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Design-Based Innovation for Manufacturing Firm Success in High-Cost Operating Environments

Abstract The manufacturing sector is increasingly looking to innovation to ensure productivity growth, especially in high-cost operating environments to achieve non-price based competition. The paper begins with an overview of regulatory, technological and consumer trends and developments impacting manufacturing. It considers the shifting balance between fragmenting and concentrating forces of global supply chains, and how manufacturing firms themselves are changing. This overview is followed by a discussion of the pivotal constituents of success for firms operating in high-cost environments, and concludes with the fundamental importance of innovation as a basis for success.

The paper then discusses value creation, value appropriation, and design-based innovation, and argues that manufacturers need to understand key differences between these paradigms. In particular, the difference between art and design is articulated, to avoid an otherwise common confusion between the two. The importance of an inter- and trans-disciplinary approach to innovation is emphasized, including the use of four value creation strategies – science and technology, design, art, and reverse-hermeneutic innovation.

The paper concludes that the design-based innovation paradigm is increasingly important within the manufacturing industry, but that its benefit can only be maximized if it is integrated with the other three value-creating approaches to innovation.

Keywords
Manufacturing
Science and technology innovation
Design-based innovation
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Introduction

In the manufacturing sector, innovation is seen as a fundamental way to ensure productivity growth. This is especially important in high-cost operating environments where there is a need to engage in non-price based competition. Non-priced based competition is made up of a series of complex strategies that ensure inimitability. Some examples of this are customer co-creation and customization, service experience delivery, ongoing design-intensive innovation processes, and the production of offerings that operate on the performance frontier through technological innovation.[1] Successful non-price based competition requires continuous provision of multi-dimensional value for money – as opposed to offerings from low-cost operating environments – and the adoption and deployment of advanced manufacturing technologies is seen as means to this end.[2]

This complex operating environment is influenced by a number of forces. These include government policy, technology development, productivity expansion and growth, ever-changing customer preferences, the shifting balance between fragmenting and concentrating forces of global supply chains, and the dynamics of change within the manufacturing firms themselves. Applying the appropriate value-creating paradigm is essential for successful innovation.

It is possible to identify four value-creating paradigms: science and technology innovation, design-based innovation, art-based innovation, and reverse hermeneutic-based innovation. Later in this paper these paradigms will be addressed in greater detail, but first there is a need to understand value creation, and the complex environment in which value-creating innovation is to take place. Value-creating innovation should not be confused with an innovation strategy or an innovation management system.

An innovation strategy is not the same as a Research and Development (R&D) strategy. Research can be defined as the conversion of money to knowledge, whereas innovation is the conversion of knowledge to money. A research strategy is the articulation of the domains in which new knowledge is to be developed. Any causality between R&D spending and firm success is ambiguous at best. However, it is still necessary to dedicate R&D resources toward competencies development to explore options for innovation, even though this practice does not assure success.[3] Spending more money on R&D is not the simple answer,[4] nonetheless, firms that invest heavily in R&D reap the benefits of invention in the form of patents and new insights that become published papers. Invention is not innovation. Invention requires the successful introduction of something new into the firm and/or marketplace.[5] In contrast, in its simplest form, an innovation strategy is the articulation of particular problems whose solutions would improve company performance, but for which there are presently no known off-the-shelf solutions.[6] Anderberg and Roos note that an innovation management system embodies the processes, systems, and structures that an organization deploys to ensure that innovation itself becomes a business process – and is managed as such – rather than a one-time solution that occurs at random. The principle characteristics of an innovation management system are described in detail in an earlier publication.[7]

Value-creating innovations are pursued to maximize the value that an innovation holds from the customers' point of view. These types of innovations are:[8]

- Efficiency improving innovations that enable cost cuts which are then (partially) passed on to customers. These innovations normally occur when the firm finds new ways of reducing the nine types of waste identified through the Lean approach – unnecessary transportation, rework, overstock, overproduction, waiting time, non-value adding activities, non-value adding processes, unused creativity, and intellectual waste, i.e., an overqualified person on the job;

1 Sharmistha Bagchi-Sen, "Product Innovation and Competitive Advantage in an Area of Industrial Decline: The Niagara Region of Canada," *Technovation* 21, no. 1 (2001): 45–54.

2 Lluís Santamaría, María Jesús Nieto, Andrés Barge-Gil, "Beyond Formal R&D: Taking Advantage of Other Sources of Innovation in Low- and Medium-Technology Industries," *Research Policy* 38, no. 3 (2008): 507–17.

3 Richard Leifer, G. Kasthurirangan, and D. Robeson, "R&D Investment and Innovativeness: Their Contributions to Organizational Success" (paper presented at the SMS conference, Vienna, Austria, October 29–November 1, 2006).

4 Barry Jaruzelski, Kelvin Dehoff, and Rakesh Bordia, "Money Isn't Everything—Lavish R&D Budgets Don't Guarantee Success. The Booz Allen Hamilton Global Innovation 1000 Tracked the World's Heaviest Innovation Spenders Against Common Measures of Performance and Success," *Strategy and Business* 41 (2005): 54–67.

5 Gina C. O'Connor, Richard Leifer, Albert S. Paulson, and Lois S. Peters, *Grabbing Lightning: Building a Capability for Breakthrough Innovation* (San Francisco: John Wiley & Sons, 2008).

6 For a detailed example of the structure and content of a comprehensive innovation strategy, see Bengt Anderberg and Göran Roos, "Recommendations for an Effective Research and Technology Management System within the BMVL" (proposal to Austrian Ministry of Defence, 2004); Bengt Anderberg and Göran Roos, "Vorschlag für ein Forschungssystem des ÖBH" [Proposal for a research system of the Austrian Armed Forces] (Vienna, Austria: Austrian General Staff, 2005).

7 Göran Roos, "Innovation Management: A Success Factor for Competitiveness" (paper presented at VTT Intelligence Forum: Tuottavuus ja T&K-Strategia Murroksessa; Miten Vastata Haasteeseen? [Productivity and R&D Strategy in Transition: How to Respond to the Challenge?], Helsinki 2007), 42–61; Göran Roos,

- Science and technology innovations that increase customer perceptions of an offering's instrumental value;
- Design-based innovations that increase perceived instrumental value for customers, in this case via artifacts that cause changes in user behavior. Such behavioral changes lead to the user feeling better off, and as a consequence, the creator of the object is better off. In other words, design-based innovations lead to a win-win situation;
- Art-based innovations that increase customer perceptions of a good's intrinsic value. In consumer goods, art can add to the perceived authenticity of the good, and thereby increase its value in the eye of the consumer.[9] This is critical in the luxury goods sector. Innovative techniques involving socio-drama and psycho-drama can have a profound impact on innovation and value creation both as a trigger in the innovation process and as a generator of aesthetic arousal in the overall customer experience, while using sensory stimuli, e.g. ambient scent and music, causes consumers to value the products higher.[10] Haptic stimuli can in a similar way increase the value perceived by customers through aesthetic arousal.[11] More can be said in relation to the innovation processes in the art domain,[12] but this is not for this paper;
- Innovations grounded in reverse hermeneutics that increase perceived instrumental and intrinsic value for customers by changing their emotional state.

To understand innovation, and hence the role of value-creating paradigms, we must first understand the key drivers of change. These drivers primarily relate to evolutions in global trends (in manufacturing), government policy, technology development, manufacturing productivity growth, shifting consumer and customer preferences, and the shifting balance between fragmenting and concentrating forces in global supply chains. The need to look for new approaches to innovation occurs because the world in which manufacturing companies operate is constantly changing.

Global Trends with Relevance for Manufacturing

Certain key global trends are mentioned in the manufacturing literature.[13] Firstly, there is a drive for higher and higher productivity as a consequence of product and service personalization. Second, there is a blurring of the distinction between product and service, and an increasing focus on providing solutions rather than offerings. Third, there is a move from mass production to mass customization, as a consequence of technological advancements, changing and diverging global demographics and evolutions in demand-driving preferences. In particular, the emergence of BRIC middle class consumers is an important demand driver. In response to customer needs and external impediments, manufacturing is forced towards ever more rapid change.

Added to demand is the pressure to be competitive brought on by the growth of cheaper labor markets. At the same time, we can see changes to supply chain operations including the globalization of supply chains and the simultaneous acceleration of innovation in global supply chain management. These changes are combining with increasing product fragmentation to generate a function-centric view – focusing on specific elements of the supply chain – rather than the traditional sector- or industry-wide view. In other words, individual firms as well as governments must now think in terms of specializing, and concentrate on specific elements of a given global supply or value chain and the associated implications for

"Manufacturing in a High Cost Environment: Basis for Success on the Firm Level," in *Global Perspectives on Achieving Success in High and Low Cost Operating Environments,* ed. Göran Roos and Narelle Kennedy (Pennsylvania: Hershey, 2014), 393–480.

8 Roos, "Manufacturing in a High Cost Environment, Firm Level."

9 James Gilmore and Joseph Pine, *Authenticity: What Comumers Really Want* (Boston: Harvard Business School Press, 2007); James Gilmore and Joseph Pine, *Beyond Experience: Culture, Consumer and Brand: Using Art to Render Authenticity in Business Arts & Business* (London: Arts & Business, 2009).

10 See for example: Anna S. Mattila and Jochen Wirtz, "Congruency of Scent and Music as a Driver of In-Store Evaluations and Behavior," *Journal of Retailing* 77, no.2 (2001): 273–89; Jochen Wirtz, Anna S. Mattila, and Rachel L.P. Tan, "The Role of Arousal Congruency in Influencing Consumers' Satisfaction Evaluations and in-Store Behaviors," *International Journal of Service Industry Management* 18, no. 1 (2007): 6–24; Treasa Kearney, *Incorporating Environmental Stimuli into the Service Profit Chain in a Retail Grocery Context: A Structural Equation Modelling Approach* (PhD thesis, Dublin Institute of Technology, 2012).

11 Stewarta Birrell, Mark Young, and Alex Weldon, "Delivering Smart Driving Feedback Through a Haptic Pedal," in *Contemporary Ergonomics and Human Factors 2010: Proceedings of International Conference on Contemporary Ergonomics and Human Factors 2010*, ed. Martin Anderson (Oxford, UK: Taylor & Francis Group, 2010), 431–39.

12 Albert Ali Salah, Hayley Hung, Oya Aran, and Hatice Gunes, "Creative Applications of Human Behavior Understanding," in *Human Behavior Understanding: Volume 8212 of the Series Lecture Notes in Computer Science* (Cham, Switzerland: Springer, 2013), 1–14.

13 See for example: CSIRO, *Manufacturing a Better Future: The Role of Science, Technology and Innovation: Report prepared*

by CSIRO for the Prime Ministers Manufacturing Taskforce (paper 8) (CSIRO, 2012); Forfás, *Making It in Ireland: Manufacturing 2020* (Dublin: Forfás, 2013); Susan Christopherson, Ron Martin, Peter Sunley, and Peter Tyler, "Reindustrialising Regions: Rebuilding the Manufacturing Economy," *Cambridge Journal of Regions, Economy and Society* 7, no. 3 (2014): 351–58.

14 The focus of the part of the German industry policy known as Industry 4.0 is grounded in the insight that countries and companies that invest in cyber-physical capability and infrastructure will be positioned to lead by exploiting the resulting increased flow of information.

localization. In addition, this development will increasingly require firms to simultaneously collaborate and compete, a process known as "coopetition."

At the same time there is accelerating technology development and accelerating diffusion and harmonization of technical capabilities and technology access across trading partners. This includes all existing general-purpose and key enabling technologies. In the short term, advanced manufacturing technologies like robotics and additive manufacturing technologies will have a major impact, as will the integration of information and communication technologies (including big data analytics and artificial intelligence) and sensors into the manufacturing process – otherwise known as the Internet of Things (IoT) at the technology level, and Industry 4.0 at the paradigm level. In the medium to long term, development will pertain to the adoption of synthetic biology-based manufacturing processes and the diffusion of capabilities enabling the creation of advanced materials to performance specifications. This is not limited to known enabling technologies – it also applies to those that are yet to be developed. The impact of ongoing technological development is exemplified by the now ubiquitous role of ICTs, and the blurring of boundaries between real and virtual worlds, and the need for manufacturing firms to master this cyber-physical interface.[14] The role of technological advancement is further exemplified by the trend towards increased reliance on modeling and simulation in the manufacturing process.

Increasing cost and risk related to emerging technology R&D means that these activities will be executed by those organizations that have enough capital to invest, and can accept higher levels of risk and increased delays in investment returns. For example, ROI after the development of new aircraft engines can be 8–10 years. As a consequence, R&D is moving to locations with a cultural acceptance for industry-related boundary conditions – defense industries to the US, transportation and other non-defense systems industries to Germany, the Netherlands, the Nordic region and parts of central Europe, cars to East Asia, and semiconductors and other sophisticated technology-based components and devices to East and Southeast Asia. There is an increased emphasis on environmental sustainability and resource efficiency, driven by the continuous requirement to derive more from less. This will further accelerate the adoption of new technologies and processes. For example, the additive manufacturing process generates only a high, single digit percentage of waste, whereas the normal subtractive manufacturing process generates a high, two-digit percentage of waste. Further environmental sustainability will be gained as more activities are moved into the virtual domain–exemplified by the increased use of modeling and simulation. Emerging, technologically enabled modes of operation have negligible environmental impact when compared to current prototyping and testing methods in the physical world. These developments and trends drive new ways of working that harness the full potential of every individual in the workplace, and attract appropriately skilled new employees.

Government Policy

Government policies are driven by political objectives and the economic 'lens' they use to view the world. The most commonly used economic lenses are neoclassical, originating out of Adam Smith's *An Inquiry into the Nature and Cause of the Wealth of Nations*, published in 1776; neo-Keynesian, originating out of John Maynard Keynes' *The General Theory of Employment, Interest, and Money*, published in 1936; neo-Schumpeterian, originating out of Joseph Alois Schumpeter's *Capitalism, Socialism, and Democracy*, published in 1942; evolutionary – which is sometimes clustered with the neoclassical and sometimes with the neo-Schumpeterian – originating out of Thorstein Veblen's *Why Is Economics Not an Evolutionary Science?*, published in 1898; and institutional, originating out of Walton Hale Hamilton's *The Institutional Approach* *to Economic Theory*, published in 1919.[15] These lenses put different emphasis on demand- vs. supply-side of policy, and on the role of government, and hence create different policy landscapes that are more or less conducive to the operation of manufacturing firms.

Technology Development

Technology development is impacting the cost of manufacturing via changes in opportunity space and demand space. Opportunity space is what is possible in terms of manufacturing, and hence determines the future supply space of manufactured goods. Demand space follows from an increasing awareness among customers and consumers of what is available. All technologies develop, but some are likely to have a greater impact than others. Those that are likely to have greatest impact are known as general-purpose technologies, or Key Enabling Technologies (KETs), and are characterized by their ability to simultaneously impact multiple industries, and create entirely new industries.[16] The list of pivotal KETs includes ICTs – Big Data, Big Data Analytics, Artificial Intelligence, algorithmic development, and IoT; Additive Manufacturing technologies; industrial and service robotics; other advanced manufacturing technologies; micro- and nano-electronics; industrial biotechnology; photonics; advanced materials; and nanotechnology.

Manufacturing Productivity Growth

There are a number of key drivers of manufacturing productivity growth that need to be understood to maximize such growth:

- *Public and private research expenditures* that enable continuing output growth without adding input.[17]
- *Learning-by-doing* (closely linked to experience curve effects) encompassing the balance between the positive productivity effects[18] that emerge from having, on one hand, past experience with the existing product design, past experience with other designs of similar products, experience with an existing product design from a competing provider, and awareness of competing providers' experience producing other similar designs;[19] and on the other hand, the rate at which the cumulative learning is depreciated.[20] Learning-by-doing can be further strengthened by stable relationships that allow for mutual learning synergies with positive productivity outcomes.[21]
- *Innovation* as a core driver of both firm[22] and industry productivity.[23]
- *Service input provision*, including R&D services; product design services; business support services (e.g., accounting, legal, IT, contact centers, etc.); provision of assets and processes services (e.g., outsourcing, contract manufacturing, solutions provision, equipment operations, preventive and corrective maintenance, vendor financing, etc.); communications services; supply chain management; channel to market services; product promotion services; transportation and logistics services; upgrade services; remanufacturing services; recycling services; disposal services; utilities provision; financial services; government support services (e.g., infrastructure, education, public safety, regulatory services, etc.).[24]
- *Labor productivity growth* by upgrading capital equipment,[25] and the associated labor skill levels;[26] replacing labor with capital equipment;[27] and skill-biased (or more generally factor-biased) technological change relating specifically to KETs and mostly studied as they relate to ICT.[28] ICT stands out because of its relative long-term presence in the economy, but it is likely that similar effects will be seen in regard to other KETs as they become established.
- *Managerial capability* has a major impact on the productivity growth in firms.[29]

15 For a summary of these economic lenses from a manufacturing perspective see Göran Roos, "Manufacturing in a High Cost Environment: Basis for success on the National Level," in *Global Perspectives on Achieving Success in High and Low Cost operating Environments*, ed. Göran Roosand Narelle Kennedy (Pennsylvania: Hershey, 2014),6–9, Table 1.

16 Roos, "Manufacturing in a High Cost Environment, National Level."

17 Bee Yan Aw, Mark J. Roberts, and Daniel Yi Xu, "R&D Investments, Exporting, and the Evolution of Firm Productivity," *The American Economic Review* 98, no. 2 (2008): 451–56; Ulrich Doraszelski and Jordi Jaumandreu, "R&D and Productivity: Estimating Endogenous Productivity," *The Review of Economic Studies* 80, no. 4 (2013): 1338–83; Sun Ling Wang and Eldon Ball, "Agricultural Productivity Growth in the United States: 1948–2011," Amber Wave, *USDA*, last modified February 4, 2014, http://www.ers.usda.gov/amber-waves/2014-januaryfebruary/agricultural-productivity-growth-in-the-united-states-1948-2011.aspx#.VXKEUc-qqkr.

18 These are listed by decreasing order of impact.

19 Rebecca Thornton and Peter Thompson, "Learning from Experience and Learning from Others: An Exploration of Learning and Spillovers in Wartime Shipbuilding," *American Economic Review* 91, no. 5 (2001): 1350–68.

20 C. Lanier Benkard, "Learning and Forgetting: The Dynamics of Aircraft Production," *The American Economic Review* 90, no. 4 (2000): 1034–54.

21 Ryan Kellogg, "Learning by Drilling: Inter-Firm Learning and Relationship Persistence in the Texas Oilpatch" (NBER Working Paper No. 15060, National Bureau of Economic Research, 2009), accessed May 12, 2016, http://www.nber.org/papers/w15060.

22 Marco Cucculelli, "Product Innovation and Firm's Growth in Family Firms: A Quantile Regression Approach," *International Journal of Entrepreneurship*

- *Firm (re)structuring* to achieve maximum benefit. Given the firm's existing capabilities, optimizing resource allocation can generate positive productivity outcomes.[30] This can be by way of diversification, vertical integration, or any other structure that achieves such optimization.
- *Operating in a highly competitive market* drives productivity by rewarding the more efficient producers and penalizing the less efficient producers, sometimes to the point of forcing the latter's exit. At the same time, this raises productivity level requirements for potential entrants.[31] Competition also contributes to enhanced productivity, since the adoption of new, higher productivity practices normally comes with an initial period of increased cost before the benefits starts to accrue – meaning that if there is no competitive pressure to increase productivity, the firm is likely to abstain from doing so in order to avoid these temporary cost increases.[32]
- *Agglomeration effects*: Members of agglomerations, or clusters, are more productive, and see more productivity improvement than firms that are not members of any agglomeration.[33] Average firms that are part of clusters show benefits over those not in clusters. These include an increase of fourteen percentage points to value added growth; seven percentage points to profitability growth; and two percentage points to wages per employee (a proxy for productivity).[34] Agglomeration effects include productivity spillovers – which exist in both the technological domain and the business practice domain, and are impacted by location, product, process, technology, and position in ecosystem. In spite of the fact that transactions and exchanges can be made almost instantly and independent of location and distance, there are transactions and exchanges that – for one reason or another – do not follow this pattern, but are instead highly sensitive to distance.[35] These activities need to be built on trust and a common institutional framework that can only be developed by face-to-face contact and hence require geographical proximity.[36] Those beneficial aspects of close proximity which firms cannot control or achieve in any other way than through close geographical and specialization proximity are what Storper calls "untraded interdependencies."[37] The strength of agglomeration effects depends on many different factors, including – but not limited to – industry, technology level, openness to exchange between participants, international linkages, labor exchange, etc.[38]
- *Deregulation or smarter regulation* can drive productivity improvements. Deregulation can enhance competition and generate stronger agglomeration effects. Smarter regulations impose productivity-reducing regulations on the organization, which force it to innovate in order to re-establish its previous productivity level, a level required to remain competitive with jurisdictions that do not have these productivity-reducing regulations.[39] Environmental regulations have a short-term negative but a long-term positive impact on innovation, which means that regulation can be a powerful tool to drive innovation within specific sectors – like construction – and technologies.[40]
- *Input market*s are, on the one hand, made more flexible if institutions improve match-efficiency, solve asymmetric information problems, or otherwise serve efficiency-enhancing roles; and, on the other hand, less flexible if rent-seeking behavior is facilitated.[41] Petrin and Sivadasan[42] found that increasing the cost of employee termination was associated with reduced allocative efficiency.
- *Demand* contributes to productivity. As an example, where a customer demands solutions and performance that does not presently exist in the market, the firm must innovate to meet this demand.[43] This has been

***and Innovation Management* 17, no. 1 (2013): 124–41.**

23 Mary Crossan and Marina Apaydin, "A Multi-Dimensional Framework of Organizational Innovation: A Systematic Review of the Literature," *Journal of Management Studies* 47, no. 6 (2010): 1154–91.

24 Michael Ehret and Jochen Wirtz, "Creating and Capturing Value in the Service Economy: The Crucial Role of Business Services in Driving Innovation and Growth," in *The Handbook of Service Business: Management, Marketing, Innovation and Internationalisation*, ed. John R. Bryson and Peter W. Daniels (Beaverton: Ringgold, 2015), 129–45.

25 Ann Bartel, Casey Ichniowski, and Kathryn L. Shaw, "How Does Information Technology Affect Productivity? Plant Level Comparisons of Product Innovation, Process Improvement, and Worker Skills," *The Quarterly Journal of Economics* 122, no. 4 (2007): 1721–58.

26 Pekka Ilmakunnas, Mika Maliranta, and Jari Vainiomäki, "The Roles of Employer and Employee Characteristics for Plant Productivity," *Journal of Productivity Analysis* 21, no. 3 (2004): 249–76.

27 John Foster, "The Australian Multi-Factor Productivity Growth Illusion," *The Australian Economic Review* 48, no. 1 (2015): 33–42.

28 Thomas Strobel, "Directed Technological Change, Skill Complementarities and Sectoral Productivity Growth: Evidence from Industrialized Countries during the New Economy," *Journal of Productivity Analysis* 42, no. 3 (2014): 255–75.

29 Cheyne Buckley and Ishita Chatterjee, "Drivers of Product Innovation by Australian SMEs: The Importance of Managerial Attitude" (part of Cheyne's Honours thesis, University of Western Australia, 2012), accessed May 12, 2016, http://www.academia.edu/2830881/Drivers_of_Product_Innovation_by_Australian_SMEs_The_Importance_of_Managerial_Attitude.

30 Yue Zhou, "Synergy, Coordination Costs, and Diversification

illustrated by Eliasson[44] in a study of the Swedish Gripen fighter project, where he showed that if the spillover value is divided by the development investment, there was a spillover multiplier of at least 2.6. This was in relation to a project where the government created a market by demanding something that could not be delivered in the existing knowledge context. The solution required substantial research, development, and innovation efforts. Eliasson concludes that public procurement of sophisticated public goods and services is an effective form of innovation policy. These findings are supported by other projects,[45] and indicate the importance of demand in productivity growth.

Shifting Consumer and Customer Preferences

Consumer preferences are shifting at an ever-increasing speed, and this is impacting the customers of manufacturing firms directly as well as indirectly. Ever-changing preferences pressure organizations to continuously shorten lead times and constantly develop new offerings. In turn, firms are forced to shift from being reactive to becoming proactive.

The Shifting Balance Between Fragmenting and Concentrating Forces in Global Supply Chains

Supply chain *fragmentation* is driven by trade barrier reduction. This reduction leads to wider consumer choice and hence an increased market. From a producer's viewpoint, this provides benefits that ensue from economies of scale, which can be capitalized upon by growing the size of production facilities, and thereby firm size. Fragmentation is affected by an increased use of an offshore workforce – enabled by the reduction in trade barriers – with the result that the firm is able to arbitrage national differences in labor cost to achieve production cost reductions. Historically, continual fragmentation of the global value chain would have been difficult to manage, but developments in ICT have created an ability to manage such fragmentation without increasing coordination costs. The crucial point here is that, currently, advanced goods are produced through complex interactions in fragmented and dynamic value chains, with varying degrees of proximity between interdependent manufacturing and service activities, and performed by increasingly specialized organizational entities – either firms, or parts of firms. This is evidenced by the rise of outsourcing and offshoring, the growing trade in intermediate goods, and the increasing ratio of global imports to global exports. The necessary management of interactions in these fragmented and dynamic global value chains requires continuous organizational restructuring, as well as a high level of coordination at the architectural level of the global value chain. This would not be possible without massive use of ICTs, and the direct development of – or indirect access to – appropriate capabilities.[46] International value chain coordination is further complicated by the continuous commoditization that occurs within any value chain,[47] as knowledge disseminates and barriers to entry are eliminated. In these situations competition becomes primarily cost-driven, and manufacturers relocate to an activity-specific, low-cost environment.

At the same time that this fragmentation is occurring, there is also supply chain *concentration.* Concentration is driven by a number of factors. Firstly, in emerging economies, wage levels are going up, and business environment quality is going down. Secondly, we see economies of scale for production becoming of less import.[48] In this environment there is a need for closer interaction with customers.[49] Thirdly, advances in technology reduce the labor cost component of manufacturing, and shortens the necessary production series to reach profitability.[50] Fourthly, at the same time as there is a reduction in the size of labor costs, there

Choices," *Strategic Management Journal* 32, no. 6 (2011): 624–39.

31 Roos, "Manufacturing in a High Cost Environment, Firm Level."

32 Thomas Holmes, David Levine, and James A. Schmitz, Jr., "Monopoly and the Incentive to Innovate When Adoption Involves Switchover Disruptions," *American Economic Journal: Microeconomics* 4, no. 3 (2012): 1–33.

33 Edward C. Jaenicke, Stephan J. Goetz, Ping-Chao Wu, and Carolyn Dimitri, "Identifying and Measuring the Effect of Firm Clusters Among Certified Organic Processors and Handlers" (paper presented at the Annual Meeting of the Agricultural and Applied Economics Association, 2009); Zanete Garanti and Andra Zvirbule-Berzina, "Regional Cluster Initiatives as a Driving Force for Regional Development," *European Integration Studies* 7 (2013): 91–101.

34 Örjan Sölvell and Mats Williams, *Building the Cluster Commons: An Evaluation of 12 Cluster Organizations in Sweden 2005-2012* (Stockholm, Sweden: Ivory Tower Publishers, 2013), 30.

35 Roos, "Manufacturing in a High Cost Environment, National Level."

36 Isaac Karlsson, *Regional Innovation Systems: Policy and Application in a Swedish Context* (Master's thesis, Department of Human Geography, Stockholm University, 2012).

37 Michael Storper, *The Regional World: Territorial Development in a Global Economy* (New York: Guilford Press, 1997).

38 Thomas Döring and Jan Schnellenbach, "What Do We Know About Geographical Knowledge Spillovers and Regional Growth?: A Survey of The Literature," *Regional Studies* 40, no. 3 (2006): 375–95.

39 Roos, "Manufacturing in a High Cost Environment."

40 See, for example, Harvey Averch and Leland L. Johnson, "Behavior of the Firm Under Regulatory Constraint," *The American Economic Review* 52, no. 5 (1962): 1052–69; E. E. Zajac, "A Geometric Treatment of Averch-Johnson's Behavior of

the Firm Model," *The American Economic Review* 60, no. 1 (1970): 117–25; Roger Cotton and Cara Clairman, "The Effect of Environmental Regulation on Technological Innovation in Canada," *Canada-United States Law Journal* 21 (1995): 239–47; Rainer Walz, Joachim Schleich, and Mario Ragwitz, "Regulation and Innovation: The Case of Renewable Energy Technologies," in *Proceedings of DIME Conference on Environmental Innovations 2008* (DIME, 2008); Pablo del Río González, "The Empirical Analysis of the Determinants for Environmental Technological Change: A Research Agenda," *Ecological Economics* 68, no. 3 (2009): 861–78; Rainer Walz, Joachim Schleich, and Mario Ragwitz, "Regulation, Innovation and Wind Power Technologies: An Empirical Analysis for OECD Countries" (paper presented at the DIME Final Conference, April 6–8, 2011, Maastricht) (DIME, 2011), accessed May 12, 2016, http://final.dime-eu.org/files/Walz_C5.pdf; Knut Blind, "The Influence of Regulations on Innovation: A Quantitative Assessment for OECD Countries," *Research Policy* 41, no. 2 (2012): 391–400; Göran Roos, *Manufacturing into the Future. Adelaide Thinker in Residence 2010–2011* (Adelaide, Australia: Government of South Australia, 2012), accessed May 12, 2016, http://resources.news.com.au/files/2012/03/18/1226303/147149-an-file-manufacturing-into-the-future.pdf; Roos, "Manufacturing in a High Cost Environment, Firm Level."

41 Chad Syverson, "What Determines Productivity?," *Journal of Economic Literature* 49, no. 2 (2011): 326–65.

42 Amil Petrin and Jagadeesh Sivadasan, "Estimating Lost Output from Allocative Inefficiency, with an Application to Chile and Firing Costs," *The Review of Economics and Statistics* 95, no. 1 (2013): 286–301.

43 Roos, "Manufacturing in a High Cost Environment,Firm Level."

44 Gunnar Eliasson, *Advanced Public Procurement as Industrial Policy: The Aircraft Industry as a Technical University*, Economics of Science, Technology and Innovation, vol. 34 (New York: Springer, 2010).

is an increase in level of skill required from the workforce. Fifthly, changes in the industrial structure mean an increasing need for high economic complexity in the form of a broad and deep industrial commons, and an increasing need for firms to be close to customers and key input providers (as discussed under agglomeration economic effects above). Finally, concentration is also driven by the need for a well-functioning institutional setting.[51]

As the forces that impact fragmentation and concentration shift, it is noteworthy that – in spite of the present imbalance being in favor of the fragmenting and dispersing forces – more than two-thirds of global manufacturing activity takes place in industries that tend to locate close to demand.[52]

Manufacturing Companies in Constant Flux

In this changing environment, manufacturing firms must change accordingly. One major shift is expansion of service activities in response to shrinking opportunities to add value via production activity.[53] More and more activity is taking place in virtual space, such that many firms straddle the cyber-physical interface. In regard to production activities, there is a simultaneous focus on 'ambidexterity' – cost minimization through increased efficiency, 'more for less' – productivity improvements, and 'smarter things in smarter ways' – value maximization through increased effectiveness and productivity improvements. Manufacturers also look to distinguish[54] space[55] (intention) from place[56] (deployment), with the intent to optimize the balance between mental, virtual and physical spaces and places;[57] and, as a consequence, delineate activities taking place in each of nine possible space/place constructs.[58] As an example, the goal of services provided by a manufacturer is to construct an augmented performance space for the service, and localize it to a given place in such a way as to optimize for augmented client performance.[59]

There is a need for management to be able to successfully navigate in this emerging, fast-paced, technology-enabled world. In this climate, increasing productivity is linked to managerial competence. This means that we find a higher average education level as required by higher levels of employee responsibility, autonomy, and managerial delegation that are in place at all levels in the organization,[60] and a higher level of ongoing education throughout these companies. This is critical in an increasingly complex and dynamic environment, where a higher degree of educational activity is understood to result in a lesser degree of bounded rationality.[61] There is also a trend towards a higher proportion of managers and board members with a technical/scientific educational background.

Accompanying this, there is greater focus on growing the firm's absorptive capacity – in other words, the routines and processes by which the firm acquires, assimilates, transforms, and exploits knowledge, which produces a dynamic capability that underpins competitive advantage.[62]

Naturally, these routines and processes are complemented with capable and competent individuals,[63] and a wide spectrum of high quality relationships – an effective resource system well deployed. In addition, there are higher levels of cooperation; these benefit economically from agglomeration (see discussion above.) Improved relationships also normally result in an increasing export share for the firm. Finally, there is an increasing focus on integrated innovation, a phenomenon that is of particular importance to this paper.

Manufacturing Company Success in a High-Cost Operating Environment

The term 'high-cost operating environment' is relative – it refers to countries whose cost level is above the average for a given set of manufacturing activities. Many of the countries covered by this term are long-standing members of this club – Switzerland and other OECD countries – but the club is taking on new members as the prosperity level of countries converges – in places like Singapore and China – in some areas of manufacturing. Hence, the present discussion will eventually become relevant for most countries, once their prosperity increases faster than the average. According to this author,[64] the basis for success in a high-cost operating environment is usually due to competing on superior value for money – known as non-price based competition – as opposed to competing on cost. This means placing an emphasis on effectiveness whilst still maintaining emphasis on efficiency – which will never dissipate – and requires an ambidextrous approach by the firm. Effectiveness – interpreted as doing the right thing – is about delivering what the customer values across instrumental, intrinsic, and extrinsic dimensions alike, to the extent that the customer values the offering higher than the money asked for in return for that offering. Efficiency – doing what you do as well as possible – is about delivering this value at the lowest possible cost, hence increasing the possibility of achieving a position where the customer values the offering more than the money requested in exchange for that offering.

An emphasis on effectiveness leads to a focus on innovation, and on productivity – defined as doing smarter things in smarter ways; whereas an emphasis on efficiency means ensuring as short a lead-time from idea to product as possible, and as rapid a cost reduction as possible for the new innovation, once it is put into production. Given the continuously increasing speed of knowledge dissemination – including the codification of tacit information – in our increasingly globalized world, and given that transaction costs are moving asymptotically towards zero as the activity in virtual space increases, firms in a high-cost operating environment must create and accumulate knowledge faster than firms in low-cost operating environments, and shield some critical part of their knowledge base – usually partly tacit – from becoming globally accessible, in order to extend the duration of what amounts to a temporary competitive advantage.[65] Put simply, at the same time as they create and accumulate knowledge, they need to convert this knowledge to a temporary competitive advantage faster than firms in low-cost operating environments. This is because in a highly dynamic market it is not possible to enjoy a long lasting competitive advantage – there is no such thing as a sustainable competitive advantage, but rather a sequence of temporary competitive advantages.[66] The ability to achieve one or both of these outcomes is frequently based on close interaction and cooperation with customers.

Building up and maintaining strong, interactive relationships with external partners – and primarily with lead customers – is critical to firm success.[67] The benefits include dramatic reduction in rework cost[68] and enhanced idea generation.[69] Maintaining close relationships and engagement with suppliers is similarly critical, as frequently they are drivers of process innovation and technology transfer,[70] especially in process industries.[71] Likewise, relationships with competitors – frequently in the form of "coopetition"–is also of great importance[72] and can lead to positive outcomes[73] such as shorter time-to-market, increased technological diversity,[74] and stimulus for new product innovations.[75] These benefits also result from engaged working relationships with research providers.[76] Crespi and colleagues[77] found that vertical linkages and cooperation within a business group account for 50 percent of total factor productivity growth, demonstrating that firms that have a higher level of cooperation are more likely to innovate successfully with positive impact on total factor productivity growth. Even with this degree of cooperation, it should be noted that knowledge creation is normally strongly influenced by particular location-specific factors in the regional innovation system, combined with social and cultural institutions and behaviors.[78]

Efficiency improvements and traditional productivity improvements are well

45 Göran Roos, "Defence Funding: An Investment, Not a Cost," *Connections*, no. 197 (2014); Göran Roos, "Supplementary Submission to the Senate Economics References Committee: Inquiry Into the Future of Australia's Naval Shipbuilding Industry—Future Submarine Program" (unpublished manuscript, last modified October 3, 2014).

46 Göran Roos, "The Constantly Changing Manufacturing Context," in *Advanced Manufacturing: Beyond the Production Line.*, ed. CEDA (Melbourne: The Committee for Economic Development of Australia (CEDA), 2014), 31–55.

47 Veronica Martinez, Andy Neely, Guangjie Ren, and Andi Smart, "High Value Manufacturing: Delivering the Promise" (Aim Report, London: Advanced Institute of Management Research, 2008), accessed May 12, 2016, https://core.ac.uk/download/files/23/138591.pdf.

48 Arti Grover, "Vertical FDI Versus Outsourcing: The Role of Technological Complexity and Absorptive Capacity," accessed May 12, 2016, https://www.researchgate.net/profile/Arti_Grover/publication/228423935_Vertical_FDI_versus_Outsourcing_The_Role_of_Technological_Complexity_and_Absorptive_Capacity/links/0912f510763bfba72e000000.pdf.

49 Babak Kianian, T.C. Larsson, and M.H. Tavassoli, "Manufacturing Renaissance: Return of anufacturing to Western" (paper presented at International Conference on Sustainable Intelligent Manufacturing, Lisbon, 2013).

50 Christian Brecher et al., "Integrative Production Technology for High-Wage Countries," in *Integrative Production Technology for High-Wage Countries*, ed. Christian Brecher (Heidelberg: Springer, 2012), 17–76.

51 Steven Globerman and Victor Chen, *Best Policy Practices for Promoting Inward and Outward Foreign Direct Investment* (Ottawa, Canada: Conference Board of Canada, 2010).

52 Katy George, Sree Ramaswamy, and Lou Rassey, "Next-Shoring: A CEO's Guide,"

The McKinsey Quarterly (January, 2014), accessed May 12, 2016, http://cltglobal.com/wp-content/uploads/2014/03/CLTglobal-McKinsey-Next-shoring-CEO-Guide-2014.pdf.

53 Göran Roos, "Servitization as Innovation in Manufacturing: A Review of the Literature," in *The Handbook of Service Innovation*, ed. Renu Agarwal et al. (London: Springer-Verlag, 2015), 403–35.

54 For an interesting discussion around the history of this separation see James Nickell, James W. Stines, and William Poteat, eds., *The Primacy of Persons and the Language of Culture: Essays by William H. Poteat* (Columbia: University of Missouri Press, 1993).

55 Max Jammer, in his *Concepts of Space the History of Theories of Space in Physics*, 3rd ed. (New York: Dover Publications, 1954), writes that Demokritus of Abdera (458–368 B.C.) stated that infinity is inherent in the concept of space. In this sense, space is complementary to matter, and is bounded by matter; and as a consequence, matter and space are mutually exclusive. Archytas of Tarentum (428–347 B.C.) distinguished between place (*topos*), or space, and matter. Space differs from matter, and is independent of it. Everybody occupies some place, and cannot exist unless its place exists. A characteristic property of space is that all things are in it, but it is never in something else—its surroundings are the infinite void itself. In the first book of *De rerum natura*, Lucretius emphasizes the maxim: "All nature then, as it exists, by itself, is founded on two things: there are bodies and there is void in which these bodies are placed and through which they move about." Here we find a clear and explicit expression of the idea that bodies are placed in the void, in space. With Lucretius, therefore, space becomes an infinite receptacle for bodies. Epicurus (341–270 B.C.) and Lucretius (98–55 B.C.)—the founders of the great materialistic school in antiquity—were the first to say distinctly that a thing might be real without being a body, hence space can be argued to exist.

56 Max Jammer described the notion of place in *Concepts of*

covered in the existing literature, frequently using the LEAN philosophy of "doing more of what you get paid for and less of what you do not get paid for" – otherwise known as waste elimination in the efficiency improvement literature.[79]

Effectiveness improvements and the associated productivity improvements are grounded in continuous integrated innovation. The concept of integrated innovation is made up of five dimensions that all need to be present at the right level, and all require deployment:[80]

1) *Enablers of Innovation*. These enablers are made up of both the relevant resources necessary for the commencement and execution of innovation and the deployment system[81] chosen for these resources. There are five headlines under which these resources can fall:[82]

- *Monetary* – resources whose tangible form can be exemplified by cash-in-hand, and whose intangible form by unutilized borrowing capacity;
- *Physical* – resources whose tangible form is anything you can touch, and whose intangible form represents aspects of things you can touch, like location;
- *Relational* – resources that come in the tangible form of a contract, for example, and in the intangible form of trust; both forms represent relationships held by individuals on behalf of the organization;
- *Organizational* – resources that emerge as the result of human endeavors concomitant to productivity that do not come under any of the other resource forms; in their tangible form, they are things like software, business processes, business systems, intelligence, etc.; and in their intangible form, they are things like corporate culture and actual organizational structure as opposed to the one on paper; and finally
- *Human* – in their tangible form, these resources are the physical presence of individuals in the firm; and in their intangible form, the skillsets of the individuals in the firm.

2) *Innovation Strategy*. Discussed above.
3) *Innovation Management System*. Discussed above.
4) *Value Creating Innovations*. Discussed above and below.
5) *Value Appropriating Innovations*. Discussed below.

Value Creating Paradigms

Having looked at the meaning of value-creating innovation, and the complex environment in which innovation is to take place, this paper returns to the four value-creating innovation paradigms identified in the beginning of this paper.[83] The differences between these approaches to value creation and innovation are summarized in Table 1.

Value-Appropriating Innovations

Once value has been created, there is a need to apply a set of value-appropriating innovations to ensure that any value created is captured by the provider and not the customer. These innovations fall under the following domains:[84]

- Innovations that ensure a better fit between an organization's offering and an explicit or tacit demand from key stakeholders, like reducing the resource footprint of the offering;
- Innovations that increase the effectiveness of the resource-deployment structure, like switching from a physical resource to a relational resource through outsourcing. Included in this domain are innovations that lock in key stakeholders through platform strategies – common in product-service systems where the only potential provider of the service is the provider of

Table 1. Value creating innovation paradigms.

	Science and Technology Innovation	Design-Based Innovation	Art-Based Innovation	Reverse Hermeneutics-Based Innovation
Lens	Objective and universally true understanding of reality	Subjective understanding of reality from the customer and/or user point of view	Subjective understanding of reality from the artist/creator/producer point of view	Emotional understanding of reality from the customer and/or user point of view
Objective	To change an objective attribute of an offering	To change customer and/or user behavior	To change customers' and/or users' subjective perception of reality	To change customers' and/or users' emotional state
Methodology	The Scientific Method + Engineering	Design Thinking + Engineering	Art + Design Thinking + Engineering	Reverse Hermeneutics + Art + Design Thinking + Engineering
Key control question	Is it universally valid, can it be expressed in a codified way, and is the outcome repeatable? Has this universally valid change increased the offering's value in the eyes of customers to such an extent that the marginal increase in customer willingness to pay exceeds the marginal increase in cost to provide the modified offering?	Has the behavior of the customer and/or user changed, and have the customer and/or user and the supplier benefited from this behavior change?	Has the customer's and/or user's subjective perception of reality changed, and have the customer and/or user and the supplier benefited from this changed perception?	Has the customer's and/or user's emotional state changed, and have the customer and/or user and the supplier benefited from this new emotional state?

the product – or the use of strategies like cost switching or market barriers;

- Innovations aimed at reducing coordination costs. Coordination cost includes costs attributable to imperfect information, and the opportunistic behavior of organizational actors that may contribute to uncertainty in the firm;
- Business Model Innovations can act both as an improvement in the appropriation of any value created – their primary application – as well as an additive increase in the value created – their secondary application.

The specific dimensions of a business model will vary by sector, firm, and activity-system; there is no specific set of dimensions that will be relevant across all firms.[85] Business model innovation involves an innovation in at least one of the constituent dimensions of the specific business model.

The impact of coordination cost-based decisions on business models is either an increase in business model precision, a broadening of the coverage in the business model, or a termination of the existing business model. One of the key strategies that a firm can use to achieve a high level of value appropriation is to widen the coverage of its business model, and participate in value chains where the firm

Space the History of Theories of Space in Physics, 3rd ed. (New York: Dover Publications, 1954). He tells us that in Book IV of his *Physics*, Aristotle (384–322 B.C.) expands on an axiomatic basis a deductive theory of the characteristics of place. Place is an accident—having real existence, but not an independent existence, in the sense of a substantial being. Aristotle's four primary assumptions are: a.) that the place of a thing is no part or factor of the thing itself, but is that which embraces it; b.) that the immediate or "proper" place of a thing is neither smaller nor greater than the thing itself; c.) that the place where the thing is can be quitted by it, and is therefore separable from it; and d.) that any and every place implies and involves the correlatives of "above" and "below," and that all the elemental substances have a natural tendency to move towards their own special places, or to rest in them when there—such movement being "upward" or "downward," and such rest "above" or "below."

57 Naeve makes the following statement to link places and spaces: *You create a place by placing a thing in space*. See: Ambjörn Naeve et al., "Integrated Industrial Workplace Model Reference Implementation: Issue 1" (working paper for Technology Enhanced Learning Livinglab for Manufacturing Environments (TELL-ME Consortium), 2014).

58 The nine combinations are: mental space and mental place; mental space and virtual place; mental space and physical place; virtual space and mental place; virtual space and virtual place; virtual space and physical place; physical space and mental place; physical space and virtual place; and physical space and physical place.

59 Naeve et al., "Integrated Industrial Workplace Model Reference Implementation."

60 Colin Davis et al., "Sector Skills Insights: Advanced Manufacturing (Evidence Report 48)" (UK Commission for Employment and Skills, 2012), accessed May 12, 2016, http://eprints.staffs.ac.uk/1688/1/evidence-report-48-advanced-manufacturing.pdf.

was not previously active, so as to reach profit pools previously inaccessible. Spring[86] identified the following themes for future manufacturing business models:

1) The decoupling of ownership from product use and the increasing presence of circular economy thinking will require the development of products, institutions, and systems appropriate to recycling, re-manufacture, and re-use, and lead to more fluid attachments between products, owners, and users.
2) Increasing importance will be placed on intrinsic and extrinsic value attributes – including sustainability, personalization, and guarantee of provenance – and the information about these facets will become 'attached' to products.
3) ICTs will increasingly enable radical deconstructing and re-constructing of the activities involved in product manufacture (broadly defined), and in product use.
4) There will be an increasing number of ways that value can be captured – in addition to a combination of strategic control of assets and mechanisms for making transactions. This will include new ways to track, measure, and remunerate.
5) Value will increasingly be created through interactions among many small organizations, rather than through actions within fewer, larger organizations.

Common business model dimensions for product-centric service business and servitized manufacturing firms are summarized in Table 2.

Table 2. Common business model dimensions for product-centric service businesses and servitized manufacturing firms.

A Generic Service Business Model for Product-Centric Businesses			A Generic Business Model for Manufacturing Businesses
Element classification	Element	Description	Description
Strategic business choices	Position in company strategy	Companies are value partners supporting their customers' (segments') value creation in order to provide solutions that meet customer needs, including subconscious needs.	Positioning of THIS business within the company's strategy.
	Offerings	Bundled services and products that meet customer needs and support customer value creation. Services are understood as processes that support customer value creation processes.	Description of the product-service-system/solution offering.
			Technology base of the product-service-system/solution offering.
			Design base of the product-service-system/solution offering.
			Art base of the product-service-system/solution offering.
			Reverse hermeneutics base of the product-service-system/solution offering.

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61 Jos Strobbe, "Firm Size in the Netherlands" (SCALES-paper N200211, 2002), accessed May 12, 2016, http://ondernemerschap.panteia.nl/pdf-ez/n200211.pdf.

62 Jim Andersén, "The Absorptive Capacity of Family Firms: How Familiness Affects Potential and Realized Absorptive Capacity," *Journal of Family Business Management* 5, no. 1 (2015): 73–89; Oliver Som, Eva Kirner, and Angela Jäger, "The Absorptive Capacity of Non-R&D-Intensive Firms," in *Low-Tech Innovation*, ed. Oliver Som and Eva Kirner (Cham: Springer, 2015), 145–64.

63 Silvia Massini, "Microfoundations of Absorptive Capacity Capabilities: The Role of Individuals in Shaping Organizational Routines" (paper presented at the Summer Conference on Opening up Innovation: Strategy, Organization and Technology, Imperial College London Business School, June 16–18, 2010), accessed May 12, 2016, http://www2.druid.dk/conferences/viewpaper.php?id=501455&cf=43.

64 Roos, "Manufacturing in a High Cost Environment, Firm Level."

65 Göran Roos, "The Role of Intellectual Capital in Business Model Innovation: An Empirical Study," in *Intellectual Capital Strategy Management for Knowledge-Based Organizations*, ed. Patricia Ordóñez de Pablo, Robert Tennyson, and Jingyuan Zhao. (Hershey, PA: IGI Global, 2013), 76–121.

66 Rahul Kapoor and Shiva Agarwal, "Unpacking the Temporary Nature of Competitive Advantage," in *Academy of Management Proceedings*, January 2014, no. 1 (New York: Academy of Management, 2014); Kuo-Feng Huang, Romano Dyerson, Lei-Yu Wu, and G. Harindranath, "From Temporary Competitive Advantage to Sustainable Competitive Advantage," *British Journal of Management* 26, no. 4 (2015): 617–36.

67 Juho Ylimäki, "A Dynamic Model of Supplier–Customer Product Development Collaboration Strategies," *Industrial Marketing Management* 43, no. 6 (2014): 996–1004.

Table 2. (*Continued*)

A Generic Service Business Model for Product-Centric Businesses			A Generic Business Model for Manufacturing Businesses
Element classification	Element	Description	Description
	Target customer segments	Select customers (customer segments) whose business may be supported by way of our services in order to utilize our core competencies to deliver services.	Identification of target customer segments, target consumer segments, and other definitive stakeholders.
	Customer relationships	Long-term relationships/partnerships; close relationships with joint processes; and dense, ongoing exchange of information. Joint processes: service providers move closer to end users/customers in the value chain.	Relationship width, depth, and frequency for each of the target customer segments and other definitive stakeholders.
			Value attribute, attribute preference, and attribute performance for each of the target customer segments, target consumer segments, and other definitive stakeholders.
	Core competencies, capacity, and tools	Competencies related to understanding customer business, processes and operations – at least to some extent, and information management within service networks. Competent personnel are required to deliver services. Capacity may be limited in some geographical areas.	Value configuration (value chain, value shop, and value network) and associated transaction and coordination cost issues.
			Resources, competitive advantage, and resource deployment structures (e.g., the IC Navigator).
	Partner network	Strategic service partners, and partners delivering services at some sites/locations. Partner networks often operate under the brand of the company acting as an integrator.	Place, role and strategy of THIS business in the business ecosystem of which it is part.
	Value proposition	Value comes from solutions supporting customer value creation. Such solutions consist of services and products.	Value proposition for each of the target customer segments, target consumer segments, and other definitive stakeholders.
Customer concerns: Understanding and supporting customer value creation	Customer value creation	Customer value creation and related processes need to be understood.	How do the target customer segments, target consumer segments, and other definitive stakeholders capture value from the offering?
	Value capture	Customer value comes from solutions best supporting their value creation – the services supplied may even add to the value of whatever the customer outcome is.	What competitive advantage does the offering enable, or contribute to, within the target customer segments, target consumer segments, and other definitive stakeholders?

(*Continued on next page…*)

68 Hans Dietmar Bürgel and Andreas Zeller, "Controlling Kritischer Erfolgsfaktoren in Der Forschung Und Entwicklung" [Controlling Critical Success Factors in Research and Development], *Controlling* 9, no. 4 (1997): 218–25.

69 Heinrich Arnold, Michael Erner, Peter Möckel, and Christopher Schläffer, "Business (Lead) Customer Involvement in the Innovation Process," in *Applied Technology and Innovation Management*, ed. Heinrich Arnold et al. (Berlin: Springer, 2010), 59–71.

70 Amy Lee, Wei-Ming Wang, and Tsai-Ying Lin, "An Evaluation Framework for Technology Transfer of New Equipment in High Technology Industry," *Technological Forecasting and Social Change* 77, no. 1 (2010): 135–50.

71 David Rönnberg Sjödin, "A Lifecycle Perspective on Buyer-Supplier Collaboration in Process Development Projects," *Journal of Manufacturing Technology Management* 24, no. 2 (2013): 235–56.

72 Saïd Yami and André Nemeh, "Organizing Coopetition for Innovation: The Case of Wireless Telecommunication Sector in Europe," *Industrial Marketing Management* 43, no. 2 (2013): 250–60.

73 Maria Bengtsson and Sören Kock, "'Coopetition' in Business Networks—to Cooperate and Compete Simultaneously," *Industrial Marketing Management* 29, no. 5 (2000): 411–26.

74 John McGrego and Simone Amorim, "Ecosystem Business Models and Architectures" (paper presented at VIII Workshop de Desenvolvimento Distribuído de Software, Ecossistemas de Software e Sistemas de Sistemas [8th Workshop on Distributed Software Development, Software Ecosystems, and Systems-of-Systems], WDES 2014, Maceió, Brasil, 2014), 33.

75 Paavo Ritala, "Coopetition Strategy—When Is It Successful? Empirical Evidence on Innovation and Market Performance," *British Journal of Management* 23, no. 3 (2012): 307–24.

76 Göran Roos and Stephen Pike, "Bridging the Gap between

University Research and Firm Innovation," in *Bridging the Gap Between Academic Accounting Research and Professional Practice*, ed. Elaine Evans, Roger Burritt, and James Guthrie. (Sydney: The Institute of Chartered Accountants in Australia, 2011), 31–50.

77 Gustavo Crespi, Chiara Criscuolo, Jonathan E. Haskel, and Matthew Slaughter, "Productivity Growth, Knowledge Flows, and Spillovers" (NBER Working Paper No. w13959, National Bureau of Economic Research, 2008).

78 Stefan Lüthi et al., "The Relational Geography of the Knowledge Economy in Germany: On Functional Urban Hierarchies and Localised Value Chain Systems," *Urban Studies* 50, no. 2 (2013): 276–93.

79 For a discussion of additional firm-specific drivers, see e.g. Roos, "Manufacturing in a High Cost Environment, Firm Level."

80 Göran Roos, "How to Get Paid Twice for Everything You Do," *Innovation Management, Ericsson Business Review*, no. 1 (2012), 45–51.

81 A deployment system is the specific way in which an organization has decided to transform one resource into another with the intent of achieving its objective.

82 Göran Roos, "The Intellectual Capital Navigator as a Strategic Tool," in *International Business Strategy and Entrepreneurship: An Information Technology Perspective*, ed. Patricia Ordóñez de Pablo (Hershey, PA: IGI Global, 2014), 1–22.

83 To wit: science and technology innovation, design-based innovation, art-based innovation and reverse hermeneutic-based innovation.

84 Roos, "Manufacturing in a High Cost Environment, Firm Level."

85 See Table 2 for the most common dimensions of a business model for a product-centric service business and a servitized manufacturing firm.

86 Martin Spring, "Which Business Models Might Ensure UK Value from Emerging Sectors?" (review commissioned as part of the UK Government's Foresight

Table 2. (*Continued*)

A Generic Service Business Model for Product-Centric Businesses			**A Generic Business Model for Manufacturing Businesses**
Element classification	Element	Description	Description
	Customer advantages	Customers obtain solutions without spending their resources beyond their core competencies.	What competitive advantage does the offering enable, or contribute to, within the target customer segments, target consumer segments and other definitive stakeholders?
	General customer prerequisites	Customer key competencies and businesses are well understood by customers. Customers accept the services and commit to developing their own business at different levels (strategic, process, operations) in order to fully benefit from the services. Purchasing know-what and knowhow.	What requirements must be fulfilled by the target customer segments, target consumer segments, and other definitive stakeholders in order to be able to benefit from the offering?
	Implementation model	Joint service configuration and implementation. Implementation involves different levels provided by service providers and customers. Setting right Key Performance Indicators (KPI's) is elementary.	How should the product-service-system or solutions offering be implemented within target customer segments, target consumer segments, and other definitive stakeholders to ensure the targeted benefits (value)?
Profitable service business	Earning logic	Earnings are accrued over time, and are based on value created. Jointly defined KPI's pinpoint over- and under-performance for all parties (provider–customer). There are agreed principles in place for dealing with performance-related risks.	Revenue Models with focus on accessing multiple profit pools, and maximizing the number of revenue streams/pricing logic combinations aimed at achieving economic value addition for the business that exceeds the revenue stream from its primary offering.
	Pricing	Value-based pricing: our service should deliver guaranteed value exceeding service-related costs. Therefore, a righteously dividable "value" surplus will be generated.	Cost structure as a function of strategic choices and identification; management objectives directed toward associated economic value added drivers; and bankruptcy predicting indicators.
Delivery	Delivery channel	Own delivery set-up or use of service delivery networks, which can be organized in various ways to enable local offerings that maintain a profitable business. Service delivery networks may not appropriate customers.	Outgoing logistics and distribution channels dedicated to each of the target customer segments, target consumer segments, and other definitive stakeholders.
			Appropriate incoming logistics and supply chain.

The Role of Design-Based Innovation

Implementing any value-creating innovation paradigm requires knowledge of what that paradigm is and how it generates value. While each of these innovation paradigms needs to be understood, this paper is concerned with design-based innovation. One of the problems we run into when we enter the design domain is confusion surrounding the many uses and meanings of the term 'design.' It can be a noun or a verb, it can relate to the engineering domain or the art domain, etc. In this paper, the definition of design is limited to the process that contributes to the creation of an artifact that changes the behavior of the customer and/or user in a predictable and desirable way. Sriram[87] defines four design categories: creative design, innovative design, redesign, and routine design (as outlined in Table 3).

The primary focus of this paper is on the innovative design process – the decomposition of the problem is known, but the alternatives for each component of the offering are unknown and must hence be synthesized – sometimes by using existing solutions and drawing on directed creativity, as well as knowledge and experience. This discussion includes, to some extent, the creative design process at the core of which lies a transformation from the subconscious to the conscious. This is due to the fact that the domain-specific knowledge – heuristic, qualitative, and quantitative – needed to generate the solution set and the set of explicit constraints – functionality, performance, ecological impact, manufacturability, resource constraints – may be only partially specified, while the set of possible solutions, the set of transformation operators, and the artifact space are all unknown. The design process is articulated by Brown[88] as a system of spaces that is iteratively passed through in an episodic way, rather than a series of orderly steps. This process draws on and combines abductive, inductive, and deductive reasoning.[89] In this process there is use of both metaphor and analogy, as articulated by Hey et al. in the following passage:

> "Metaphors frame and assist the designers in defining the design problem. Metaphors are commonly used to map users' understanding, activities and reactions to a product. They help make sense of customer needs or physical attributes from the source of inspiration. Metaphors' exceptional communication ability provides meaning to a design situation; a cafeteria when seen as an oasis for its visitors becomes a different place entirely. Analogy, in contrast, primarily maps the causal structure between the source product or system in one domain to the target design problem being solved. The causal structure includes a devices' functional solutions, geometry or component configuration."[90]

A generic process for design thinking tends to include the following spaces:

- Understand the prerequisites of the problem – the market, the customer, technology, perceived constraints, etc.;
- Observe users in real life situations using a variety of ethnography techniques to develop empathy for users;
- Define insights – create a point of view for reframing the problem;
- Ideate and prototype multiple alternatives in short iterations;
- Test by getting feedback, then modify and reiterate solutions, and if necessary, problem formulation.[91] This stage is frequently summarized as an iteration of the circular process: Observation → Analysis → Genesis → Test, until the solutions criteria are fulfilled.

Articulating a unified understanding of design is not made any easier by the fact that many activities labeled as design are actually activities that would fall under the heading of "art-based innovation" in our discussion above, and some even encroach on the reverse hermeneutic-based innovation domain.[92] For our

Future of Manufacturing Project, Government Office for Science, London, 2013).

87 Duvvuru Sriram et al., "Knowledge-Based System Applications in Engineering Design: Research at MIT," ***AI Magazine*** **10, no. 3 (1989), 79.**

88 Tim Brown, "Design Thinking," ***Harvard Business Review*** **86, no. 6 (2008).**

89 Roger Martin, ***The Design of Business: Why Design Thinking is the Next Competitive Advantage*** **(Boston, Mass.: Harvard Business Press, 2009).**

90 Jonathan Hey, J. Linsey, A.M. Agogino, AND K.L. Wood, "Analogies and Metaphors in Creative Design," ***International Journal of Engineering Education*** **24, no. 2 (2008): 283.**

91 Sam Bucolo and Perer King, ***Design for Manufacturing Competitiveness*** **(Sydney: Australian Design Integration Network(ADIN)/CSIRO/UTS, 2014); "Human-Centered Design Toolkit"** ***IDEO*****, accessed May 12, 2016, https://www.ideo.com/by-ideo/human-centered-design-toolkit; "The Bootcamp Bootleg,"** ***Stanford*** **d.school, accessed May 12, 2016, http://dschool.stanford.edu/use-our-methods/the-bootcamp-bootleg/.**

92 For an interesting discussion on the complexities in the field of design, see Lucy Kimbell, "Rethinking Design Thinking: Part I," ***Design and Culture*** **3, no. 3 (2011): 258–306; Lucy Kimbell, "Rethinking Design Thinking: Part 2,"** ***Design and Culture*** **4, no. 2 (2012): 129–48; and Ulla Johansson-Sköldberg, Jill Woodilla, and Mehves Çetinkaya, "Design Thinking: Past, Present and Possible Futures,"** ***Creativity and Innovation Management*** **22, no. 2 (2013): 121–46.**

Table 3. Different design types.

	Creative Design	Innovative design	Redesign	Routine design
Does an a priori decomposition of the problem into a set of levels that represent component or object hierarchy choices for the solution of the problem exist?	No	Yes	Yes	Yes
Do the alternatives for the different hierarchies established exist?	No	No	Partially	Yes
Designers' approach to the problem	Divergent thought process	Fundamental domain principles used to develop alternatives for the different hierarchies established	An existing design is modified to meet changed functional needs	Appropriate alternatives are sought for each subpart that satisfy the constraints
Key element	Transformation from subconscious to conscious	Novel combination of existing components. Creativity Theory of inventive problem solving (TRIZ)[i]		

Examples of various theoretical contributions	
• Pahl & Beitz[ii]	Identify essential problem, need or task → Establish function structures → Create specifications for solution → Search for working principles → Combine principles into concept variants → Concept preliminary layouts → Test embodiment with respect to solution principles → Form variants of assemblies → Optimize design → Arrive at definitive layout → Finalize production documents
• Buzan & Buzan[iii]	Identify goal (implicit) → First burst of associative ideas around the goal (brainstorming) → First reconstruction and revision → Incubation → Second reconstruction and revision (analysis and decision-making) → The final stage of matching solution with goal
• McKee[iv]	Inciting incident → Establish context → Define conflicts → Search for resolution → Critical choices which are most likely to lead to success → Climax → Reversal → Resolution
• Nydahl[v]	Define current situation which inherently creates the motivation and reason for moving toward another goal → Establish specifications for the ideal final goal → Set up conceptual template of a potential solution → Establish detailed structure of solution template in iterations addressing material, information, and communications systems → Overlay solution template on current situation → Evaluate best fit of solution in context of current situation for activation → Dedicate a general application or template for all other systems
• Kurtz & Snowden[vi]	Define known domain (cause and effect of situation are repeatable and predictable) → Establish parameters of knowable domain (cause and effect may mismatch in time and space) → Explore complex domain (cause and effect are coherent only in hindsight) → Explore chaotic domain (cause & effect relations are completely incomprehensible) → Return to complex domain → Establish second known situation
• Pahl & Newnes[vii]	Problem as point → Problem as field → Idea generation → Idea evaluation → Insight, integration and pattern matching → Solution as field → Solution as point (ideal final result)
• Bucolo & King[viii]	Reframe (clarity of purpose) → Envisage (become your market) → Exploring (be the disruptor) → Prototyping (integrate your business model) → Questioning & Learning (change the experience)

i The power of TRIZ is clear by finding that most, if not all, design heuristics observed are subset of the complete TRIZ set of approaches. See Seda Yilmaz, Shanna R. Daly, Collen M. Seifert, and Richard Gonzalez, "How Do Designers Generate New Ideas? Design Heuristics across Two Disciplines," *Design Science*, 1 (2015), e4.

ii Gerhard Pahl and Wolfgang Beitz, *Engineering Design*, 1st ed. (London: Springer, 1984).

iii Tony Buzan and Barry Buzan, *The Mind Map Book: How to Use Radiant Thinking to Maximize Your Brain's Untapped Power* (New York: Plume, 1993).

iv Robert McKee, *Story: Substance, Structure, Style, and the Principles of Screenwriting* (London: Methuen, 1997).

v Ole Nydahl, *The Guru Yoga Meditation on the 16th Karmapa* (New York: Firewheel, 2000).

vi Cynthia Kurtz and David Snowden, "The New Dynamics of Strategy: Sense-Making in a Complex and Complicated World," *IBM Systems Journal* 42, no. 3 (2003), 462–83.

vii Anja-Karina Pahl and Linda B. Newnes, "Co-Evolution and Contradiction: A Diamond Model of Designer-User Interaction," in *Use and Redesign in IS: Double Helix Relationship?*, ed. Hans-Erik Nissen, Peter Bednar, and Christine Welch (Santa Rosa, CA: Informing Science Press, 2007), 127–202.

viii Sam Bucolo and Peter King, *Design for Manufacturing Competitiveness* (Sydney: Australian Design Integration Network(ADIN)/CSIRO/UTS, 2013).

purpose the work by Carlgren[93] forms a good foundation, since it focuses on design thinking as an enabler of innovation and argues for a focus on what design thinking can do in various settings, thus putting focus on context and outcome. She suggests that design thinking should be understood as a set of five principles: human-centeredness, diversity, problem framing, experimentation, and prototyping, each of which are enacted and embodied through a number of mindsets, practices, and techniques. These principles are informed by design practice, but may play out differently in each particular context. She goes on to argue that one characteristic that stands out is a strong focus on mindset change as something to strive for, which aligns well with the definition we have adopted in this paper.

As stated above, design-based innovation plays a role in both the value creating and value appropriating areas of the innovation process. The definition of design appropriate for ongoing operations in a firm is a modified version of a statement by Bessant.[94] This modification is shown below, in bold text:

> "[d]esign is essentially the application of human creativity to a purpose – to create products, services, buildings, organizations and environments which meet people's needs **and change their behavior in a desired way that makes both the provider and the user perceive themselves as being better off**. It is the systematic transformation of ideas into reality, and it is something which has been going on since the earliest days of human ingenuity."

When done well, design, has been shown to positively impact firm performance;[95] and the larger the investment in design, the more important that design is done effectively. Effectiveness is enabled and strengthened through design management, which then further enhances its impact on firm performance.[96]

The role of design will be different as a consequence of an individual firm's unique combination of operating environment, strategy, and business model. For example, in a firm focusing on efficiency and associated productivity improvements, the focus will be on design-for-manufacturability and on a cost-efficient balance between function, form, and fit,[97] in addition to producing offerings that satisfy articulated customer needs, and change users' behavior in such a way as to make both the user and the firm perceive themselves to be better off.[98]

From the discussion in this paper it is clear that there is one major trap and one set of requirements that become critical when design is used as a tool for the manufacturing industry. The trap is confusing the use and definition of art with design – something seen quite frequently in architectural education for example. The requirements are for every participant in the value-creating process that represents a given paradigm to have enough understanding of the other paradigms to both contribute to them and make use of them in a synergistic way. This is particularly critical for engineers who are frequently educated in the science and technology paradigm, but who are expected to contribute to the practical

93 Lisa Carlgren, *Design Thinking as an Enabler of Innovation: Exploring the Concept and Its Relation to Building Innovation Capabilities* (Gothenburg, Sweden: Chalmers University of Technology, 2013).

94 John Bessant, "Why Design?" in *Design in Business: Strategic Innovation through Design*, ed. Margaret Bruce and John Bessant (New York: Financial Times Prentice Hall, 2002), 3–17.

95 Julie Hertenstein, Marjorie B. Platt, and Robert W. Veryzer, "The Impact of Industrial Design Effectiveness on Corporate Financial Performance," *The Journal of Product Innovation Management* 22, no. 1 (2005), 3–21.

96 Ricardo Chiva and Joaquín Alegre, "Investment in Design and Firm Performance: The Mediating Role of Design Management," *Journal of Product Innovation Management* 26, no. 4 (2009): 424–40.

97 David F. Ciambrone, *Effective Transition from Design to Production* (Boca Raton, FL: Taylor & Francis, 2007).

98 Roos, "Manufacturing in a High Cost Environment, Firm Level."

implementation of solutions in the other paradigms. For designers, this means understanding the distinction between the design and art paradigms, as well as having a sufficient understanding of the paradigms of reverse hermeneutics and science and technology to be able to both contribute to work done in these paradigms as well as draw on the insights generated by these paradigms for use in the design paradigm. This bears reflecting on for those educational institutions claiming to educate designers to work in the manufacturing sector.

Conclusion

In a high-cost operating environment, where most drivers are changing relatively rapidly, deploying design-based innovation is increasingly important to effectively engage in non-price based competition. Design-based innovation as a standalone approach is less valuable than if used in an integrated way with the other three innovation paradigms – science and technology, art, and reverse-hermeneutics. This integrated use means that an inter- and trans- disciplinary way is needed. This requires that the individuals involved have deep domain knowledge as relates to their own paradigm, but also that they have sufficient domain knowledge about each of the other paradigms to be able to work effectively in a team that will deploy an integrated innovation approach using all four paradigms. The present education of designers aimed at working in the manufacturing industry needs to be strengthened with this broader understanding to secure the utility value of the designers to this industry.

In the value capture innovation sphere of manufacturing firms, design plays two key roles: Firstly, it provides an opportunity to design new business models; and secondly, it provides an opportunity to improve the fit between the explicit or tacit needs of the customer and the offering, and hence increase the value of the offering in the eyes of the customer, facilitating higher value capture.

In the value-creating innovation sphere, design provides an opportunity to innovate – not only to improve the fit between the explicit or tacit needs of the customer and the offering, but also to create an artifact that changes the behavior of the user in such a way that the user feels better off having adopted this new behavior – frequently in their interaction with the artifact – and as a consequence of this new behavior, the artifact provider also achieves a state of being better off. It is the inter- and trans-disciplinary approach that forms the fundament for achieving this outcome in the value-creating domain.

From the discussion in this paper it can be inferred that the demand for designers from the manufacturing industry will increase, but this may be a temporary effect unless the available designers are able to really add value to these firms by having a good understanding of not only their own field, but also all adjoining fields. At the moment, the number of designers that fulfill this requirement are very few, and the reason for this is the way in which design education is presently executed at many institutions around the world.

Commentary

Integrating Design into the Overall Innovation System

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I was very pleased to see this article, which brilliantly analyzes the possibilities and impact of design innovation on the manufacturing industry. The article describes well how design can and should be connected to the dynamic changes taking place in the manufacturing industry as a result of unforeseen advancements in the technology sector, the development of management systems, and revolutionary market and consumer behaviour. Roos notes that design-based innovation will have increasing importance when it comes to non-price based competition.

Göran Roos rightly notes that the full benefit of design-based innovation can only be felt through deep integration with three other value creating innovation approaches – science and technology based innovation, art-based innovation, and reverse hermeneutic-based innovation. I would like to add that the key to maximizing the benefit of design is its *integration into a company's overall innovation system*. This would ensure that design thinking is an integral part of all business activity, and can thus have the greatest impact on the innovativeness of a company as a whole, and thus its manufacturing systems. *This would mean that companies should have Chief Design Officers, which is rarely the case today.*

The article points out how important it is to see the great challenges in the *transformation from a product-based industrial system to a service-based system, where products deliver services, instead of the product being the hero.* This transition also requires customers to shift their mindset away from price concerns, to better quality and service with a better experience. Design-based innovation has the power to increase the perceived instrumental and intrinsic value of products and services through the aesthetic appearance of the product/service, its ease of use, and through suggesting novel ways of doing what are – or become – everyday tasks. At best, this will change people's behavior and open up new horizons for the company.

Roos notes the importance of the innovation environment. *Innovation ecosystems will be decisively important not only in terms of competitiveness, but also as boosters of novel innovations.* As the complexity of problems rapidly increases, companies who can become active players in dynamic innovation ecosystems will be those who benefit the most. Successful ecosystems build synergy by enabling cities, universities, companies, NGOs, students, and individuals to collaboratively tackle the central issues shaping national and local policies, and business strategies. This obviously makes cooperation and knowledge dissemination easier, and the flow of ideas more effective. Dynamic innovation ecosystems have become strategically important "platforms" for innovative competition. Local and national innovation and design strategies should therefore put emphasis on establishing these platforms. This puts design innovation in a new context, and creates completely new demands, which should be noted in education.

At the end of his extremely thorough article, Roos carries out an analysis of the different design categories, and their methodologies and problem-solving processes. *This demonstrates an evolution in and diversification of design as a discipline.* He says that "for our purposes, the work by Carlgren forms a good foundation since it focuses on *design thinking as an enabler of innovation* and argues for a focus on what design thinking can do in various settings, thus, putting focus on context and outcome. She suggests that design thinking should be understood as a set of five principles: *human-centeredness, diversity, problem framing, experimentation, and prototyping – that are enacted and embodied through a number of mindsets, practices, and techniques.*[1]

I would like to add few essential aspects to Carlgren's excellent definition: *1) a holistic way of looking at problems, 2) visionary thinking, and 3) user-driven innovation as a core of human-centeredness.* Holism – the drive and capacity to simultaneously consider multiple aspects related to a problem – and the search for a holistic solution are key issues in design. Visionary thinking refers to both visionary ideas and the ability to visualize new, yet to be developed potential solutions. This has multiple impacts on the problem solving process, as it provides a means to illustrate to decision makers what a solution combining the ideas of different experts could look like. This supports, guides, and hastens decision-making processes.

User driven innovation is the most important aspect, as it can have the greatest possible impact. It is a much broader idea than merely "observing users in real life situations using a variety of ethnography techniques"[2] as Roos describes. Involving potential users as *real life experts* in the innovation process greatly expands the pool of ideas influencing possible solutions. This is sometimes understood as "seeing users as designers," but this is a false interpretation.

Roos notes that "[f]rom the discussion in this paper it is clear that there is one major trap and one set of requirements that become critical when design is used as a tool for the manufacturing industry. The trap is confusing the use and definition of art with design – something seen quite frequently in architectural education for example."[3] He is right about the confusion, which is often inherited from the context of design education – universities of art. The top design university in the world is called the Royal College of Art, after all. Despite this confusion, the issue highlights an extremely important facet of design thinking – the aesthetic. As Roos notes, design can be understood as a *specific way of solving problems* (see Carlgren above) and *as the final aesthetic outcome*. The best and most successful companies – like Apple – combine these two aspects seamlessly in their innovation and manufacturing processes.

1 Lisa Carlgren, *Design Thinking as an Enabler of Innovation: Exploring the Concept and Its Relation to Building Innovation Capabilities* (Gothenburg, Sweden: Chalmers University of Technology, 2013).

2 Göran Roos, "Design-Based Innovation for Manufacturing Firm Success in High-Cost Operating Environments," *She Ji: The Journal of Design, Economics, and Innovation* 2, no. 1 (Spring 2016), forthcoming.

3 Ibid.

How Can Australia Compete Globally While Operating as Class Leader in the High-Cost Environment?

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Where Things Stand

Australia has greatly benefited from the insatiable appetite for its iron ore, coal, and natural gas resources of its Asian and distant neighbors. This voracity has resulted in billions of Australian dollars being repatriated into Australian industries such as mining, energy and infrastructure, which enabled firms operating in these industries to pay higher wages. On a positive note, the income generated from selling raw materials to the world has resulted in a soft landing for Australia's economy, while the rest of the world has been drawn into – and continues to struggle with – the global financial crisis of 2008 and 2009. The story is not all bad!

While Australia's mineral and resources sector has grown exponentially, the Australian manufacturing sector has fallen behind – some would even argue that it has fallen off a very high cliff. This is especially true for Australia's proud automotive industry. All major car producers in Australia – Ford Australia, General Motor's Holden (subsidiary), Toyota – have now publicly announced that they will be closing their factory doors in 2017. The departure of Australia's automotive industry will lead to the elimination of thousands of jobs – and will result in an even larger flow-on effect in the wider supplier and distribution system.

Over the last ten years, the Australian economy has moved from a low-to-medium cost environment to a high-cost environment, where it has become the leader. According to Boston Consulting (BCI) Group,[1] Australia now ranks as number one on the list of countries researched for highest average manufacturing labor costs.

Australia is presently 60% more expensive than the United States of America; 24% more expensive than Germany; 20% more expensive than Brazil; 18% more expensive than Switzerland, and, last but not least 13% more expensive than France. Both the United States of America and Mexico have dramatically improved their competiveness in manufacturing against other economies listed on the BCG Index (see figure C1).[2]

Australian Competitiveness in High-Cost Environments

It is fairly easy to decipher how success is achieved in a low-cost operating environment – build efficiency in the production environment, and protect easy access to production inputs for which there exists a comparative advantage.

The high-cost environment is more challenging. In order to achieve success, a firm has to provide the highest value for the lowest cost. It is a fallacy that this cannot be achieved, but success is only possible

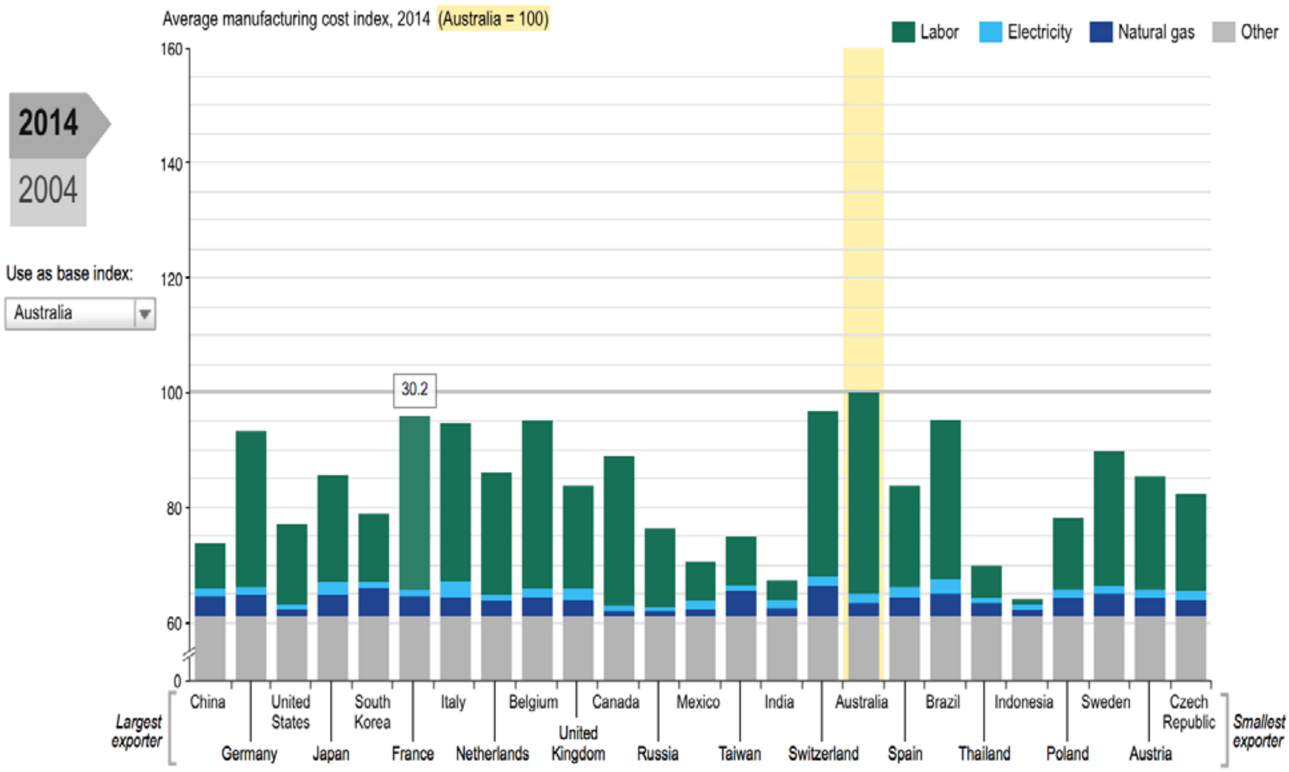

Figure C1(Wesselius) Average manufacturing cost index, (Boston Consulting Group, 2014). Image from BCG.

when the firm is engaged in a process of (continuous) innovation through integration – and when it does not fall into the classical trap of implementing innovation loosely, on an ad-hoc basis. Australian innovation grounded in new business models, systems integration, high performance workplaces, and invention for example – alongside the unquestionable benefit of design skills that provide practical outcomes – will be key to retaining a vibrant manufacturing sector in Australia.

It is also important to note that in these high-cost environments, new thinking around creativity and design integration combined with axioms of integrated innovation, business analytics, and customer experience will need to be incorporated. In parallel, firms working in high-cost environments need to adopt an open – or at least semi-open – approach to business innovation, knowledge acquisition and information brokering, sustainability, platform thinking, and develop deeper and more meaningful connections with the growing services and solutions culture.

Roos[3] has noted that integrated innovation is comprised of five dimensions – 1) enablers of innovation, 2) innovation strategy, 3) innovation management system, 4) value-creating innovations, and 5) value-appropriating innovations. As he underlines in the article published here, each of these elements must be present, and deployed correctly, for innovative measures to take hold.

The Australian High-Cost Environment, Going Forward

In order for Australian firms that operate in high-cost environments to deliver sustained competitive advantage, future Australian workplaces – and future manufacturing overall – must adopt new approaches to both leadership and management.

Concurrently, there must be a transformation within the workforce to engage with change and innovation. Firms will need to be open to providing 'additionality' – effects, behavior changes, or any other results that can be traced directly to novel interventions – both in terms of their absorptive capacity to integrate and diffuse existing knowledge as well as when developing new measures that pave the way toward the emerging skills-based manufacturing ecosystem.

Interdependency in Australia's elaborate production system will provide ample opportunity for firms to collaborate, develop networks and clusters among private and public entities, and establish partnerships with research and learning and teaching providers to test, experiment, and validate new ideas.

The future workforce will be required to not only specialize, but also engage in a deeper and more meaningful way with boundary-crossing competencies such as creative thinking, problem finding and solving, teamwork, and communication.

There is a lot to look forward to, but outcomes and positive externalities do not happen overnight and for sure not by themselves. In Australia, business as usual within the firm – and the government – is not an option.

1 David Tapper, "Australia's Manufacturing Cost Competitiveness: Losing Ground," *bcg perspectives* (blog), August 19, 2014, https://www.bcgperspectives.com/content/articles/lean_manufacturing_globalization_australia_manufacturing_cost_competitiveness/.

2 The Boston Consulting Group's *Global Manufacturing Cost-Competitiveness Index* identifies and compares shifts in relative costs using data from 2004 to 2014 for a range of countries. For more information, see https://www.bcgperspectives.com/content/interactive/lean_manufacturing_globalization_bcg_global_manufacturing_cost_competitiveness_index/.

3 Göran Roos, *Manufacturing into the Future. Adelaide Thinker in Residence 2010–2011* (Adelaide, Australia: Government of South Australia, 2012), accessed May 12, 2016, http://resources.news.com.au/files/2012/03/18/1226303/147149-an-file-manufacturing-into-the-future.pdf.

Author's Response

The Hurdles to Getting Design Accepted in Manufacturing Firms

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The two commentaries provided for the article "Design-Based Innovation, Manufacturing Firm Success and High-Cost Operating Environments" raise a number of valid points.

In his insightful comments, Sotamaa points out that it is fundamental that design and design thinking is integrated into a manufacturing company's overall innovation system. The validity of this claim can be grounded in the work by Bucolo and King[1] where the impact of design was shown through 14 case studies of manufacturing companies, as well as by other similarly strong and aligned arguments put forward in recent years.[2] Whilst the desirability of design in manufacturing firms is uncontested, the journey to achieving the Chief Design Officer as a recognized position in manufacturing firms tend to face the following hurdles:[3]

- There is currently a battle for design ownership being waged in many organizations, apparently driven by a long-standing tradition that associates product development with engineering design and design for manufacturability. With the increasing popularity of design inside the business community, many want to appropriate the design space. Similar to how responsibility for innovation has already been distributed across organizations, and there is pressure for the same to happen with design. Managers responsible for earning profit want to own the resources that contribute to their key performance indicators. The more siloed the organization is, the higher this hurdle seems to be.
- The design field is ontologically confused. Often designers have different views about whether there is a difference between "design thinking" and "design," and if there exists a rigorous process or not. This is not helpful if designers are to be recognized as a profession, and gain status as such within organizations.
- The design field is not recognized – and does not recognize itself – as a profession. This means that there are differing views as to whether it is a good thing to teach design principles to managers. This contributes to a lack of clarity in many organizations about any benefits there could be to having a dedicated Chief Design Officer – as opposed to sending a few managers off to get some design training.
- Due to the confusion between art and design, managers uneducated in design principles are only aware of aesthetics as it relates to a product or service, and hence downgrade its importance. This is further compounded by many designers' inability to use the language of business, and measure the impact of their work as it relates to the firm's bottom line.

The above hurdles can also be viewed as a failure on the part of senior managers and designers to engage in the right type of discussions. Conversations are often of a controlling nature – order giving, a mentoring nature – teaching or guiding the mentee towards the appropriate tools for a job, or a delegating nature – setting goals whilst leaving the freedom to choose how these are to be achieved, and supporting through follow-up conversations. None of these types of conversations generate the necessary partnership between managers and designers that would serve to underpin business success. What managers and designers need is a collaborative conversation that touches upon goals, beliefs, values, and quality.[4]

Sotamaa also adds three important aspects to Carlgren's definition – a holistic way of looking at problems, visionary thinking, and user-driven innovation as the core of human-centeredness. I am in total agreement with Sotamaa that these further strengthen our understanding of design thinking as an enabler of innovation.

Wesselius in his commentary raises the issue of Australia's challenges as it emerges from a mining boom into a globally connected world without having to overcome the challenges that many other countries faced as a consequence of the global financial crisis. These challenges basically boil down to increasing Australia's economic complexity, since economic complexity is a driver of national prosperity. Australia's present economic complexity is substantially lower than most of the countries it competes with – specifically those in the manufacturing space. This challenge is made greater by the reduction in economic complexity that will take place as a consequence of the closure of the automotive industry concentrated in Victoria and South Australia. Economic complexity theory proposes that since natural resources and monetary capital are scarce, it is primarily by increasing the amount of knowledge in an economy that more products can be made available for production, specifically for export. The amount of knowledge that is put to use in an economy can be expressed by how many different products an economy exports, and how many economies are able to export a given product – concepts expressed using the terms "diversity" and "ubiquity" respectively. The more knowledge that is required to produce a product or service, the fewer the number of economies that have the ability to produce it; and the more diverse the product and service portfolio of a country, the broader its knowledge base.[5] One of the knowledge components that can contribute to both diversity and ubiquity is design, due to its ability to enable non-price based competition. What we have yet to learn is what contribution design can make to opportunity value – the value to be gained from shifting production to unexploited, higher complexity prospects; and to opportunity gain – the benefit of producing new products in terms of providing capacity for producing even more complex products. If design can contribute to these attributes, it may very well generate newly revealed comparative advantages for Australia, by enabling Australia to export more than its fair share of these new offerings. It is clear from the above discussion that design is just one of several domains that must be deployed in an integrated way to facilitate Australia's journey towards increased economic complexity, and hence increased economic prosperity – which is why the concept of integrated innovation becomes so important at the firm level. Given the multiplier effect, it is also clear why manufacturing has a higher prosperity impact than services.[6]

1 Sam Bucolo and Peter King, *Design for Manufacturing Competitiveness* (Sydney: Australian Design Integration Network(ADIN)/CSIRO/UTS, 2013).

2 Tuuli Itkonen, "Design in Finland—From Aesthetic Outcomes to Strategic Input" (master's thesis, Aalto University, 2015), accessed May 13, 2016, http://epub.lib.aalto.fi/en/ethesis/pdf/14255/hse_ethesis_14255.pdf; P. Saritha, "The Need and Role of Design Management in Business: An Outlook," *International Journal of Trade & Global Business Perspectives* 4, no. 2 (2015): 1711–16; Alessandro Deserti and Francesca Rizzo, "Design and the Cultures of Enterprises," *Design Issues* 30, no. 1 (2014): 36–56; Reeta Noukka, "Organizational and Managerial Practices in Finnish In-house Design Management" (master's thesis, Turku School of Economics, 2011), accessed May 13, 2016, http://www.doria.fi/bitstream/handle/10024/114031/12757.pdf?sequence=1.

3 Sean D. Carr, et al., "The Influence of Design Thinking in Business: Some Preliminary Observations," *Design Management Review* 21, no. 3 (2010): 58–63.

4 Hugh Dubberly, "What Can Steve Jobs and Jonathan Ive Teach Us about Designing?" *interactions* 19, no. 3 (2012): 82–85.

5 César A. Hidalgo and Ricardo Hausmann, "The Building Blocks of Economic Complexity," in *Proceedings of the National Academy of Sciences* 106, no. 26 (2009): 10570–75.

6 Göran Roos, "Manufacturing in a High Cost Environment: Basis for Future Success on the National Level," in *Global Perspectives on Achieving Success in High and Low Cost Operating Environments*, ed. Göran Roos and Natalie Kennedy (Hershey, PA: IGI Global, 2014), 1–51; Göran Roos, "Manufacturing in a High Cost Environment: Basis for Success on the Firm Level," in Roos and Kennedy, *Global Perspectives*, 393–480; Allan O'Connor, Kai Du, and Göran Roos, "The Intellectual Capital Needs of a Transitioning Economy: A Case Study Exploration of Australian Sectoral Changes," *Journal of Intellectual Capital* 16, no. 3 (2015): 466–89; Göran Roos, "The Constantly Changing Manufacturing Context," in *Advanced Manufacturing—Beyond the Production Line* (Melbourne: Committee for Economic Development of Australia/CEDA, 2014), 31–56; Göran Roos, "Technology Development and the Future of Work," *B+I Strategy*, March 3, 2015, accessed April 30, 2016, http://www.bmasi.net/es/opinion/articulos/item/1147-technology-development-and-the-future-of-work/1147-technology-development-and-the-future-of-work; Göran Roos, "Why Servitization Is an Increasingly Critical Strategy for Manufacturing Firms," *B+I Strategy*, January 13, 2014, accessed April 30, 2016, http://www.bmasi.net/es/opinion/articulos/item/698-why-servitization-is-an-increasingly-critical-strategy-for-manufacturing-firms/698-why-servitization-is-an-increasingly-critical-strategy-for-manufacturing-firms; Göran Roos, "The Innovation Ecosystem," in *Australia Adjusting: Optimising National Prosperity* (Melbourne: Committee for Economic Development of Australia/CEDA), 107–122; Göran Roos, "Why a Healthy Manufacturing Sector Is a Must for any Advanced Economy with Ambitions to Maintain Economic and Social

Wellbeing," ***B+I Strategy*****, January 15, 2014, accessed April 30, 2016, http://www.bmasi.net/es/opinion/articulos/item/365-why-a-healthy-manufacturing-sector-is-a-must-for-any-advanced-economy-with-ambitions-to-maintain-economic-and-social-wellbeing/365-why-a--healthy-manufacturing-sector-is-a-must-for-any-advanced-economy-with-ambitions-to-maintain-economic-and-social-wellbeing.**