 2008 (ISCO-08) using a Statistics Canada concordance table. Likewise, we then matched each of the ISCO occupations to the corresponding occupation found in the O*NET database using similar tables and applying professional judgment as needed,vv to determine the most suitable match for Canadian occupations in instances where several COPS / NOC to ISCO to SOC mappings were possible.

A key assumption underpinning the analysis is that the skills assessments under O*NET are valid for Canadian occupations. Given the reality of intra-occupational and geographic disparities within the United States, we judged that applying the U.S. skills rating profiles to occupations in Canada would be a reasonable extrapolation.

CANADA		U.S.	
COPS/NOC	OCCUPATION	SOC	OCCUPATION
N2145	Aerospace engineers and other professional engineers, n.e.c.	17-2011.00	Aerospace engineers
N2222	Agricultural and fish products inspectors; Forestry technologists and technician and conservation and fishery officers	45-2011.00	Agricultural Inspectors
N2151	Architects	17-1011.00	Architects, except landscape and naval
N2221	Biological technologists and technician	19-4021.00	Biological technicians
N2134	Chemical engineers	17-2041.00	Chemical engineers

4. Determining the average importance and proficiency level

Based on our mapping technique, we then examined how the skills importance and level (proficiency) ratings relate to Canadian occupations and their skills groupings. We calculated an average skills importance rating for each Canadian grouping, by weighing the ratings of each occupation within a grouping with the number of projected job openings between 2016 and 2024. The skills ratings for occupations that are predicted to experience a relatively higher number of job openings carry greater weight than those set to experience fewer openings. Moreover, we utilize the full nine-year range of available projections in our weighting to lessen the impact of any given year on the average.

We replicated this process to obtain a similar matrix for skills levels (proficiency).

This methodology yielded a skills importance ratings spectrum. As indicated below, the most basic and social skills are shown to be generally important across the different groupings. There are exceptions: science (most valued by the natural and applied sciences, and health groupings), technical skills generally (most valued by the trades and transportation, natural resources / agriculture and manufacturing / utilities industries groupings), and resource management skills (most valued by managerial occupations).

5. The future demand for skills in the Canadian labour market

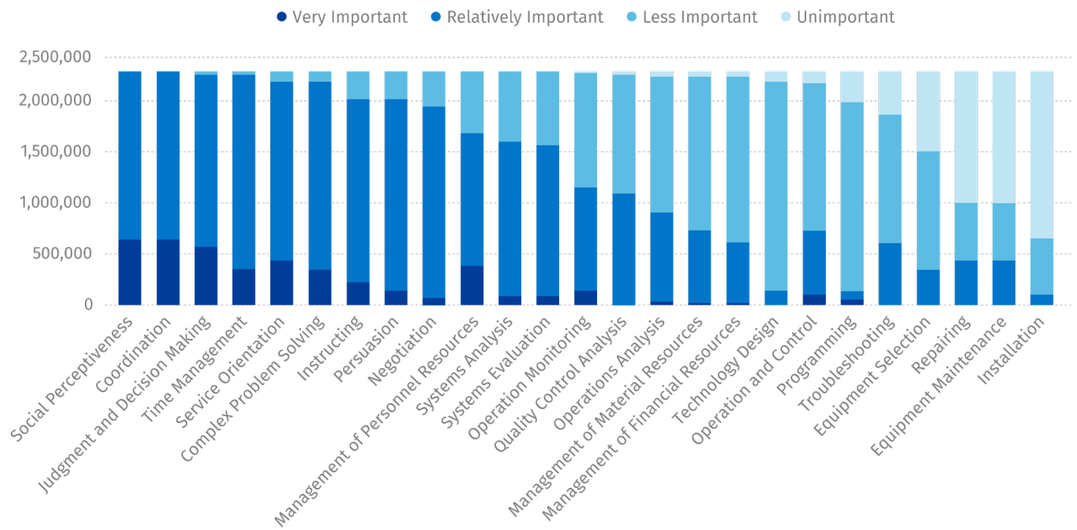
In order to test our hypothesis that basic, social and complex problem solving skills will matter to a majority of job openings across groupings, while more specialized science and technical skills will be targeted to specific sectors, we examined the number of projected job openings in 2018-21 for each of the 35 skills in terms of their relative importance and proficiency levels.

To do so, we assigned each “importance” rating into one of four categories: “very important” (values greater than 3.67), “important” (values between 2.33 and 3.67), “less important” (values between 1 and 2.33), and “not required” (values equal to 1). The same procedure was carried out for proficiency ratings, which were categorized as “high proficiency” (values greater than 4.67), “medium proficiency” (values between 2.33 and 4.67), “basic proficiency” (values between 0 and 2.33) or “no proficiency” (values equal to 0).

From this rule, we obtained the distribution of projected job openings by skill importance and proficiency-level rating. This showed that basic skills, including verbal and written communication, active listening and learning, critical thinking and mathematics will matter greatly for the majority of projected job openings across industries. Notwithstanding labour market competition, most job openings will require medium, not “expert” proficiency tied to long work experience.

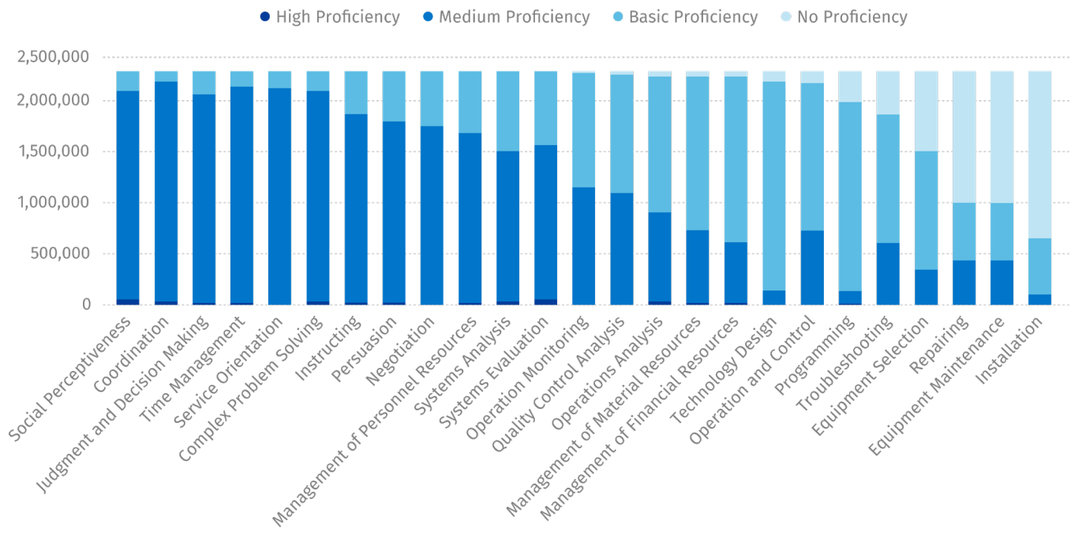
CROSS-FUNCTIONAL SKILLS

Total job openings (2018-2021) for which each skill is deemed: very, relatively or less important



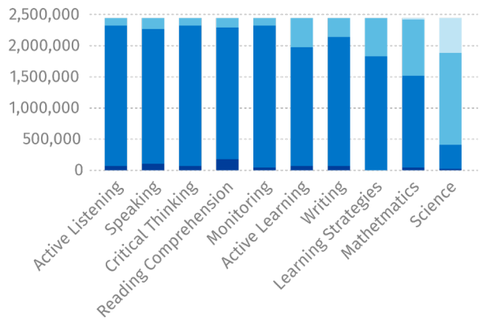
CROSS-FUNCTIONAL SKILLS

Total job openings (2018-2021) for which each skill is required a level of: high, medium or basic proficiency



BASIC SKILLS

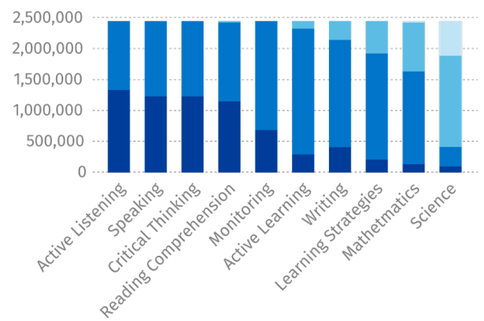
Total job openings (2018-2021) for which each skill is deemed: very, relatively, or less important



We then obtain the distribution of projected job openings by importance for cross-functional skills. The distribution graphs show that the relative importance of cross-functional skills varies more than that of basic skills overall, with social skills, complex problem solving skills and time management deemed important for a majority of projected job openings across industries, and technical skills deemed generally less important for projected job openings overall.

BASIC SKILLS

Total job openings (2018-2021) for which each skill is required a level of: high, medium or basic proficiency



The proficiency level required for cross-functional skills varies as well, with medium proficiency (but not "expert" proficiency) required for social skills across industries overall, and generally less proficiency needed for technical skills. This result suggests that social skills, and systems skills to a lesser extent, will matter to occupations across industries, including scientifically- and technically-oriented ones.

6. Establishing skills clusters

An extension to our analysis of ESDC's groupings was to rearrange occupations into clusters based on their respective skills ratings profiles as mapped from O*NET. This allowed for a more robust skills analysis as the groupings tend to represent a wide distribution of different skills levels. The clusters would also provide a clearer indication of what career mobility may be possible between occupations whose skills profiles are relatively similar, subject to bridging the necessary knowledge requirements between occupations.

We grouped the 292 occupations into six clusters according to the similarity / proximity of skills between occupations using deep learning algorithms.

DEEP LEARNING ALGORITHM

First, a measure of skills proximity was calculated as follows:

$$\text{Prox}(x,y) = (p_x i_x - p_y i_y)^2_{\text{SKILL-1}} + (p_x i_x - p_y i_y)^2_{\text{SKILL-2}} + \ldots + (p_x i_x - p_y i_y)^2_{\text{SKILL-35}}$$

Where:

p = the level of proficiency for a skill for an occupation

i = the importance of the skill for an occupation

x = primary occupation (e.g. NOC 0011)

y = comparator comparison

Comparisons of occupations with high / low proximity scores had skills sets that were more / less similar to each other. A total of 42,486 comparisons were made. We applied K-means, expectation maximum, tree and automated network networks (ANN) clustering algorithms to the skills proximity scores to cluster occupations based on the proximity of their skills. The results of each algorithm were analyzed to determine the homogeneity of the skills within each grouping, resulting in a final selection of an ANN algorithm with six occupational clusters.

We used automated network networks clustering based on Kohonen training to determine the underlying clusters, by applying competitive learning to preserve the topological properties of the input space and to transform high-dimensional data space into low-dimensional space.

Kohonen training is an algorithm that assigns cluster centres to a radial layer by iteratively submitting training patterns to the network, and adjusting the winning (nearest) radial unit center, and its neighbors, toward the training pattern.

To further reduce noise in defining cluster meanings, reduction of activation functions (Euclidean distances) from a cluster centre were used. For additional clarity in defining clustering meanings as well as for validation purposes, clustering of occupations based on skills proficiency as well as skills proficiency and importance were performed independently. The results were used to tune up the clustering definitions based on differences between

CLUSTERS

This process yielded our six clusters:

As with the previous ESDC groupings, we weighted the ratings of each occupation within a cluster with the number of projected job openings between 2016 and 2024, to obtain an average skills importance and level rating for each cluster.

Also, we applied the previous rules to determine the relative importance and level required of each skill, for the projected 2018-2021 job openings in each cluster. For example, the distribution graphs below show the relative importance of basic skills for each cluster.

7. Automation, job opening projections and future skills

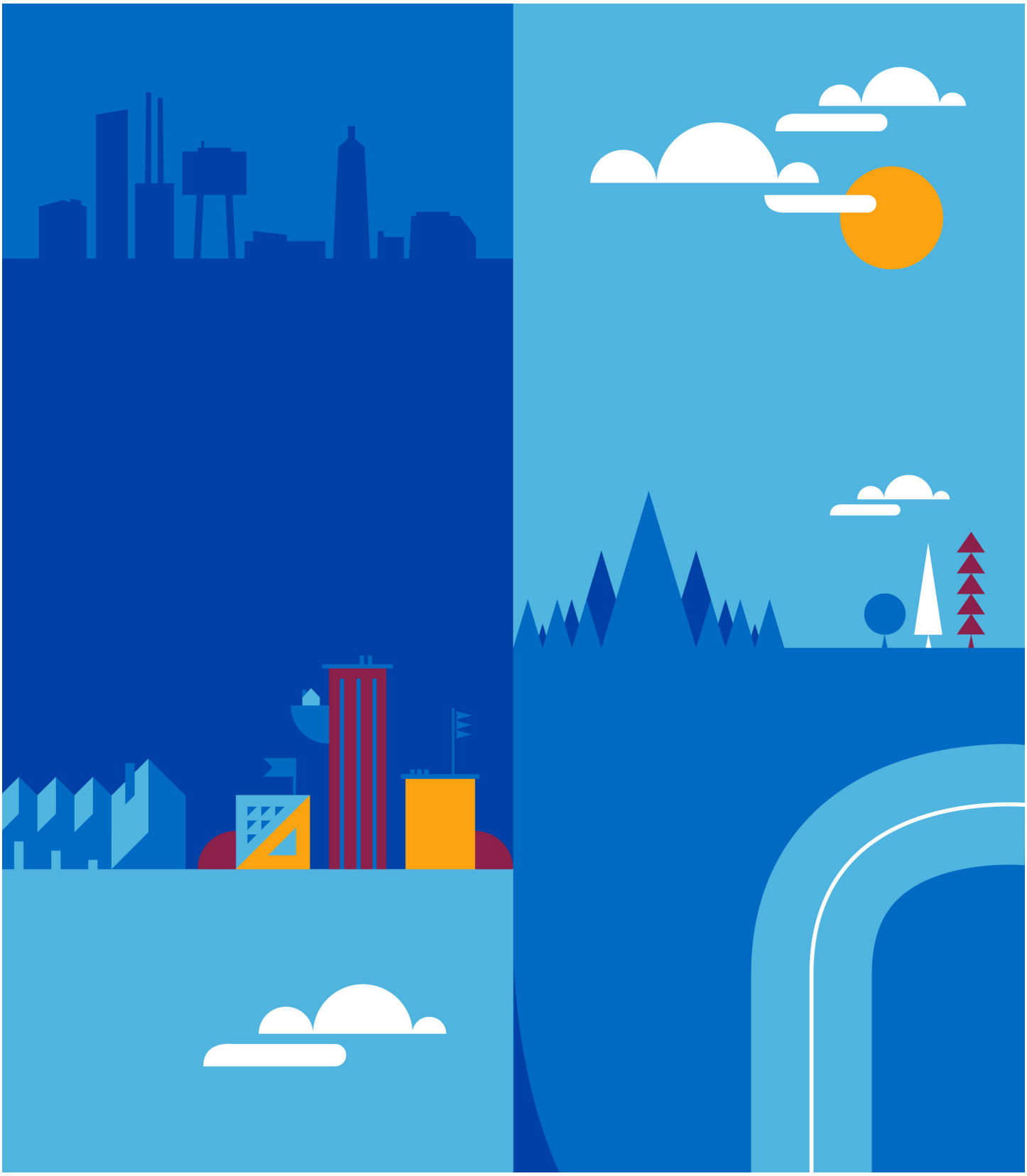
Although our focus was on the short-term future, an important consideration when considering longer term skills prospects is the impact that automation may have on future job tasks — including potentially disruptive ones. It is very difficult – if not impossible — to forecast with any accuracy the magnitude of automation's impacts on future job openings, for multiple reasons.

We therefore restricted our research to considering the automatability of existing occupations, based on what is known about existing technology.

To do this, we leveraged a study by C. Frey and M. Osborne, *The Future of Employment: How Susceptible Are Jobs to Computerisation?* (Oxford, 2013), which calculated automatability probabilities for a wide range of U.S. occupations. Having already mapped U.S. to Canadian occupations, we now map automatability probabilities back to Canadian occupations as well:

We obtained a list of occupations by cluster and their degree of automatability. More knowledge-driven clusters (those including a large number of occupations involving non-repetitive cognitive and complex non-repetitive manual tasks) are generally less susceptible to automation than less knowledge-driven ones.

SUSCEPTIBILITY TO AUTOMATION	SOLVERS	PROVIDERS	FACILITATORS	TECHNICIANS	CRAFTERS	DOERS
80% or more	0%	6%	49%	42%	74%	33%
60-79%	0%	5%	10%	21%	22%	47%
40-59%	2%	4%	10%	13%	0%	13%
20-39%	2%	12%	14%	13%	4%	7%
10-19%	2%	10%	7%	8%	0%	0%
Less than 10%	93%	63%	10%	4%	0%	0%



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