PRODUCT DESIGN, RESEARCH AND DEVELOPMENT

A CANADIAN MANUFACTURING PERSPECTIVE

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Product Design, Research and Development: A Canadian Manufacturing Perspective

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Cat. No: Iu44-60/2012
ISBN: 978-1-100-51673-8
IC registration #: 60989

Aussi offert en français sous le titre *Conception, recherche et développement de produits : Une perspective canadienne du secteur manufacturier*.

PRINTED ON RECYCLED PAPER:
COVER: 30%
INSIDE PAGES: 30%

PRODUCT DESIGN, RESEARCH AND DEVELOPMENT

A CANADIAN MANUFACTURING PERSPECTIVE

Highlights

In today's global marketplace, Canadian manufacturers' ability to compete with firms around the world increasingly depends on their capability to generate viable product ideas and translate them into commercial success. Product design, research and development (PDR&D) is essential to drive commercialization and growth in the Canadian manufacturing sector.

To capitalize on current and future market opportunities, Canadian manufacturers are rethinking their PDR&D strategies. While keeping core PDR&D activities internal, many manufacturers are coordinating other business activities with supply chain partners, universities, and centres of excellence and forming strategic alliances and joint ventures. Manufacturers are being driven to implement open innovation by evolving customer requirements and increasing global competition; sharing knowledge and capacity enables manufacturers to commercialize quickly and reduce their product development risk.

Industry Canada has partnered with Canadian Manufacturers and Exporters, the Institute for Product Development, the Design Exchange, the Association of Canadian Industrial Designers, and Montreal Living Lab to share strategic information on how Canadian manufacturers can leverage PDR&D to innovate and compete on a global stage. This report identifies best practices and trends, and provides insights into current and future industry needs.

Key Findings

- The Canadian manufacturing sector is at the forefront of new product commercialization.
- Product design, research and development (PDR&D) is a cycle of continuous improvement over time that includes four stages: *product idea generation; product selection; product development;* and *launch.*
- In addition to research and development (R&D), core business activities such as industrial design, product engineering, testing, and market research are required to ensure product innovations are commercially successful.
- Substantial investment in PDR&D is being made with the aim of extending the market life of products through product extension strategies, which drive long-term profitability and future iterations of product development.
- An increasingly common method for manufacturers to develop new products is through open innovation with outside organizations, such as supply chain partners, research institutions, and centres of excellence.
- The majority of Canadian manufacturers perform R&D activities in Canada, regardless of head office location.
- Accessing new sources of product innovation outside the company, increasing design capacity, and accessing specialized skills from the global workforce and new markets are among the top drivers for conducting global PDR&D.
- Few Canadian manufacturers outsource R&D activity to providers in Canada or abroad.
- In Canada, between 2007 and 2009, more than twice as many Canadian manufacturing firms opened a new R&D facility or expanded capacity than those that reduced R&D capacity, with a greater percentage of large firms expanding compared to small and medium-sized manufacturers.
- An emerging trend in the Canadian manufacturing industry is the development and implementation of proactive intellectual property (IP) strategies, aligned with innovation and business strategies, which maximize the potential value from the information generated by the PDR&D process.
- Best-in-Class manufacturers are in a better position to protect IP resulting from their PDR&D initiatives and also invest in advanced PDR&D technologies and processes to effectively launch new products to market.

Table of Contents

Table of Figures

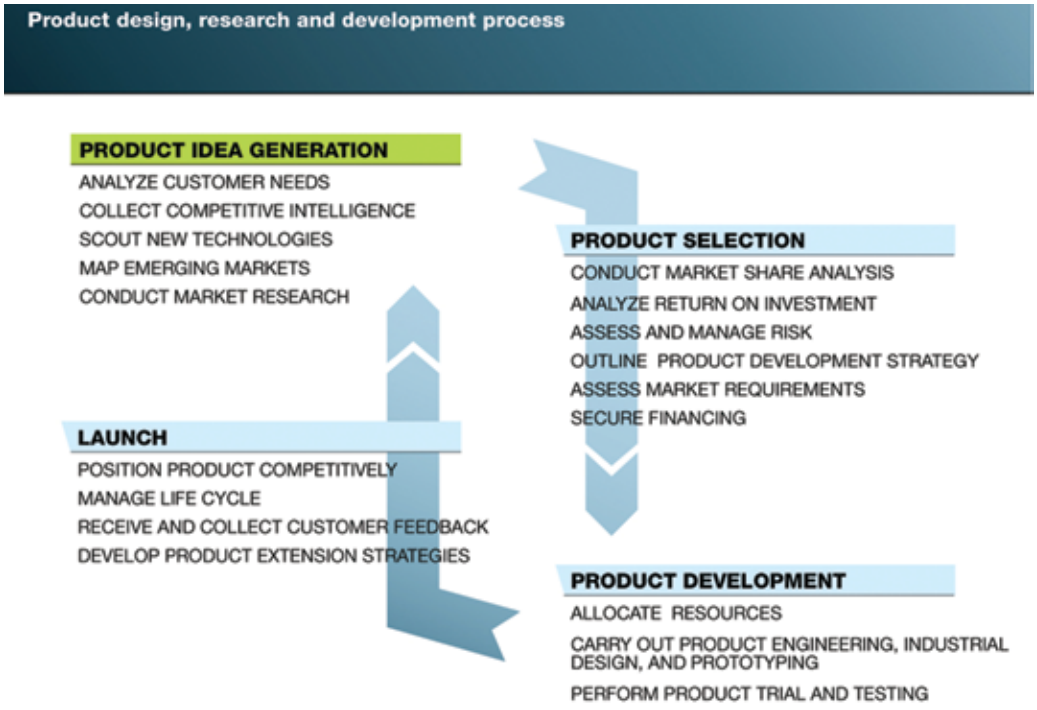
List of Tables

Background

The extent to which Canadian manufacturers invest in product design, research and development (PDR&D) is a key determinant of their competitiveness, as PDR&D drives commercialization, export opportunities and growth. In 2008, the Canadian manufacturing sector invested close to $39 billion in PDR&D activity to link ideas and concepts to the creation of new and improved products.[1]

The PDR&D process is a cycle of continuous improvement over time with iterative feedback and recurring input from development team members as well as executives, sales and marketing groups, and production teams. The process involves four stages: *product idea generation; product selection; product development*; and *launch* (Figure 1).

Figure 1[2]



To begin the PDR&D process, manufacturers generate product *ideas* and evaluate whether they could be commercially viable. This step involves conducting extensive market research, scouting new technologies, and mapping potential emerging markets to assess customer needs. In the *product selection* stage, manufacturing firms further assess product ideas along with potential risks and financing options, and plan for product development to determine what resources are required to design and launch a product to market. Following this, industrial design, product evaluation, modelling, prototyping/testing, and refinement activities are completed in the *development* stage. Once a product has been successfully developed it is then integrated into production processes, and ultimately the new product is then promoted and *launched* in the marketplace.[2]

At each stage of the process, manufacturers assess progress and realign their strategies to maximize the probability of success. In addition, customer feedback and refinement — a key component of the PDR&D process — feeds into manufacturers' competitive intelligence and process revisions, and drives product extension strategies and new product introductions.[2]

Research and development (R&D), which encompasses basic research, applied research and experimental development, is central to product innovation and signals a firm's commitment to the generation and commercial application of new product ideas.[3] Core activities such as industrial design, product engineering, testing, and market research are also required to ensure product innovations are commercially successful.[2]

To strengthen their competitiveness in the global market, Canadian manufacturers are rethinking their product innovation business models, investing in capacity, and implementing innovative tools and practices. An emerging strategy is global resource allocation, where product innovation is undertaken across geographical boundaries and PDR&D is coordinated with

multiple stakeholders. As well, leading manufacturers are determining their products' intellectual property (IP) status at each stage of the process and using IP tools such as industrial designs, trade secrets, patents and trademarks to maximize the potential value of the information generated.[2]

This report provides insights on:

- Trends in product innovation
- Product design, research and development business models
- Canadian investment in R&D and engineering facilities
- Intellectual property strategies
- Advanced technologies and process adoption
- Best-in-Class analysis

Emerging Trends in Product Innovation

The competitive nature of the manufacturing industry, potential risks, and business ambitions all influence the innovation business strategies undertaken by Canadian manufacturers.[4] In general, companies pursue a mix of two product innovation strategies: the first is new product innovation,* which is essential to push the boundaries of existing markets and to discover and pursue new opportunities in the global economy; the second involves substantial investment in R&D and product design to extend the market life of products through product extension strategies that drive long-term profitability and future iterations of product development (Figure 2).

Figure 2[5]

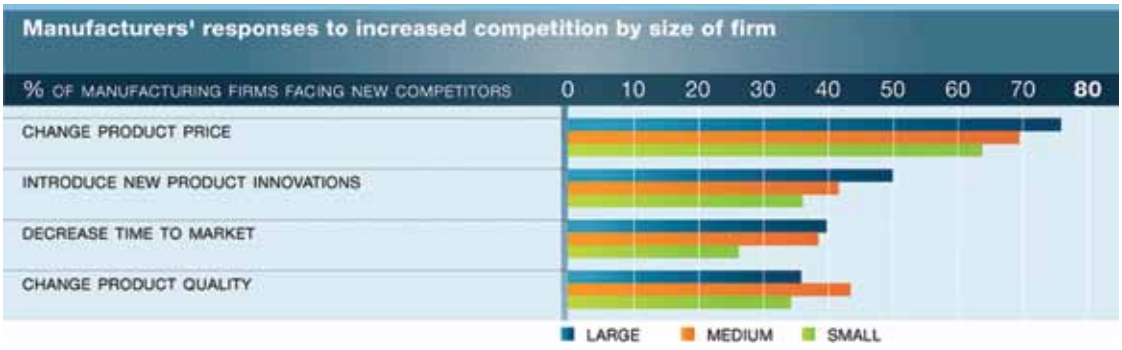
Canadian manufacturers seek to introduce profitable product innovations by generating viable product ideas, securing start-up investments, effectively managing product development (time to market) and production scale-up (time to volume), and developing product extension strategies.[5] When designing new products, manufacturers weigh the benefits with the costs of reducing time to market (e.g., greater market share combined with higher development costs), and also consider the time required to reach volume production and deliver payback. Manufacturers must decide if and when to invest in product extension strategies to maximize revenue, and when to invest in the next generation of product introductions.

** A product innovation is the market introduction of a **new or significantly improved** good with respect to its capabilities, user-friendliness, components or sub-systems. Product innovations (new or improved) must be new to the enterprise, but they do not need to be new to its market. Product innovations could have been originally developed within the enterprise or by other enterprises.*

Challenges manufacturers face include assessing these factors early on and re-evaluating decisions at each step of the process to determine the likelihood that a product idea will generate payback, prior to investing significant time and resources.[5]

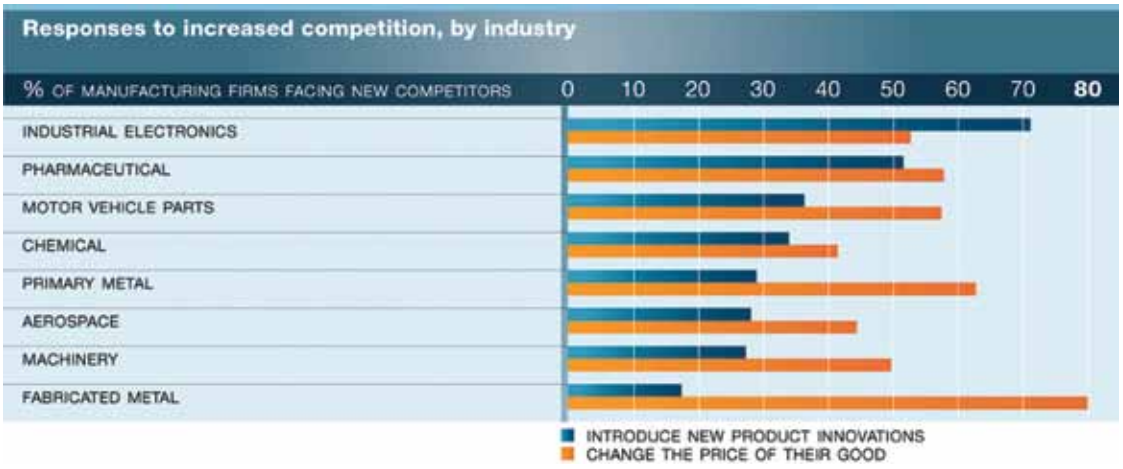
As competition increases, the most common response by Canadian manufacturers is to compete on price, often coupled with the use of enhanced cost reduction strategies. Manufacturers also react by improving product quality, introducing innovative products, and accelerating product introductions (first-to-market advantages) (Figure 3). These responses reflect Canadian manufacturing firms' focus on a mix of both new product development and product extension strategies.[2]

Figure 3*[6]



Reliance on new product development and product extensions varies by manufacturing industry (Figure 4). For example, industrial electronics manufacturers focus more on new product development and speed to market to meet narrow market windows and short product lifecycles, whereas the aerospace industry concentrates its efforts on product extension (new features, higher quality, and lower cost) due to the high risk and complexity of new product development and long product life cycles.[2]

Figure 4[6]



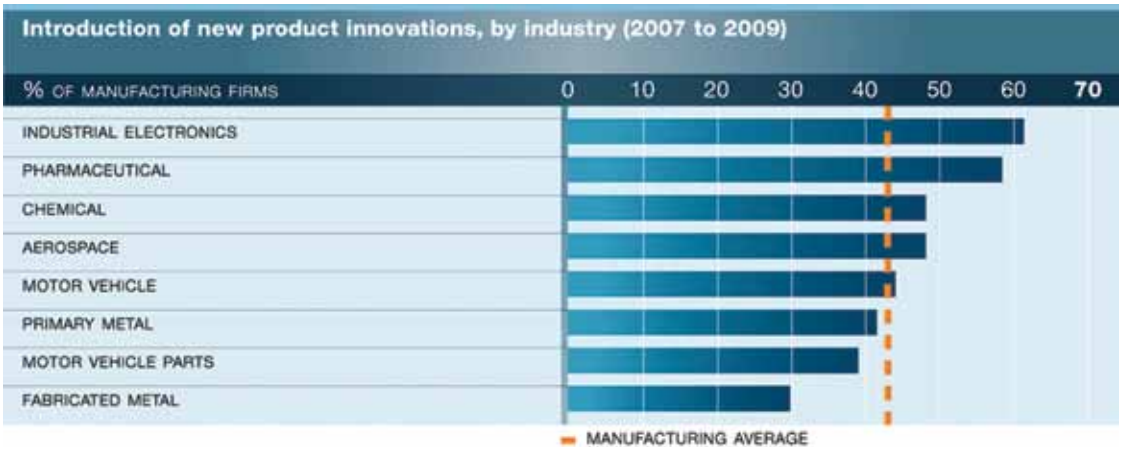
Meanwhile, motor vehicle and motor vehicle parts manufacturers focus on product extensions in areas such as vehicle efficiency through platform and component improvements, weight reductions, and cost reduction through design and process optimization. Pharmaceutical manufacturers' product extension strategies include developing drug delivery system variants and new combinations for improved efficacy.[7] In some industries, such as fabricated metal manufacturing, where product differentiation is based largely on price, firms focus their R&D and engineering resources on increasing efficiency of production processes to reduce costs.[2]

** Small = 20-99 employees; medium = 100-499 employees; and large = at least 500 employees.*

In terms of new product commercialization, the Canadian manufacturing sector is at the forefront. Between 2007 and 2009, 43 percent of Canadian manufacturers introduced new product innovations, compared to 13 percent of all other industries.* In addition, nearly as many manufacturers (22%) introduced new service innovations to complement their product offerings compared to firms in other industries (25%).[6]

Canadian aerospace manufacturers are developing new and improved products in many areas such as advanced aircraft structures (fuselage and wing components, horizontal and vertical stabilizers, and subassemblies), avionic systems, and critical engine systems and components. The chemical industry also invests in PDR&D to formulate biochemical and green products, and speciality chemicals developed on a customer basis (Figure 5).[2]

Figure 5[6]



Motor vehicle parts manufacturers focus new product development efforts in areas such as advanced powertrain components, lightweight and bio-materials, and thermoplastic composites and parts. Meanwhile, motor vehicle manufacturers put effort towards developing chassis and body sub-systems, fuel cell technology and hybrid electric technology. The industrial electronics industry places significant focus on new product development, with over 60 percent of firms introducing new products between 2007 and 2009.[6] In this industry, manufacturers are designing electrical systems and hardware for products such as carrier-grade telecommunications equipment, embedded microprocessors, and digital signal processing equipment. In addition, some manufacturers offer mechanical, structural and thermal design solutions for enclosures that encompass a wide range of plastic, metal and other material technologies (Table 1).

Table 1: Examples of product innovation, by industry[2]

INDUSTRY	PRODUCT EXTENSION	NEW PRODUCT INNOVATION
Motor Vehicle	• Product testing and R&D to improve noise, vibration and harshness • R&D and engineering to optimize designs to achieve cost and weight targets and improve functionality	• Next-generation engines, transmissions and drivelines design • Hybrid electric vehicle technology development • New platform development • Fuel cell technology
Motor Vehicle Parts	• Cost reduction through process innovation and developing state-of-the-art production systems • Product testing to improve durability, operational performance and strength	• Advanced powertrain components (energy-efficient engines, transmissions and drivelines) • Thermoplastic composites and parts • Lightweight and bio-materials to improve efficiency and environmental impact

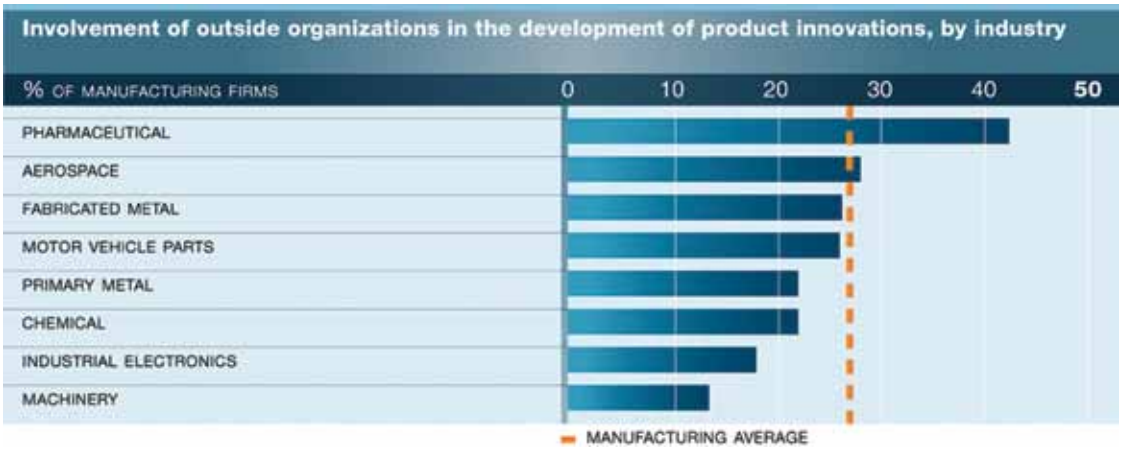
** "All other industries" includes: agriculture, forestry, fishing and hunting; mining, quarrying, and oil and gas extraction; utilities; construction; wholesale trade; retail trade; transportation and warehousing; information and cultural industries; finance and insurance; real estate and rental and leasing; professional, scientific and technical services; management of companies and enterprises; and administrative and support, waste management and remediation services.*

Table 1: Examples of product innovation, by industry[2] (cont.)

INDUSTRY	PRODUCT EXTENSION	NEW PRODUCT INNOVATION
Aerospace	• Composite and lightweight components • Platform extensions for multiple purposes • Noise pollution and fuel efficiency • Optimizing maintenance tasks and improved aesthetics	• New major platforms development • Advanced engine and subsystems development • Avionics development
Industrial Electronics	• Enhanced cost reduction strategies for extremely low-volume, high-mix manufacturing • Multiple platforms for different industry applications, such as telecommunications, aerospace, defence, automotive and consumer electronics	• Electrical and hardware design for products such as large high-speed, carrier-grade telecommunications equipment, embedded microprocessors • Mechanical, structural and thermal design solutions for enclosures that encompass a wide range of plastic, metal and other material technologies
Pharmaceutical	• Product extension through the introduction of drug delivery system variants (prolonged release formulations) • New combinations with other drugs for improved efficacy and new indications	• Development of new pharmaceutical products through drug candidate selection, pre-clinical and phase I (first human administration), phase II (target population) and phase III (large sample of up to several thousand patients) clinical trials

An increasingly common method for manufacturers to develop product innovations is through open innovation.* In Canada, 24 percent of manufacturers stated that product innovations were mainly developed with the support of outside organizations,[6] such as supply chain partners and research institutions. Evolving customer requirements and increasing global competition are driving manufacturers to look for partners to share knowledge and capacity, allowing them to innovate more quickly and to share product development risks (Figure 6).[8]

Figure 6[6]



The degree of collaboration varies by industry. For example, many pharmaceutical firms (42%) develop new products with input from external organizations such as other pharmaceutical companies, research laboratories, and universities. Several aerospace and automotive parts manufacturers develop new products with external involvement. In these industries, firms make use of centres of excellence, university research partnerships and research institutes, and also work with other firms within the supply chain to leverage PDR&D efforts.[2]

Open innovation within the context of PDR&D enables Canadian manufacturers to more easily gain and integrate needed product knowledge from external partners and to effectively introduce products with greater commercial potential. In order to do so, Canadian manufacturers first identify which partners (customers, suppliers, and competitors) to collaborate with in an open innovation process, and then design methods and tools to collect and effectively integrate information into their PDR&D processes.[9]

** Open innovation includes sourcing and integrating external knowledge of customers, suppliers, universities and research organizations, and competitors, as well as gaining revenue from un-commercialized IP portfolios.*

Product Design, Research and Development Business Models

Intensified global competition is driving Canadian manufacturers to adapt their business processes and activities to effectively develop commercially viable products. This includes revising their business models in order to better access and manage multidisciplinary and globally distributed knowledge that has increased the complexity of PDR&D.[10]

The majority of Canadian manufacturers perform R&D activities in Canada, regardless of head office location. In addition, a high percentage of manufacturers perform product engineering activities in Canada (80%), with no substantial difference between Canadian-owned and foreign-based firms (Figure 7). This is, to a certain extent, due to the fact that these activities are linked to the later stages of product development closer to production, which is the core business operation of manufacturers.[2]

Figure 7[6]

Despite the fact that PDR&D business models vary across industries and firms, some of the most influential factors that affect manufacturers' decisions to perform these activities in a specific location are similar. Access to talent and embedded knowledge, innovative environments (e.g., clusters), financial incentives, general operating costs, proximity to other core business operations and customers, and level of IP protection are several examples.[11] However, Canadian manufacturing firms generally make decisions related to R&D focus on a per-project basis, and units within the same company compete for product design mandates.[2]

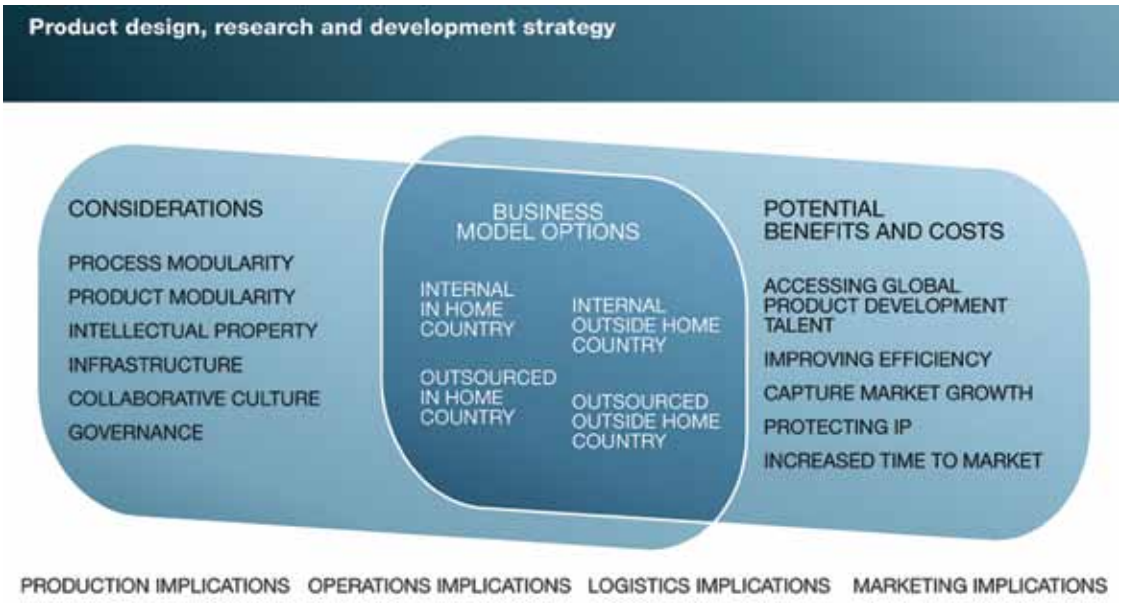
The degree of foreign parent involvement in R&D decisions differs by industry and is closely linked to the level of foreign ownership (Figure 8). For many manufacturers, R&D decisions for new product mandates are primarily made by the global head office. Conversely, product extension decisions mostly occur at the plant level where R&D and engineering activities that focus on enhanced cost reduction are mainly performed.[2] The higher level of foreign parent involvement in the pharmaceutical industry reflects the need for central coordination of long-term drug development conducted in treatment-specific R&D and production facilities around the globe.[2]

Figure 8[6]

While keeping core PDR&D activities internal, global manufacturers coordinate PDR&D efforts between business units and supply chain partners, and form strategic alliances and joint ventures.[12] Global manufacturers invest in PDR&D activities in multiple countries, set up cooperation agreements and technological alliances, and outsource PDR&D activities to service providers.[13]

When a manufacturer integrates a global PDR&D strategy into its overall business planning, production, operations, logistics and marketing implications must be considered to assess the potential benefits and costs of internalizing or outsourcing specific PDR&D tasks.[14] Manufacturers can then develop their deployment strategies to determine the mix of options to pursue (Figure 9). Typically, manufacturers centre their deployment strategies around their main production activity.[2]

Figure 9[2,14]



Accessing new sources of product innovation outside the company, increasing design capacity, and accessing specialized skills from the global workforce and new markets are among the top drivers for conducting global PDR&D. Large manufacturers also typically leverage local expertise or capabilities to adjust product offerings to comply with local requirements or customer preference.[2]

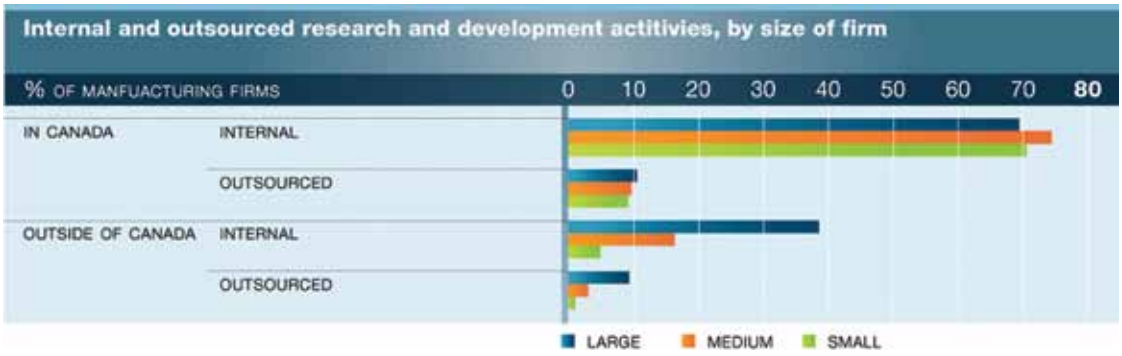
It should be noted that gaining the full benefits of a global PDR&D strategy in an efficient and cost-effective way can be challenging. North American manufacturers must manage the impact of changes across dispersed teams and ensure quality standards of design are maintained, while retaining company knowledge of product design decisions and protecting IP (Figure 10).[15]

Figure 10[15]

To meet these challenges, manufacturers assess a number of factors when developing their global PDR&D strategies. Among these considerations are the type of management and project planning systems in place, the sophistication of the information and communication technology environment (a reliable information system is required so that design information is secure and accessible from any location), the level of process modularity (method to split development work to be distributed globally), the degree of product modularity (design of subsystems that can be completed by teams in different locations and then integrated into a final product), the firms' collaborative culture (ability of design teams in different time zones and with different cultural practices and languages to work together efficiently) and the IP protection strategy adopted.[14]

Overall, Canadian manufacturers internalize core R&D activities to maintain ownership over project directions, timelines and outcomes, but leverage external expertise or capability for specialized functions.[2] In Canada, the majority of manufacturers (70%) conduct R&D activities in-house regardless of the size of firm (Figure 11).

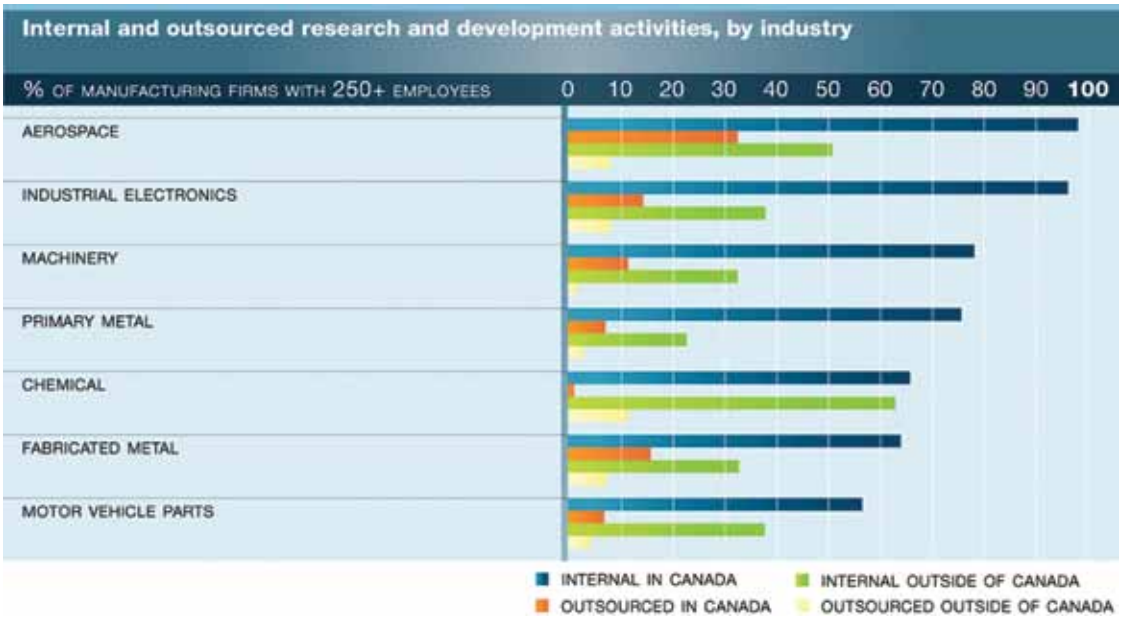
Figure 11[6]



Large manufacturers outsource R&D activities to partners located in Canada and abroad at a similar level (10%). Medium-sized and small* Canadian manufacturers with a limited global footprint tend to favour local business partners in their R&D outsourcing strategies. Outside of Canada, more than twice as many large Canadian manufacturers (30%) perform R&D activities compared to medium-sized firms (14%) and small firms (5%) (Figure 11). For product engineering activities, manufacturers adopt a similar pattern.[6]

With more than 90 percent of firms with more than 250 employees conducting R&D in Canada, the aerospace and industrial electronics industries have the highest percentages of manufacturers developing their products in-house in Canada (Figure 12).

Figure 12[6]



** Small = 20-99 employees; medium = 100-499 employees; and large = at least 500 employees.*

In the aerospace and automotive industries, original equipment manufacturers (OEMs) increasingly specify overall system requirements and then delegate to their suppliers the responsibility to engineer and design a component or sub-system. Typically, advanced R&D for strategic components such as hybrid powertrain systems or composite wings is performed internally.[2]

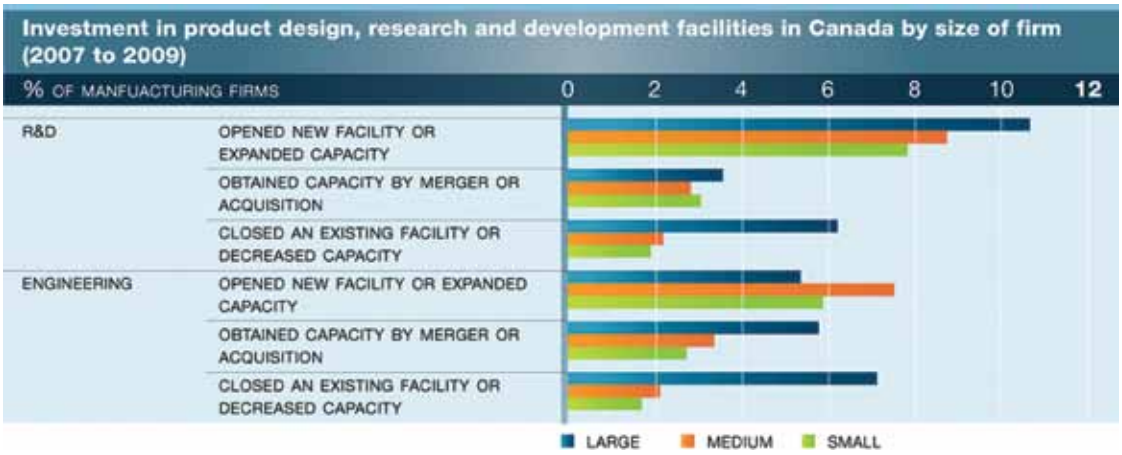
Canadian Investment in Research and Development Capacity

Research and development has become increasingly mobile over the past decade, with large multinational firms creating global R&D networks to adapt products to local markets, acquire assets and gain knowledge.[16] Manufacturers' decisions to invest in R&D and product engineering facilities are complex. When deciding to expand capacity in Canada or abroad, firms weigh several strategic factors, such as the skilled workforce of a region, IP protection, culture and regulatory environment, market size and growth potential, presence of clusters, suppliers and centres of excellence, and the need to access foreign markets.[16]

Large multinational manufacturers are establishing R&D and product engineering facilities in multiple locations worldwide. Firms generally invest in two types of global R&D: *adaptive* and *asset-seeking*. Adaptive R&D aims to adjust product offerings to local market conditions; it tends to be closely related to production activities and is required to ensure that products meet customers' needs and that time to market is minimized. Asset-seeking R&D investment aims to acquire strategic assets such as new technologies and to gain access to expertise. With this type of investment, manufacturers generally consider supply-related factors in locating R&D facilities.[16]

In Canada, between 2007 and 2009, more than twice as many Canadian manufacturing firms opened a new R&D facility or expanded capacity than those that reduced R&D capacity, with a greater percentage of large* firms expanding compared to small and medium-sized manufacturers (Figure 13).

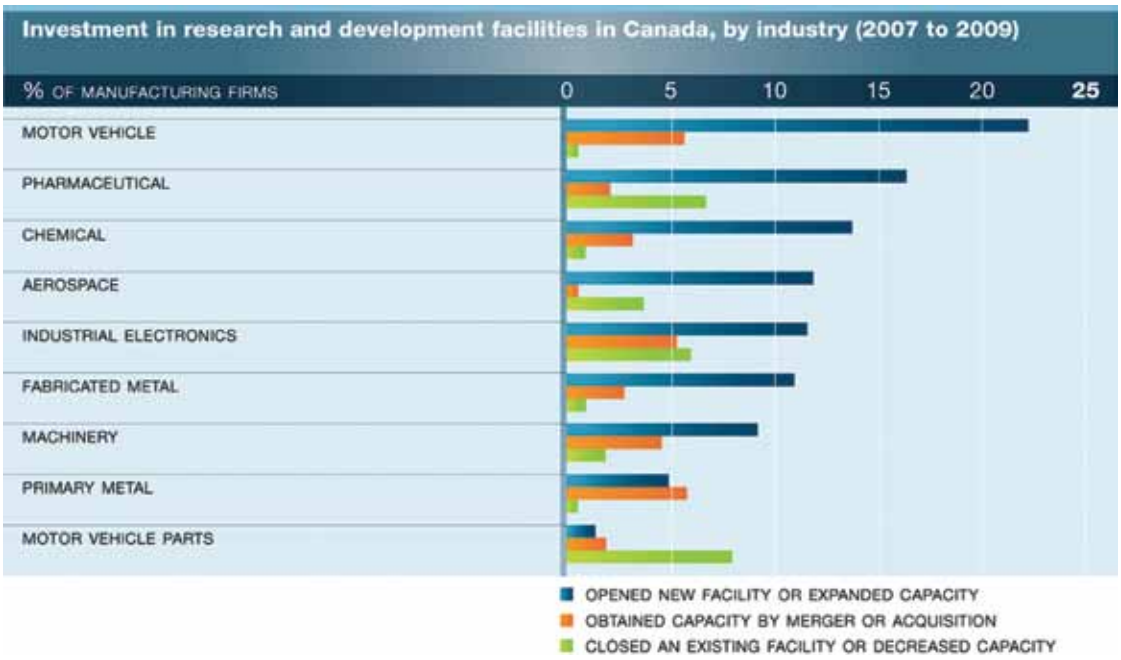
Figure 13[6]



Investment in R&D facilities and capacity in Canada varies by manufacturing industry. For example, 22 percent of motor vehicle manufacturers opened R&D facilities between 2007 and 2009, with some firms focusing on powertrain dynamometer research, fuel cell testing, and R&D on a broad range of advanced production and prototype engine technologies.[2] Conversely, the evolving business model in the auto parts manufacturing industry has led to some firms focusing more on a build-to-print business model (Figure 14).[2]

** Small = 20-99 employees; medium = 100-499 employees; and large = at least 500 employees.*

Figure 14[6]



Firms in the aerospace industry have increased R&D capacity almost solely through organic expansion, while firms in the pharmaceutical manufacturing industry have expanded R&D capacity to focus on new drug discoveries. Industrial electronics manufacturers are expanding R&D capacity — in many cases with university collaboration — to focus on the development of next generation electronics such as micro-electromechanical systems for silicon chips and electrical and hardware design for products such as carrier-grade telecommunications equipment and embedded microprocessors.[2]

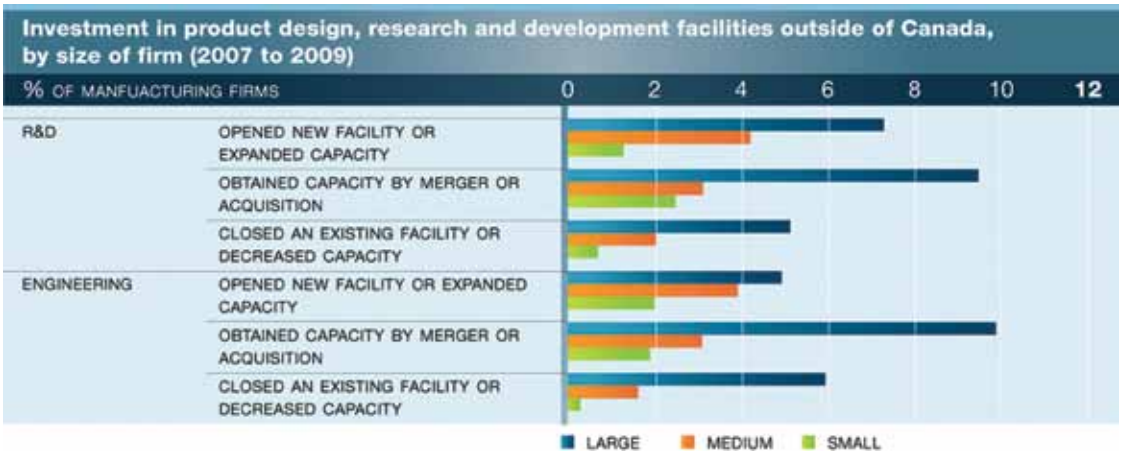
From 2007 to 2009, a greater percentage of manufacturers opened new R&D facilities or expanded capacity than those that reduced R&D capacity, regardless of head office location. Meanwhile, a greater percentage of manufacturers with Canadian head offices expanded R&D capacity compared to their foreign counterparts (Figure 15).

Figure 15[6]

In addition to investing in PDR&D capacity in Canada, close to 10 percent of large* manufacturing firms obtained R&D and engineering capacity internationally through mergers and acquisitions during the 2007-2009 period (Figure 16). Organic investment is generally chosen for adaptive R&D that is closely linked to production. Mergers and acquisitions are a common method of expansion and technology sourcing, asset-augmenting R&D, and footprint expansion.[2]

** Small = 20-99 employees; medium = 100-499 employees; and large = at least 500 employees.*

Figure 16[6]

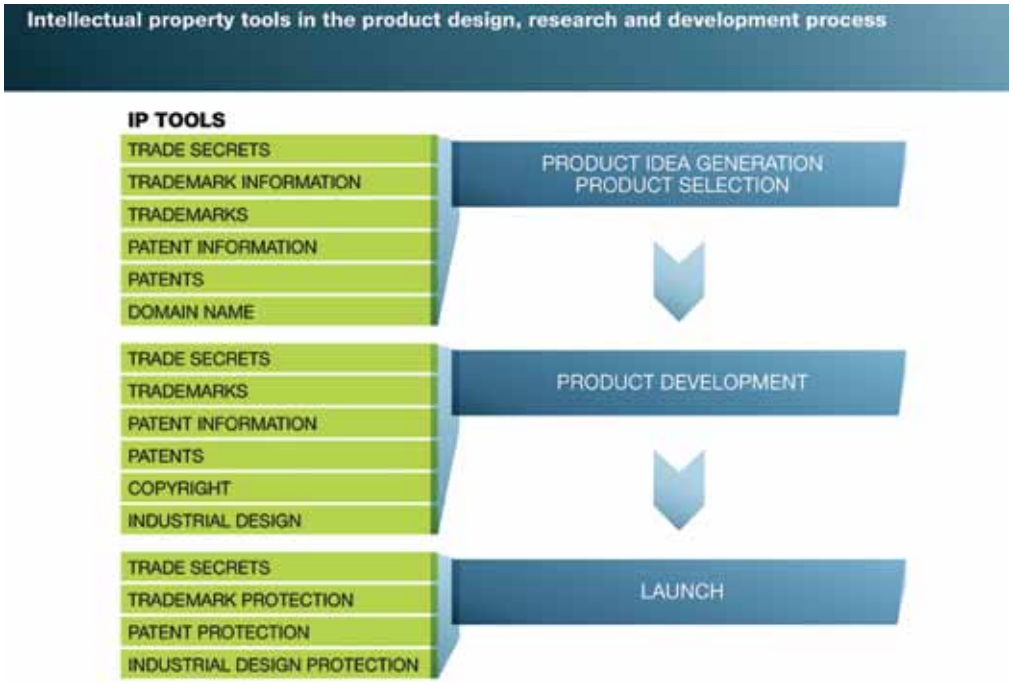


In terms of international investment in R&D capacity, manufacturers consider many factors. For example, with high-growth opportunities in emerging economies, some manufacturers invest in R&D capacity to support global product platforms and local product requirements.[17]

Intellectual Property Strategies

Product design, research and development generates information that is vital for commercial success, and that information needs to be managed and protected effectively. Canadian manufacturers are developing and implementing proactive IP strategies, aligned with innovation and business strategies, to maximize the potential value from the information generated by the PDR&D process.[2] Addressing IP considerations from the initial stages of PDR&D, continuously assessing the product's IP status, and determining what IP tools are most appropriate at each stage are key elements to an effective IP strategy (Figure 17). Equally important in IP strategies is defining how product information (e.g., specifications, design data, embedded technologies) is protected, both internally and in teams that involve external partners.[2]

Figure 17[18]



During the *product idea generation* stage of the PDR&D process, treating initial concepts and related information as trade secrets*[19] is a key protection tool utilized by Canadian manufacturers until other IP tools may be used.[18] In addition, trade secrets play an important role for product specifications and related information — including technologies and manufacturing processes — which firms often decide to keep confidential throughout a product's life cycle.[20] In general, secrecy is a major element of a firm's IP strategy and is often considered more important than formal IP tools such as patents.**[21] Confidentiality agreements (non-disclosure agreements) that specify penalties for non-compliance are another important measure to protect trade secrets covering product specifications that result from PDR&D performed both within the firm and in an open innovation process.[2]

Manufacturers use multiple sources to generate product ideas. One source is global IP databases that provide information on what products competitors are developing. IP databases can also yield technical details of a previously developed technology or manufacturing process that is relevant to a product under development.[18] IP databases are helpful for manufacturers to assess the risks of potential infringement on other organizations' IP rights from the idea generation phase through to the end of the PDR&D process.

In the *product development* stage, Canadian manufacturers utilize many IP tools to protect the increasing amount of product information generated and to facilitate collaboration with partners. For example, many manufacturers register industrial designs in the product development stage to protect the visual features of products and extend the protection afforded by patents. Additionally, industrial design protection is well adapted to redesigns performed in the context of product extensions.[18]

When performing PDR&D in open innovation partnerships, manufacturing firms specify IP ownership at the onset of projects and use confidentiality agreements to facilitate collaboration and maximize the potential value of R&D investment. An emerging trend within an R&D partnership with universities, service providers or suppliers is to assign the IP rights of the business application of the technology to the user (e.g., a manufacturer), while the developer (e.g., a university) retains the IP rights to the specific technology. This includes the rights to commercialize the product for clients who are not competing with the user, notably in technological applications in other industries. The increase in open innovation partnerships is also changing firms' willingness to commercialize IP by licensing, assigning or acquiring IP rights to technologies.[8] Assessing IP portfolios for potential revenues through licensing or assigning IP rights is another element of a proactive IP strategy.[22]

Marketing considerations are also an integral part of a firm's IP strategy. In the early stages of developing the visual and textual elements of a new product's brand (i.e., logos, product names and slogans), a proactive approach includes assessing whether those elements may be registered and used as trademarks by examining available trademark information. Trademarks help support a firm's marketing strategy by differentiating its products from its competitors while leveraging the product's established name beyond the length of its patent coverage.[18] Equally important in the early stages of product innovation is the assessment of the availability, and the subsequent registration, of Internet domain names related to a product's branding elements to help maximize the advertising footprint.[2] Finally, firms generally seek IP protection for geographic areas where they plan to sell their products.

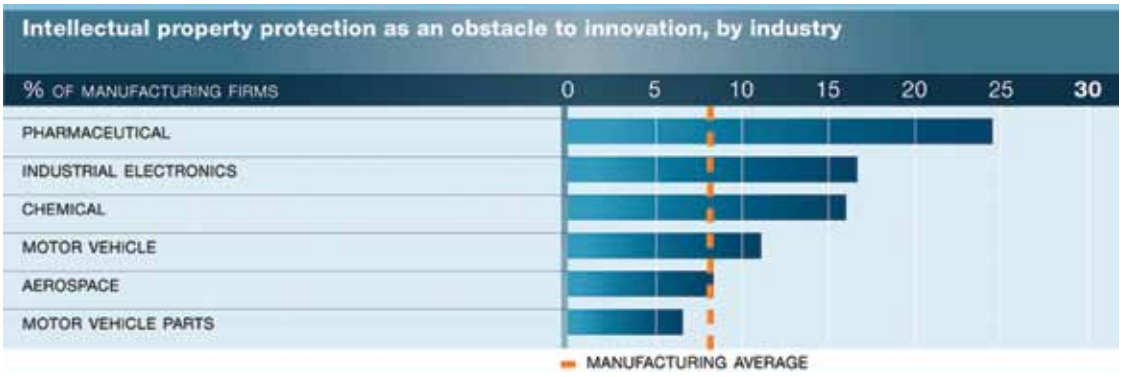
Ensuring that available IP protection tools are applied according to a firm's own strategy by the time the product is launched is crucial to protect and leverage the investment made in the PDR&D process. After the product is launched, monitoring the IP environment and taking action when infringement occurs is another element of a firm's IP strategy to help retain its competitive advantage.[2]

Even though firms in the industrial electronics and the pharmaceutical manufacturing industries rely on multiple IP protection tools, the use of patents dominates both industries. Industrial electronics firms typically rely on a large number of patents, whereas pharmaceutical firms tend to rely on fewer, but potentially extremely valuable, patents.[23] In both industries, patents are often subject to challenges by competing firms. The cost of such challenges may be seen as an obstacle to innovation by some pharmaceutical firms and, to a lesser extent, industrial electronics manufacturing firms (Figure 18). However, 55 percent of Canadian manufacturers that indicated IP protection as an obstacle to innovation were able to implement successful mitigating measures.[6]

** Trade secrets are usually formulas, patterns, compilations, devices, processes, codes, and data that are specific to its owner, that give a firm a business advantage over a competitor, and that are kept secret or confidential.*

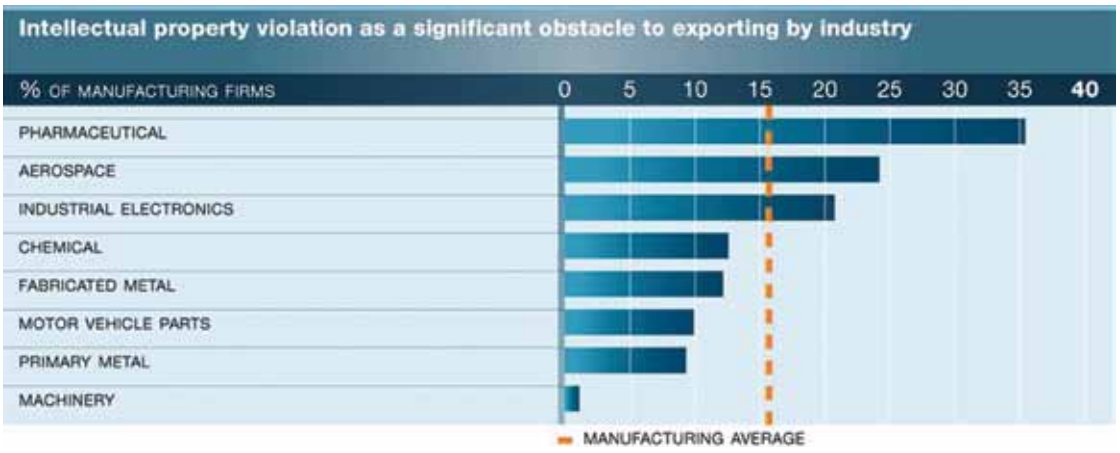
*** A patent gives the right to exclude others from making, using or selling an invention.[19]*

Figure 18[6]



When pursuing export markets, 16 percent of Canadian manufacturing firms indicate that IP violation is a significant obstacle.[6] For pharmaceutical and aerospace manufacturers, this issue is particularly critical (Figure 19). For instance, counterfeit replacement aerospace parts entering the supply chain are significant concerns for maintenance operations.[2]

Figure 19[6]



In response to potential IP violations, some firms rely on speed to market instead of formally registering IP to leverage the competitive advantage of new product innovation and product extensions. Costs and requirements of multi-jurisdiction IP registration and, more importantly, the defence of IP are barriers for manufacturers exporting new products.[2]

Best-in-Class Analysis — Intellectual Property

Protecting design specifications is an important aspect of safeguarding product information generated during product innovation performed both within a firm and in open innovation partnerships. Overall, Best-in-Class (BiC) firms* are in a better position to protect IP resulting from their PDR&D initiatives. In open innovation partnerships, BiC firms are more likely to limit the information (e.g., product specifications and design data) shared with external partners to the level required for the portion of the product those partners are developing (Figure 20).

** BiC firms are the top 20% performers in the following three metrics: percentage of products launched/delivered on time; increase in product revenue since engaging in a global PDR&D initiative; and decrease in PDR&D costs. Laggards represent the bottom 30% of firms benchmarked to the same metrics.*

Figure 20[24]

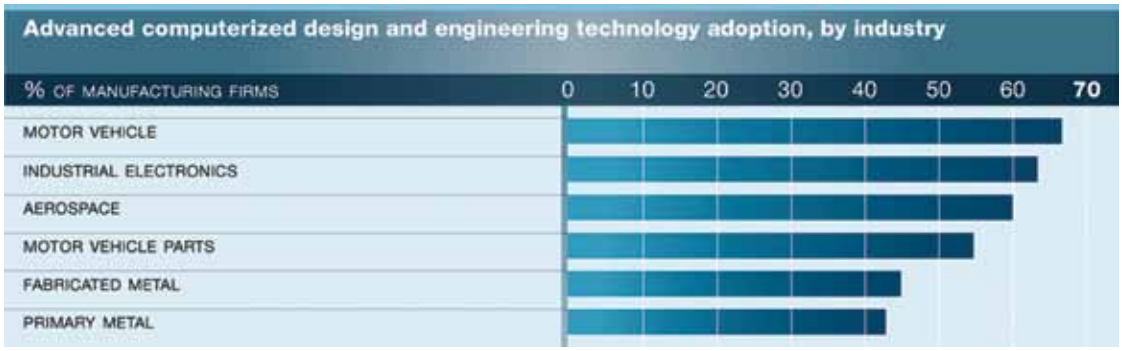
Another solution is to ensure that the level of access to product design specifications (whether a user can view the specifications) is defined according to functional roles in the enterprise. BiC firms are twice as likely to implement such a solution, compared to laggards.[24] BiC firms also distinguish themselves by the implementation of defined standards for providing product design data to other business units. For example, sharing the visual representation of a product design instead of a complete data file is a measure implemented by BiC firms.[24]

Advanced Technologies and Process Adoption

In response to competitive pressures, Canadian manufacturers are seeking to reduce development time for new products while implementing extension strategies for their current products through a combination of new features and cost reductions. To that end, firms are optimizing product innovation by implementing new processes and adopting new technologies.[24]

The adoption rates of advanced computerized design and engineering technologies between small, medium-sized and large* Canadian manufacturing firms do not differ substantially (41%, 45% and 50%, respectively); however, specific advanced technology applications do vary by industry. For example, motor vehicle manufacturers are adopting computer assisted engineering tools that enable simulation and virtual testing as part of their Virtual Product Development strategies.[2] In general, more than 60 percent of firms in the motor vehicle and industrial electronics industries use advanced** computerized design and engineering technologies (Figure 21).

Figure 21[6]



Rapid prototyping techniques are also being used to accelerate the product innovation process. Firms are using additive manufacturing methods such as 3D printing to produce prototypes suitable for aerodynamic testing purposes in a significantly shorter time frame, since the need for tooling is eliminated.[25]

** Small = 20-99 employees; medium = 100-499 employees; and large = at least 500 employees.*

*** Advanced technologies are new technologies that perform a new function or improve some function significantly more than commonly used technologies in the industry or by competitors.*

An emerging trend in PDR&D is the adoption of tools that integrate technologies and enable firms to manage the PDR&D process according to a product life cycle management (PLM) approach. PLM consists of managing all phases of a product's life cycle, from idea generation through to product retirement. Although PLM software that supports firms' product development efforts may integrate only a subset of all the tools required in the process, product data management is a core function of PLM solutions.

In general, PLM tools not only facilitate decision making at each stage of the process by enabling internal stakeholder access to relevant product information, but they also allow integration with supply chain partners. For example, integrating suppliers in the PDR&D process is facilitated with PLM systems that provide access to up-to-date product design data.[2] When product variants are based on a common platform, this ability is particularly crucial — for two reasons. First, changes in platform design need to be validated against all product configurations. Second, partners developing subcomponents or subsystems affected by platform design changes require timely notification and relevant details regarding such changes.[2]

Aerospace firms are also using simulation tools to support design-for-maintainability initiatives. Aircraft maintenance is a key component in end-users' total cost of ownership, and is therefore an important factor in purchase decisions. Chemical manufacturers are leveraging PLM capabilities in the design and development of their products to help achieve compliance with regulatory requirements. Finally, industrial electronics firms' compliance with environmental mandates can be facilitated with a PLM system that manages compliance from the early stages of product design by integrating component compliance data from suppliers while documenting overall product compliance.[2]

Best-in-Class Analysis —Advanced Technologies

Best-in-Class (BiC) manufacturing firms* are more than twice as likely as laggards to rely on PLM tools in their PDR&D processes. In addition, many BiC manufacturing firms utilize virtual prototyping to decrease product development costs by significantly reducing the need to produce physical prototypes. Virtual prototyping also reduces the overall PDR&D cycle by allowing design changes to be evaluated more quickly (Figure 22).[26]

Figure 22[24]

The adoption of design translation tools** is also a differentiating factor for BiC firms. R&D partnerships often involve stakeholders whose computer-aided design tools are not directly interoperable. BiC firms are four times more likely than laggards to have design translation capabilities that facilitate open innovation with their product innovation partners.[24]

Similarly, design collaboration tools also set BiC firms apart from their competitors. These include real-time virtual meeting tools that leverage advanced features such as prototype visualization and design modification and evaluation, allowing design changes to be explored in real-time during collaborative design sessions while significantly reducing the length of the product development cycle.[2]

** BiC firms are the top 20% performers in the following three metrics: percentage of products launched/delivered on time; increase in product revenue since engaging in a global PDR&D initiative; and decrease in PDR&D costs. Laggards represent the bottom 30% of firms benchmarked to the same metrics.*

*** "Design translation tools" refer to software solutions that convert computer-aided design (CAD) files from one format to another. These tools facilitate collaborative design when partners use CAD systems that are not interoperable.*

Final Remarks

Canadian manufacturers are at the forefront of new product commercialization and have the potential to continue enhancing their product innovation capacity. The findings presented in this report demonstrate that product design, research and development plays a vital role in the competitiveness of Canadian manufacturing industries. PDR&D helps manufacturers create, innovate and commercialize. It involves interplay between design, engineering and R&D, forming a systematic approach that integrates holistic thinking, research methods and strategic planning.

The findings presented in this report draw important linkages between the PDR&D process, product innovation, commercialization, export opportunities, IP and technology. These connections can help inform a continuous dialogue across businesses, governments and academia to continue to improve the competitive and dynamic business environment for the Canadian manufacturing industry.

Annex — Tables[6]

Table A-1

Manufacturers' response to increased competition, by size of firm* (2009)

	% of manufacturing firms		
	Small	Medium	Large
Change product price	63.5%	71.3%	67.6%
Introduce new product innovation	36.1%	39.7%	48.2%
Decrease time to market	26.1%	35.9%	43.1%
Change product quality	34.1%	42.9%	40.6%

Table A-2

Percentage of manufacturers who introduced new product innovations, by industry (2007– 2009)

Manufacturing	42.6%
Food manufacturing and beverage manufacturing	38.0%
Food manufacturing	36.5%
Animal food manufacturing	42.9%
Dairy product manufacturing	44.8%
Meat product manufacturing	29.7%
Seafood product preparation and packaging	9.8%
Bakery and tortillas manufacturing	35.3%
Beverage and tobacco product manufacturing	55.9%
Textile mills and textile product mills	45.9%
Textile mills	55.3%
Textile product mills	40.4%
Clothing manufacturing	34.7%
Cut and sew clothing manufacturing	30.6%
Leather and allied product manufacturing	61.7%
Wood product manufacturing	34.3%
Sawmills and wood preserving	31.6%
Veneer, plywood and engineered wood product manufacturing	25.6%
Other wood product manufacturing	38.2%
Paper manufacturing	33.8%
Pulp, paper, and paperboard mills	44.1%
Converted paper product manufacturing	31.5%
Printing and related support activities	29.1%
Petroleum and coal product manufacturing	50.1%
Chemical manufacturing	50.3%
Chemical manufacturing except pharmaceutical manufacturing	48.4%
Basic chemical manufacturing	43.2%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	47.0%
Pharmaceutical manufacturing	59.0%
Paint, coating and adhesive manufacturing	57.9%
Pesticide, fertilizer and other agricultural chemical manufacturing, soap, cleaning compound and toilet preparation manufacturing, and other chemical product manufacturing	47.2%
Plastics and rubber products manufacturing	57.8%

** Small = 20-99 employees, medium = 100-249 employees, and large = at least 250 employees.*

Table A-2 (cont.)

Plastic product manufacturing except motor vehicle plastic parts manufacturing	59.9%
Motor vehicle plastic parts manufacturing	61.9%
Rubber product manufacturing	42.2%
Non-metallic mineral product manufacturing	37.6%
Primary metal manufacturing	41.9%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	46.1%
Alumina and aluminum production and processing	36.6%
Ferrous metal foundries	29.7%
Non-ferrous metal foundries	48.3%
Fabricated metal product manufacturing	30.0%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	41.7%
Architectural and structural metals manufacturing	30.6%
Boiler, tank and shipping container manufacturing	42.2%
Machine shops, turned product and screw, nut and bolt manufacturing	19.2%
Coating, engraving, heat treatment and allied activities	15.1%
Machinery manufacturing	57.1%
Other machinery manufacturing*	59.9%
Mining and oil and gas field machinery manufacturing	40.4%
Sawmill and woodworking machinery manufacturing	50.3%
Rubber and plastics industry machinery manufacturing	57.8%
Computer and electronic product manufacturing	61.8%
Computers and peripheral equipment manufacturing	65.3%
Communications equipment manufacturing	67.6%
Telephone apparatus manufacturing	61.1%
Radio and television broadcasting and wireless communications equipment	73.3%
Semiconductor and other electronic components manufacturing	58.9%
Navigational and guidance instruments manufacturing	62.2%
Electrical equipment, appliance and component manufacturing	56.3%
Electrical lighting equipment manufacturing	74.8%
Household appliance manufacturing	72.6%
Electric equipment manufacturing	47.4%
Other electrical equipment and component manufacturing	52.7%
Motor vehicle manufacturing	44.4%
Motor vehicle body and trailer manufacturing	47.9%
Motor vehicle parts manufacturing	39.3%
Aerospace product and parts manufacturing	48.4%
Railroad rolling stock manufacturing	54.5%
Ship and boat building	43.5%
Other transportation equipment manufacturing	43.8%
Furniture and related product manufacturing	37.8%
Miscellaneous manufacturing	52.6%
Medical equipment and supplies manufacturing	70.1%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing.*

Table A-3

Percentage of manufacturers who involved outside organizations in the development of product innovations, by industry (2007– 2009)

Manufacturing	27.1%
Food manufacturing and beverage manufacturing	29.4%
Food manufacturing	28.7%
Dairy product manufacturing	25.2%
Textile mills and textile product mills	35.6%
Textile mills	29.7%
Clothing manufacturing	15.9%
Cut and sew clothing manufacturing	15.9%
Leather and allied product manufacturing	35.6%
Wood product manufacturing	32.3%
Veneer, plywood and engineered wood product manufacturing	7.5%
Paper manufacturing	28.4%
Pulp, paper, and paperboard mills	11.0%
Converted paper product manufacturing	33.2%
Petroleum and coal product manufacturing	35.6%
Chemical manufacturing	25.7%
Chemical manufacturing except pharmaceutical manufacturing	21.7%
Basic chemical manufacturing	11.4%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	36.3%
Pharmaceutical manufacturing	41.7%
Paint, coating and adhesive manufacturing	11.7%
Pesticide, fertilizer and other agricultural chemical manufacturing, soap, cleaning compound and toilet preparation manufacturing, and other chemical product manufacturing	24.7%
Plastics and rubber products manufacturing	41.5%
Plastic product manufacturing except motor vehicle plastic parts manufacturing	42.3%
Motor vehicle plastic parts manufacturing	38.4%
Non-metallic mineral product manufacturing	37.0%
Primary metal manufacturing	21.7%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	23.0%
Ferrous metal foundries	15.4%
Non-ferrous metal foundries	9.9%
Fabricated metal product manufacturing	26.3%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	22.8%
Architectural and structural metals manufacturing	17.6%
Machinery manufacturing	13.4%
Other machinery manufacturing*	15.2%
Sawmill and woodworking machinery manufacturing	27.5%
Rubber and plastics industry machinery manufacturing	0.0%
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	9.6%
Metalworking machinery manufacturing	5.5%
Computer and electronic product manufacturing	17.8%
Computers and peripheral equipment manufacturing	17.2%
Communications equipment manufacturing	9.6%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing.*

Table A-3 (cont.)

Telephone apparatus manufacturing	9.1%
Radio and television broadcasting and wireless communications equipment	8.9%
Semiconductor and other electronic components manufacturing	33.1%
Navigational and guidance instruments manufacturing	10.8%
Electrical equipment, appliance and component manufacturing	18.4%
Electrical lighting equipment manufacturing	29.0%
Household appliance manufacturing	24.8%
Electric equipment manufacturing	25.3%
Other electrical equipment and component manufacturing	5.2%
Transportation equipment manufacturing	24.3%
Motor vehicle manufacturing	11.1%
Motor vehicle body and trailer manufacturing	16.3%
Motor vehicle parts manufacturing	25.8%
Aerospace product and parts manufacturing	27.8%
Railroad rolling stock manufacturing	33.3%
Ship and boat building	27.7%
Furniture and related product manufacturing	19.6%
Miscellaneous manufacturing	31.4%

Table A-4

Percentage of manufacturers (250+ employees) whose research and development decisions were made by or jointly with foreign parent, by industry (2009)

	R&D Location	R&D Focus
Manufacturing	34.6%	34.2%
Food manufacturing and beverage manufacturing	22.4%	17.8%
Food manufacturing	21.1%	16.9%
Fruit and vegetable preserving and specialty food manufacturing	30.8%	23.1%
Dairy product manufacturing	22.2%	11.1%
Meat product manufacturing	0.0%	0.0%
Seafood product preparation and packaging	5.3%	5.3%
Beverage and tobacco product manufacturing	33.3%	26.3%
Clothing manufacturing	0.0%	0.0%
Cut and sew clothing manufacturing	0.0%	0.0%
Wood product manufacturing	12.1%	21.5%
Sawmills and wood preserving	0.0%	9.1%
Other wood product manufacturing	16.7%	25.0%
Paper manufacturing	41.1%	43.8%
Pulp, paper, and paperboard mills	33.3%	33.4%
Converted paper product manufacturing	50.0%	55.5%
Printing and related support activities	35.0%	30.0%
Chemical manufacturing	62.3%	55.9%
Chemical manufacturing except pharmaceutical manufacturing	50.3%	56.7%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	71.5%	71.5%
Pharmaceutical manufacturing	81.8%	54.6%
Plastics and rubber products manufacturing	34.0%	34.0%
Plastic product manufacturing except motor vehicle plastic parts manufacturing	27.5%	27.5%
Non-metallic mineral product manufacturing	52.0%	68.0%

Table A-4 (cont.)

Primary metal manufacturing	56.4%	56.4%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	50.0%	50.0%
Fabricated metal product manufacturing	26.4%	31.0%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	38.9%	44.4%
Architectural and structural metals manufacturing	18.8%	18.8%
Machinery manufacturing	33.8%	24.8%
Other machinery manufacturing*	38.7%	25.8%
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	14.3%	14.3%
Metalworking machinery manufacturing	0.0%	0.0%
Computer and electronic product manufacturing	40.9%	39.1%
Communications equipment manufacturing	27.2%	29.9%
Navigational and guidance instruments manufacturing	54.6%	54.6%
Electrical equipment, appliance and component manufacturing	46.0%	50.7%
Transportation equipment manufacturing	44.8%	41.7%
Motor vehicle body and trailer manufacturing	0.0%	11.1%
Motor vehicle parts manufacturing	51.1%	46.7%
Aerospace product and parts manufacturing	46.2%	38.5%
Furniture and related product manufacturing	16.7%	25.0%
Miscellaneous manufacturing	29.5%	29.5%

Table A-5

Percentage of manufacturers who performed internal and/or outsourced research and development activities, by size of firm (2009)**

	In Canada		Outside of Canada	
	Internal	Outsourced	Internal	Outsourced
Small	70.3%	9.4%	5.0%	1.1%
Medium	74.3%	8.9%	14.4%	2.3%
Large	72.2%	11.9%	30.5%	7.4%

Table A-6

Percentage of manufacturers (250+ employees) who performed internal and/or outsourced research and development activities, by industry (2009)

	In Canada		Outside of Canada	
	Internal	Outsourced	Internal	Outsourced
Manufacturing	72.2%	11.9%	30.5%	7.4%
Food manufacturing and beverage manufacturing	74.7%	16.5%	19.4%	9.7%
Food manufacturing	77.6%	15.5%	16.8%	5.9%
Fruit and vegetable preserving and specialty food manufacturing	61.5%	0.0%	30.8%	0.0%
Meat product manufacturing	88.9%	16.7%	0.0%	0.0%
Seafood product preparation and packaging	73.7%	31.6%	15.8%	15.8%
Bakery and tortillas manufacturing	83.3%	0.0%	16.7%	8.3%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing*

*** Small = 20-99 employees, medium = 100-249 employees, and large = at least 250 employees.*

Table A-6 (cont.)

Beverage and tobacco product manufacturing	52.5%	21.3%	35.4%	35.4%
Clothing manufacturing	85.7%	14.3%	10.6%	7.2%
Cut and sew clothing manufacturing	81.8%	18.2%	0.0%	9.1%
Wood product manufacturing	69.2%	12.6%	11.8%	0.0%
Sawmills and wood preserving	90.9%	9.1%	0.0%	0.0%
Paper manufacturing	67.3%	20.0%	27.1%	13.7%
Pulp, paper, and paperboard mills	77.8%	27.8%	16.7%	11.1%
Converted paper product manufacturing	55.6%	11.1%	38.9%	16.7%
Printing and related support activities	60.0%	0.0%	40.0%	0.0%
Chemical manufacturing	62.6%	3.5%	57.5%	20.6%
Chemical manufacturing except pharmaceutical manufacturing	61.9%	0.0%	59.4%	11.0%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	85.7%	0.0%	85.7%	0.0%
Pharmaceutical manufacturing	63.6%	9.1%	54.5%	36.4%
Plastics and rubber products manufacturing	77.7%	12.4%	30.1%	8.8%
Plastic product manufacturing except motor vehicle plastic parts manufacturing	72.5%	15.0%	30.0%	7.5%
Non-metallic mineral product manufacturing	56.0%	0.0%	44.0%	0.0%
Primary metal manufacturing	71.3%	6.8%	21.5%	3.0%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	77.3%	4.5%	18.2%	4.5%
Fabricated metal product manufacturing	60.5%	14.9%	31.0%	6.5%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	55.6%	16.7%	50.0%	11.1%
Architectural and structural metals manufacturing	68.8%	25.0%	12.5%	6.3%
Machinery manufacturing	73.5%	10.8%	30.7%	1.7%
Other machinery manufacturing *	74.2%	12.9%	41.9%	0.0%
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	85.7%	0.0%	0.0%	0.0%
Computer and electronic product manufacturing	90.8%	13.8%	35.8%	7.8%
Communications equipment manufacturing	100.0%	7.6%	30.4%	7.6%
Radio and television broadcasting and wireless communications equipment	100.0%	12.5%	50.0%	12.5%
Navigational and guidance instruments manufacturing	100.0%	0.0%	63.6%	0.0%
Electrical equipment, appliance and component manufacturing	88.6%	24.9%	50.7%	14.9%
Transportation equipment manufacturing	63.3%	14.9%	35.9%	6.3%
Motor vehicle body and trailer manufacturing	88.9%	22.2%	11.1%	0.0%
Motor vehicle parts manufacturing	53.3%	6.7%	35.6%	4.4%
Aerospace product and parts manufacturing	92.3%	30.8%	46.2%	7.7%
Furniture and related product manufacturing	86.1%	5.6%	16.7%	2.8%
Miscellaneous manufacturing	64.6%	5.9%	29.4%	0.0%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing.*

Table A-7

Percentage of manufacturers who invested in product design, research and development facilities in Canada, by size of firm* (2007– 2009)

	Engineering			Research and Development		
	Obtained capacity by merger or acquisition	Opened new facility or expanded capacity	Closed an existing facility or contracted capacity	Obtained capacity by merger or acquisition	Opened new facility or expanded capacity	Closed an existing facility or contracted capacity
Small	2.7%	5.8%	1.7%	3.0%	7.7%	1.9%
Medium	2.6%	7.5%	1.6%	2.3%	8.0%	1.8%
Large	5.7%	6.2%	5.3%	3.9%	10.5%	4.8%

Table A-8

Percentage of manufacturers who invested in product design, research and development facilities in Canada, by industry (2007– 2009)

	Obtained capacity by merger or acquisition	Opened new facility or expanded capacity	Closed an existing facility or contracted capacity
Manufacturing	3.0%	7.9%	2.1%
Food manufacturing and beverage manufacturing	2.1%	7.1%	0.3%
Food manufacturing	2.3%	7.2%	0.3%
Animal food manufacturing	7.1%	0.0%	0.0%
Fruit and vegetable preserving and specialty food manufacturing	8.6%	10.7%	2.5%
Dairy product manufacturing	0.0%	15.0%	0.0%
Meat product manufacturing	5.4%	6.5%	0.0%
Seafood product preparation and packaging	0.7%	0.0%	0.7%
Bakery and tortillas manufacturing	0.0%	11.3%	0.0%
Beverage and tobacco product manufacturing	0.0%	6.1%	0.0%
Beverage manufacturing	0.0%	5.5%	0.0%
Textile mills and textile product mills	4.5%	7.6%	3.2%
Textile mills	5.3%	5.0%	5.2%
Textile product mills	4.1%	9.1%	2.0%
Clothing manufacturing	0.5%	6.7%	2.3%
Cut and sew clothing manufacturing	0.0%	6.2%	2.7%
Leather and allied product manufacturing	0.0%	4.7%	2.8%
Wood product manufacturing	4.0%	7.0%	1.5%
Sawmills and wood preserving	0.0%	5.9%	1.4%
Veneer, plywood and engineered wood product manufacturing	5.7%	6.8%	2.8%
Other wood product manufacturing	5.6%	7.6%	1.1%
Paper manufacturing	3.0%	3.0%	3.1%
Pulp, paper, and paperboard mills	0.0%	0.0%	2.8%
Converted paper product manufacturing	3.7%	3.7%	3.1%
Printing and related support activities	5.2%	2.0%	1.7%
Petroleum and coal product manufacturing	3.9%	3.8%	3.9%
Chemical manufacturing	2.9%	14.2%	1.9%
Chemical manufacturing except pharmaceutical manufacturing	3.1%	13.7%	0.9%
Basic chemical manufacturing	5.7%	3.1%	0.0%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	6.4%	15.4%	5.2%
Pharmaceutical manufacturing	2.0%	16.3%	6.6%
Paint, coating and adhesive manufacturing	1.9%	13.6%	0.0%
Pesticide, fertilizer and other agricultural chemical manufacturing, soap, cleaning compound and toilet preparation manufacturing, and other chemical product manufacturing	2.1%	16.5%	0.6%

** Small = 20-99 employees, medium = 100-249 employees, and large = at least 250 employees.*

Table A-8 (cont.)

Plastics and rubber products manufacturing	3.1%	7.9%	1.0%
Plastic product manufacturing except motor vehicle plastic parts manufacturing	2.3%	8.1%	0.5%
Motor vehicle plastic parts manufacturing	12.6%	6.3%	3.5%
Rubber product manufacturing	2.7%	7.8%	2.7%
Non-metallic mineral product manufacturing	4.1%	4.1%	0.6%
Primary metal manufacturing	5.7%	4.8%	0.5%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	6.3%	5.0%	1.1%
Alumina and aluminum production and processing	4.6%	0.0%	0.0%
Ferrous metal foundries	6.6%	3.5%	0.0%
Non-ferrous metal foundries	4.1%	9.6%	0.0%
Fabricated metal product manufacturing	2.7%	10.8%	0.9%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	0.8%	12.0%	0.0%
Architectural and structural metals manufacturing	4.8%	14.6%	0.2%
Boiler, tank and shipping container manufacturing	6.0%	15.6%	0.0%
Machine shops, turned product and screw, nut and bolt manufacturing	0.0%	5.1%	0.0%
Coating, engraving, heat treatment and allied activities	2.9%	2.9%	8.6%
Machinery manufacturing	4.5%	9.1%	1.8%
Other machinery manufacturing *	2.8%	8.3%	2.4%
Mining and oil and gas field machinery manufacturing	4.6%	13.1%	1.0%
Sawmill and woodworking machinery manufacturing	12.7%	0.0%	0.0%
Rubber and plastics industry machinery manufacturing	5.2%	5.2%	0.0%
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	14.2%	18.1%	3.4%
Metalworking machinery manufacturing	3.1%	6.4%	0.0%
Computer and electronic product manufacturing	5.2%	11.5%	5.9%
Computers and peripheral equipment manufacturing	0.0%	22.1%	7.4%
Communications equipment manufacturing	8.9%	17.7%	4.1%
Telephone apparatus manufacturing	5.6%	22.2%	5.6%
Radio and television broadcasting and wireless communications equipment	14.6%	14.1%	5.6%
Semiconductor and other electronic components manufacturing	7.3%	17.8%	4.0%
Navigational and guidance instruments manufacturing	4.2%	4.3%	9.1%
Electrical equipment, appliance and component manufacturing	2.7%	15.4%	3.7%
Electrical lighting equipment manufacturing	0.0%	23.9%	4.6%
Household appliance manufacturing	9.0%	0.0%	0.0%
Electric equipment manufacturing	3.0%	13.9%	6.7%
Other electrical equipment and component manufacturing	1.4%	18.3%	1.6%
Transportation equipment manufacturing	1.6%	4.2%	5.2%
Motor vehicle manufacturing	5.6%	22.2%	0.0%
Motor vehicle body and trailer manufacturing	0.6%	1.7%	4.5%
Motor vehicle parts manufacturing	1.8%	1.3%	7.9%
Aerospace product and parts manufacturing	0.0%	11.8%	3.6%
Railroad rolling stock manufacturing	0.0%	9.1%	0.0%
Ship and boat building	2.7%	0.0%	0.0%
Other transportation equipment manufacturing	6.3%	12.5%	6.3%
Furniture and related product manufacturing	0.3%	6.9%	3.7%
Miscellaneous manufacturing	0.6%	6.4%	5.6%
Medical equipment and supplies manufacturing	0.7%	6.3%	12.4%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing.*

Table A-9

Percentage of manufacturers who invested in product design, research and development facilities outside of Canada, by size of firm* (2007– 2009)

	Engineering			Research and Development		
	Obtained capacity by merger or acquisition	Opened new facility or expanded capacity	Closed an existing facility or contracted capacity	Obtained capacity by merger or acquisition	Opened new facility or expanded capacity	Closed an existing facility or contracted capacity
Small	1.9%	2.0%	0.3%	2.5%	1.3%	0.7%
Medium	1.9%	2.9%	1.3%	1.8%	2.6%	2.1%
Large	8.2%	5.9%	4.2%	8.1%	7.9%	3.4%

Table A-10

Percentage of manufacturers who indicated intellectual property as an obstacle to innovation, by industry (2009)

Manufacturing	8.0%
Food manufacturing and beverage manufacturing	7.4%
Food manufacturing	7.4%
Animal food manufacturing	21.8%
Fruit and vegetable preserving and specialty food manufacturing	4.9%
Dairy product manufacturing	4.5%
Meat product manufacturing	3.1%
Seafood product preparation and packaging	2.9%
Bakery and tortillas manufacturing	3.1%
Beverage and tobacco product manufacturing	6.9%
Beverage manufacturing	7.3%
Textile mills and textile product mills	13.4%
Textile mills	8.5%
Textile product mills	16.3%
Clothing manufacturing	2.1%
Cut and sew clothing manufacturing	0.0%
Leather and allied product manufacturing	14.2%
Wood product manufacturing	3.3%
Sawmills and wood preserving	6.5%
Veneer, plywood and engineered wood product manufacturing	5.7%
Other wood product manufacturing	0.9%
Paper manufacturing	4.4%
Pulp, paper, and paperboard mills	10.0%
Converted paper product manufacturing	3.2%
Printing and related support activities	2.0%
Petroleum and coal product manufacturing	7.7%
Chemical manufacturing	17.5%
Chemical manufacturing except pharmaceutical manufacturing	15.9%
Basic chemical manufacturing	11.3%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	11.3%
Pharmaceutical manufacturing	24.4%
Paint, coating and adhesive manufacturing	17.0%
Pesticide, fertilizer and other agricultural chemical manufacturing, soap, cleaning compound and toilet preparation manufacturing, and other chemical product manufacturing	17.8%
Plastics and rubber products manufacturing	14.6%

** Small = 20-99 employees, medium = 100-249 employees, and large = at least 250 employees.*

Table A-10 (cont.)

Plastic product manufacturing except motor vehicle plastic parts manufacturing	15.1%
Motor vehicle plastic parts manufacturing	10.5%
Rubber product manufacturing	13.3%
Non-metallic mineral product manufacturing	3.8%
Primary metal manufacturing	3.5%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	6.0%
Alumina and aluminum production and processing	0.0%
Ferrous metal foundries	3.1%
Non-ferrous metal foundries	0.0%
Fabricated metal product manufacturing	4.1%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	3.3%
Architectural and structural metals manufacturing	2.9%
Boiler, tank and shipping container manufacturing	3.0%
Machine shops, turned product and screw, nut and bolt manufacturing	6.2%
Coating, engraving, heat treatment and allied activities	6.5%
Machinery manufacturing	13.6%
Other machinery manufacturing*	14.6%
Mining and oil and gas field machinery manufacturing	10.4%
Sawmill and woodworking machinery manufacturing	25.0%
Rubber and plastics industry machinery manufacturing	20.8%
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	15.3%
Metalworking machinery manufacturing	9.2%
Computer and electronic product manufacturing	16.7%
Computers and peripheral equipment manufacturing	15.3%
Communications equipment manufacturing	20.4%
Telephone apparatus manufacturing	22.2%
Radio and television broadcasting and wireless communications equipment	29.9%
Semiconductor and other electronic components manufacturing	16.5%
Navigational and guidance instruments manufacturing	18.9%
Electrical equipment, appliance and component manufacturing	19.5%
Electrical lighting equipment manufacturing	20.0%
Household appliance manufacturing	27.2%
Electric equipment manufacturing	9.4%
Other electrical equipment and component manufacturing	27.0%
Transportation equipment manufacturing	7.7%
Motor vehicle manufacturing	11.1%
Motor vehicle body and trailer manufacturing	4.7%
Motor vehicle parts manufacturing	6.6%
Aerospace product and parts manufacturing	8.3%
Railroad rolling stock manufacturing	9.1%
Ship and boat building	16.4%
Other transportation equipment manufacturing	12.5%
Furniture and related product manufacturing	3.6%
Miscellaneous manufacturing	7.3%
Medical equipment and supplies manufacturing	11.6%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing.*

Table A-11

Percentage of manufacturers who indicated intellectual property violation as a significant obstacle to exporting, by industry (2007– 2009)

Manufacturing	15.2%
Food manufacturing and beverage manufacturing	13.7%
Food manufacturing	14.0%
Animal food manufacturing	0.0%
Fruit and vegetable preserving and specialty food manufacturing	10.6%
Meat product manufacturing	0.0%
Seafood product preparation and packaging	5.6%
Beverage and tobacco product manufacturing	9.4%
Beverage manufacturing	7.5%
Textile mills and textile product mills	22.4%
Textile mills	27.2%
Textile product mills	18.2%
Clothing manufacturing	23.9%
Leather and allied product manufacturing	12.2%
Wood product manufacturing	2.9%
Sawmills and wood preserving	9.0%
Veneer, plywood and engineered wood product manufacturing	0.0%
Other wood product manufacturing	0.0%
Paper manufacturing	5.7%
Pulp, paper, and paperboard mills	8.7%
Converted paper product manufacturing	4.7%
Printing and related support activities	7.0%
Petroleum and coal product manufacturing	18.9%
Chemical manufacturing	17.3%
Chemical manufacturing except pharmaceutical manufacturing	12.6%
Basic chemical manufacturing	3.5%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	0.0%
Pharmaceutical manufacturing	35.6%
Paint, coating and adhesive manufacturing	13.9%
Pesticide, fertilizer and other agricultural chemical manufacturing, soap, cleaning compound and toilet preparation manufacturing, and other chemical product manufacturing	19.6%
Plastics and rubber products manufacturing	13.9%
Plastic product manufacturing except motor vehicle plastic parts manufacturing	14.2%
Motor vehicle plastic parts manufacturing	26.6%
Rubber product manufacturing	6.3%
Non-metallic mineral product manufacturing	22.0%
Primary metal manufacturing	9.3%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	10.8%
Alumina and aluminum production and processing	14.4%
Ferrous metal foundries	0.0%
Non-ferrous metal foundries	11.8%
Fabricated metal product manufacturing	9.9%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	17.7%
Architectural and structural metals manufacturing	0.8%
Boiler, tank and shipping container manufacturing	5.6%
Coating, engraving, heat treatment and allied activities	0.0%
Machinery manufacturing	25.9%

Table A-11 (cont.)

Other machinery manufacturing*	30.2%
Mining and oil and gas field machinery manufacturing	20.6%
Sawmill and woodworking machinery manufacturing	18.5%
Rubber and plastics industry machinery manufacturing	18.6%
Metalworking machinery manufacturing	11.4%
Computer and electronic product manufacturing	20.7%
Computers and peripheral equipment manufacturing	24.2%
Communications equipment manufacturing	38.3%
Telephone apparatus manufacturing	40.0%
Radio and television broadcasting and wireless communications equipment	36.6%
Semiconductor and other electronic components manufacturing	9.3%
Navigational and guidance instruments manufacturing	17.9%
Electrical equipment, appliance and component manufacturing	23.3%
Electrical lighting equipment manufacturing	14.6%
Household appliance manufacturing	39.9%
Electric equipment manufacturing	24.5%
Other electrical equipment and component manufacturing	18.3%
Transportation equipment manufacturing	17.4%
Motor vehicle body and trailer manufacturing	20.5%
Motor vehicle parts manufacturing	12.1%
Aerospace product and parts manufacturing	24.3%
Railroad rolling stock manufacturing	30.0%
Ship and boat building	31.0%
Furniture and related product manufacturing	4.1%
Miscellaneous manufacturing	20.8%

Table A-12

Percentage of manufacturers who adopted advanced computerized design and engineering technology, by industry (2009)

Manufacturing	42.2%
Food manufacturing and beverage manufacturing	16.9%
Food manufacturing	17.5%
Animal food manufacturing	17.0%
Fruit and vegetable preserving and specialty food manufacturing	20.6%
Dairy product manufacturing	20.9%
Meat product manufacturing	16.8%
Seafood product preparation and packaging	6.5%
Bakery and tortillas manufacturing	14.6%
Beverage and tobacco product manufacturing	7.7%
Beverage manufacturing	8.2%
Textile mills and textile product mills	31.3%
Textile mills	33.0%
Textile product mills	30.3%
Clothing manufacturing	27.9%
Cut and sew clothing manufacturing	30.8%
Leather and allied product manufacturing	21.7%
Wood product manufacturing	36.0%
Sawmills and wood preserving	19.7%
Paper manufacturing	30.3%
Pulp, paper, and paperboard mills	21.4%
Converted paper product manufacturing	32.3%
Printing and related support activities	28.7%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing.*

Table A-12 (cont.)

Petroleum and coal product manufacturing	23.0%
Chemical manufacturing	17.9%
Chemical manufacturing except pharmaceutical manufacturing	17.1%
Basic chemical manufacturing	18.3%
Resin synthetic rubber and artificial synthetic fibres and filaments manufacturing	37.6%
Pharmaceutical manufacturing	21.2%
Paint, coating and adhesive manufacturing	15.5%
Pesticide, fertilizer and other agricultural chemical manufacturing, soap, cleaning compound and toilet preparation manufacturing, and other chemical product manufacturing	13.5%
Plastics and rubber products manufacturing	48.9%
Plastic product manufacturing except motor vehicle plastic parts manufacturing	50.7%
Motor vehicle plastic parts manufacturing	55.7%
Rubber product manufacturing	34.0%
Non-metallic mineral product manufacturing	36.8%
Primary metal manufacturing	42.8%
Iron and steel mills and ferro-alloy manufacturing; steel product manufacturing from purchased steel; non-ferrous metal (except aluminium) production and process	31.6%
Alumina and aluminum production and processing	36.3%
Ferrous metal foundries	55.9%
Non-ferrous metal foundries	65.3%
Fabricated metal product manufacturing	45.0%
Forging and stamping; cutlery and hand tool manufacturing; hardware manufacturing; spring and wire product manufacturing; other fabricated metal product manufacturing	52.2%
Architectural and structural metals manufacturing	45.6%
Boiler, tank and shipping container manufacturing	64.4%
Machine shops, turned product and screw, nut and bolt manufacturing	43.2%
Coating, engraving, heat treatment and allied activities	12.2%
Machinery manufacturing	66.6%
Other machinery manufacturing*	61.7%
Mining and oil and gas field machinery manufacturing	54.0%
Sawmill and woodworking machinery manufacturing	72.3%
Rubber and plastics industry machinery manufacturing	68.5%
Metalworking machinery manufacturing	82.6%
Computer and electronic product manufacturing	63.4%
Computers and peripheral equipment manufacturing	46.0%
Communications equipment manufacturing	77.1%
Telephone apparatus manufacturing	61.1%
Radio and television broadcasting and wireless communications equipment	76.7%
Semiconductor and other electronic components manufacturing	70.2%
Navigational and guidance instruments manufacturing	61.1%
Electrical equipment, appliance and component manufacturing	60.9%
Electrical lighting equipment manufacturing	58.9%
Household appliance manufacturing	68.1%
Electric equipment manufacturing	67.7%
Other electrical equipment and component manufacturing	52.6%
Transportation equipment manufacturing	55.0%
Motor vehicle manufacturing	66.7%
Motor vehicle body and trailer manufacturing	57.7%
Motor vehicle parts manufacturing	54.9%
Aerospace product and parts manufacturing	60.0%
Railroad rolling stock manufacturing	72.7%
Ship and boat building	29.8%
Other transportation equipment manufacturing	56.3%
Furniture and related product manufacturing	49.0%
Miscellaneous manufacturing	50.0%

** Machinery manufacturing except mining and oil and gas field machinery manufacturing; sawmill and woodworking machinery manufacturing; rubber and plastics industry machinery manufacturing; ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing; and metalworking machinery manufacturing.*

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