



Convergence innovation in the digital age and in the COVID-19 pandemic crisis

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ABSTRACT

Sustainable innovation is imperative for organizational survival and success in the turbulent market environment of the digital age, especially more so in the current COVID-19 pandemic crisis. This paper presents convergence innovation (CI), powered by the exponential fusion effect of the various objects, technologies, ideas, and strategies, as a new sustainable core competence of organizations. We present the concept of CI including its autonomous ecosystem enabled by advanced technologies, unique life cycle features, relationships with other innovation approaches, and its purpose of value creation for the stakeholders and beyond (for the greater good). The paper also explores how CI can be a catalyst for managing the current COVID-19 pandemic and charting the path to post crisis. The study makes contributions to both innovation literature and to practicing managers with new insights on sustainable innovation strategies for organizational performance and beyond.

1. Introduction

The business environment is turbulent and in constant change. What is different in today's digital age is that changes are occurring at unprecedented rates of velocity and scale (Brosseau, Ebrahim, Handscomb, & Thaker, 2019). The destructive current situation brought by the global pandemic of COVID-19 is but an extreme example. Today many organizations, especially small and medium enterprises (SMEs), no longer enjoy the luxury of developing strategies for intervals of several years but are struggling to find survival plans for the next quarter or months (Blackburn, LaBerge, O'Toole, & Schneider, 2020). The wave of megatrends, such as globalization, advances in technologies, environmental concerns, changing demographics, urbanization, the global pandemic crisis, and other forces, is making the marketplace increasingly uncertain. The environment is becoming even more complex as those megatrends themselves are also evolving at an increasing rate. For example, globalization has already been undergoing much deeper changes than the rhetoric of trade tensions and nationalistic fervor (Lund, Manyika, Bughin, Krishnan, Seong, & Muir, 2019). Many emerging economies, such as China and India, have developed large domestic markets and thus their reliance on global trade has decreased significantly. The coronavirus pandemic crisis has accelerated the geopolitical division and so profoundly disrupted supply chains of most business enterprises that many are beginning to wonder whether this is the end of

globalization as we know it (Karabell, 2020).

Simultaneously, advances in digital technologies occur at the speed of light, such as cloud-based ubiquitous computing, big data analytics, artificial intelligence (AI), machine learning, Internet of Things (IoT), autonomous systems, smart robots, 3-D printing, and virtual and augmented reality (VR & AR). These technologies are not only changing the way organizations function and people live, but they have also proven to be enormously valuable in attacking social problems. For example, advanced digital technologies are extensively applied to testing, contact tracing, and treating people for the coronavirus; to quickly restructuring supply chains; to supporting tele-work and remote education which will permanently change the nature of work and education in the future; and searching for robust solutions to derailed economic and social structures (Sneader & Singhal, 2020). The current unprecedented pandemic crisis is prompting many organizations to be in a state of urgency for innovation, e.g., re-purposing businesses, products, materials, etc. to quickly deploy innovative solutions to such problems as the limited testing and treatment capacity for preventing the virus from spreading, key material shortages due to supply chain disruptions, helping people in need, and safely reopening the economy (Bello, Collins, Dreischmeier, & Libarikian, 2020; Stoll, 2020). To compete successfully in the hyper-competitive and unstable environment, organizations must develop dynamic capabilities based on agility, flexibility, resilience, and speed (Aghina, De Smet, Lackey, Lurie, &

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Muraka, 2018). Thus, sustainable innovation has become a strategic priority for every type of organization, be it a business, government, or nonprofit enterprise (Ettlie, 2006; Lee & Lim, 2018; Veronica, Alexeis, Valentina, & Elisa, 2019).

Innovation has been defined in different ways, based on purpose, process, or disciplinary perspectives. In this paper, innovation is defined as “deployment of new ideas and/or technologies in fundamentally different ways to create new or additional value for continued success of the organization and its stakeholders” (Adner & Kapoor, 2010; Lee, 2018). In the current digital age, innovation is not equivalent to technology-enabled automation for the economies of scale, as demonstrated by the industrial paradigm of mass production pioneered by the Fordism in the early 20th century (Hakansson & Ford, 2002). Today, innovation can be based on convergence of seemingly heterogeneous and unrelated things that can create an exponential outcome based on the economies of convergence and network (Coolican & Jin, 2018; Hedvall, Jagstedt, & Dubois, 2019; Metcalfe, 2013; Reim, Sjodin, & Parida, 2019). Innovation based on the exponential effect of convergence, which we label as convergence innovation (CI) in this paper, is much more dynamic than automation as it leverages the quantum force of fusion of various objects, ideas, people, functions, technologies, organizations, industries, and societies (Lee & Lim). The key feature of CI is the ecosystem, which is designed to make necessary decisions or actions autonomously, through scanning the environment with the support of smart sensors, AI, IoT, big data analytics, machine learning, and ambient computing. The extracted relevant information is then sent to the next level for evaluating innovation ideas derived from both internal and external sources for implementation (Lee & Lim, 2018).

CI would be a sustainable core competence for not only creating value but also pursuing a smart future where people, society, and the environment all flourish (Hedvall et al., 2019; Lee & Lim, 2018; Lee & Trimi, 2018). Although it was not labelled as CI, convergence of different objects and technologies has been widely applied to manage critical issues. For example, even in this digital age, there still are 1.2 billion people who live in energy poverty without access to electricity due to extreme poverty (Hunt, 2017). WakaWaka was established with the convergence of solar science, mechanical engineering, telecom, crowdfunding, and design thinking to produce inexpensive handheld devices that provide solar-powered LED light. WakaWaka has brought not only electric light to people but it also enabled communication with outside world by making charging cell phones possible (Lee, 2018). Clean drinking water is a critical resource in short supply for over 1.5 billion people around the world. Warka Water converged architectural engineering, physics, and meteorology to build water towers which collect clean condensed water every day in high dry areas of Ethiopia (Lee & Lim, 2018). The current COVID-19 pandemic magnifies a critical role that CI can play for crisis management. CI can be invaluable in managing the destructive effects of personal, economic, and societal shutdown (Bello et al., 2020). The role of CI for organizational strategies, especially in times of urgency, presents a new template of sustainable innovation for managing urgency with agility and resilience (Desmond-Hellmann, 2020).

This study makes contributions to both theory and practice of innovation. For the contribution to innovation literature, we present the new concept of CI, the major forces that enable the development of a platform-based ecosystem, the structure of CI as a self-managing autonomous ecosystem, the very different (from typical innovation) CI's life cycle, and CI's relationships with other sustainable innovation strategies. This study also makes practical contribution as it sheds new insights for developing organizational agility through CI as a competitive competence in the digital age. Perhaps the most vivid practical contribution of our study would be that we outline how CI can help manage the challenge of COVID-19 (for on-demand testing, technology-enabled contact tracing of infected patients, effective isolation of vulnerable people, the protection of first responders, developing treatment and vaccines, dealing with supply chain and economic challenges,

and opening up the economy), and prepare for a permanently different post-pandemic world and future.

The remainder of the paper is organized as follows. In the next section, we present the theoretical framework of CI, including a review of the digital age, with the emergence of the Fourth Industrial Revolution (4IR) and digital transformation that engender the imperative of sustainable innovation. Then, we present the concept of CI including the evolution of innovation, the structure of CI, and the life cycle of CI in the digital age. Section 3 articulates the significance of CI in managing the current COVID-19 pandemic crisis, focusing on the role of CI in reimagining the post-pandemic period. Section 4 discusses the framework for various strategies for sustainable innovation and their relationships. The paper concludes with Section 5, which provides a brief summary of the study, theoretical and practical contributions of CI for organizational sustainability, and limitations of the study and future research needs.

2. Theoretical framework of CI

Human history can be characterized as a series of innovation. Humans have strived to search for ways to improve the quality of life, from the hunting-gathering age to agrarian economy, industrial age, information age, and now knowledge economy (Lee, 2018). Every innovation initially brings a major shakeout as happened in automobiles, PC manufacturing, smartphones, and the like. The number of producers would first increase steadily, and then, as the value pool consolidates, it will drop rapidly (Bughin, Catlin, Hirt, & Willmott, 2018). Thus, when the new change is being operationalized, a period of relatively tranquil equilibrium would prevail only to be punctuated by new innovations that are superior to previous ones (Siebel, 2019). As witnessed by the four major revolutions (agriculture, industry, information, and digital), the frequency, speed, and magnitude of impact of such disruptions have been accelerating (Bughin & Woetzel, 2019; Lee & Lim, 2018).

Every organization, regardless of its size and purpose, has a chain of activities to create value added. The main purpose of innovation is searching for effective approaches to improve the value chain for the organization and its stakeholders (Freeman, 2004; Harrison & Freeman, 2017). The innovation literature has a rich tradition based on extensive research over the years (Adner & Kapoor, 2010; Carrillo, Druehl, & Hsuan, 2015; Chesbrough, 2003; Chesbrough & Brunswick, 2014; Christensen, Rayneer, & McDonald, 2015; Cohen & Levinthal, 1990; Crossan & Apaydin, 2010; Ettlie, 2006; Gobble, 2014; Lee & Lim, 2018; March, 1991; Tapscott, 2006; Von Hippel, 2017). As such, we will not review innovation literature here. However, it should be pointed out that, in recent years, the pace of innovation has been frantic due to the rapid advances in technologies, sciences, digital transformation of organizations; the compounding effect of the increasing complexity of the extended global value chains; and the recent COVID-19 pandemic crisis (Bello et al., 2020; Ip, 2020; Stoll, 2020; Tonby & Woetzel, 2020). Thus, innovation has become an imperative for organizational sustainability and has demonstrated its significance during the current pandemic crisis (Stoll, 2020). Nevertheless, doing things fast and doing them right have proven to be not an easy task for organizations. In this section, we will discuss the emergence of CI in the digital age, evolution of innovation, structure of CI, and life cycle of CI,

2.1. Digital age and sustainable innovation

Today we live in the digital age which is often described as the era of Fourth Industrial Revolution (4IR) or digital transformation (DT). The concept of 4IR originated in Germany for developing smart manufacturing. The core of 4IR is the convergence of advanced technologies for cyber connectivity of physical systems and automatic control of manufacturing processes (PwC, 2016; Scalabre, 2019). Since the introduction of 4IR as a major debate topic at the Davos Economic Forum (2016), its concept has spread rapidly throughout the world and

has been embraced as a means of sustainable innovation by all types of industries, governments, and nonprofit organizations.

With the popularity of 4IR, many consider it synonymous with DT. However, they should be differentiated based on two aspects. First, the core drivers of 4IR are technologies (Scalabre, 2019), whereas DT is based on the convergence of not just advanced technologies, but also ideas and strategies. Second, the primary purpose of 4IR is to improve the efficiency and effectiveness of the organization's value chain. However, DT has a much broader and higher aspirational purpose, not only for greater value creation for an organization but also for the shared goal of the stakeholders (Freeman, 2004; Harrison & Freeman, 2017; Lee & Trimi, 2018; Miles, 2012).

DT is not just digitalization, which is the process of improving the existing systems with the application of advanced digital technologies. DT entails a fundamental reinvention of the way things are done by individuals, organizations, governments, and society (O'Halloran & Griffin, 2019). DT is enabled not only by advanced technologies, but also co-creation of shared goals (Porter & Kramer, 2011; Von Briel, Schneider, & Lowry, 2019) by converging strategies and creative ideas. DT has helped develop autonomous systems, social networks (Li & Bernoff, 2008), and AI-powered smart systems (e.g., smart homes, infrastructure, cities, and countries) (Rogers, 2016). These developments have enabled the creation of ambient intelligence and the paradigm of "smart everything" (Streitz, Charitos, Kaptein, & Bohlen, 2019). DT has helped organizations develop global value chains with connectivity, agility, flexibility, and dynamic capabilities, all imperatives for sustainability of business enterprises in the age of urgency (De Smet & Gagnon, 2018). DT has also enabled governments and nonprofit institutions to become smart digital entities with human and social e-services, citizen participation systems, 7/24 policing, and the like (Lee & Trimi, 2018). Both 4IR and DT have provided an impetus to the development of CI.

2.2. Convergence innovation (CI)

In this paper, we propose CI as a sustainable innovation strategy, with its autonomous ecosystem, in the turbulent digital age. CI can help organizations implement effective strategies for value creation with agility even in the unprecedented time of the current pandemic.

2.2.1. Evolution of innovation

The concept and practice of innovation have evolved throughout history, going through different phases or stages. Each successive innovation phase is based on the accumulated knowledge and learning of previous phases, thus accelerating the speed and the scope of innovation in the new phase. For example, while it took 15 years after the Spanish Flu pandemic (1918–1920) to discover the virus (in 1933), it took only few weeks to discover the COVID-19 virus.

The key phases of innovation evolution are: (1) Closed innovation (internal R&D focused, strictly protected as the source of competitive advantage), (2) Collaborative innovation (collaboration with partner organizations to create world-class global value chains in the form of strategic alliances, joint ventures, technology licensing agreements, and market partnerships), (3) Open innovation (searching for new sources of innovation ideas by leveraging collective intelligence and open sources), (4) Co-innovation (partnership of organizations, which share same basic goals, engages in co-creation of value with each bringing its world-class core capabilities to the value chain), and (5) Convergence innovation (bundling or fusing seemingly unrelated objects, ideas, or experiences, from all kinds of external sources including organizations and people from different industries and countries that share aspirational goals of stakeholders (Freeman, 2004) and for the greater good (Baldwin, 2016; Hunt, 2017; Lee & Lim, 2018; Lee & Olson, 2010). CI has a quantum power which comes from the ability to integrate the strengths of different innovation elements: incrementally (horizontally) and drastically (vertically), as shown in Fig. 1.

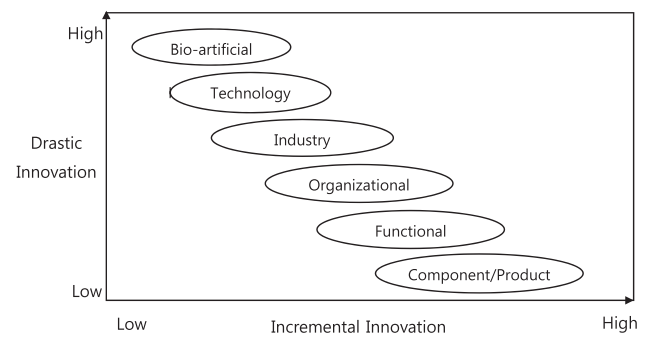


Fig. 1. Convergence in the incremental-drastic innovation space.

2.2.2. Structure of CI

In the hypercompetitive global business environment, an organization's sustainability depends on its agility, adaptability, and resilience (Teece, 2014; Von Briel et al., 2019). The primary purpose of CI is to support such organizational competitiveness. Fig. 2 shows the key elements of CI and the self-managing innovation ecosystem, which is structured like a spider web with several layers, where each layer performs certain functions (just like an instrument section in an orchestra) and all layers connect, coordinate, and work together in harmony to produce a powerful, quantum innovation outcome. The ecosystem structure is composed as follows:

Layer 1 is the direct *contact point* with the market forces, including customers, competitors, market conditions (e.g., economic, cultural, political, and environmental conditions), and technological developments. This layer is composed of a web of AI-enabled smart sensors that can pulse the conditions and movements in the marketplace. The collected data by sensors are transmitted in real-time for big data analytics. The relevant information extracted by the data analytics system is forwarded to the autonomous decision-making system, which is supported by machine learning, IoT, and other digital technologies, invokes instantaneous implementation of required actions. The higher-order collaboration or decision-making issues are forwarded to Layer 2 and above.

Layer 2 has a host of connected innovation *subsystems* such as internal R&D, connect and develop (C&D) for external sources, collaboration networks with partner organizations and other stakeholders (e.g., customers, communities, and governments), and open source systems (e.g., open innovation, crowd sourcing, and public sources). These subsystems are connected to the organization's tacit filter system, which processes and evaluates ideas from the various sources, including those that are transmitted from Layer 1 based on the organization's capabilities and strategies.

Layer 3 has a value *co-creation platform*, where the organization attempts to co-create shared goals with major stakeholders, including customers, suppliers, other partner organizations, community, governments and society at large (Porter & Kramer, 2011; Ramaswamy & Ozcan, 2014). The major decision problem at the platform involves priorities assigned to different goals associated with each stakeholder entity. Thus, strategic decisions based on the organization's vision and long-term goals at the top management level would be required.

Layer 4 is the highest level of the ecosystem from which the purpose of innovation transcends down to lower layers for implementation. While value creation is the immediate goal of most organizations as their performance as well as for the interest of all stakeholders (Freeman, 2004), the ultimate goal of innovation can be much more far reaching and aspirational than that. The goal of innovation should be for the greater good (beyond that for the organization and its stakeholders) - creating a smart future where people, organizations, and the environment all flourish (Hunt, 2017; Lee & Trimi, 2018).

The proposed CI is in line with the current active research on *autonomous organizations* as proposed by Libert, Beck, and Davenport

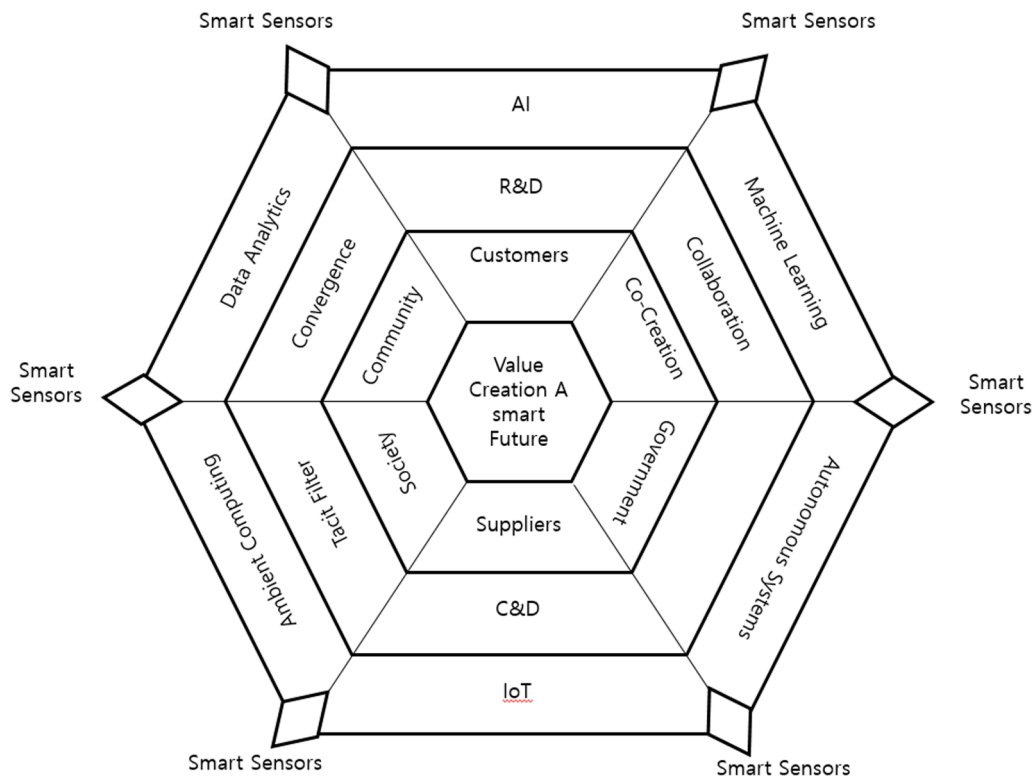


Fig. 2. Convergence innovation ecosystem.

(2019). While self-driving enterprises are not reality yet, many functional areas have seen innovations toward *semi-autonomous* operations as follows (Gilder, 2018; Libert et al., 2019).

- Operations/supply chain management (SAP enterprise systems)
- Documentation and knowledge work (Microsoft)
- Financial services (roboadvisorpro)
- Marketing, advertising, customer relationship management (Marketo, Salesforce, 6sense)
- IT services (Oracle, IBM, IPsoft)
- Cognitive decision making (IBM Watson, Google AlphaGo Zero)

Libert et al. (2019) suggested the following scale to measure a system’s autonomy:

1. Human controlled, with autonomous systems providing supporting data/information
2. Human controlled, with most systems operate autonomously with preset guidelines and warnings
3. System controlled, with frequent human intervention and support for decision-making
4. System controlled, with human intervention for critical decision problems
5. Completely system controlled, with no human intervention or support

While most of the autonomous operations listed above are at the 1minus or 1 level at best based on the measuring scale, the proposed CI would be at around level 3.

2.2.3. Life cycle of CI

Innovation is rarely a one-shot process. Instead, it usually involves a life cycle (Ettlie, 2006). The first mover advantage, based on new technologies and/or new business models, may last several months, years, or even longer, until new entrants with new innovative products/

services disrupts the market. We have witnessed the change of fortune for many once world-class organizations such as Kodak, Research in Motion (Blackberry), Blockbuster, Nokia, Nieman Marcus, Sharp, and many others. Moreover, in the competitive digital age, the innovation life cycle has become much shorter as organizational core competences are based on fast developing technologies (Lee & Trimi, 2018).

Typically, the innovation life cycle resembles the S-curve of technology (Christensen, 1992; Ettlie, 2006). At the start of the curve, a new idea is planted for different ways of creating value with required resources committed. Many innovative ideas, inventions, patents, or business models may not pass this phase and their S-curves would not even get started. Some may receive management support and required resources for implementation but dwindle without reaching the take-off stage. Some other innovations may have long life cycles with steady marginal rates of return (e.g., consumer products, paper products, and food items). However, a successful innovation would have an S-curve as shown in Fig. 3a: after launching the innovation, the marginal rate of return increases exponentially until it reaches the inflection point - this is typically the ‘harvesting’ phase of innovation where the marginal rate

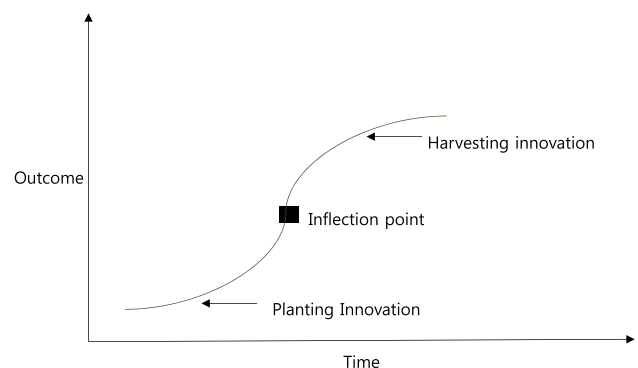


Fig. 3a. Innovation life cycle S-curve.

of return begins to diminish until it reaches the peak of the curve. In order to minimize loss, the firm may abandon the innovation S-curve before its return begins to turn into negative and it may start a new cycle instead. An enlightened firm may have a proactive strategy for continuous innovation. When the first innovation S-curve reaches its peak point, it may launch the next S-curve by leveraging the learning experience from previous ones and new technological advances (see Fig. 3b). In the life cycle figure, X-axis represents time, while Y-axis shows the outcome of innovation in terms of value added (e.g., value chain efficiency, new products/services, new customer value, new markets, or new business models).

CI S-curves in the digital age would be different than the continuous innovation S-curves shown in Fig. 3a and Fig. 3b, which are based on the economies of scale or network. CI will typically have shorter S-curves and the successive S-curve would start from a higher point than the peak of the previous curve, due to exponential effect of convergence. Also, the length and trajectory of S-curves would vary depending on the nature of the innovation. In addition, the transition line from the peak of the previous S-curve to the starting point of the next S-curve would be jagged and jumpy, just like the general pattern of technology development (Lee & Olson, 2010). The new starting points of successive S-curves would depend on the nature of convergence and technologies involved. The typical S-curves of CI for a successful organization in the digital age are presented in Fig. 4.

3. Significance of CI in the Covid-19 pandemic crisis

The mega trends or even giga trends we alluded to in Introduction have brought digital transformation of organizations, economies, and societies (Aghina et al., 2018). To survive and flourish in the digital age, organizations strive to become agile entities. This is a daunting journey for many organizations, but they have no choice but take this difficult path toward DT. In addition, the speed of transformation is unprecedented. The digital age demands organizations to become not only agile, adaptable, and resilient, but also be extremely innovative. To become such nimble organizations, innovation should be the top strategic priority. While most organizations do understand the importance of innovation, many have been, at least until the COVID-19 crisis, nudged into it rather than jump-starting with a sense of urgency (Stoll, 2020). Now, the enormous destructive power of COVID-19 pandemic shook the world in lighting speed and most organizations, especially SMEs, are in a total chaos. Organizations now long for the once dreaded old times of digital transformation (Blackburn et al., 2020).

China announced a pneumonia of unknown cause on December 31, 2019. Within two months, the number of infected patients and deaths accelerated across the globe and WHO declared it as a pandemic on March 11, 2020 (Desmond-Hellmann, 2020). In a matter of several

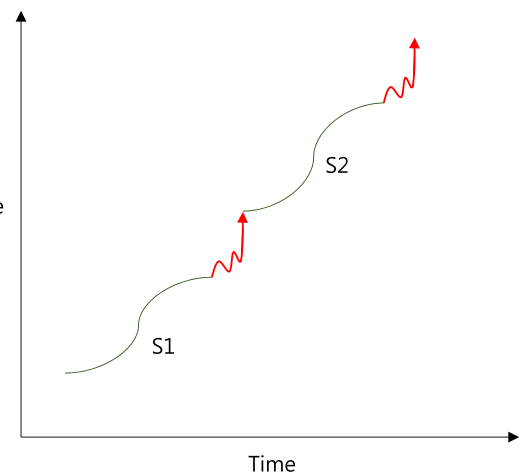


Fig. 4. Convergence innovation S-curves.

weeks, the number of jobs created during the past 10 years or so in the US disappeared and more than 30 million workers filed for unemployment support. The coronavirus pandemic has not only impacted people’s health (more than 3 million people infected and 200,000 + deaths world-wide as of April 30, 2020 according to the World Monitor) and is devastating the economy of almost every nation, but it has also altered the very fabric of everyone’s life (the way people work, travel, socialize, learn, love, exercise, etc.). In this unprecedented time of isolation, despair, and economic hardship, organizations need to be extra nimble, resilient, and purposeful, indicating the urgent need of effective innovation (Stoll, 2020).

In the pandemic state, people are sequestered in isolation, major parts of economy are shut down, schools are on the online education mode, those who still have jobs work remotely from home, and first responders risk their lives to treat infected patients, deliver food to isolated people, and protect the safety of the community. The two most critical tasks for the leaders are: first, how to manage the virus now (social distancing, testing, contact tracing of infected people, treatment of the patients, etc.) and develop an effective vaccine as soon as possible (in a matter of 8–9 months instead of the usual minimum of 18 months); and second, when and how to open the economy again. These two tasks require agile innovation in necessity, the exact purpose of CI (Bello et al., 2020; Lee & Lim, 2018).

3.1. Innovation for managing the pandemic

In the face of the raging pandemic, the most urgent step to take is deploying effective activities in place. Ironically these activities are the core elements of CI, indicating that CI is not only for ordinary times, but it is even more effective in times of crisis. To manage the pandemic crisis, the following activities are important.

- *Real-time environment scanning:* In order to understand the severity and magnitude of the virus, a society needs smart infrastructure of preparedness. It is impossible to fight the virus without the nerve center which can collect and analyze data. South Korea has been singled out as the most successful nation in managing the pandemic through its public health infrastructure, the outcome of the country’s lessons from failures in battling MERS (the Middle East Respiratory Syndrome) in 2012. The critical chain of events for effective management of the pandemic involves: testing, tracing contacts of infected persons, quarantine or treatment, securing the care capacity (medical staff, hospital facilities, ventilators, personal protective equipment (PPE), and after treatment logistics), etc. Korea utilized its well-established public health infrastructure with a “do-check” approach in the crisis rather than the usual “check-do” protocol of

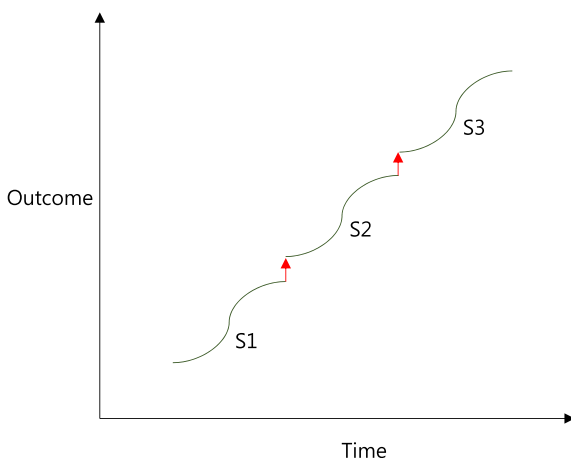


Fig. 3b. Continuous innovation S-curves.

most governments (Reuters, 2020). With its world-leading mobile communication systems, contact tracing was done instantaneously, the key for the containment of the virus.

- *Seamless flow of data, analytics, and information for decision making:* The key to innovation success is that the valuable information extracted from data analysis is quickly applied to decision making. The rapid spread of the virus paralyzed most economic machines, especially air transportation, hospitality and tourism, entertainment, sports, and education industries. In the USA, SMEs were especially hit hard as many had to cease their operations completely. While the federal government and Federal Reserve acted quickly to develop economic stimulus plans, they were still not fast enough to counter the tsunami of the economic impact of the pandemic (Stoll, 2020).
- *Collaboration network:* COVID-19 is a global pandemic. It cannot be controlled, nor can its treatment and vaccine be effectively implemented, by just one country in isolation. International collaboration among public health organizations, governments, and medical professionals is essential to share information such as the DNA of the original virus in Wuhan, China, treatment successes or failures, infection patterns, etc. (Desmond-Hellmann, 2020). Within the US, there have been extraordinary public-private partnerships for combating the virus. For example, the Federal Drug Administration (FDA) approved Gilead Science's intravenous drug Remdesivir on May 1, 2020 in lightning speed of several days, after the drug showed 31% improvement in recovery among 1063 severely ill patients (Associated Press, 2020). There were other partnerships formed quickly among scientists, private foundations, pharmaceutical firms, and university research centers to develop effective vaccines for the coronavirus (Copeland, 2020; Desmond-Hellmann, 2020).
- *Agile innovation:* The pandemic crisis has brought human tragedy, economic damage, and social torment. However, one success story of the current experience with the pandemic would be how organizations have learned to innovate fast in crisis. There have been many examples. Retailers that have been contemplating for months to devise implementation plans for a curb-side delivery service to customers, developed the system in a matter of few days when the pandemic crisis hit. Ford Motors, that has been working for years to develop electric cars that can compete with Tesla without much success, switched some of its operation lines to produce medical ventilators in a matter of a few weeks during the pandemic (Stoll, 2020). So did True Value Co., which switched two of its production lines from paint to FDA-approved hand sanitizer in two weeks (Ip, 2020). The pandemic crisis has awakened American ingenuity from their flat-footed innovation efforts in ordinary times into agile innovators in the time of pandemic crisis.
- *Exponential power of convergence:* In the time of COVID-19 crisis, organizations and people are becoming extraordinarily creative to find new solutions, be it for making masks or face shields for medical staff, delivering meals to nursing homes or first responders, or collaborating for searching for new vaccines. This is where the true exponential power of convergence is being found when different objects, technologies, disciplines, companies, industries, or talented people come together (Ip, 2020).
- *For the greater good:* To fight the common enemy in COVID-19, people, companies, health organizations, and innovators are being united. The battle cry is "We are together to defeat the pandemic." The shared goal of people working together on innovative ideas to defeat the virus is for the greater good, a brighter future. It took 15 years to discover Spanish influenza virus (from 1918 to 1933), but it took only few weeks to isolate the Covid-19 virus (Ip, 2020). This is the power of convergence of technologies, people, and organizations all working together for a shared purpose of the greater good.

3.2. Pivoting for the post-pandemic future with CI

When the pandemic shows a marginal decline in its infection rate,

governments need to slowly open the economy. The pandemic has caused enormous economic damages, not to mention people's emotional and social agony. However, it is time to reimagine what is possible if organizations and governments pivot effectively for the post pandemic period. AC (after coronavirus) will not be normal as BC (before coronavirus) as people's and organizations' behaviors have been permanently altered in many ways. We believe the concept of CI will be a big help for the pivoting process as follows.

- *Developing autonomous infrastructure for public health:* Scientific experts have warned that COVID-19 may remain for at least two years even if effective vaccines are found and applied. Thus, to protect from this and future pandemics, a smart infrastructure should be developed to collect data in real-time and support decision making accordingly. This autonomous ecosystem should include the collaboration platform for global as well as domestic information sharing and collective actions.
- *Mobilizing innovation at speed and scale:* Governments, business enterprises, and nonprofits have learned that innovative actions must take place fast and at the appropriate scale. China, India, and South Korea have developed digital ecosystems for virus control through the testing-tracing-isolating process. Such systems have proven effective for containing the spread of the pandemic (Tonby & Woetzel, 2020).
- *Data visioning:* The coronavirus crisis has taught people to rely on and trust data. The White House Coronavirus Task Force presentations have attracted much attention of Americans as renowned scientists discussed the data-driven actions including the efforts to flatten the curve of the number of infected people. Big data analytics will play greater roles in supporting the autonomous innovation ecosystem and collaboration platforms.
- *Flexible and resilient operating systems:* The pandemic caused enormous disruptions on global supply chains for organizations. The vulnerability of operating systems will prompt the development of new nimble operating systems with contingent collaborative relationships as well as reshoring of operations (Bello et al., 2020).
- *Remote or "untact" services:* The pandemic has permanently altered people's behavior in every respect, from hand shaking to learning, exercises, socializing, traveling, and entertainment. Many educational institutions will find online teaching as a major part of their services in the future. Likewise, people would prefer "untact" (no contact) services in hospitality, retailing, and even healthcare areas (Lee & Lee, 2019).
- *High-touch digital transactions:* The pandemic has forced many consumers to switch their purchasing behavior from high-touch personal experience to high-touch digital transactions. This behavioral change is not only for low cost consumer products but also for high-end purchases such as jewelry, art, automobiles, or even real estate. Many digitally challenged senior citizens have learned to use online purchases, thus expanding the customer base for many retail businesses (Bello et al., 2020).
- *Prioritizing life:* The tortuous experience of the pandemic, not only for those who suffered the disease or deeply affected by its mortality but also for ordinary people who experienced social isolation for the first time, have had the chance to reevaluate what is important in life. The outpouring expression of appreciation and support of first responders in hospitals, nursing homes, grocery stores, policemen and firefighters, and many others is the outcome of the feeling that "we are together to defeat the enemy." The importance of doing things for "the greater good" and for the better future is now deeply ingrained in people's heart (Lee & Lim, 2018).

4. Sustainable innovation strategies

Innovation strategies depend on the vision and competence of top management, industry type, composition of stakeholders, and culture

(country, region, religion, etc.). Regardless, every organization has a value chain, a network of functions and activities for value added. To sustain themselves, organizations must continuously innovate to improve their value chains through the various strategies and approaches. Some of the most prominent innovation strategies practiced by organizations and their relationships are as follows:

- **Incremental (evolutionary) and drastic (revolutionary) innovation:** Incremental innovation, also referred to evolutionary or exploitative innovation, attempts to continuously improve current value creating activities. When an organization is confident that its value chain is well designed and functioning properly, the firm's innovation strategy would be focused on the continuous improvement of the current system. Many Japanese firms are well known for Kaizen, JIT, and lean management, all concerned with continuous innovation for existing systems (Lee, 2015). However, while about 70% of innovation projects are this type, they are believed to contribute only about one-third of corporate profits (Stokes, 2006). On the other hand, drastic innovation, often referred to as revolutionary or explorative innovation, is about exploring the unknown to discover fundamentally different ways of creating value (March, 1991). Many US corporations are known for this innovation approach by developing new products/services, reengineering their business processes (BPR), formulating new business models, and transforming the value chain for creating new customer value.
- **Disruptive and non-disruptive innovation:** Disruptive innovation is a rather complex concept. The basic notion is that firms tend to overshoot their markets with applications of new technologies to meet the demand of their mainstream and high-end customers, which opens a window of opportunities for newcomers to attract the low-end customer of the market (Christensen et al., 2015). In the process though, the new market entrants can grow so rapidly that they may eventually overthrow incumbent market leaders (Adner, 2001). There are many such examples, like Honda, Samsung Electronics, Xiaomi, Netflix, etc., which completely disrupted the market. The idea of disruptive innovation so caught the enthusiasm of corporate executives and it became such a greater battle cry of businesses in the digital age that many even began to believe that innovation is synonymous with disruption (Kim & Mauborgne, 2019). However, many innovations that result in completely new products, services, markets, business models, or new solutions do not actually disrupt the existing situation but offer new possibilities. Recently, non-disruptive innovation has been proven to be as important as disruptive innovation with its value creating capabilities. Kim and Mauborgne (2019) suggested Microfinance, Viagra, life coaching, Post-It-Notes, health clubs, and environmental consulting as good examples of non-disruptive innovations. Although non-disruptive innovation may be less painful than disruptive innovation in terms of transition costs, it can cause disruptions to incumbent organizations and the market (Christensen et al., 2015).
- **Ambidexterity in innovation:** From the above discussion of incremental vs. drastic innovation and disruptive vs. non-disruptive innovation, it should be clear that every organization should develop a proper balance between the opposing innovation approaches. Such attempt is ambidexterity in innovation, which strives to reduce tension between the two opposing types (O'Reilly & Tushman, 2013). In the digital age, many organizations pursue agility, flexibility, resilience, and dynamic capabilities through drastic and non-disruptive innovations (Raisch, Birkinshaw, Probst, & Tushman, 2009; Teece, 2014). Simultaneously, organizations should pursue their existing competitive advantage through relatively stable incremental yet disruptive innovations. Thus, managing ambidexterity among opposing approaches of innovation is becoming increasingly important.

- **Convergence innovation:** As discussed already, innovation in the digital age is rarely based on a single creative idea or technology. Instead, it often requires a creative bundling, integration, or fusion of seemingly unrelated things, idea, technologies or strategies to create extraordinary outcomes and possibilities (Baldwin, 2016; Lee & Trimi, 2018). Thus, CI has a wide range of applications throughout the value chain.

Fig. 5 presents an abstract scheme of how different *innovation approaches* are related in the value creating sphere (vertical axis). The horizontal axis shows the main *purpose* of innovation in three broad categories: (1) The least sophisticated step of trying to find new solutions to existing problems; (2) The medium level of sophistication of redefining existing needs or problems and finding solutions; and (3) The highest level of complexity of identifying or creating new needs and finding solutions (Kim & Mauborgne, 2019). Incremental and disruptive innovations tend to focus on searching for new or better solutions to the existing needs or problems. For example, Uber, Airbnb, and Xiaomi's smartphone are new innovations that improved the existing products or needs, becoming possible threats to incumbents in the market. On the other hand, drastic and non-disruptive innovations focus more on identifying new value creating needs or problems and finding possible solutions for them. Some examples are Apple with its smartphone and tablets, which with their drastic innovation created completely new market, without disrupting any incumbent or market.

The ambidexterity approach to innovation aims to find a good balance between two opposing innovation strategies. At the left-end of the figure, where innovation efforts are concentrated on incremental and disruptive approaches, the role of ambidextrous innovation would be relatively limited. Likewise, at the right-end of the figure, where drastic and non-disruptive innovations are dominant, the ambidextrous approach would not be prominent. Thus, the area where ambidextrous approach plays a major role would be around the center part of the innovation continuum where existing needs or problems are re-defined and new solutions are developed by either innovation approach. For CI, it plays significant roles throughout the value creation process, regardless the degree of sophistication involved or the purpose of innovation. In other word, CI with its autonomous ecosystem can generate exponential results whether the primary purpose of innovation is finding better value creating opportunities for well-defined needs (e.g., cash cow products/services), quickly changing needs that require redefinition (e.g., global supply chains), or formulating completely new needs and solutions (e.g., new business models, new customer value, new market, or new vaccines for COVID-19).

5. Conclusion

We live in the digital age where changes are complex, turbulent and massive in scale. The compounding effect of numerous market forces has resulted in the environment of 4IR and digital transformation. To survive and thrive in this new market environment, organizations must be agile with dynamic capabilities. In the face of unexpected crises, such as market gyrations (e.g., economic recessions), political uncertainties (e.g., geopolitics and trade wars), climate change, wars, health issues (e.g., the global pandemic of COVID-19), put organizations to the ultimate test of sustainability. To survive but also flourish in the time of crisis, organizations need to rely on their innovation capabilities. Sustainable innovation has become imperative for enterprises, governments, and nonprofits.

5.1. Impact and contribution of the study

Innovation is often regarded as synonymous with application of sophisticated technologies that disrupts the existing process of value creation. However, as the global community is learning the most important lesson from the current global crisis of coronavirus, innovation is the

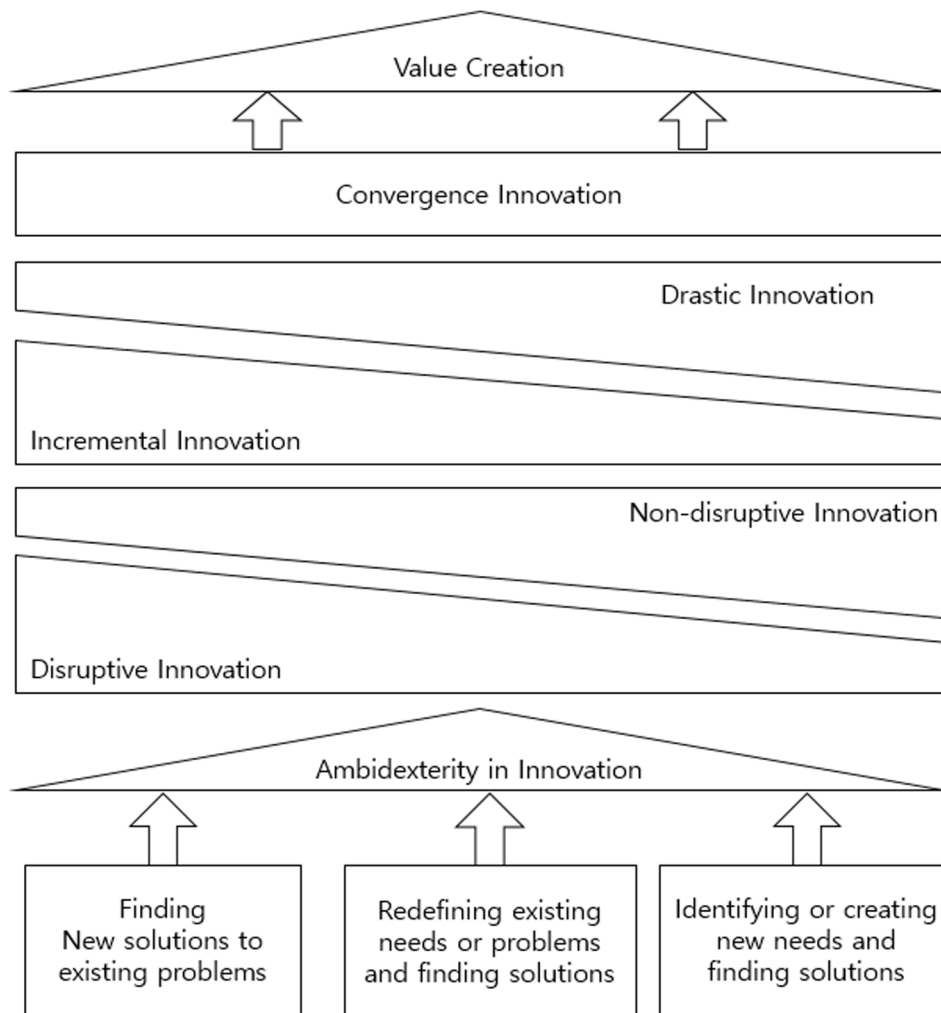


Fig. 5. Strategic innovation approaches.

product of urgency. Many organizations, regardless of their size, purpose, or location, have never seen such sense of urgency and purpose to find solutions to fight the virus and the massive economic and social disruptions that it has brought (Desmond-Hellmann, 2020). Furthermore, innovation, especially in the time of crisis, requires not only collective intelligence to repurpose for shared goals, but also collaborative efforts to converge different ideas with speed and utmost determination (Bello et al., 2020). This paper is very current in this time of crisis in that it presents the concept of CI, a new innovation approach, that converges new ideas and strategies for value creation and beyond, and that with its autonomous ecosystem pulses the changing environment in real-time (with the support of digital technologies) for on-demand decision making. CI supports people, organizations, and other entities do well by doing good. Thus, CI is the new and emerging sustainable innovation approach for organizations in the digital age.

This study contributes to the theory and practice of innovation in several ways. First, we presented how changing giga market force in the 4IR and DT age, especially in this unprecedented time of global pandemic, have made sustainable innovation imperative for organizational success and people's well-being. Second, we review the power of convergence for value creation for people, organizations, governments, and society at large. Economies of convergence, the creative fusion process of objects, technologies, ideas, and strategies can create a quantum force which is much greater than the economies of scale and the economies of network. Third, we present the concept and structure of CI as a self-managing ecosystem for value creation and beyond. The

core of CI is its ecosystem, which is enabled by advanced digital technologies such as AI, IoT, big data analytics, and VR/AR, that enables its sensing capabilities for the dynamics of market forces and transmit critical information for autonomous decision making. We also suggest how the life cycle S-curve of CI is different from the typical innovation life cycle. The S-curve of CI in the digital age tends to be shorter and a new S-curve may start after a series of discontinuous upward movements that are enabled by new technologies. Fourth, we discuss the differences and relationships among the various sustainable innovation strategies for three basic purposes, ranging from finding new solutions to existing problems to redefining existing needs and finding solutions for them to identifying new needs and finding solutions. We believe these new perspectives will contribute to the innovation literature and provide new insights to practicing managers in strategizing in the formulation efforts for sustainable innovation. Another critical contribution of this paper is we articulated the functions and capabilities of CI vis-a-vis the current global fight against the formidable COVID-19 pandemic. We believe this is the first study that relates how convergence innovation can be a key weapon for managing global emergencies such as pandemic crises.

5.2. Limitations and future research

This study has some limitations. First, the conceptual idea and structure of CI we proposed in the paper needs empirical research for its practical applications. However, the development of market forces,

especially the velocity of advances in new technologies, is rapid and complex. In that sense, our study may seem somewhat futuristic. We believe the ultimate purpose of innovation, creating a smart future, requires new approaches that are ahead of time. Second, the topic of sustainable innovation is quite broad and abstract. Consequently, our proposed CI and its relationship with other innovation strategies are also abstract. In today's dynamic environment, however, such abstraction is needed to capture the strategic importance of sustainable innovation for organizations in the digital age. These limitations offer new research opportunities in the future.

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