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Disruptive Innovation:
An Appropriate Innovation Approach for Developing Countries

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Abstract

In the promotion of indigenous technological innovations in developing countries, there has been a natural tendency to focus on the grand, radical innovation approach in their hurry to catch up with developed countries. It has become evident in recent research that radical innovation for new product/market creation has a very high failure rate, and it requires very substantial investment in time, funding and senior management attention for companies or countries to foster this important innovation approach. In this paper, we provide a tutorial review of the above problem and discuss the alternative disruptive innovation approach. We recommend that disruptive innovation should be given due attention as it could have a higher chance of success especially for emerging local enterprises. It is an effective approach for creating new, affordable products/services for the un-served mass markets in developing countries. Companies could subsequently build up-market products using sustaining innovations, either incremental or radical, for local and global markets. Indeed, a more careful analysis has revealed that many large enterprises in the developed countries actually were developed on the back of disruptive innovations during their initial establishments. Five examples from Asia are briefly presented to substantiate the feasibility of creating disruptive innovation in developing countries. The difference between disruptive technology development and that of conventional imitation and adapt approach is then studied. Finally, the positive coupling of disruptive innovation and complementary assets is discussed.

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Introduction

Many developing countries have realized that science and technology development is essential to sustainable economic development (Tidd, Bessant and Pavit, 2005). They will hence invest precious resources to accelerate the development of their universities and national research institutes. As they are also keen to turn the research outcomes into successful products/services, they would either emulate what they could observe/learn by themselves or invite experts from the advanced countries as technology advisors. In both cases, the developing countries would likely be attracted and hence pay special attention to commercialization (through start-ups or technology transfer from universities/research-institutes to their local enterprises) using the breakthrough or radical innovation approach (Abernathy and Clark, 1985; Leifer et.al, 2000; O'Connor and Ayers, 2005; Day, Schoemaker and Gunther, 2000; Finkelstein and Sanford, 2000). It is, however, important to understand that radical innovation based on superior technologies is not necessarily the best or the only feasible approach, although it is indeed an essential and attractive class of technological innovations for achieving high growth.

All successful technological companies need continuous (incremental) innovations to address the ever-changing needs of current customers and achieve continuing growth. But they must be supplemented by periodic infusion of discontinuous innovation. Radical innovation is one major class of discontinuous innovation. There are many different definitions of radical innovation in the literature. In this paper, in order to better differentiate it from other type of innovations, we shall use that proposed by

Leifer et al (2000) which states that it is one with the potential to produce one or more of the following goals :

- an entirely new set of performance features;
- improvements in known performance measures of five times or greater;
- a significant (>30%) reduction in cost (without sacrifice of known performance).

Great companies which last for many decades, such as IBM, GE, Motorola, HP, Siemens, Philips, 3M, United Technologies, General Motors and Dupont, regularly punctuate ongoing incremental innovations with radical innovations.

But attempts at grand, radical innovations, including those at the great companies, have produced more failures than successes (Leifer et al, 2000; O'Connor and Ayers, 2005). One famous example in recent years was the failure of the IRIDIUM satellite communication system inspite of its technological prowess with over 1000 patents (Finkelstein and Sanford, 2000). While there seem to be many examples of small, entrepreneurial firms (particularly from the Silicon Valley in the US) generating radical innovations and taking them to market, the fact is that the majority of them also failed or were eventually acquired by large firms. A recent study has even shown that over the last decade, only a small percentage of Venture-Capital (VC) funded start-ups in the US were in the tier 1 (truly breakthrough discovery) and tier 2 (fundamental technology improvement) innovation categories as the limited-life nature (typically 8 years) of VC funds would discourage investments into long, risky projects in spite of their very high upside potential (Stuck and Weingarten, 2005).

It has become clear that the radical innovation approach for new product/market creation is extremely difficult to implement even in advanced, developed countries like US, Europe and Japan as it requires very significant investment in time, funding and senior management attention. It is thus important for developing countries to understand this inherent nature of radical innovation and proceed selectively with open eyes and caution. In addition, it may be wise for the developing countries to consider introducing/promoting in parallel an alternative approach called disruptive innovation by Harvard Professor Clayton Christensen (Christensen, 1997; Christensen and Rayor, 2003; Christensen et al, 2004). Compared with radical innovation, disruptive innovation has much less technological uncertainties and could create more affordable products for the developing marketplace. Disruptive innovation is less glamorous but may have a much better chance of success. The ability to introduce either radical or disruptive innovation and know when to apply them would provide additional technology options (Boer, 2002)) and enhance a company's dynamic capabilities (Teece, et al, 1997).

The paper is organized as follows. The next section briefly reviews the general characteristics of the radical innovation life cycle which makes the course of this innovation approach so difficult. It is followed by an outline of the disruptive innovation approach. The job-to-be-done market analysis and the potential application of disruptive innovation to capture market opportunities in emerging countries are then discussed. Five examples of disruptive innovation in Asia are briefly presented and analyzed. The paper ends with discussions on how the local owners of complementary assets could also use disruptive innovation to go beyond the imitation and improve

strategy and on other implications for countries or companies which would like to promote the disruptive innovation approach.

The Radical Innovation Approach

Analog Devices Inc. developed a Micro-Electromechanical System (MEMS) accelerometer which would displace the conventional sensor and which could be mass produced at an order-of-magnitude lower cost (Leifer, et al, 2000). When the idea was first mooted in the 80's, its commercial potential was not clear at all but it had the fortunate support of a project champion – Richie Payne who was a research manager and an Analog Devices Fellow. The company's founder and "retired" CEO, Ray Stata also endorsed it, which was critical as the project could then bypass the formal evaluation process which would have stopped its development. A small team started R&D in the MEMS device in 1988. It took 9 years to reach commercialization. At a later stage of development, the project almost failed as it could not find a viable market until a lucky break occurred which brought in Siemens as a strategic partner to develop the air-bag application in automobiles. Even after commercialization, the new operating division experienced negative cash flows for a few years and it needed the faith of its leaders who resisted short-term pressure and pressed on. By end of 1999, over 50% of the air-bag crash sensors used worldwide were produced by this Micromachine Products Division of Analog Devices. The core technology has subsequently found new and tremendous market opportunities in other fields such as optical networks, biomedical devices and games consoles.

The radical innovation example of the MEMS accelerometer demonstrated the typical lengthy, complex and highly uncertain process that IBM's Silicon-Germanium semiconductor technology, Xerox's Docu Tech (print shop in a box), Dupont's Biomax, General Motor's Hybrid car, Texas Instrument's Digital Light Processor and other successful radical innovation cases had to go through (Leifer et al, 2000; William and Morris, 1999). They belong to the most difficult types of radical innovation: either innovation in the "white spaces" between a company's existing businesses (Type II) or innovation outside a company's current strategic context (Type III). They have to deal with large technology and market uncertainties. The least difficult type of radical innovation is one within the market domain of existing business units (Type I) as they have to deal mainly with technology uncertainty only; they are needed to sustain or dominate existing business.

Radical innovations, especially those for new product/market creation, are extremely difficult to manage. Leifer et al. (2000) summarized the complex process characteristics of radical innovation life cycles and contrasted them with those of incremental innovation. Five of these characteristics are shown in Table 1 (Leifer, et al, 2000). A radical innovation usually could take 10 years or more, from concept to commercialization. The trajectory of development is marked by multiple discontinuities and changes occur in response to unanticipated events, outcomes and discoveries. Idea generation and opportunity recognition occur sporadically throughout the life cycle, often in response to discontinuities in the project trajectory. Formal management processes such as those based on stage-gate decision making criteria would have killed most radical innovation projects; the formal process has real value only when the project enters later stages of development. The business model

evolves through discovery-based technical and market learning; the business plan must evolve as uncertainty is reduced. As radical innovation is extremely difficult to manage from start until successful commercialization, the market size must be large enough, for instance more than US$200 million as mentioned in Leifer et al (2000), in order to justify the large investment and sustained effort required. The difficulty and risk here are aggravated by the fact that it is extremely difficult to estimate the ultimate market size in the initial phases of the project. The upside gain is of course tremendous, as those few companies which have succeeded at developing and commercializing radical innovations could dominate the market for a longer period. The radical innovation approach is, however, attractive for all major companies which wish to seek large differentiation periodically through unique, major technological and market breakthroughs.

The Disruptive Innovation Approach

When companies have established a market foothold, they could not remain static. Owing to strong competition, they would need to develop technologies continuously to foster improved product performance. They are known as sustaining technologies as they involve incremental and/or radical innovations to fend off competitions by continuous improvement of the newly established products. For instance, the thin-film heads, the magneto-resistive heads and than the giant magneto-resistive heads are radically new technologies to sustain the lead of incumbent disk-drive companies against other storage companies or start-ups in the data storage industry (Christensen, 1997). Occasionally, disruptive technologies emerge (Christensen, 1997). They result in worse product performance, at least in the near-term, when compared with current

technologies used in the established market. They are hence largely ignored by the incumbents who are either preoccupied in developing sustaining technologies or do not find the new/inferior technology attractive when compared with the up-market business volume and margins. However, such disruptive technologies have other features, such as being cheaper, smaller, simpler to use, etc., which allow them to be used by new entrants at the lower end or in a new, niche market. This is an important characteristics as it clearly differentiates between a disruptive technology from other poor technologies which should not be pursued. Meanwhile, the keen competition in the mainstream, established market could have caused the performance of the sustaining technology to overshoot what the customers could utilize or absorb. Then in a few more years, after the disruptive technology has improved to a stage where its performance could meet the performance of the mainstream market, customers may rapidly switch over to this new technology which they have ignored in the past, hence causing a major “disruption” to the incumbents. This process is illustrated in Figure 1. The classical examples of how the entrants disrupted the incumbents when the 14 inch disk drive product was successively replaced by 8 inch, 5.25 inch and finally by 3.5 inch disk drive products during the 80s and 90s clearly substantiated the disruptive process (Christensen, 1997).

For disruptive technologies to succeed, two conditions must be satisfied. First, there must be performance overshoot in the mainstream market, causing customers to be over-served. This occurs frequently in high-tech products/services as competitors intensify their R&D and try to be the first to introduce new features to satisfy the high-end market needs. Second, incumbents must be attracted to higher-end/higher-margin markets, hence willing to run away when attacked from “below”. For instance,

when personal computers were first introduced, the margin was only 20% on a US$2000 product; they were not attractive to minicomputer vendors who were keener to move to the higher-end minicomputer market where they could enjoy 45% margin on a US$250,000 minicomputer (Christensen, 1997). When the minicomputer giant, Digital Equipment Corp. finally woke up to the serious threat of microcomputers, it was too late to change its well established processes and values which were internalized for sustaining the minicomputers business. The resultant disruption in the marketplace caused the once greatly admired minicomputer giant, Digital Equipment Corp., to collapse rapidly.

Disruption is also a relative term. For instance, the Internet was a disruptive technology to many start-ups which tried to create new applications, but was a sustaining technology to Dell Computers as it helped it to improve its current business operations. In another example, the newly invented transistors had a tremendous promise in the early 50s to replace vacuum tubes. Hence engineers in vacuum tube product manufacturers such as RCA and Westinghouse expended a major effort in improving the transistors in order to be the first to introduce them into their current products of table-top radios, floor-standing TVs, early digital computers, etc. as they viewed transistors as a sustaining, radical technology. They did not succeed as their management could not keep on funding expensive R&D for many years which did not lead to revenue generation through product sales. Sony, on the other hand, applied transistors differently to create the world's first pocket radios which attracted young customers who appreciated the portable, affordable and "good enough" product. It was successful and profitable. Sony then went on to invent portable TVs and developed

other affordable consumer products. It was a disruptive business model enabled by an appropriate transistor technology.

It is appropriate at this juncture to mention that researchers had sometimes confused the practitioners by mixing up the use of the terms radical innovation and disruptive innovation as both are discontinuous and could lead to the toppling of incumbents. But there are important differences. Radical innovation is associated with a superior technology and it launched a direct "attack from the top" when introduced. Disruptive innovation is associated with "an initially inferior" technology and it will execute a gradual "attack from below" when introduced. Radical innovation is also much more difficult as it has to overcome both technological and market uncertainties as shown in Figure 2. There were also potential confusion as both innovations could create new markets. The difference, however, could be quite large as one is based on high performance while the other is based on "good enough" performance for non-consumption. The differentiation could be better appreciated using Figure 3. As scientists/engineers have all along been educated in universities which emphasized the importance of R&D in creating emerging/new technologies which would eventually replace old ones as shown in Figure 4, they have inadvertently developed the "default" inclination in proposing radical innovation. Yet all the examples in Figure 4 were not due to successful radical innovations. They were all examples of disruptive innovations in their initial introductions, with progressive improvement of performance among the disruptive firms themselves and finally becoming good enough to replace the old technologies/products (Christensen, 1997).

Finally, it should be appreciated that the disruptive innovation approach is an effective tool for “new market creation”, irrespective of whether it would result in an eventual disruption in the mainstream market. The new market being created could be very substantial and could represent a new growth business (Utterback and Acee, 2005). This approach is thus highly recommended for both established companies and new start-ups by Christensen who has estimated that the probability of creating a successful, new growth business could be 10 times greater if the innovators pursue a disruptive strategy rather than a sustaining one (Christensen and Raynor, 2003).

Markets For Disruptive Innovations

Disruptive innovation is quite pervasive as some smart entrepreneurs have learnt to exploit disruptive opportunities even long before Christensen discovered and explained it as a systematic, repeatable process. Christensen gave many examples such as minicomputers, microcomputers, PDAs, digital cameras, internet appliances, steel mini-mills, micro-turbines, fuel cells, etc. Indeed, many Asian brand name companies, such as Toyota, Sharp, Sony, Canon, Acer and Taiwan Semiconductor Manufacturing Corp, grew to greatness on the backs of disruptive innovations (Christensen 1997; Christensen and Raynor, 2003).

With suitable technologies which provide unique advantages (such as being cheaper, smaller, smarter, etc), disruptive innovators need to ask the following questions in order to determine what markets are to be addressed initially (Christensen and Raynor, 2003) :

1) Are there customers at the low end of the market who would be happy to purchase a product with less (but good enough) performance if they could get it at a lower price (but still with a reasonable margin for us)?
2) Is there a large population of people who historically have not had the money, equipment, or skill to do things for themselves, and as a result have gone without it altogether or have needed to pay someone with more expertise to do it for them? (i.e. are there non-consumers who could become our customers and hence enable us to create a new market?)
3) For the above types of potential market (low-end and new-market), does our product help our targeted customers get a job done that they have always been trying to get done – but have not yet been able to do in a simple, convenient way? (Christensen (9) has called it the "job-to-be-done" market analysis.)

Indeed, Mr Akio Morita, the co-founding Chairman of Sony was a master of "job-to-be-done" market analysis. Between 1950 to 1982, he and his small core team of managers helped Sony successfully identify and develop 12 different new-market disruptive growth businesses, including transistor pocket radio, portable TV, VCR and Walkman (Christensen, 1997). Once a target market is identified, the appropriate technology might be developed by drastically simplifying sophisticated technologies often available from incremental or radical innovations within the company. As illustrated in Figure 5, the purpose is to incorporate only sufficient and good-enough technological features to create simple, rule-based and more idiot-proof applications. The cost is usually much reduced as a result. Thanks to many entrepreneurs worldwide who are visionary and brave to launch such disruptive products, our modern daily lives have been improved by personal computers, mobile phones, etc.

The rapid economic development of China, India and other Asian countries in recent years has caught the attention of local entrepreneurs and entrepreneurial companies as the developing countries themselves could be huge, growth markets for many technology products. But importing foreign products designed for the developed world to these emerging markets would only reach the upper-middle class consumers as the majority still could not afford them for many years to come. Disruptive innovation offers an alternative and powerful approach to develop affordable products tailored to the specific needs (job-to-be-done) of these mass non-consumers. The following analysis of the telecoms market provides a representative scenario.

In wealthier, developed countries, the teledensity (measured by the number of phone lines or mobile phones per 100 people) increases with per-capita income (measured by Gross Domestic Product (GDP) per-capita adjusted by purchasing power parity). Wealth therefore drives telecoms growth. It is viewed differently in the more forward-looking developing countries as their leaders have started to realize that telecoms could drive wealth creation. Analysis done by the International Telecommunications Union has suggested that every 1% of increase in teledensity could result in an increase of 3% in GDP in the developing countries. These leaders would thus try to accelerate the construction of telecoms infrastructure to connect their countries to the world in order to attract foreign investments, hoping to rapidly create jobs and other economic benefits. The correlation between per-capita income and teledensity is shown in Figure 6 (Ryan, 2004). It can also be seen from the figure that the income levels among countries could be extremely different. While the teledensity reaches near saturation level in the developed countries, it is very much lower in the

developing countries with much lower per-capita income. Hence technologies such as cellular mobile phones designed for the developed countries may not be affordable by the majority of the population in developing countries. The fact is that about 4 billion people, which is 2/3 of the world population still do not have access to a phone of any kind. Yet most efforts by telecoms vendors worldwide have focused on the needs of developed countries and of high-end consumers in the developing countries. The example of a company which thought differently and thus adopted a disruptive innovation approach is given in the next section. The potential mass markets in this so-called "Bottom of the Pyramid (BOP)" has recently caught the attention of academics and the private sector. Multinational companies (Prahalad, 2004; Brown and Hagel, 2005; Ted and Hart, 2004) have indeed started to establish R&D centres in the developing economies to explore the feasibilities and opportunities of products first developed for these BOP markets, instead of relying on the old strategy of firstly exporting products directly from the developed world to serve the top end of the pyramid customers before adapting them for the next level of medium level customers.

One other important observation from Figure 6 is that China is in a very unique position. It is almost right in the middle and it has a huge domestic market which spans from low-ends (poor rural areas) to high-ends (progressive major cities). It can thus launch disruptive innovations targeting the non-consumers in either developing markets or advanced markets as there are local non-consumers of both categories in China. Coupled with its capacities for low-cost manufacturing, China could position itself to be the world's largest source of disruptive innovations in the early part of the 21st century. Similarly, India could soon develop such a potential owing to its size and

rapid advancements in recent years. Multinational companies which have R&D centres in these two countries hence also enjoy this additional advantage.

Examples of Disruptive Innovation in Asia

We shall briefly present five successful cases of disruptive innovation in the following. They have been developed in Asia initially to tap the growth market opportunities in their home countries and have since grown to be successful global companies. They span broad areas, from home appliance, wireless communications to renewable energy.

Galanz (China)

Galanz Enterprise was a Chinese textile and garment manufacturer established in 1978. In 1992, it was seeking a new growth engine (Christensen and Raynor, 2003). Microwave ovens would hardly seem to be a logical choice. A low-end strategy was also not attractive as most of the world's microwave oven manufacturing operations had started to migrate to China. But Galanz decided to try to reach non-consumers domestically (unknowingly adopted a disruptive innovation approach). At that time, only 2% of all Chinese households owned a microwave oven. Most families just did not have kitchens large enough to accommodate microwave ovens built with Western kitchens in mind. Galanz decided to develop a simple, energy-efficient microwave oven that was small and cheap. The product was well received and sales grew steadily, allowing the company to take advantage of economies of scale to reduce the product's price to reach more in the mass market. By 2000, it owned the Chinese market with a 70% market share. With a strong foothold at the low-end market, it

continued its R&D to add features and functionality – first for the high-end Chinese customers and then for established customers in developed countries. By 2005, more than 50% of its products were for international exports under the Galanz brand. In 2000, Galanz began trying to replicate its success by disrupting the home air conditioning industry with a low-end product. Again, it built a simple, affordable, energy-efficient product that was good enough to cool the small homes and apartments in which most Chinese live. To these non-consumers, even a relatively limited product seems like a gift from above. The strategy worked and Galanz has established a foothold in the air conditioning market. It also lost no time to add more advanced R&D capability and export its air conditioners to global markets. Within 4 years, it has become the second largest Chinese air-conditioner exporter. Galanz is fast establishing a global brand name as an innovative home appliance supplier. Its worldwide export of home appliance products which are mainly microwave ovens and air conditioners generated a revenue exceeding US$2 billion in 2007. Its global market share in microwave ovens was more than 40%.

Haier (China)

Summer is traditionally a slack season for the washing machine business in China. Most families just do not use washing machines in summer. The sale of washing machine will sag sharply every summer. But Haier's washing machines have become exceptions. Haier was incorporated in 1984 as a household refrigerator manufacturer (www.haier.com). Over the past 20 years, Haier followed the guidelines of "helping customers solve any problem they confronted", which brought significant prosperity to the company. In 1996, facing the stagnancy of washing machine sales in summer, Haier decided to try to reach non-consumers (adopting a disruptive innovation

approach unconsciously). Haier developed a smaller washing machine with high, medium, low water level that can even wash one underwear or one pair of socks. They named it “mini magical child”. The product adopted “concentric washing” technology, with high-efficiency and low-noise. It had a small cubage, saving water, electricity, weight and space. Once the “mini magical child” was introduced into the market, it sold like hot cakes, and its sale was growing steadily. Its new customers included singles in cities who had to tolerate the accumulation of smelly clothing, due to sweats in summer, for a week to use the normal size washing machine; with the new Haier product, they could wash them every day. Based on the “mini magical child”, Haier developed another product series: XQMB with 12 different wash modes. With little competition in such slack season, the XQMB had sold about 2 million units, and they have been exported to 68 countries in Europe, Africa, America and Asia. With its success in “mini magical child”, Haier continued its R&D to add other features and functions to its washing machine. They include pachyrhizus washing machine, shrimp washing machine, etc. Nowadays, the customers can wash nearly everything with Haier’s washing machines.

Reliance (India)

In the telecommunication business, the Global Systems for Mobile Communications (GSM) has been widely adopted in Europe and elsewhere including Asia mainly for mobile applications. It has very high performance owing to its architecture to handle site-to-site handoffs at vehicular speeds and carrier-to-carrier roaming. But its high cost was not affordable by the large middle/low end mass market in under-developed countries such as India. The Code Division Multiple Access (CDMA) is a simpler, fixed wireless local loop technology which is capable of providing wireless service over

distances up to 20 km from the base station. Reliance Communication, a major player in telecommunication industries in India, took great advantage of this simpler CDMA technology (licensed from USA) to launch “Monsoon Hungama” under Reliance India Mobile. Although it did not have the same roaming capability of GSM, it was sufficient as a limited mobile phone within a city area. It solved the “last mile” connection by helping telecom operators rapidly and economically reach out to new subscribers without the time consuming and costly installation of copper wires to individual households. Started as a dream of Dhirubhai Ambani, the founder of the Reliance Group, to make a phone call cheaper than a postcard, the R&D took three years to produce a new Base Transceiver Station (BTS). On July 1 2003, amidst market uncertainty, Reliance Communication launched “Monsoon Hungama”, a special offer of instant multimedia mobile phone and connection for just Rs 501 (around US$12.7). Owing to its affordable entry pricing, low monthly charges, and strong marketing campaign, it achieved instant success and set a world record for acquiring one million customers in 10 days. Since then, other CDMA service providers have joined the competition which were welcome by customers who could not afford the more expensive GSM service. In 2007, more than 44 million customers in India have benefitted from this affordable CDMA wireless phone service, while Reliance continued to enjoy 57% of CDMA market share (Bai et al, 2007).

Suzlon (India)

India wind power major Suzlon Energy (www.suzlon.com), is flying high on the global demand for renewable energy. Started just 12 years ago, it has become the world’s fifth largest wind turbine manufacturer with a market share of 6 per cent. Suzlon’s founder, Tulsi Tanti, moved into the wind power business by chance. Unhappy with

the erratic power supplies and rising energy costs at his textile mill in Gujarat, India, Tanti set up two windmills in 1990 with turbines imported from a German company – Suedwind. He soon discovered that the windmills indeed provided a reliable source of energy and were much cheaper than conventional energy, the costs of which kept rising. They were also environmentally friendly. Understanding the huge business potential from "getting this unique job done", Tanti exited his textile business and set up Suzlon Energy in 1995 with a modest capital of US$600,000. The strategy of Suzlon has been to capitalize on the low manufacturing cost of India and provide end-to-end customized solutions which are affordable by its Indian industrial clients. When its initial turbine supplier, Suedwind folded due to financial difficulties in 1997, Suzlon took over its manpower to start R&D centres and manufacturing of turbines. Subsequently it also acquired a rotor blades manufacturer in the Netherlands. Its product range includes wind turbine generators in capacities from 350 KW to 2.1 MW and with customized versions suitable for a variety of climate ranging from hot, dry deserts to humid coasts, to near freezing plains. Although Suzlon's products were not suitable for conventional applications in the city areas, they were welcome by customers which had large manufacturing or other operations in rural areas with poor or costly access to conventional power supply and which need high power consumption at affordable cost. Suzlon's business grew steadily in India and eventually captured more than 50% share in the wind power market. While its Indian business continued a steady growth, its overseas sales had seen even greater growth, rising from 8% in 2004 to over 70% in 2006. Orders came from Australia, China, South Korea, Brazil, Italy, Portugal and Spain. Its global revenue in 2007 exceeded US$900 million. It has a bright future as the global wind power market is expected to grow at an annual rate of over 25% for the next five years.

Yadea (China)

Yadea was a young, successful gasoline motor-bike company with design and manufacturing capabilities in 2004 (www.yadea.com). In anticipation of the Chinese government's move to reduce pollution in the urban area by prohibiting gasoline motor-bikes, it had earlier started to design electric motor-bikes to substitute gasoline motor-bikes. It had also started to design electric bicycles for the increasingly affluent Chinese who might be less willing to pedal manually for commuting to work. When the new regulation was implemented in 2004, Yadea immediately launched its electric products aggressively. They won customers quickly as they found the products to be affordable and quiet. The Chinese roads in cities also had bicycle/bike lanes which made them safe to ride. With the rising price of petrol, the running cost of the electric products was comparatively much cheaper (Fairley, 2005). Meanwhile the public transport systems in many Chinese cities, towns and villages are still not good enough and this is a long-term problem for the government to resolve. Business grew at an annual rate of over 100% and Yadea sold more than 500,000 electric bicycles/bikes in 2007. The electric products succeeded inspite of being inferior in conventional measures of power, top-speed, maximum distance per full-charge when compared with conventional gasoline motor-bikes. They were however, cheaper to own and run, while its zero emission overcame the new government regulations. The electric products could satisfy the large market gap between manual bicycles and gasoline motor-bikes. The much lighter and affordable electric bicycles are appealing to ladies and elders who were not customers of gasoline motor-bikes. The young people who want to travel faster and longer distance are attracted to the well designed and fashionable light-weight electric motor-bikes. With such a strong foothold now at the

niche market, the electric products would continue to improve with strong R&D in the power capacity of the brushless dc motor drive, and the ever-advancing technology of the battery (with improved life-time, reduced weight and reduced cost). They could soon disrupt the gasoline motor-bikes for longer-range applications in the rural areas while the improvements are good enough even without the help of government regulations (which do not apply in most rural areas). The emergence of these electric products is potentially disruptive to the conventional gasoline motor-bike suppliers from the advanced countries with large market shares in other developing countries. The successful Chinese manufacturers would start to export their products to seek new markets in other developing countries after the peak demand of the phenomenal growth in the Chinese market is over in a few years time.

Innovation Strategies for Owners of Complementary Assets

The successful commercialization of an innovation requires that the new invention/ knowhow be utilized in conjunction with the services of other assets. Services such as marketing, competitive manufacturing, distribution and after-sales support are always needed. These services are often obtained from companies with specialized complementary assets especially when lower cost and pricing are critical (Teece, 1986; 2000). Owing to the lack of indigenous R&D and the resultant invention/knowhow in the past, many Asian companies, large and small, have developed complementary assets through technology transfer from the multinational companies which either outsource production/manufacturing of components/systems to low-cost but high-quality companies in the developing countries, or partnership to tap local marketing/ distribution resources to rapidly gain market access. Some of these owners of

complementary assets, in more recent years, have also started to use strategies such as imitate, imitate and adapt, and imitate and improve to create new products and processes. When they combine imitation/ improvement with complementary assets, they could succeed in the commercialization of inventions originated from the advanced countries (Teece, 1986; Nieto and Quevedo, 2005; Liu and Buck, 2007).

As disruptive innovation does not involve breakthrough R&D which are costly and highly uncertain as in the case of radical innovation, owners of complementary assets will find it an attractive alternative strategy to create their own products using either the low-end or new-market disruptive innovation approach. Through the job-to-be-done market analysis, potential disruptive innovation products could first be conceived especially for the emerging marketplace in developing or newly developed countries. When coupled with their complementary assets, these companies are well positioned to create rapid and sustainable growth based on successful execution of disruptive innovation. Alternatively, owners of complementary assets could also invest in start-ups which have recognized the market needs and have created the potentially disruptive products. This kind of combination may free the owners of complementary assets to focus on their core competence development while leveraging the creativity and vitality of small innovative companies for new product R&D. As companies using the conventional imitiate and improve strategy still face the potential downside of lower margin for matured products, lack of brand name, need for paying royalties to patent owners, etc (Teece, 1986; Poon and MacPherson, 2005), those which use the disruptive approach would create new products/services resulting in emerging developing economies.

Indeed, all the five successful examples outlined in the previous section either already possessed critical complementary assets, or acquired/developed such complementary assets in their home countries and in the target markets, which went a long way in easing their innovation/commercialization paths. Another opportunity for owners of complementary assets is from the new trend of modular architecture due to vertical disintegration (Christensen, 1997; Brown and Hagel, 2005). When a completely new product is introduced to the market, for instance due to a radical innovation, a proprietary architecture involving extensive interdependence within the hardware/software components has to be employed. With time, the product becomes matured and a dominant design would force the companies to seek new avenues to earn attractive margins. They solve the problem by moving towards a modular architecture which effectively enables the disintegration of the industry. Specialized firms which are suppliers of modular components would emerge. This has given a window of opportunity for owners of complementary assets such as low-cost manufacturing to quickly enhance its R&D capability and design skills to grow their business while improving their margins; with their "good enough" disruptive technologies, they become ODM (original design manufacturers) as the global outsourcing activities of major multinational companies intensify.

Implications and Concluding Remarks

The disruptive innovation approach could be used by both established companies and new start-ups to create new products at the low-end of an established market or in an entirely new market. It could also be applied to create good-enough, affordable products suitable for the under-served people in the developing countries. After

securing a disruptive foothold, companies can then move up-market using sustaining (incremental and/or radical) innovation to serve higher-end customers in local as well as advanced countries worldwide. This innovation approach should be given due attention by all companies which want to achieve sustained growth, including those larger, established companies which are investing heavily in developing radical innovations. A tutorial review of the disruptive innovation approach has been given in this paper and substantiated by five successful examples in Asia. The positive coupling of disruptive innovation with complementary assets has also been discussed.

The usually sophisticated breakthrough type of technologies from universities and research institutes will naturally appeal to start-ups or established companies which search for commercialization opportunities through the radical innovation approach. With suitable simplifications, these technologies might also be adapted and applied in conjunction with the job-to-be-done market analysis to create potentially disruptive products in both developed and developing countries. It should be noted that simplifications and low-ends do not always imply that there are little technical challenges in disruptive innovations. For instance, in the above case of Galanz, it has to date created more than 600 patents protecting its state-of-the-art microwave technologies; it has also developed state-of-the-art manufacturing technologies needed to reduce production cost. The disruptive innovation approach is especially promising for companies which want to capture the opportunities to introduce affordable products which could appeal to the majority of customers in the developing countries. And these markets are huge with eager customers who are currently non-consumers. Christensen et al. (2004) have highly recommended this strategy and

called it “targeting the bottom of bottom” as it could create a strong foothold for future growth with lots of headroom as the countries grow economically.

Disruptive innovation also requires rather different organizational capabilities and management approach compared to the sustaining innovation approach (Christensen, 1997). The resources, processes, and values of an organization well developed for sustaining innovations could become major obstacles in identifying emergent market opportunity, developing a new business model and managing a disruptive business which needs to start small initially owing to market uncertainties. Creating an autonomous unit to develop the disruptive business may thus be necessary for a large, established company. The role of the senior executives would include sensing when a disruptive opportunity is emerging and determining which of the corporate resources and processes to bring to the new business and when to create the autonomous unit if necessary (Christensen and Raynor, 2003). In addition, a company founded on the back of disruptive innovation may lose its capability to start another disruptive innovation when it grows larger and strengthens its capability to compete based on subsequent and necessary sustaining, incremental or radical innovations. Managing the transition to become an established company without losing the pioneering disruptive innovation culture and capability will be a major management challenge. Becoming a serial disruptor should be a long-term goal of companies which want to achieve continuous growth. This will require that the company’s senior management develops the capability in cultivating a dual culture of managing both sustaining and disruptive innovations which will prepare them well to identify opportunities and to pursue them with confidence. For disruptive innovation in the high-tech areas, the R&D engineers who are good at dealing with technical challenges will also need to be

trained in management and other non-technical tasks that confront them as they are essential members in the disruptive innovation team. Educational courses in the management of innovation for engineers are very much lacking in developing countries and this challenge deserves urgent attention.

Radical and disruptive innovations are two important categories of discontinuous innovations. In practice, there exist other successful innovations which could not be classified strictly as radical or disruptive although they are discontinuous. They lie somewhere between radical and disruptive. This is an area worthy of further research as it could create new opportunities for entrepreneurial companies in the developing countries. Universities and public research institutes in developing countries have accumulated intellectual properties from their basic research. How they could be harnessed by the local enterprises through simplification to create potential disruptive technologies and how such contributions should be assessed in terms of licensing fees would need further research to ensure a win-win outcome for both parties. With the new trend of Open Innovation (Chesbrough, 2003), it is also feasible for companies in the developing countries to tap into external sources of knowledge and technology originated from the developed countries.

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	Incremental	Radical
Project time line	Short term – 6 months to 2 years.	Long term – 10 years or more.
Trajectory	Continuous and predictable.	Multiple discontinuities; many starts and stops.
Business Case	Detailed plan.	The business model evolves through discovery-based technical and market learning.
Organizational Structure	Formal team within a business unit.	Project often starts in R&D, migrates into an incubating unit, and transits into a goal-driven project organization.
Resources and Competences	Standard based on past experience.	Creativity and skills in resource and competency acquisition are critical.

Table 1: Some Characteristics of Radical Innovation

Disruptive Technologies
(Performance Overshoot)

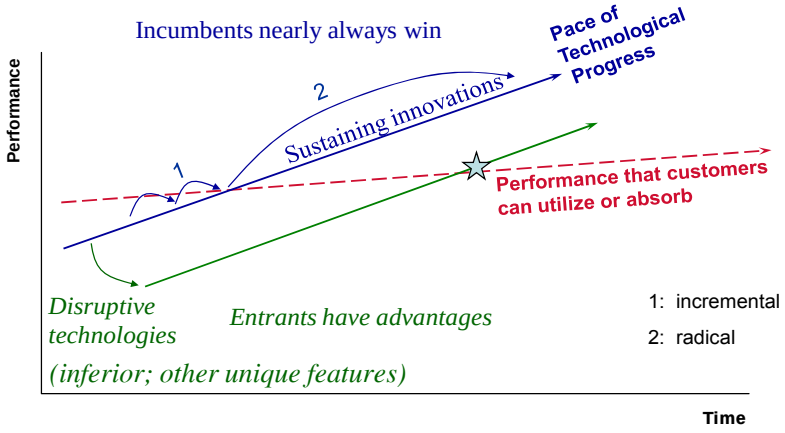


Figure 1: Disruptive Innovation Process

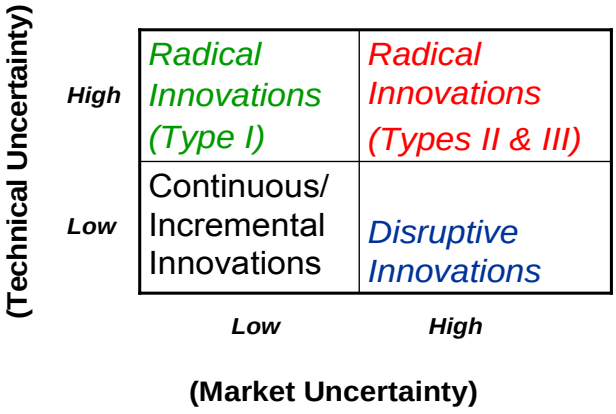


Figure 2: Comparison of Uncertainties

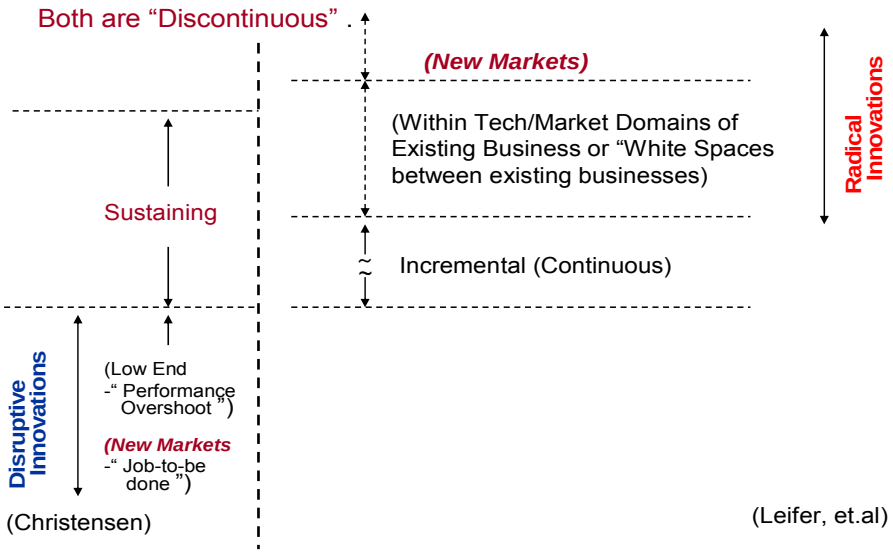


Figure 3: Radical vs Disruptive Innovations

Emerging/New Technology		Old Technology
Transistor		Vacuum Tube
Minicomputer		Mainframe Computer
Personal Computer	replacing ⇒	Minicomputer
3.5 inch Diskdrive		5.25 inch Diskdrive
Digital Camera		Film-based Camera
Flat-panel LCD TV		CRT TV

Figure 4: Technology Advancements Leading to Replacement of Obsolete Technologies

Disruption is facilitated by "Good Enough" technology that makes things more idiot-proof

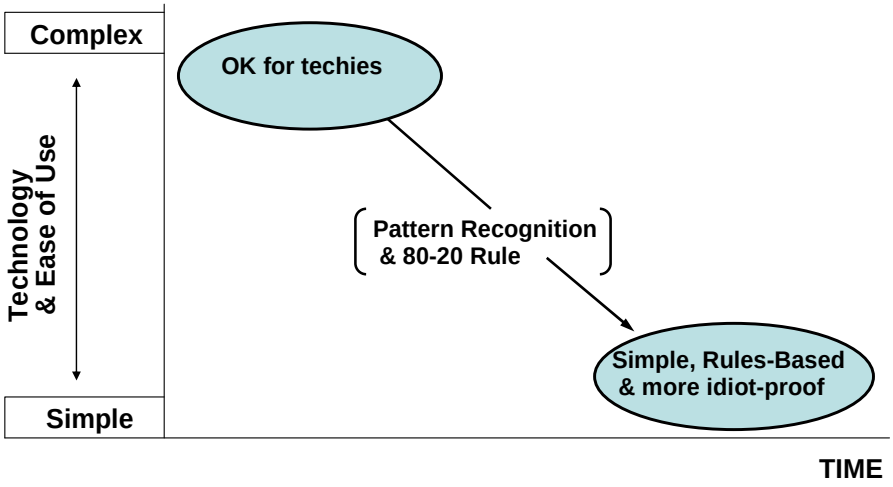
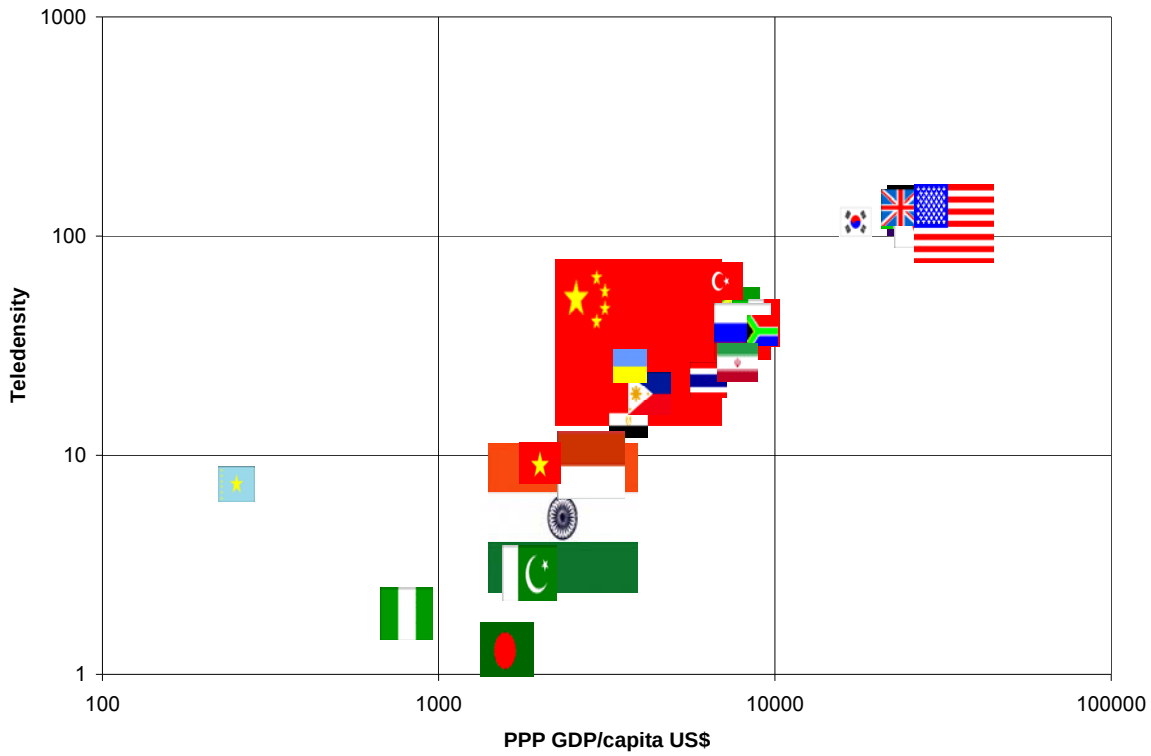


Figure 5: Simplifying the Technology for Disruptive Innovation



Source: RHK Inc. using data from World Bank, ITU, and other sources (used with permission from RHK Inc.)

Figure 6: Correlation between Teledensity and Per-Capita Income

Data use PPP-adjusted GDP data. PPP, or purchasing power parity, relates absolute GDP to local spending power: how much does it cost to buy similar goods?

Whose flag is whose? Bottom left square, from L to R: Republic of Congo, Nigeria; Bottom middle square, from L to R, rising, Bangladesh, Pakistan, India, Vietnam, Indonesia; Middle square, L to R China, Ukraine, Egypt, Philippines, Thailand, Iran, Brazil, Turkey, Russian Federation; South Africa; Mexico; Top right, L to R – South Korea, UK, Germany, France, Japan, Italy, United States. These are all the nations with populations >40M (except Ethiopia and Myanmar … off-scale, lower left)

Teledensity is the number of phone lines plus mobile phones per 100 persons. The relative population of each country is depicted by the size of the flag.