

Fuel Cell Supply Chain: Canadian Manufacturing Suppliers Landscape Analysis

K. Malek, J. Yang, F. Girard

*National Research Council Canada, Energy, Mining, and Environment, 4250 Wesbrook Mall,
Vancouver, Canada V6T 1W5, kourosh.malek@nrc.gc.ca*

Summary

We provide a landscape analysis for Canadian manufacturing suppliers of fuel cell technologies by focusing on identification and categorization of targeted manufacturing equipment suppliers. The manufacturing needs are identified by fuel cells original equipment manufacturers (OEMs) and are fine tuned by the execution of a landscape gaps analysis. The needs for Canadian manufacturers are classified into three specified areas, defined by the OEMs; high precision liquid injection molding; fast tooling (e.g. 3D printer) for production of thermoformed tray; and vision system for touch-less inspection and quality testing. The landscape of the newly added suppliers, particularly in the machine vision system area, was then analyzed in a great detail. The analysis of the database showed a relatively strong supply chain on machine vision systems, with a wide range of capabilities existing from software solution to high resolution cameras, camera components, image analysis equipment, and hardware integration. We have also identified firms active in liquid injection modeling and thermoplastic trays. The gap analysis has shown lack of existing services and equipment with specializations on quality control processes during fuel cell fabrication. Moreover, further analysis is required to categorize existing capabilities in these two areas, particularly those relevant to fuel cell manufacturing processes.

1. Introduction

Manufacturing Readiness Levels (MRLs) of fuel cell technology is an important market indicator that can demonstrate risks of fuel cell production, directions for key research and developments and means to improve cost-effectiveness of manufacturing process and quality control considerations [1]. The existence and quality of a strong local and national supply chain is critical for early market penetration within fuel cell automotive sector. This work follows previous efforts led by Industry Canada to coordinate and develop the Canadian supply-chain for fuel cell stack (engine) manufacturing. Previous efforts were focused broadly on (i) the identification of OEM requirements, (ii) the development of a database of potential Canadian suppliers and (iii) an analysis of supply chain gaps to be addressed. It was determined that further effort was required to expand the existing database to include specific manufacturing

equipment suppliers based on the additional needs identified by OEMs such as Mercedes Benz Fuel Cell (MBFC) and Automotive Fuel Cell Cooperation Corp. (AFCC). Further activities are needed to identify specific manufacturing equipment that are specified by fuel cell OEMs, with detailed analysis of the landscape and existing service and equipment gap. Moreover, it is necessary to develop an actionable plan to attract suppliers in those areas through joint R&D projects, a new-tri-party consortium program with specific recommendations with respect to supply chain structure. In consultation with partner OEMs, three types of manufacturing tools were identified as the primary needs, those that local Canadian companies could potentially supply. The tools and services thereof are categorized as High precision liquid injection molding (LIM); Fast tooling (e.g. 3D printer) and production of thermoformed tray (TFT); Vision system (VS) for touchless inspection and quality testing.

The aim of this work is thus to expand on existing fuel cell supply chain database, with primary objective to include manufacturing equipment suppliers from the auto and other sectors around high precision liquid injection molding, fast tooling and production of thermoformed tray, and vision systems for touchless quality testing. The project targeted the three above manufacturing areas. The landscape analysis and identification of suitable potential suppliers were conducted by clearly defining fuel cell OEMs equipment, their requirements in more technical detail, along with performance specification and cost targets; gather database of suppliers and their attributes in an Excel sheet; and analysis of suppliers landscape using advanced data visualizations and jointly identify a short list of suitable suppliers to be engaged by OEMs.

2. Methodology

We have initially built up sub-databases of Canadian manufacturers in the three areas as defined by OEMs. Then the landscape analysis was executed to investigate how the geographic distribution, capabilities, and services should be best configured to produce a competitive and sustainable industry in Canada. In the first step, we updated and expanded the existing database developed by Automotive Part Manufacturing Association (APMA) in 2013-2014. The search for Canadian suppliers with specific capabilities was performed both manually and automatically. Manual efforts included searching keywords through general search engines (i.e. Google) as well as various industrial search engines available in Canada (i.e., FRASERS, Canadian Plastics, MFG.com, Canadian Trade Index, KOMPASS, etc.) and checking details of firms by looking into their web content. In this way, a short but very explicit list of suppliers that meet the manufacturing area was obtained. Then the North American Industry Classification System (NAICS) codes were analyzed to identify the industry sectors involved, and the searchable keywords were identified and summarized. Automatic search was based on the NAICS codes and keywords obtained from the manual efforts. Therefore, the manual search needed to be executed prior to this step. According to the analysis results of NAICS codes, we used Industry Canada's Canadian Company Capabilities database as a source of suppliers in the related industrial segments. Based on the analysis of keywords in the companies'

descriptions/profiles, all suppliers were screened and a longer list of potential suppliers was obtained and analyzed to determine the supplier's suitability.

The companies' searchable information and the relevant product attributes were listed in a spreadsheet along with the following headings:

- Name of the company
- Address
- Industry Canada profile
- NAICS code
- Social media presence
- Revenue and size of company (i.e. number of employees) extracted from Industry Canada's database
- Capabilities provided

Initial analysis was conducted on the existing 107 companies as included in the APMA's fuel cell supply chain database, trying to identify the possible inclusion of the potential suppliers requested by OEMs, both manually and automatically. Additional suppliers were obtained through a global search with the methods stated in above steps, whereas additional steps were repeated to obtain a list of suppliers for each specified area. The list of suppliers was then imported to the a data analysis and visualization tool, by which the analysis of suppliers' landscape was conducted. Finally, with better defined technical details provided by OEMs, a short list of suitable suppliers was identified. Note that the short list of suitable suppliers was only obtained for some equipment for those that we had received the technical descriptions from the OEMs.

3. Results and discussions

3.1 Manufacturing requirements

Three types of manufacturing tools were initially proposed by OEMs to start with. However, the details of the technical requirements for each tool were better understood until a complete suppliers' landscape and their capabilities were identified. Therefore, we have ultimately refined the original database and its associated technical requirement specific areas compared to that was provided initially by OEMs. Figure 1 illustrates the process flow and relationship between available technologies, OEM's requirements and supplier database.

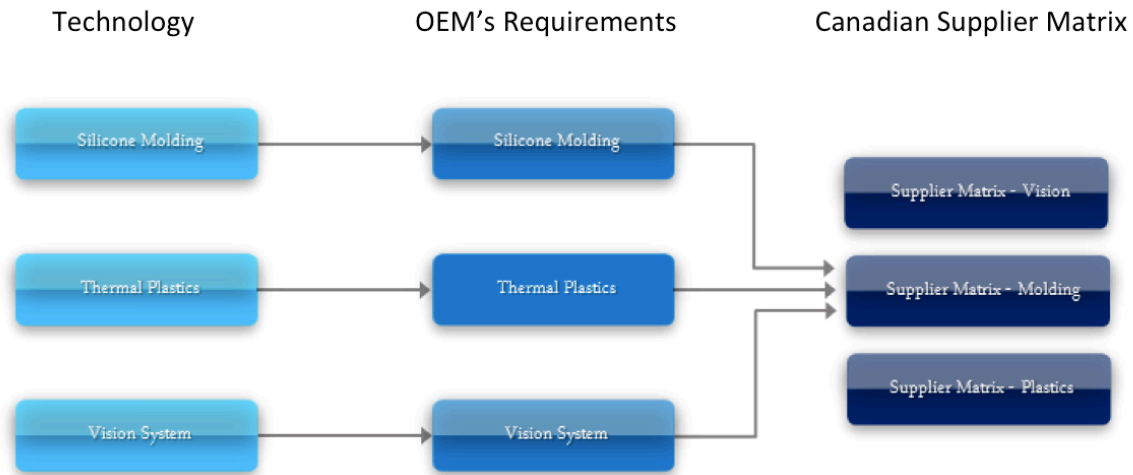


Figure 1. Schematic relationship between exiting technologies, manufacturing requirement and available Canadian suppliers.

3.2 Supplier database

The resulting database consists of Canadian suppliers who have capabilities in one or more of these areas: Liquid injection molding; 3D printers for production of thermoformed tray; Thermoformed tray; Vision systems for touchless quality testing. Individual databases were constructed in a spreadsheet and were available for viewing, testing and further refinements. An alternative data visualization using a proprietary platform was also used for data analysis. To view the full list of the suppliers and their capabilities, we allowed selected members to register and have access to the database and analysis.

3.3 Keywords

The keywords were used in both manual and automated searches for each interested area. Note that only a preliminary search was performed on the 3D printer as it was ranked with low priority by OEMs. Figure 2 provides the list of used keywords in each category.

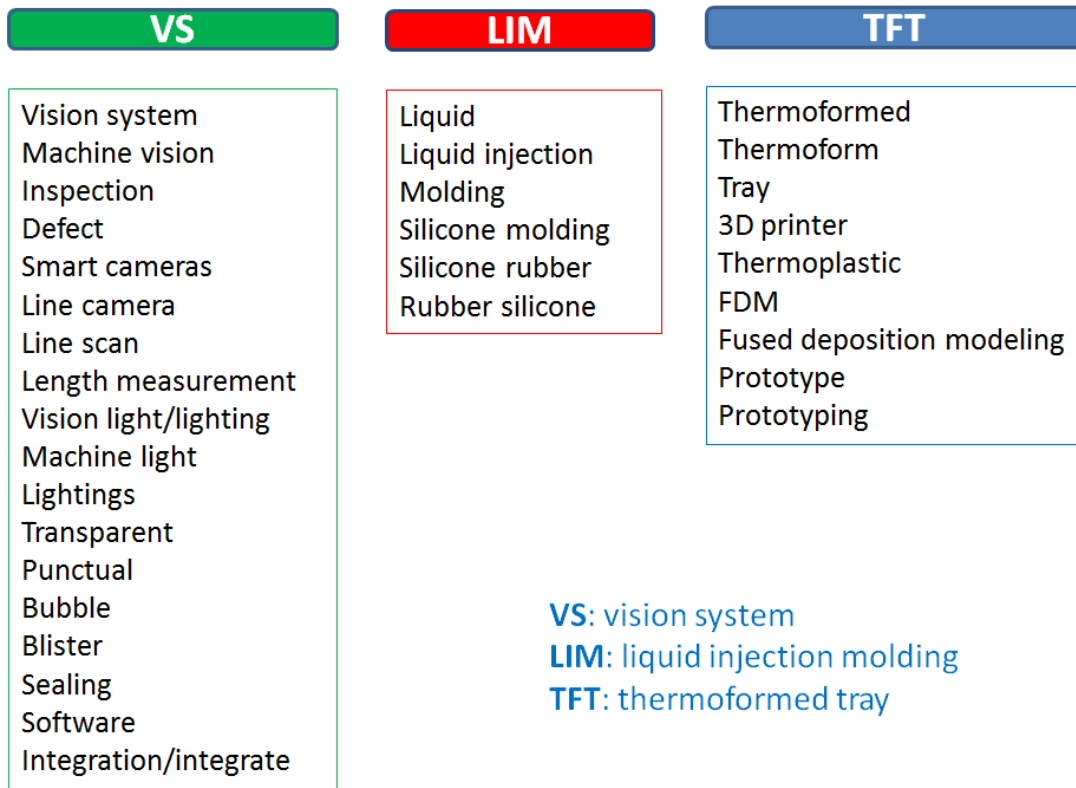


Figure 2. Primary keywords used in both manual and automated searches for each interested area.

3.4 An Example of Automatic Search: APMA data

Based on the given keywords, the companies' descriptions/profiles are swept and the statistical results on the presence frequency of each keyword were obtained, Figure 3. For example, as shown in the following screenshot of the statistical results, the keywords of Injection molding, Prototyping were listed in the second row and were used as screening criteria. In the company description, taking the company of "ABC Group" as listed in row 5 for example, we found the keyword of "Injection molding" appears once and "Thermoforming" appears once, while other keywords are missing. The latter implies that two out of seven keywords are met by this company. Statistically, larger ratio of the keywords is met in a company's description, better chance the company would be further identified as one of the potential suppliers to the OEMs' needs. Therefore, we believe that a larger volume of the data can be screened using this methodology.

1	# Records	24	17	16	7	3	2	1
2		Injection molding	Prototyping	Fuel cells	Plastic injection molding	Vision systems	Tooling	Thermoforming
3	Aalbers Tool & Mold Inc.	1			1			
4	Aarkel Tool and Die	1						
5	ABC Group	1						1
6	Acrolab Ltd		1					
7	Active Mould & Design Limited	1						
8	Applied Precision Inc.		1					
9	Arlen Tool Co. Ltd.	1						
10	Associated Plastics		1					
11	Automotive Fuel Cell Cooperation			1				
12	Ballard Power Systems			1				
13	Briadco Tool & Mould Inc.	1						
14	Canada Analytical & Process Technologies		1	1				
15	CaRPE-FC			1				
16	CCS Global Group Inc. (The)			1		1		
17	Circle 5 Tool & Mold Inc.	1						
18	Coltech Optronics Inc.	1						
19	Core Tool & Mold LTD		1	1				
20	Crest Mold Technology Inc	1						
21	CrossChasm Technologies Inc		1					
22	Dana Canada Corp. Power Technologies Gr	1		1				
23	DSA Daten und Systemtechnik			1				
24	Dynaplas	1	1					
25	Ebco Industries Ltd.		1					
26	Energy Systems Design Laboratory			1				
27	FBT Inc			1			1	
28	G.S. DIE AND DESIGN		1				1	
29	Glider Guard Tool & Die Inc.	1						
30	Greenlight Innovation			1				
31	Hydrogenics			1				
32	Hyphen Services (Christie Digital)		1					
33	Integrity Tool & Mold Inc	1			1			
34	Iscan & Truhen Ltd		1					

Figure 3. Statistical results on the presence frequency of each keyword.

3.5 An Example of supplier database

The table below shows an example of the spreadsheet database for Vision Systems used in quality testing. More searchable items in columns are not included in this example due to the space limitation.

Table 1. An example of the spreadsheet database for Vision Systems.

Corporation Name	Address	Market Segment (NAICS)	# employees	Website (URL)
ATS Automation	730 Fountain St. N. Building #2, ON N3H 4R7, Canada	333299	2500	https://www.atsautomation.com
KEYENCE CANADA INC.	5800 Explorer Drive, Suite 320, ON L4W 5K9, Canada	423840	4000	https://www.keyence.ca
Global Controls	216-7357 Woodbine Ave, ON L3R 6L3, Canada	541330		website unavailable, from Industry Canada
Allied Vision Technologies Canada Inc.	300 – 4621 Canada Way, BC V5G 4X8, Canada	333315		http://www.alliedvisiontec.com
Mercator Robotec Inc.	330 Gage Ave., Unit #11, ON N2M 5C6, Canada			http://www.mercatorrobotec.com
Cognex Corporation	One Vision Drive Natick, MA 01760-2059, USA	334513		http://www.cognex.com/
Teledyne DALSA	605 McMurray Road Waterloo, ON N2V 2E9, Canada	334110		https://www.teledynedalsa.com
Abraham Innovation Systems Inc. (AISi)	111 Esna Park Drive Unit #1 Markham, ON L3R 1H2, Canada			http://abrahaminnovations.com/
OMRON Canada Inc. (OCI)	885 Milner Avenue Toronto, ON M1B5V8, Canada	334410		http://industrial.omron.ca/en/home
Applied Precision Inc.	6150 Kennedy Road, Unit #8 Mississauga, ON L5T 2J4, Canada	541510		http://www.appliedprecision.ca/
Creaform Inc.	5825, rue St-Georges Lévis, Québec Canada, G6V 4L2	541690		http://www.creaform3d.com/
Point Grey Research Inc.	12051 Riverside Way Richmond, BC V6W 1K7 Canada			http://www.ptgrey.com/
VISIONx Inc.	210 Brunswick Pointe-Claire, Quebec H9R 1A6 Canada	511210		www.visionxinc.com
Ahearn & Soper Inc.	100 Woodbine Downs Boulevard , Toronto (Etobicoke), ON M9W 5S6, Canada	417310	100	http://www.ahearn.com/

3.6 Visualizations and analysis

Figure 4 shows geo-map distribution of suppliers in each specific area by province or region where suppliers exist or provide services. This visualization enables viewers to identify regions in Canada, which are particularly active in the chosen capability area. This is the first layer of analysis and landscape scan before drilling down into more details and looking at a particular region or business clusters. Ontario, Québec, Alberta and British Columbia host companies active in Vision System, whereas southern Ontario is the sole region representing Liquid Injection Molding. Companies active in thermoformed plastics were found in both Ontario and British Columbia.

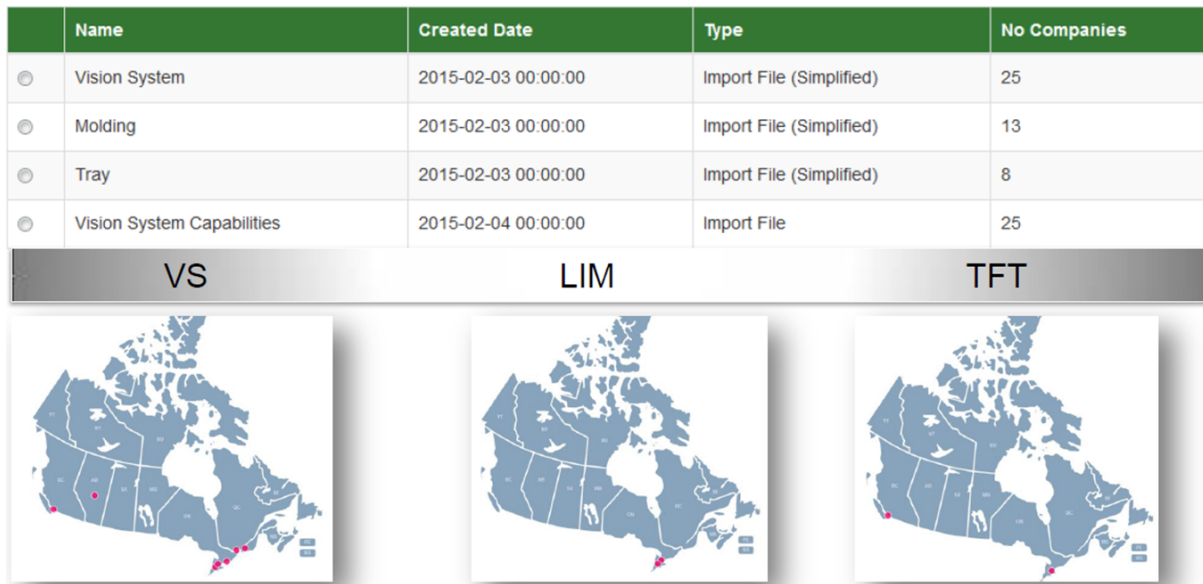


Figure 4. Geo-map distribution of suppliers in each categories.

An analysis of relevant NAICS codes was also performed, where the demographic data (including industry segments and the number of companies per segment) is displayed in the charts for each specified area, Figure 6. It can be seen that companies active in Vision Systems are classified into more industry segments compared to LIM and TFT. These findings highlight the value of the work to identify potential suppliers that would not be easily found through one single sector, e.g. auto suppliers.

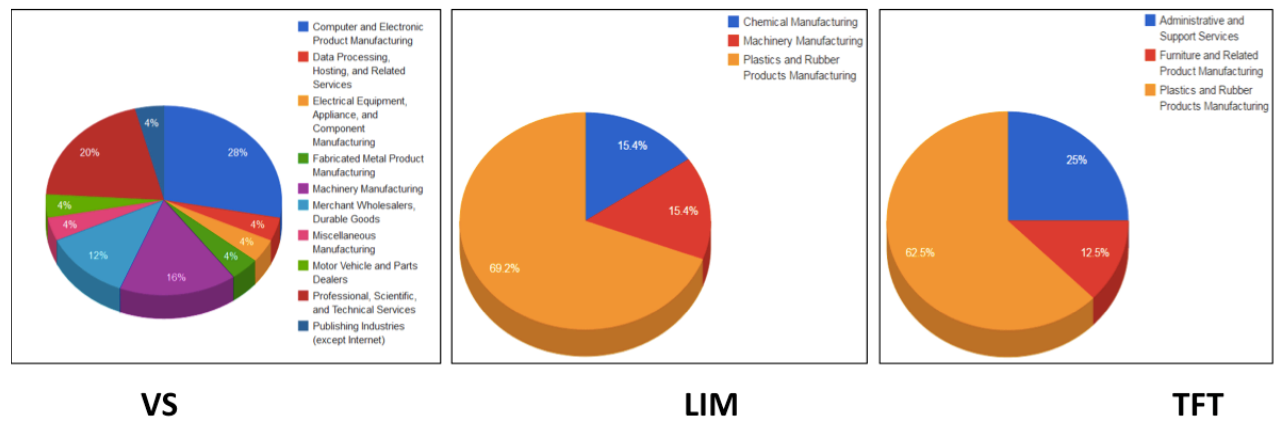


Figure 6. firm capability analysis based on NAICS codes.

The keywords (FDM & thermoplastic) for 3D printers were defined for the search as follows. First of all, OEMs required that materials used for 3D printers should be Polyphenyl ether (PPE) or other polymer materials. After a wide search of the available 3D printing technologies, FDM, SLA, SLS, and Polyjet (see below for details) were chosen as the most popular ones [2] Fused Deposition Modeling (**FDM**) printing process forms three-dimensional objects on an FDM machine from CAD-generated solid or surface models. A temperature-controlled head extrudes thermoplastic material layer by layer. The rapid prototype emerges from the FDM 3D printer as a solid three-dimensional part without the need for tooling. An **SLA** Prototype (Stereolithography) is built by passing a laser over a vat of resin and ‘growing’ the SLA Prototype, layer by layer. Selective Laser Sintering (**SLS**) printing is form of additive manufacturing which can be used to create durable, metal, plastic, or rubber-like prototypes on a SLS 3D printer directly from any 3D CAD model in as little as one day. **Polyjet** 3D printer forms rapid prototypes, by laying hundreds or thousands of 28 micron layers of resin on top of one another. It turned out that thermoplastic materials can only be used with the FDM printing technology. Therefore, the keywords “FMD” or “Fused Deposition Modeling” and “thermoplastic” were retained throughout our analysis.

4. Case study: Defining capabilities and analysis for vision system

Vision systems can be segmented either by their component functionality or by the application that the system is designed for. In consultation with Industry Canada and partner OEMs, the former approach was chosen. There are two major types of vision systems available in the

market: (1) an integrated smart camera, which is a fully integrated unit designed specifically for an application, and (2) a custom-built system composed of separate components. The integrated smart camera provides plug-and-play solution but with limited tuning capabilities and often have proprietary software / hardware requirements. Custom-built systems have a greater degree of flexibility so that the state-of-the-art capabilities can be built in according to the user's specific needs, Figure 7. However, a higher degree of engineering and integration are required. In this work, the vision system was segmented into: (i) lighting, lens, sensor, processor and communication (hardware); (ii) detection, integration and 3D transformation with analysis (software); and (iii) system engineering and component integration expertise (engineering, knowledge and experience).

Companies By Capability

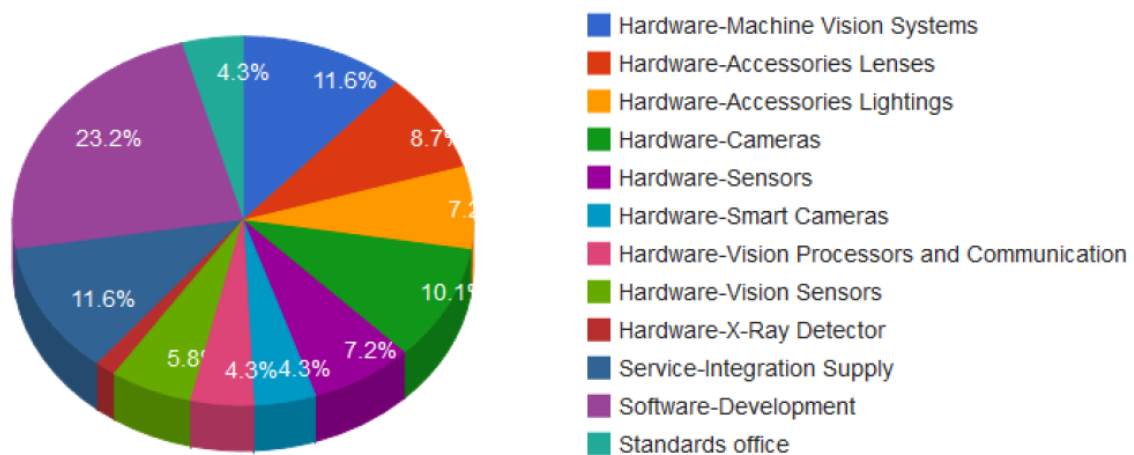


Figure 7. Distribution of companies by their capabilities in vision system category.

Analysis of the vision system segments in Canada reveals that supplier capabilities exist within both vertically integrated large division of multi-national global player like ATS Automation and Omron, and small but highly specialized component suppliers like Point Grey, a pioneer of lenses and specialized camera –based in Richmond, BC. Both types of companies are important. The choice of vendor will depend primarily on the key technical parameters to address. For example, fast processing rate requirement from manufacturing may benefit from a vertically integrated company who can address this issue at multiple engineering levels. We have also employed several existing tools [3,4] to visualize the overall ecosystem for all categories where user was able to zoom in to individual capability or individual companies.

5. Conclusion and further work

Building upon a general fuel cell supply chain database, a more specific supplier landscape analysis was performed within specific categories proposed by fuel cell OEMs. The definition of specifications and taxonomy are critical to provide a useful set of data for analysis and supply management purposes. This work focused on specific areas for supplier analysis along with clear specifications from OEMs to help demonstrate the usefulness of this approach to build a supply chain for fuel cell manufacturing. Further work is required with more detailed specifications on the already identified technical areas. Also continuous interaction with OEMs and integrators is essential to populate the rest of the supply chain, that is required for fuel cell manufacturing. Compared to searching within automotive list of suppliers, the value of our work has been demonstrated where a typical supplier that is not currently involved in the auto supply chain, has potential to become a significant supplier for fuel cell manufacturing. In addition, the integration with big data analytics methodology is necessary in order to enable users to translate gigantic databases into useful business intelligence around suppliers.

6. Acknowledgements

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¹ D. Wheeler and M. Ulsh, Manufacturing Readiness Assessment for Fuel Cell Stacks and Systems for the Back-up Power and Material Handling Equipment Emerging Markets , <http://www.nrel.gov/hydrogen/pdfs/45406.pdf>

² <http://www.laetechnologies.com/rapid-prototyping>

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⁴ R.C. Basole. Visualization of interfirm relations in a converging mobile ecosystem. Journal of Information Technology, 24:1, 144– 159, June 2009.