PRODUCT DESIGN AND DEVELOPMENT:
A Canadian Manufacturing Perspective

DESIGN EXCHANGE
PROMOTING CANADIAN DESIGN

Canadian Manufacturers & Exporters

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PRODUCT DESIGN AND DEVELOPMENT
A Canadian manufacturing perspective

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Executive summary

Defined as the design of all the goods and services that compose the process through which a good or service is created, product design and development (PD&D) has been brought to the forefront of international competitiveness by the shift from trade in goods and services to trade in tasks.[1]

Citing cost pressures and global competition as the two top drivers for global PD&D, close to 60% of North American firms have global design strategies in place and more than 40% are currently pursuing global design networks.[4] Given this context, Canadian manufacturers need metrics that allow benchmarking for PD&D tasks in order to facilitate investment in key areas of PD&D.

PD&D investment

Investment in PD&D can be done either in-house or through outsourcing (domestic or foreign). In-house PD&D is defined as the internal investment that a firm makes in terms of the personnel and capital related to PD&D. Outsourced PD&D is defined as the purchase of PD&D services from service providers.

Overall investment in PD&D as percentage of sales, increased by 29% for Canadian manufacturers between 1991 and 2004. While both in-house PD&D investment and outsourcing increased, it was outsourcing that contributed the most to this trend.[7]

Data at the manufacturing sub-sector level is mixed, with some sectors such as computer and electronics more than doubling their investment in PD&D as percentage of sales for the same time period, while others such as clothing manufacturing saw a decrease in this metric.

Key performance indicators (KPIs)

The top three PD&D KPIs have been identified by firms as being time to market, new product success rate, and percentage of revenue from new products.[9]

Canadian manufacturers had an average percentage of revenue from new products of 16.1%. This KPI varies by sector, being highest for semiconductor and other electronic component manufacturers (32.4%) and lowest for sawmills and wood preservation (9.8%).[10]

Canadian manufacturers had an average time to market for new products (defined as the time it takes from the conceptualization of a product to its delivery to the market) of 13.7 months between 2002 and 2004. This KPI varies between sectors, with pharmaceutical and medicine manufacturers having the highest (27.5 months) and pulp, paper and paperboard mills the lowest (9.2 months).[10]

Best in class analysis

Best in class firms (BiC) are defined as the ones who have more than 35% of their revenue that comes from new or significantly improved products.[14]

BiC practices vary widely by sector. In comparison to laggards, BiC firms invest more in PD&D. More BiC firms have R&D dedicated teams, use commercialization techniques and market research. More specifically, more BiC firms use post-introduction advertising campaigns, distribution agreements, international marketing partnership and after-sales consumer feedback.

Size of firm analysis

Small and medium enterprises (SMEs) are defined as firms with less than 25 million Canadian dollars of revenue. More have R&D and marketing dedicated personnel than large firms. Yet, they do not introduce more new products to market and their percentage of revenue from new product is only slightly above that of large firms (16 vs. 15%).[14]

It is interesting to note that there is no difference in the percentage of SMEs and large firms citing lack of funds as an impediment to PD&D. SMEs use less intellectual property (IP) right protection tools than large firms. This is true for both formal and strategic IP tools.

Introduction

The shift from trade in goods and services to trade in tasks brings product design and development (PD&D) to the forefront of international competitiveness. Trade in tasks means that a product might be designed in one country, integrated in another and mass produced in a different one.

This shift[1] implies that globalization is causing major re-adjustments by creating pressures to not only reallocate resources across sectors, but also within firms and their workforce.[2] In this context, firms that have a better understanding of how high value added tasks are being integrated in Canada, how much is invested and what returns they produce, will have a competitive edge in national and international markets.

Defined as the design of all the goods and services that compose the process through which a good or a service is created,[3] the PD&D task has not escaped this global trend. Citing cost pressures and global competition as the two top drivers for global PD&D, close to 60% of North American firms have global design strategies in place and more than 40% are currently pursuing global design networks.[4]

Canadian manufacturers need metrics that allow benchmarking practices for PD&D tasks in order to facilitate increased investment in PD&D. This can improve their access to global value chains, their competitiveness and their penetration of new national and international markets.

Industry Canada partnered with the Design Exchange (DX) research committee and the Canadian Manufacturers and Exporters (CME) to initiate research on PD&D metrics and benchmarking as the first step in the PD&D initiative.

This study provides firms with practical metrics that can be used to benchmark their levels of investment and performance in PD&D, as well as a best in class analysis that can be used to determine what best performers are doing differently from the rest.

The first section provides manufacturers with a detailed picture of the level of in-house and outsourced investment in PD&D in Canada and compares it with that of the United States (U.S.). The second section looks at PD&D key performance indicators (KPIs) for manufacturing in Canada and compares the performance in terms of these KPIs with the U.S. The third section provides a best in class analysis, allowing firms to look at what PD&D best in class firms are doing differently. The last section provides an analysis by size of firm.

Together, the four sections allow firms to benchmark their PD&D investment and performance against their own specific subsector in Canada and the U.S., as well as to understand what differentiates PD&D best in class firms.

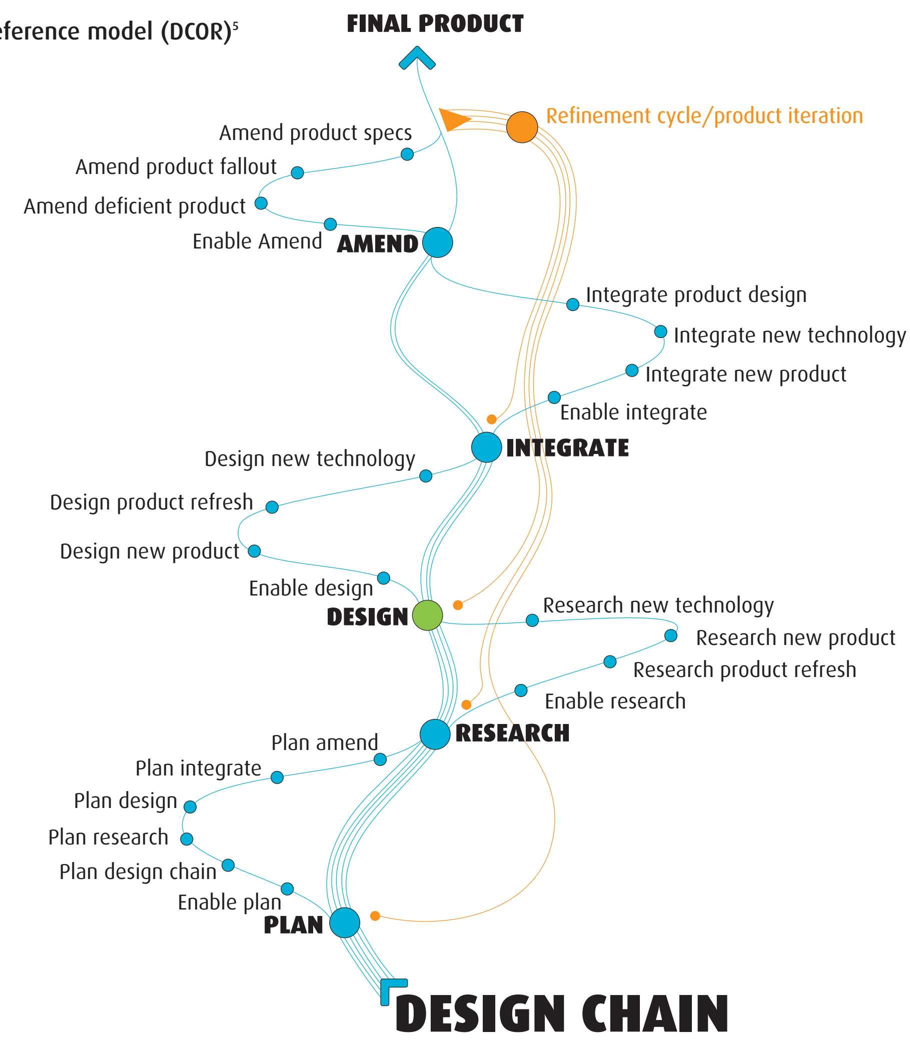
Impact of PD&D

With six major phases that span from the conceptualization of the product to its production and end with its commercialization, the PD&D chain of operations (Figure 1) illustrates how this activity is incorporated into many different steps of the production process. It is targeted to both reactive and pro-active PD&D projects.

The initial phase, planning, is defined as the moment when an idea or a necessity driven by market or technological pressures appears, and the plan that is developed in order to answer this necessity. This is followed by the research phase, when specific research is done in order to determine whether or not the initial issue can be solved. The third phase is the design one. It is at this point in time that the first prototypes are designed and tests are performed. The following two phases, integration and amendment are part of the manufacturing process. The integration phase incorporates the prototypes into the manufacturing process, while the amendment phase is designed to answer any issues

FIGURE 1

Design chain reference model (DCOR)[5]



Supply Chain Council (SCC), 2007, "Design chain operations reference model 1.0" that might appear during the integration and to determine which of the previous four steps need to be revised. The final step, not included in Figure one, is commercialization. It refers to the commercialization efforts and investment for a given product.

All of these phases are highly integrated, with multiple level synergies between each of them. For instance, while performing the third phase, design, the model allows for a backward and forward two way dialogue with all other phases. Designers will be in constant communication with engineers and researchers in the second phase to better understand the technology behind the new product. This will allow them to integrate it, and improve it, as best as possible. At the same time, they will be in constant communication with technicians and engineers in the fourth phase to produce a design that will be compatible and easy to integrate during prototyping and manufacturing. R&D is defined by Statistics Canada as the "systematic investigation carried out in the natural and engineering sciences by means of experiment or analysis to achieve a scientific or technological advance"*. In the DCOR model these activities are mainly captured in the Research phase. Although not explicit in the DCOR model, marketing managers are included in this study to the extent that they contribute to the development of a new product.

The impact of PD&D in the competitiveness of firms is extremely important. Best in class firms in terms of PD&D are able to develop important improvement and efficiencies in their product design chain operations.

For instance, research from Aberdeen Group shows that North American best performers‡ are able to bring complex products to market 99 days earlier than laggards on average. This advantage is still significant for average and simple products (77 and 79 days respectively).

* Source: Statistics Canada, "Research and Development in Canadian Industry"

‡ Best performers are defined as the top 20% in terms of product revenue targets, product and development cost targets, product launch dates, and product quality expectations.

PD&D investment

Investment in PD&D can be done either in-house or through outsourcing (domestic or foreign). In-house PD&D is defined as the internal investment that a firm makes in terms of the personnel and capital related to PD&D. Outsourced PD&D is defined as the purchase of PD&D services from service providers (for more information on the methodology, please see Annex II).

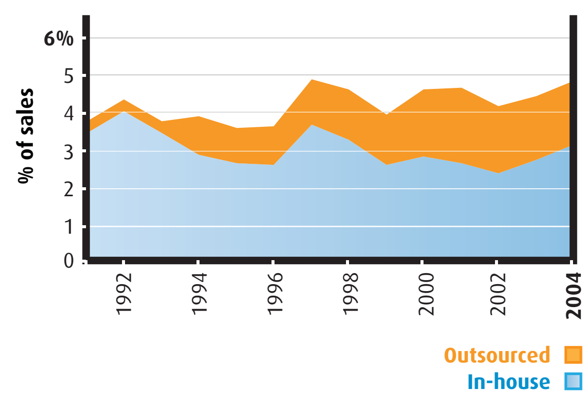
This section looks at investment trends in PD&D in Canada for manufacturers and select sub-sectors. It then compares investment in Canada with that in the U.S.

I. Canadian perspective

As the next figure shows, investment in PD&D in Canada, as percentage of sales, has increased 29% since 1991.[7]

FIGURE 2

PD&D investment in Canada, manufacturing average as percentage of sales[7]



Although investment in PD&D seems to be variable, with periods of strong growth (1996-1997, 1999-2000 and 2002-2004), it is interesting to see that the PD&D model has evolved continuously towards one where more PD&D is outsourced. Outsourcing of PD&D increased continuously between 1991 and 2004, with an overall growth of 404%.

SECTOR PERSPECTIVE

In terms of sectors, aerospace is one of the top PD&D investing sectors in Canada as measured by investment in dollars and as percentage of sales (Figure 3, see Annex I for specific sector data).

FIGURE 3

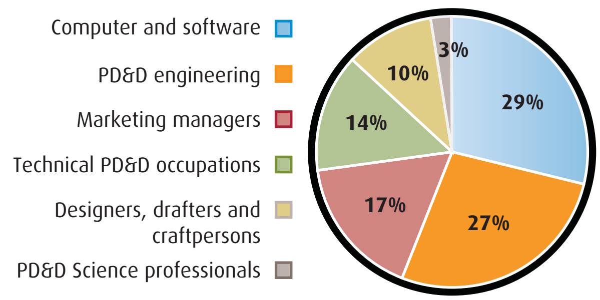
PD&D investment as percentage of sales and growth for select manufacuring sub-sectors.[7]

IN-HOUSE PD&D

The following figure illustrates the composition of in-house PD&D occupations for Canadian manufacturers. In 2004 PD&D wage bill represented 13% of total, of which computer and software occupations represented 29%, followed by PD&D engineers (27%) and by marketing managers (17%).[7]

FIGURE 4

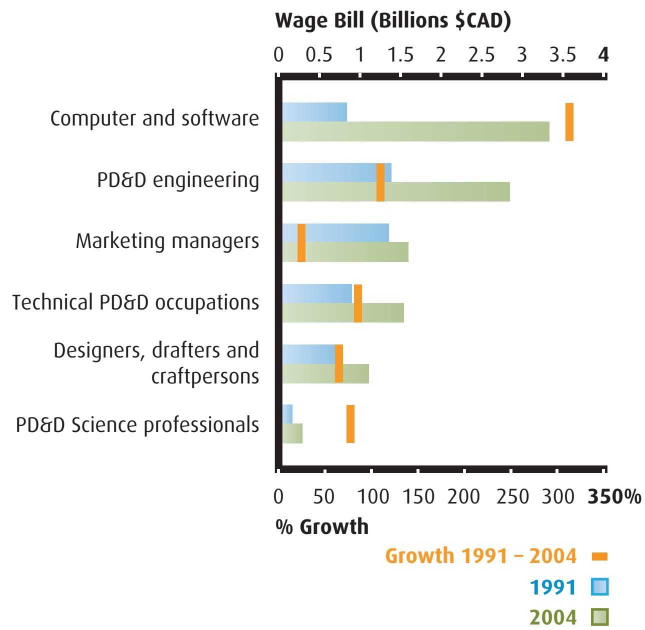
Composition of PD&D occupations, manufacturing, 2004.[7]



The occupations aggregate that increased the most between 1991 and 2004 are computer and software, followed by PD&D engineers and by technical PD&D occupations, each with respective growths of 314%, 107% and 84%. All of the PD&D occupation aggregates had positive growth in the 1991-2004 period (Figure 5).[7]

FIGURE 5

Evolution of in-house PD&D, Canada.[7]



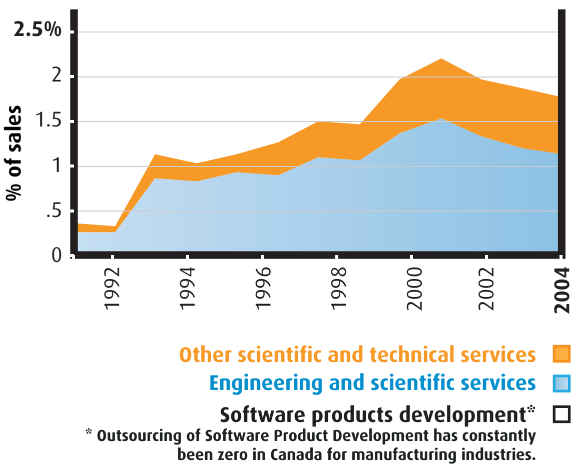
The percentage of the total PD&D wage bill that each of these aggregates represent has also been shifting. Computer and software went from third position to first, and marketing managers have seen a steady decrease, going from first to third position.

OUTSOURCED PD&D

The following figure looks at outsourced PD&D in a more detailed manner. It shows that most of the increase (61%) in PD&D outsourcing is due to an increase of 371% in PD&D engineering services between 1991 and 2004. The increase in outsourcing of this particular PD&D activity started in 1993 and has been relatively continuous since then, with a decreasing trend between 2001 and 2004.[7]

FIGURE 6

Outsourced PD&D in manufacturing, Canada.[7]



Outsourcing of PD&D scientific and technical services increased 532% between 1991 and 2004. Outsourcing of software product development has remained close to 0% since 1991. Although at first glance this may seem surprising, it may be due to the definition of software product development as a commodity. It is defined as the outsourcing of the creation of completely new software, data frames, and related products. If a company buys a computer assisted design (CAD) program off the shelf it will not be seen as a purchase of a PD&D service, it is the purchase of a good. However, if the company decides to make adjustments to the CAD program, this is considered PD&D. Because of intellectual property rights, firms tend to develop such expertise in-house.

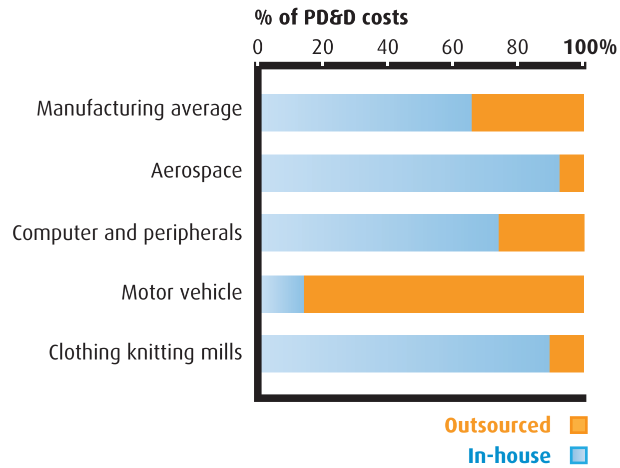
II. Canadian business model variation

Although at the macro level the manufacturing sector in Canada tends to do a majority of PD&D in-house (65% on average), the measure is extremely sector specific.

As the following figure shows, in-house PD&D varies between different manufacturing sub-sectors. Certain sectors perform a very high percentage of PD&D in-house (90% for aerospace manufacturers), while other sectors mostly outsource this activity (80% for motor vehicle manufacturers).[7]

FIGURE 7

PD&D business model in Canada, 2004.[7]

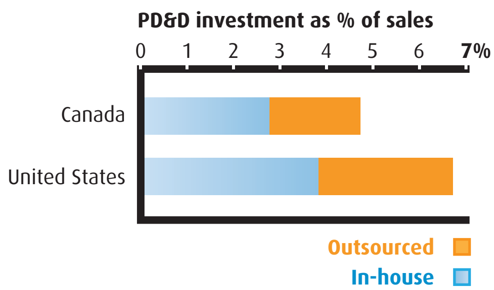


Although there is a lot of variability in the PD&D design model, 75% of Canadian manufacturing sub-sectors do more PD&D in-house. The top three manufacturing sub-sectors in terms of percentage of total PD&D investment done in-house are aerospace products and parts, clay products and refractory, and electrical equipment and components. The top three manufacturing sub-sectors in terms of percentage of total PD&D that is outsourced are motor vehicles, magnetic and optical media, and rubber products respectively.

III. International comparison

PD&D investment as % of sales is 45% higher in the U.S. than in Canada (Figure 8). To note also is the difference in the business models between these two countries. Canada performs a slightly larger portion in-house than the U.S., 64% compared to 55%. However, as illustrated in the previous section, the PD&D business model varies within manufacturing sub-sectors.[8]

FIGURE 8
PD&D investment in 2003.[8]

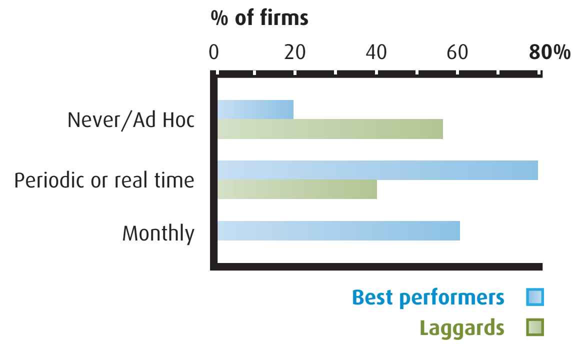


For example, Canadian computer and electronic manufacturers invest 9% more than their U.S. counterparts. Please see Annex 1, Tables 1 & 2 for detailed data on PD&D investment by manufacturing sub-sectors and country.[†]

Operational key performance indicators

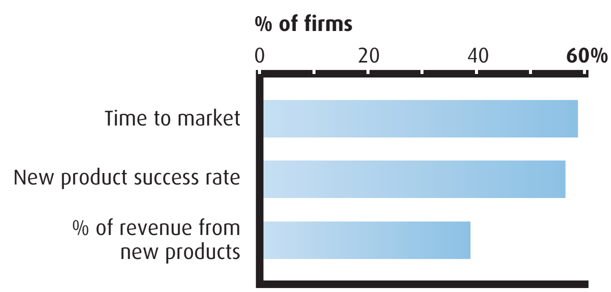
North American best performers are six times more likely to measure key performance indicators (KPI) on a monthly basis than laggards. Twice as many measure them periodically.[9]

FIGURE 9
KPI measurement frequency.[9]



The top three product design and development KPIs have been identified by firms as being time to market, new product success rate, and percentage of revenue from new products.

FIGURE 10
Top 3 PD&D KPIs.[9]



The following sections show an overview of two of the top three KPIs for Canada and their comparison with the U.S. Data for new product success rate is not publicly available for all manufacturing sub-sectors.

IV. Canada

TIME TO MARKET

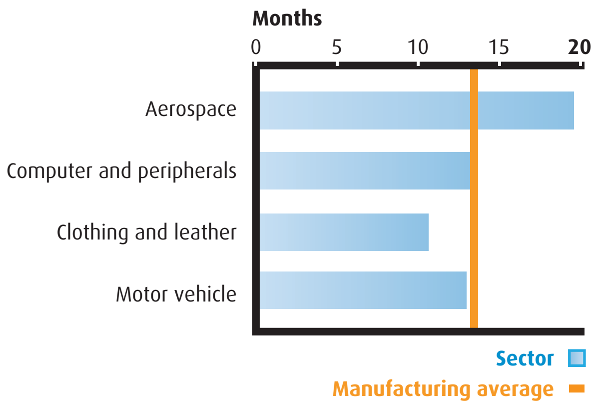
Time to market is defined as the time it takes from the conceptualization of a product idea to the time it is ready to be distributed. As a key performance indicator, a faster time to market reflects a better integration of the design, manufacturing and managing processes, as well as a more effective application of

[†] Data for the Canada/U.S. comparison is for 2003 because of data restrictions for the U.S.

design and design management principles. This is translated by fewer product iterations, amendments and modifications, which allows for first to market advantages and thus the potential for higher profit margins and higher market penetration.

Firms with shorter times to market abandon PD&D projects less often. In particular, manufacturers with a time to market of more than six months abandon PD&D projects twice as often as those with times to market of less than six months.[10]

FIGURE 11
Average time to market.[10]



Average time to market for manufacturers in Canada between 2002 and 2004 was 13.7 months. However, depending on the nature of the product (complexity, seasonality, etc) this KPI varies by manufacturing sectors. For instance, clothing and leather manufacturers who face seasonal trends, bring their product to market 24% faster than manufacturers on average while aerospace manufacturers, facing high product complexity, regulations and product quality requirements, take 35% longer on average than the manufacturing average.

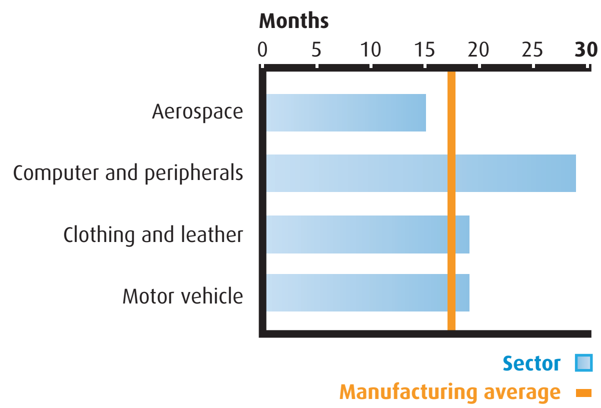
Another measure for time to market is the percentage of firms with a time to market of less than 12 months. This measure improved for Canadian manufacturers between 1999 and 2004, increasing from 48% to 69%. Computer and electronic equipment provides an interesting illustration of this KPI. Computer and electronic equipment manufacturers have one of the highest averages in time to market, yet the percentage of firms with less than twelve months was 24% in 2005, compared to18% on 1999 (increase of 33%). This suggests a sector adapting to market pressures by reducing their time to market.

PERCENTAGE OF REVENUE FROM NEW PRODUCTS

Percentage of revenue from new products reflects the extent to which a firm's profits are directly linked with PD&D, it is defined as the revenue that is generated by a new or highly improved product.

Computer and peripheral manufacturers are one of the top sectors in terms of investment in PD&D (both as percentage of sales and in nominal terms), and also belong to the sector with the largest percentage of revenue from new products.

FIGURE 12
Select sectors for % of revenue from new products, Canada.[10]

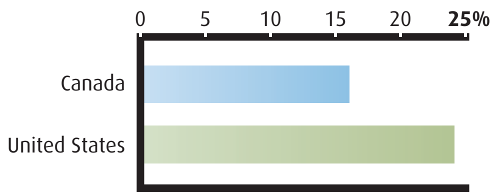


Between 2002 and 2004, the percentage of revenue from new products for the aerospace sub-sector was 15%, compared to 19% for motor vehicle.

V. International comparison

FIGURE 13

% of revenue from new products for manufacturers, 2005.[13] *



Percentage of revenue from new products is 45% higher in the U.S. than in Canada.

Best in class analysis

Best in class firms (BiC) are defined as those that have more than 35% of their revenue from new or significantly improved products. This threshold was chosen because it represents the top 20% of firms.[þ]

This section will look at how BiC firms compare to laggards in the three main links of the PD&D chain (idea generation, conversion and diffusion), and what they are doing differently.

* Data for Canada and the U.S. are from two separate surveys.

þ All of the results presented in this section have been determined to be statistically significant unless specified otherwise. This means that the differences between BiC firms and laggards are proven to happen for more than 95% of the firms. The specific test used is t-student test.

The first trend that appears is that BiC firms invest more in PD&D than laggards (Figure 14).

FIGURE 14

Percentage of firms with given amounts of investment in innovation, as % of total expenditures.[14]

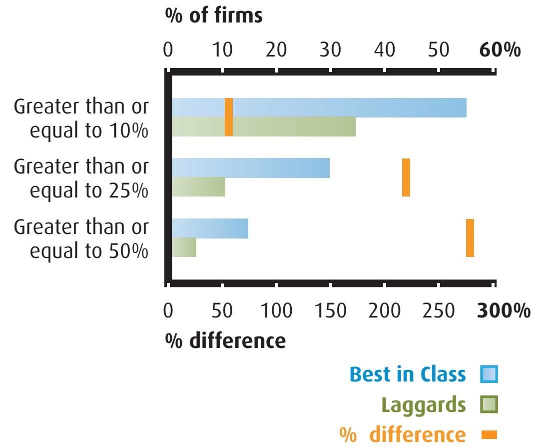
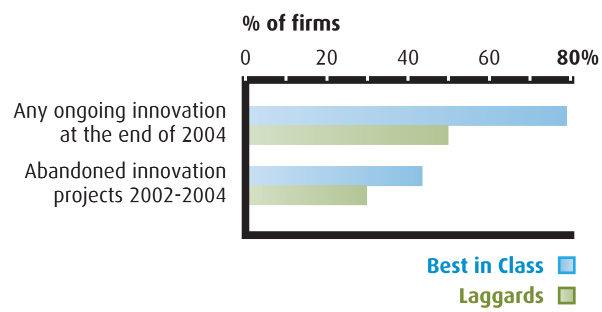


Figure 15 shows that there are more BiC firms that have ongoing PD&D initiatives than laggards (58% difference), and that there are also more that have abandoned initiatives in the past (61% difference).[14]

FIGURE 15

Amount of innovation projects.[14]

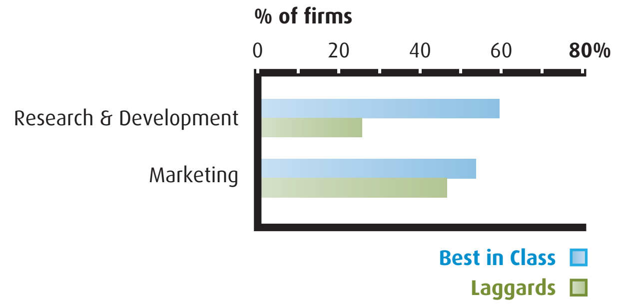


This suggests that BiC firms are less risk averse than laggards. Yet, allocating more resources alone does not guarantee success.

On top of investing more, BiC firms allocate a larger portion of their human resources to R&D (Figure 16).

FIGURE 16

At least 10% dedicated personnel.[14]

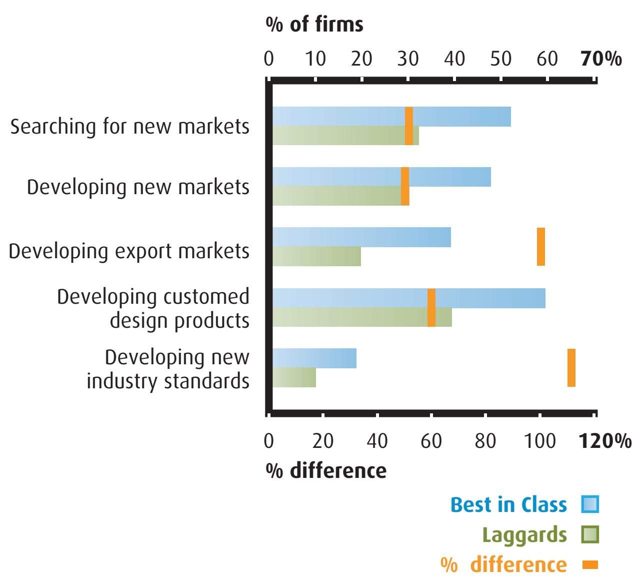


127% more BiC firms have at least 10% of their workforce in R&D dedicated teams. The difference between BiC and laggards is not significant for marketing dedicated teams.[14]

Research on new markets and processes also plays a role in the performance of firms. Figure 17 shows the percentage difference between the number of BiC firms and laggards in terms of their success factors.

FIGURE 17

Commercialization and market success factors.[14]



More BiC firms consistently search for new markets, develop new niche and export markets, custom design products and new industry standards.

FIGURE 18

Use of commercialization processes for manufacturers.[14]

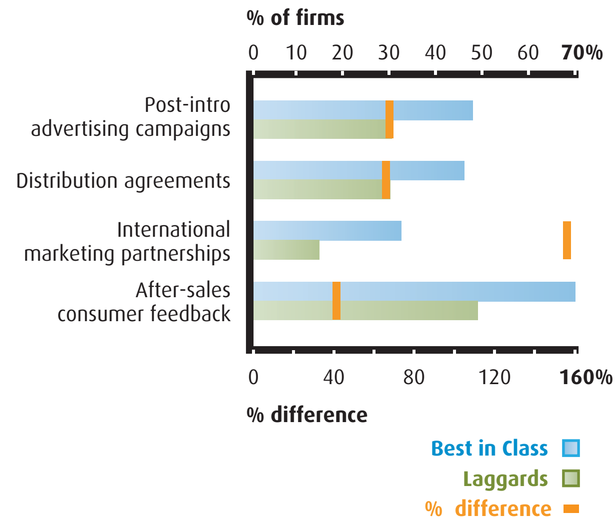
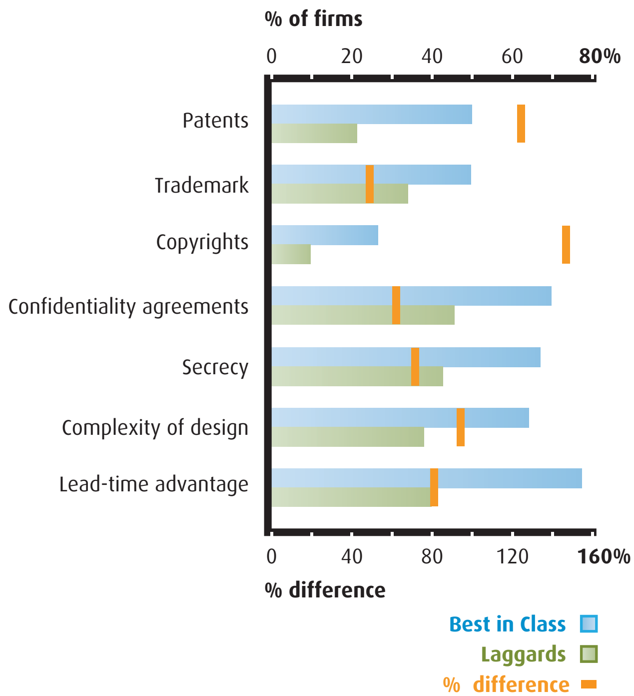


Figure 18 shows that more BiC firms use post product introduction commercialization techniques. This is key for the success of a given PD&D project. A firm may excel at generating new ideas and developing new products, but may have weak systems to bring them to market. The importance of this last link in the design chain is accentuated by the fact that the number of innovative firms that compete for substitute products has increased in the past decade, making it tougher to get consumers to adopt a given new product instead of another.

Another important aspect of the PD&D is intellectual property (IP). As Figure 19 shows, more BiC firms consistently use IP tools than laggards. The difference is largest for copyrights and patents.

FIGURE 19

Use of Intellectual Property.[14]



Other interesting findings indicate that more BiC firms use Canadian venture capital than laggards (23% compared to 7%) and that twice as many BiC firms partner with universities in their own province than laggards. While only 6.9% of laggards partner with U.S. universities, the percentage increases to 35% for BiC. Innovation partnerships can play a major role in the effectiveness of PD&D because they allow firms to gain expertise and new ideas.

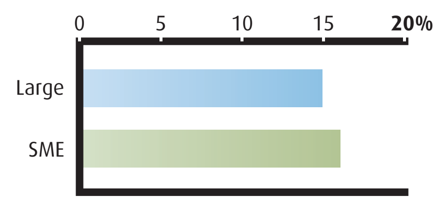
Size of firm analysis

This section will illustrate the major differences and similarities in terms of partnerships, practices and KPIs between SMEs and large firms for manufacturers in Canada. SMEs are defined as firms with less than 25 million Canadian dollars of revenue.

On average, SMEs do not introduce more new products to market than large firms.

FIGURE 20

Percentage of revenue from new products.[14]



As Figure 20 shows, large firms do not generate more revenue from new products than SMEs. The same is true for time to market, where there is no significant difference by size of firm. However, as Figure 21 shows, more large firms had ongoing PD&D initiatives at the end of 2004 than SMEs (although more abandoned them).[14]

FIGURE 21

Amount of innovation projects.[14]

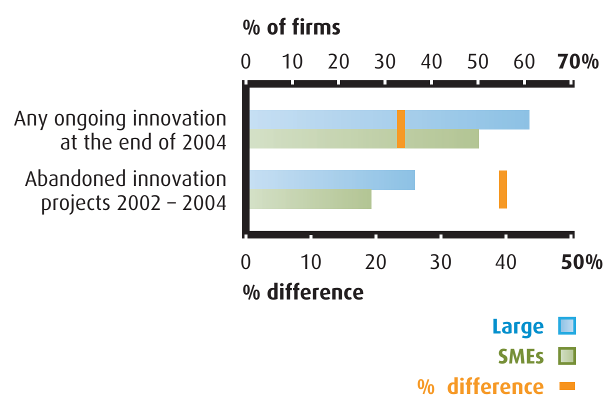
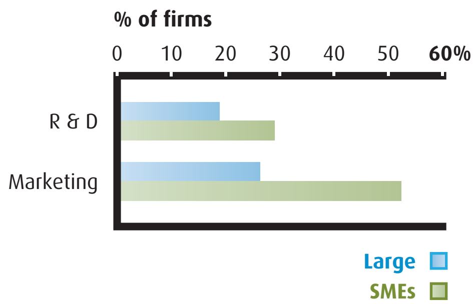


Figure 22 shows the difference between SMEs and large firms in terms of R&D and marketing dedicated personnel.
59% more SMEs have at least 10% of their personnel dedicated to R&D. The difference is larger (101%) for marketing dedicated personnel.

FIGURE 22
At least 10% dedicated personnel.[14]

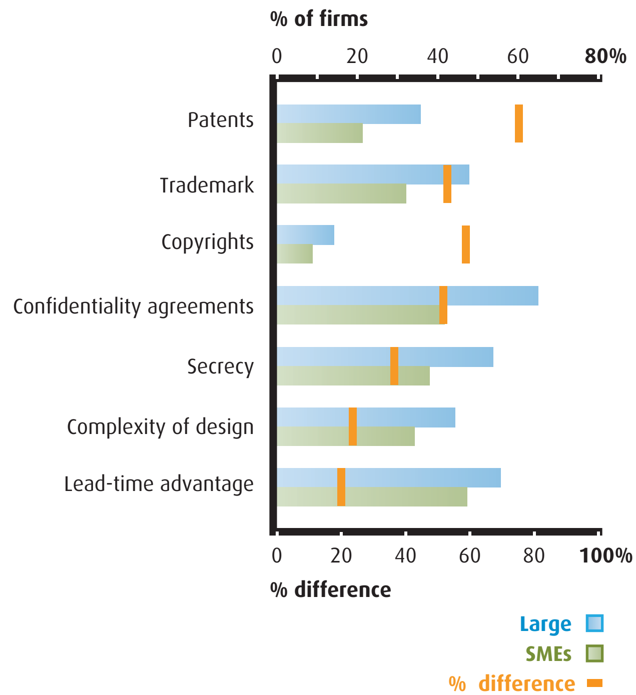


Another difference between SMEs and large firms is that large ones cooperate more with universities, as well as with federal and provincial laboratories than SMEs. More specifically, twice as many large firms cooperate with universities in North America than SMEs.[14]

There is no difference between the number of SMEs and large firms citing lack of funds as what prevented them from performing PD&D. Yet, SMEs are more likely to receive external funding, more specifically from American based venture capital and angel/family investors.

Finally, as Figure 23 shows, large firms consistently used more intellectual property rights measures to protect their new products.

FIGURE 23
Use of IP protection.[14]



Conclusion

Although increased since 1991, PD&D investment levels in Canada were still below those of the U.S. in 2003. Time to market measures for Canada have improved between 1999 and 2004. Yet at the aggregate level Canada is still below the U.S. for percentage of revenue from new products.

More BiC firms have R&D dedicated teams and have more ongoing PD&D initiatives then laggards. They also develop more niche and export markets, custom design products and new industry standards.

Finally, there is not a significant difference between the number of SMEs that cite funding problems as a key issue for PD&D when compared to large firms. However, more large firms use IP protection tools than SMEs.

Notes

TABLE 1

PD&D investment and KPIs manufacturing sub-sectors Canada.

	PD&D INVESTMENT (% OF SALES) 2004			KPIs (2002 – 2004)	
	In-house	Outsourced	Total	Average % of revenue from new products	Average time to market (months)
Manufacturing	3.2%	1.8%	5.0%	16.1%	13.7
Food manufacturing	1.1%	0.6%	1.6%	12.9%	12.5
Beverage and tobacco product Manufacturing	2.2%	1.5%	3.7%		
Textile mills	1.9%	1.0%	2.9%	16.5%	13.4
Textile product mills	2.6%	0.7%	3.4%		
Clothing manufacturing	9.8%	0.8%	10.5%	18.8%	10.4
Leather and allied product manufacturing	13.3%	2.6%	15.9%		
Wood product manufacturing	0.7%	0.7%	1.3%	13.8%	15.1
SAWMILLS AND WOOD PRESERVATION	0.3%	0.5%	0.8%	9.8%	–
VENEER, PLYWOOD AND ENGINEERED WOOD PRODUCT	0.6%	0.4%	1.0%	19.4%	13.4
OTHER WOOD PRODUCT MANUFACTURING	0.6%	0.5%	1.1%	14.1%	11.7
Paper manufacturing	3.2%	0.5%	3.7%	13.3%	12.2
PULP, PAPER AND PAPERBOARD MILLS	3.2%	0.4%	3.6%	21.0%	9.2
CONVERTED PAPER PRODUCT	3.0%	0.5%	3.5%	10.5%	13.6
Printing and related support activities	1.7%	0.2%	1.9%	12.0%	11.8
Petroleum and coal products manufacturing	0.4%	0.8%	1.1%	10.9%	23.3
Chemical manufacturing	5.2%	2.8%	8.0%	12.1%	15.0
PHARMACEUTICAL AND MEDICINE	11.0%	10.3%	21.2%	9.8%	27.5
Plastics and rubber products manufacturing	2.3%	2.1%	4.5%	14.9%	13.4
Non-metallic mineral product manufacturing	4.1%	0.7%	4.8%	12.4%	14.4
Primary metal manufacturing	1.4%	0.4%	1.8%	13.1%	15.6
Fabricated metal manufacturing	2.5%	0.7%	3.2%	13.2%	13.7
Machinery manufacturing	6.6%	1.5%	8.1%	18.6%	14.2
COMMERCIAL AND SERVICE INDUSTRY MACHINERY	11.4%	3.1%	14.5%	19.1%	15.3
Computer and electronic product manufacturing	11.9%	6.3%	18.2%	25.6%	18.2
COMPUTER AND PERIPHERAL EQUIPMENT	12.4%	5.0%	17.3%	28.3%	14.1
COMMUNICATIONS EQUIPMENT	13.1%	5.9%	18.9%	23.0%	14.6
AUDIO AND VIDEO EQUIPMENT	12.9%	1.8%	14.7%	28.5%	16.3
SEMICONDUCTOR AND OTHER ELECTRONIC COMPONENT MANUFACTURING	12.2%	10.4%	22.6%	32.4%	19.1
NAVIGATIONAL, MEASURING, MEDICAL AND CONTROL INSTRUMENTS MANUFACTURING	9.0%	17.1%	26.2%	22.7%	21.2
MANUFACTURING AND REPRODUCING MAGNETIC AND OPTICAL MEDIA	4.5%	19.9%	24.3%	30.1%	12.0
Electrical equipment, appliance and component manufacturing	6.9%	2.1%	8.9%	21.2%	16.1
COMMUNICATION AND ENERGY WIRE AND CABLE MANUFACTURING	14.2%	6.3%	20.5%	10.8%	21.5
Transportation equipment manufacturing	3.9%	3.8%	7.7%	22.3%	14.4
MOTOR VEHICLE MANUFACTURING	0.8%	5.4%	6.2%	18.6%	12.5
MOTOR VEHICLE BODY AND TRAILER	2.4%	0.4%	2.9%		
MOTOR VEHICLE PARTS	3.0%	1.6%	4.6%	19.7%	14.6
AEROSPACE PRODUCT AND PARTS	20.1%	1.9%	22.1%	14.5%	18.5
Furniture and related product manufacturing	2.9%	1.2%	4.2%	14.8%	9.8
Miscellaneous manufacturing	12.0%	1.3%	13.3%	18.1%	12.1

TABLE 2

PD&D investment and KPIs International comparison

<table>
<tr><th rowspan="2"></th><th colspan="2">PD&D INVESTMENT 2003</th><th colspan="2">KPI: % of revenue from new products</th></tr>
<tr><th>Canada</th><th>U.S.</th><th>Canada</th><th>U.S.</th></tr>
<tr><td>Total Manufacturing</td><td>4.6%</td><td>6.6%</td><td>16.1%</td><td>23%</td></tr>
<tr><td>Food manufacturing</td><td>1.3%</td><td>4.5%</td><td rowspan="2">12.9%</td><td rowspan="9">16%</td></tr>
<tr><td>Beverage and tobacco product Manufacturing</td><td>3.4%</td><td>1.4%</td></tr>
<tr><td>Textile mills</td><td>2.9%</td><td rowspan="2">3.2%</td><td rowspan="2">16.5%</td></tr>
<tr><td>Textile product mills</td><td>3.6%</td></tr>
<tr><td>Clothing manufacturing</td><td>3.5%</td><td>2.9%</td><td rowspan="2">18.8%</td></tr>
<tr><td>Leather and allied product manufacturing</td><td>3.8%</td><td>3.1%</td></tr>
<tr><td>Wood product manufacturing</td><td>1.5%</td><td>1.6%</td><td>13.8%</td></tr>
<tr><td>Paper manufacturing</td><td>5.3%</td><td rowspan="2">2.1%</td><td>13.3%</td></tr>
<tr><td>Printing and related support activities</td><td>7.0%</td><td>12.0%</td></tr>
<tr><td>Petroleum and coal products manufacturing</td><td>2.0%</td><td>1.6%</td><td>10.9%</td><td rowspan="4">12%</td></tr>
<tr><td>Chemical manufacturing</td><td>3.6%</td><td>5.5%</td><td>12.1%</td></tr>
<tr><td>PHARMACEUTICAL AND MEDICINE</td><td>16.4%</td><td>5.4%</td><td>9.8%</td></tr>
<tr><td>Plastics and rubber products manufacturing</td><td>4.2%</td><td>12.3%</td><td>14.9%</td></tr>
<tr><td>Non-metallic mineral product manufacturing</td><td>2.7%</td><td>2.1%</td><td>12.4%</td><td rowspan="6">20%</td></tr>
<tr><td>Primary metal manufacturing</td><td>2.1%</td><td>2.6%</td><td>13.1%</td></tr>
<tr><td>Fabricated metal manufacturing</td><td>5.0%</td><td>3.0%</td><td>13.2%</td></tr>
<tr><td>Machinery manufacturing</td><td>3.9%</td><td>6.2%</td><td>18.6%</td></tr>
<tr><td>Computer and electronic product manufacturing</td><td>20.1%</td><td>11.6%</td><td>25.6%</td></tr>
<tr><td>Electrical equipment, appliance and component manufacturing</td><td>12.5%</td><td>5.8%</td><td>21.2%</td></tr>
<tr><td>Transportation equipment manufacturing</td><td>2.7%</td><td>5.5%</td><td>22.3%</td><td></td></tr>
<tr><td>MOTOR VEHICLE MANUFACTURING</td><td>6.5%</td><td rowspan="3">9.3%</td><td rowspan="2">18.6%</td><td rowspan="3">17%</td></tr>
<tr><td>MOTOR VEHICLE BODY AND TRAILER</td><td>3.3%</td></tr>
<tr><td>MOTOR VEHICLE PARTS</td><td>5.5%</td><td>19.7%</td></tr>
<tr><td>AEROSPACE PRODUCT AND PARTS</td><td>27.7%</td><td>13.0%</td><td>14.5%</td><td></td></tr>
<tr><td>Furniture and related product manufacturing</td><td>2.4%</td><td>2.4%</td><td>14.8%</td><td>16%</td></tr>
<tr><td>Miscellaneous manufacturing</td><td>11.7%</td><td>4.0%</td><td>18.1%</td><td></td></tr>
</table>

Annex II: Methodology

This annex provides a better understanding of the methodology used to develop the PD&D investment model.

I. In-house PD&D investment

- Select PD&D related occupations
- Calculate wage bill for selected occupation in the service providing sector

Result 1:

$$\frac{VA_{S\_P}}{Wage\_bill_{S\_P}} = \alpha$$

Where:
- *P indicates PD&D occupations specific data*
- *S indicates service providing sector specific data*
- *VA: value added*

- Calculate the PD&D occupations' wage bill for all sectors within manufacturing
- Apply the value added weight (α) to the PD&D wage bill to obtain an estimate for internal PD&D in each manufacturing sector

Result 2:

$$\alpha * Wage\_bill_{M\_P} = ß$$

Where:
- *M indicates manufacturing sectors*

- Calculate the R&D wage bill/R&D capital expenditure ratio
- Apply this ratio as a weight to β in order to get a proxy for variation of PD&D capital renewal and maintenance cost between different sectors

Final result:

$$\frac{Total\_R\&D\_expenditure_{M}}{R\&D\_wage\_bill_{M}} * ß = PD\&D\_internal\_cost\_proxy$$

II. Outsourcing costs

Outsourcing costs represent tasks that have been purchased from third parties. Data for these costs come from the input output tables and show how much PD&D is purchased by any given economic sub-sector by year.

Annex III: Glossary

Product design and development (PD&D): Design of all the goods and services that compose the process through which a good or a service is created. In this case, the word design is used in a very broad way. It incorporates how a product looks, but also new technologies and innovation that goes into the product or/and into the production process of the product.

Trade in tasks: Defined as the "vertical disintegration of production across borders" (Grossman and Hansberg, 2006). In other words, it reflects the idea that a good can be produced through the integration of production phases that are in many different countries. Given firms in different countries will be responsible for the design task, others for the manufacturing task, others for the testing task, and so forth.

Global value chains: Global value chains (GVCs) include the full range of activities that are required to bring a product from its conception to its end use and beyond (i.e., design, production, distribution). Value chain activities can be contained within a single firm or divided among different firms, and can be contained within a single geographical location or spread over wider areas. For example, firms are increasingly outsourcing some of their activities to third parties, locating parts of their supply chains outside their home country (offshoring), and partnering with other firms through strategic alliances and joint ventures.

Key performance indicators (KPIs): A measure which is of strategic importance to a company or department. For example, a product design and development metric is percentage of revenue from new products.

In-house PD&D investment: In-house PD&D is defined as the internal investment that a firm makes in terms of the personnel and capital related to PD&D.

Outsourced PD&D investment: Outsourced PD&D is defined as the purchase of PD&D services from service providers.

Time to market: Time to market is defined as the time it takes from the conceptualization of a product idea to the time it is ready to be distributed.

Percentage of revenue from new products: Percentage of revenue from new products reflects the extent to which a firm's profits are directly linked with PD&D, it is defined as the revenue that is generated by a new or highly improved product.

Best in class firms (BiC): Best in class firms (BiC) are defined as those that have more than 35% of their revenue from new or significantly improved products. This threshold was chosen because it represents the top 20% of firms.

SMEs: Small and medium sized enterprises. For the purposes of this study, they have been defined as those firms with yearly revenues of less than 25 million dollars.

Product Iteration: Procedure in which repetition of a sequence of operations yields results successively closer to a desired result. In the case of PD&D, it describes the necessity to repeat steps of the development of a product.

References

1 The Economist, "The great unbundling", January 18th 2007.
2 Richard Baldwin, "Globalisation: the great unbundling(s)".
3 Karl Ulrich and Steven Eppinger 2004, "Product Design and Development".
4 Aberdeen Group (2006), "Global Design benchmark report"
5 Supply Chain Council (SCC), 2007, "Design chain operations reference model 1.0".
6 Aberdeen Group (2006), "Simulation driven benchmark report".
7 Economic modelling based on data from Statistics Canada (Census, LFS and IO tables) and Jacobson consulting.
8 Economic modelling based on the Census, LFS and OI tables for Canada; and IO tables, Census and BEA for the U.S.
9 Aberdeen Group (2006), "The mechatronics systems design and benchmark report".
10 Statistics Canada, Survey of Innovation 2005.
11 Statistics Canada, Survey of Innovation 1999 and 2005.
12 Survey of Innovation. Statistics Canada.
13 Data for Canada comes from Statistics' Canada "The survey of innovation, 2005"; for the U.S. from a special request to Aberdeen Group based on "The product innovation agenda benchmark report", 2005.
14 Statistics Canada, special tabulation based on the "Survey of innovation 2005".