The New (Economy) Steel: Learning at the Regional and Firm Levels

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I. Introduction

At the height of the state-centric industrial age, it was said that countries were founded on two things: a flag and a steel industry. In the post-industrial period, sub-regions of nation-states have risen alongside municipalities and continents to compete against nations as *loci* of economic – and, increasingly, political - activity. Although the steel sector is no longer the central player in this emerging economic order, the story of its transition to a new economy *modus operandi* is instructive as to the way in which learning environments grounded in regional innovation systems and driven by ever-advancing customer needs and global competition are allowing quintessentially 19th and 20th century businesses to survive – and in some cases thrive - in the current era.

This paper sets out to characterize the way in which regional and firm-based learning is transforming the competitiveness of Canada's leading suppliers of automotive steel: the Big Three integrated mills, Algoma, Stelco, and Dofasco; two cutting edge mini mills, Sidbec-Ispat, and Ipsco; and three pioneering steel service centres, Samuel Manutech, Russel Metals Inc. (formerly Russelsteel)[1], and Renown Steel, a subsidiary of Slater Steel. Our central argument is that the steel-auto cluster displays two relevant but somewhat competing variations of the learning environment theme – *regional* innovation and *system* integration. In describing the emerging learning environments inhabited by

[1]In 1984, Winnipeg based Russelsteel was sold to Federal Industries of Winnipeg, Manitoba. In 1995, Federal Industries (then known as "Fedmet") changed its name to Russel Metals Inc, headquartered in Mississauga, Ontario. In May, 1995 Russelsteel, Winnipeg, a wholly owned subsidiary of Russel Metals Inc., followed suit and is now known as "Russel Metals, Winnipeg."

Canadian steel companies, we identify and describe a regional learning cluster of integrated steel mills in the Southern Ontario. In conjunction with highlighting the regional nature of learning in the steel industry, we point to the dichotomous local and continental nature of the learning networks in which steel producers are increasingly embedded. In highlighting the characteristics of these clusters, we show that the emergence of the global steel market has driven five of the eight channels of industrial learning[2] commonly associated with regional clusters: 1. research and development (R&D); 2. media and education; 3. mergers and acquisitions and joint ventures; 4. organized market trade, defined by Lundvall as the user-producer interface (Gertler, 2001a, p.10); and 5. foreign direct investment.

Two overarching themes pervade our discussion. The first is that steel manufacturing is now part of the new economy: divisions of steel companies teach each other, firms exchange information with other firms about best practices, steel suppliers learn from auto companies and vice versa, and company researchers share knowledge with their counterparts in government labs and universities. In this regard, Canadian steel is engaging in the same knowledge-intensive activity as industries more typically identified with the hi-tech economy.

The second recurring theme is *globalization*, which is an ever-present determinant force in the business models and marketing strategies of Canadian steel producers. Our research situates the rise of the regional cluster and system integration in the context of a broader climate of significant change in international steel markets. The new knowledge-intensive production processes and parts manufacturing roles of Canadian steel companies

[2]Gertler has outlined 8 channels of industrial learning: 1. Media/education; 2. Travel; 3. Management consultants; 4. Trade (simple market); 5. Trade (organized market); 6. Alliances (extra-market collaboration);

discussed in this paper are in large part the result of increased competition from steel imports produced by foreign competitors taking advantage of technologies that allow for steel to be made more cheaply and quickly. Not only is the impact of global trade compelling steel companies to be partners in learning environments, in every case examined companies are themselves going global, as they forge alliances abroad or establish divisions overseas in an attempt to gain competitive advantage and expand their markets. It is not too much to say that steel has changed from being a stereotypical national industry to become a NAFTA-based and even global industry, with direct investment in the USA and Mexico and joint ventures with Japanese, European, Mexican and Brazilian producers. Canadian companies also actively participate in the global steel-auto Ultra Light Steel Auto Body (ULSAB) consortium.

Before commencing, it is important to emphasize that this study constitutes a preliminary snapshot of the major trends in the steel-auto relationship and of the impact of learning on the steel supply chain. The paper aims to describe the patterns of production and operation of contemporary automotive steel companies based on information that is publicly accessible, and we leave the task of explaining the deep significance of region and the differing firm and sub-sectoral approaches that we have identified to later stages of research. The following are just some of the issues that we flag here and hope to elucidate further as the study moves into the fieldwork phase: What are the relative strengths and weaknesses of the regional steel cluster in Southern Ontario? In what ways are these strengths and weaknesses tied to the actions of local, provincial, and national government policies? What barriers exist in the learning process to thwart the transition from traditional or mixed supplier of automotive steel to system integrator status?

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7. Mergers and Acquisitions; 8. Foreign direct investment. See Gertler, 2001a, p.9).

Our discussion is organized as follows. The first section provides an overview of the transition from the old steel to the new steel and highlights in general terms how regional clusters and the concept of "system integration" are driving much of the innovative practices occurring in the Canadian steel manufacturing sector. The ensuing sections constitute in-depth case studies of the leading Canadian automotive steel suppliers, examining the continental and local learning networks in which the various sub-sectors of the industry are embedded. We conclude the paper by remarking on the marked absence of governmental activity in generating innovation in the contemporary steel manufacturing sector, as well as by highlighting the regional/firm learning divide that we identify as splitting the industry into two distinct industrial learning models.

II. Laying out the Conceptual Framework: Regional Innovation and System Integration

As suggested above, from a regional innovation perspective, the steel-auto cluster displays two relevant but somewhat competing themes – the regionally located learning cluster and the industry-driven system integration theme. The principle dividing line between these two trends situates traditional steel producers on the classical regional cluster side of the divide, while their competitors in the minimills and service centres inhabit intra-firm learning networks that dwell in more subtle, firm-based learning environments than the direct institutional, private-public relationships between the players in the traditional steel-auto network. In the ensuing discussion, we provide a brief synopsis of the evolution of the steel industry from an old economy actor to a new economy industry and highlight the relevance of clusters of regional innovation and the concept of system integration in understanding this transition.

In the last two decades the steel-auto rapport has grown out of its traditional linear supply model into a complex, vertical and overlapping learning relationship marked by collaborative contact between steel and auto producers at almost all stages of production of either basic steel or steel automotive parts. Whereas auto companies formerly bought unprocessed steel and steel parts as primary materials or secondary components, steel firms are now assuming a greater portion of the technical tasks in the production chain and are assuming a leadership role in much of the coordination of the chain's technical and operational performance. (Belzowski and Flynn, 1995, p.20) It is predicted that the marketing and leadership responsibilities of basic auto design will be the chief tasks of auto producers. (Belzowski and Flynn, 1995, p.32)

Just as the steel-auto relationship has become more complex so too has the steel making sector itself, as emerging technologies have allowed the BFs and EAFs, as well as the service centres, to manufacture raw materials and undertake "downstream" manufacturing activities. Traditionally, integrated plants made steel in Basic Oxygen Furnaces (BFs). Canada's three BF steel makers, Algoma, Dofasco, and Stelco, sold their product primarily to steel service centres (SCs), which handled approximately 80%, by volume, of total shipments of steel to auto manufacturers. Much of this would then be re-bundled and supplied to parts manufacturers who would then provide finished parts and sub-assemblies to the equipment manufacturers. (Warrian, 2001a, p.9)

From the 1960s to the 1980s, the minimill, or Electric Arc Furnace (EAFs) producers, which rely on recycled scrap for steel making, began to challenge the production dominance of the integrateds in the low end wire and rod markets. Using smaller scale, scrap-charged electric furnaces, the minimills had a substantial productivity and cost advantage at the hot metal end.

In response to the capacity of minimills and service centres to produce the primary commodity and manufacture parts, particularly in Canada, the integrateds began to increase production capability by incorporating EAF technology through acquisitions of technology or subsidiaries. As this gap in commodity production closed, however, the minimills launched another challenge to the dominance of the integrateds by starting to produce some of the higher value-added flat products used for automobile components. The new rolling capacity of the minimills, initially propelled by the development of thin slab casting, allowed the EAFs to compete in the lucrative flat product market. In response, some of the integrateds have now directly incorporated this latest minimill technology into their own operations. (Warrian, 2001a, p.3)

An additional threat to the erstwhile predominance of the integrateds has been the capacity of service centres to contract manufacturing of auto parts or sub-components. Traditional steel service centres employed a simple linear processing technology and business model, receiving coils from major steel producers and cutting them to length with slitter and shearing machines. The steel was then shipped to stampers and other parts manufacturers. Currently, however, service centers are adopting downstream processing capacity, using robotic shears and laser cutting technologies that can be programmed not only to cut coil, but to run continuously and cut it to CADCAM specifications. (Warrian, 2001b, p.3) The manufacturing service centres pose a serious challenge to the position of both the integrateds and the minimills, as total service centre market share rose by 6% alone in 2000. (Dofasco, 2000, p.6)

These competitive pressures within the steel sector have combined with increasing competition from abroad to encourage the production of value-added basic steel and to foster a process of steel-auto system integration. Canadian companies are attempting to gain competitive advantage over their offshore competitors by fulfilling more of the technical and broader logistical tasks of the auto production process. Whereas competitive advantage used to be determined by the capacity to produce commodity steel quickly and cheaply, Canadian operations are now offering more high-end products and services to customers as alternatives to cheap imports. In Asia alone, production of steel is projected to increase by 37.2 million tons in the next decade and much of the steel produced in Asia and elsewhere is finding its way into the North American market. (Warrian, 2001a, p.2) Hence, it is not surprising that North American steel companies are turning to technological innovation to create competitive advantage. It is estimated that 50% of steel products sold today were not available ten years ago. (Algoma, 2000, p. 2)

As suggested in our opening remarks, the traditional integrated mills, the minimills, and service centres inhabit a learning environment characteristic of that inhabited by new economy, knowledge-driven industries. As we show below, Lundvall's thesis that hi-tech economies breed close, educative interaction between technology users and producers is born out in the Ontario regional cluster, as producers seek to meet clients' needs and partner with other firms, universities and community colleges and government in order to do so. (Gertler, 2001, p.10)

We will also show how the *nature* of the learning environments inhabited by the traditional steel producers is markedly distinct from that of their competitors in the minimill and service centre areas. As we illustrate in our case studies, the learning environment of integrated mills is dominated by the interaction between the traditional big three on both sides of the steel-auto aisle: Stelco-Dofasco-Algoma and GM-Ford-Chrysler. These players are very much situated in cross-cutting local and continental learning clusters, as the continental span of the auto industry encourages Canadian-American inter-firm collaboration on developing technical knowledge and technology through industry associations, while Canadian steel producers partner with the Canadian and Ontario governments as well as Canadian universities to produce the next generation of steel processing technology.

Another educative environment emerging in the steel manufacturing field is the learning network emerging between the minimills and service centres and auto parts manufacturers. As we will show, the steel company players in this network are smaller and non-traditional. The issues in this learning environment are driven by downstreaming and involve issues of knowledge sharing about engineering, manufacturing, design and fabrication issues in auto parts and sub-assembly processes. In many respects, we will show how this is a more disperse and subtle set of network relationships than the direct institutional relations between players in the traditional steel-auto network. We argue that these learning relationships are driven by the more fluid, cooperative production process referred to as "system integration." Defined by Belzowski and Flynn (1995) as the shift in technical and coordination responsibilities from auto assemblers to suppliers of both basic automotive materials and parts, (p.20) system integration is a useful concept because it gives researchers a basic test – that of "functional transfer" – to determine whether a company's position in the supply chain is changing. In turn, this test helps us distinguish between leading edge automotive suppliers in the minimill and service centre sectors of the supply chain and those mired in traditional vertical supply practices.

III. Canada's Automotive Steel Producers: The Role of Learning in the New (Economy) Steel Industry

i. The Integrateds: Algoma, Stelco, and Dofasco

Canada's integrated steel producers have experienced a challenging period of adaptation to the realities of the global steel market, as they have had to upgrade their equipment to meet EAF production capacity and deal with the parts manufacturing competence of both the EAFs and the steel service centres. The threat posed by the integrateds' minimill and service center competitors has been compounded by the problem of cheap products being dumped on the North American market. As the overview below illustrates however, Canada's big three steel companies have manifested divergent strategies of regional and inter-firm learning so as to cope with these market forces. However, the learning environment theme is far from pre-dominant, as we show that the degree of embeddedness of each firm in a learning environment varies significantly between the traditional steel producers.

Algoma Steel, headquartered in Sault-Ste-Marie, Ontario has responded to increased competition by streamlining its operations and seeking to produce steel of higher quality at a lower cost. In 1998, the firm reorganized itself into business units as part of a longer-term effort to provide an enhanced focus for each major product line with the aim of providing better service to customers. (Algoma, 1998, p.2) A year later, Algoma decided to concentrate purely on the lucrative flat-rolled steel market, producing sheet and plate. (Algoma, 1999, p.1) In restricting its product focus, Algoma shut down its shape products caster, structural mill, and seamless tubular mill. (Algoma, 1999, p.1) The result is that in 2000, 81% of Algoma's sales were in sheet product, and the remaining 18% were from plate sales. (Algoma, 2000, p.19) Unfortunately, Algoma completed this strategic re-positioning of its product lines just at the point where demand and prices in the flat rolled market plunged at the same time that their traditional diversification might have sheltered them somewhat from the downturn.

In addition to reorganizing its operations and restricting its product line, Algoma has made capital investments designed to bring the speed and quality of its steel production in line with that of its competitors. Algoma produces hot rolled sheet at two complexes - the state of the art Direct Strip Production Complex (DSPC) Mill and the 106" Strip Mill. Algoma's DSPC was developed in partnership with the National Research Council's (NRC) Bessemer Project. (NRC, 1995) The DSPC is the world's leading advanced thin slab casting and rolling mill. A steel facility designed and supplied by the Italian engineering firm, Danieli, the DSPC has a potential annual capacity of 2.2 million tons. In 2000, the DSPC produced 90, 000-105,000 tons/month of product. Steel from the DSPC is setting new standards for surface quality, dimensions, shape and consistency, achieving dimensions to within one quarter of ASTM standards.

The DSPC offers three advantages in production time and quality over the previous coil producing process. First, the DSPC produces hot rolled coils faster than the traditional process. Whereas previously liquid steel was cast into 8-inch slabs, cooled for storage and then reheated and rolled into coiled sheet and plate, the DSPC converts liquid steel directly into hot rolled coils using the continuous casting process that feeds steel directly from the basic oxygen furnace into the DSPC. (Algoma, 1997, p.7) In addition, the DSPC allows for a greater range of customized slab production, accommodating widths ranging from 31” to 63” and gauges down to 0.040”, less than the thickness of a dime. (Algoma, 1997, p.7) Finally, the DSPC mill produces superior surface quality through sophisticated computer control and monitoring. (Algoma, 1997, p.7)

Algoma’s 106" Strip Mill provides another example of the company’s quest to manufacture value-added basic steel products. It is one of the widest strip mills in North America, capable of manufacturing sheet and light gauge plate to a maximum slit edge width of 96". Medium and high carbon steels as well as HSLA formable grades and floor plate are produced at this facility.

In addition, Algoma's Plate Mill is highly automated, assuring product consistency across the entire product range. Using continuously cast steel slabs, the Plate Mill rolls both carbon and high-strength low alloy (HSLA) plate up to 3860 mm (152") wide, the widest steel plate manufactured in Canada. Floor plate is rolled to a maximum width of 2440mm (96"). In addition, Algoma operates its own in-plant heat treating facility to produce a wide range of Normalized and Quench & Tempered steel plates which are required for either high-strength, abrasion-resistant and/or military applications.

Algoma’s ladle refining metallurgy is also the result of highly sophisticated developments in metallurgical science. The main benefit of in-ladle metallurgy is that it allows producers to generate more tons per hour at a lower cost and also improves quality through improved temperature control. The reason is that refining and trimming takes place outside the furnace, resulting in time and energy efficiencies. This steel making technique also makes a significant contribution towards greater product consistency, particularly in the areas of fracture toughness and plate ductility. These are all qualities of great importance in highly stressed plate applications.

While the pursuit of low cost, high-value added basic steel has been at the forefront of Algoma's response to present market conditions, it has pursued system integration by the creation of a separate manufacturing division, Quality Blanks International (QBI). Established as a separate business unit of Algoma in 1997, QBI is located in Burlington, Ontario and it custom tailors blanks for automotive customers. (Algoma Steel Inc., 2001) The customization of blanks requires a degree of technical capacity and coordination between Algoma and auto producers that fulfills a basic requisite of system integration.

Based on our current understanding of Algoma's automotive steel operations, Algoma appears to be embedded in a learning environment that emphasizes value-added production as opposed to the design and engineering of auto parts. Its partnership with NSERC during the development phase of the DSPC is the clearest example of Algoma's benefiting from an educative, private-public relationship. However, there is no evidence that Algoma benefits from the same degree of regional sharing environment as its counterparts located in southern Ontario. There is little evidence of Algoma partnering with universities or community colleges in order to improve its business practices, though it has been active with the local community college in worker training through the Canadian Steel Trade and Employment Congress (CSTEC).[3]

In addition, although Algoma has invested significantly in technical upgrades in the last few years, the company has not taken over functions previously carried out by assemblers, with the exception of the Quality Blanks stamping division. Aside from customizing blanks for automotive clients, however, the bulk of Algoma's operations pertain to producing higher quality steel more cheaply. While improvements in quality are made by complying with industry standards through the industry-wide, standards-driven learning environment – such as the QS9000 quality assurance standard that is sweeping the North American auto parts industry[4] - Algoma does not appear to partake in the sorts of inter-firm relationships or industrial associations that bolster significantly the learning relationships of its integrated competitors in southern Ontario. The extent to which this is a manifestation of Algoma's central Ontario location or its corporate organization, however, is unclear.[5]

Like Algoma, Stelco has streamlined its operations in the last few years, notably by withdrawing from the container manufacturing market in 1995. Stelco currently produces cold rolled, galvanized, and prepainted products for the auto market at four divisions: Lake Erie Steel, Stelco Hilton Works, and Stelwire Ltd, all located in southern Ontario, and at Stelco McMaster Ltée in Contrecoeur, Quebec. Stelco is moving toward high value-added product, however a substantial portion of its business still resides in basic steel products. In 2000, the company produced more basic steel than manufactured product: 5.6 million tons basic steel compared to 4.7 million tons of steel products. (Stelco, 2000, p.3)

Stelco's technological facilities and capital upgrades are similar to those of Algoma, though not as technologically dramatic as the DSPC. Lake Erie Steel, a fully

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[3] CTEC is a joint-venture between the United Steelworkers of America (USWA) and Canada's steel producing companies. It provides a range of services to employers, employed and unemployed workers both inside and outside the steel industry. (http://www.cstec.ca)

[4] QS 9000, or "Quality System Requirements QS-9000," is the common supplier quality standard for Chrysler Corporation, Ford Motor Company, and the General Motors Corporation. QS-9000 does not apply to all suppliers of the Big Three: it applies to suppliers of production materials, production and service parts, heat treating, painting and plating and other fiNissang services. (http://qs9000.asq.org)

integrated steelmaking facility, has a hot strip mill that is ISO 9002 and QS 9000 certified. Its facilities include a coke oven battery consisting of 45 ovens; one blast furnace (75,300 cubic feet working volume); a two-vessel basic oxygen furnace ship, a Ruhrstahl Heraeus – Oxygen Blowing vacuum degasser; and a twin-strand slab caster. In addition, all the steel processed at Lake Erie Steel is rolled in a hot strip mill, creating superior quality steel. (Stelco, 2001a)

Stelco Hilton Works is an integrated steel making and processing complex in Hamilton. Its production facilities include a coke oven battery, two blast furnaces, in-ladle metallurgy capacity, and a continuous slabcasting complex. In 1997-98, the company made an $85 million upgrade to the plate mill. Steel from the hot strip mill destined for the cold mill is pickled at one of three pickle lines. (Stelco, 2001a)

Stelco McMaster Ltee is a minimill located in Contrecoeur, Quebec. It makes billets, specialty bars, reinforcing bars, and merchant bars with automotive applications. It is equipped with a 130-ton, German-engineered Demag eccentric bottom tapping arc-furnace, a ladle metallurgy station, and a four-strand billet caster. (Stelco, 2001a) Finally, Stelwire Ltd. has a computerized tunnel rod cleaning and coating line with two state of the art high capacity continuous annealing furnaces. (Stelco, 2001a)

In addition to maintaining and improving its base production capacity, Stelco has manifested some of the characteristics of a system integrator. Stelco has enhanced quality by incorporating galvanizing capacity at its Hilton Works plant. Galvanized steel is used to fight the effects of corrosion on exposed vehicle body panels and is used widely by the worldwide automotive industry. In addition, through Stelco's 60% ownership of Z-Line, a joint-venture, zinc-coating line with Mitsubishi-owned MC Steel Operations (Canada) Inc.,

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[5] For instance, Algoma is not involved with the Ultra Light Auto Body initiative.

Stelco participates in the management, operation, and marketing of the hot dipped galvanized and galvanneal sheets that are currently in high demand in the automotive custom panel market. (Stelco, 2001b)

Through product and process development undertaken at the individual businesses, Stelco is positioning itself to add value to automotive products through its in-house, customer-driven innovation. For instance, Stelco scientists have produced bake-hardenable steels for dent resistance and formability. (Stelco, 2000, p.18) Researchers at the company have also worked on producing extra-strength grades of hot-rolled sheet that are used in automaking, (Stelco, 2000, p.18) and staff at Hilton Works are researching dual-phase and transformation-induced-plasticity steels that provide automotive customers with higher strength and more formable materials that allow for the creation of lighter and safer vehicles. (Stelco, 2000, p.19)

In addition to its on-site research activities, Stelco has been a partner in the Ultra Light Steel Auto Body initiative, an aggressive $22 million project to demonstrate how to optimize the qualities of steel to produce lightweight auto structures that meet a wide range of mass, cost, performance and safety targets. The program is managed and funded by an international consortium of 35 of the world's leading steel producers. (ULSAB, 2001) Other industry-based projects with which Stelco has recently been involved include:

1. American Iron and Steel Institute (AISI) – the AISI Advanced Process Control programme was completed in 1998 and sponsored by fourteen member companies of the AISI. Its purpose was to develop advanced process sensors and software to maintain the competitive advantage of North American steel producers. During 1998, significant progress was achieved in the areas of microstructural engineering of hot strip mills, optical sensors and controls for improved BOF operation, and on-line measurement of mechanical properties.
2. AISI Committee on Manufacturing Technology – Stelco is participating in a select number of the seventeen projects launched in the last two years covering a variety of process, product, and environmental technologies. (Stelco, 1998, p.14)

Rounding out Stelco's corporate research innovation strategy are two academic research chairs it funds at McMaster University and the University of British Columbia. The aim of these initiatives is to strengthen the links between steel metallurgy, manufacturing and product design. Chair holders are expected to work toward the development of high-strength, coated steel in terms of new alloys, coatings, forming and fabrication technologies and steel product design and to collaborate with Stelco and other companies. (McMaster Steel Research Centre, 2001)

Clearly Stelco is manifesting a more active role than Algoma in the emerging learning environment surrounding the hi-tech manufacturing of steel. Of the six channels of industrial learning discussed in this paper, Stelco manifests participation in four: research and design through in-house innovation and its partnerships with universities via endowed chairs; organized market trade through its membership in the ULSAB project and its creation of blanking and forming companies; an extra-market alliance in the Z-Line venture with Mitsubishi, and activity in a private-public learning partnership with universities. As with Algoma, however, the majority of Stelco's capital investments pertain to improving efficiency and quality in the basic steel production process. While Stelco is playing an active role in the creation of learning partnerships with assemblers and others in the steel-automotive supply chain, as well as with local learning institutions, it is not undertaking the type of functional and coordinating activities undertaken by system integrators.

By far the best example of a learning organization in its class is Dofasco, the leading integrated steel producer in Canada. Like Algoma and Stelco, Dofasco has kept apace with basic steel production technology by acquiring EAF, continuous slab caster, and galvanizing technologies. Dofasco's leadership in the automotive steel industry, however, stems from its knowledge-intensive activities which span in-house research and development and inter-firm learning.

From 1990 to 2000, Dofasco invested $2 billion in investments intended to make it a knowledge-intensive, high-value added company. The cornerstone of the company's innovation initiative has been its *Solutions in Steel* strategy. Conceptualized by company executives in 1995, *Solutions in Steel* was developed to transform Dofasco from a mere manufacturer of steel to a system integrator. In terms of product development, *Solutions in Steel* seeks to make Dofasco a producer of high quality, value-added steel and steel products. (Dofasco, 1999, p.2) In addition, it posits a role for Dofasco in the manufacturing process itself. This second aspect of *Solutions in Steel* has driven integration at Dofasco. One of the earliest initiatives developed from the *Solutions in Steel* strategy was the 1997 "body-in-white" initiative, in which Dofasco stripped down the shell of a major automotive customer's best-selling vehicle in order to show the car manufacturer how new steel technology could reduce weight, cut costs, and strengthen overall design. (Dofasco, 2000b) This program resulted in several benefits to automakers, including improved strength, a 25 percent reduction in weight, and a three per cent lower production cost. The body-in-white program began a new trend that has since become an industry standard. From the standpoint of system integration, the "body-in-white" strategy manifested the technical responsibilities (R&D) and coordination (supplier-assembler contact during the manufacturing process) characteristic of system integration.

The *Solutions in Steel* strategy has been made effective by its embrace of innovation. The company has innovated products and production processes in three ways: in-house research; joint ventures; and acquisitions of leading-edge steel technology companies.

First, the in-house Innovation Group at Dofasco has been at the forefront of developing value-added products. For instance, recently it patented Zyplex, a versatile, ultra-strong, ultra-light and unique steel laminate that radically reduces the weight of conventional steel in transportation applications. (Dofasco, 2000, pp.12, 16) Also adding to its R&D activities is Dofasco's participation in the ULSAB project.

Dofasco has expanded its operations to include three new production processes that generate cutting-edge products for the automotive sector. The first is Hamilton's DoSol Galva (DSG) facility, a state-of-the-art galvanizing line that is a joint venture of Dofasco (80%) and Sollac (20%), a division of Usinor of France. Usinor is Europe's largest producer of high-quality flat-rolled automotive steel. DSG can produce 450,000 tons/year when at capacity. DSG uses Usinor's technology in the production of exposed hot dip galvanized coatings. Dofasco is the exclusive marketer of the line's output in North America, which produces exposed galvanneal, *Extragal* (exposed galvanized), and unexposed galvanized and galvanneal. *Extragal,* a galvanized coating developed in the 1980s, is the feature product of DoSol Galva. It is a new product on the North American automotive market that is an alternative to electrogalvanized steel and has excellent friction behaviour, allowing for the easy flow of material into the die for deep drawn parts. Deep drawing is a cold forming process in which a flat blank of sheet metal is shaped by the action of a punch forcing the metal into a die cavity. It differs from other drawing processes in that the depth of the drawn part can be greater than its diameter. Also, compared with other coated materials, *Extragal* also exhibits very similar performances in term of crystal size/morphology and phosphate coating weight. *Extragal* is less sensitive to cratering defects during E-Coat than Galvanneal and also achieves an excellent paint appearance. (Dofasco, 2001b)

In addition to adding specialized galvanized materials to its product offerings, Dofasco has added a Tubular Product Stream to its operations, opening two tube mills in Hamilton, Ontario and one in Monterrey, Mexico. Tubular products have a wide range of applications in automotive manufacturing, creating truck frames (rear and front rails, crossmembers); engine cradles; instrument panels; roof rails; radiator supports; seat frames; body side rails; control arms; and space frames. Dofasco's tubular mills were conceived and built to meet Dofasco's North American customer's growing needs for value-added, highly specialized tubular products and possess the hydroforming capacity to meet the increasing complex parts requirements of manufacturers. Hydroforming entails taking a tube and placing it in a forming die, then shaping the tube in accordance with the die through the application of internal water pressure. (www.steel.org) The hydroforming process is particularly ideal for automotive structure parts such as engine cradles, radiator supports, and body rails. Dofasco's tubular production is exemplary of its emerging role as a system integrator. At Dofasco Hamilton's No.1 Tube Mill, customers benefit from specialized Customer Service Teams that get involved in managing projects for customers from the earliest stages of a project.

In May, 2000 Dofasco significantly increased its innovative capacity by acquiring Powerlasers Inc, a manufacturer of laser welded automotive blanks and other components that held 1/6 of the North American market for laser blanks in 2000. GM, Toyota, Volkswagen, Chrysler, BMW, Honda, and Volvo are among the manufacturers already using laser welded automotive blank and related component technology. Laser welded grades and thicknesses within a specific part, in effect 'steel plywood', place the steel's physical attributes where they are most needed and remove weight that does not contribute to performance. Out of this process comes a lighter auto part that provides superior structural rigidity, fewer emissions and better fuel economy due to reduced weight, and cost-effectiveness through reduced scrap, increased structural efficiency and part consolidation.

As well as having the capacity to manufacture laser welded blanks, Dofasco has greatly increased its innovation capacity through its acquisition of Powerlasers, which has an Advanced Technology Centre in Kitchener, Ontario that does research on hardware, including lasers, robotics, metallurgical and mechanical applications. Its innovations to date include: bypass pre-trimming, which saves time and reduces waste; and laser cutting creates curved end multiple welds, which is a cost efficient process. Current research projects of Powerlasers include laser applications for patch welding, tailored tubes, laminate welding, inserted laser welded blanks, plastics welding and non-linear welding. (Dofasco, 2001, p.17)

Dofasco has also been at the leading edge of expanding its markets by opening foreign plants. Dofasco de Mexico, a wholly owned subsidiary situated in Monterrey, will produce large diameter steel tubing for automotive hydroforming applications and meet additional steel processing needs in the Monterrey region. Upon completion, Dofasco de Mexico will be the only steel producer with processing and manufacturing facilities in

Mexico capable of producing tubular products to meet the demanding specifications required for hydroforming applications. (Dofasco.ca/NEWS/body_news_frameset.html) Capacity production at the Monterrey plant is projected to be 150,000 tons of steel tubing per year.

Dofasco's new Brazilian joint venture, Vega do Sul, is equally intended to position Dofasco for entry into the lucrative South American market, producing *Extragal* for the South American Auto Industry.[6] Dofasco's partners in the Brazilian project are Usinor (45%); Companhia Sidevurgica de Tubarao of Brazil (25%); Corporacion Gestamp of Spain (an international steel service centre and stamping operator) (10%).

Dofasco has also been expanding its markets through e-Commerce, with 60% of its business being conducted over the internet. (Dofasco, 2000, p.17) As part of the ANX – Advanced Network exchange trading partner – Dofasco has access to trading partners in several industry sectors via a secure and reliable global network IT and infrastructure based on standard Internet technologies. The ANX network was introduced by the Automotive Industry Action Group (AIAG) in 1995. It facilitates the re-engineering of supply chains by connecting trading partners and electronically allowing them to collaborate on product design and development, soliciting and processing orders; and facilitating just-in-time manufacturing and post shipping schedules. (strategis.ic.gc.ca) Dofasco is also an investor in e-STEEL – an e-Commerce service that provides the steel industry with a neutral, secure online exchange, and a source for up-to-date industry information. (www.e-steel.com/investors) Suppliers use the e-STEEL Exchange to expand their marketing reach, grow their customer base, and reduce their transaction costs. The e-

STEEL Exchange helps buyers grow their base of suppliers, find better prices and lower purchasing costs. (strategis.ic.gc.ca) At the company level, Dofasco's EDI – Electronic Data Interchange – allows it to keep in touch with its customer base. The company also offers browser-based self-services access – such as order status via the public internet; the intent of the launch of this service is to accelerate the learning curve on how to use internet technologies to improve customer service.

Dofasco has also been a leader in generating a learning environment in which it can grow by sponsoring three university research chairs, two in metallurgy held at McMaster and UBC respectively, and one in process automation at McMaster. (Dofasco, 2001a) According to Executive Vice President and General Manager Don Pether, the research chair initiative, "drives innovation and engages young people in learning more about [the steel] business," with virtually daily interaction taking place between Dofasco staff and researchers at McMaster and UBC. (Pether, 2000d) Dofasco has also undertaken firm-to-firm learning initiatives, exchanging employees for three months at a time with Australia's BHP steel company. Dofasco has also extended its learning environment into the auto industry, sending employees to work for a year at Toyota, Nissan, and IHI. Finally, Dofasco's employees are active in learning about different business practices in industry educative seminars and workshops provided by industry organizations such as AISI and the International Iron and Steel Institute (IISI). (Dofasco, 2001a)

Clearly Canada's integrated steel firms display a broad range of responses to the challenges posed by the contemporary steel market. Dofasco leads the pack in innovation initiatives, manifesting activity in all five channels of industrial learning profiled in this

[6] Ownership of Vega du Sol is as follows: 45% owned by Usinor; Companhia Sidevurgica de Tubarao of Brazil owns 25%; Corporacion Gestamp of Spain (an international steel service centre and stamping

study: research and development (R&D); mergers and acquisitions and joint ventures; organized market trade, defined by Lundvall as the user-producer interface (Gertler, 2001a, p.10); foreign direct investment; private-public partnerships, particularly the relationship between steel companies and the universities and community colleges. (Gertler, 2001a, pp.9-10)

Dofasco's learning-driven *Solutions in Steel* strategy have paid off, with the company acquiring three specific new technologies of direct application to the high-end automotive component market: large diameter tubing for hydroforming; advanced galvanized steel; and laser-welded blanks. Dofasco has also proven to be the leader in adapting its business model to the new economy, as it has assiduously extended its presence abroad, pursued e-Commerce opportunities, and undertaken firm-to-firm and firm-university learning collaborations.

In addition to Dofasco's significant contribution to the emergence of a knowledge-intensive steel industry, the company is manifesting attributes of a system integrator. Its hydroforming and laser welded blanks divisions are manifesting the sort of close, customized relationship with automotive assemblers that characterizes system integration.

Stelco is the middleman in this story. Much of Stelco's focus remains on the traditional key to competitive advantage in the steel industry: enhancing production capacity. From 1997 to 2000, Stelco invested $834 million, contributing to the company's overall productivity growth, which has doubled since 1990. (Stelco, 2000) While Stelco has sought out opportunities to enhance its knowledge-base and develop high value-added products, it lags far behind Dofasco. The company has been active in building partnerships with universities in its endowment of several academic chairs, but it is not an

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operator) owns 10%.

active player in e-Commerce, nor has it expanded into overseas markets. Stelco's joint venture with Mitsubishi's MC Steel at the Hilton Works Z-Line has allowed it to market a new value-added product in the form of zinc-coating, however the company is notably absent from the hydroforming and laser-welded blanks businesses. This being said, some of the in-house research products and the project management services offered to customers at Hilton Works signal that Stelco may be moving in the direction of system integration.

The laggard of the big three integrated plants is Algoma. Despite its involvement in the revolutionary DSPC, the company is mired in debt and has responded to the obstacles of contemporary steel markets by shearing off unproductive units from its business and acquiring technology that will allow it to compete with the faster EAF and service centre steel processing operations. Algoma is conspicuously absent from the nexus of activities that generate high value-added business: the company lacks an independent research and development strategy and appears to make little attempt to foster knowledge-based collaboration with other firms or post-secondary institutions. Similarly, Algoma is not involved in either the profitable galvanizing or tubing segments of the steel industry. As a result of focusing mainly traditional steel making and producing services, Algoma remains forced to compete with its service centre rivals on the basis that it provides in-house first stage blanking that allows it to have full control over quality. (Algoma Steel Inc., 2001)

The story of the new economy steel industry in relation to the big three integrated mills is as much a continental story as it is a local one based in southern Ontario. While Stelco and Dofasco are involved in the learning environment in Hamilton area, they are also active in a North America wide network of firms, research institutes, and industrial associations that are bolstering competitiveness in North American steel production.

ii. The Minimills

Canadian minimills continue to be aggressive players in the new steel market, manifesting the sort of hi-tech learning relationships, collaborative customer relations, and global operational platforms necessary to gain and maintain a solid clientele. Unlike the integrateds, the minimills inhabit a learning environment that is industry-driven as opposed to nestled in a geographically fixed learning region. This business-to-business educative nexus is driven by system integration.

Canada's fourth largest steel producer is Ispat-Sidbec, a minimill in Contrecoeur, Quebec that is a subsidiary of Ispat International NV, the world's first global steel producer with holdings in Europe, Asia, the Caribbean, Canada and the United States and steel shipments of 16.4 million tons in 2000. (Ispat International NV, 2000) Sidbec is one of four wholly owned minimill subsidiaries that have made Ispat the world's leading producer of Direct Reduced Iron (DRI) in the world.

Sidbec produces a range of high quality flat and long steel products at three integrated facilities. Sidbec's products include hot, cold and galvanized sheet, wire rods, wire, bar and pipe products. (Ispat International NV, 2000, p.4) The heart of Sibec's production strength is its Contrecoeur facility that is equipped with two DRI Midrex plants; two 140-tonne electric arc furnaces with a capacity of 1.6 million tpa of liquid steel; two 140-tonne ladle furnaces; a single strand continuous slab caster; a six strand continuous billet caster; a hot strip mill; and a cold rolling mill equipped with a pickling line. (Ispat-Sidbec, 2001) Sidbec's two other operations are its Longueil plant, with a bar mill with 16 stands and automatic bundling equipment, and its Montreal operation that has a six stand CW pipe mill.

Sidbec and its minimill counterparts in Mexico, Trinidad, and Germany give Ispat International NV a competitive advantage from their DRI processing capacity that allows minimills to make steel from a mix of scrap and iron pellets. The capacity to manufacture steel from used metal products gives Sidbec-Ispat and other minimills a competitive advantage over BF producers, which make steel more expensively from iron ore. However, as part of a *global network* of minimills, Sidbec suffers when the price of steel falls and energy prices rise. In 2000, Sidbec's DRI plant was temporarily shut down due to rising gas prices. During the shut-down, Ispat-Caribbean in Trinidad was called on to supply Sidbec's raw material. Ispat-Caribbean's more favourable energy pricing allows it to gain competitive advantage over its Canadian and American minimill counterparts in the production of primary product in times of rising gas prices. (Ispat NV, 2000, p.4)

In addition to its EAF production capacity, Sidbec is a competitive player in the galvanized and tubular markets via two automotive-related joint ventures. Sorevco is a galvanizing hot dip galvanizing facility in which Sidbec holds 50% interest in a limited partnership with Met-Chem, an international consulting company servicing the mining, metallurgy, and mineral processing industries. (Met-Chem, 2001) Sidbec's second knowledge-intensive, value-added joint venture is Delta Tube, a tube-making facility in which Sidbec has 40% ownership in a limited partnership. As part of Ispat International, Sidbec is involved in an e-commerce strategy with Commerce One, a leading technology provider in the business-to-business portal sector. Ispat's use of e-commerce is designed to save processing costs of transactions and to enhance its access to a larger, more global supplier base. (Ispat International NV, 1999)

While Ispat says that its growth strategy is targeted at creating a global steel company aligned with the needs of customers, a review of its publications does not reveal a concerted, centralized plan for system integration. While system integration in the steel-auto supply chain is taking place incrementally through the activities of business units and their subsidiaries – such as Sidbec's Sorevco plant – there is no sign that Ispat is taking a leadership role in downstreaming automotive production practices or even in making higher value added products. Rather, it appears to be principally focused on expanding its extant commodity production capacity and marketing its products to a wider customer base.

Whereas Sidbec appears to focus equally on price competition and developing new products and services (through its joint ventures), Ipsco has aggressively added hi-tech processing and customization features to its offerings. It has installed a cut-to-length processing line at its new Toronto Works plant to directly challenge the traditional integrated mills in supply of plate to the transportation equipment sector. The line can custom cut plate up to ¾" thick and lengths from 2' to 60'. In addition, Ipsco produces "high strength micro alloyed steels," which are produced by adding minute quantities of alloy materials in the production process. Ipsco also uses temper leveling, a technique that combines a cold rolling reduction of less than three percent with leveling. This eliminates the "memory" that forms in conventional leveling operations during the hot rolling process and thus makes Ipsco's product more resistant to breaking and bending. Ipsco's more durable grade of steel is highly marketable to the manufacturing industry that is increasingly using laser cutting technology for which improved physical qualities of plate are crucial. (Warrian, 2001a, p.9)

However, applying the test of “function transferability” to the case of Ipsco, it becomes apparent that the company is as yet very limited supplier of automotive steel. Its custom cutting capacity constitutes a downstreaming function, making this part of its operations integrated into the auto manufacturing process. However, hi-tech initiatives such as temper leveling are evidence of Ipsco’s participation in a learning environment rather than of its closer ties to auto assemblers.

In summary, it is clear that the minimills appear to be focused on trying to maintain their cost advantage over the large integrateds in the production of steel. However, this overview indicates that minimills are also moving closer to the knowledge-based activities pursued by the leading integrateds. In its Sorevco and Delta Tubes joint ventures, Sidbec is generating a learning environment between itself as a primary product producer and higher value-added enterprises. In addition, Ipsco is competing for market share by integrating the needs of its customers into the production process itself through its experiments with steel microstructures and rolling memory out of the steel. (Ispat-Sidbec, 2001)

Marked differences separate these minimills from their integrated counterparts, specifically Dofasco, in terms of the degree of integration achieved to date, however. Whereas the minimills are adopting industry-wide standards (formal and informal) for products, there is as of yet no evidence that minimills have formed the same close, interconnected rapport with auto producers that is maintained by Dofasco. In the long run, however, it remains to be seen whether the longstanding relationship built between the integrateds and the auto manufacturers over the course of the first century of car production will give the integrateds an advantage over minimills in the era of system integration.

iii. Service Centres

Perhaps the biggest challenger to the traditional dominance of the integrateds and the more recent market position of the minimills is the integrated service centre. Once distributors of steel products, service centres are emerging as sophisticated and highly adaptable actors in the steel-auto supply chain. The status of steel service centres as non-producers of basic steel appears to give them an edge in the race towards system integration, as they appear to be incorporating downstreaming activities more quickly and more expansively than either of their steel producer counterparts.

Russel Metals Inc. is one of Canada's largest metals processing and distribution centres. (Russelmetals Winnipeg, 2001a) Founded in Winnipeg and headquartered in Mississauga, the company purchases metal in large volumes from producers principally in North America, adds value by providing a wide range of value added services, and then distributes the product to a broad base of approximately 15,000 end users. (Russelmetals, 2001a) Whereas it began in the business of distributing both imported and exported steel products to manufacturing industries, 50% of Russel's revenues are now generated through steel processing at its service centres. The company's Canadian service centre divisions are Russel Metals, Métaux Russel, Drummond McCall, B&T Steel, and McCabe Steel. Together, these plants produce hot rolled bars, plate products, sheet, cold finish bars, structural shapes, and tubing for automotive production. (Russelmetals, 2001a)

In addition to possessing state-of-the-art processing equipment, Russel consciously offers a range of custom services to its clientele. The company offers value-added custom processing services, starting with a direct CAD link program for fast and accurate on-line downloading of customer specifications. With these electronic drawings, Russel can offer the following range of technologically advanced services: shearing, slitting, cutting to length, which creates sheets of plate by cutting metals into pieces and along the width of coil; laser, flame and plasma cutting, which allows metal to be cut to produce various shapes according to end user supplied drawings; leveling, which entails flattening metal to uniform tolerances for proper machining; tee-splitting, involving the splitting of metal beams; edge trimming, and cambering round out its customizing capabilities. (Russelmetals, 2001a)

In addition to its ability to receive a wide range of custom processing orders, Russel Metals offers ancillary design assistance, general contracting, and pre-assembly subcontracting services. For instance, the company can provide clients with "reverse engineering" of flat parts in order to create cost-efficient CAD drawings from DXF files. (Russelmetals, 2001b)

The company also coordinates the parts processing phase of production for clients who might require further processing on equipment that is not available at Russel Metals. This general contracting service allows customers to "one-stop-shop" at Russel, saving them time and transportation costs as Russel acts as a general contractor, coordinating the entire job through subcontractors qualified to meet Russel's quality programme standards. It also ensures that one company – Russel Metals – is responsible for the total finished part. (Russelmetals Winnipeg, 2001a)

Finally, Russel Metals also offers pre-assembly parts construction services as an alternative to in-house metals processing. (Russelmetals Winnipeg, 2001c)

The advantages of sub-contracting for automakers include reduced capital investment by converting fixed costs to variable costs both in equipment and manpower, as clients only pay for a service when it is required. Also, manufacturers that sub-contract can eliminate the under-utilization of equipment and thereby increase the availability of valuable manufacturing space. Finally, sub-contracting services such as that offered by Russel Metals shortens the receivable cycle by delaying payables until parts are to be used for assembly.

Russel Metals is much further along the path to system integration than either its staunchest integrated or minimill competitors. While its steel producing counterparts are making expenditures on equipment that will allow them to producer higher quality product at less cost, Russel Metals has been pouring its resources into research, design, and manufacturing initiatives. The result is that Russel Metals' operations display a high degree of function transfer, as the firm undertakes an increasing number of assembler responsibilities.

Similarly, Samuel Manutech (SMT) of Toronto is a former steel service centre that sells complex welded components to the transportation industry, with a particular focus on autos. In 2000, the company completed a three-year transition plan that took it from being a steel service centre manufacturing commodity welded stainless steel pipe and tube to manufacturing specialty engineered solutions for its customers. This revolution in its business agenda came about under the auspices of SMT's *Continuous Improvement Program*, an initiative that established an environment of learning about best practices in the company between divisions and between firms. (Samuel Manutech, 2001) With the first three years of its value-added and system integration plan underway, SMT continues to seek to expand its market share, projecting investments of $48 m. in 2001 to ensure that its facilities remain state-of-the-art and so that its products and services meet and exceed the needs of the marketplace. (Samuel Manutech, 2000, p.4)

SMT has three divisions that relate to its automotive parts business. The first is Associated Tube Industries (ATI). ATI has 19 continuous forming welding mills[7] with plasma and TIC welders. Its services include technical support to clients in the development of new products and processes. In order to effectuate this task, ATI possesses several scientific labs, including a Quality Lab, Engineering Lab, and Metallurgy Lab. SMT's Roll Form Group undertakes custom roll-forming and secondary manufacturing for clients and offers integrated operations for notching, slotting, and embossing. (Samuel Manutech, 2001)

SMT's final auto-related division is its Steel Pickling Group, comprised of Nelson Steel; Samuel Steel Pickling; Nelson Consulting and Technology. The Pickling Group has 2.3 million tons capacity/year and offers high-volume hot rolled steel processing operations for pickling, side trimming, slitting, oils or pickle dry, dry lube, and special coatings. In 2001, SMT will acquire WorldClass Processing of Pennsylvania and install a new push-pull pickle line into Southern Ontario. World Class Processing is a pickling facility that fits nicely with the existing pickling locations and it extends SMT's processing capabilities to include an in-line temper mill and the ability to process 409 series stainless steel. (Samuel Manutech, 2000, p.3)

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[7]"Associated Tube Industries." Cited at: www.associatedtube.com/pages/faq.html

Researchers at the Pickling Group are process innovators that add value to the division's product. For instance, *Hydro Surge* is a patented hydrochloric acid pickling process that utilizes injection through specially machined parts in the sides of shallow granite pickling tanks. The high velocity injection attacks scale where it is the heaviest – on the edges – then turbulent action cleans the entire coil surface uniformly.

In addition, SMT's Pickling Group has patented *CoilBrite*, a sprayless rinse system that removes acid residue and iron oxide from coil surfaces without "line stop" staining. (Samuel Manutech, 2001b) *CoilBrite* is a pickling system in which the steel remains submerged in tanks with special additives, eliminating the staining that is caused by air reaching the surfaces during line stops. (Samuel Manutech, 2001b)

An overview of SMT's businesses reveals that its business is less focused on system integration and more geared toward knowledge-intensive steel production processes. While SMT's tubular products division is undertaking more sophisticated component production, its pickling group is engaged in research and development and innovative production practices typical of basic steel producers.

The final service centre we examined is Renown Steel, a division of Slater Steel. Renown provides high speed, close tolerance precision slitting and blanking of tin plate, hot and cold rolled, galvanized, electro-galvanized and pre-painted steels to customers in the automotive, consumer products, construction, furniture, hardware, packaging and container industries. Renown operates from a new (as of 1997) 160,000 square foot plant that has five high-speed slitters, and one cut-to-length blanking line. Two of Renown's slitters have gamma ray gauge monitors and penhold detectors. In addition, the plant has state of the art slitting capacity using shimless tooling manufactured to 40 millionth of an inch tolerance, capable of speeds of 2000 ft/minute. (Slater Steel, 2001)

Renown completes our initial examination of system integration in the Canadian steel service centre industry by illustrating that the evolutionary range present in other industries supplying the North American auto industry –from traditional steel maker to system integrator– is represented also in the steel service centre segment of automotive steel supply chain. The distinction between function transfer and knowledge-intensive business practices is critical. While Renown is employing pioneering technologies in its production facilities (particularly evinced by its use of gamma ray gauge monitors and penhold detectors), its business operations do not reflect the takeover of core assembly responsibilities from auto companies.

Our overview of the emerging system integration capacity of service centres in the steel-auto supply chain reveals, on the one hand, the extent to which these smaller, more flexible, non-commodity producing companies are posing a serious challenge to the position of both integrateds and minimills. One of the obviously critical advantages that service centres may gain over their integrated and minimill counterparts is their ability to take advantage of cheap imported steel. As non-producers of the raw commodity, service centres are able to take full advantages of pricing wars between domestic and offshore steel makers, enabling them to save costs at the start of the production process and invest in technologies that enhance the speed and quality of the process.

In addition, service centres are able to take advantage of their role as a non-commodity producer to focus more intensely on end-product concerns and service provision. The leeway created by not actually manufacturing basic steel appears to have been so advantageous to service centres that some – such as Russel Metals and SMT – are quickly eclipsing the service provision capacity of minimills and even the much larger integrated operations in terms of design assistance and project management. To a certain degree, service centres are also proving to be more actively involved in research and development, as illustrated by SMT's absorption of smaller, more specialized innovators.

However, the mixed model represented by SMT and the case of the knowledge-intensive, but "traditional," steel supplier Renown Steel raise questions about the causal origins of the evolution of steel service centres toward a system integration model. Is Russel Metals's success in adopting a system integration model indicative of its relative strengths as a service centre *per se* or does the key to understanding Russel Metals's success lie elsewhere, such as in its corporate mindset or investment capital resources? Questions such as these remain to be elucidated in the later stages of research.

IV. The Absence of Government

In the face of the daunting challenges facing the Canadian steel industry, it is interesting to note that there is currently no direct government activity bolstering the survival chances of Canadian steel companies. In the mid-1990s, the National Research Council (NRC) funded an effort to develop a new steel making process led by a consortium of major steel companies known as Project Bessemer. (NRC, 1995, p.6) As described above, the project led to the creation of the Direct Strip Processing Complex at Algoma, a world leader in thin slab casting. Project Bessemer's five year term ended in 1998. The NRC has since then undertaken no new projects relating to the steel industry.

However, indirect government support for steel innovation has been more forthcoming. For instance, the federal government contributed matching funds to Dofasco's gift of a chair in metallurgy to McMaster University. (McMaster, 1996) However, Paul Martin's indirect subsidization of Canadian industry, via the Canada Research Chair Foundation, offers no funding for innovation in steel, as none of over 200 current scientific chair holders is doing research in steel or steel-related areas.

From a regional innovation system viewpoint, the government of Ontario has provided limited support to the development of a learning environment by contributing $3 million to the $9 million McMaster University Steelmaking Centre. The provincial contribution was in partnership with Dofasco. (Ontario Challenge Fund, 2001) The mandate of the Steelmaking Centre is to improve iron making, electric furnace steelmaking, waste processing and process control strategies.

V. A Cross-Industry Overview of Activity in the Canadian Steel-Auto Supply Chain

As we argued at the beginning of this discussion, our overview of the activities of key players in the Canadian steel-auto relationship reveals a supply chain in full transformation from a linear, commodity-to-processing relationship to a complex, overlapping and bi-directional rapport between steel producing firms and between steel and auto companies.

As Canadian steel companies respond to relentlessly increased domestic and international competition, they are turning towards more advanced processing systems that add value to their product. Table 1.0 details the new processing activities undertaken across each of the three sub-sectors. (See Appendix)

In relation to the learning environment literature, we see evidence that each player in the Canadian steel industry is benefiting from membership in a nexus of learning relationships. The extent to which regional innovation is bolstering Canadian steel competitiveness is not clear across the industry, however. As our cases illustrate, there is more evidence of local and continental extra-firm learning on the part Stelco and Dofasco than in any other company or sub-sector of the industry.

In addition, we have identified learning of a different kind taking place in the minimill and service centre sub-sectors of the steel manufacturing industry. While we have shown these companies to be profiting from new economy learning relationships, these educative linkages are happening on an informal level and between firms as opposed to between firms and associational, governmental, or educational institutions. As the lines between commodity producer and secondary manufacturer becomes blurred in the auto supply chain, it remains to be seen how region impacts the learning capacity of these actors in the automotive steel supply chain.

VI. Conclusion

In this paper, we have outlined the current auto-related activities of some of the key players in the three sectors of the Canadian steel industry. The discussion was framed around the proposition that the 21st century would see the dawn of new learning relationships in which companies would make best practices and research and development pillars of their profit-making strategies in order to stay competitive amidst the fierce competition of global markets. In this paper, we have summarized evidence of a myriad of learning partnerships across the landscape of the new steel industry.

While our fact-finding exercise reveals the emergence of a steel sector that is more closely entwined with the design and assembly of the final automotive product, the extent to which Canadian steel companies are system integrators varies a great deal across firms and sub-sectors of the industry. It is quite possible at this stage of analysis that this account of the rapprochement between steel and auto producers is incomplete due to either a lack of publicly accessible documentation or the absence of an overall theme of an integrating strategy articulated by certain of the steel companies. For instance, Dofasco's *Solutions in Steel* has become the virtual subtitle of the company, and the term is omnipresent in Dofasco documents.

The reasons for this variation remain to be investigated in future work. However, it is possible to suggest that there is more at play here than poor corporate communications. Only two companies enunciated a conscious agenda for innovative change: Dofasco, through its *Solutions in Steel* initiative, and Samuel Manutech with its *Continuous Improvement Program*. Perhaps the failure of other companies to view innovation as a business survival strategy signals differences in corporate culture and attitudes that are germane in explaining the unevenness in integration extant.

Of course, many other factors could explain the developmental inconsistencies of system integration in the Canadian steel industry. The preoccupation of regional innovation systems scholars would be the extent to which the locations of these companies lend themselves to fostering knowledge-sharing relationships. On this view for example, Algoma's outlier role in steel-auto innovation lies in its distance from the hub of integrated steelmaking activity in southern Ontario. Ironically, the most dramatic auto-related steel making innovation in the last 20 years, the DSPC, is a stranded asset.

In addition, while minimills face a challenge breaking into the flat rolled market, they now have to compete with service centres, the early adopters and distributors of their flat products, for the business of parts makers and car assemblers. (Warrian, 2001a, p.9)

In conclusion, a working paper constructed from the synthesis of publicly accessible corporate documentation is bound to raise more questions than it answers. Although there is much more work to be done in elucidating the factors pushing and pulling integration in steel-auto collaboration, it is clear that greater convergence between suppliers and manufacturers will be the way of the future.

Appendix

Table 1.0: Knowledge-Intensive Activities

	Algoma	Dofasco	Stelco	Ispat-Sidbec	Ipsco	Russel Metals	Samuel Manutech	Renown Steel (Slater)
Tailor/Laser Welded Blanks	Quality Blanks International	Powerlasers	-	-	-	-	-	-
Hydroforming	No activity – Algoma shut down its seamless tubular mill in 1999.	No.1 Tube Mill, Hamilton No.2 Tube Mill, Hamilton Dofasco de Mexico	-	-	-	-	-	-
CAD Drawings/DXF Files	-	-	-	-	-	CAD/DXF Custom Drawing.	No.	No.
R&D		Innovation Group. ULSAB Project. Powerlasers (subsidiary)	Research chairs (McMaster, UBC) ULSAB Project.	Research group at Hilton Works.	Unknown.	Unknown.	ATI. Pickling group.	Unknown.
Galvanizing Lines	-	Do Sol Galva.	Z-Line (joint venture with MC Steel of Mitsubishi Corp.)	Sorevco (joint venture with Met-Chem)	-	-	-	-

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