Service-oriented Management of the Digital Enterprise

1 <u>The Context</u>: Digital Enterprise – the next frontier for innovation, competition and productivity

1.1 Factories of the Future 2020

The "Factories of the Future" public-private partnership identifies and realises innovation-driven transformations in European manufacturing sectors by pursuing a set of development priorities along the following research and innovation domains:

- Total enterprise integration: the Manufacturing Integration Framework (MIH) linking business processes with production and supply processes
- Advanced manufacturing processes
- Adaptive and smart manufacturing systems
- Digital, virtual and resource-efficient factories
- Collaborative and mobile enterprises
- Human-centred manufacturing
- Customer-focused manufacturing

In this actual global development context, the mission of higher education is to study and teach the overall enterprise architecture and core technologies to establish a comprehensive, Internet-scale platform for networked management and production that will encapsulate the right abstractions to link effectively and scalable the various stakeholders (product firms, manufacturing plants, material and component providers, technology providers, key services) to enable the emergence of a feasible and sustainable Internet economy for industrial production.

This accomplishment of this mission is currently based on three viewpoints:

VP1. **Smart Enterprise**: Novel controls based on ICT convergence in mixed batch planning and product scheduling, automation, robotics, quality control, environment and resource instrumenting.

VP2. **Digital Enterprise**: Novel operations based on product and process modelling, management and simulation, including field operations.

VP3. **Virtual Enterprise**: Novel management of complex supply chains across production sites and including logistics and material flows across the product life cycle, including field operations

The actual context follows also the trend of shifting from the good-dominant logic to the service-dominant logic, which is best represented by *after-sale services* (A-SS) or *Product-Extension Service* (PES) enhancing the utility that the ownership of the product delivers to the customer (e.g. install, configure/tune, repair, maintain and upgrade, take-back etc.)

Thus, a new opportunity of Industrial Business arises: the actual customer need leads to the opportunity to create significant added value in customer operations, which aligns also with the perspective of customer-focused production (Fig. 1).

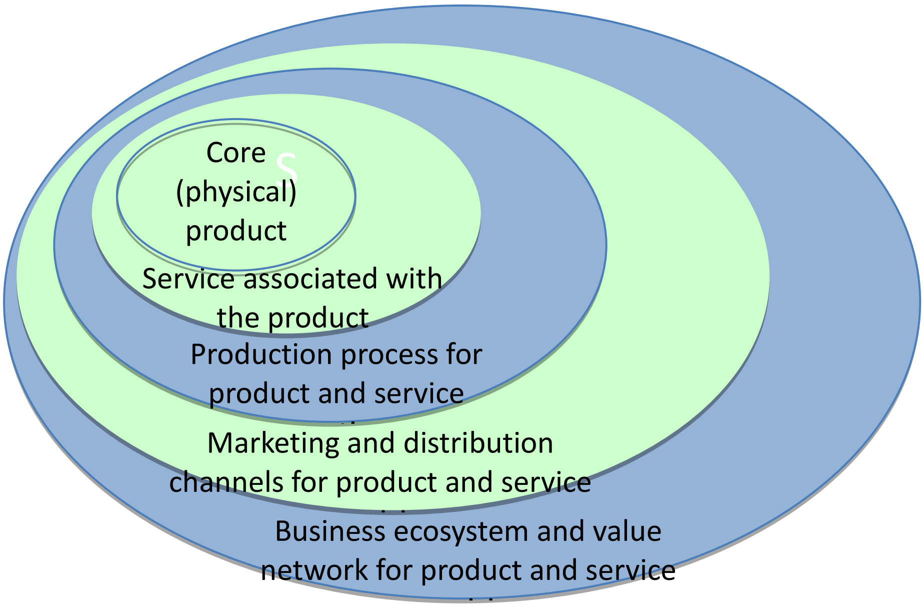


Fig. 1 Opportunity of Industrial Business in the Digital Enterprise

1.2 Business Analytics from Big Data for Decision Optimization

The manufacturing sector was an early and intensive user of data to drive quality and efficiency, adopting information technology and automation to design, build, and distribute products since the dawn of the computer era. In the 1990s, manufacturing companies racked up impressive annual productivity gains because of both operational improvements that increased the efficiency of their manufacturing processes and improvements in the quality of products they manufactured. Manufacturers also optimized their global footprints by placing sites in, or outsourcing production to, low-cost regions. But despite such advances, manufacturing, arguably more than most other sectors, faces the challenge of generating significant productivity improvement in industries that have already become relatively efficient.

We believe that big data can underpin another substantial wave of gains. These gains will come from:

- **Improved efficiency in design and production**,
- Further **improvements in product quality**, and
- **Better meeting customer needs** through *more precisely targeted products* and *effective promotion and distribution*.

Big data can help manufacturers reduce product development time by 20% to 50% and eliminate defects prior to production through *simulation* and *testing* (the Digital Enterprise viewpoint). Using real-time data, companies can also *manage demand planning* across extended enterprises and global supply chains, while reducing defects and rework within production plants. Overall, big data provides a means to achieve dramatic improvements in the management of the complex, global, extended value chains (the Virtual Enterprise viewpoint) that are becoming prevalent in manufacturing and to meet customers' needs in innovative and more precise ways, such as through *collaborative product development based on customer data*.

We base these conclusions on an examination of multiple production subsectors encompassing both discrete and process manufacturing, from basic manufacturing subsectors such as consumer goods and food, to advanced manufacturing sub sectors such as automotive and aerospace. We drew upon global best practice examples of the use of big data to identify seven levers of value creation, describe the range of potential impact, and the barriers that have to be overcome to capture that value.

The manufacturing sector has been the backbone of many developed economies and remains an important driver of GDP and employment there. However, with the rise of production capacity and capability in growth-market economies, manufacturing has become an increasingly global activity, featuring extended supply chains made possible by advances in information and communications technology. While globalization is not a recent phenomenon, the explosion in information and communication technology, along with reduced international freight costs and lower entry barriers to markets worldwide, has hugely accelerated the industrial development path and created increasingly complex webs of value chains spanning the world.

Increasingly global and fragmented manufacturing value chains create new challenges that manufacturers must overcome to sustain productivity growth. In many cases, technological change and globalization have allowed countries to specialize in specific stages of the production process. As a result, *manufacturers have assembled global production and supply chain networks to achieve cost advantages*. For example, a typical global consumer electronics manufacturer has production facilities on almost every continent, weighing logistics costs against manufacturing costs to optimize the footprint of their facilities. Advanced manufacturers also often have a large number of suppliers, specialized in producing specific types of components where they have sustainable advantages both in cost and quality.

To continue achieving high levels of productivity growth, production enterprises will need to leverage large datasets to drive efficiency across the extended enterprise and to design and market higher-quality products. The manufacturing sector generates data from a multitude of sources, from instrumented production machinery (process control), to supply chain management systems, to systems that monitor the performance of products that have already been sold.

And the amount of data generated will continue to grow exponentially. The number of RFID tags sold globally is projected to rise from 12 million in 2011 to 209 billion in 2021. IT systems installed along the value chain to monitor the extended enterprise are creating additional stores of increasingly complex data, which currently tends to reside only in the IT system where it is generated. Manufacturers will also begin to combine data from different systems including, for example, computer-aided design, computer-aided engineering, computer-aided manufacturing, collaborative product development management, and digital manufacturing, and *across organizational boundaries in*, for instance, *end-to-end supply chain data*.

Production enterprises can use big data across the value chain. *Big data has the potential to enable 7 performance improvement levers for manufacturers*, affecting the entire value chain (Fig. 2). These performance improvement levers are related to the five components of the **Manufacturing Value Chain** (MVC):

1. Research & Development and Product Design
2. Supply Chain Management
3. Production
4. Marketing and sales
5. After-sales services

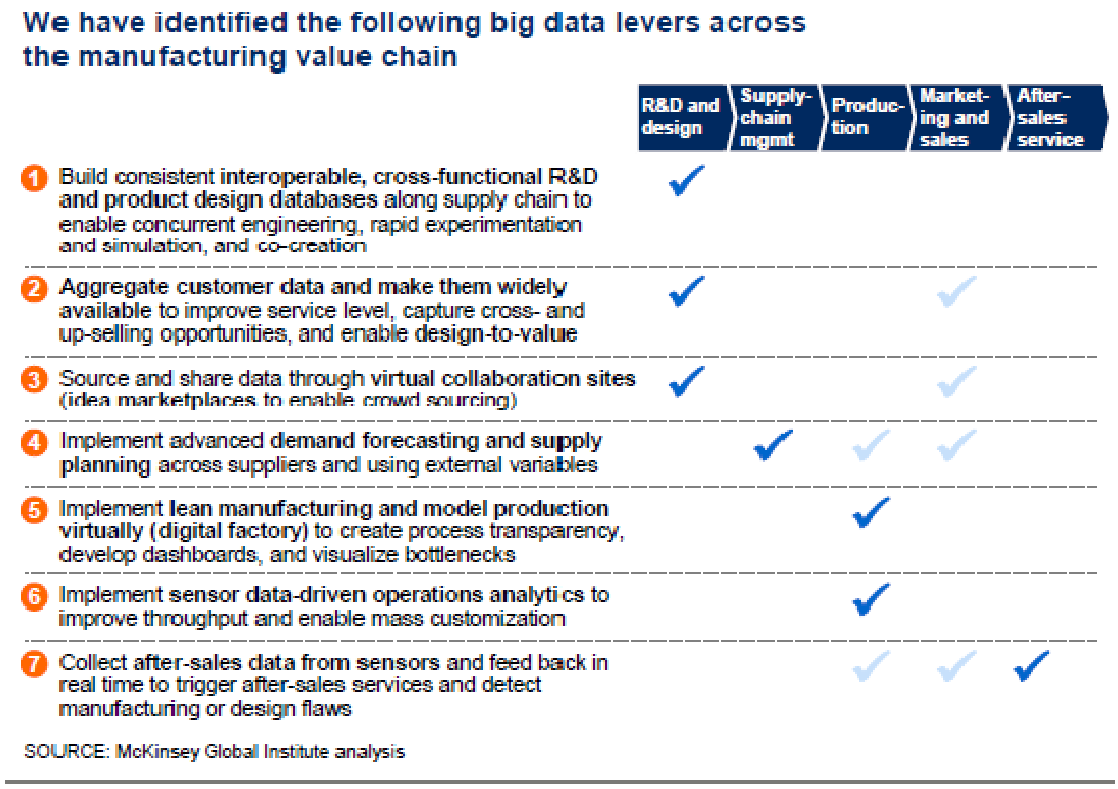


Fig. 2 The 7 Big Data levers across the manufacturing value chain (MVC)

1.2.1 Research & Development and product design

The use of big data offers further opportunities to accelerate product development, help designers home in on the most important and valuable features based on concrete customer inputs as well as designs that minimize production costs, and harness consumer insights to reduce development costs through approaches including open innovation.

(1) Product lifecycle management.

Over decades, production companies have implemented *IT systems to manage the product lifecycle* including: computer aided-design, -engineering, -manufacturing, product development management tools, digital manufacturing and more recently digital marketing. Manufacturers could capture a significant big data opportunity to create more value by instituting **product lifecycle management** (PLM) platforms that can integrate datasets from multiple systems to enable effective and consistent collaboration. For example, PLM could provide a platform for "*co-creation*," e.g., bringing together internal and external inputs to create new products. In this context, having the OEM *co-create designs with suppliers* can be extraordinarily valuable. PLM platforms can also significantly *enable experimentation at the design stage*. Designers and manufacturing engineers can share data and quickly and cheaply *create simulations to test different designs*, the *choice of parts and suppliers*, and *the associated manufacturing costs* (the Digital Enterprise viewpoint). This is especially useful because decisions made in the design stage typically drive 80% of manufacturing costs.

Leading players in advanced industries are already embracing the collaborative use of data and controlled experimentation. However, while the payoff for this opportunity is large, manufacturers will likely need to invest significantly upgrade their systems, which in many cases are decades old. In addition to the technical work of integrating datasets from different IT systems, manufacturers will need to ensure that staff members from different functions

(R&D, production) and organizations (OEMs, suppliers) use these tools to collaborate. Today, a lack of collaboration across silos is closer to the norm.

Note that in addition to reducing development time, manufacturers, as a result of using integrated PLM, are able to improve quality and reduce resources in order to develop more derivatives or product extensions.

(2) Design to value

While obtaining customer input through market research has traditionally been a part of the product design process, many manufacturers have yet to systematically *extract crucial insights from the increasing volume of customer data to refine existing designs* and *help develop specifications for new models and variants*.

Best-in-class manufacturers conduct conjoint analyses to determine how much customers are willing to pay for certain features and to understand which features are most important for success in the market. Conjoint analysis is a statistical technique that involves providing a controlled set of potential products and services to elicit end users' preferences through which an implicit valuation of individual elements that make up the product or service can be determined.

These companies supplement such efforts with *additional quantitative customer insights mined from sources such* as point-of-sales data and customer feedback. New sources of data that manufacturers are starting to mine include *customer comments in social media and sensor data that describe actual product usage*.

However, gaining access to comprehensive data about customers in order to achieve holistic insights can be a significant barrier for manufacturers; distributors, retailers, and other players can be unwilling to share such data, considering them to be a competitive asset. Nevertheless, the size of the prize for successfully designing to value can be substantial, especially in sub sectors with high product differentiation and changing customer preferences.

(3) Open innovation

To drive innovation and develop products that address emerging customer needs, manufacturers are relying increasingly on outside inputs through *innovative channels*. With the advent of Web 2.0, some manufacturers are inviting external stakeholders to submit ideas for innovations or even collaborate on product development via Web-based platforms.

Open innovation through big data has been extended to advanced industries as well. An additional benefit of these open innovation techniques is that they create more brand engagement from participants in these efforts, as well as a positive "halo" effect as these initiatives become more widely recognized.

1.2.2 Supply chain

(4) Advanced demand forecasting and supply planning.

Manufacturers, especially those producing fast-moving consumer goods, have significant additional opportunities to improve demand forecasting and supply chain planning. The volatility of demand has been a critical issue for production companies. Their retailing customers have pushed hard for increased flexibility and responsiveness from suppliers, given the diverging and ever-changing preferences of consumers. Other trends, such as the *increasing use of promotions* and *tactical pricing*, have only magnified volatility issues facing suppliers.

Manufacturers can improve their demand forecasting and supply planning by the improved use of their own data. But far more value can be unlocked when companies are able to *integrate data from other sources* including *data from retailers*, such as promotion data (e.g., items, prices, sales), launch data (e.g., specific items to be listed/de-listed, ramp-up/ramp-down plans), and inventory data (e.g., stock levels per warehouse, sales per store).

By taking into account data from across the value chain (potentially *through collaborative supply chain management and planning*), manufacturers can smooth spiky order patterns. The benefits of doing so will ripple through the value chain, helping manufacturers to use cash more effectively and to deliver a higher level of service. Best-in-class manufacturers are also accelerating the frequency of planning cycles to synchronize them with production cycles. Indeed, some manufacturers are using near-real-time data to adjust production. Others are collaborating with retailers to shape demand at the store level with time-based discounts.

1.2.3 Production

Big data are driving additional efficiency in the production process with the application of simulation techniques to the already large volume of data that production generates. The increasing deployment of the "Internet of Things" is also allowing manufacturers to *use real-time data from sensors to track parts, monitor machinery, and guide actual operations*.

(5) Digital factory

Taking inputs from product development and historical production data (e.g., order data, machine performance), manufacturers can apply advanced computational methods to *create a digital model of the entire manufacturing process*.

Such a "digital factory" - including all machinery, labour, and fixtures - can be used to *design and simulate the most efficient production system*, from layout to sequencing of steps, for a specific product. "**Internet of Things**", a new technology applied to the MVC, refers to sensors and actuators within networks of physical objects. Leading manufacturing enterprises have used this technique to optimize the production layout of new plants, particularly when there are myriad constraints such as space and utility distribution. Plants designed with these techniques also have realized substantial reductions in assembly hours, cost savings, and even improved delivery reliability.

(6) Sensor-driven operations

The proliferation of Internet of Things applications allows manufacturers to optimize operations by *embedding real-time, highly granular data from networked sensors in the supply chain and production processes*. These data allows ubiquitous process control and optimization to reduce waste and maximize yield or throughput. They even allow for innovations in manufacturing that have not been possible thus far.

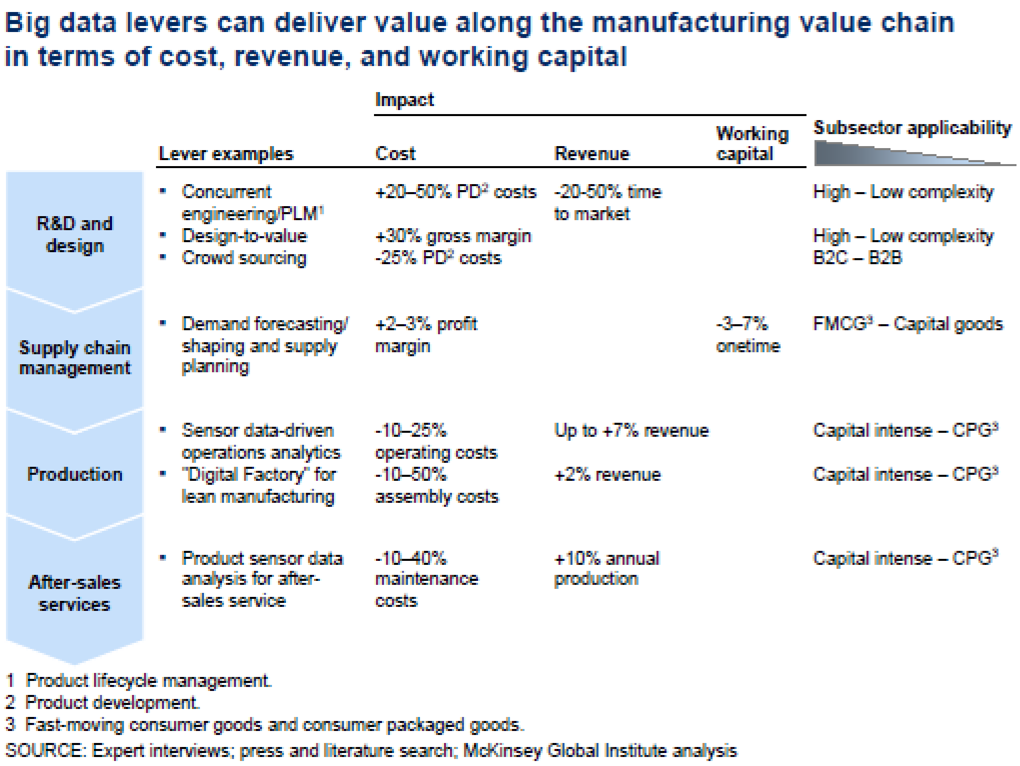
1.2.4 Marketing and sales

Manufacturing companies are using data from customer interactions not only to improve marketing and sales but also to inform product development decisions. Increasingly, it is economically feasible to *embed sensors in products* that can "phone home," *generating data about actual product usage and performance*. Manufacturers can now obtain *real-time input on emerging defects and adjust the production process immediately*. R&D operations can share these data for *redesign and new product development*. Many construction equipment manufacturers already embed sensors in their products, and this can provide granular real-time data about utilization and usage patterns, enabling these manufacturers to improve demand forecasts as well as their future product development.

1.2.5 After-sales services

There are also many opportunities to leverage large datasets in the marketing, sales, and after-sales service activities. In many sectors, opportunities range from the segmentation of customers to applying analytics in order to improve the effectiveness of sales forces. An increasingly important application for manufacturers is *using sensor data from products once they are in use to improve service offerings*. For example, *analysing the data reported by sensors embedded in complex products* enables manufacturers of aircraft, elevators, and data-centre servers to *create proactive smart preventive maintenance service packages*. Other manufacturers have been able to transform the commercial relationship with customers from one in which they sell a product to one in which they sell a service (Product-Service Extensions).

Big data in aggregate underpins substantial productivity potential and innovation. For manufacturers, opportunities enabled by big data can drive productivity gains both through improving efficiency and the quality of products (Fig. 3). Efficiency gains arise across the value chain, from reducing unnecessary iterations in product development cycles to optimizing the assembly process. The real output value of products is increased by improving their quality and better matching customers' needs.



Big data levers can deliver value along the manufacturing value chain in terms of cost, revenue, and working capital

	Lever examples	Impact: Cost	Revenue	Working capital	Subsector applicability
R&D and design	• Concurrent engineering/PLM[1]	+20–50% PD[2] costs	-20-50% time to market		High – Low complexity
	• Design-to-value	+30% gross margin			High – Low complexity
	• Crowd sourcing	-25% PD[2] costs			B2C – B2B
Supply chain management	• Demand forecasting/ shaping and supply planning	+2–3% profit margin		-3–7% onetime	FMCG[3] – Capital goods
Production	• Sensor data-driven operations analytics	-10–25% operating costs	Up to +7% revenue		Capital intense – CPG[3]
	• "Digital Factory" for lean manufacturing	-10–50% assembly costs	+2% revenue		Capital intense – CPG[3]
After-sales services	• Product sensor data analysis for after-sales service	-10–40% maintenance costs	+10% annual production		Capital intense – CPG[3]

1 Product lifecycle management.
2 Product development.
3 Fast-moving consumer goods and consumer packaged goods.
SOURCE: Expert interviews; press and literature search; McKinsey Global Institute analysis

Fig. 3 Big data drives productivity gains through improving efficiency and product quality

Beyond pushing productivity, big data enables innovative services and even new business models in manufacturing. *Sensor data have made possible innovative after-sales services.* The ability to track the use of products at a micro-level has also made possible monetization models that are based not on the purchase of a product but on *services priced by their usage*, as we have described.

The ability to exchange data across the extended enterprise has also enabled production to be unbundled radically into highly distributed networks (the Virtual Enterprise viewpoint).

Some of the most powerful impacts of big data apply across entire manufacturing ecosystems. Big data plays a pivotal role in ensuring that these ecosystem webs function well and continue to evolve. Indeed, new data intermediaries or data businesses could begin to emerge. They could, for example, capitalize on the economic value of data that describes the flow of goods around the world.

At present, production enterprises must tackle organizational, cultural, and talent challenges to maximize the benefits of big data.

Much of the value that big data can create in manufacturing requires the *access and varied use of data from multiple sources across an extended enterprise*. So to fulfil the potential for value creation in this sector will require production companies to invest in IT as well as to make organizational changes. The additional IT investment necessary may not be insignificant. Some of the big data levers above discussed, including updating a PLM platform that can link across various IT systems, will be costly. Nevertheless, the long-term payoff should outweigh the cost.

Other investments will be required to develop interfaces and protocols to share data effectively across the extended enterprise. The standardization of interfaces according to SOA and ESB concepts will be critical and may require industry-wide partnerships to achieve. Strongly departmentalized companies, with multiple IT systems and overlapping and/or redundant data in different operations and divisions, are clearly at a disadvantage.

To obtain the benefits of design-to-value, for instance, a *company needs to have a free interchange of data among marketing and sales, R&D, and production*. So, in many organizations, achieving success will require strong leadership and a cultural shift to establish the mind-sets and behaviours to breech today's silos. Many organizations will need to *undertake organizational change programs* to enforce the necessary shift -groups that have never shared their data will not start to do so simply because the IT systems are in place.

Many of the levers also require access to data from different players in the value chain. To optimize production planning, data from various tiers of suppliers will be necessary. Demand planning will require customer data from retailers. To access such pools of data, manufacturers will need to be thoughtful about establishing the right value propositions and incentives.

Manufacturing companies will also need to build the capabilities needed to *manage big data.* Despite the fact that the sector has been dealing with large datasets for two decades, the rising volume of data from new sources along the supply chain and from end markets requires a new level of storage and computing power and deep analytical expertise if manufacturers are to harvest relevant information and insights. There is a shortage of talent with the right experience for managing this level of complexity; this represents one strong motivation for organizing the MDE Master program.

Manufacturers will need not only to recruit new such T-shaped talent but also to remove organizational obstacles that today prevent such individuals from making maximum contributions.

Finally, where big data applications touch consumers and other end users, there are privacy issues. *One of the most promising ideas is using product sensor data to create* finely targeted after-sales services or cross-selling. But employing this lever will be possible only if consumers don't object to suppliers monitoring how they use their products. *Manufacturers must therefore address privacy concerns proactively, in collaboration with policy makers, and communicate with end users about choices and data transparency.*

Production enterprises have tremendous potential to generate value from:

1. The **use of large datasets**,
2. **Integrating data across the extended enterprise**, and
3. **Applying advanced analytical techniques** to raise their productivity both by *increasing efficiency* and *improving the quality of their products*: in our emerging market, production

enterprises can begin to build competitive advantage that goes beyond their (thus far) relatively low labour costs.

2 Motivation: Qualifying graduates with the necessary skills to service, reengineer and manage sustainable enterprises

1.2 Sustainable enterprise excellence, resilience and robustness

Sustainable enterprise excellence, resilience and robustness (SEER[2]) balance the complementary and competing interests of key stakeholder segments, including society and the natural environment and increases the likelihood of superior and sustainable competitive positioning and hence long-term enterprise success that is defined by continuously relevant and responsible governance, strategy, actions, performance and impact.

This is accomplished through ethical, efficient and effective (3E) *enterprise governance strategy and leadership* that emphasize superior organization design & function, innovation, enterprise intelligence & analytics, operational, supply chain, customer-related, human capital, financial, marketplace, societal, and environmental strategy and performance.

Sustainable enterprise excellence results from driving 3E triple top line strategy throughout enterprise culture, processes, and activities to produce superior triple bottom line 3P *performance* (through management of policies, people and partnership) and consequent impact that is simultaneously pragmatic, innovative and supportive of enterprise resilience and robustness (Fig. 4).

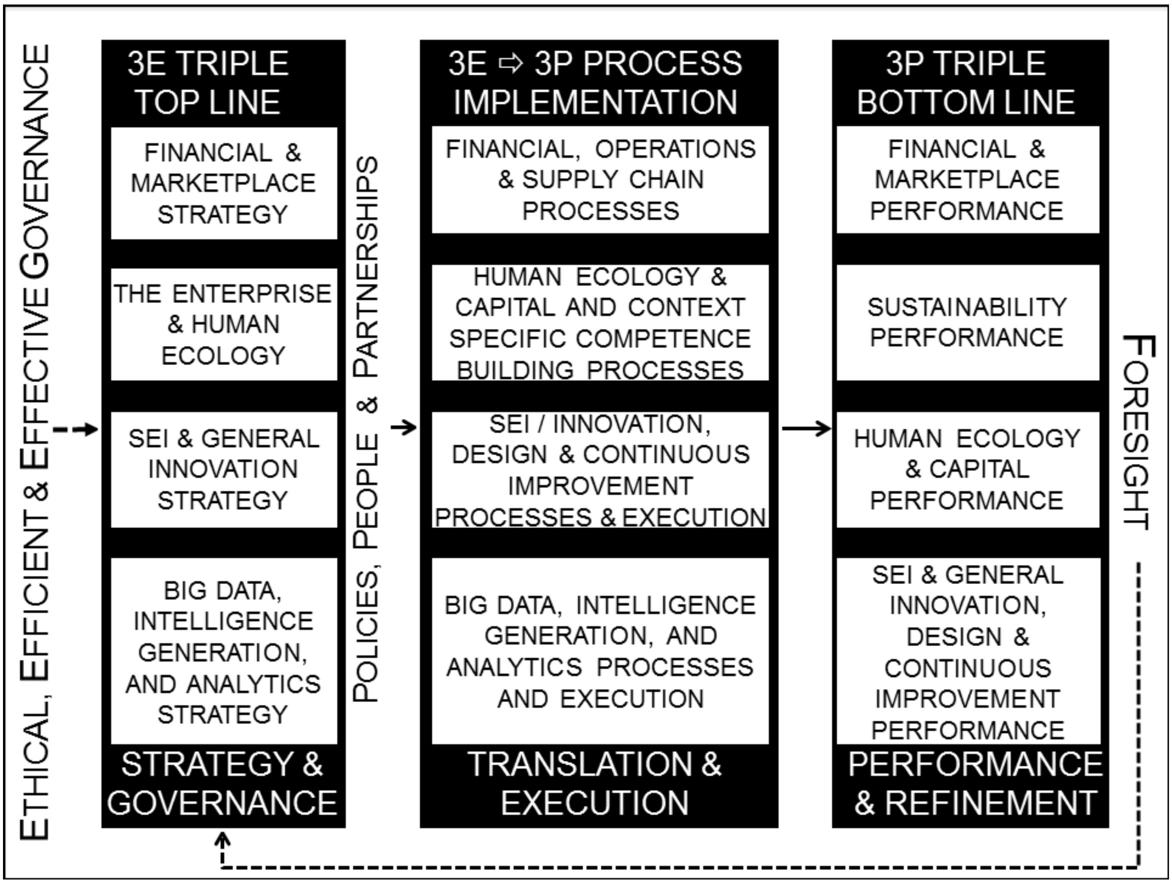


Fig. 4 3E Enterprise governance, strategy and leadership for sustainable excellency

Resilience is characterized in the MDE Master-related context as the enterprise's capacity to self-renew through innovation and adapt its responses over time to negative shocks or extreme challenges.

In the same enterprise sustainability context, **robustness** is resistance or immunity to such impacts and challenges – that is, the enterprise's capacity to form and execute an array of strategies, policies, partnerships, and practices that maintain enterprise competitive position or transform extreme challenges into opportunities, thus avoiding any necessity to rebound.

The **Social-Ecological Innovation** (SEI) to be promoted in the new MDE Master program manifests at the interface of *sustainable innovation* and *innovation for sustainability*:

- <u>Sustainable innovation</u> is central to organizational culture when innovation is regular, rigorous, systematic, systemic, and *a focal part of enterprise strategy*.
- <u>Innovation for sustainability</u> explicitly targets social or environmental outcomes that are tangibly and positively linked to *both general and enterprise financial performance* so that SEI partially enables transformation of triple top line strategy into triple bottom line performance.

Table 1 contains the six foundations to sustainable enterprise excellence, resilience and robustness (SEER^2) and their compass point elements leading to achievement of triple bottom line 3P performance:

Table 1 The 6 foundations to SEER^2 and their compass point elements

No.	SSER^2 foundations	Compass point elements
1	**Triple top line strategy & governance**	Financial & Marketplace Strategy for SEER2 & Supply Chain Strategy
		The Enterprise & Human Ecology Strategy
		Social-Ecological Innovation (SEI) and General Innovation Strategy
		Big Data, Intelligence Generation, and Analytics Strategy
2	**Process implementation, translation and execution**	Financial, Operations & Supply Chain Processes for SEER^2
		Human Ecology, and Context Specific Competence-Building
		SEI / Innovation, Design & Continuous Improvement Processes & Execution
		Big Data, Intelligence Generation, and Analytics Processes & Execution
3	**Financial & marketplace performance & impact**	Financial & Marketplace Results Traceable to Supply Chain Performance
		Financial & Marketplace Results Traceable to Human Capital Investment
		ROI & Reinvestment in Innovation, Design & Continuous Improvement: R&D
		Financial & Marketplace Results Traceable to Big Data, Intelligence Generation and Analytics
4	**Sustainability (SEER^2) performance w / Embedded economic, innovation &analytic impact**	Sustainability Results Traceable to Supply Chain Performance & Analytics
		Sustainability Results Traceable to Human Capital Engagement & Analytics
		Environmental Sustainability Results & Refinement and Analytics
		Societal Sustainability Results & Refinement and Analytics
5	**Human ecology & Capital performance & Impact**	Impact of Human Ecology & Capital on the Supply Chain
		Impact of Human Ecology & Capital on Trajectory, Agility and Velocity
		Impact of Human Ecology & Capital on Innovation Capacity
		Impact of Human Ecology & Capital on Organization Design
6	**SEI & general innovation, design and continuous improvement (CI) performance & impact**	Impact of Innovation, Design & CI Across and In the Supply Chain on SEER^2
		Impact and Interaction of Innovation, Design & CI with Human Ecology & Capital on SEER2
		Impact of Innovation, Design & CI on Other Non-Financials & Intangibles
		Impact and Interaction of Big Data, Intelligence Generation, and Analytics with and on Innovation, Design & CI Relative to SEER^2

There is a strong motivation to stimulate a creative participation of students to hands-on training and R&D activities, and based on representative case studies from industry to propose them scenarios requesting innovative solutions for performance improvement through technical coordination and organisational management. Such innovation approaches will be formulated in the internal and external SEI assessment of the enterprise (see Fig. 5).

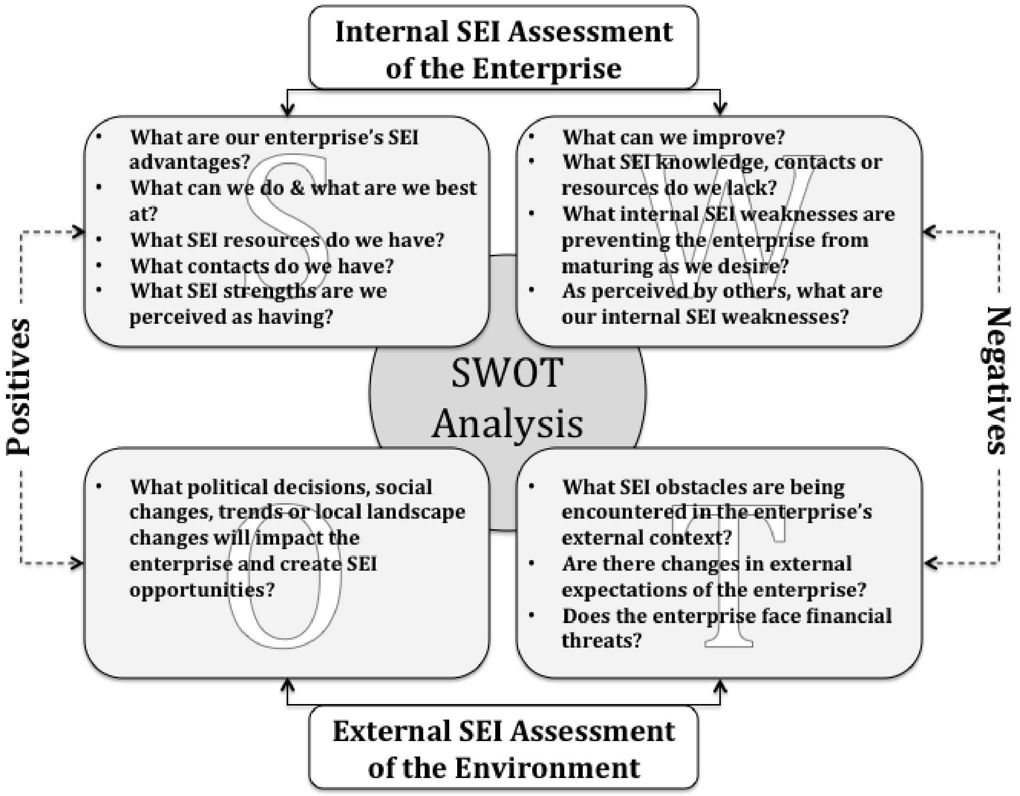


Fig. 5 SWOT analysis as motivation framework for skills development on SEI

It is necessary to promote basic strategies that may be embedded in enterprise innovation efforts, motivated by 10-R design and innovation for the environment life-cycle actions in sustainable, efficient, agile & robust enterprises (Table 2):

Table 2 10-R design and innovation for the enterprise environment life-cycle actions

"R"	Action	Description
R1	Reduce	Reduce material and energy consumption throughout the product or service life cycle
R2	Reuse	Design the product or service in ways that enable and encourage simple reuse
R3	Recycle	Recycle as much as possible and design products for simpler disassembly and recycling
R4	Replace	Replace any environmentally or humanly damaging substances or actions with more environmentally or socially friendly alternatives
R5	Rethink	Rethink every product or service and functions thereof
R6	Redirect	Consider how products and services may be redirected to secondary and tertiary uses
R7	Renew	Design physical products so that they are simply renewed, repaired, revised or updated in order to prevent premature replacement
R8	Reconsider	Reconsider designing your array of products and services in ways that allow component elements to be used in multiple members/locations of the array, thus reducing overall resource consumption, inventory, and component degradation, while also improving overall renewal capability
R9	Redesign	Consolidate all other 9R elements in every design and innovation strategy, decision and action, including human capital related and organizational design ones
R10	Reinvest	Reinvest a strategically determined amount of percentage of savings / costs recovered from the other 9-R design and innovation for the environment actions