Strategic business transformation through technology convergence: implications from General Electric’s industrial internet initiative

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Abstract: Technology adoption is crucial for an organisation to remain competitive in the marketplace. Traditionally, two technologies – operational technology (OT) and information technology (IT) – have operated independently from one another; however, technological advancements that businesses are experiencing have increased the overlap and convergence of these two areas. Industrial organisations are investing heavily in the integration and alignment of these technologies and expect to benefit in several ways from this convergence, such as through increased productivity, reduction in cost, and real-time intelligence. This paper presents the case of General Electric (GE) and studies the various transitional phases and transformation dimensions that GE is experiencing, to manage this technology convergence. The evaluation of GE’s experience indicates that convergence-related business transformation is nonlinear, and that some dimensions and stages of transformation previously thought to be relevant may not be pertinent for successful business transformations through technology convergence.

Keywords: business transformation; industrial internet; Industry 4.0; operational technology; information technology; technology convergence; machine2machine.


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Strategic business transformation through technology convergence

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1 Introduction

The internet and information technology (IT) revolution in the late twentieth century has been the biggest game-changer in the history of business since the industrial revolution, which began almost two centuries ago.

This revolution has affected all fields of business, from consumer to industrial sectors, and has introduced new challenges in managing the pace of rapidly changing technology (Conway, 1999). To remain competitive, companies have invested heavily in IT and have willingly undergone tremendous transformation in their vision, strategies, markets, business models, processes, and even core values (Agarwal and Prasad, 1998).

Researchers have become increasingly interested in analysing the value of investment in IT as a source of competitive advantage and in examining how firms realise these benefits (Bharadwaj, 2000; Mata et al., 1995). Studies have shown that IT alone has not provided firms with a sustainable advantage, but that firms have benefited from strategic planning, IT integration, organisation learning, and innovative applications of IT (Powell and Dent-Micallef, 1997; Mata et al., 1995; Tippens and Sohi, 2003; Teece et al., 1997). In this context, Gartner (2006, 2011) has studied the collaboration of IT and operational technology (OT), and claims that the combination and convergence of these two technologies offers a unique opportunity to companies, with the potential to revolutionise the world. Having recognised the potential of information and OT convergence, traditional industrial heavyweights such as General Electric (GE), Siemens, and Schneider are investing heavily in realigning and embedding their IT capabilities into their physical equipment. This convergence is expected to enable companies to offer value added services like advanced analytics and real time intelligence to their customers. This internet revolution in manufacturing domain is often referred to as Industry 4.0, which has a strong linkage to cyber-physical systems as well (Maier et al., 2014). Companies, based on their focus, have assigned different names to this initiative. GE, focusing more on connecting machines and people, is following the industry term ‘industrial internet’ given by industry experts. Siemens has recently launched its Vision 2020, which is yet to be implemented, and Schneider has dubbed their approach to this merging of technologies as ‘EcoStruxure™’.

This paper includes a case study on GE and focuses on the ‘industrial internet’ initiative to analyse the business transformation stages that GE is undergoing and the impact on its various business segments. First, an extensive literature review is presented, to reveal the current state of research in the field of IT-enabled business transformation. Then, the study conceptualises a theoretical framework to analyse the different stages and dimensions of transformation during technology convergence. Implications for theory and practice are presented, and the paper concludes with suggestions for further research.
2 Literature review

2.1 IT-enabled business transformation

There is strong theoretical and empirical evidence attesting to the benefits of IT investment when it is embedded in, and complemented by, other resources or skill sets (Bharadwaj, 2000; Powell and Dent-Micallef, 1997; Mata et al., 1995; Tippens and Sohi, 2003; Teece et al., 1997). The resource-based view (RBV) is a comprehensive framework for studying the relationship between IT investment and a firm’s performance. The RBV framework links performance to the accumulation of an organisation’s unique set of resources.

A significant amount of research has been conducted on the topic of IT-enabled business transformation (McKeown and Philip, 2003; Qingfeng et al., 2008; Storbacka et al., 2013; Venkatraman, 1994). These studies analyse the ways in which large corporations embrace the potential of IT (Dutta and Biren, 2001). As with other approaches to business transformation, IT-enabled business transformation is a long-term proposition that requires capital investment. Businesses have not only restructured their organisations but also redesigned business processes to reap the full benefit of IT and networking (Gregor et al., 2006).

These transformations have frequently led to improved productivity and new product offerings (Brynjolfsson and Hitt, 2003), but their impact on organisational processes is still unclear (Bharadwaj, 2000).

Qingfeng et al. (2008) summarise the literature on IT-enabled business transformation (Venkatraman, 1994; Tushman and Romanelli, 1985; Dutta and Biren, 2001; Hartman et al., 2001; Hauge, 2002; Slavin and Woodard, 2006), and highlights five critical organisational dimensions affected during IT-enabled transformation. Table 1 explains the dimensions, based on additional literature review by the authors. These dimensions are used to develop the conceptual framework in subsequent sections.

Table 1 Five dimensions of IT-enabled business transformation

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>Strategy and vision</td>
<td>Strategy is the method of aligning a company and its environment; it defines a firm’s configuration of activities and the manner in which they interrelate (Porter, 1991, 2001). Vision comprises the purpose and goals defined by an organisation, and strategy is the roadmap to achieve those purposes and goals (Olsen and Denoble, 1981).</td>
</tr>
<tr>
<td>Organisation structure</td>
<td>Organisation structure is the allocation of organisational resources that are employed to meet organisational objectives (Chandler, 1962).</td>
</tr>
<tr>
<td>Product and market</td>
<td>Products are referred to as both tangible and intangible offerings and services. A market is the place where these are sold (Dutta and Biren, 2001).</td>
</tr>
<tr>
<td>Business process</td>
<td>Business processes are the organisational activities that a business undergoes in its routine functioning (Besson and Rowe, 2012).</td>
</tr>
<tr>
<td>Corporate culture</td>
<td>The core organisational values set the corporate culture, which defines the organisation behaviour both internally and externally (Flamholtz, 2001).</td>
</tr>
</tbody>
</table>

Source: Adapted from Qingfeng et al. (2008)
The benefit of technology-enabled transformation is marginal if it is superimposed on any of these dimensions in their current state. Instead, benefits are fully realised when each of these dimensions is redesigned and adapted according to the new strategy and vision of the organisation. Using research and practical evidence, Venkatraman (1994) has defined the five stages of IT-enabled business transformation, along with explaining the potential benefits of each and the level of business transformation required. Table 2 provides a summary of those five stages, which are also the basis for the theoretical framework of this study.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Stage name</th>
<th>Potential benefit</th>
<th>Level of business transformation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
<td>Localised exploitation</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Stage 2</td>
<td>Internal integration</td>
<td>Moderately low</td>
<td>Moderately low</td>
</tr>
<tr>
<td>Stage 3</td>
<td>Business process redesign</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Stage 4</td>
<td>Business network redesign</td>
<td>Moderately high</td>
<td>Moderately high</td>
</tr>
<tr>
<td>Stage 5</td>
<td>Business scope redefinition</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Source: Venkatraman (1994, p.74)

‘Localised exploitation’ refers to the establishment of isolated, decentralised IT units within different parts of an organisation. These are generally standard IT applications requiring minimal changes to business processes. During ‘internal integration’, organisations go through technical interconnectivity and business process interdependence. Technical interconnectivity deals with the interoperability of different systems and applications through a common platform. Business process interdependence deals with roles and responsibilities among the different functions. There may be managerial resistance when there is a probability of reducing their power base because of streamlining and integration of processes. IT capabilities are used as a lever to redesign the business processes instead of merely overlaying the IT functions on the existing structure and rectifying existing weaknesses.

‘Business process redesign’ is the most critical stage for technology-enabled transformation. Besson and Rowe (2012) define business processes as the procedures through which a firm engages in its routine organisational activities. Merely superimposing the new technical capabilities on the current structure will not yield the same benefit as a redesign. ‘Business network redesign’ occurs when organisations learn and leverage the IT capabilities of the networks and ecosystems of partners or joint ventures to offer better products and services and reduce time to market.

Finally, during ‘business scope redefinition’, the organisation aligns and adapts the corporate scope based on internal capabilities and capabilities developed through the extended network. This business scope redefinition can be either a factor triggering transformation or an outcome of the transformation (Muzyka et al., 1995).

While these stages are presented sequentially, the literature does not explicitly show a specific order of the stages. Instead, the order varies from case to case, based on factors such as the size of the firm and the industry in which the firm operates.

The five dimensions of Qingfeng et al. (2008), along with Venkatraman’s (1994) five stages, effectively condense the IT-enabled business transformation studies that were
conducted in the past. As these models have been used in past studies (Larsen and Klischewski, 2004; Helen et al., 2003; Poon and Swatman, 1997) this study follows the same stages and dimensions to develop the conceptual framework.

2.2 Technology convergence – a new way of benefiting from IT investment

Technological convergence is defined as “the tendency for different technological systems to evolve toward performing similar tasks. It is the integration of previously separate technologies to interact with each other synergistically” (Olawuyi and Friday, 2012). This study focuses on the convergence of OT and IT, which have previously operated independently of each other. OT is an established term that is defined as “the techniques that an organisation uses in its workflow activities” (Pugh et al., 1963, p.310). Gartner (2011) defines it as hardware and software that detects or causes a change through the direct monitoring and/or control of physical devices, processes, and events in the enterprise. OT revolves around automation, and involves monitoring and controlling the physical equipment. Until recently, both IT and OT operated in their own silos. However, as these two technologies advanced, they began to experience a significant amount of overlap and convergence between the silos. While the underlying technologies of OT systems, such as platforms, software, security, and communications, are becoming more like IT systems, IT is supporting OT in building standards, enterprise architecture (EA), support and security models, software configuration practices, and information and process integration (Gartner, 2011).

Businesses across sectors such as healthcare, power, aviation, energy, and transportation are experiencing the benefits of reduced costs, optimised business processes, and increased productivity through the convergence of these two technologies. A smart grid is a prime example of this convergence. It is a synthesis of IT and OT, where OT is responsible for energy planning, asset and resource allocation, and decision making on real-time data; and IT ensures the success of this decision-making by providing the hardware capabilities to run algorithms, yield data and application integration, enable business intelligence, etc. This has resulted in increased reliability, greater fuel efficiency, and significant reduction in operating costs (Gartner, 2011). With technology convergence, industrial companies like GE hope to realise financial and productivity benefits by efficiently utilising IT with their physical equipment and enhancing the intelligence of machines by offering real-time information and predictive analytics (Evans and Annunziata, 2012).

There is strong evidence in the literature that IT alone cannot provide sustainable performance gains unless other resources or skills in an organisation complement it (Bharadwaj, 2000; Tippens and Sohi, 2003; Teece et al., 1997). This paper discusses the concept of gaining a performance advantage by embedding IT into physical equipment-oriented technologies. This is a relatively new topic and is currently in the early phases of implementation. Therefore, not much research has been conducted in this area. Using GE as a case study, this study discusses the various stages and dimensions of transformation experienced by an organisation and attempts to build a conceptual framework to examine the impact of technology convergence, which can be further developed to understand how other companies are managing the transition.
3 Theoretical framework

A conceptual framework that was grounded in the generic stages and steps of IT-enabled business transformation, as suggested in the literature review, was used to study how GE managed the technological convergence and redesigned its businesses.

Figure 1 is a schematic description of the framework used for the study. This framework is a collation of the approaches and stages discussed in the current literature on IT-enabled business transformation. Venkatraman (1994) suggested that the transformation starts at the local level in the organisation, progresses to the inter-organisational level and, finally, expands to a sector-wide transformation (Poon and Swatman, 1997). This model has been used for studies on technology-enabled transformation, to determine the process ownership challenges encountered during this organisational change (Poon and Swatman, 1997). Consideration has also been given to extending the framework from large-scale corporations to small and medium-sized enterprises’ IT adoption (Helen et al., 2003; Poon and Swatman, 1997). This study uses the same model in conjunction with the five critical organisational dimensions proposed by Qingfeng et al. (2008) to explore GE’s experiences when initiating technology convergence.

Figure 1 Conceptual framework

Integrating IT and OT to develop resources such as intelligent machines is a relatively new concept, with significantly higher impact on business processes than simple IT enablement, as this initiative involves the entire organisation. To fully understand this phenomenon, it is necessary to look at the organisational dimension and the transformation stages together, rather than separately, as has been the case in prior research. Hence, the conceptual framework, as shown in Figure 1, combines the transformation stages with the critical organisational transformation dimensions. This theoretical framework was used to analyse GE’s industrial internet initiative, extrapolating the current IT-related models in literature to study this new phenomenon of technology convergence.
Venkatraman (1994) suggested that the transformation stages are linear and do not overlap; however, the dimensions do not follow a certain order. In the conceptual framework, this study looks at the logical order of these stages and subsequently enhances this framework with findings from the case study.

4 Methodology

The objective of this study is to examine the matrix of phases and dimensions when a business undergoes a technology-enabled business transformation and attempts to align its OT and IT. This study introduces the new phenomenon of embedding IT into the equipment-oriented technology of OT, and building a software layer around the physical equipment that imparts intelligence to the machines. GE is among the first companies to initiate this IT-OT convergence, making it an appropriate research subject for a case study by virtue of the fact that it is a ‘unique case’ (Yin, 1994). A qualitative case study approach was used to collect and analyse the data (Eisenhardt, 1989; Yin, 2003). This approach was chosen for the GE case study because “interviews are a highly efficient way to gather rich, empirical data, especially when the phenomenon of interest is highly episodic and infrequent” (Eisenhardt and Graebner, 2007). Ten qualitative, guided expert interviews were conducted with appropriate experts and practitioners within the organisation (Witzel, 2000), each lasting between 30 and 40 minutes. Interviews were semi-structured and a questionnaire addressing the research objectives was designed. Interview partners were selected from different units and levels within the company to avoid potential bias (Eisenhardt and Graebner, 2007). Table 3 shows the designations and business units within GE that are represented in the interviews.

Table 3 Interview participants

<table>
<thead>
<tr>
<th>GE businesses</th>
<th>Designation</th>
<th>No. of interviews</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Centre, USA</td>
<td>Commercial manager,</td>
<td>4</td>
<td>September 2013</td>
</tr>
<tr>
<td></td>
<td>communication team,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>team leaders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corporate Research, Germany</td>
<td>Principal scientist</td>
<td>1</td>
<td>October 2013</td>
</tr>
<tr>
<td>Software Centre, India</td>
<td>Product managers</td>
<td>2</td>
<td>September 2013</td>
</tr>
<tr>
<td>GE Healthcare IT, USA</td>
<td>Marketing</td>
<td>2</td>
<td>October 2013</td>
</tr>
<tr>
<td>Intelligent Platform, USA</td>
<td>General manager</td>
<td>1</td>
<td>October 2013</td>
</tr>
</tbody>
</table>

Corporate documentation analysis was done using company supplied internal documents and strategy papers to validate the information gathered (triangulation).

GE was chosen as the subject of the case study because of its special market position, size, and global nature, as well as its unique initiative to converge IT and OT. Further, as GE is a multinational conglomerate operating in a wide variety of business segments, we could also study the impact of this initiative across multiple industrial sectors. Because it has been a prime example of continuous business transformation and has offered innovative services to keep ahead of the market (McKeown and Philip, 2003), GE was deemed an appropriate choice for this study.

Neither author is affiliated with, or formerly employed by, GE or any of its subsidiaries; hence, there are no conflicts of interest to declare.
5 Case analysis

5.1 GE and the industrial internet initiative

GE traces its beginnings to Thomas A. Edison, who established Edison Electric Light Company in 1878. In 1892, a merger between Edison General Electric Company and Thomson-Houston Electric Company created GE. GE exists in more than 160 countries and employs around 307,000 employees worldwide (http://www.ge.com).

GE has segregated its business into eight separate divisions: aviation, healthcare, GE capital, home and business, power and water, oil and gas, energy management, and transportation. In addition to these eight divisions, GE operates its corporate global research centres, which focus on advanced technologies and industrial research; these centres are located in the USA, India, China, Germany, and Brazil. Recently, with the industrial internet initiative under global research, GE has started a new centre of excellence for software and analytics at San Ramon, California. GE began the IT enablement journey almost a decade ago and currently has approximately 13,000 software professionals worldwide. This investment demonstrates that GE, despite being an industrial company, also has a proven presence in the software business. The software business within GE generates revenues amounting to four billion USD, and it is expected to grow at a steady rate (http://www.gereports.com/post/75376897042/2013-the-year-in-review). GE embarked on their new initiative, the industrial internet, in late 2011; the following paragraphs explain the initiative from both internal and external perspectives. The new industrial internet solutions contributed to one billion USD revenue in 2014 (http://247wallst.com/industrials/2014/10/17/ge-delivers-solid-earnings-with-record-backlog/).

From an external perspective, maturing technologies like big data analytics and cloud computing were ready to become scalable into the industrial world. There was fierce competition in sustained activities to enter the big data analytics arena. Burgeoning cost pressure since the 2008 recession had combined with higher productivity demand from customers to create mounting pressures on GE, and it believed that analytics and other support capabilities could help it survive such pressures.

From an internal perspective, GE sells the equipment and follows up with service packages with guaranteed availability and reliability. Currently, GE has an equipment and services backlog of more than 250 billion USD (http://247wallst.com/industrials/2014/10/17/ge-delivers-solid-earnings-with-record-backlog/), and believes that the only way to grow in this scenario is to add value on top. Business in North America and Europe can be expanded by providing more value in long-term service contracts for the already installed base.

“GE’s vision inside out is, really, to transform our services business to move to the next era, so that we are more than a Gillette playbook.” Commercial manager, Software COE, interviewed by N. Agarwal (September 8, 2013)

The industrial internet is a phenomenon that involves the merging of the digital world with the world of machines. It is the convergence of the global industrial systems with the power of advanced computing, analytics, low-cost sensing, and new levels of connectivity provided by the internet. GE describes the industrial internet as having three essential elements: intelligent machines, advanced analytics, and people at work. It
begins with embedding sensors and advanced instrumentation in the machines and the collection of large volumes of data, which are then analysed to offer real-time intelligence. Investment in this technology convergence had a significant impact on GE’s strategy, leading to a new vision and direction for the company. As CEO Jeff Immelt puts it, “We are making a major investment in software and analytics. We know that industrial companies need to be in the software business”.

For internal purposes, the key performance indicator that GE plans to adopt, to measure the incremental monetisation of the value from industrial internet technologies, is ‘dollar per installed base’. GE commenced this journey in 2011 and claims that this new initiative has the potential to increase productivity greatly. According to Evans and Annunziata (2012), a mere 1% improvement in efficiency can save trillions of dollars in the coming years across all businesses using intelligent operation capabilities.

5.2 Analysis and results

Based on the objective of this research and on the theoretical framework, GE’s strategic initiative of the industrial internet was analysed through the matrix of phases and dimensions of business transition. This study found all five phases to be applicable to the current GE strategic transition and mapped GE’s journey toward the convergence of technologies onto these five phases, indicating the dimensions affected and challenges observed in each of the stages.

5.2.1 Phase 1: localised exploitation

IT-enabled transformation starts with the decentralised approach of ‘localised exploitation’. Here, the organisation tries to leverage and exploit the potential of IT, starting with individual localised units. Standard IT applications are deployed with minimal changes to the organisation structure using a decentralised approach, leading to IT capability development in these individual business units. GE adopted a unique approach to localised exploitation more than a decade ago. Before the industrial internet was initiated, each of GE’s business units had its own IT or software team, historically motivated by a need for faster decision making.

Figure 2 shows the eight businesses of GE and their respective IT units. Businesses where IT significantly contributes to the revenue and those that conduct software development have been given different names, such as intelligent platform (which reports into energy management). In other businesses, where IT is a routine and standard function for internal use, a separate entity has not been created.

Figure 2 Localised IT units within GE businesses
With the implementation of localised exploitation, GE had established multiple software development units across its lines of business. However, this led to the duplication of IT technologies, as well as a reduction in organisational learning across businesses.

5.2.2 Phase 2: internal integration

GE started the Global Software Centre in San Ramon, to centralise and integrate its software activities across businesses. GE created this corporate unit to work on advanced analytics and OT capabilities and serve as the nerve centre for connecting and aligning all GE software development employees. The establishment of this centre was motivated by a variety of internal and external factors such as rising software costs, lack of cross learning across business units, lessons from competition failures, and the realisation that 90% of the developments in today’s online world are similar and only 10% are differentiated between sectors.

GE had a history of successfully managing centralised functions such as human resources and financial planning; however, software was integrated individually into each business. This meant that various business units individually developed standards, platforms, architecture, and security controls without sharing or exchanging information and knowledge. Technical integration was needed so that different systems could operate and communicate on a single platform across businesses, which implied a need for common standards, a technology platform, security, and controls across the businesses.

Through software centre, GE wanted to renew its focus on IT and wanted to create a common platform that could be used by other business to build their respective software services on. GE also saw the competition failing because they lacked centralisation and tried to embed IT into OT by building decentralised IT capabilities. Thus, GE created the centre of excellence for software capabilities, to provide a common place for all its businesses to interact, share, and work on common standards, technologies, platforms, and architectures, irrespective of their businesses. This integration, which happened at both the technical and organisational levels, was necessary to build the underlying technology for intelligent business operations. Centralisation also involved moving employees and expertise from different businesses into the software centre to leverage the existing advanced analytics and machine learning skills possessed by individual businesses. Currently, GE has 13,000 software employees, and it would be unrealistic and expensive to move all these employees to the Software Centre in the short term. However, GE attempts to create multiple hubs for software development across the world, such as in the USA, India, China, and Europe, wherein employees can access, and start from, the same platform.

The Centre works on two different layers of software development, namely, the ‘infrastructure layer’ and the ‘platform layer’. The infrastructure layer handles the data centres that manage and consume the structured and unstructured data, and the platform layer is the scalable software programming that overlays the infrastructure layer. For the platform layer, GE strives to develop a platform that can be operated on all GE devices as well as non-GE devises and used to develop sector-specific applications. GE draws an analogy from the iOS platform, which is installed on all Apple products and opened to specific developers to develop applications on. This platform has been launched in October 2013 with the name ‘Predix™’.
This internal integration and centralisation is expected to offer cross-sectoral learning and scalability in both infrastructure and platform layers.

5.2.3 Phase 3: business process redesign

Localised exploitation and internal integration are both evolutionary phases of business transformation. However, business process redesign is amongst the most revolutionary phases (Venkatraman, 1994). Besson and Rowe (2011) define business processes as the procedures through which businesses engage in their routine organisational activities. Most industrial companies still operate using the ‘industrial revolution’ business processes of roles and responsibilities, line and staff functions, etc. To reap the benefits of technology enablement, using advanced analytics to create intelligent business operations, GE needed to redesign their business processes from the foundation.

“Business transformation, in my view, is most important aspect of GE’s Industrial Internet journey. Software is bringing up a fundamental rethink of GE’s business model.” Commercial manager, Software COE, interviewed by N. Agarwal (September 8, 2013)

GE defines a business process as the full value chain of activities that constitutes new product development, i.e., the end-to-end process from ideation to development to final commercialisation of the product. The company contends that the most critical dimension of transformation toward this initiative of converging IT and OT has been the transformation of business processes. From GE’s perspective, even for an entity of its size, this is challenging but not impossible, with the optimal level of management commitment and support.

Traditionally, GE dominated highly technical fields such as aviation and energy, producing the most advanced jet engines and turbines. The commercialisation cycle of this advanced technical equipment ranges from 10 to 15 years. However, as GE enters the software business, which is known for short commercialisation cycles, it is faced with vastly different business processes in its hardware and software businesses.

Currently, without changing the legacy business processes of their traditional offerings, GE is redesigning the business processes for software development and related functions. The underlying factor behind this redesign is timeliness to market. With technical integration, GE was able to centralise its software and analytics capabilities and develop standards and platforms that were used by the individual businesses to develop their functional software products, allowing faster time to market. Traditionally as different businesses were working independently, the software developed was also traded internally for cross sector usage, which slowed down the development process and increased the cost. With the software development centre, this practice is expected to stop, thereby accelerating the go to market time for the products.

The business operations for software development are changing. Instead of developing the individual platform repeatedly, business IT teams collaborate with software centre teams to leverage their software capabilities and best practices. The Global Research Centre helps the functional team define the scope of these efforts, as well as roles and responsibilities. The various units collaborate to work on product development, beginning with ideation and ending with the marketing of the software product.

The software centre has developed a robust operating platform for analytics and big data, known as Predix™, as well as advanced software technologies and newer
paradigms, such as cloud computing, which the business units use to develop industry specific applications. This requires governance activities across the different units, and highly values communication and cooperation.

Transformation at the business process level is critical. GE plans to follow a venture capitalist funding model, internally named as the ‘ten X’ model, for its software business. This model involves initially investing in multiple software technologies and then selecting and increasing resource allocation to the one or two with the greatest potential to succeed. GE also initiated a new technique called ‘Fastworks’ which helps GE act more like a 21st century start up and includes working closely with customers for product development activities.

5.2.4 Phase 4: business network redesign

The three prior phases of IT-enabled business transformation were restricted to the changes occurring within the organisation. Business network redesign involves developing and leveraging networks outside the organisation, for example, with partners, suppliers, and academia, and developing new technologies or enhancing existing ones.

With the convergence of operational and information technologies, GE is focused on embedding sensors into its traditional machines and leveraging the collected data with software and analytics. However, instead of taking on the development of new technology all by itself, GE is partnering with IT giants to deploy already proven capabilities in order to expedite the delivery of new products to the market.

**Figure 3** Key partners of GE
Business network redesign is a critical step in GE’s strategic transition, which GE calls ‘the ecosystem play’. There are two elements of this ecosystem play, namely technology and go-to-market. GE is not the first company to invent this technology convergence but it claims to be the front-runner of this revolution. Being a relatively new player in the software industry, GE does not aspire to develop proprietary basic software technologies from the basics. Therefore, the objective is to develop the infrastructure and platform layers and select the best available technology that allows GE to offer scalable solutions both to the GE businesses internally and to their customers. GE’s investment in the software company Pivotal is an example of a technology-focused ecosystem approach. Pivotal is developing an open-cloud agnostic platform for all cloud-based services that is highly scalable based on the open-source software technology called Hadoop. Components of the Pivotal offering will be integrated into GE’s platform architecture and will be used to collect and analyse data. The platform, Predix™, will be used as the common technology platform across the various GE business lines for further software development efforts involving big data and analytics. In contrast, the partnership with Accenture is an example of a go-to-market ecosystem approach, where GE wants to leverage the technical expertise and installed base of Accenture to develop sector specific applications and rapid commercialisation.

GE has always operated in an oligopolistic environment and hence lacks experience in driving partnership ecosystems. Now, as GE enters the industrial internet space, it plans to strategically redesign its business network and use the Ecosystem approach to successfully align and merge its IT and OT capabilities. GE plans to leverage this ecosystem to develop the functional features required by its clients. Further, partnerships with AT&T, Intel, and Cisco are helping to increase the technological sophistication that GE is able to bring to the marketplace. AT&T will provide the wireless communications capabilities for remote monitoring and maintenance; Intel will embed virtualisation and cloud-based, standardised interfaces within the GE Predix™ platform; and Cisco will provide collaborative networking capabilities. GE has partnered with Amazon to leverage its cloud infrastructure to offer and extend GE’s product offerings on cloud.

GE’s competitors, viz. Siemens, Schneider, and Asea Brown Boveri (ABB), are all striving toward this convergence in their own way. ABB acquired a company called ‘Ventyx’ which was a leading provider of software solutions for managing energy networks, to develop the same IT capabilities. Schneider started an initiative called EcoStruxure that is focused on energy efficiency – this is an effort to create an intelligent energy management system that allows the measurement and management of energy usage across data centres and industrial plants. Siemens has recently announced its Vision 2020, where it talks of business analytics and data-driven services as a growth area by the year 2020. The significant differentiator between the industrial internet and these other initiatives is the centralised, cross-sectoral approach that is employed in a top-down manner directly by GE’s leadership. ABB’s Ventyx acquisition and Schneider’s EcoStruxure initiative only focus on energy efficiency and smart grid applications. Siemens’ Vision 2020 is a cross-sectoral approach; however, it has been launched very recently (May 2014) and is in implementation phase.
5.2.5 Phase 5: business scope redefinition

Redefining the business objectives of the organisation means reconsidering the organisation’s future vision. GE’s leadership team has clearly redefined the company’s vision as moving from product to solution orientation. The industrial internet initiative is an outcome of this strategic redefinition. Leadership plays a very important role in communicating the vision of the organisation and the company’s direction, as well as in clarifying the strategy that will be employed to achieve success. It is critical, during this redefinition, to maintain the corporate culture and retain stakeholder trust in the company. GE, under the leadership of Jeff Immelt and the Board of Directors, is leading the transformation. The vision of the industrial internet as the new direction in the progress of the company, helping GE move toward becoming a more solutions-oriented organisation, is being communicated to the employees, customers, and stakeholders. The entire organisation is involved in priority redefinition, and there is a great deal of focus on internal and external communication.

5.3 Discussion

The industrial internet represents a significant business transformation for GE, with the development of new capabilities and the creation of new strategies and processes, all intended to enhance its competitive position in the market (Prahalad and Oosterveld, 1999). As Tushman and Romanelli (1985) suggested, the logical beginning of this business transformation is strategic transition, followed by the alignment of the organisation structure, products, markets, and business processes. The transformation in GE started with business scope redefinition, wherein GE leadership teams gave the company a new strategic orientation, shifting the focus from a product-oriented to a solutions-oriented company. The industrial internet appears to have been the result of this new strategic focus, which is consistent with findings from past research that business scope redefinition can be the triggering factor for transformation or can be an outcome of the transformation (Muzyka et al., 1995).

In GE’s case, the localised exploitation, involving decentralising IT and deploying standard IT across businesses, does not appear to have been part of the current business transformation initiative. Instead, this phase was likely a prerequisite to the technology convergence, which led to the embedded IT capabilities within the organisation. Today, in a scenario where most of the companies, in general, are already IT-enabled, realigning IT with OT is the next logical step in organisational growth.

Technology convergence appears to be the new medium for developing unique capabilities based on IT investment. With the industrial internet, GE is enhancing its operational technologies as the next step to the earlier execution of localised IT enablement. Organisations implementing technology convergence need sufficient IT capabilities across their businesses in order to build the software and analytics layer around their physical equipment. Along with its software capabilities, GE’s strong history of product development is playing a crucial role in supporting the standards and architectures for the industrial internet. Both capabilities are being aligned and developed to further enhance the company’s physical equipment and endow it with real-time intelligence.
As part of its technology convergence, GE is returning to a centralised approach to IT by establishing a common platform of IT standards, Predix, on which all its physical equipment can easily operate. Equipment across various sectors, from CT scanners to locomotives and from transformers to jet engines, can potentially operate on this new platform.

GE recognises that this internal integration and the corresponding changes to business processes will affect the entire company, and that the active involvement and focus of the company leadership is required for the initiative to be successful. To facilitate the internal integration, GE is changing its organisation structure and centralising IT capabilities in a new software centre of excellence. As for the redesign of business processes, GE is confronting challenges requiring operational changes in software development. Instead of repeatedly developing individual platforms, business units collaborate with the software centre team to leverage their software capabilities and best practices.

GE foresees many obstacles in this transformation process, the foremost among them being resistance to change and the acceptance of centralised platforms within individual business units. The top management’s involvement in communicating the vision helps in breaking these barriers quickly; however, the acceptance is still inadequate. For example, healthcare IT (HCIT) is the single largest IT unit within GE. Although GE expects to have lower costs in the long term, it does not expect an immediate effect on HCIT offerings, and insists on keeping the go-to-market and delivery options with the individual businesses themselves.

“There is no immediate effect on HCIT in terms of governance or change in business processes. Even in the long term, when we will use the COE platform and develop our applications on the top, the go-to-market, CRM, and delivery responsibilities will be with the HCIT business only.” HCIT marketing manager, interviewed by N. Agarwal (October 23, 2013)

Overall, each phase of this technology convergence appears to have been time consuming, involving significant capital investment. GE claims to have invested 1 billion USD in this initiative over the course of three years.

The business transformation phases at GE seem to be nonlinear and overlapping in nature, especially at the business network and business process redesign stages. In both these stages, companies can experience concurrent changes in organisational dimensions, such as business processes and the market and product focus.

5.4 Theoretical implications

Prior research has theoretically and empirically proven the benefits of IT investment when it is embedded and complemented by other resources or skill sets, whereas the direct impact of IT on a firm’s performance remains unclear (Bharadwaj, 2000; Powell and Dent-Micallef, 1997; Mata et al., 1995; Tippen and Sohi, 2003). This study supports the RBV in utilising IT capabilities to develop unique skill sets and explores the relatively new phenomenon of combining IT and OT to gain IT investment benefits. The IT–OT technology convergence is expected to revolutionise the industrial world and can be a mechanism for realising performance gains through IT investment. This study demonstrated that the development of new capabilities through IT and OT convergence not only transforms business processes but also affects major organisational dimensions, from strategy and vision to products and markets.
Technology convergence is a bigger initiative than the enablement of IT into business processes. This study has shown that Venkatraman’s (1994) model is applicable to this type of business transformation involving technology convergence. However, in this new era, most firms are already IT-enabled and strive for sustainable benefits by embedding IT or combining IT with other resources. The first stage of IT-enabled business transformation, localised exploitation, has become a default or prerequisite in organisations today. This research expands the Venkatraman model by considering both the organisational dimensions and stages and mapping the dimensions onto the transformation stages. In prior studies, the transformation stages were deemed to be linear in nature (Venkatraman, 1994), but the GE case study shows evidence of nonlinearity and overlap across stages.

The conceptual framework shown before relies on the hypothesis that all five organisational dimensions play an equal role during all the five stages of IT-enabled business transformation. However, the GE case study illustrates that each stage of the transition has an impact on a unique set of dimensions. Business scope redefinition influences the dimension of strategy and vision while internal integration influences the organisation’s structure. During the business process redesign and business network redesign stages, the two dimensions of business process and products and markets are impacted.

This study also identifies organisation structure as a transformation dimension that has not been fully explored but that plays a critical role in a technology convergence process. The authors suggest that the role of corporate culture in these converging business transactions is vague. Although corporate culture did not have a significant impact on GE, this may differ in other industries. Evaluating the role of this dimension in other organisations would be an important step in future research. For example, in the case analysed, the strong leadership and high focus on both internal and external communication about the initiative has softened the impact on GE’s corporate culture.

Finally, the study introduces the concept of convergence of IT and OT as a medium to develop unique capabilities within a firm, which can be linked to performance gains.

5.5 Managerial implications

Strategic business transitions are both time and capital consuming processes that must be initiated early enough to provide the organisation with a competitive advantage in the marketplace. The first step in the process requires redefining the business scope and transforming the strategy and vision of the company. At GE, this process began almost three to four years before establishing the software centre in 2012, when the leadership team redefined the company’s vision and repositioned it as a solutions-oriented firm. Internal integration was achieved by redesigning the organisation’s structure, resulting in the establishment of a new, centralised software centre of excellence. The centralisation of software capabilities enabled GE to leverage learning across the organisation and provided a common platform to facilitate collaboration across all business units. IT integration also improved GE’s time to market with new products and provided operational flexibility within organisation.

Companies can experience concurrent changes in organisational dimensions, such as business processes and market and product focus. Transforming business processes is a revolutionary step (Venkatraman, 1994) for an organisation, and defining the roles and
responsibilities of various business units, resolving governance issues, and redesigning product ownership are areas that require management supervision and support. For industrial organisations, where the project management process for software development, from ideation to commercialisation, differs substantially from hardware product development, the transition can be especially challenging. Building new skills within the organisation and partnering with other business entities through the redesign process can be helpful in managing this transition.

5.6 Limitations and future research

Convergence of technology is a relatively new field in which a limited amount of research has been conducted. For this reason, this paper assumes that transforming businesses by aligning OT and IT follows phases and dimensions similar to those seen with IT-enabled business transformation, which is better represented in the literature. While few industrial companies have embarked on this alignment, some, including GE, are moving in that direction. The GE case analysis, however, is limited to a single case study and requires more research, to generalise the framework.

This study demonstrates that the convergence of OT and IT is an upcoming topic that is receiving attention from the industrial sector because of its potential to improve a firm’s performance through IT investment. Moreover, it provides an overview of the phases and dimensions being affected by this transition and proposes a conceptual model defining the stages and dimensions of transformation that a firm goes through. This model is validated for a single case in the industrial sector, but can be further developed by looking at other sectors and companies working toward embedding IT into OT. This is an evolving field and, therefore, needs follow-up research to better understand how other companies/sectors are adopting this phenomenon. Finally, this study can be further developed in the context of an RBV framework, where technology convergence is a resource developed through IT investment that is designed to improve a firm’s performance.

References


