The Impact of Disruptive Technologies

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Summary

The age of disruptive innovation is upon us, with technologies like Artificial Intelligence and 3D printing offering many new opportunities for humanity. However, disruptive innovation also brings its own fair share of challenges for Singapore.

Singapore's SMEs who have historically lagged behind in productivity and growth, now face both increased competition and an increasingly difficult environment. The growing startup scene was also initiated to take full advantage of the opportunities for disruptive innovation, but is still lacking in original, high growth and game changing startups.

Singaporeans, more than half who work for SMEs, will thus face disappearing jobs, compounded by the rapid rise of automation in the workplace. The middle class is especially likely to suffer from skills mismatches, increased job polarization and churning. Unemployment, wage stagnation and the potential hollowing out of the middle class may also challenge our social fabric and disrupt our meritocracy.

Moving beyond current policies, I propose a smorgasbord of policies to redouble our focus on R&D, promote our winning SMEs and consolidate uncompetitive firms. Efforts to encourage startups will have to be refined to produce the high tech, world-changing winners that are vital for growth in the new economy. Education will evolve to create a new generation of Singaporeans who will thrive in the highly competitive and constantly evolving landscape of the future. Retraining policy and social safety nets will also have to be recalibrated to handle increased strain and improve effectiveness.

The path ahead will not be easy. But agile government, well-crafted policies and an open mind-set to the possibilities around will allow us to ride waves and avoid being swallowed by the onrushing tide of change.

297 words
Introduction

Disruptive Innovation, from Artificial Intelligence to 3D Printing\(^1\) and the Internet of Things\(^2\) will lead to many opportunities for growth and progress in the future. However, it also brings its own set of challenges. The combination of intense competition, a rapidly changing business landscape, and the evolving nature of work will significantly challenge Singapore’s economic foundations. Addressing these challenges will require major shifts in policy.

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\(^1\) 3D Printers use a range of laser-based or advanced printing techniques to build up models layer by layer and have a number of compelling advantages over traditional manufacturing techniques. They are able to build models of mind-boggling geometrical complexity from scratch, waste far less material, and offer unprecedented flexibility in manufacturing (Cummings, 2010).

\(^2\) The Internet of Things (IoT) has been defined as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies (International Telecommunication Union, 2015).
The evolving landscape of competition

MNC Domination

In this new era of disruptive innovation, companies driven by innovation, technology and skills will be able to dominate the economy, developing products and services that will become increasingly important to the functioning of the economy and other products.

Given the wide applicability of technology, technological expertise in one highly applicable domain will allow firms to develop products in multiple markets. This will become de rigueur in the future, with powerful, particularly technological, MNCs dominating the marketplace with their economies of scale, expertise and intellectual property. Singapore will be no exception to this.

Tough times ahead for our SMEs

Singapore always had a competitive export oriented sector dominated by foreign companies and a less competitive domestically oriented sector comprised mainly of smaller local companies (Auyong, 2014). SMEs employ the majority of our workforce, but have historically faced lagging productivity compared to MNCs. (Tan, 2014) indicated that Singapore’s indigenous GDP has dropped significantly over the past decade, from 72% to 57%, indicating that the more productive export-oriented MNCs have continually managed to outgrow and outcompete the domestic sector.

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3 Google, for example, not only dominated its original search engine market with powerful algorithms, but also moved across to non-adjacent ones, like mobile payments and developed new markets like self-driving cars using that same expertise.

4 (Tan, 2014) remarked that “modest productivity growth appears to be far more serious for small and medium enterprises (SMEs) than multinational corporations (MNCs) which compete effectively in international markets and tend to be much more efficient and well organized.”

5 Percentage of GDP accruing to resident citizens and PRs and local companies
Singaporean SMEs also face difficulty in attracting labour, as opposed to their MNC brethren. This may be due to 83% of Singaporeans preferring to work for MNCs, in contrast to an average of 55% globally (Randstad Workmonitor, 2017). SMEs rely heavily upon foreign workers, and have had trouble in adjusting to the recent tightening of foreign worker regulations. In the longer term, the rapid development of their own countries combined with Singapore’s domestic politics may continue to reduce foreign worker inflows.

Industrial companies also face the erosion of barriers to entry. The rise of 3D printing will allow the easier production of customized goods, emboldening foreign companies and startups. On the other hand, productivity increases through the usage of other high-potential technologies like machine learning and data analysis depend heavily on intellectual expertise and economies of scale, confining their usage to MNCs or the rare startup with deep pools of talent. In the future, SMEs will continue to be squeezed by MNCs offering greater career advancement, prestige and pay, and the new startups who offer equity as a path to wealth in attracting talent, exacerbating the talent gap. Increased MNC presence may also increase competition for resources, further hamstrunging SMEs. Furthermore, not only are our SMEs absent from the fast growing and productivity high-tech sector (INSEAD & Altair, 2010), they also face difficulty in adjusting to technological change, perhaps owing to low awareness, a dearth of expertise and worries about cost.

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6 (Roffey Park, 2015) identified that of 401 Singaporean SMEs identified that four-fifths find it hard to attract suitable employees at least some of the time, and identified that a lack of skilled labour was a particular problem for them.

7 With reference to the 2017 Budget, The Singapore Business Federation (SBF) argued that the deferment of foreign worker levies by one year for only the marine and process sectors should have been extended across other sectors which are also experiencing cost challenges (The Straits Times, 2017).

8 Singaporean SMEs face difficulty in attracting younger employees, let alone talent (Singapore Business Federation, 2017)

9 Less than half (39%) of all businesses in Singapore claim to have embarked on any form of technological change or adaptation in 2016, despite technological disruption being a major economic force. (Singapore Business Federation, 2016)
Singapore’s SMEs thus face a perfect storm of increased costs, more competition and productivity problems in the near future. Troubled and stagnating SMEs may thus present a potentially severe dragging force on economic growth, considering that they currently contribute to half of GDP (The Business Times, 2016).

**Singapore’s startup scene: Increasing quantity, decreasing quality?**

Perhaps to develop another pillar of economic growth and take advantage of disruptive innovation, Singapore devoted significant government support to Singapore’s startup scene. This appears to have borne results, with the number of startups doubling since 2004, and the number in high-technology sectors increasing by 70% from 2003 to 4,800 in 2015 (Committee on the Future Economy, 2017).

However, governmental support may have contributed to inefficient and distorted growth. A two-year study by the National Research Foundation revealed that 24% of the Singaporean startups have yet to achieve revenue, while 29% of them are still cashflow negative despite generating revenue (National Research Foundation, 2017). Moreover, just 8 per cent of the tech startups were high-growth “gazelles”, with average annual sales of S$4m ($2.9m). And even out of these companies, many were copying successful ideas from elsewhere rather than pursuing innovation — less than one-third of “gazelles” were introducing new products, the researchers found (Financial Times, 2017). Therefore, it is clear that the startup scene in Singapore has yet to fully mature as a pillar of the economy.
Employment

The changing nature of work

With SMEs employing 70% of the local workforce (Government of Singapore, 2017), difficulties for SMEs will soon bleed into the workforce. While it is possible that Singaporeans will move to successful MNCs or startups, technological disruption and automation mean that the types of jobs that remain are unlikely to be the same. (Frey & Osborne, 2013) calculated that 47% of jobs are currently at high risk of being automated, including accountancy, legal writing, technical writing and a lot of other white-collar occupations. Although many of these will not be fully automated, occupations will still see significant shifts in the nature of tasks (Autor D. , 2015).

And even if our SMEs manage to adapt and compete, they will do so via the aforementioned embracement of technology and automation, contributing to the rapidly changing nature of work.

An expanding skills gap

However, if automation does continue, it will no longer be about automating low and high skilled tasks as in the past, but about automating routine tasks (Autor D. and Dorn, 2013). In short, nonroutine tasks in which workers hold a comparative advantage over AI are likely to remain: interpersonal interaction, dexterity, adaptability, and problem solving (Autor D. , 2015). Furthermore, the need to manage and deploy AI effectively will also alter and create jobs that require synergy between AI and skilled workers (The Executive Office of the President, 2016)
Yet, these possibilities are dimmed by Singapore’s current skills mismatch, especially amongst graduates.¹⁰ Future changes in tasks due to automation will exacerbate the mismatch, contributing to unemployment.

Finding similar paying jobs may prove to be difficult for PMETs, as the skilled and middle income jobs resistant to automation may require long periods of study and difficult technical education.¹¹ IT, despite great potential, suffers from an extreme skills gap due to a dearth of technical education and outdated curriculum.¹² Singapore’s older cohort of workers¹³ and the ageing population (Wong Kai Wen, 2013) will also inhibit retraining efforts.

In contrast, low-skilled and easily picked up tasks like flipping burgers are also resistant to automation (Autor D. H., 2014).¹⁴ Therefore, much of Singapore’s PMET middle class may be forced down the skill level, exacerbating income inequality and causing social unrest.

¹⁰ (Monetary Authority of Singapore, 2016) noted that PMETs accounted for more than two-thirds of the residents laid off in H1 2016, larger than their share in the workforce. Furthermore, while half of the job openings in H1 were targeted at PMETs (professionals, managers, executives and technicians), only 39.6% of resident PMETs made redundant re-entered the workforce within six months, which is lower than for resident clerical, sales & service workers (57.1%), and production & transport operators, cleaners & labourers (58.2%). This may indicate a significant skills mismatch, particularly among PMETs, implying a lack of transferable skills.

¹¹ Medical consulting, occupational therapy, and (effective)programming are a few examples of difficult areas to reach.

¹² According to the Infocomm Development Authority (IDA), 30000 specialists may be required as fields such as cyber security, data analytics and application development clamour for more professionals by 2017. The government is currently attempting to churn our more graduates an update their curriculum (The Straits Times, 2016).

¹³ (Manu, et al., 2012) noted that education levels in our [Singaporean] older cohorts are generally low, with only around 14% of individuals in their 50s having benefited from tertiary education. Furthermore, as a large proportion as women among the older generation have limited work experience, as suggested by the low labour force participation rate in Singapore for women in the 50-60-year-old cohort as compared to other OECD countries. All of this suggests that a significant share of the older population has struggled to benefit from recent technological changes.

¹⁴ According to Polanyi’s Paradox many of the tasks we perform rely on tacit, intuitive knowledge that is difficult to codify and automate. Think of how difficult it is to cook without recipes, much less program a robot to do so!
With future technological changes mobilizing highly skilled workers with more differentiated hierarchies, we may also face an increasingly “winner takes all economy”, employing less people and paying superstars more (Frank, 2007). This will also privilege the high income, who are resistant to both retraining and automation, considering that many of their jobs require immense education, high cognitive levels, and creativity.

The impact downstream

Finding jobs after unemployment has been linked to lower wages, especially for experienced individuals, perhaps owing to skill deterioration and an evolving workplace. With automation replacing many older roles and increasing the skills mismatch, workers will be paid less and stay unemployed for longer. Moreover, long term unemployment in an ageing population will have severe effects for our population’s health, wellbeing and healthcare costs.

Singapore has always placed importance on high social mobility (The Straits Times, 2015). The hollowing out of middle class jobs will reduce the middle rungs of the job progression ladder, inhibiting occupational mobility. In the long run, this means reduced educational opportunities for children in low income families, contributing to socio-economic stratification.

15 (Garciano & Hubbard, 2007) found that the hierarchical leveraging of knowledge based skills increased productivity (making it desirable for firms), and also increased income inequality in lawyers, increasing the income ratio between the 95th and 50th percentiles from 3.7 to 4.8. It is possible that increased levels of technology will promote such hierarchical leveraging, further increasing income inequality intra firm or industry.

16 Interestingly, Polanyi’s Paradox may also apply here. For example, it’s nigh impossible for an AI to argue in court, create new startup ideas, or even design a bridge.

17 (The Executive Office of the President , 2016) reported that experienced (U.S.A) workers who lose their jobs and have to start over find themselves, on average, earning wages at least 10 percent less than what they earned in the jobs they lost, and workers with more than 20 years of experience in their prior job face wages that are nearly a quarter less than they had previously been making.

18 Men who faced unemployment over five years were twice as likely to die during the following 5.5 years as men who remained continuously employed. (Morris, Cook, & Shaper, 1994)

19 The Ministry of Trade and Industry noted that it will also be harder for the young entering the job market as they face a broken job ladder, impinging social mobility. (Ministry of Trade and Industry, 2014)
Supporting Singaporean companies and productivity

Avenues for improving the SME environment

(Lai, 2014) showed that in Singapore, intra-sector differences in productivity are larger than inter-sector differences, implying that it is the individual nature of companies that has greater influence over productivity compared to industry-specific conditions. She also suggested that the government should “help the strong, not the weak.”, recommending the usage of lump sum payments to encourage the consolidation and acquisition of firms under more productive management. To augment this proposal, Skillsfuture credit and career counselling services could be added onto the cash incentive for the sellers20, creating better career support for equity owners selling their businesses.

Singapore also needs to do more to enhance the information available to SMEs in the legal, technological and productivity fields. (Boston Consulting Group, 2013) also noted that the majority of SMEs had data privacy concerns in adopting technology and data analytics, and that SME laggards would be willing to invest more in IT if they were better advised on how to do so. Government agencies like the Infocomm Development Authority of Singapore (IDA) could open up software and technical expertise for SMEs to ‘try out’ methods of improving productivity, like what A*STAR already does for hardware21.

The SBF National Business Survey 2016/17 noted that 78% of SMEs are keen to venture into ASEAN, but are unaware of the opportunities brought by FTAs, and face difficulty in achieving compliance and productivity (Singapore Business Federation, 2021). The monetary incentive should be tied to the size of the acquisition, to avoid abuse. Further incentives/subsidies could be given depending on the nature of the acquisition itself, such as the layoffs (If any), plans for retraining, product redesign or strategy, to encourage the productive use of acquisitions.

20 The monetary incentive should be tied to the size of the acquisition, to avoid abuse. Further incentives/subsidies could be given depending on the nature of the acquisition itself, such as the layoffs (If any), plans for retraining, product redesign or strategy, to encourage the productive use of acquisitions.
21 https://www.a-star.edu.sg/Collaborate/Programmes-for-SMEs/Overview.aspx
IE Singapore and SPRING will have to enhance their efforts in reaching out to small businesses to achieve greater understanding and give more advice.

**Refining and expanding startup support**

Professor Wong Poh Kam, who led the two-year study by the National Research Foundation, noted that “we are not investing enough in high-growing, high-risk types of startups. Rather, we tend to be investing in slow-growing, barely profitable startups”. (Today Online, 2017) In addition, he also noted that Singapore’s copy of Israel’s co-funding scheme was less stringent, especially in requiring investment into deep technology, resulting in lower quality and higher inefficiency (Financial Times, 2017). The same survey also pointed out that venture firms may not have the risk profile, expertise and understanding of deep technology, and instead be drawn to copycat models and service-based companies with shorter runways (National Research Foundation, 2017).

The public sector must take the lead here, by strengthening criteria to focus on potential game-changing technologies, and avoid the creation of unproductive “zombie firms”. Criteria should be reoriented to focus on research-based startups deploying new technology and models, as well as those who have alpha prototypes upon founding, to ensure product viability pre-funding.

Deep technology in its early life cycle could be supported by allocating funds for technical and commercial beta testing and allocating resources like servers to support the running of prototypes. For research based projects, encouraging connections between experts and startup founders in the relevant technical fields may also prove useful.

A few studies also show some intriguing correlations between a few leading indicators and startup success, which could be used for strengthening criteria. A study by
Startup Genome revealed that of startups who have pivoted once or twice (3.6x better user growth than those who have pivoted more than twice or not at all) and having mixed teams of technical and business focused founders (2.9x User Growth) are all significant leading indicator of growth (Startup Genome, 2011).

Partnerships between startups and SMEs for productivity innovations should be encouraged. The startup would benefit from testing and refining their products, while the SMEs, as “Beta Testers”, will have opportunities to try out new innovations.22 IE Singapore could also broker multiparty overseas projects between Singaporean SMEs and startups, who may be able to enhance each other’s competitive edge and increase growth opportunities. Public sector initiatives, particularly involving the ‘Smart Nation’ pilot projects, could also be outsourced to technical startups to give them opportunities to develop their products.

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22 The public sector could try to subsidise some of the cost of introducing innovation, but must be careful to ensure that real productivity/effective transformation is caused by the product. Empty platitudes of innovation must be avoided, for we the run the risk of a huge money sink.
Promoting R&D and productivity on a broader scale

R&D driven by companies, particularly MNCs, is vital to innovation and growth for both the firm and the nation (Kogan, Papanikolaou, Seru, & Stoffman, 2012). The Global Innovation Index (Cornell University; INSEAD; WIPO, 2016) noted that Singapore’s R&D expenditure is primarily government backed, and that Singaporean SMEs were severely lacking in this area. A*STAR and other research organisations should enhance support for public-private partnerships in applied research and innovation, especially in critical industry clusters, with the end goal of creating independent organic R&D in SMEs.

The rapidly digitising workplace means that flexitime and other work arrangements may be an increasingly viable alternative to in-office hours. (Comfort, Johnson, & Wallace, 2003) showed that flexitime was related to increased job satisfaction, increased satisfaction with pay and benefits, reduction in paid sick days, and higher participation rates in work-related training. Dispensing such benefits may thus allow for increased productivity and fertility,23 as well as promoting a stronger company culture.

23 (Castles, 2003) proved that there was a significant link between flexible work arrangements, parental benefits and fertility.
A new generation of Singaporeans for a new economy

Singapore has built its success on having a skilled workforce able to meet economic demand. In this rapidly changing environment, we need a new generation of Singaporeans; skilled enough to move ahead of competition, self-directed enough to stay ahead, and entrepreneurial enough to forge his or her own path.

Creating pertinent skills

Jobs that rely on skills involving Creativity, Dexterity and Interpersonal relations will still be largely dominated by humans (Bernstein, Raman, Brynjolfsson, & McAfee, 2015). As such, a shift in focus to soft skills like emotional intelligence, creativity and interpersonal skills at the secondary and primary school level may allow the staving off of unemployment.

While Singapore has placed a great deal of resources on its technical institutes, there is still a significant gap in salary\(^2\), where university is viewed as the apex of an education, resulting in many polytechnic students going on to university (The Straits Times, 2016).

(Ho, 2014) suggested that the leaving age of polytechnics and ITEs be amended to the same time as universities, with more time for increased rigour and longer term internships. Longer term internships may also increase the skill level and modernization efforts of firms, helping productivity. A compromise between this proposal and the status quo may be to extend the period for diplomas in critical STEM fields and others resistant

\(^2\) In Singapore, the median starting salary for graduates with a four-year electrical engineering degree was S$3,135 ($2,370) in 2013, compared with S$1,750 for those who studied the same subject at a technical institute (Bloomberg, 2015).
to automation, allowing the students to benefit from increased academic rigour and experience to enable a higher starting salary and better productivity.

At the same time, Singapore’s new focus on developing programming and coding skills from young is being tested (The Straits Times, 2016). However, finding skilled IT professionals to teach may be difficult, especially given Singapore’s IT skills gap. Moreover, teaching programming necessitates constant revisions, with the rapidly evolving landscape and even the possibility of algorithms coding themselves (Wired, 2016).

**Encouraging Self-Learning**

To free up resources for soft skill development while ensuring technical competency, I propose re-orienting our educational paradigm around self-learning. Students should be taught how to learn by themselves and become Creators, not Consumers of information. Doing so will allow students to better adapt to careers centred around nonroutine tasks, adjust to an ever-changing landscape, and develop specialized competencies.

Subjects that can be self-taught effectively should have time apportioned for online learning via Massive Open Online Courses (MOOCs). Tests can be slowly replaced by student-initiated research, prototypes, and creative works. The school year could be

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25 The health sciences, for example, will continue to be in demand, with phlebotomists, nurse technicians and radiologists benefiting from technology augmenting, not substituting their jobs.

26 According to the Infocomm Development Authority (IDA), 30000 specialists may be required as fields such as cyber security, data analytics and application development clamour for more professionals by 2017, (The Straits Times, 2016)

27 Considering the wide and ever-changing variety of languages, requirements and possibilities, programming is generally highly amenable to self-learning. In fact, it is considered necessary for programmers to self-learn.

28 Interpersonal skills, public speaking, emotional intelligence, as well as physical experiments should stay in the classroom, of course.
amended to have a month sectioned out for uncontrolled online learning beyond the curriculum, for students to create prototypes, engage in deep research and experiments.\textsuperscript{29} 

Moreover, a core program based around meta-learning, “learning how to learn”, interpersonal and emotional skills, combined with a renewed focus on career and pathway counselling will take full advantage of the rise in MOOCs and allow students to self-direct and self-learn more effectively.

**Promoting creativity and entrepreneurship**

This change in worldview would allow for reductions in the time teachers spend on assessment, content delivery and administrative work. Reducing that load may allow MOE (Ministry of Education) to pay more and demand higher quality from teachers. We can also do more to promote risk-taking, reduced rigidity and less hierarchy, by encouraging teachers to be motivators, mentors and explorers who challenge their students to learn and solve novel problems autonomously or explore new approaches together. Israel, who originally took this approach in teaching their soldiers, has seen great success from these students in computer science and entrepreneurship (Israel21c, 2017).

Students may also benefit from enhanced diversity in the choice of examinable subjects and research taking up a greater proportion of grades as opposed to test-based assessment. Students should be encouraged to pursue difficult and challenging projects/research and pursue more partnerships with tertiary education, through encouraging students to work with college research in areas of interest.

\textsuperscript{29} Whether such things should form part of their grades or not is debatable. Considering the need to develop and intrinsic desire for learning, I would suggest not doing so. Perhaps peer-sharing could be a requirement, to create peer-pressure, as well as distribute knowledge.
On a tertiary level, overseas exchange programs could be augmented by apportioning of some time for internships in foreign firms. Doing so may improve the diversity of experiences and encourage the importation of entrepreneurial practices and attitudes.

**Encouraging retraining and upgrading**

However, educational reforms will take time, so it is also important to ensure that the current workforce continues to engage in skills upgrading, to avoid stagnating salaries and unemployment. While initiatives like Skillsfuture have created opportunities for improvement, the link between skills upgrading to increased income needs to be strengthened.

Consulting firms about the various professional certifications that Skillsfuture provides may increase their usage as screening criteria, increasing the link between skills development and income. If possible, developing roadmaps for certain careers and associating them with various courses like what the SAF(Singapore Armed Forces) does will enhance the willingness to reskill among workers.30 Further career counselling, increased information about differing careers, and feedback from industry members should be made publicly available to improve decision making.31

30 Certain careers, especially those requiring specific engineering and technical skillsets would be amenable to such road mapping.
31 See 80,000 hours, a non-profit organisation for a detailed example of career information. URL: https://80000hours.org
Recalibrating Singapore’s social safety net

To alleviate the opportunity cost of not earning while retraining, the low income and recently unemployed could be given an increased stipend or reimbursement, during retraining periods. It may also be important to link firms and jobs with specific courses. For example, the public sector could enhance matching the unemployed to jobs through the promotion of certain identified courses.\(^{32}\)

More psychological and counselling support could also be given for the unemployed and their families. Doing so will not only help ease the inevitable tension and stress, but also help families cope with the renewed financial burden while reskilling and upgrading in the process of finding new careers.

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\(^{32}\) If unemployed person X wants to join a firm, but doesn’t have the skills required, he/she can be interviewed and then sent for the relevant course co-sponsored by the public sector, perhaps contingent upon a bond to the firm once he/she is employed, perhaps like a mini-scholarship. Of course, this presumes that the person is only lacking that particular necessary skill, and that the course is sufficient for actual on-job competency.
Conclusion

Disruptive innovation and its technologies hold great potential for Singapore, but will also bring its own fair share of challenges. Most critically, the wave of innovation may hollow out Singapore’s core of SMEs and PMETs, greatly damaging our social fabric.

The public and private sectors must embrace new methods of thinking, overturn old paradigms and actively experiment in order to meet the onrushing tide. Embracing change will be the only way to successfully navigate the tumultuous waters ahead.

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