National Trades Union Congress

FUTURE OF MANUFACTURING: CRAFTING SKILLS SECURITY AND MASTERING UNCERTAINTY

Research Partnership between National Trades Union Congress (NTUC), NTUC LearningHub and the Lee Kuan Yew Centre for Innovative Cities, Singapore University of Technology and Design

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National Trades Union Congress (NTUC), NTUC LearningHub and
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CONTENT

Executive Summary

Heart of our Research

We cannot give workers job guarantees.
But we must give workers Skills Security.
Skills Security is a term we coined from our research insights. We define Skills Security at the interaction and intersection of two levels:

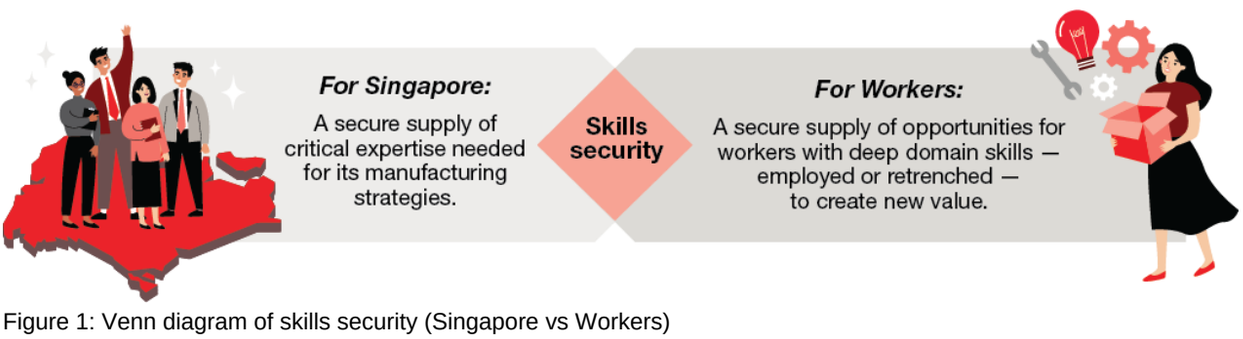


Figure 1: Venn diagram of skills security (Singapore vs Workers)

Because if we ensure this supply, we secure the stock of skills that Singapore needs for its manufacturing sector to automate, digitalise, transform, compete, and excel. But skills security—as we have defined it—is hardly discussed, much less practised. It stands in stark contrast to what we do for supply chain security. Where for example, because the pandemic showed us how fragile just-in-time supply chains are, we now practise just-in-case too. Making sure workers and Singapore secure skills with the same systems-thinking as we secure supplies, is at the heart of our research.

Report Flow and Structure and Recommendations

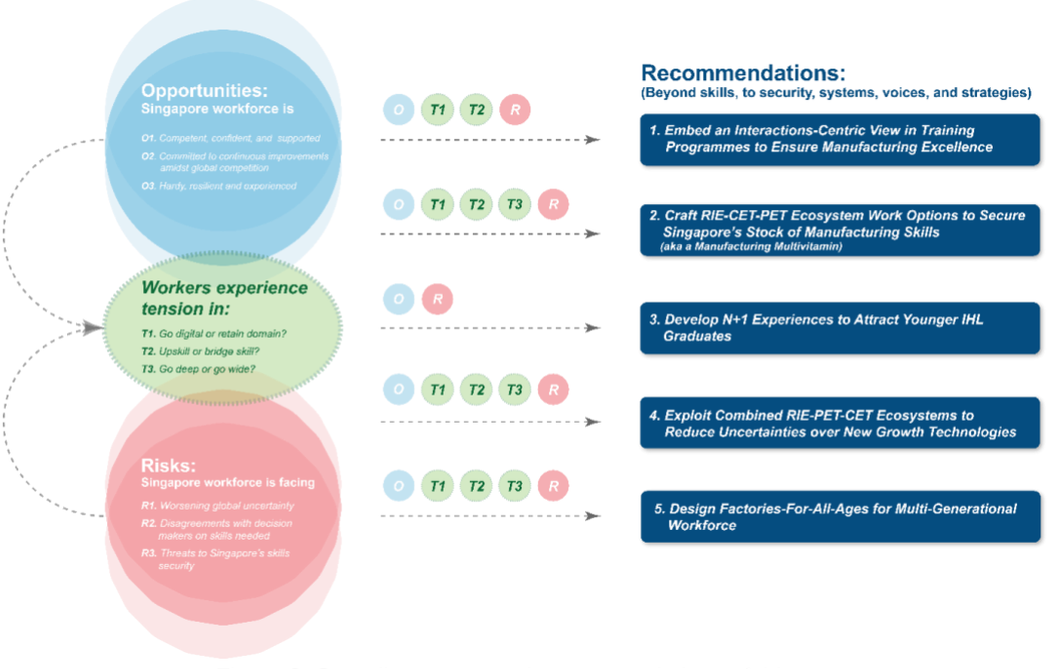


Figure 2: Overall structure and recommendations of this report

Chapter 1: Background

This Future of Manufacturing study arose from NTUC senior leadership's determination to better engage workers as Singapore's manufacturing faces renewed strengths and threats in a changing post-pandemic world.

The research builds on the SUTD LKYCIC's research on Mastery in the Digital Age in the manufacturing sector. The fieldwork involved 250 hours of observations and 60 interviews/focus groups on how workers work, interact, and innovate. The combined ground experience of these workers was close to 800 years. One aim of the current study was to see how insights from the Distributed Mastery Model (Appendix D), one of the main findings of that study, could be extrapolated to inform the future of manufacturing. In this study, we augment this deep fieldwork with 11 targeted interviews, a focus group with about 18 participants, and two surveys with 600 manufacturing workers as well as 1000 workers from other industries in total.

Depth and Breadth

The additional fieldwork covers a spectrum of manufacturing industries but uses Additive Manufacturing (AM) and Energy & Chemical (E&C) to bookend the industries in advanced manufacturing. This is because they represent the extremes of scale, whether they are emerging or established, and whether they emphasise innovation or incremental improvements (see Figure 3). All other industries fall in between these extremes.

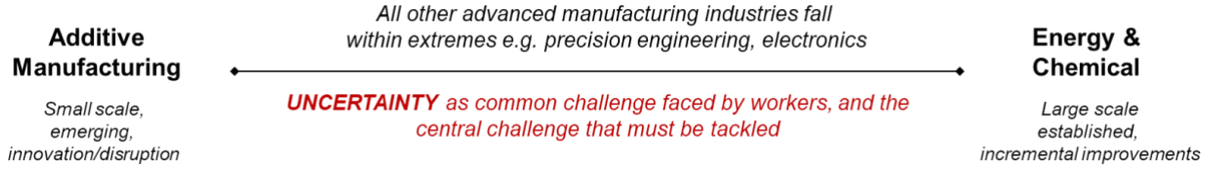
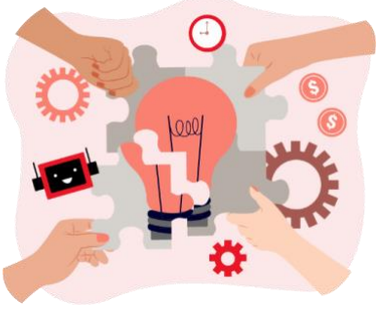


Figure 3: Spectrum of Engineering Industries (AM–E&C)

Coupled with our earlier and existing research, our insights are thus drawn from AM, E&C, Precision Engineering (covering contract manufacturing, and robotics innovation), and Electronics (e.g., semiconductors).

Together, they give depth and breadth to our insights.



Chapter 2: Manufacturing in Singapore — Much to Be Optimistic for, Many Risks to Be Managed

In this section we explore the current opportunities and risks surrounding the manufacturing sector in Singapore, with an emphasis on its workforce. We do this from multiple angles: workers' voices, national strategies, industry trends, past and present continuities, and global economics and politics. We find there is much to be optimistic about in the opportunities ahead, but also many risks that need to be managed. For workers, navigating these opportunities and risks requires resolving three tensions. We summarise these in the figure below, and describe them in detail in the following pages:

Figure 4: Workers encounter many opportunities and risks in the Singapore manufacturing sector today, leading into tensions that need to be resolved

Opportunity #1: The Singapore Workforce is Competent and Confident, and Supported by Singapore's Commitment to Grow the Manufacturing Sector and Prepare Its Workforce

The Singapore manufacturing workforce is competent and confident. As part of this project, we asked workers in a survey whether they think they have the skills needed for the next 2-3 years in the industry (see Figure 5). A majority of 76% were at least moderately confident (i.e., they answered "very much", "quite", and "moderate"), with only 24% responding that they believe they don't or only slightly have the skills necessary. What this indicates is that the wider manufacturing workforce still feels confident with their skills, at least for the near future.

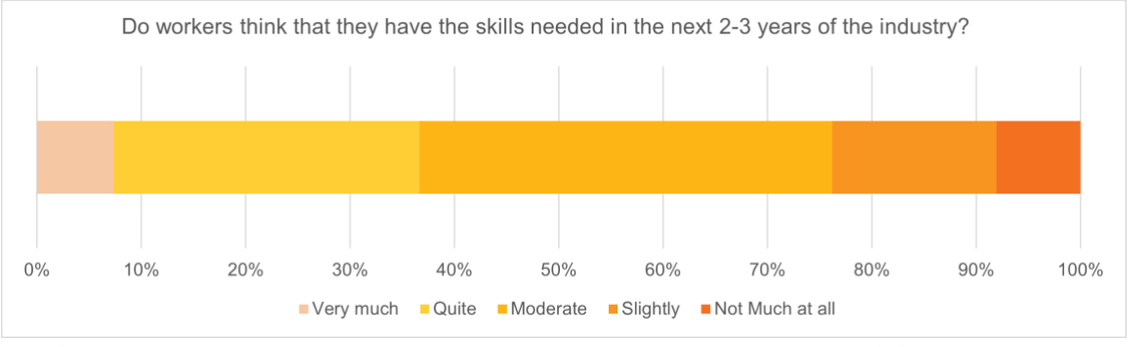


Figure 5: Manufacturing workers feel that they have most of the skills needed for the next 2-3 years in the industry

We also see this confidence in how transferable and versatile they perceive their skills to be. In a second survey, we asked workers to rate their confidence to pursue a career in a different industry, with their current skills and qualifications. Manufacturing workers rated themselves the highest, compared to other groups of workers, in their ability to move to other sectors, with 47% saying that they were confident in doing so (Figure 6).

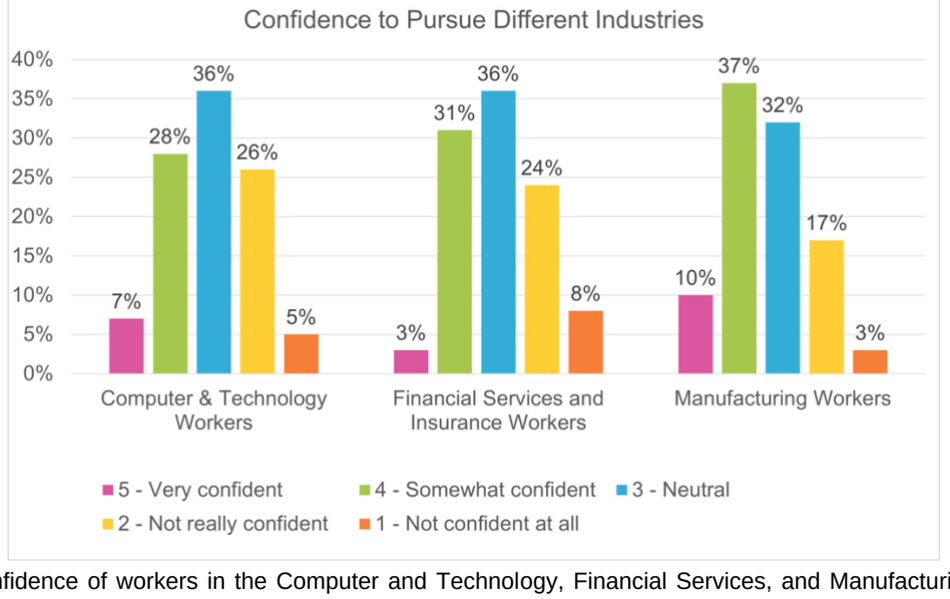


Figure 6: Confidence of workers in the Computer and Technology, Financial Services, and Manufacturing sectors to pursue careers in other industries

The Government is committed to growing the manufacturing sector. As part of the Singapore Economy 2030 plan, the Government has outlined an ambitious 10-year plan to increase the manufacturing value-add by 50% by 2030 and maintain its share of about 20% of GDP (The Straits Times, 2021). Currently, the manufacturing sector accounts for 22% of Singapore's GDP (MTI, 2023). The Manufacturing 2030 plan outlined by the Government is a clear signal of its desire to maintain manufacturing as one of the key drivers for Singapore's future economy. To do this, the Government is pushing the adoption of Industry 4.0 applications in industry, attracting more global and local companies to pursue advanced manufacturing techniques here. An example is the National Additive Manufacturing Innovation Cluster (NAMIC), a national initiative set up with the objective of accelerating the adoption of emerging additive manufacturing technologies in Singapore. To continue attracting leading-edge investments, the Government extended the Pioneer Certificate (PC) incentive and Development and Expansion Incentive (DEI) which provides incentives for companies to "introduce technology, skillsets or knowhow into an industry that are substantially more advanced than the average prevailing in Singapore." (EDB, 2022).

Singapore's strategies include support for the workforce. When it comes to the workforce, Singapore is stepping up its efforts to train, attract and retain talent in the sector—which currently accounts for 13% of total employment in Singapore—and at the same time ensure that good manufacturing jobs are created for Singaporeans (MTI, 2023). We have also seen how, as the value-added by the manufacturing sector has increased over the years, its share of workforce has also decreased, emblematic of the country's transition from low-cost and labour-intensive production to high-value manufacturing characterised by Industry 4.0 (see Appendix A for changes in the manufacturing workforce demographics over the last five years). The Company Training Committee (CTC), a tripartite initiative launched by the Labour Movement and supported by the Government was set up to train and upgrade the existing workforce in companies across all industries. Specifically for the manufacturing sector, in 2022 the Government released the 'Manufacturing Employer Handbook', which provides companies with human capital best practices, and tools to help them structure career progression pathways, with the eventual aim of improving talent retention in the industry. To maintain the workforce pipeline in the manufacturing sector, Singapore also launched a pilot 'Accelerated Pathways for Technicians & Assistant Engineers (Manufacturing)' grant to support selected manufacturing companies on the hiring, training, and career progression of ITE graduates joining the sector (MTI, 2022).

The Singapore manufacturing sector has a workforce that is competent and confident in their skills at present, and the ongoing initiatives from the Government targeted at supporting the workforce can help to sustain this competence and confidence through to the long-term to achieve the Manufacturing 2030 plan.

Opportunity #2: The Singapore Workforce is Committed to Continuous Improvement and the Need to Stay Ahead of Global Competition

Manufacturing workers display insight when it comes to what is needed to succeed in the industry. In our survey we asked workers to rate the importance of different competencies in their profession. As shown in Figure 7 below, “Learning from my mistakes” and “Staying ahead of global competition” were rated as the first and second-most important competencies respectively, ahead of competencies related to the possession of domain knowledge, the use of new technologies, being passionate at work, and staying ahead of local competition.

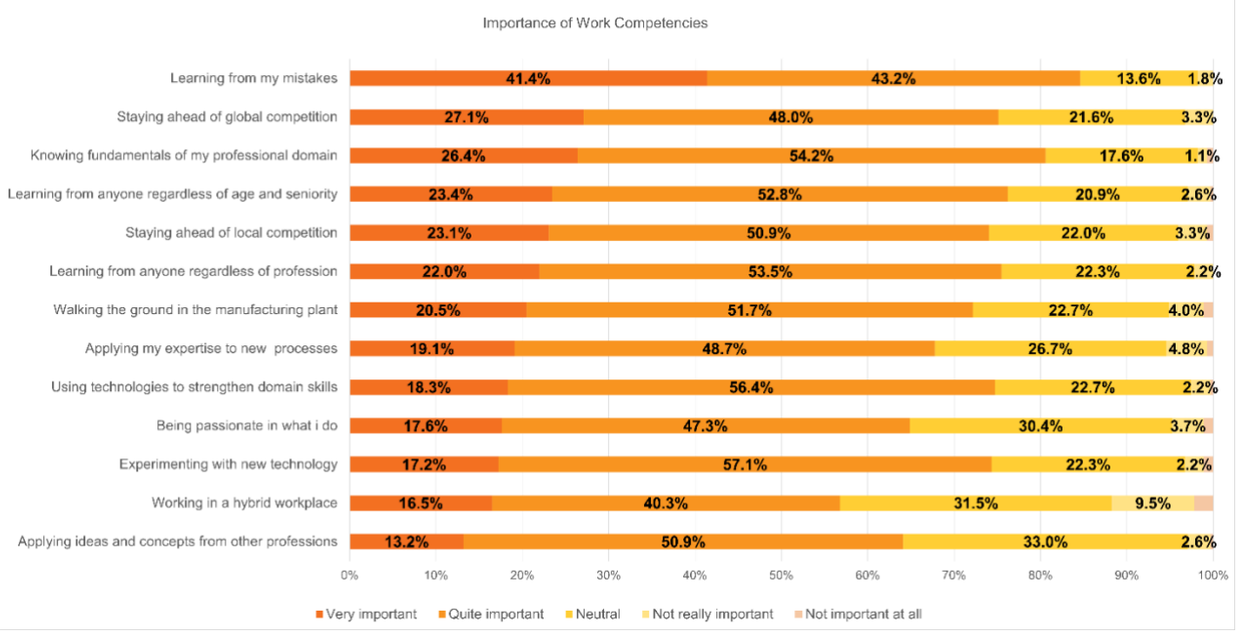


Figure 7: Importance of various work competencies, as rated by manufacturing workers

We interpret these results as such: workers value learning from their mistakes as it presents them with an opportunity to improve. This drive to better oneself is part of a strong sentiment among the manufacturing workforce on the importance of continuous improvement. An engineer in the energy & chemicals industry captures this:

> *So, to me the kind of understanding and having a certain framework and structure in recognising* ***the knowledge and competency, for a certain type of job is important and this could change from time to time when we progress into different eras. It will definitely change****. So, when we, looking at this framework,* ***we need to understand that and need to, you know, update ourselves as well, the framework.*** *So that it will always stay relevant and optimum to make full use of the time for the very scarce resource.*
> (E&C Engineer)

We saw this sentiment echoed by many of our interviewees; while any sector can benefit from continuous improvement, the dynamic nature of the manufacturing sector (a topic that

will be explored further in the next sub-section) seems to require it, as an engineer in the AM sector describes:

> *I guess, for me, it's just interest in the topic, I think you just need to be invested into the technology to some extent,* ***you need to aspire to make a change and then make improvements to the process and the [additive manufacturing] industry.*** *And I guess if you don't have that you're going to, I mean, you can still find, like you can still run processes, and you can still work on topics that don't require that.* ***But I think it is more important than in other industries to have the drive to improve something.***
> (AM Engineer)

The competency that was rated as the next most important by manufacturing workers ("Staying ahead of global competition") reveals an awareness among workers that the manufacturing sector and workforce here not only needs to perform well on its own merits but also needs to out-perform global competition. As we will expand on in the later sections covering the risks to Singapore's manufacturing sector, a significant threat to the sector is from external factors, i.e., global competition for investment flows. Having a workforce that is keenly aware of these global dynamics and has the drive to improve is an important ingredient in maintaining Singapore's competitiveness in the manufacturing sector.

Opportunity #3: The Singapore Workforce is Hardy, Resilient, and Experienced

The Singaporean manufacturing workforce is also hardy, resilient, and experienced. This is because the average Singapore manufacturing worker is in their 50s (Figure 8) and have experienced:

- between two to four decades of highs and lows.
- more volatile swings compared to other sectors.
- multiple cycles of crises, recessions, and international competition.

This is clear when we review past developments in the manufacturing sector in Singapore and how it has affected workers in terms of their employment and wages. Through this macro viewpoint, we characterise the industry as one that is more volatile when compared to other industries, and what this says about workers who have remained in the industry long-term.

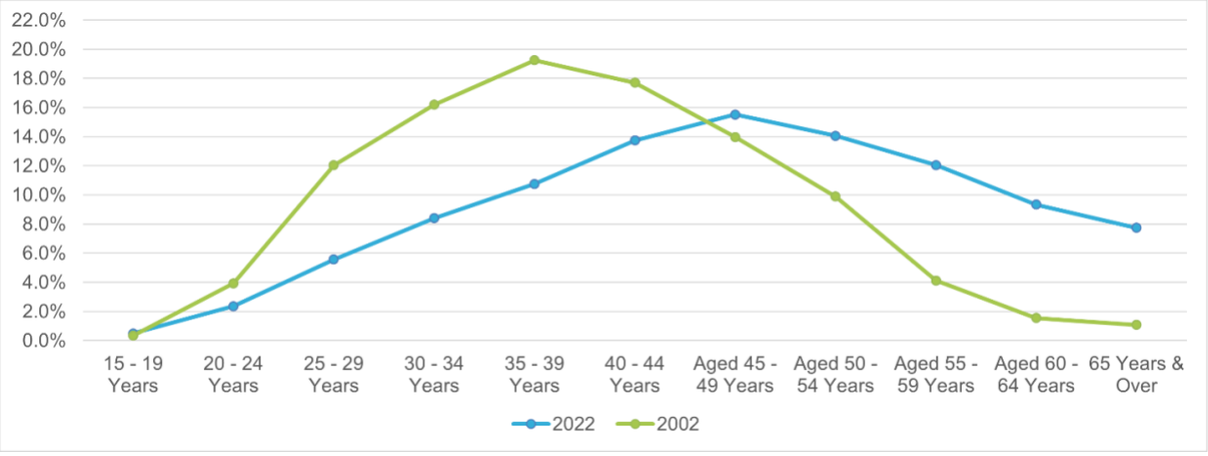


Figure 8: Percentage of workers by age group in the manufacturing sector, in 2022 and 2002 (Singapore Department of Statistics, 2022)

Highs and lows of the manufacturing sector in Singapore

The manufacturing sector of Singapore is filled with highs and lows, more so compared to other industries. Over the last 20 years the manufacturing sector has experienced more volatile swings in output growth rates as compared to the IT or Finance sector (Figure 9).

Figure 9: Annual growth rate in percentage of various industries in Singapore, from 2000-2021 (Singapore Department of Statistics, 2022)

These swings affect workers in a real way, and we can see this when we look at annual employment change during the same period. During the downturn years of 2008 (due to the Global Financial Crisis) and 2019-2020 (US-China trade war and a cyclical downturn in the electronics industry), the manufacturing sector is the only one to experience a negative change in employment, i.e., an actual decrease in employment before bouncing

back the subsequent year (Figure 10). It is also reflected in their wages; growth rates in wages fall during these periods before recovering in the subsequent years (Figure 11).

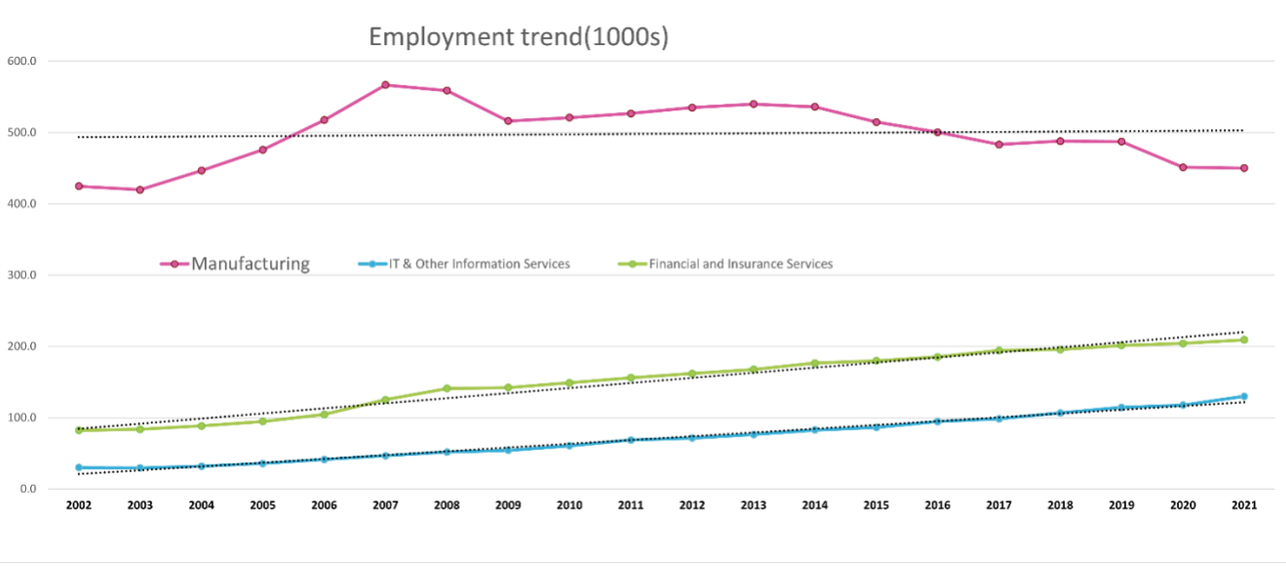


Figure 10: Annual change in employment by percentage of various industries in Singapore, from 2002-2021 (Singapore Department of Statistics, 2022)

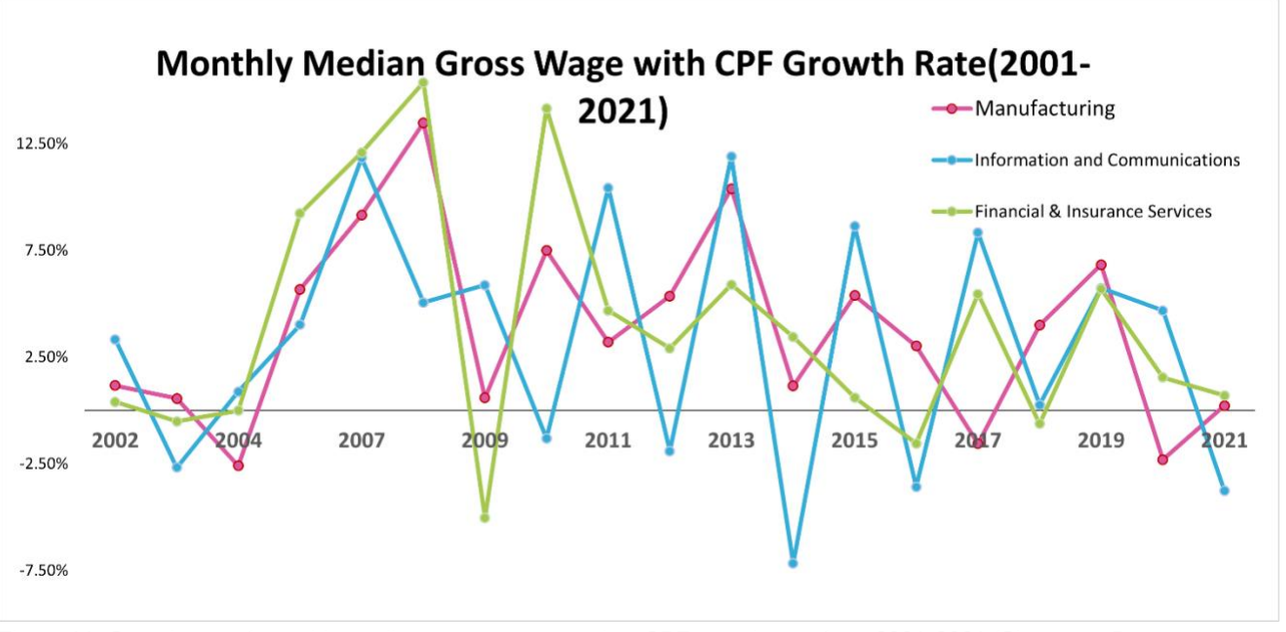


Figure 11: Growth rate of monthly median gross wages against CPF growth rate, from 2001-2021 (Singapore Department of Statistics, 2022)

Furthermore, these volatile swings are not just a recent phenomenon. Looking back further, we observe a pattern of downturns and subsequent recoveries. During Singapore's first recession in 1985, annual wages in the manufacturing sector fell from $16,073 in 1985 down to $15,193 in 1987. Singaporean workers had a bitter pill to swallow: employer CPF contributions were cut by 15% and a 2-year wage restraint was introduced (Lee, 1987). These measures worked and allowed Singapore to remain competitive, benefitting from the growth of personal computing during the following years and producing close to 50% of the world's hard disks between 1986 to 1996.

Despite these swings throughout the years, the manufacturing sector remains a key part of the economy: as of 2022 manufacturing made up a substantial 21.6% of GDP, up from 18% of GDP in 2013.

Manufacturing workers are experienced and resilient

Workers who remain in the manufacturing sector over the years would go through multiple periods of downturns and recovery. These experienced workers have lived through the volatility of the last two decades outlined in the previous section, and those who have stayed would have gained resilience through the coping mechanisms that they developed and relied on over the years. And this is also a substantial stock of skills that has been built up and a source of strength that must be maintained to keep Singapore's manufacturing competitiveness.

More so than in other industries, workers in manufacturing would be prepared to face economic shocks or swings in their industry, having been through it in the past. They are in a strong position to face the competition, crises, volatility in the coming years, and emerge stronger to seize the opportunities necessary to realise Singapore's manufacturing ambitions.

Risk #1: The Singapore Workforce is Facing Worsening Global Uncertainty That Could Overwhelm Even Their Experience and Resilience

However, the worsening global uncertainty fuelled by multiple crises pre-, during, and post-pandemic and now all happening at the same time, coupled with intensifying international competition could prove to be overwhelming for the Singapore worker even with the experience, resilience, and hardiness we described in the preceding paragraph.

We have previously described how the manufacturing sector in Singapore is characterised by periods of growth and contraction. We can identify two continuities present throughout: Firstly, manufacturing in Singapore is export-driven and that means it is inherently dependent on demand from the main consumer countries such as the US and China. Market volatility would cause shockwaves which would lead to a decline in manufacturing output here, potentially leading to layoffs as companies downsize—some of which we can already see happening now[1]. Secondly, the industries that comprise the manufacturing sector in Singapore will continue to evolve as we adapt to this volatility and move up the value chain. The skills in demand from workers will change and/or expand as new industries are created in which Singapore can develop a competitive advantage. These continuities are the reason why the manufacturing sector can be described as dynamic, and experienced workers in the industry are aware of the need to continuously improve and are more resilient than most (as we have described in the previous sections).

[1] https://www.straitstimes.com/singapore/jobs/retrenchments-in-q4-2022-double-of-q3-mom-report

This worsening uncertainty from crises and competition accelerates these continuities, but also dislocates them at the same time, causing more volatility for workers that might be beyond their individual capacities to cope.

Pre-pandemic continuities	**Pandemic and Post-pandemic acceleration and dislocation**	**Worsening uncertainty**
Export oriented manufacturing, vulnerable to external volatility	• Energy and commodities risks (e.g., from war in Ukraine) • Recession and inflation risks • Geopolitical risks (e.g., US-China) including tech wars, supply chain reconfiguration	• Shrinking global demand and reduced manufacturing output and investments • Disruption of existing supply and value chains • Increased layoffs and dislocations
Constant move up the manufacturing value chain.	• International competition intensifies as “economic pie” shrinks due to above factors. • International skills gaps narrow as countries move up value chain. • International outsourcing accelerates with expanded remote work possibilities	• Accelerated pace of change demanding accelerated frequency of upskilling • Increased number of current and potential competitors, including expanded threat to jobs lost due to outsourcing. • Pressure to focus on efficiency and cost-cutting, with impact on wages, workload, and wellbeing

Table 1: Worsening uncertainties arising from post-pandemic developments

As the Financial Times stressed in a recent editorial, “[e]conomists have faced an unusually uncertain world since 2020. They have had to take positions on epidemiology, war scenarios, supply chain shifts, and rapidly evolving domestic and international policies.” And that is why “[r]ecent criticism of erroneous forecasts needs to be tempered.” If even the economic experts find it hard to cope with the uncertainty, what more the workers who are at the receiving end.

In addition to the known risks above, there is also the emerging implications of the push for ally-shoring. Rising economic competition between the US and China has led to the erosion of rules-based global trading in recent years, and latest developments point to this only worsening in the future. In 2018, US and China levied steel and soybean tariffs against one another in a tit-for-tat exchange during the US-China Trade war. In 2022–2023 the focus has pivoted to semiconductors, with the US unilaterally imposing export controls that restrict sales to China of the most advanced computer chips as well as the manufacturing

equipment for making those chips (TIME, 2023). In retaliation, China has hit back by launching a cybersecurity review of Micron, one of the largest domestic chipmakers in the US (South China Morning Post, 2023). All of these are visible steps towards the creation of separate US and China trade blocs should things continue to escalate. Cognisant of this trend, western countries and firms are beginning to embrace 'friendshoring', i.e., to create alternative supply chains in countries regarded as political/economic allies (WEF, 2023). Competition for this rerouting of global investment flows will be fierce. Whether foreign companies decide on "friendshoring" to Singapore, or our ASEAN neighbours, or instead on "reshoring" (returning production to a company's home country, which is becoming more attractive given rising protectionist policies abroad), remains largely unknown.

These increase the uncertainty and volatility that workers face. They face questions such as whether Singapore can continue to drive innovation to remain competitive and prepare its workforce for these new opportunities. They face questions in the long run about the emergence of new manufacturing industries and the expansion and/or relocation of existing ones. They also face questions about whether they will be well-prepared with the right skills and or if they would be able to adapt to these potential developments.

While manufacturing workers are no strangers to uncertainty, these expanded and recent technological and geopolitical developments are accelerating uncertainties in the ways that manufacturing workers do their work, the opportunities available in the sector and the skills that are required of them. Workers may be unable to cope with these uncertainties on their own, and as a result, will need additional support to continue driving the sector forward.

Risk #2: Workers and Corporations May Disagree on What Workers Need, Causing More Competition, Threats, and Risks to Workers

The uncertainties workers face described in the previous section will be less acute if it was clear what needs to be done to strengthen the workforce. However, there is a risk that during discourses on the future of work, workers' voices are overpowered and that the solutions proposed to help workers may differ from what they need.

This disagreement between workers and decision makers is consistent with extant research literature and findings. In this section we outline this risk based on past research conducted on the subject, and summarise the effects it may have, including how this disagreement can cause a paradox where more upskilling leads to more risks and competition.

A recent literature review on future of work discourses (Schlogl et al., 2021) found that the dominating voices tend to be those of "business consulting groups, who have a vested interest in framing the problem in a way that offers business consultancy [to companies and governments] and a reconfiguration of the workforce as the solution" (p. 320). This includes the common theme of framing technology disruption on workers as the dominant force when in fact our analysis of tasks and skills disruption suggests corporate decisions

can be just as disruptive to workers. Their resultant main message is thus "Thou shalt upskill" (p. 320), that places an unbalanced responsibility on the shoulders of individuals, while corporations are "least called upon to change anything, except to proactively prepare for changing expectations of workers, supply chains, and cost structures due to automation" (p. 320).

For example, the World Economic Forum highlighted the importance of digitalisation to build resilience in an economy and drive further growth. Southeast Asia's digital economy is projected to surpass US$330 billion by 2025 and estimated to reach up to US$1 trillion in 2030, growing twice as fast as GDP in most countries (WEF, 2023). The report points out that digitalisation will be a key contributor to the growth of the manufacturing sector: The adoption of 5G networks has the potential to digitalise industries at scale, while emerging technologies such as AI, advanced automation and the IoT will disrupt traditional methods of production (Industry 4.0) and drive further increases in productivity. They recommend that the rapid pace of this digitalisation leads to increased worker interaction with digital technologies and the automation of more and more human tasks. For workers to remain relevant, they require high levels of digital literacy and new skills to adapt to the new, digital ways of doing work.

When corporate voices overpower worker voices as such, the framed problem and solutions have three glaring inconsistencies. First, it ignores whether workers—with this unbalanced responsibility—can cope with the growing and worsening risks and uncertainties. Second, it limits instead of liberates workers because it may exacerbate existing corporate-worker power relations and inequalities (Aroles et al., 2019). Third, it fails to clarify how, if all are advised to upskill towards similar skills, companies and governments are all converging and thus competing on price, instead of differentiating on unique skills advantages and capturing premium value.

This disagreement between workers and decision makers is also consistent with our research.

For example, in the survey we conducted, we asked workers to rate the importance of different competencies in their profession, and subsequently to rate how good they think they are at it. We define the delta between what workers rated "how important it is" and "how good I am at it" as a mastery gap, i.e., the higher the mastery gap for a competency, the more workers felt like the competency was important but that they were not sufficiently capable at it. We found that the top three mastery gaps that must be closed is:

1) Staying ahead of Global competition
2) Staying ahead of Local competition
3) Applying new technology (including but not limited to digital technologies)

Applying new technology is third on the list. And as we pointed out in the preceding paragraphs, if everyone follows the same advice to digitalise with similar skills and technologies, it will intensify competition, making coping with global and local competition even harder.

In addition, when we go beyond the headlines to analyse what skills being disrupted at the deeper and more granular level of tasks (see Appendix E), we find that the corporate voices in fact contradict themselves. They predict growth in the same tasks they say will be disrupted by technology. Our analysis also shows that the tasks that have the most growth will be interaction tasks, which is consistent with the survey results of the workers.

Hence, if we fail to give voice to the workers, but instead let their voices be overpowered by decision makers, the workers and Singapore manufacturing-at-large might face more—instead of less—risks and threats.

Risk #3: The Singapore Workforce Faces Threats to Their Own and Singapore's Skills Security if Risks #1 and #2 Are Poorly Managed

If workers are unable to cope with the worsening uncertainty and volatility, and there is a mismatch in what skills they need against what they are given training in, it will compromise their own work prospects and Singapore's strategies and ambitions in manufacturing.

Singapore would have failed in Skills Security.

Skills Security is a term we coined based on the insights from this project. We define skills security at the interaction and intersection of two levels:

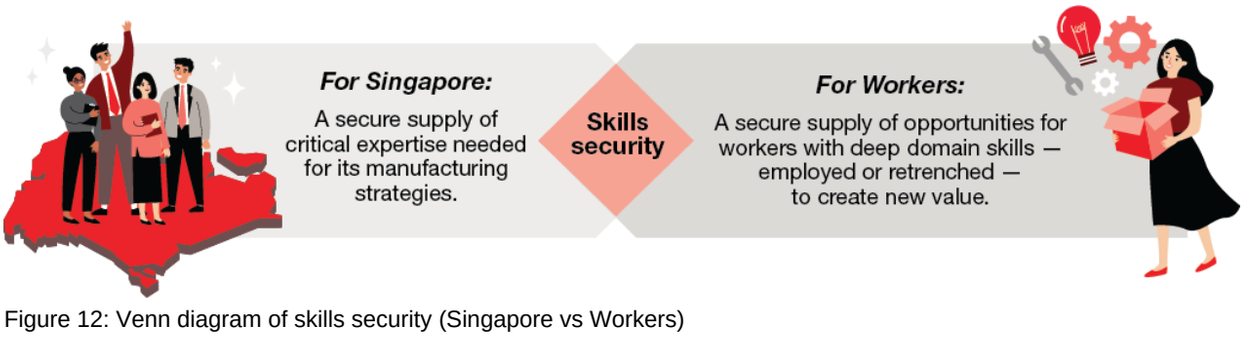


Figure 12: Venn diagram of skills security (Singapore vs Workers)

Skills security for both Singapore and workers is the priority because it is the only way Singapore can secure the expertise needed for its strategies to success. Because if we ensure this supply, we secure the stock of skills that Singapore needs for its manufacturing sector to automate, digitalise, transform, compete, and excel. And in doing so, we also secure the future prospects of workers.

We assess that failing to secure skills is a substantial risk. This is because skills security is hardly discussed, much less practised. It stands in stark contrast to what we do for supply chain security. Where for example, because the pandemic showed us how fragile just-in-time supply chains are, we now practise just-in-case too.

The contrast is starker when we see that, geopolitically, countries have set out aggressive industrial policies, redoubling investments in key areas (such as semiconductors), and in

the case of Japan, have even set out a Ministry for Economic Security. These, however, can only go so far without the right skills and talent.

This also includes securing a pipeline of younger technology professionals to join the industry. As we have seen earlier, the average age of the manufacturing workforce has been inching up (Figure 11). The extensive experience and substantial stock of skills is now a strength, but without younger entrants, the experience and stock can diminish even before we have achieved Singapore's manufacturing strategies and ambitions.

This risk is acute given how unattractive manufacturing is to younger workers. In our survey we asked workers in other industries to rate how appealing it would be to join the manufacturing sector. Notably, only 37% of those aged between 25-34 years old found manufacturing to be appealing. This compared to 49% of those aged above 55 years old who found it appealing (see Figure 13).

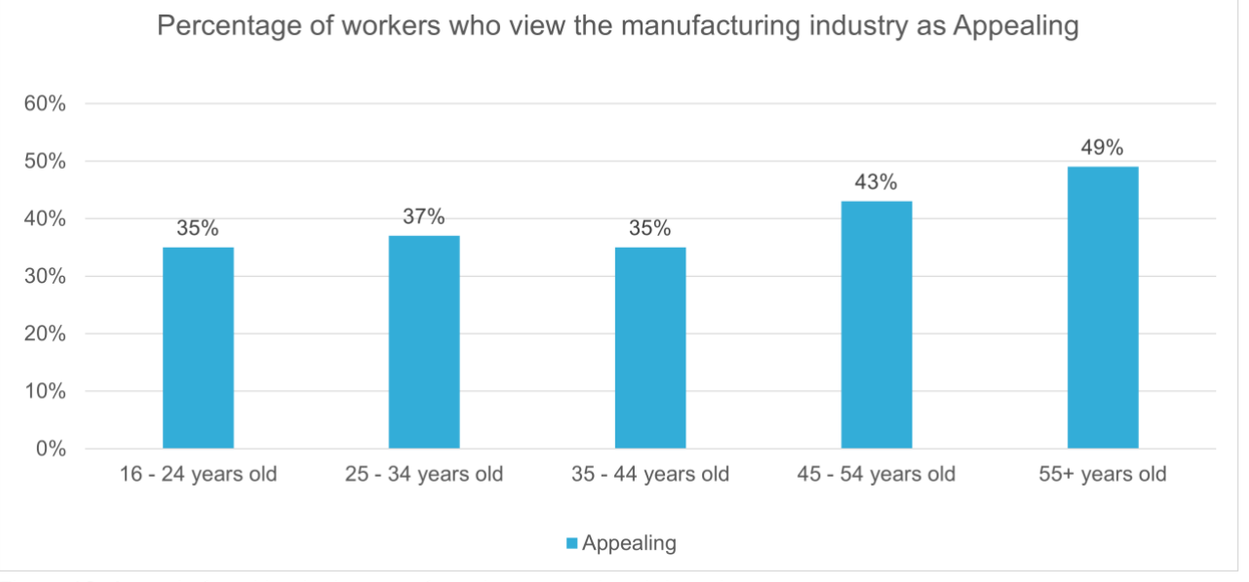


Figure 13: Appeal of working in the manufacturing sector, breakdown by age group

This risk is even more acute given how existing workers in manufacturing, compared to other industries, would like to make a switch. In our survey, 57% of manufacturing workers would like to pursue a career in a different industry from that which they are currently in. This compared to only 35% of non-manufacturing workers (Figure 14a). When we look only at those working in technical roles within manufacturing, the number is even higher: 70% would like to switch to a different industry (Figure 14b).

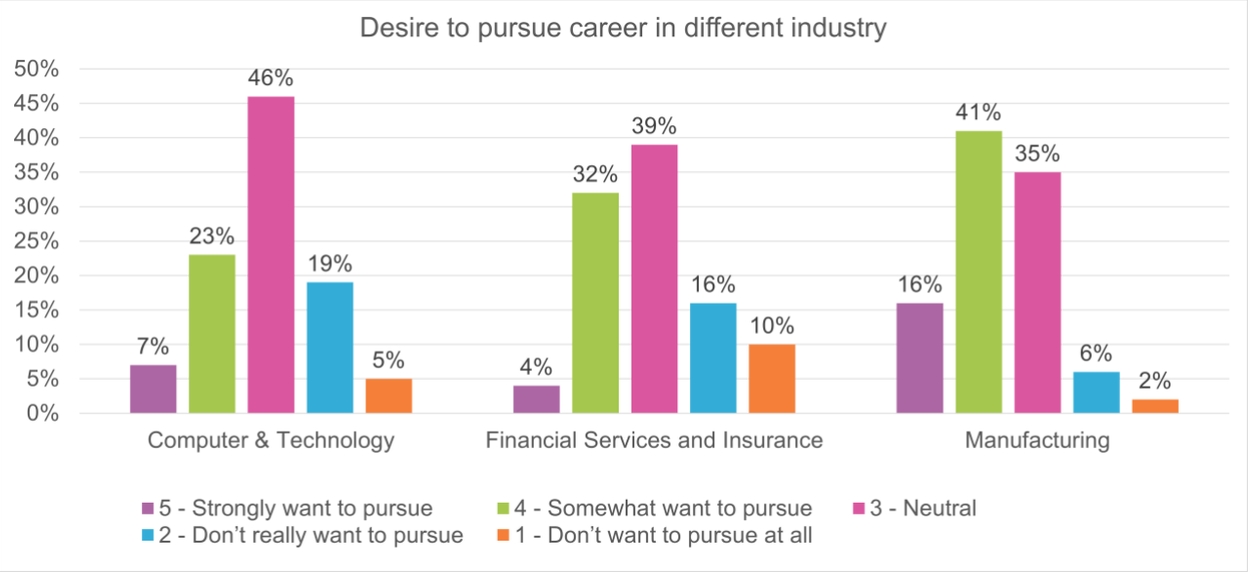


Figure 14a: Desire of workers in the Computer and Technology, Financial Services, and Manufacturing to pursue a career in a different industry

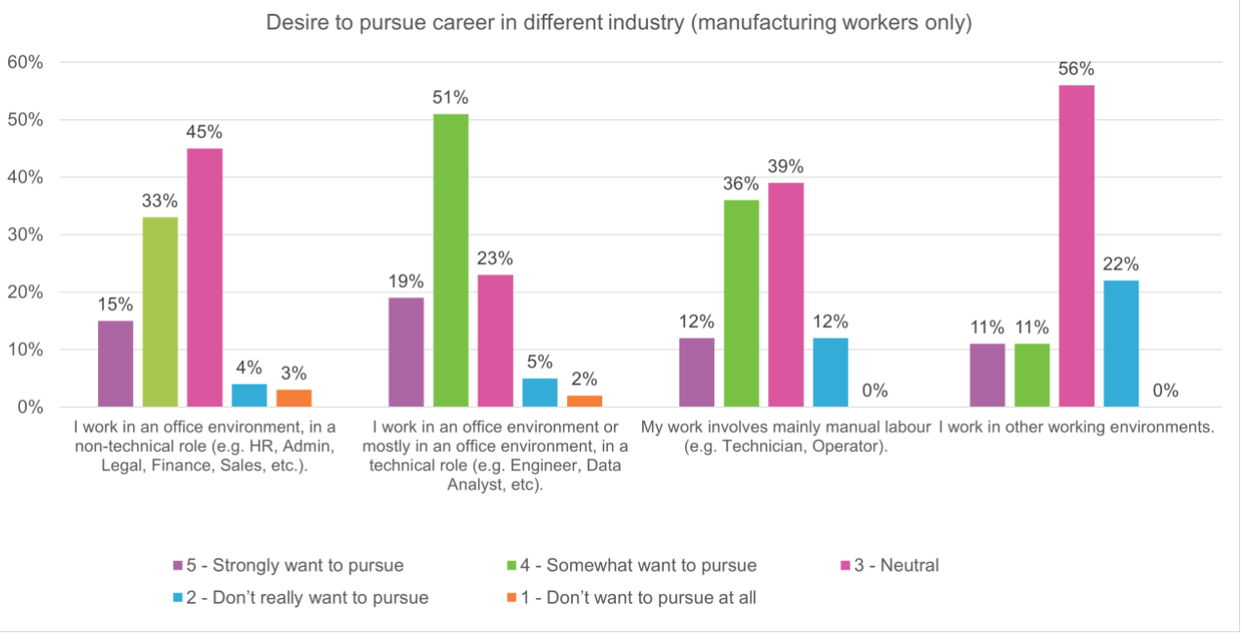


Figure 14b: Desire of manufacturing workers in different roles to pursue a career in a different industry

As there are no precedents for Skills Security, it must be crafted. Failing to craft it is to fail eventually in securing the future of manufacturing for any country and its workers.

One of the aims of this report, then, is to outline how we can safeguard Skills Security in Singapore. In the next section, by drawing extensively on interviews and surveys conducted with manufacturing workers, we provide deeper insight into the uncertainties that workers experience when they are made to navigate the opportunities and risks in the industry. We use this focus on workers' voices and experiences to guide the recommendations that can help safeguard Skills Security later in this report.

Chapter 3: Deep Dive — How Workers Experience Uncertainty

In this section, we do a deep dive into how workers experience on the one hand tremendous opportunities in the years ahead, and on the other hand, worsening risks on the economic, technological, and geopolitical fronts.

We do this deep dive because if we want more workers to thrive, we must understand in-depth what they experience. Moreover, as we point out in Risk #2, if their voices are often overpowered, dedicated effort must be made to understand them.

The power of giving them voice is captured in the following diagram on the full spectrum of uncertainties they face:

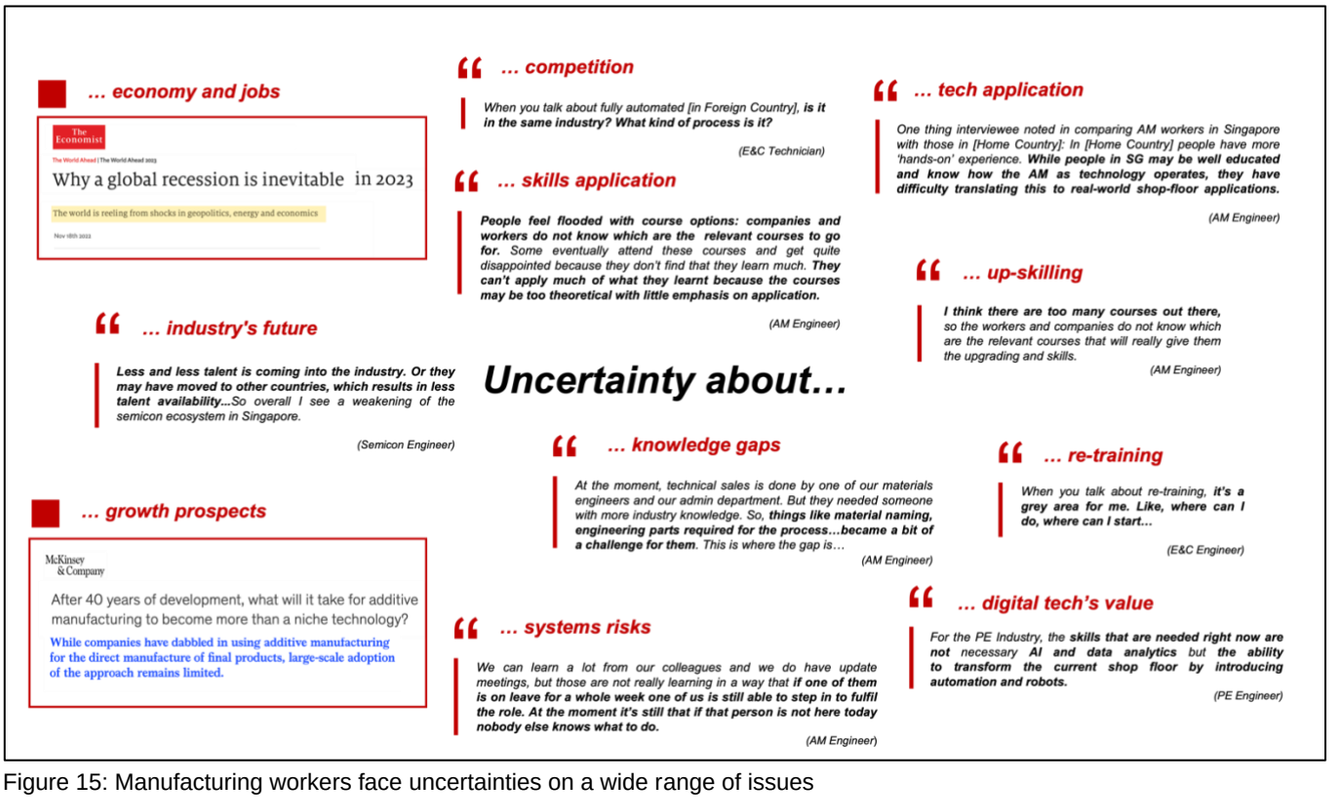


Figure 15: Manufacturing workers face uncertainties on a wide range of issues

Diving deeper, we found that for workers, these uncertainties arising from navigating tremendous opportunities and worsening risks can be categorised into three tensions:

Figure 16: The uncertainties arising from the opportunities and risks facing manufacturing workers are categorised into three tensions

We present our findings around three tensions we have identified: 1) 'Going Digital or Retain the Domain?'; 2) 'Skilling Up or Bridging Skills?'; 3) 'Going Deep or Going Wide?'. We illustrate each tension drawing on our data, after which we will distil a core point for each tension that will then inform the recommendations we provide at the end of this report.

Tension	**What Workers Hear and are Told**	**What Workers Experience and Believe**	**Takeaway**
1. Going Digital or Retain the Domain?	"The future will be built on digital skills"	"Domain skills will always be fundamental"	Develop digital skills that supplement, not supplant domain expertise
2. Upskilling or Bridging Skills?	"Up-skill and re-skill to keep up"	"Bridging skills to build a cohesive path forward"	Emphasise the bridging of skills to act as a 'glue' across hands-on, theory, and people-interactions
3. Going Deep or Going Wide?	"Accumulate skills to excel in your role"	"Train for multiple roles to create new value, anywhere"	Develop workers for multiple roles as a deliberate strategy to diversify risks and mitigate uncertainties

Table 2: Summary of three tensions arising from uncertainties facing manufacturing workers

Tension #1: Going Digital or Retain the Domain?

> *The foundation of traditional technologies, they make up the foundation of any new cutting-edge technology. So, for newer cutting-edge technology to emerge, there has to be some form of foundation. So therefore, this foundation has to be instilled in—has to be instilled in engineers.*
> (AM Robotics Trainer)

While workers are receptive to furthering their digital skills, there remains a strong focus on domain knowledge. However, this does not always align with company, industry, and national initiatives that primarily seem to encourage the uptake of digital skills. This results in a mixed bag of views and opinions related to the relationship between digital and domain skills: do they enhance or obstruct each other? While workers are told that the future will be built on digital skills, their own views suggest that domain skills will always remain the fundament on which the future is built.

Domain knowledge is viewed as more important than digital skills

In our survey we asked manufacturing workers to indicate how important they view several competencies for their profession (see Figure 17). The figure shows that the percentage of respondents that ranked competencies related to their domain as 'very important' is higher than those who see competencies related to digital technology as 'very important'. E.g., 'Knowing fundamentals of my professional domain' ends up third and even 'Walking the ground'—which, as a routine practice, is increasingly becoming less important because of automated operations from control centres—is viewed by more respondents as very important than 'Using technologies' or 'Experimenting with new technologies'. Moreover, several competencies that relate to interactions between humans, such as learning from others or being aware of and staying ahead of competition, are ranked quite high.

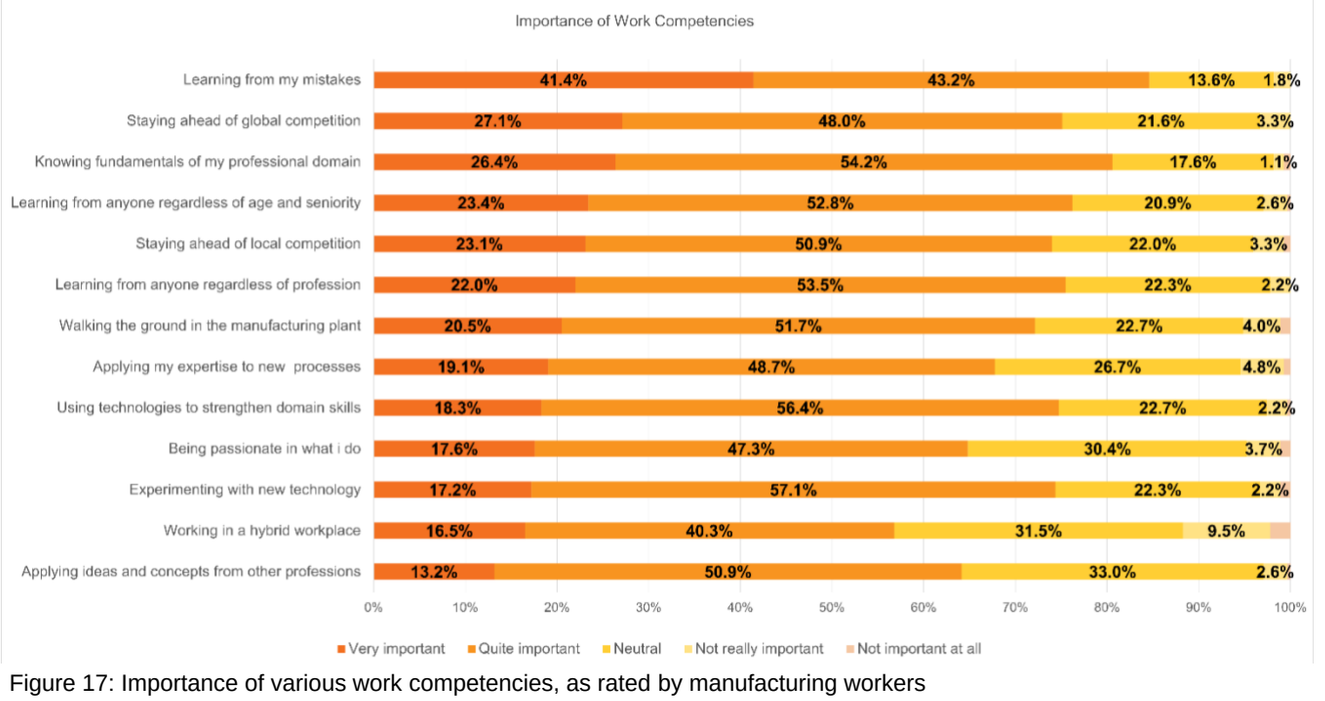


Figure 17: Importance of various work competencies, as rated by manufacturing workers

Experienced workers: “Digital skills can *complement* domain skills”

This is not to say that respondents are not receptive to new and digital technologies. When we asked respondents whether they think digital skills will hinder or boost the development of their domain skills, 54% answered that digital skills will boost their existing domain skills (see Figure 18), suggesting that we need to start thinking of digital skills as complementary to domain skills rather than as a replacement of it.

Looking more detailed into the responses of this question, we, interestingly, found a positive correlation ($r=0.137$, $p<0.05$) between the age of respondents and how much they think digital skills will boost domain skills. Meaning that the older workers are, the more positive their view is on digital skills.

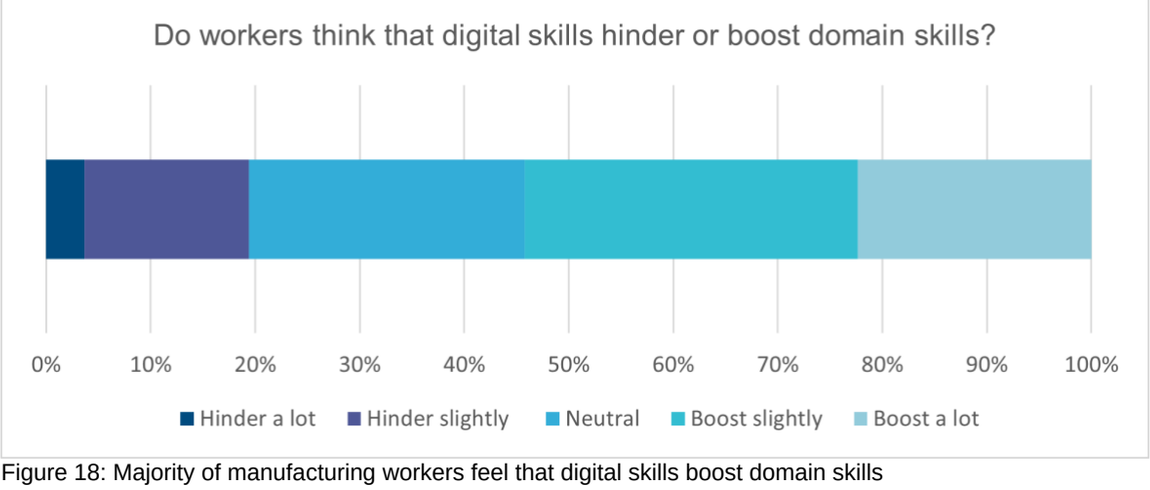


Figure 18: Majority of manufacturing workers feel that digital skills boost domain skills

In the context of digital-domain integration which we mentioned above, we interpret these results in the following way. Older workers may already have a solid foundation of domain skills, and therefore may have a better idea of where digital technology could be applied in useful ways. Rather than the view that digitalisation ‘disrupts’ processes, these experienced workers may be able to better see where digital technology is relevant in existing workflows and can be used in concert with domain skills for a net gain in productivity.

As for younger workers for whom the digital world is second nature, they might feel that the increasingly digitalised nature of the workplace hinders them from picking up the domain expertise in their industry. With increased emphasis on digital skills and the prevalence of automation, they may feel like they know the procedures but are lacking in the domain knowledge necessary to fully understand the manufacturing process. For example, going back to the competency of ‘Walking the ground’ introduced earlier: whereas older workers may have developed their technical sensibilities over the course of decades by walking the ground, i.e., knowing the production floor intimately, younger workers may have much less exposure to this and immediately start their work from a digital control room.

Overall, the data of the survey indicate that respondents in assessing the question ‘Going Digital or Retain the Domain?’ think about this not in terms of ‘either-or’ but in terms of ‘both-and’. To explain this in more detail, we will next turn to some quotes derived from our qualitative interviews.

Uncertainty around digitalisation: Losing touch with...

Many of our respondents spoke about one of the potential disadvantages of digitalisation in terms of ‘losing touch with...’. One engineer, for example, mentioned that it has created a distance between engineers in the field and engineers in the office:

> *I've a lot of friends from different engineering industries, and what I gather from most of my friends is they don’t really spend much time with the ground technicians to really understand the pain or understand the products and stuff. Because as engineers, we are mostly in the office, and then we try to assume what was the problem or what can be improved. But we’re not really addressing what needs to be done.*
> (E&C Engineer)

The otherwise holistic process of manufacturing is now being operated from several different locations each with their own viewpoints. In a sense, the quote shows that this has to some extent been detrimental to interactions between workers. The ‘losing touch’, sometimes, was also mentioned in a very literal and physical sense:

> *The increasing need for and importance of hands-on or ‘field’ experience: There are now many engineers who are only doing data analytics in the office and rarely enter the field anymore. As a result, they can’t distinguish between water and acid.*
> (E&C Technician)

> *Nature of job as a technician means need to do daily checking. Robots cannot match human touch. Even as automation is being implemented in the Lab, one must still check if the sample is correct (E.g., If one pours petrol into heavy distillation, it will catch fire). Even though the signals can tell you that everything is working well, it does not beat physically looking at the process to ensure that everything is working well.*
> (E&C Technician)

Overemphasising the digital ironically creates risks to workers' employment, something that is well explored in the literature (e.g., Bainbridge, 1983): the more processes are being automated, the more fundamental human contributors or controllers become; yet the more processes are being automated the less opportunity there is to develop human expertise. As a result, tasks that are now performed by digital skills are likely to become even more automated to compensate for the lack of human expertise.

AM engineers experience a gap between their and other manufacturing sectors

Since the AM sector is much younger, especially compared to E&C, manufacturing workers in the sector deal with different variants on this issue. Rather than digitalisation posing challenges towards existing processes and practices, a key concern within AM seems to be on how to implement the largely digital process of 3D printing within industries that still operate by a more physical or mechanical logic. This is the issue of uncertainty around the development of the AM industry as a whole and, more specifically, on how these developments can be applied concretely.

For instance, some respondents mentioned that even though AM is often touted the 'next big thing' in manufacturing they did not yet see a significant uptake in other industries implementing AM technologies and even openly questioned if this would happen anytime soon:

> *Right now, I guess a lot of the [manufacturing] market is still focused on traditional manufacturing methods. There is no need for them currently, or there's no reason for them to look outside. How can we manufacture this part differently? Because they simply wouldn't know how to manufacture it either. So, I think right now, it will take a bit of time until more and more people get in touch with the technology and started creating their own thoughts and find their own applications.*
> (AM Application Engineer)

In this sense, the integration of a largely digital sector (AM) into other manufacturing sectors that still operate by less digital logics seems challenging and not something that will automatically be solved over time with technologies such as 3D printing becoming more mainstream. For instance, it is also a matter of thinking about the sort of skills that are needed to accomplish this. One AM engineer addressed this explicitly, saying that:

> *At the moment, technical sales is done by one of our materials engineers and our admin department. But they needed someone with more industry knowledge. So, things like material naming, engineering parts required for the process…became a bit of a challenge for them. This is where the gap is…*
> (AM Engineer)

In other words, and this is what we explore in more detail in the next section, the manufacturing sector seems to require skills bridging different domains (such as technological, sales, and core disciplinary ones). Just knowing the technology well is insufficient and 'bridging skills' are those skills that facilitate the integration of digital and domain.

Key takeaway: In the push for digital transformation there has often been great emphasis on upgrading the digital skills of the workforce. Workers feel that while digital skills are a

necessary part of the future, domain expertise remains the core of their mastery. Thus, priority should be placed on preserving the existing domain expertise within the manufacturing industry, and the introduction of digital technology should be done in a way which enhances but not replaces domain expertise.

A good question to ask at this juncture is **whether digital technology can be implemented in such a way that it facilitates interactions between people and the development of domain skills**. Such **domain-digital literacy** will thus be one of the core points informing our recommendations.

Tension #2: Upskilling or Bridging Skills?

Domain-digital literacy bridges domain and digital skills. As the workers' voices in the preceding section shows, they know this involves bridging hands-on with theory, and people-technology interactions. What is uncertain is how they can bridge these skills distributed across hands-on, theory, people, and technology; and who can help them do so. Why such bridging skills (e.g., between the specific technology and the broader system or context) is so important, is shown in the following quote quite vividly. An older E&C Engineer states that many younger engineers entering the workforce may be very tech savvy without really understanding the entire system of people and processes behind the technology.

> ***We call them Nintendo engineers. Because basically they are just playing, it's like playing a game right.*** *So, I don't know if I have a fully formed opinion about that, I see that, I see that they come in and they are the most comfortable with the technology and there is no question. They expect that it works this way. How could you have ever not? Of course, it works this way.*
> (E&C Engineer)

The quote reiterates the previous point that we made, namely that workforce development should be more focused on the integration of digital skills into the domain of professionals rather than being solely preoccupied with learning a new, digital skill per se. It also builds on the previous point in providing another tension: whereas workers often hear that upskilling and reskilling is important to keep up, they themselves believe that bridging skills are more important for building a cohesive path forward.

Workers are open to picking up new skills, but are uncertain about the why, where and what of existing initiatives

We saw in our interview data that for many workers there remain quite some practical issues that temper their enthusiasm to follow upskilling courses.

When you talk about re-training, it's a grey area for me. Like, where can I go, where can I start…
(E&C Engineer)

Workers whose courses are determined on an institutional level, e.g., through their company, experience similar uncertainty when it comes to (i) being overwhelmed by the number of options available to them and, (ii) in identifying why and how chosen courses would benefit them in terms of upskilling. The following two quotes highlight this:

People feel flooded with course options: companies and workers do not know which are the relevant courses to go for. Some eventually attend these courses and get quite disappointed because they don't find that they learn much. They can't apply much of what they learnt because the courses may be too theoretical with little emphasis on application.
(AM Engineer)

I think there are too many courses out there, so the workers and companies do not know which are the relevant courses that will really give them the upgrading and skills.
(AM Engineer)

The keyword that seems to stand out here is: relevance. From the answers of our respondents, it seems that for many of them it is unclear which courses to follow and how the courses contribute to their skillsets and career development. Courses should be integrated into the actual work more concretely, or the relevance of them should be articulated more clearly. Otherwise, upskilling may seem more like a burden to workers than contributing to their expertise, as the following engineer expresses when asked why he decided to not attend certain courses:

God, I don't know where to start. I give you an example. So, they told me to go for reskilling of a forklift [driving], easier for you to understand. I said: "Why?" They say, because it's a government ruling that every few years you have to [do this course]. So I told them: "Every day, I've been driving forklift. Why you want me to reskill? To reskill what?" So sometimes, it makes no sense for me to go to such, such… Yes of course, I get this off time, and I'll be having a good time. It's good for me, but okay… Sometimes I just "yayaya" but don't go lah.
(E&C Engineer)

This was also reiterated in our survey when we asked how much influence workers experience having in determining which upskilling courses to attend. While the responses were quite evenly distributed, there was a noteworthy and significant positive correlation between 'income' and 'level of influence' ($r=0.191$, $p<0.01$). This could be interpreted as people who have less decision-making power in the company in general experience having less influence on the courses they follow. This makes the relevance of these courses less

immediately obvious to them and may bring about uncertainty pertaining to one's own career progress.

One potential way to address this issue could be for decision-makers in companies or institutions to make a point of expounding on the objectives and the relevance of these courses to workers themselves so that they are aware of how it is designed to help them and would therefore be more likely to be engaged with the learning. This removes the asymmetry of information between decision makers and workers, and ensures that the rationale for promoting certain upskilling courses is not lost on workers.

In our interviews, workers not only spoke about the uncertainties they sometimes face when it comes to upskilling, but also about what they would deem as relevant new skills to learn. We interpreted these as 'bridging skills' which we will elaborate below.

Workers emphasise the need for 'bridging skills' that act as glue in the multi-layered, complex manufacturing process

> *For the Precision Engineering Industry, the skills that are needed right now are not necessarily AI and Data Analytics but the ability to transform the current shop floor by introducing automation and robots.*
> (PE Engineer)

This quote echoes some of the sentiments described earlier: picking up digital skills just for the sake of it is often not what makes workers and companies thrive. Much more useful seems to be the *application* of such new skills and technologies into the specific domain of the workplace so that work can be done better. In other words, merely picking up computer coding is—from the view of our respondents—inferior to learning how computer coding can enhance the existing processes and practices, i.e., bridge different types and sorts of skills.

Another engineer captures this, in comparing his experience of working in Singapore's AM sector with that in his home country:

> *So I was working basically half time, hands on. I'm very, I'm very tactile, when it comes to my work I, I know my way around the shop floor, so to speak. And that's maybe something that, I didn't get the same feeling that everyone here has the same background in that regard.*
> (AM Engineer)

So while Singaporean AM workers are well educated, they may lack important hands-on experience, which would involve a more playful way of tinkering with materials or experimenting with the technology. This is reflected in the difficulty of translating their theoretical knowledge to real-world shop-floor applications. A similar sentiment was expressed by an E&C engineer at a focus group discussion:

> *Polytechnic students should be the bridge between practice (ITE) and theory (university). But they are also increasingly becoming more theoretical which is not necessarily the skill industry is waiting for.*
> (E&C Technician)

These examples highlight that while improving digital skills can help to drive advancements, the industry still needs a strong base of manufacturing know-how or domain expertise to translate these new innovations into industrial applications. Rather than thinking of digital skills and technologies as something you can 'add on' to the domain, it needs to be much more firmly integrated into the domain, and the domain rather than the digital should be leading. What these bridging skills specifically are will depend on the industry and organisation.

It is usually thought in the AM field that this would pertain bridging different disciplinary skills. While it was pertinent that experts need the deep technical know-how of these new, cutting-edge technologies, it was also clear that the industry is primarily of value when other manufacturing industries will integrate AM technologies into their production. Hence, finding useful applications for cutting-edge technologies and being able to communicate these with others would require bridging the AM domain and the domain of the customer.

For E&C, it could cover practices that bridge more theoretical aspects and more hands-on aspects of work in order to maintain a holistic systems view of the manufacturing process that is so important to the safety of the industry:

> *Okay. We have diploma here, which is a very good step, and then we have a degree here, which is a very good step. I think the diploma itself, they should put more emphasis on hands-on. Once you get that going, you can go for that degree. I think it would be very good because a lot of [people with only a] degree do not understand what is happening on the ground. They know this plus this equals this. They know that. But they don't know exactly what will happen if in between something goes wrong. So, before you go for your degree or during your diploma, I think you should go through some sort of training or hands on. And it should be a strict one and not something that we take lightly. That's the part I think they are lacking, diploma and degree. Degree, some of them don't have basic also because they go for A levels then straight go to a degree. So they missed a lot of things. In between.*
> (E&C Engineer)

While these examples show the great variety of bridging skills, the survey gave some more general insights into how manufacturing workers believe these could be developed.

People-people interactions and people-technology interactions are deemed most helpful

In our survey we presented respondents with a list of initiatives. These were derived from our Mastery in a Digital Age study as well as interviews conducted for this study. We asked

respondents to rank these initiatives in terms of how helpful they thought they would be for them (see Figure 19). Noticeably, the two initiatives that were ranked highest concern those that, 1) improve interactions and learning possibilities between people of different disciplines, and 2) training that specifically focuses on the integration of new digital skills with existing domain skills. We interpret this as an indication of workers' desire to develop 'bridging skills', i.e., skills that enable the interaction between different people and between people and technologies. Such skills can act as a sort of 'glue', ensuring that as workplaces become increasingly more digital it remains embedded in the core of one's work.

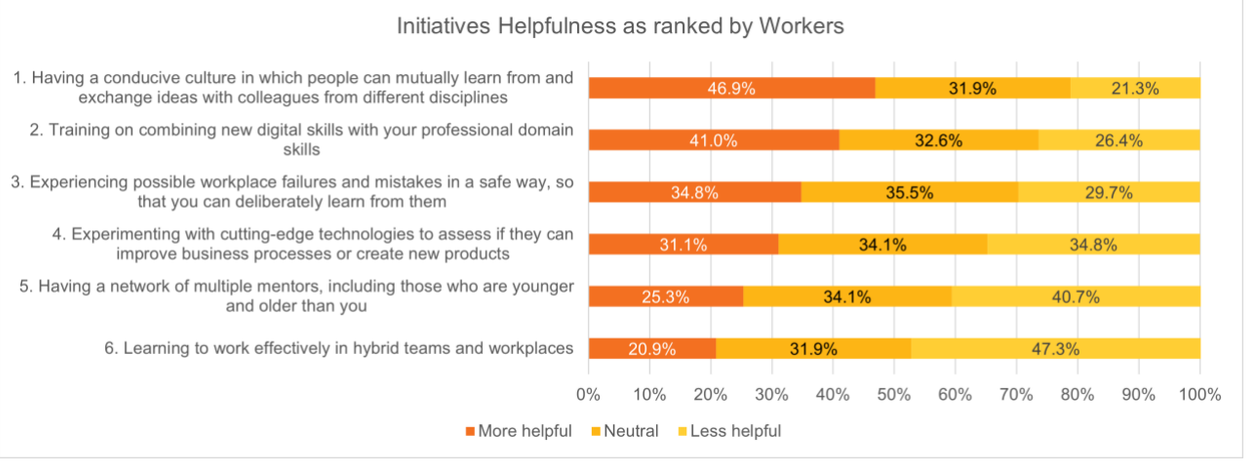


Figure 19: The helpfulness of various initiatives targeted to workers, as rated by manufacturing workers

Key takeaway: Bridging across hands-on, theory, and people-interactions can act as a 'glue'. It ensures that as workplaces digitalise and expertise requires increasingly more digital skills , different areas of the manufacturing process still hold together.

However, current up/re-skilling emphasise individual skills within a specific area (e.g., digital *or* domain) rather than interactions between people and the technologies they work with. Moreover, it leaves it to individual workers to develop these bridging skills. From our previous studies we know that this causes disappointment and even disillusionment with up/re-skilling.

Emphasising the bridging of skills can rectify this. It will raise the returns to our investments into skills. And it is likely that this needs an ecosystem of mentors/trainers/etc.

Tension #3. Going Deep or Going Wide?

Linear career/transformation/upskilling pathways push workers to be multi-skilled but within increasingly specialised roles. It is what the future of manufacturing demands, but this raises risks because it becomes more uncertain what they can do if these specialised roles are disrupted. The same pathways are also silent on how workers can manage these raised risks and uncertainties. While workers hear that they, in order to excel in their role, should accumulate skills progressively, they actually believe that training for multiple roles would be more beneficial to them to create new value, anywhere:

> *Training and learning again, it's, how to say, this oil and gas job, is a very, niche, career, you know, very specialised. When you're talking about re-training, you need to tell yourself that, hey, you cannot, depend on this industry, for long.*
> (E&C Technician)

Workers are well aware of the risk of overspecialisation in one's role. The uncertainties this brings to the table are the potential creation of an overdependency on specific skills and competencies. While this on the one hand creates value for the company and for workers' own expertise, this is not a guarantee for the future.

> *The thing about such a complex manufacturing process in such a huge company is that the more complicated the manufacturing process gets right, the more specialised each role becomes... In a smaller company, if you say that you're a manufacturing engineer, actually you could also be an equipment engineer. You could be walking the line, you could be working on utility costs, capacity, all these kinds of things. But in a big company, if you're a manufacturing engineer, they will give you such a pigeonholed role. And you can do that for years and years and years, you know. Of course, one thing is that the engineer will feel kind of like tired, they want a role switch, some, some will successfully do that they will change to a different role, so they can learn more new things. But there are those who are okay with it. And they will just continue in that, that role, but they don't progress, or they don't expand. It's very risky.*
> (Semicon Engineer)

Overdependency may not be the most viable strategy for today's age where manufacturing tasks, jobs, and even entire industries may transform rapidly due to digitalisation or external factors such as shifting geopolitics. Like a well-managed investment portfolio that spreads risks, a well-thought-out career strategy should be considered too.

A pertinent question to ask for skills development, then, is whether it should focus on 'going deep' or 'going wide', and whether it would be possible to strike a balance between the two. In this section we first look at some of the workers concerns around specialisation. We then turn to the things they suggest themselves on how this issue can be addressed. Overall, workers seem to have quite a resilient approach when it comes to their thinking about their employability—which is a strength Singapore's manufacturing sector can draw on.

Workers experience several uncertainties because of specialisation

Most concerns that workers expressed regarding overspecialisation were quite practical in nature. And interestingly, for many the issue is related to learning and training. One Precision Engineering technician, for example, provides an illustrative example of why their company chose for a 'cross-training' strategy:

> *Our company is not a big organisation with many sub functions and so on. So a lot of things are actually, resources are very lean. We never train 1 person to do just 1 job. We call it cross-training, multiple jobs and so on.* ***Everybody should know a few sub assembly processes. That's how we cater for all these unforeseen circumstances, go for MC, go for leave. So we still have people who are able to manage.*** *Cross training is important, it is not enough to have 1 person to do that job, or [even] if that is an easy job [to them], you are wrong, you make sure you have a backup. So all this training is very important.*
> (PE Technician)

While this company chose a strategy that aims to spread the risk in terms of assuring that the skillset of employees was broad rather than only specialised, the reality is that in most companies this is not the case.

Overspecialisation may inhibit learning

We heard from multiple workers that following training or courses was often simply not an option. This had to do with the fact that the manufacturing process was already organised in such a 'lean' way that the production line could not afford losing manpower for the day.

> *A lot of times we're working on what we need to do to deliver. We can learn a lot from our colleagues, and we do have update meetings, but those are not really learning in a way that* ***if one of them is on leave for a whole week one of us is still able to step in to fulfil the role. At the moment it's still that if that person is not here today nobody else knows what to do.***
> (AM Engineer)

Companies that are too 'lean' can be a real issue for workers, especially when thinking about the importance of learning new skills or freshening up existing accreditations or competencies.

Overspecialisation may inhibit job mobility

What's more, on top of companies being 'lean', many require a form of specialised depth of skills and knowledge that helps the production process but not the individual worker per se. An engineer in the semiconductor industry reflects on this issue in talking about people who have stayed in the industry for a long time:

> *Those that stay for a very long time, they have to have reached a level whereby their expertise is really so specific. And also, I think, valued by this particular company such that it will be difficult for them to move out, I feel. I mean, once you stay that long, right, you've built up all your knowledge and skillset in this specific industry, right, it also becomes more and more difficult to move on. And if they feel valued by the company, I don't think they would have any reason to want to go elsewhere.*
> (Semicon Engineer)

As we will show in one of the next sections, manufacturing workers are in general quite optimistic about their perceived job mobility. However, this quote is a reminder that the development of only deep skills at the cost of broader, bridging skills may temper this. Bridging skills may increase job mobility of manufacturing workers because it opens up the possibility of bridging roles, too.

Overspecialisation benefits the company, not necessarily the worker

While most respondents understand and agree that manufacturing often requires specialised knowledge, many felt it primarily benefited their employer rather than themselves. For example, during a focus group discussion with E&C engineers and technicians one of the sentiments we felt was that workers ideally saw the role of upskilling as helping them to remain competent in their own job or in adjacent jobs, while also helping them acquire a better pay. In practice, however, upskilling primarily led to a higher workload without being compensated for it.

Two engineers explicitly mentioned they would like to learn skills that would prepare them for a wider set of roles or jobs than their current one, in order to be better prepared for future career options. An AM engineer, for example, mentioned that most of the skills she learns are directly related to a project she needs to work on. In other words, learning is ad-hoc and benefits the company but not always immediately the worker. Instead, she would like to:

> *...to have a bit of time or a window to develop ourselves. And it doesn't have to always be, like, programming skills or things like that. One of the things that we also need, maybe things like managing people... I think a lot of times, as an engineer, you know, if you want to progress in your career, at some point, you might become a manager. But, we didn't learn how to be a manager. And this could be important in trying to make sure that your team is happy. And make sure that you know, you're communicating, you're being*

> *the correct bridge between the higher management and the people that do the day-to-day work. I feel like these are skills that I would want to have when I reach that sort of position.*
> (AM Engineer)

This seems to be an overall concern for workers in the manufacturing sector, as it was reiterated by another engineer as well:

> *But if you are staying in the field, yes you get paid a lot. but you don't, you don't learn so much of the other skill set. Such as soft skills or other core functions, like you don't learn about T&L, you don't learn about accounting, you don't learn about cost function. All these kinds of things,* ***because in the field, most of the time, you will be the only engineer there, and there are very few opportunities to learn things outside of your work.***
> (E&C Engineer)

Now we have covered some of the practical concerns that workers feel uncertain about when it comes to becoming too specialised in one's job, we want to turn the attention to a more optimistic scenario: workers, in general, feel quite confident in their job mobility and also identify more generic 'engineering skills' that would help them move out of a specific sector—when necessary.

Workers are moderately confident in their job mobility

In our survey we asked workers whether they believe they have the skillsets that allow them to pursue other roles within or outside the industry. The results show that a majority of workers are more confident than not. 79% of respondents were at least moderately confident that they had such a skillset to pursue other roles within the industry, and 70% were at least moderately confident on having the skillset to pursue roles outside the industry (Figure 20).

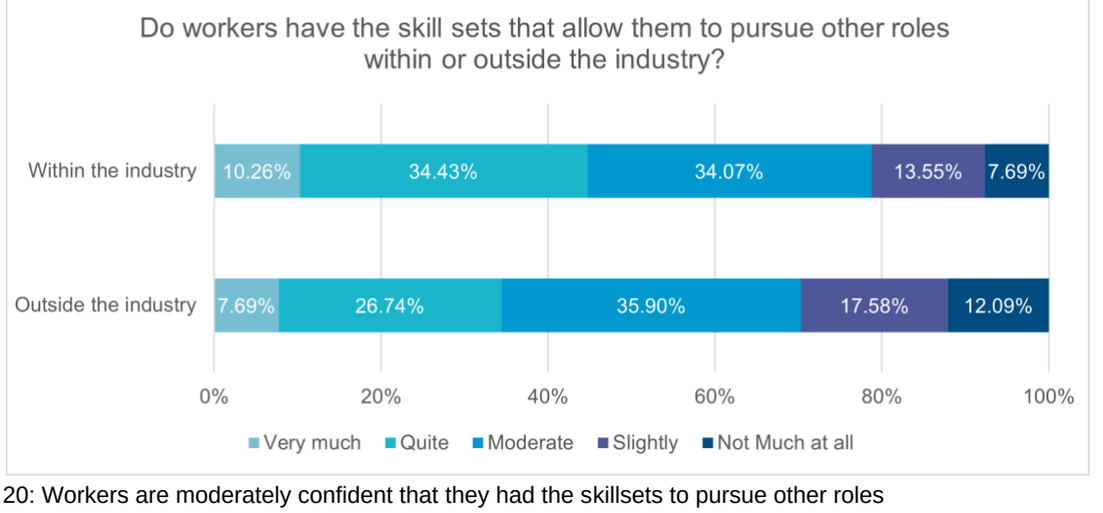


Figure 20: Workers are moderately confident that they had the skillsets to pursue other roles

In the previous paragraphs we highlighted how manufacturing workers accumulate skills that are overly specialised, i.e., specific and non-transferable. The results of this survey suggest that the wider manufacturing workforce also possesses other skills that they believe are transferable to different roles within the industry (and also to roles outside the industry, to a lesser extent).

To identify what these skills could be, we turn to our interviews with engineers who have some confidence in crossing into other roles.

Workers identify 'generic engineering skills' that could contribute to them bridging roles

In our interviews several respondents hinted at what we interpret as an already existing trait in the manufacturing sector that provides an opportunity for workers to bridge between roles. For instance, throughout our interviews we were quite surprised to hear that the educational background of engineers we spoke with did not necessarily match their current industry (for example, a mechanical engineer working in the semiconductor industry; an electronic engineer working in E&C, etc.). Engineers themselves liken this to the idea of certain engineering skills being rather transferable, i.e. there exists a sort of engineering mindset that is similar across industries. See, for example, the following two quotes:

> *Even from what I see within our department is that a lot of the engineering skills are easily transferable. So there are some, like the industry knowledge, I guess, is things that you need to pick up if you were to change to a different company. So say, if I moved to, like an energy generation company, I think a lot of the sort of like, I guess, maybe soft skills, like analysis, or critical thinking things like that would be very helpful. I would need to pick up on things like a bit of the energy generation technology. But I think generally, if you're working in that company day to day, this process happens like really quickly. Yeah. And I still have colleagues that do a bit of like programming. I'm sure this is easily transferable to maybe like electronics or software.*
> (AM Engineer with background in sustainable energy engineering)

> *I believe it's very easy. Because as long as you have some kind of manufacturing background, you're already pretty much as equipped as you can be. There are no, you cannot go to university and study additive manufacturing explicitly. Like maybe there's some small unis offer something in that direction, but the big uni, the broad majority will not have will not have had the opportunity to go to uni and say, Okay, I want to major in additive manufacturing, maybe there's some small course but you know, no big thing. So there are no educational requirements when it comes to that aspect, I guess. So a lot of it was driven by personal interest. There are a lot of people here that, you know, they started out with a small 3d printer at home, and then they thought additive manufacturing, quite cool. And they learned simply or they got into the topic by playing around and then eventually got more into touch and got more serious about it. And if you have any form of*

manufacturing background, and the right interest, I think you're already well equipped. Okay, on top of, you know, the requirements I mentioned earlier, where you meet some data analysis, etc.
(AM Engineer with background in foundry engineering / material science)

What these quotes tell us are two things. Firstly, respondents themselves also suggest that having broader skills that are industry agnostic are valuable. Industry specific skills are often learned on the job anyway, because even within similar industries the equipment or processes to work with may be vastly different. Second, our respondents seem to imply that having a strong generic skillset that transcends specific industries may make them rather mobile as manufacturing engineers. These insights paint a hopeful picture for the future of manufacturing on a national, Singaporean level. As we have described in detail before, the industry is characterised by its volatility. This has always been so and will most likely remain so for the near future. Thus, Singaporean workers may be well off being equipped with broader skills that prepare them for multiple roles so they can adjust with the whims and woes of the market.

Key takeaway: Career/transformation/upskilling pathways should **go beyond multi-skilling within a role**. They should instead **develop workers for multiple roles** as a deliberate strategy. The recent pandemic experience reinforced how employees and employers are both capable of the mindset shift for this.

With multiple roles, workers can **diversify the risks and uncertainties** they face. They also **bridge roles**, expanding their—and the companies' and industries'—critical capacity to **bridge skills** (see earlier point).

Chapter 4: Recommendations — Crafting Skills Security and Giving Workers Voice Through the RIE-CET-PET Systems to Master Uncertainty and Create a Singapore Advantage

Our recommendations revolve around resolving the tensions and uncertainties that workers encounter as they navigate the opportunities and risks in the years ahead. We summarise how these are all linked with this diagram:

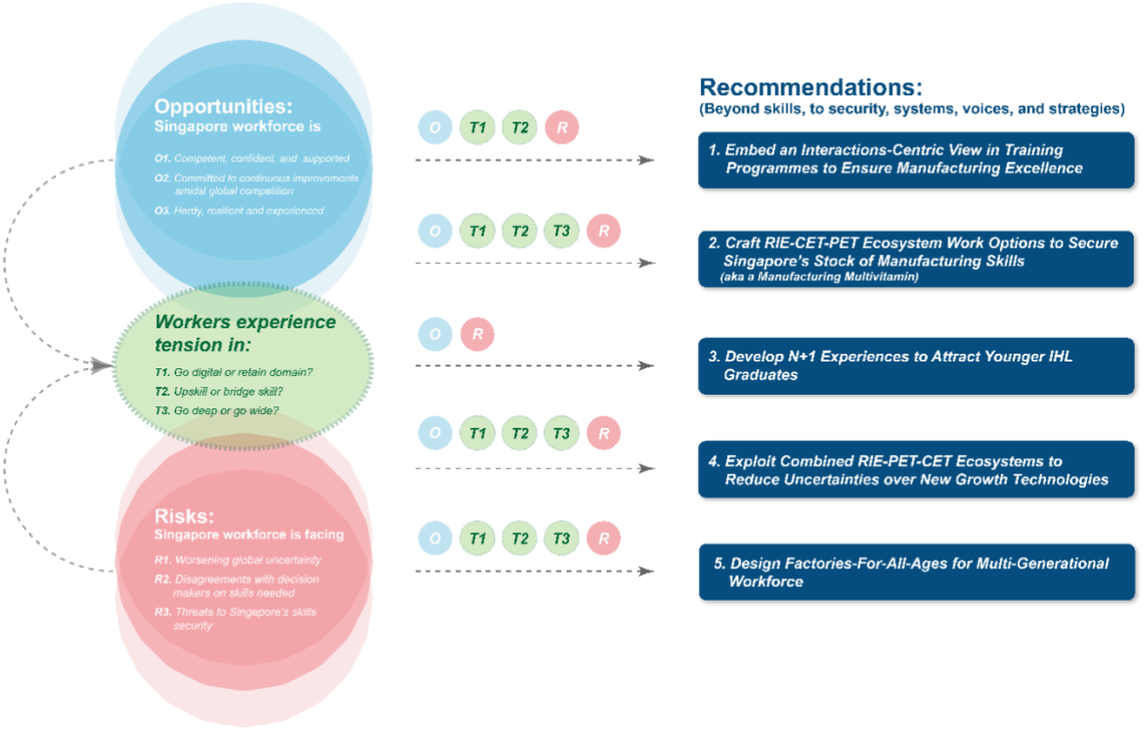


Figure 21: The opportunities, risks and tensions outlined in the previous sections inform our recommendations

The overarching objective of the Recommendations is to safeguard Skills Security (see section on Risks, especially how Risk #3 can only be managed if Risk #1 and Risk #2 are managed). It is the only way Singapore can secure the expertise needed for its strategies to succeed and have the stock of skills that Singapore needs for its manufacturing sector to automate, digitalise, transform, compete, and excel.

Skills Security must however be crafted because it cannot happen naturally or with the current strategies. That is why in addition to describing how the Recommendations can be implemented, we also draw the links between the opportunities, tensions, and risks to each Recommendation. This is because the links make clear how each Recommendation crafts Skills Security to target specific risks and tensions to capture the opportunities.

Cognisant of the diversity of job roles and levels within the manufacturing sector, we have taken cue from EDB's classification of job archetypes and streamlined workers into the following five broad categories which we have mapped our recommendations against.

	Operators	Technician	Engineers: Domain Specialists	Engineers: IT Specialists	Plant Managers
R1: Embed an Interactions-Centric View in Training Programmes to Ensure Manufacturing Excellence	✓	✓	✓	✓	✓
R2: Craft RIE-PET-CET Ecosystem Work Options		✓	✓	✓	✓
R3: Develop N+1 Experiences to Attract Younger IHL Graduates		✓	✓	✓	
R4: Exploit Combined RIE-PET-CET Ecosystems to Reduce Uncertainties over New Growth Technologies		✓	✓	✓	✓
R5: Design Factories-for-All-Ages for Multi-Generational Workforce	✓	✓	✓	✓	✓

Table 3: Mapping of recommendations to job archetypes

We know that the future of manufacturing in Singapore is advanced, high-tech, and will command a smaller manpower footprint as the country continues to grow the sector by 50 per cent as it advances towards its 2030 ambitions (CNA, 2021). Hence, the concept of a "Just Transition", while mostly used in the discourse on climate action and the green transition, would also be applicable to the manufacturing sector as workers must be ensured that they will not be left behind in the transition to Industry 4.0. While we attract younger workers into the sector in our bid to grow the pipeline of local talent, upgrading the skills and domain knowledge of existing workers remains crucial. We have taken a stab at envisioning what this the future of talent attraction, development, and retention for the manufacturing sector looks like, to ensure a future of manufacturing that not only thrives on its own merits but also continues to engage and appeal to the workers of tomorrow.

Recommendation #1: Embed an Interactions-Centric View in Training Programmes to Ensure Manufacturing Excellence

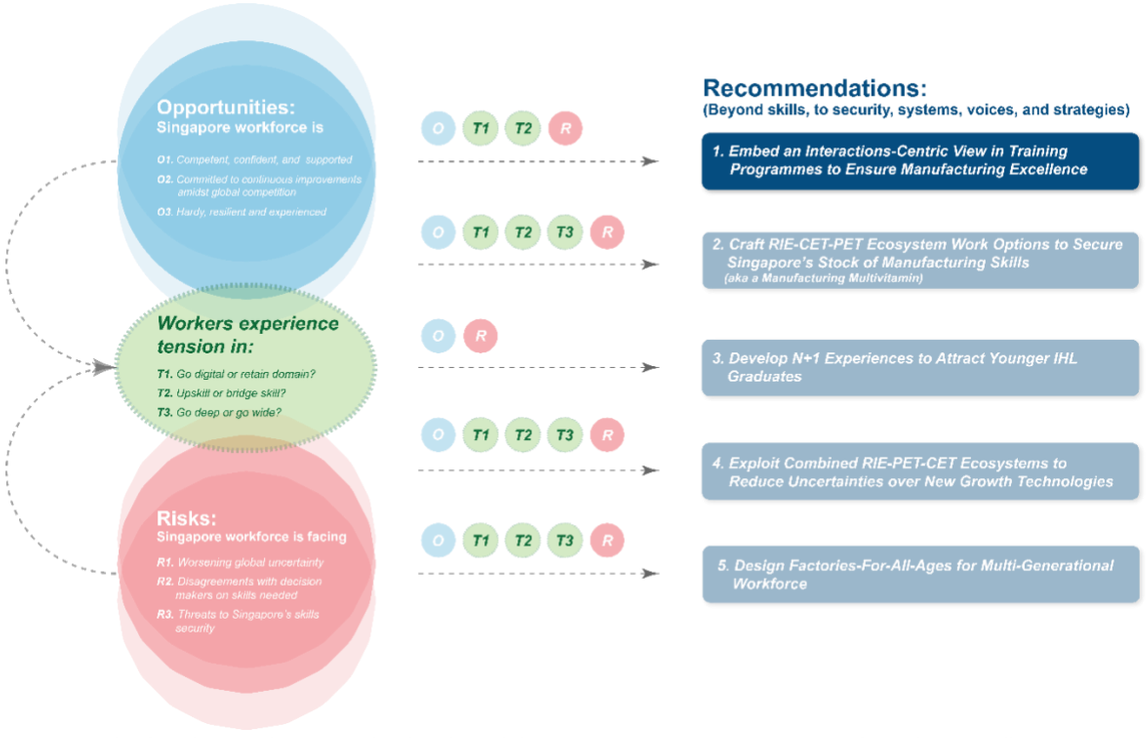


Figure 22: Embed an interactions-centric view in training programmes to ensure manufacturing excellence

The first recommendation is to embed an interactions-centric view[2] in training programmes to ensure manufacturing excellence, reduce the uncertainty over the value of upskilling and to raise the global competitiveness of the workforce.

From the survey of workers and our interviews with them about what they say they need, three competencies must be prioritised:

1) Combining the domain and digital
2) Practising and experiencing deliberate failures
3) Closing the following competency gaps:
    - Global competition
    - Local competition
    - Applying new technologies

In our Distributed Mastery model (Appendix D) we outlined what the future of expertise in an increasingly digital workplace looks like. One aim of the current study was to see how insights from this Distributed Mastery model could be extrapolated to inform the future of manufacturing. Our findings indicate that the Distributed Mastery model can be used to think about developing the manufacturing workforce. Specifically, this takes workers

[2] An interactions-centric view refers to a grounding in domain fundamentals and interactions essential to manufacturing excellence. Such a view is important because expertise is now distributed across people and technologies, and workers must build the meta-skills to access this distributed expertise through interactions within an ecosystem.

beyond an individual-centric view of upskilling to an interactions-centric view, that is also grounded in the domain fundamentals and interactions essential to manufacturing excellence. Together, these can inform what must be done to assure that Singaporean workers can face an uncertain future ahead. Below we provide some examples of what this may look like.

Taking an interactions-centric view instead of an individual-centric view will also strengthen workers' capacity for the contested global economic future. They will know how to work with an expanded number of suppliers and collaborators as supply chains become diverse with trends in shorter and regional supply chains, and geopolitical developments such as ally-shoring.

Implementation

Training courses and on-the-job training can be adapted or redesigned to target the three areas above.

In the instances where the companies and workers have tight timelines and are unable to spare the time for training, they can be incorporated into requisite regulatory courses (e.g., safety), as well as any existing courses that employees are already required to attend.

Three ideas on how they can be incorporated:

1) Combining the domain and digital. Existing and upcoming digital transformation and training initiatives in companies must analyse and assess the impact on human capabilities and how digital technologies can complement the domain expertise that is fundamental to the companies' competitiveness. In our Distributed Mastery Model, we identified several ways in which this can be done. We briefly touch on these below, together with quoted experiences/observations from our fieldwork as examples:

- *Understand the impact of technology on human competencies*

Going beyond a technological-deterministic perspective on workers requires focusing on understanding how technology impacts the way people do their jobs and how it changes their skills and competencies. An example from our fieldwork:

> *And the worst is that they say that certain phenomena are correct because the tools are correct. So, like, for example, why is this happening? So you may say, because the software says so. I mean, this is not acceptable because you have to go further. The software says so, because? Why? Because why? And then, as you start answering all, that is where you make use of your basic knowledge."*
> (Chemical Engineer)

Understanding the impact of technology with such granularity is important because it allows identifying where people can become complacent, where human capabilities will matter even more, and how technology can be used in the most sensible way. This involves trade-

offs, as implementing new technology usually means to reduce human expertise in some areas and amplify it in others:

> *"So, it's bound to a trade off in some of the new technology. Nobody does filing today, last time we used to use a U-channel. 2mm height, U- channel block, file for one week, until become flat. That was the kind of training. Today we don't do that. They try to tell you, why waste the time? Just use the machine to sand it down. But they don't understand a lot of the skills involved, you know?... So these are techniques. But today they don't do that. You still need the old technology. So there's a lot of things changing. But then, there's also good things, let's put it that way. The 3D printer. I just put in and walk away, tomorrow I can collect my part. I don't learn anything. Correct? So digitalisation is advantageous, but it also involves dropping some of the old skills."* (Manufacturing Engineer)

- *Applying new technologies i.e. experiment/innovate with new technologies*

Adding on to the previous point, training initiatives can also facilitate experimentation and innovation through new technologies. Doing so via training courses ensures that workers themselves become part of this process rather than having their work practices changed by ideas of external parties or consultants. This moreover helps to retain the connections of new technologies with the domain knowledge of workers. One example clearly demonstrates this, with an engineer sharing how they created their own video tutorials to pass down knowledge between workers:

> *"I'm fine with some face to face, I mean we get our engineers to have this physical training with us. But once we finalise the product, video tutorials or some kind of work instruction have to come in, and have to be in place, because that is to retain knowledge. If you don't have those, it cannot be right. For example, if today I want to train you, I will tell you something. We do have cases in this let me share with you, which made me very pissed off. The engineer goes to the technician, whatever he says to this technician is super good, and he writes it down and it becomes almost like a bible. After that engineer will think he is an expert already, and then we expect this guy to go and rain. So he trains using his bible, to train. The other person writes it down again and this is something that I cannot accept. So that's the purpose behind the training video, followed by some kind of standard work instruction or whatever in the manual form. If you don't come out with all these, whatever we do is ever consistent, based on that. It's based on memory and I can tell you we are still not perfect. There will be some kind of deviation."*
> *(Precision Engineering Engineer)*

These are relatively easy innovations but since they are developed through training sessions and with/by the workers involved, they are of immediate value to their work.

2) Practising and experiencing deliberate failures. The courses can also include explicit efforts to design deliberate failures to improve learning in the workplace. We can already draw on existing practice, such as this example from our fieldwork:

> *So, what they will do to you in the training right, they will psycho you… they will purposely screw up your job although you plan everything perfectly, screw up your job and see how you deal with failure… But he just tries to question you and test you. And he will make you work, running here, and there, like an idiot. Once you have done everything smoothly, he will go behind your back, and just turn off something, and you have to fix the problem. Why? What this is to train our mental toughness. And I see that in my company basically, everybody who leaves the company, we can see that become so much tougher mentally.*
> *(E&C Technician)*

This in fact is particularly relevant for safety-related courses such as those in the energy and chemical industry. In fact, instructors of the Diploma for Chemical Engineering at Singapore Polytechnic are already experimenting with this as a potential avenue to educate technicians and engineers that are more confident and competent.[3]

3) Assessing local and global competition through existing local and regional benchmarks. For example, we can assess the threat of regional and global competition from the outsourcing possibilities of hybrid/remote work that was accelerated by the pandemic and could be accelerated further by the cost-cutting that companies are pursuing to cope with inflation and recession risks.

Where benchmarks do not exist or are too expensive to procure, they need to be part of a larger industry-wide or Singapore-wide effort—we explain how in Recommendation 5.

[3] Cheah, S. M. (forthcoming). Chemical engineering education: Pedagogy for learning from failure in process plant operations. *Proceedings of the 19th International CDIO Conference*, Norway.

Recommendation #2: Craft RIE-PET-CET Ecosystem Work Options to Secure Singapore's Stock of Manufacturing Skills (aka a Manufacturing Multivitamin)

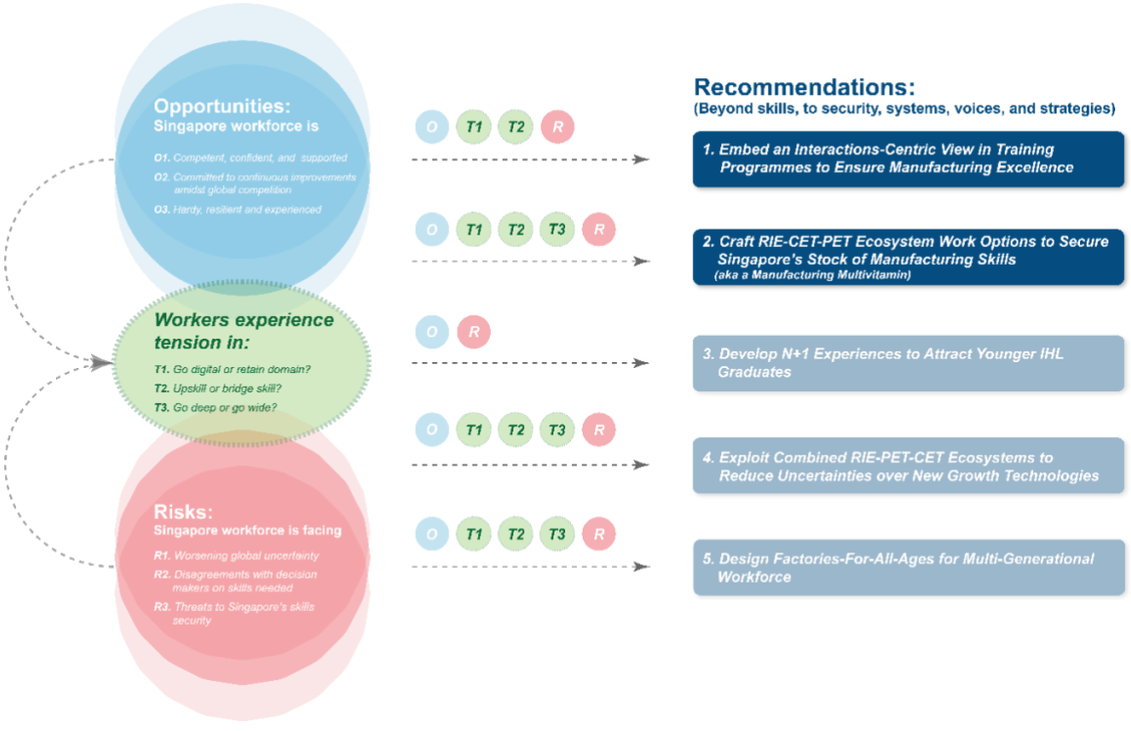


Figure 23: Craft RIE-PET-CET ecosystem work options to secure Singapore's stock of manufacturing skills (aka a manufacturing multivitamin)

Having ensured manufacturing excellence, we must ensure we retain workers in manufacturing for Singapore's skills security.

At the same, we have seen from the discussions on Tensions, that our workers also risk being too specialised. This is the nature of work in the manufacturing sector, but when dislocations happen, their over-specialisation makes it hard find new options, leading to workers leaving the industry.

They find it hard because when there is an industry downturn, there will be few opportunities for the same role within their same industry. We use a real-life example to illustrate: J is trained as a mechanical engineer. Upon graduation, he was able to move quickly into the direct role of an engineer in semiconductor manufacturing, earning an amount commensurate to his qualifications, eventually progressing to a managerial position. If he is dislocated in an industry downturn:

- he will be unable to find a similar role within the same industry as hiring might be frozen.
- he risks being paid less if he moves to a different role or to a different industry (or paid nothing if he starts his own venture).

If the above leads to him leaving the industry, his experience and expertise will be lost too.

Implementation

We hence propose a Research Innovation & Enterprise-Pre-Employment Training-Continuing Education and Training (RIE-PET-CET) Ecosystem Work Options Strategy. This Strategy complements existing PET-CET initiatives in Singapore. The existing initiatives focus on placing affected workers in similar roles within the same industry, or different roles in different industries (see grey boxes in Figure 24). As we pointed out in the earlier paragraphs, this might be hard to do in an industry downturn and may result in lower pay, position, and under-utilisation of experience and expertise.

The RIE-PET-CET Ecosystem Work Options Strategy (see green box in Figure 24) overcomes this by drawing on the strength of Singapore's RIE ecosystem to increase certainties about pay and potential to make the most of their existing skills. We can place them in roles within IHLs and Research Institutes because IHLs and Research Institutes often appreciate having industry experience and expertise to inform their education, training, and research programs, and IHLs and Research Institutes have a pool of experienced industry professionals to draw on. At the same time, the dislocated workers will be able to work with students and researchers to experiment and be exposed to different, new, and emerging technologies and ideas. This strategy could be employed in situations where dislocated workers have no industry-related employment options in the event of a downturn. When the industry recovers, they are in an even better position when they re-join the industry, and the new experience could even lead to new links and partnerships between industry, research institutes, and IHLs.

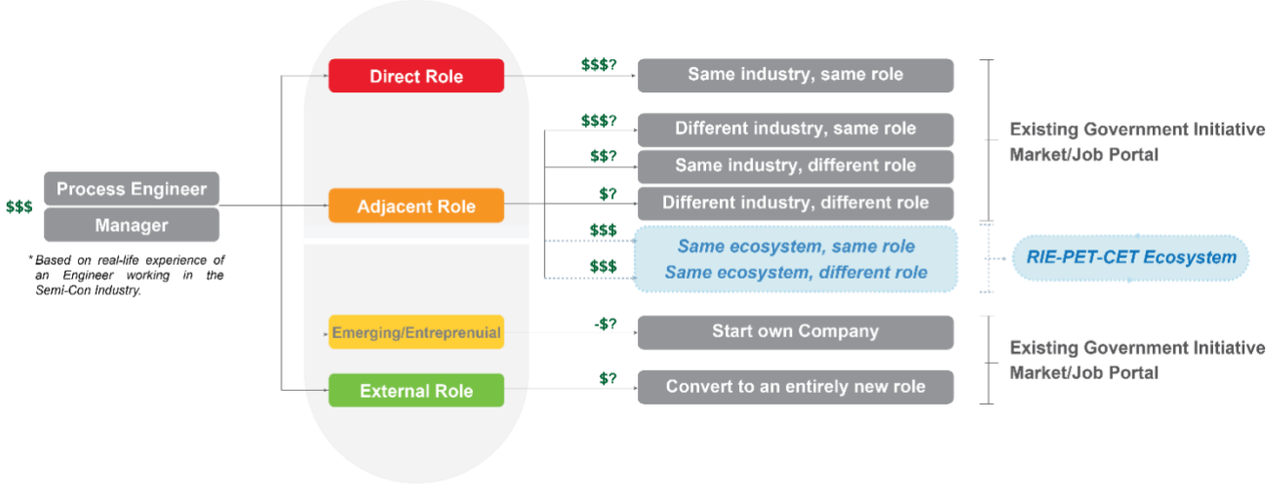


Figure 24: RIE-PET-CET Ecosystem Work Options generated by the Multivitamin Strategy (The Multivitamin Strategy is a recent research insight from LKYCIC that describes a method of offering resilience to workers by diversifying their pathways and increasing mobility between these pathways on the basis of shared tasks.)

In addition, by keeping them within manufacturing, Singapore retains and secures its skills for the future. To do so, decision makers can take advantage of the factors that encourage workers to stay (see Figure 25).

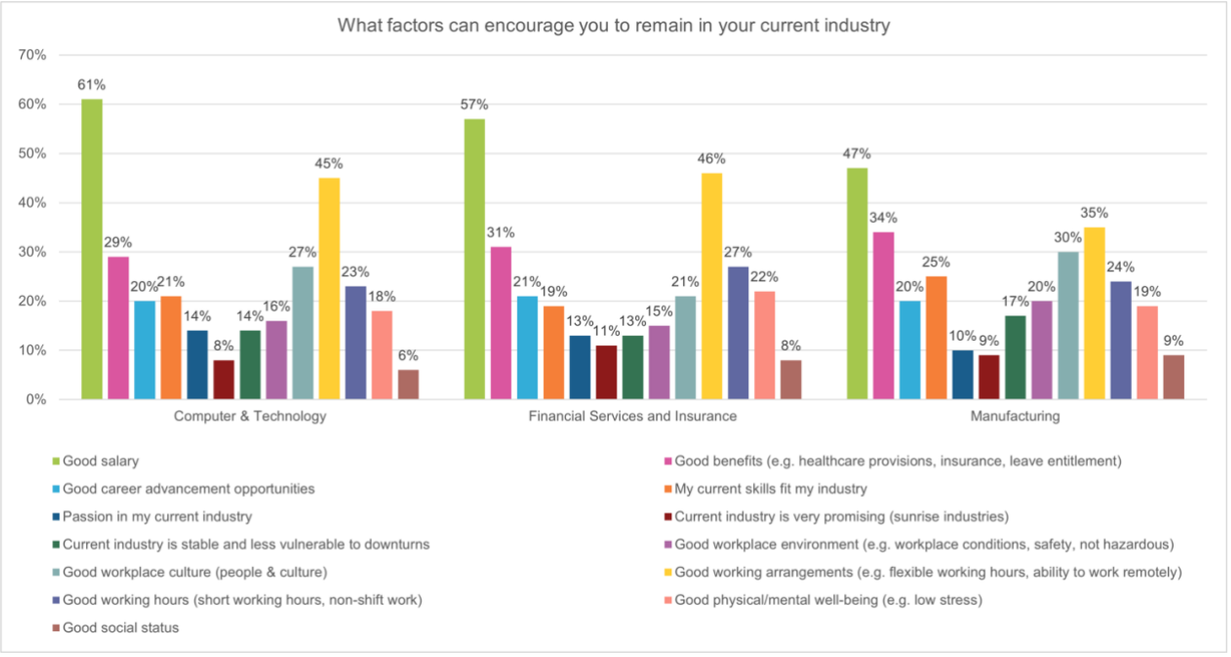


Figure 25: Factors that can encourage workers in the Computer and Technology, Financial Services, and Manufacturing to remain in their industry

Expanding work options through the RIE-PET-CET Ecosystem is also consistent with our latest research into what makes for career resilience. In addition to incorporating emerging ideas from career scholars, publications, and organisations ranging from OECD to Harvard Business Review[4] we have also developed the Multivitamin Strategy[5] which lays out multiple pathways so that workers and employers can diversify their bets across multiple tracks, including direct roles, adjacent roles, emerging/entrepreneurial roles and external roles (see Appendix F). Moving opportunistically across multiple pathways creates fluidity. One can thus think of the RIE-CET-PET Ecosystem Work Options as the Manufacturing Multivitamin Strategy.

[4] These include Ibarra's 2002 article on "How to Stay Stuck in the Wrong Career", updated for COVID-19 in Harvard Business Review's 2021 collection on Career Resilience.

[5] The Multivitamin Strategy is a recent research insight from LKYCIC's project on Designing Resilience Task-by-Task that was funded by SIMPDF. It is a new way of designing career experiences for individuals using AI and human insight. In the same way that taking a multivitamin offers resilience on multiple fronts, a career multivitamin offers resilience to workers by diversifying their pathways and increasing mobility between these pathways on the basis of shared tasks. As opposed to conventional methods of job transitioning/job search, the Multivitamin Strategy uses tasks because jobs are disrupted task-by-task, and not skill-by-skill.

Recommendation #3: Develop N+1 Experiences to Attract Younger IHL Graduates

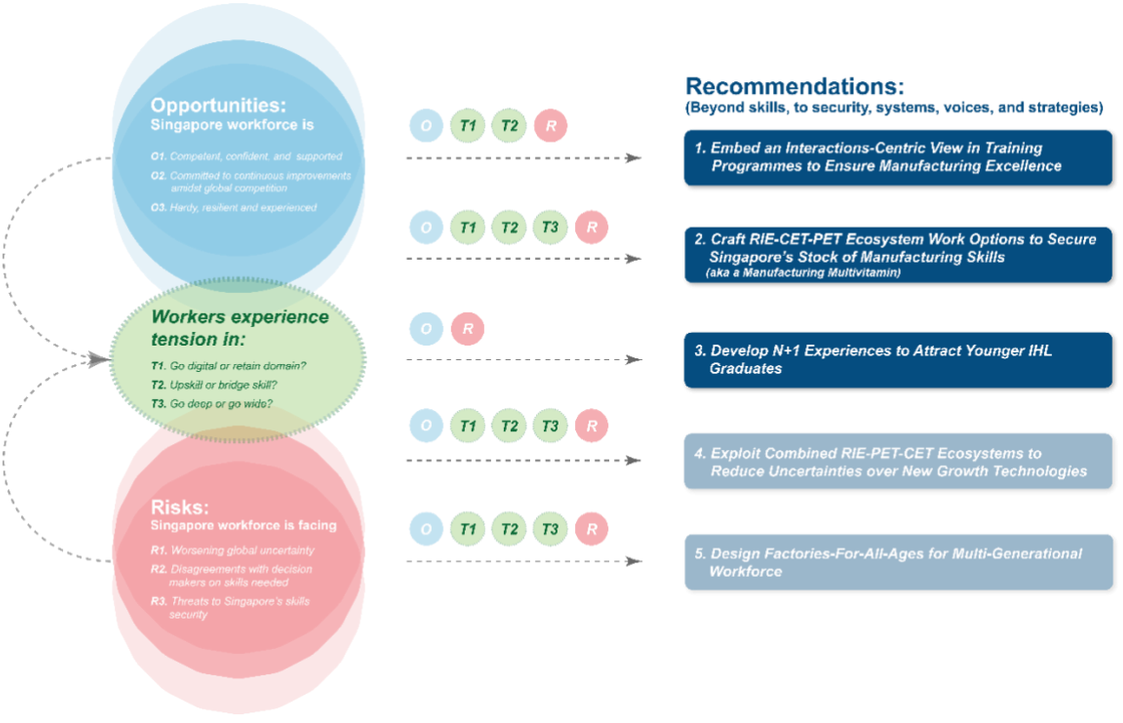


Figure 26: Develop N+1 experiences to attract younger IHL graduates.

The third recommendation focuses on attracting younger IHL graduates because without new workers entering the industry, skills security will break down in the future.

Industry-Ready and Future-Ready N+1 training, internships, and mentorships can be co-developed with IHLs to incorporate emerging and next-generation technologies, work tasks, skills, and interactions (e.g., interacting with Robotic Process Automation or RPA). N+1 is a terminology commonly used in the semiconductor industry to refer to the next-generation technological node. Next-generation technologies are what we need to be training IHL graduates for; these are being implemented—or will be implemented in the next 2-3 years—in companies, but are not taught in schools yet, and which graduates will need to be adept in.

This reduces young workers' uncertainty about career prospects and reduces industry uncertainty over long term talent and skills pipeline. Higher-skilled graduates might also make it possible to be offered higher salaries to attract more talent (who are now drawn to the salaries in other sectors). Moreover, higher salaries will tackle head-on the number one push factor—low salaries—for younger manufacturing workers. In our survey, we saw that younger manufacturing workers tended to view low salaries as the main factor that would make them leave the manufacturing sector (Figure 27).

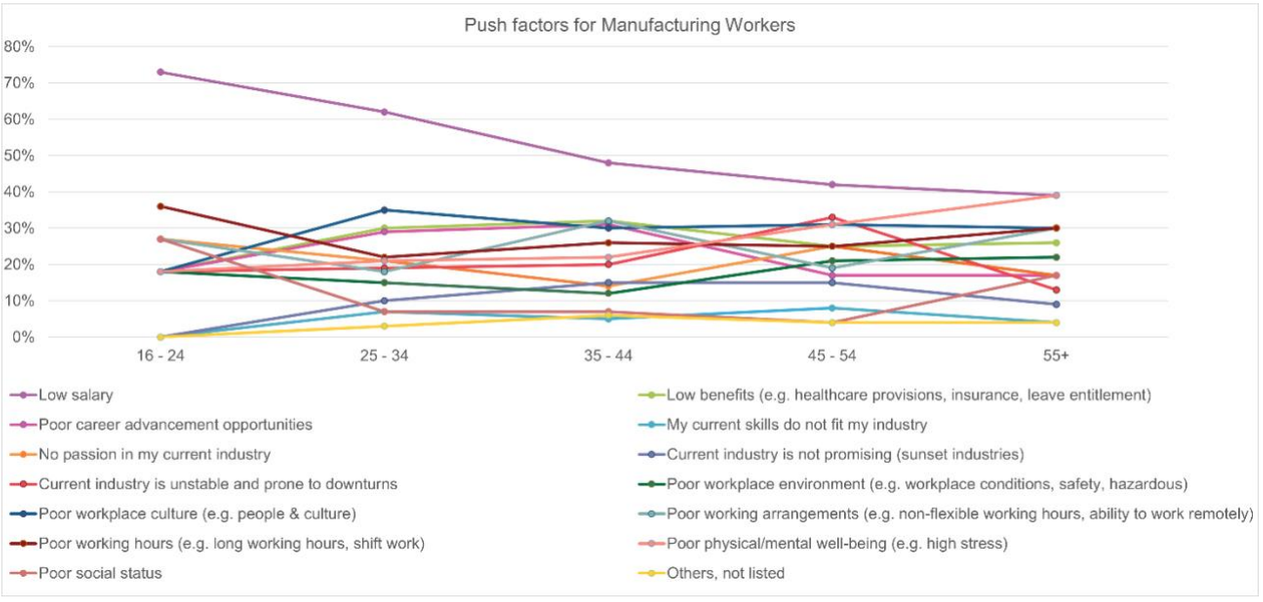


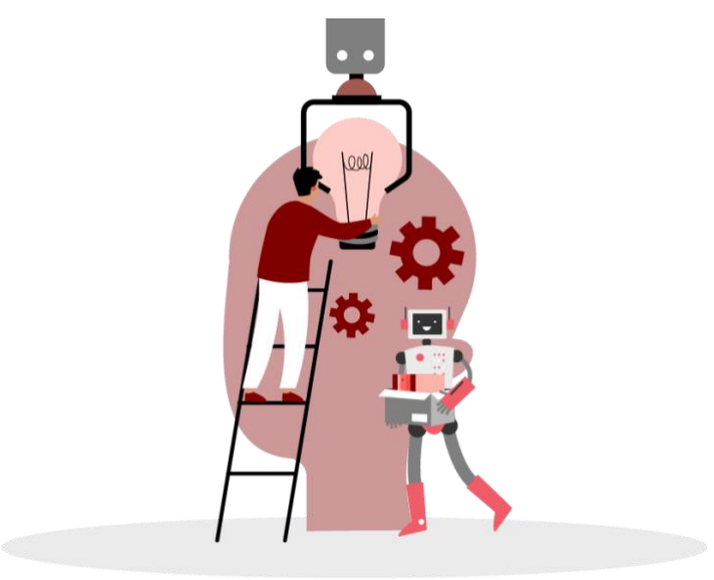
Figure 27: “Push” factors that cause manufacturing workers to consider leaving the sector, breakdown by age

Implementation

These N+1 training, internships, and mentorships can be co-developed between youth groups and/or organisations with IHLs by enhancing existing initiatives such as internships, industry projects, and work-study programs.

The key difference with existing initiatives is an explicit focus on next-generation technologies. Where the next-generations technologies are not available in Singapore yet, the young talent can be sent overseas to sites or suppliers where there they can be found.

In addition, there can be collaborations with Trade Associations and Chambers (TACs) to identify existing or future problem statements in the industry that IHLs and partner organisations could contribute to using next-generation solutions.



Recommendation #4: Exploit Combined RIE-PET-CET Ecosystems to Reduce Uncertainties Over New Growth Technologies

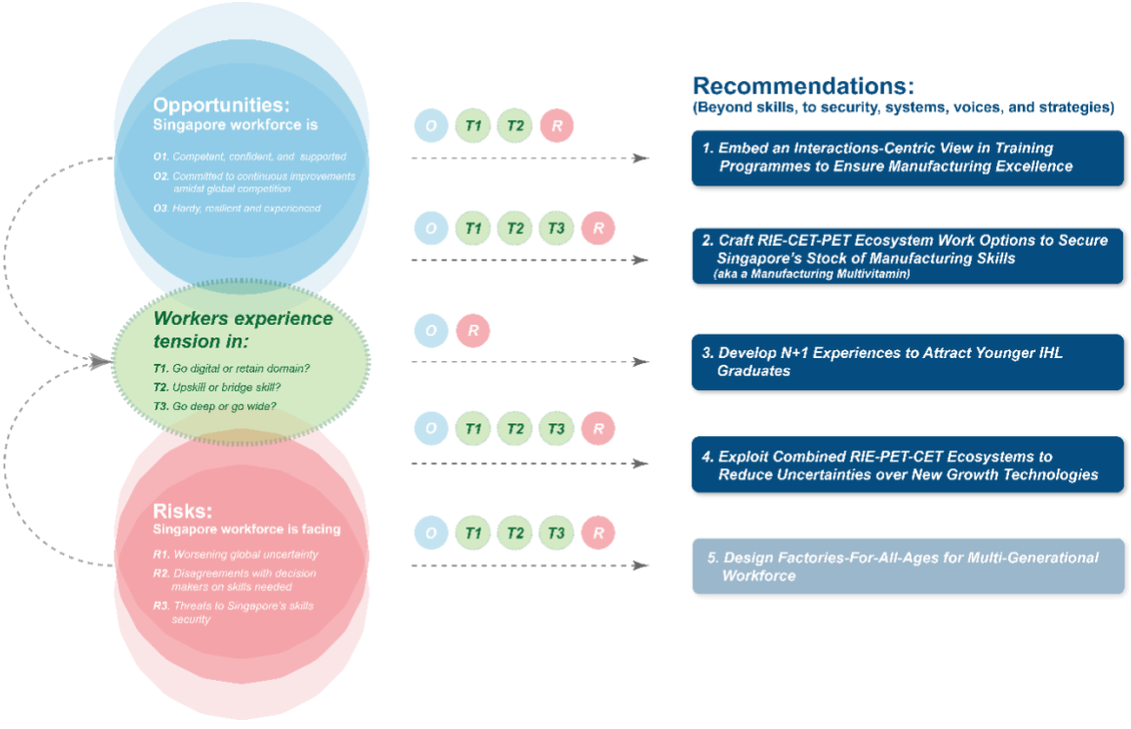


Figure 28: Exploit combined RIE-PET-CET ecosystems to reduce uncertainties over new growth technologies

With N+1 initiatives and the RIE-CET-PET Ecosystem Manufacturing Multivitamin, we can build on them to allow workers to go beyond the PET-CET skills ecosystem to the RIE (Research-Innovation-Enterprise) ecosystem. This will reduce the uncertainty of new technologies, applications, and innovations for workers. Workers can also create new value that reduces uncertainty of their competitiveness and increases their value (and more likely to earn more and less likely to be displaced). Just as importantly, we are drawing on the high confidence and competence that manufacturing workers have (which we have pointed out earlier in this report).

Using AM as an example:

- workers and companies are both uncertain about the speed and scale of new growth technologies.
- Singapore has invested in research in these fields, but applications remain uncertain.

The RIE ecosystem may allow workers a channel for experimentation with new technologies to actively probe, bridge, and even create the future.

This would in turn deepen our manufacturing strengths and create new competitive advantages.

Implementation

We recommend building on existing, institutionalised training initiatives that workers and companies can build upon. This ensures we can start and see results sooner than later, and that there is sustained support for experimentation and innovation. It also means workers who are SuperLearners (see our previous study “Polarising of Job Opportunities—Charting New Pathways and Adopting New Technologies”[6]) can help to lead the way, and support for them is sustained too.

[6] http://www.otcinstitute.org.sg/wps/wcm/connect/b5b9d3b5-7883-4f99-8fef-b0566af29e4d/LRC2018-Polarising+of+Job+Opportunities.pdf?MOD=AJPERES

Recommendation #5: Design Factories-for-All-Ages for Multi-Generational Workforce

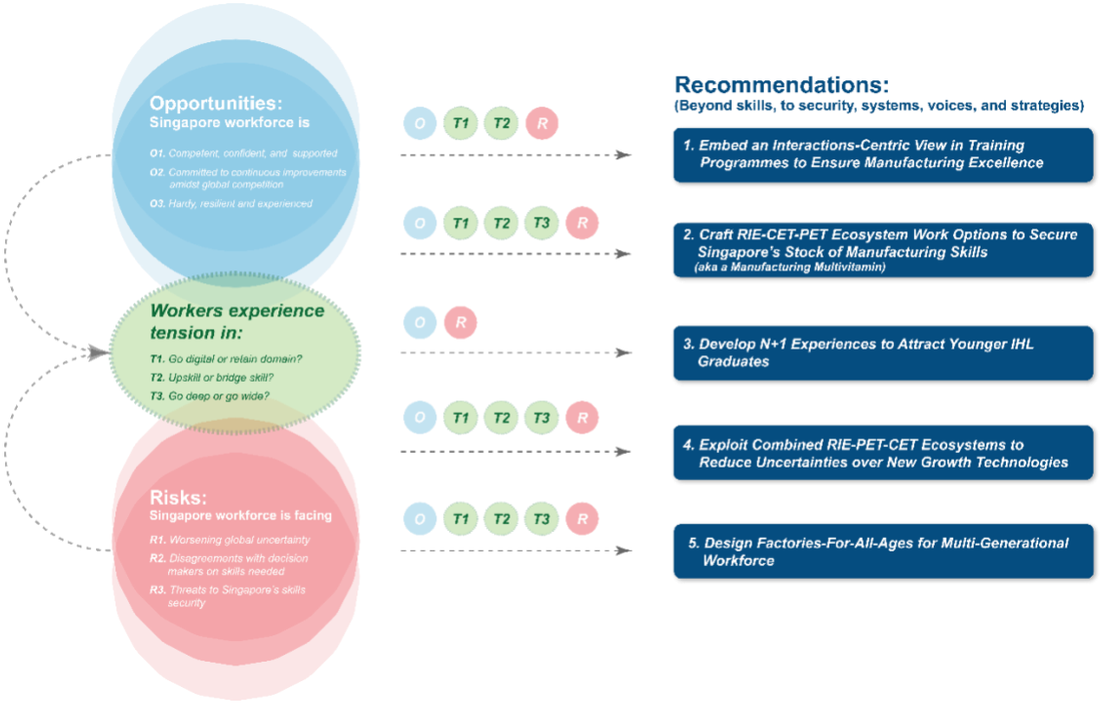


Figure 29: Design Factories-for-all-ages for multi-generational workforce

The fifth recommendation takes all the above recommendations to envision future factories where all ages feel they have a future and where they work well with each other.

We call these Factories-for-All-Ages, where inclusive multi-generational workplaces reduce uncertainty about the future by signalling to workers across generations that they have a future together, and within generations that their professional, physical, and psychological future will be nurtured.

This also addresses the importance that manufacturing workers place on workplace environment. In our survey, we found that 20% cited a good workplace environment as a factor that can encourage them to stay in their industry, as compared to ~15% of workers in other sectors (Figure 25).

Implementation

A select group of organisations across the public-private-people sectors can be identified to first develop the roadmaps for designing and building Factories-for-All-Ages, and subsequently to design and implement them.

We provide a few examples of possible projects based on our fieldwork. They include:

1) Using accessible technologies to raise domain-digital literacy together:

Creating a multi-generational workplace that is inclusive is important so that workers across generations can learn from each other. In our Distributed Mastery Model, we had outlined how mastery in the digital age is distributed across people-people interactions. Within multi-generational workplaces, this mastery is also distributed between people of different age groups, seniorities, and hierarchies.

Digital transformation and automation in manufacturing does not replace the skills and expertise of the older generations. Rather, these skills remain valuable because they aid in troubleshooting when issues arise and gives them a more holistic view of the process; therefore, they are useful to younger workers entering the industry. Conversely, the older generation will need to pick up digital skills and new technologies as they are increasingly important in streamlining production and improving productivity.

However, in some cases workers may be resistant to new technologies because they do not see the immediate benefit, or they are used to their old ways of doing things. In our previous fieldwork, we saw how the gradual, incremental introduction of new technologies can be helpful so that workers are given time to adapt:

> *We just say by this date, usually this is a common practice, by this date, we will phase out the old one. You no longer look at the old one. So you have this period, this amount of time to learn the new system. But of course we wouldn't make the new system very difficult. Like learning a totally new software. It's not like that. It will be just a very simple kind of upgrade.*
> (E&C Engineer)

Additionally, as suggested by our Distributed Mastery model, this would provide an opportunity for companies to rethink workplace learning and to encourage multi-directional mentorship. Where traditional mentorship has been unidirectional (from senior to junior), multi-directional mentorships (see, for example, Poon et al., 2023; Yang et al., forthcoming) can benefit both young and old workers. While senior workers can pass on their embodied knowledge and deep experience to juniors, juniors who tend to be more familiar with the digital aspects of work (because they acquired their technical skills in a digitalised setting) can provide new perspectives and accelerate digital transformations in the workplace. This cross-learning can aid in improving domain-digital literacy for all workers in the workplace.

2) Improving ergonomics for older workers:

Figure 30: Ergonomics-focused Porsche Leipzig Factory (Picture Credit: © Martin Klindtworth for the Financial Times)

> *When I see my other older colleagues, I think I can work much longer in this facility, maybe (in) the next three decades.*
> (Mid-Career Porsche Employee)

As we have shown earlier in our report, the average age of manufacturing workers has been increasing. Therefore, there is a need to increase focus on workplace ergonomics, in order to create an inclusive workplace environment that allows workers to remain healthy and capable into their later years.

"Cobots" or collaborative robots which are tools designed for direct human-machine interaction within a shared space, can be used to aid workers tasked with repetitive or physically demanding tasks where viable.

Where robots are not suitable, wearable ergonomic aid devices that help mitigate repetitive strain injuries are another option that can be explored. Examples of these include wearable sleeves on elbows or knees that can support joint movement during repetitive tasks (Figure 31).

Figure 31: Example of a design concept for a wearable device that can provide knee extension assistance for workers who spend long hours walking/climbing

These can be developed as part of a direct initiative via Recommendation 3 (i.e. N+1 effort to attract young talent, showing how they can make a difference), and Recommendation 4 (i.e. exploit the RIE-PET-CET Ecosystem). If such devices are deemed by companies as a lower priority because they are seen as a cost instead of contributing to the bottom line, it can be a national RIE-PET-CET effort to design affordable bring-your-own-devices innovations that individual older workers can afford. This could even be subsidised to enable our ageing workforce to continue to perform well at work. And given workforces are ageing worldwide, these innovations could even find an international market.

Most importantly, a workplace environment should be designed with ergonomics in mind. Workstations can be designed such that workers can avoid uncomfortable postures when doing their daily work. For example, in the Porsche Leipzig factory, vehicles on the assembly line are lowered and rotated 90 degrees on to its side, so that workers can work on the underbody without having to look up and strain their necks (Financial Times, 2019).

3) Increasing engagement and energy for higher levels of well-being
By looking at work on a more granular level, we can start breaking down a job into tasks that we can classify as either energising/engaging or de-energising/disengaging. This is helpful—especially so because nobody hates or loves everything they do in their job—because it allows to design interventions that improve the worker's experience of their job and workplace.

Take for example the figure below (see Figure 32) which is a breakdown of tasks for an Automation Engineer in the semiconductor sector. 14 routine and non-routine tasks were identified that the worker did in their job. Specifically, four tasks were identified that were very exhausting and not engaging for the worker, such as Task Two (T2) of developing manufacturing specifications for equipment and machines. This can help individual workers, teams, leaders, and organisations better understand their workers well-being by pinpointing specific tasks that are exhausting and not engaging. Through this, better work processes and work experiences can be created that are more motivating and beneficial for the worker and this can bolster the worker's productivity.

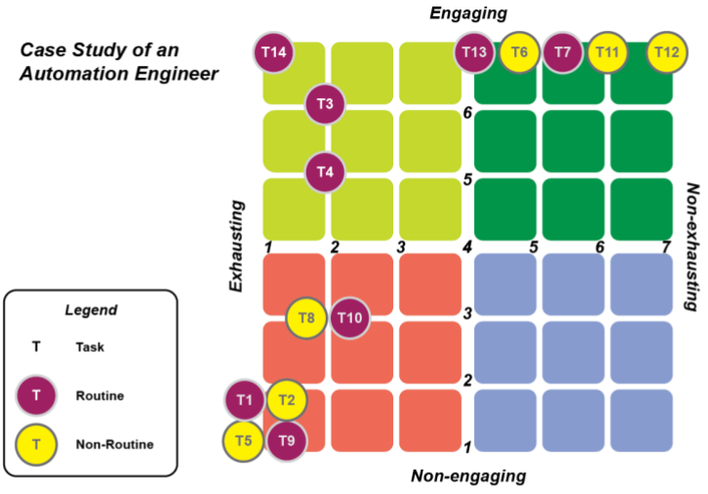


Diagram: *Well-being matrix of an Automation engineer in the semi-conductor sector (Goh & Poon, 2021)*

Task Description

- **T1** Analysing workforce utilization and production schedules and costs to determine optimum equipment efficiencies.
- **T2** Developing specifications for manufacture, and determining materials, equipment, material flows, capacities of plant and systems.
- **T3** Organising and managing project labour and the delivery of materials, plant and equipment.
- **T4** Establishing standards and policies for installation, modification, quality control, testing, inspection and maintenance according to engineering principles and safety regulations
- **T5** Inspecting plant to improve and maintain performance.
- **T6** Directing and maintenance of equipment and coordinating the requirements for new designs and maintenance schedules.
- **T7** Advising management and operators on new production methods, techniques and equipment.
- **T8** Liaising with materials buying, storing and controlling departments to ensure a steady flow of supplies.
- **T9** Conduct analyses addressing issues such as failure, reliability, or yield improvement.
- **T10** Create or maintain formal engineering documents, such as material specifications, packaging requirements and standard operating procedures.
- **T11** Develop or validate product-specific test protocols, acceptance thresholds, or inspection tools for quality control testing or performance measurement.
- **T12** Design engineering systems for the automation of industrial tasks.
- **T13** Coordinate with colleagues to plan workplace bonding activities.
- **T14** Coordinate with vendors to maintain and purchase equipment and processes.

Figure 32: Well-being matrix of an Automation Engineer in the semiconductor sector (from Goh & Poon, 2021)

If Singapore can design such Factories-for-All-Ages, it will open up a global opportunity because many countries across Asia and Europe are now facing the same challenges as populations age and workforces become increasingly multi-generational.

Chapter 5: Conclusion — The Value of Worker's Voices in Creating a Strategic Advantage Only Singapore Can Achieve

When we listen closely to workers' voices when constructing the Future of Manufacturing, like we have done in this report, there is much to look forward to but also much to prepare for.

Singapore's existing pool of manufacturing workers are an asset. With a median age of 50, many of them have experienced the highs and lows in the sector and as a result they had to build up resilience. Our survey and interview results obtained through the course of this project paints the picture of a workforce that is confident in their skills and their ability to adapt to disruptions in the sector. A majority of manufacturing workers feels that they have most of the skills needed in the industry for the near term. Further, they perceive themselves to be more versatile than others, with a higher confidence in their skills enabling them to move between industries if they desire.

At the same time, there is much to prepare for. Worsening global uncertainty could lead to disruptions in global supply chains, affecting the opportunities available for workers in the manufacturing sector here and the skills that are required. In order to maintain Singapore's foothold in manufacturing, we need to maintain Skills Security in the manufacturing sector.

We can get a glimpse of how to do this by giving voice to workers.

Through extensive fieldwork and surveys conducted we identified how tensions arise when manufacturing workers experience uncertainties around their future opportunities, relevance, and further development of their skills. Insights from this deep dive on the experience of workers informs our recommendations on how to raise the mastery of manufacturing workers and how to retain Singapore's stock of skills by creating multi-role options for workers.

Our surveys also provide insight into the current worker sentiments around the manufacturing sector. While higher salaries are the common thread for workers in any industry wanting to make a change, manufacturing workers have a stronger desire to switch to a different industry, more so than workers in other industries. This poses a threat to Singapore stock of manufacturing skills. With Singapore's existing RIE ecosystem there is an opportunity to create new value for existing manufacturing workers. At the same time, Singapore needs to secure a steady stream of talent into the manufacturing sector. Here, much needs to be done. Our surveys indicate that the manufacturing sector is not attractive to Singaporeans, in particular younger workers. The manufacturing sector is perceived to have poorer working environments and salaries as compared to other sectors. To change this perception in the long term, Singapore needs to develop a manufacturing sector that provides forward-looking, exciting growth opportunities, introducing and driving new technologies that attract the best talent to join the sector. In the next decade or two, we will

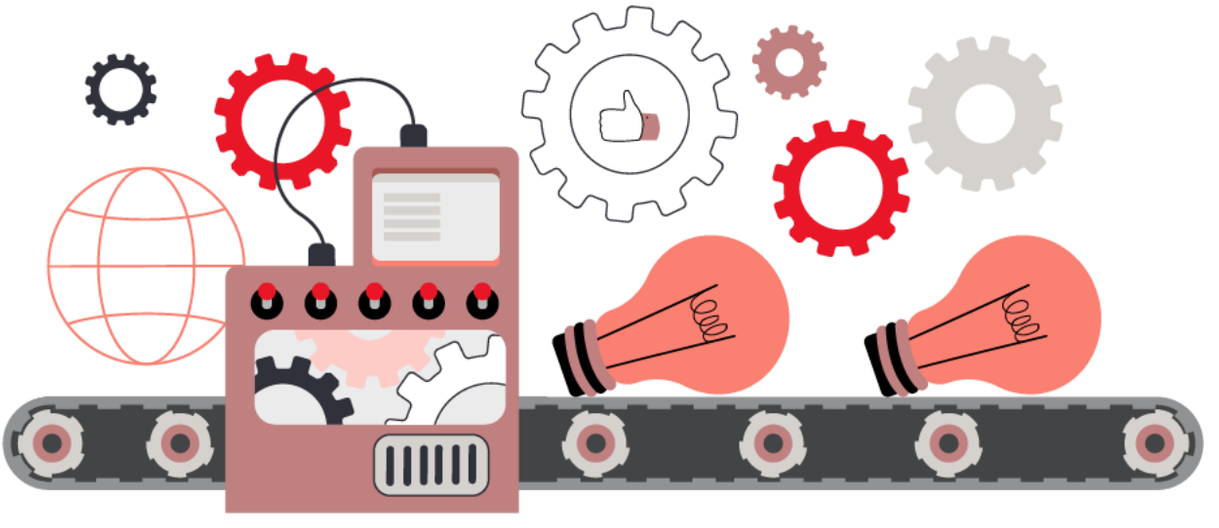
see a lot of older workers retire from the manufacturing sector. And with them, the sector will lose a wealth of knowledge and expertise. This can partially be augmented with new and ‘smart’ technologies. But, as we have shown in this report, this in itself is not enough to retain the deep domain fundamentals in the industry. For this, we need more forward-looking initiatives that supports human capital, rather than seeking to replace it. In the recommendations section of this report, we have given several first solutions on how this could be done.

By making these preparations and drawing on the strengths of our workers, we can create a strategic advantage for Singapore and Singaporeans that no other country can. Singapore is in a unique position because:

- few countries have the systems in place to give workers voice.
- few countries also have made the extensive and broad-based investments in PET and CET.
- few countries have made the sustained investments in Research, innovation, and enterprise strategies.

Hence, when taken all together, our Recommendations can help achieve an additional strategic objective beyond Skills Security. Our Recommendations—by combining the workers’ voice with exploiting a combined RIE-PET-CET ecosystem—takes full advantage of what Singapore has that few countries have.

And when we succeed, our Recommendations will secure skills with the same systems-thinking as we secure supply chains and create a strategic advantage unlike any other.

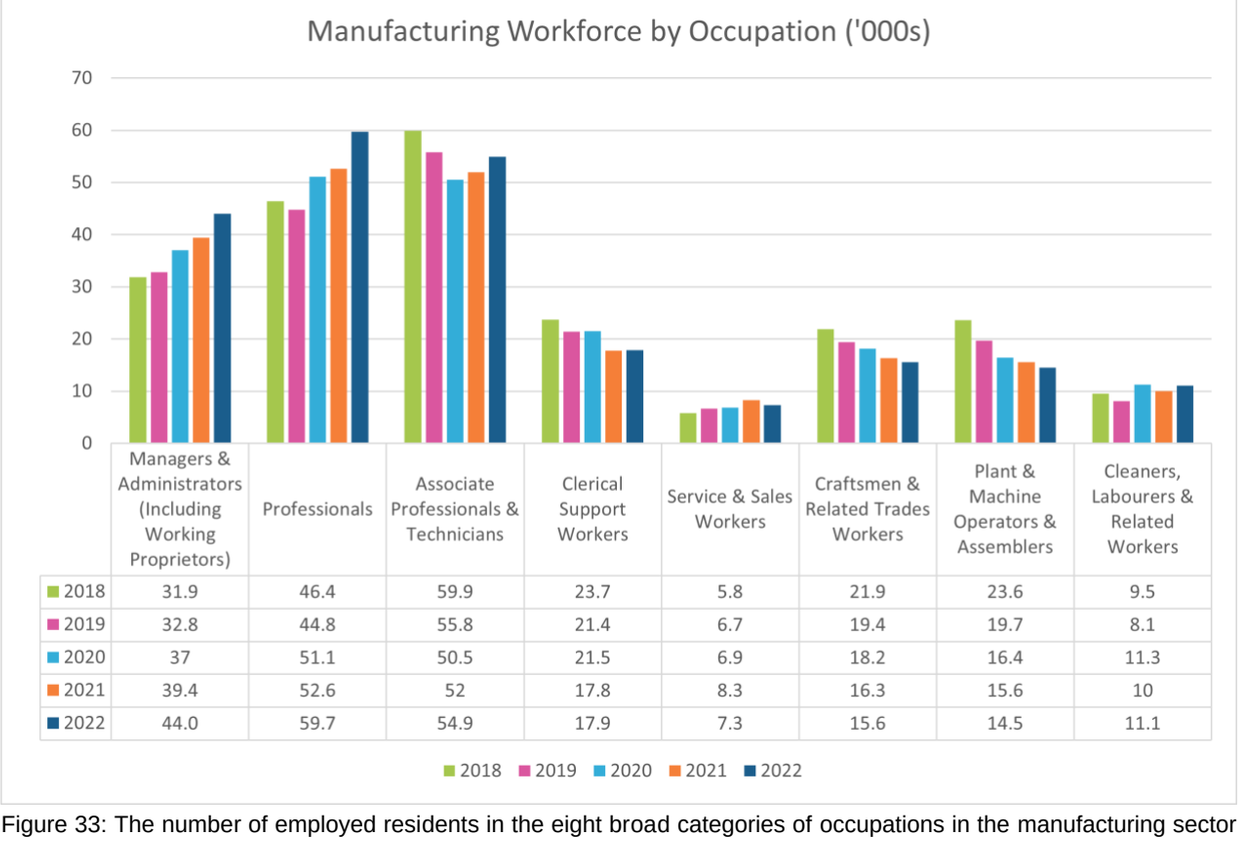


Appendix A: Manufacturing Workforce Demographics

A brief analysis of trends of the workforce in the manufacturing sector over the past five years was done based on data from the Ministry of Manpower's annual and quarterly Labour Force reports. The number of filled occupations typical of "white-collar" roles (i.e., in the PME categories) has seen a steady increase while the inverse has been observed in the number of filled occupations typical of "blue-collar" roles (i.e., in the “operators” and “technicians” categories). This is corroborated by the highest education qualification levels commanded by the manufacturing workforce as well, with the majority of the workforce holding at least a Diploma or Professional Qualification.

The trend observed in job vacancies, however, is less straightforward. 2021 marked an increase in demand for not just PMET-roles but also occupations in the "Production & Transport Operators, Cleaners & Labourers" group. This may have been due to the acceleration of demand of electronics during the COVID-19 pandemic. In that year, the manufacturing output hit $88.09 billion—a 27.99 per cent increase from the output in 2020. Even as the manufacturing sector in Singapore progresses towards higher-value production processes and operations, operators and technicians still remain a key occupation group of the manufacturing workforce.

Employed Residents in the Manufacturing Sector Aged Fifteen Years and Over by Occupation From 2018 to 2022



	Managers & Administrators (Including Working Proprietors)	Professionals	Associate Professionals & Technicians	Clerical Support Workers	Service & Sales Workers	Craftsmen & Related Trades Workers	Plant & Machine Operators & Assemblers	Cleaners, Labourers & Related Workers
2018	31.9	46.4	59.9	23.7	5.8	21.9	23.6	9.5
2019	32.8	44.8	55.8	21.4	6.7	19.4	19.7	8.1
2020	37	51.1	50.5	21.5	6.9	18.2	16.4	11.3
2021	39.4	52.6	52	17.8	8.3	16.3	15.6	10
2022	44.0	59.7	54.9	17.9	7.3	15.6	14.5	11.1

Figure 33: The number of employed residents in the eight broad categories of occupations in the manufacturing sector aged fifteen years and over shows a trend that is emblematic of the sector’s transition away from labour-intensive production and towards high-value production. The share of PMEs has steadily increased over the past five years, while the number of Craftsmen, Plant & Machine Operators & Assemblers, and Clerical Support Workers has declined

Employed Residents in the Manufacturing Sector Aged Fifteen Years and Over by Highest Qualification Attained and Occupation Groups From 2018 to 2022

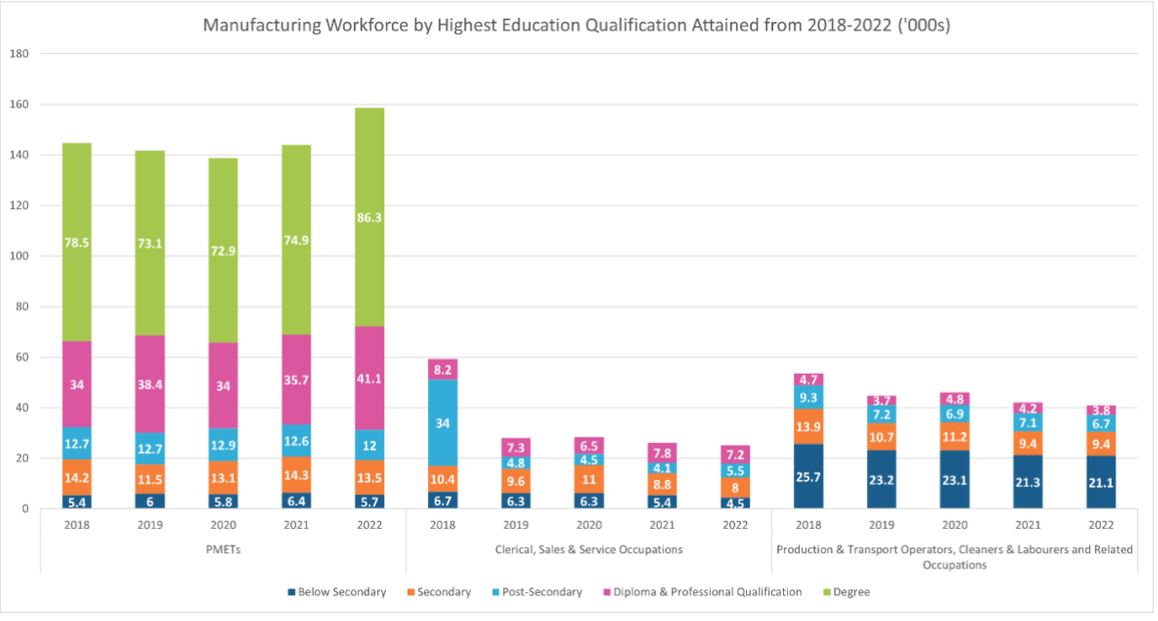


Figure 34: The number of employed residents in the three occupation groups in the manufacturing sector aged fifteen years by highest qualification attained shows an increase in the number of PMETs holding at least a Diploma or Professional Qualification. This may mirror the increase in high-value jobs that require specific, technical skill sets and domain, theoretical knowledge transferred within the setting of an Institute of Higher Learning. There has been an overall decrease in residents employed in roles typical of blue-collar workers and the share of those holding at least a Diploma or Professional Qualification remains small.

Number of Vacancies in the Manufacturing Sector by Occupation From 2018 to 2022

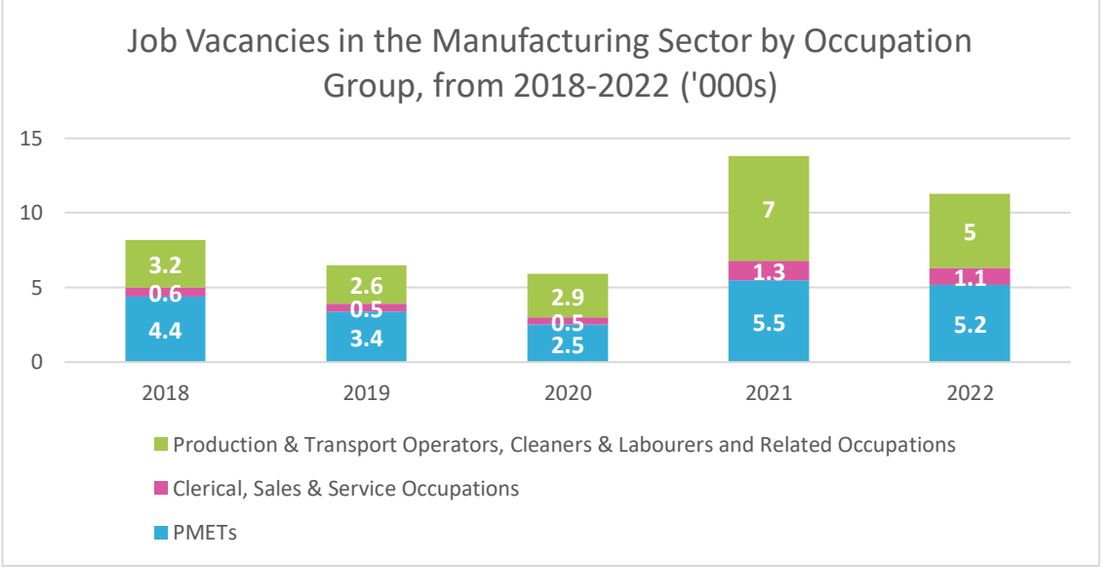


Figure 35: The number of vacancies for PMETs in the Manufacturing sector has undergone swings in the past five years and saw a sharp increase following 2020. The number of vacancies for Operator/Technician roles has also seen similar swings across the past five years. These vacancies are job posts which a company/organisation is actively recruiting employees for. The swings observed could be representative of the cyclical nature of the manufacturing sector explored in Chapter 2.

Appendix B: Survey Methodology

Sample

Survey 1:

A survey of 300 workers in the manufacturing sector was carried out to provide quantitative data to supplement the qualitative interview findings. The workers were aged between 19 to 73 years old, with a median age of 34. 136 of the survey respondents were male, and 164 were female. No gender differences were found among all the questions. Workers of various roles and departments were recruited for this survey, including engineers, technicians, accounting, and administration.

Survey 2:

A survey of 1300 workers across different industries was carried out. 300 of the respondents were from the manufacturing sector, 200 were from the Financial Services & Insurance sector, 200 were from the Computer & Technology sector, and the rest were from various other sectors. The median age of those surveyed was 30 years old. 600 of the survey respondents were male, and 700 were female. Workers of various roles and departments were recruited for this survey, including engineers, technicians, accounting, and administration.

Underpinnings

Survey 1:

The questions of the survey are created based on Distributed Mastery Model from the Mastery in a Digital Age study. The Distributed Mastery Model identified branches of masteries distributed between people-to-people interactions, and people-to-technology interactions. It can serve to be a diagnostic tool in identifying gaps and areas of improvement within workers and so the survey takes advantage in testing out this model's diagnostic function. A diagram of the model and its different branches is attached below. The survey therefore tests out worker's proficiency or lack thereof in the different areas such as ability to traverse different disciplines, using deliberate failures to empower themselves, and their embodied sense of the technologies they work with. In the survey, the specific phrasing of the masteries from the model had been adjusted to fit the context of the manufacturing workers better.

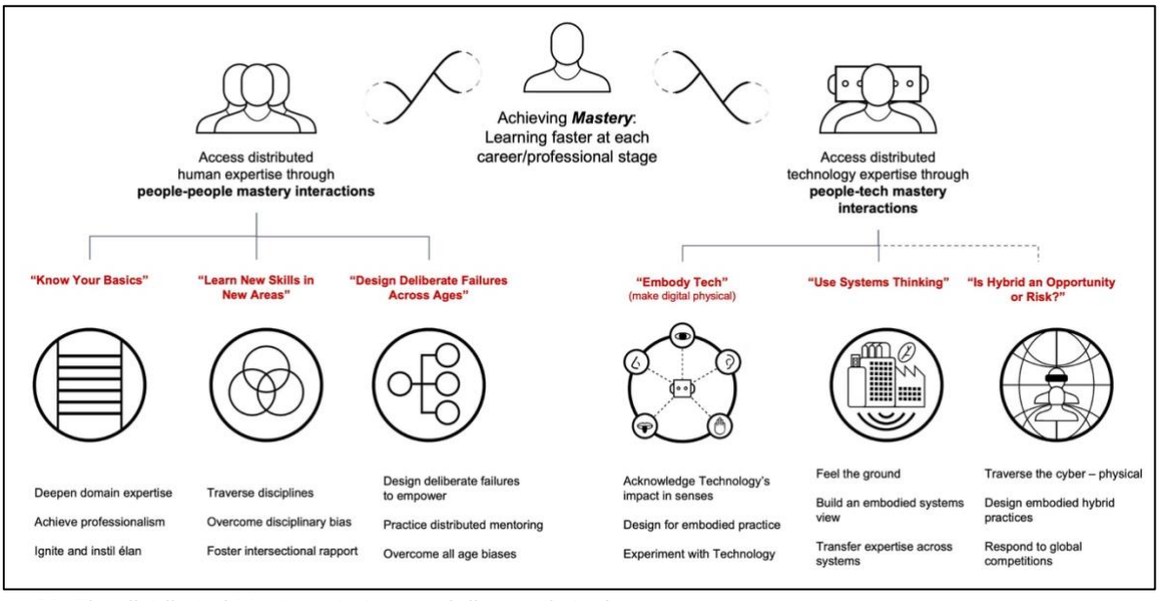


Figure 36: The distributed Mastery strategy and diagnostic tool

Survey 2:

The second survey was based on a need to ascertain the attractiveness of the manufacturing sector to workers within and outside of manufacturing. In the survey, questions were posed to investigate the entry and attrition of workers into and out of the manufacturing sector. The survey also tests out the causal factors leading to one wanting to leave or join the industry, their confidence to do so, and the barriers that they perceive.

Survey Structure

Survey 1:

The survey consists of 3 general sections of questions. The first section focuses on workers' experience and outlook, with questions on their certainty of different aspects of their work in the future and their perceived influence on their workplace. They were also asked about how appealing different alternative roles are for them to take on and how confident they think their skillsets allow them to perform those roles. These questions help reinforce or provide alternative insights to findings we got from the interviews.

The second section of questions focuses on assessing competencies of the workers based on the different "masteries" that were derived from our previous study on Mastery in a Digital Age. These competencies include interactions between people such as interdisciplinary mastery and intergenerational mentoring, and interactions with technology such as the use of digital skills to foster domain skills and the ability to exploit technology to experiment and innovate. The survey respondents were asked to rate their perceived level of competency on these different masteries, and also on their perceived importance of them. Any discrepancy between their competency and the perceived importance would therefore indicate potential gaps in their work.

The last section of questions focuses on potential recommendations that workers could find helpful to their industry and themselves. They were asked to rank the appeal and helpfulness of different possible programme initiatives, and on the different CEC roles are to them. These questions would help provide suggestions on which recommendations are favoured and perhaps could be prioritised.

Survey 2:

The survey consists of 3 general sections. The first section serves to assess worker's willingness and confidence to switch to a different industry from that which they are currently in. This serves to establish a baseline of the likelihood of workers from the manufacturing sector and also other industries to make a career switch to a different industry.

The second section focuses on ranking the attractiveness of different industries to workers across all sectors. The survey respondents were asked to rank the appeal of different industries and also the ease of entry given their existing skills and qualifications. Focus was also placed on the manufacturing sector in particular, with a question targeted at non-manufacturing workers to assess their view of the manufacturing sector.

Finally, the last section focuses on the causal factors leading to workers wanting to change to a different industry, and the barriers preventing them from doing so. Conversely the factors leading to workers wanting to remain in their existing industry was also assessed.

On both the first and second survey, descriptive analysis was carried out on the survey results. Correlation analysis was also run between the different questions and the demographic factors, such as income, age, and work experience. The specific questions and their result analysis would be elaborated on as and when they are relevant in the insights section.

Appendix C: Survey on the Attractiveness of the Manufacturing Sector

1. Age

The median age of a Singaporean manufacturing worker as of 2022 is 45-49 years old.

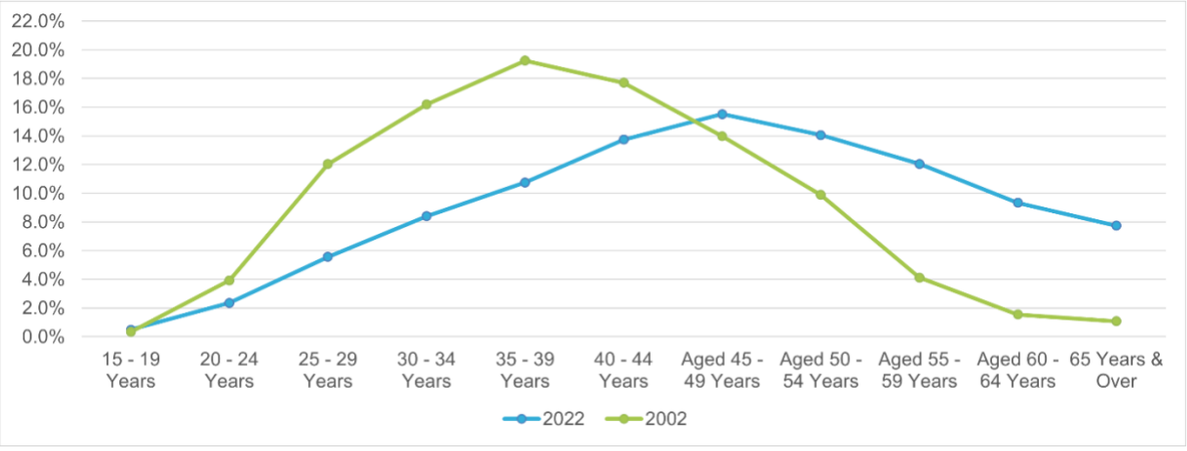


Figure 37: Percentage of workers by age group in the manufacturing sector, in 2022 and 2002

Among the survey respondents, the median age of manufacturing workers surveyed was 25 - 34 years old.

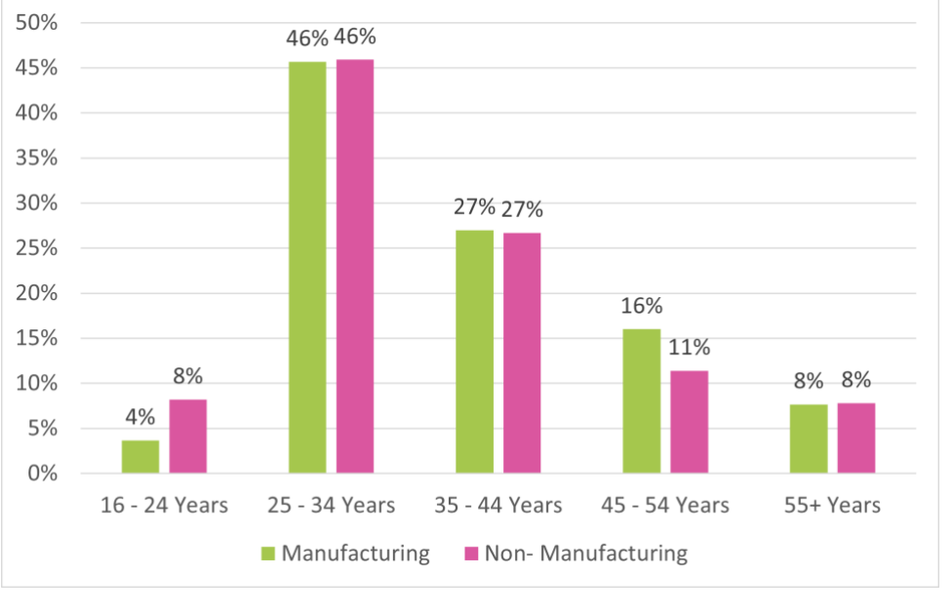


Figure 38: Percentage of workers by age group in the manufacturing and non-manufacturing sectors surveyed

2. Industry and Work Environment

Of the 1300 participants of the survey, 300 were from the Manufacturing sector, 200 were from Computer & Technology, and 200 from the Financial Services and Insurance sector.

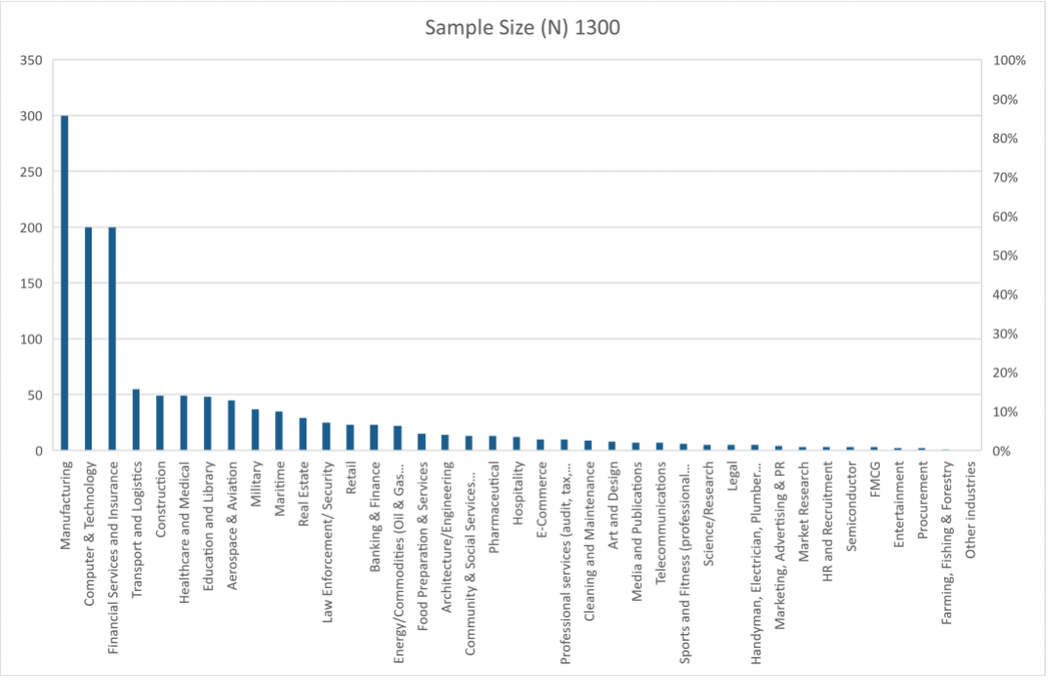


Figure 39: Industry breakdown of survey respondents

Of the manufacturing workers surveyed, 48% work in a technical role in an office-based work environment. 38% work in non-technical roles, and 8% perform work mainly involving manual labour.

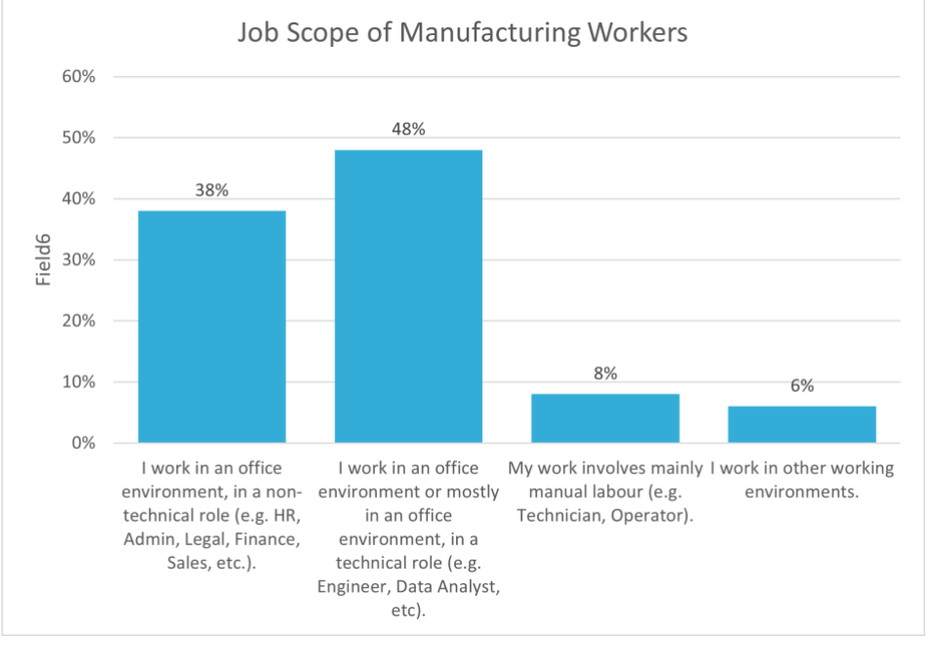


Figure 40: Job Scope of manufacturing workers

Of the non-manufacturing workers surveyed, a majority of 59% work in an office environment. 17% work in a service-line (customer-facing) environment.

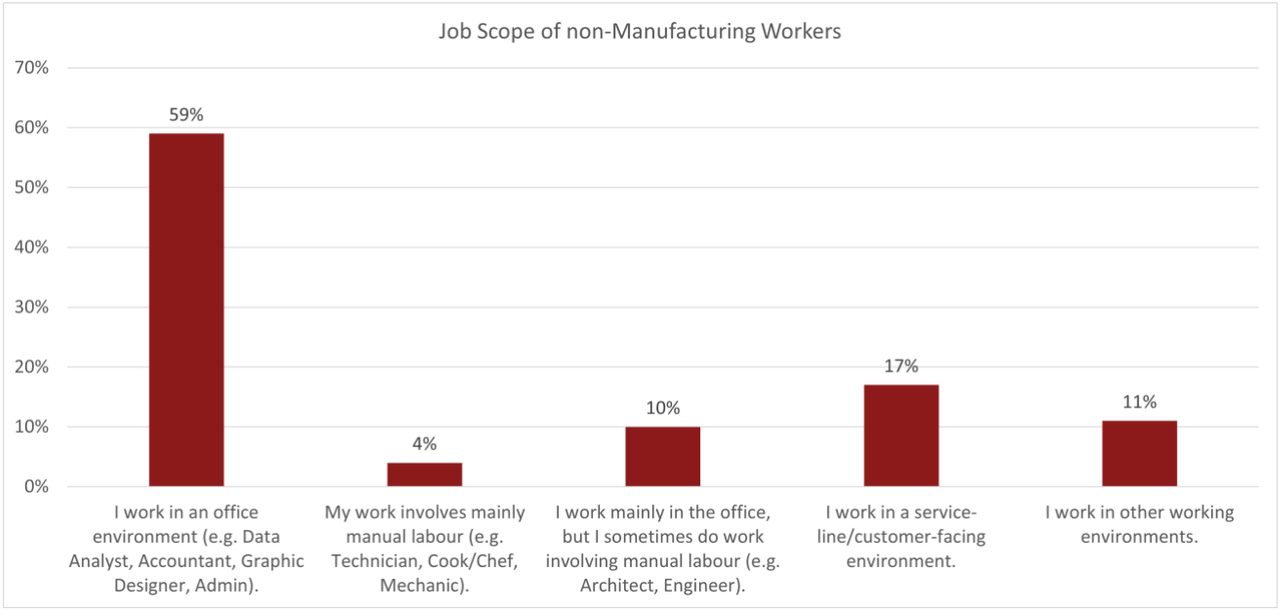


Figure 41: Job Scope of non-manufacturing workers

3. Confidence/Transferability of Manufacturing Workers

As compared to workers in other sectors, manufacturing workers are more confident to pursue a career in a different industry with their skills.

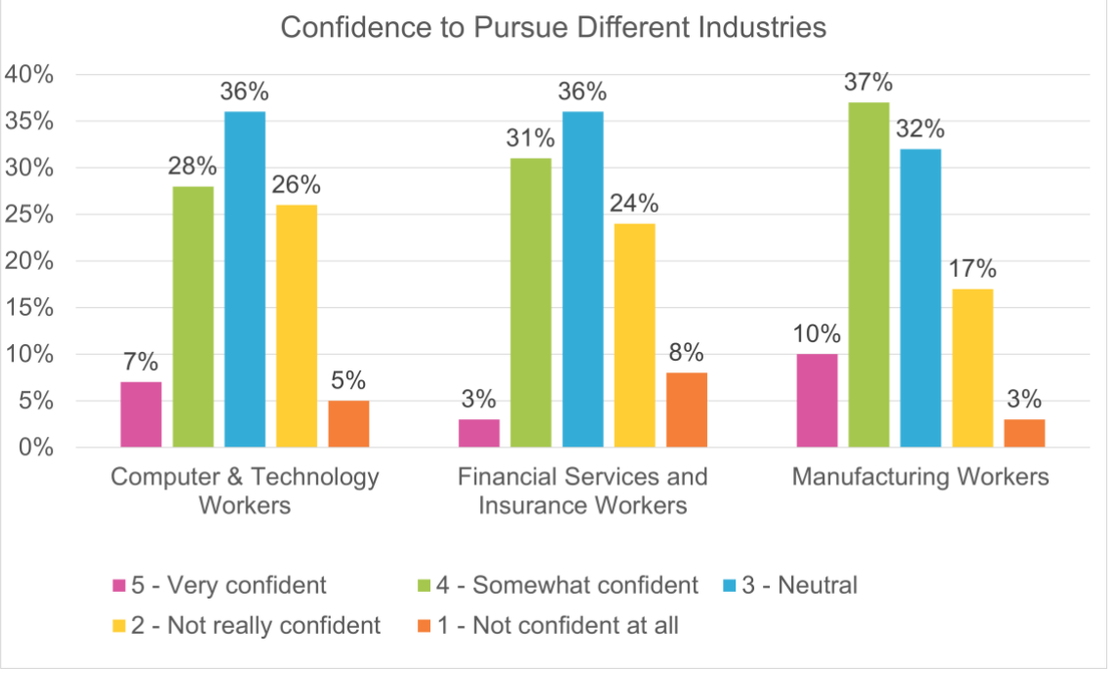


Figure 42: Confidence of workers in the Computer and Technology, Financial Services, and Manufacturing sectors to pursue careers in other industries.

Manufacturing workers also view themselves as being more versatile with their skills and have relatively equal confidence to work in a wider range of sectors.

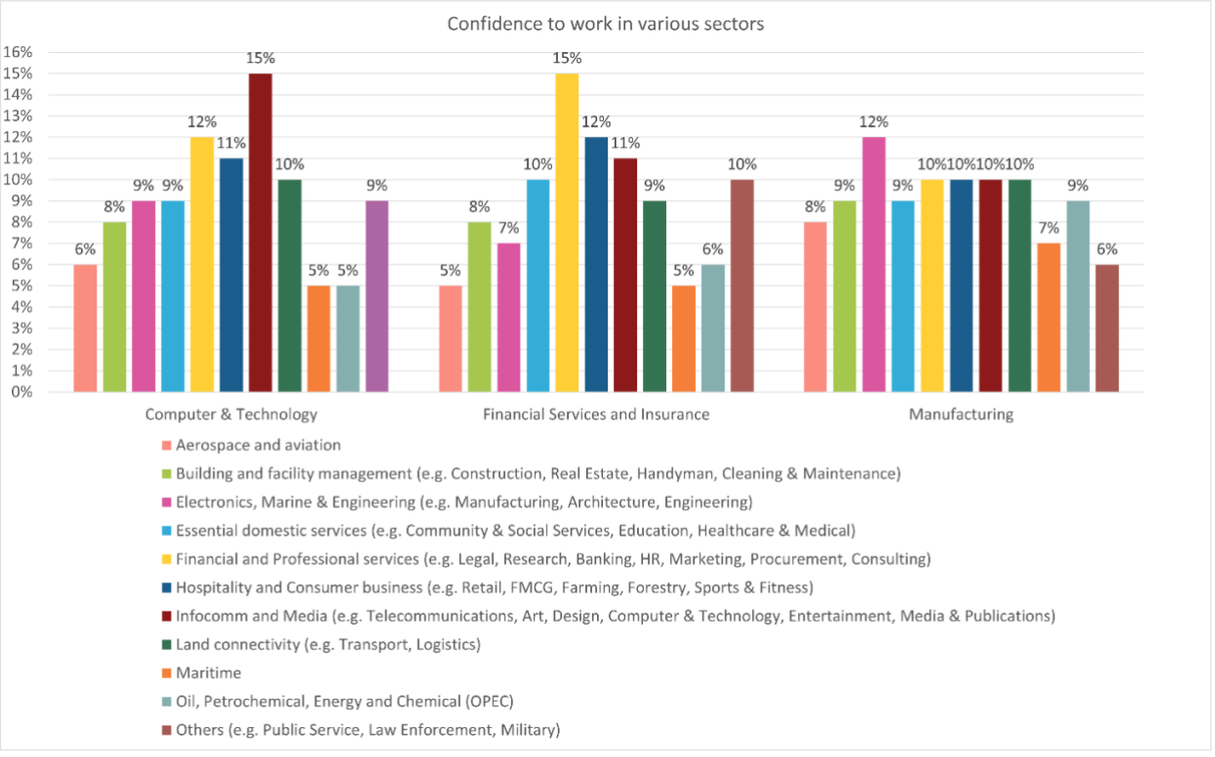


Figure 43: Confidence of workers in the Computer and Technology, Financial Services, and Manufacturing to pursue careers in various other industries

When asked about the barriers that prevent workers from changing to other industries, “Not enough skills for the new industry”, “Do not want to take risks”, and “Satisfied with current industry (38%)” are cited as the top factors for all workers.

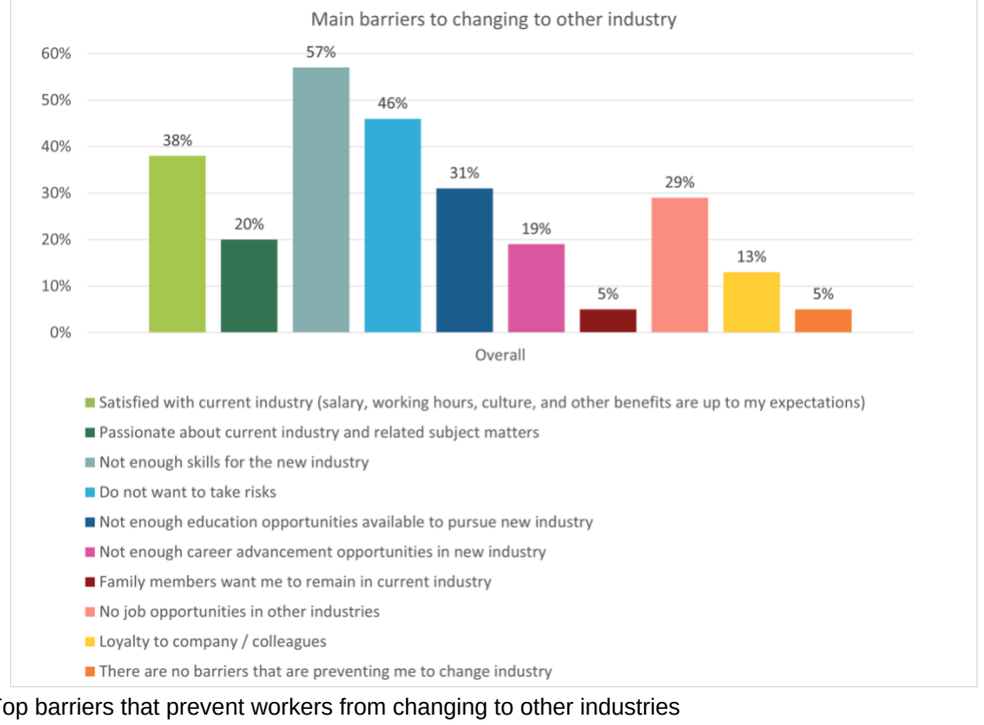


Figure 44: Top barriers that prevent workers from changing to other industries

For manufacturing workers, they view “do not want to take risks” and “passionate about current industry” as less of a barrier compared to workers from other sectors. They tend to view “no job opportunities in other sectors” as a greater barrier relative to workers from other sectors.

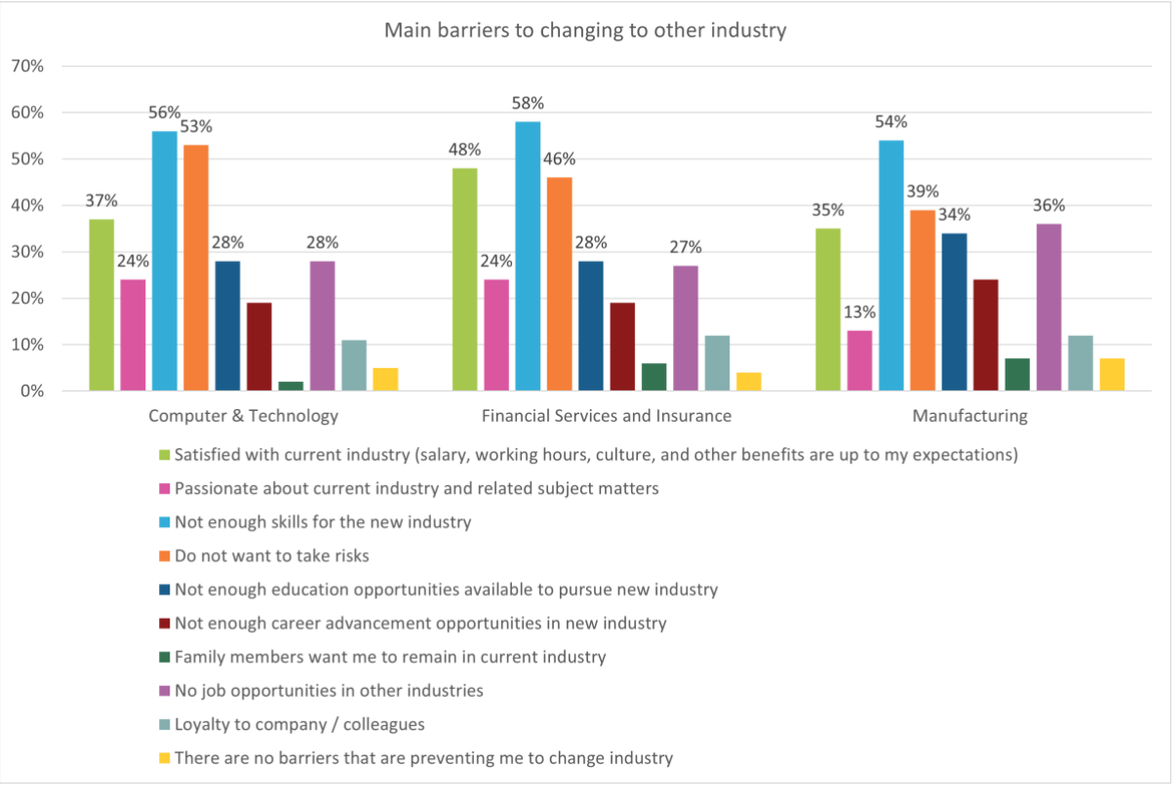


Figure 45: Top barriers that prevent workers from changing to other industries, breakdown by workers from the Computer and Technology, Financial Services, and Manufacturing sectors.

4. What Can Encourage Manufacturing Workers to Remain in the Industry

Across all sectors, salary and good working arrangements are the key factors that can encourage workers to remain in their current industry.

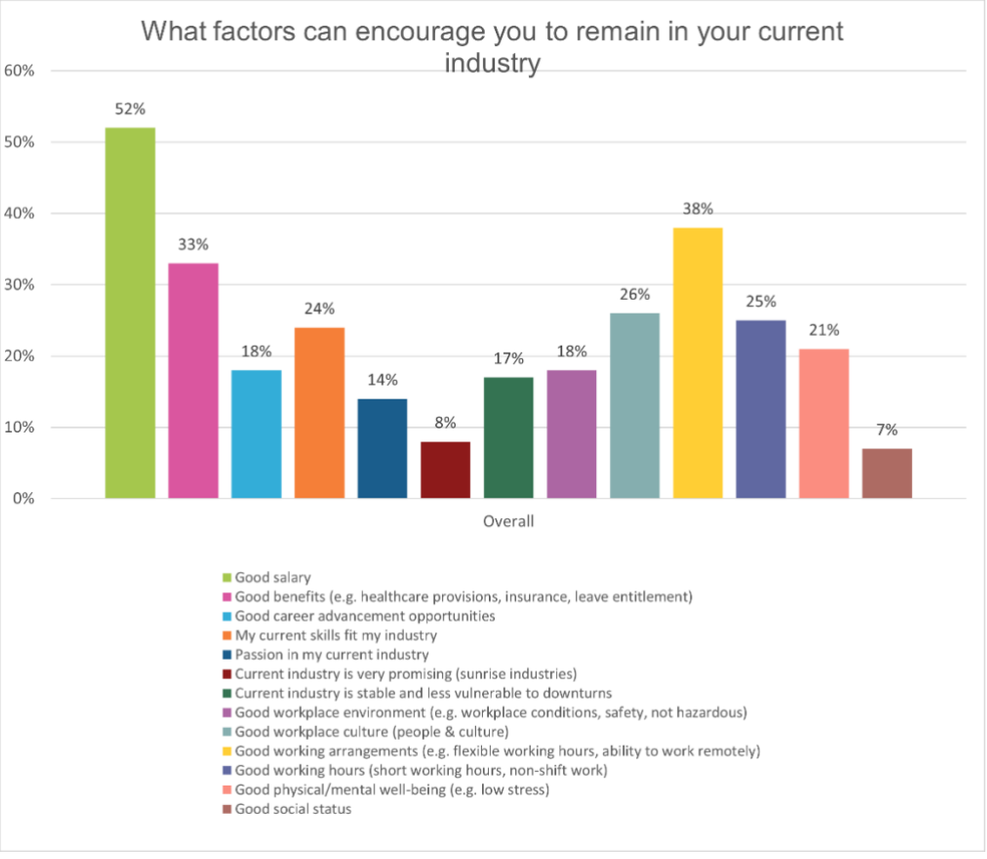


Figure 46: Factors that can encourage workers to remain in their current industry

Compared to workers from other sectors, manufacturing workers tend to place relatively more importance on a good workplace environment, that their current skills fit their industries, the workplace culture, and the stability of their industry.

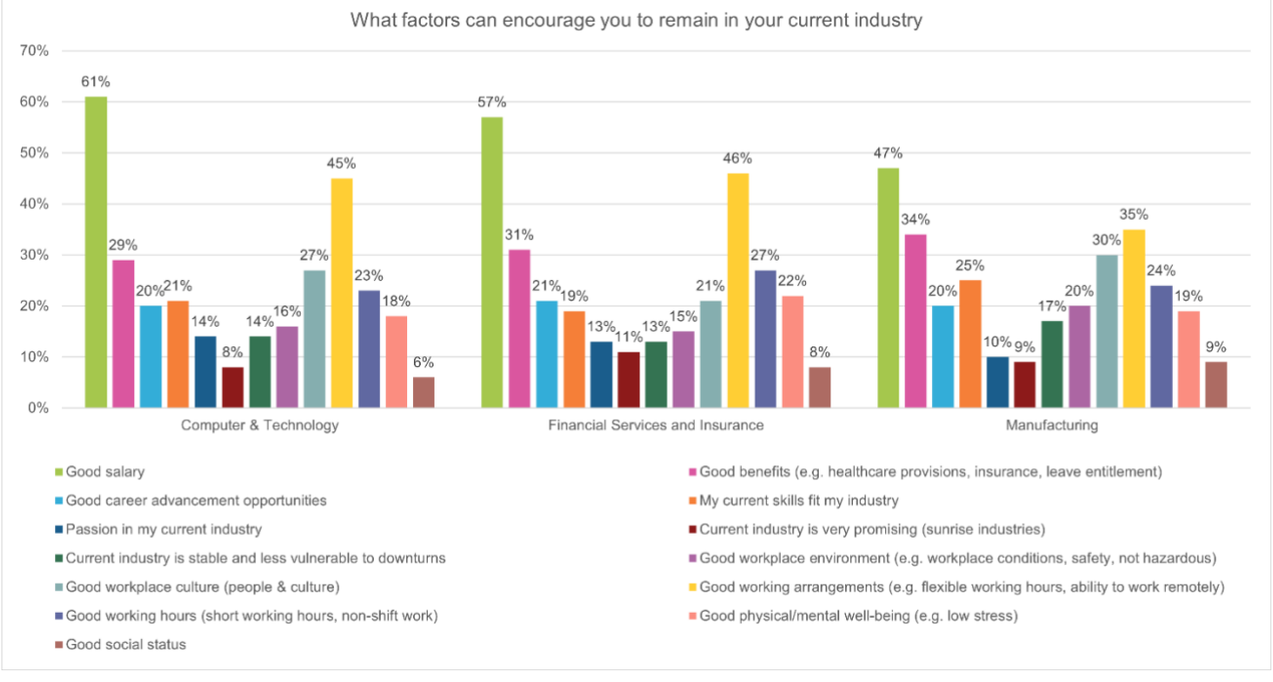


Figure 47: What factors can encourage workers in the Computer and Technology, Financial Services, and Manufacturing to remain in their industry

5. What Causes Manufacturing Workers to Want to Leave the Industry

The main “push” factors that cause manufacturing workers to want to leave the sector are low salaries, poor workplace culture, and low benefits.

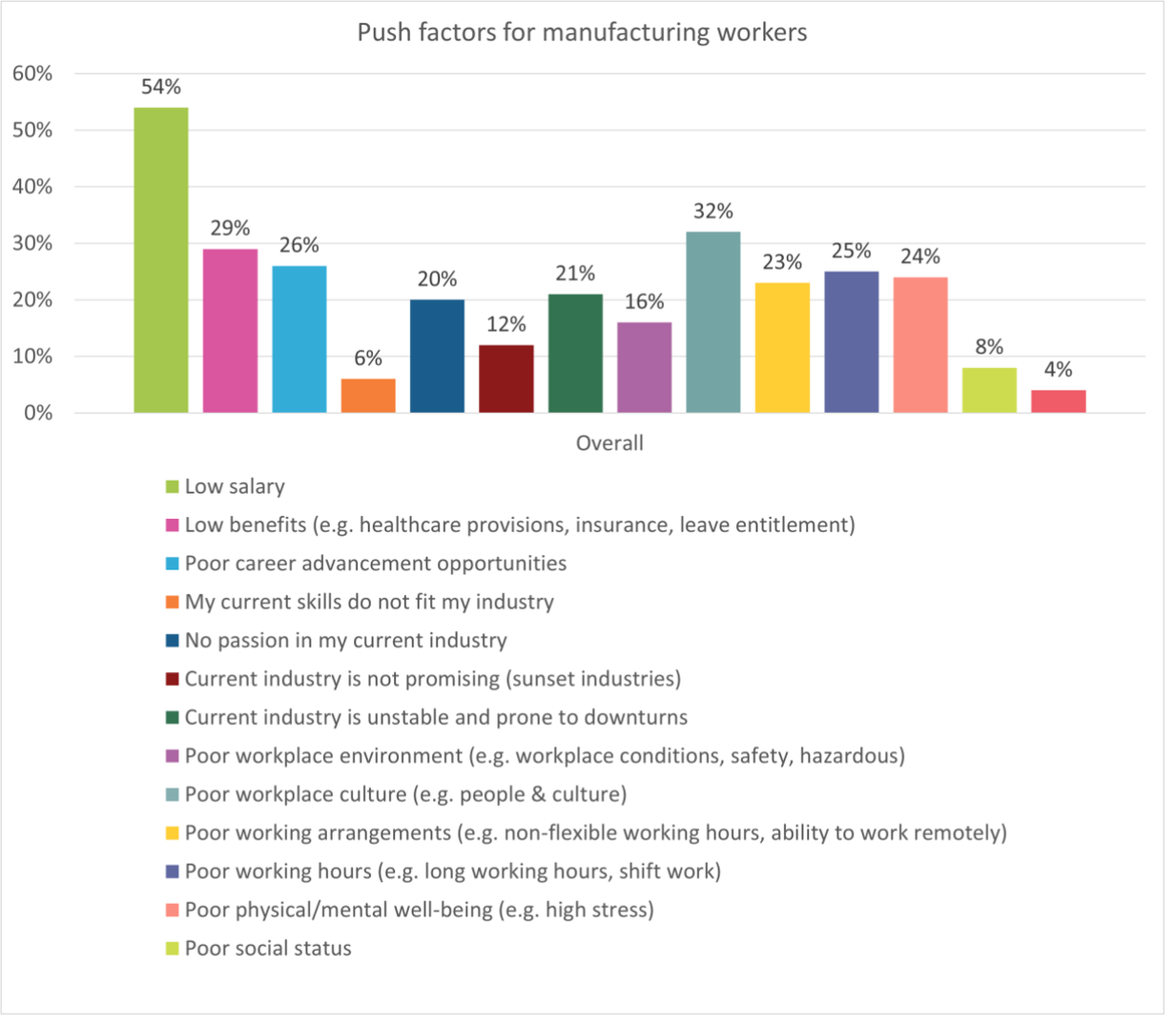


Figure 48: “Push” factors that cause manufacturing workers to consider leaving the sector

Younger manufacturing workers tend to view salary as a more significant push factor.

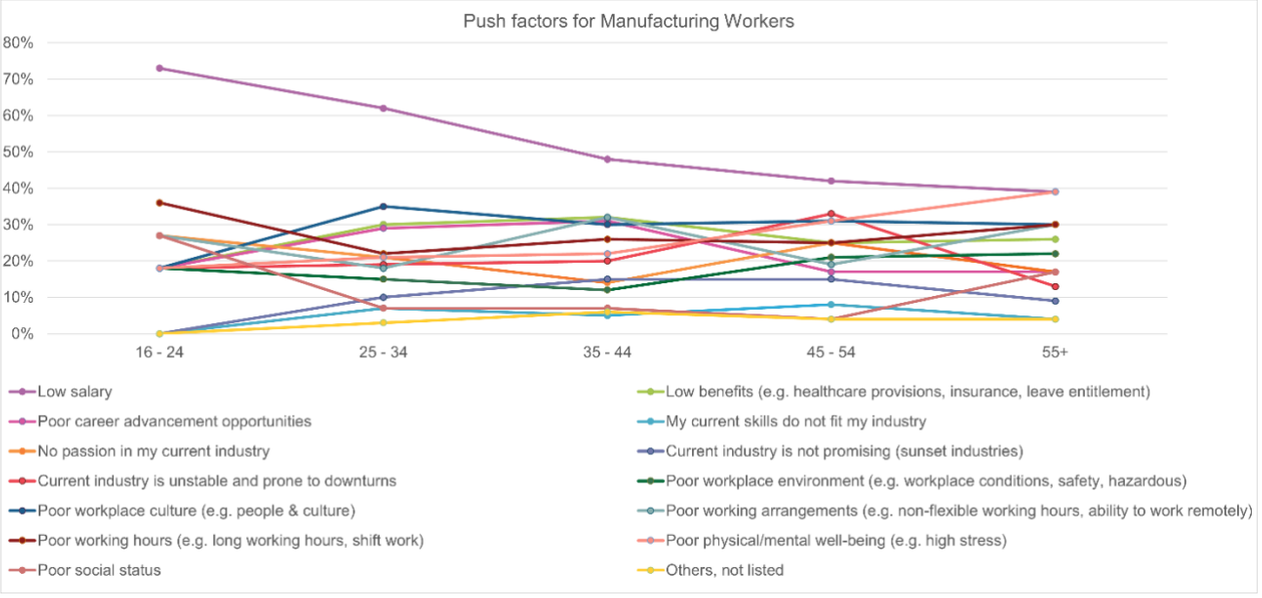


Figure 49: “Push” factors that cause manufacturing workers to consider leaving the sector, breakdown by age

6. What Appeals to Manufacturing Workers

In general, workers from all sectors view the Financial and Professional Services, and Infocomm and Media sectors as most appealing.

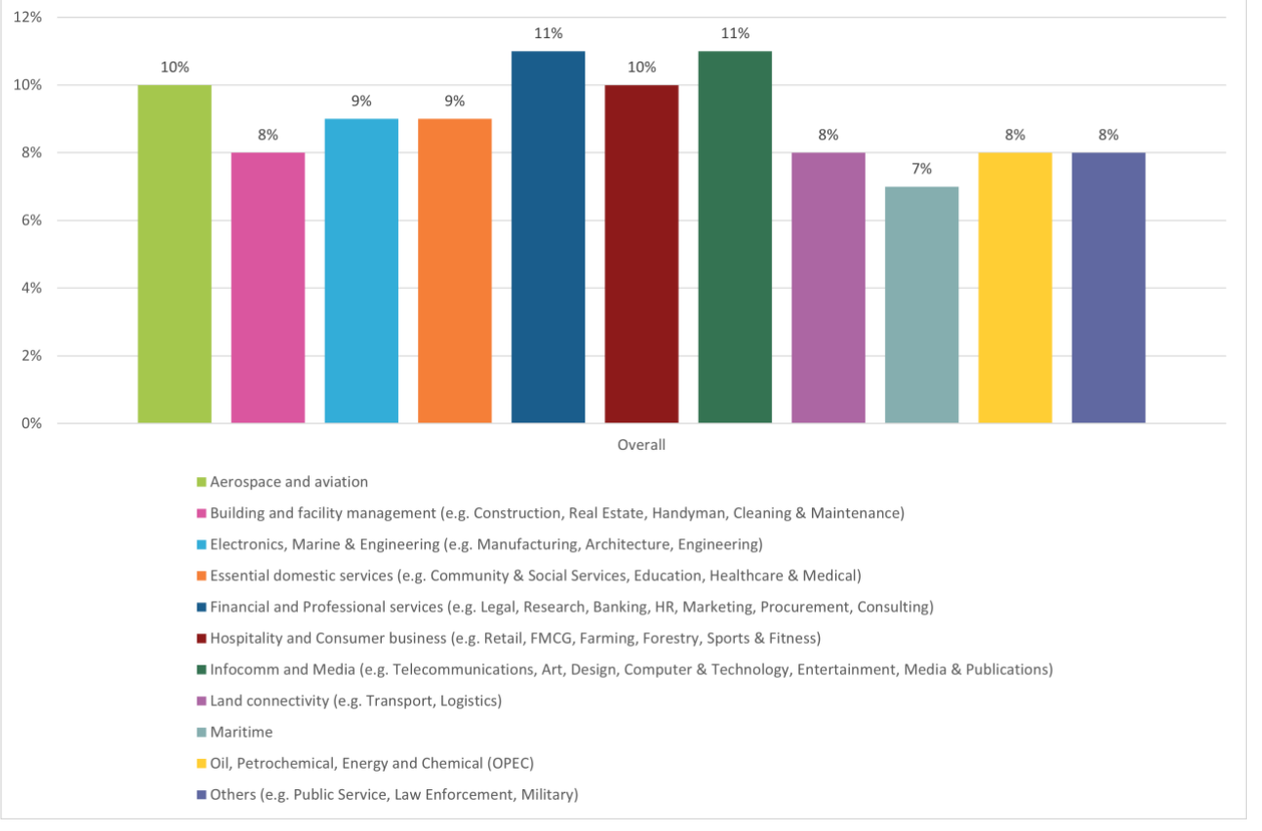


Figure 50: Appeal of various sectors to workers

This holds true for manufacturing workers as well; they view the Financial and the Infocomm/Media sectors as most appealing.

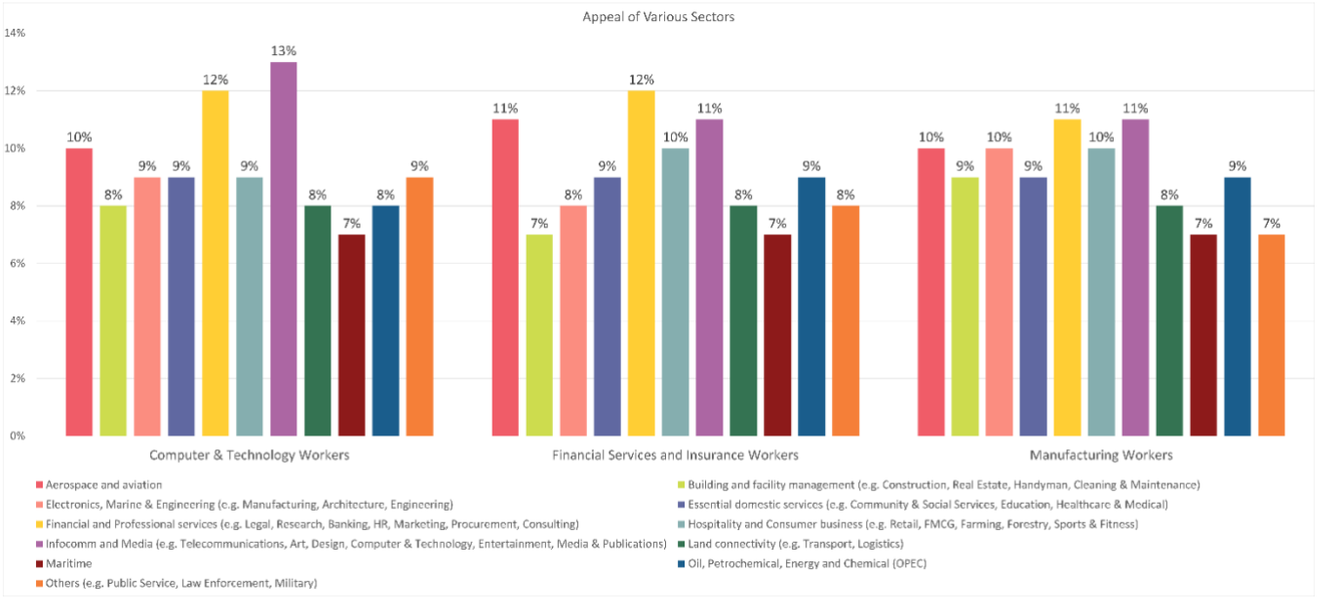


Figure 51: Appeal of various sectors to Computer and Technology, Financial Services, and Manufacturing workers

When asked to consider which factors were the most important to consider if workers were to change to a different industry for their next job, a better salary was most important. This was followed by better working arrangements, better benefits, and a better workplace culture.

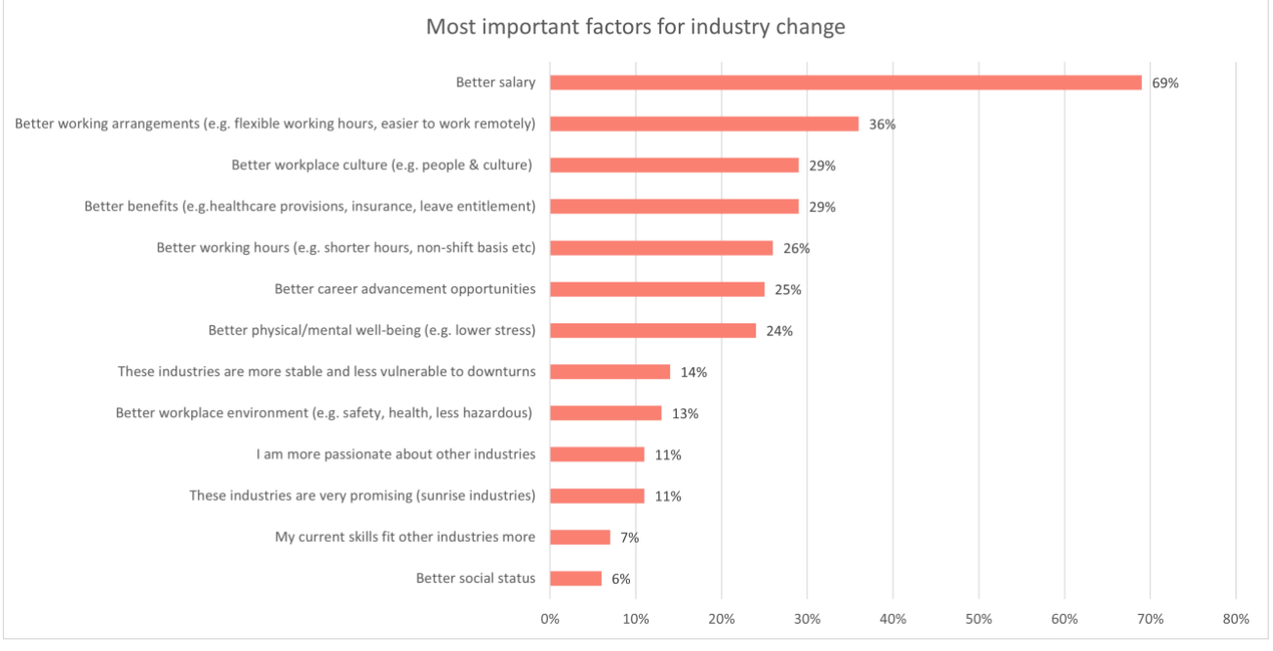


Figure 52: Most important factors that are taken into consideration for workers changing to a different industry

Looking specifically at manufacturing workers, the top few factors remain the same for manufacturing workers as it is for workers from other sectors. However, they tend to place relatively more importance on a better workplace environment, and stability of the industry.

Figure 53: Most important factors that are taken into consideration for workers changing to a different industry, breakdown by workers from different industries

7. How Likely is it for Manufacturing Workers to Stay in the Industry, and for Workers From Other Sectors to Join Manufacturing

Manufacturing workers have a stronger desire to pursue a career in a different industry (57% want to pursue), as compared to workers from other sectors (35% want to pursue).

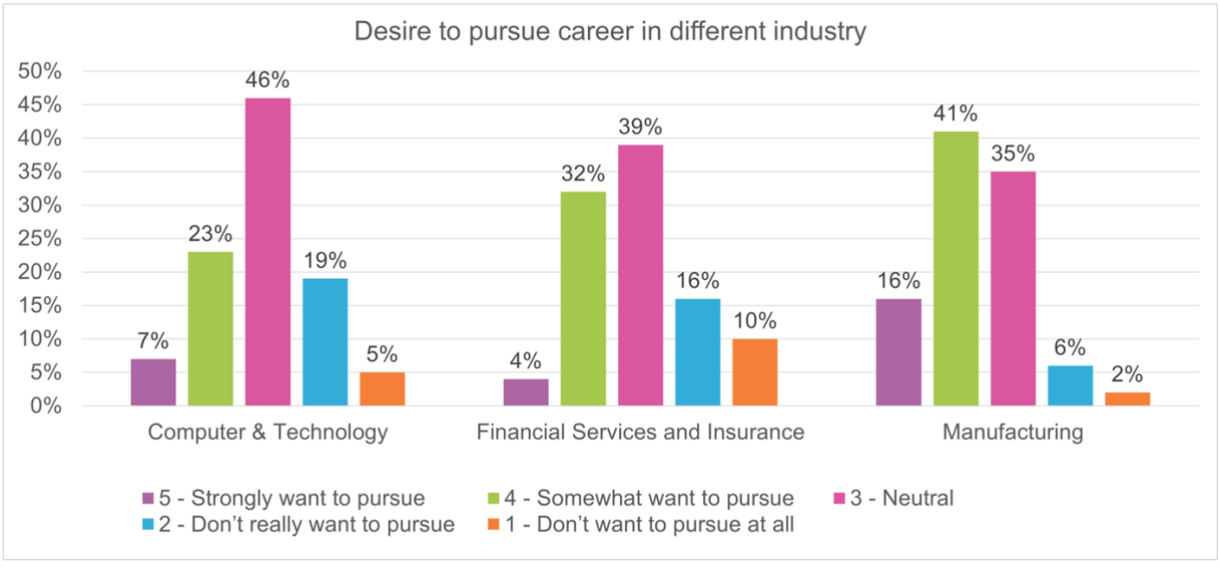


Figure 54: Desire of workers in the Computer and Technology, Financial Services, and Manufacturing to pursue a career in a different industry

Of the manufacturing workers, those in a technical role are most keen to pursue work in other industries (70% want to pursue).

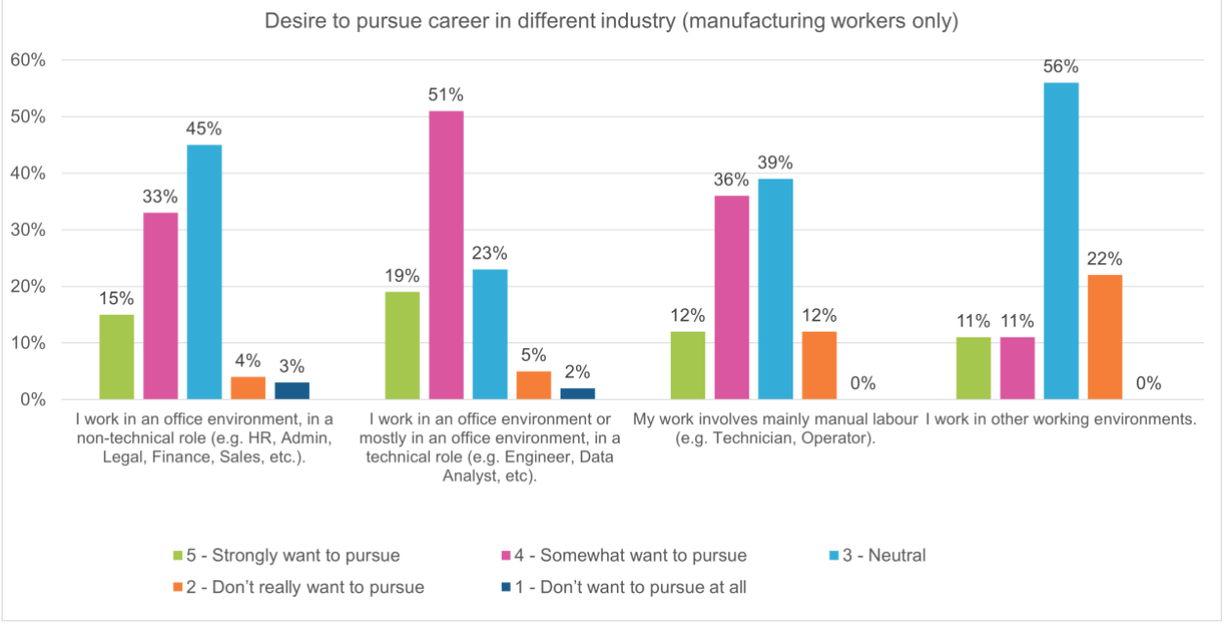


Figure 55: Desire of manufacturing workers to pursue a career in a different industry, breakdown by work environment

Workers who are older, have higher incomes, and/or have higher job positions have less of a desire to pursue a career in a different industry.

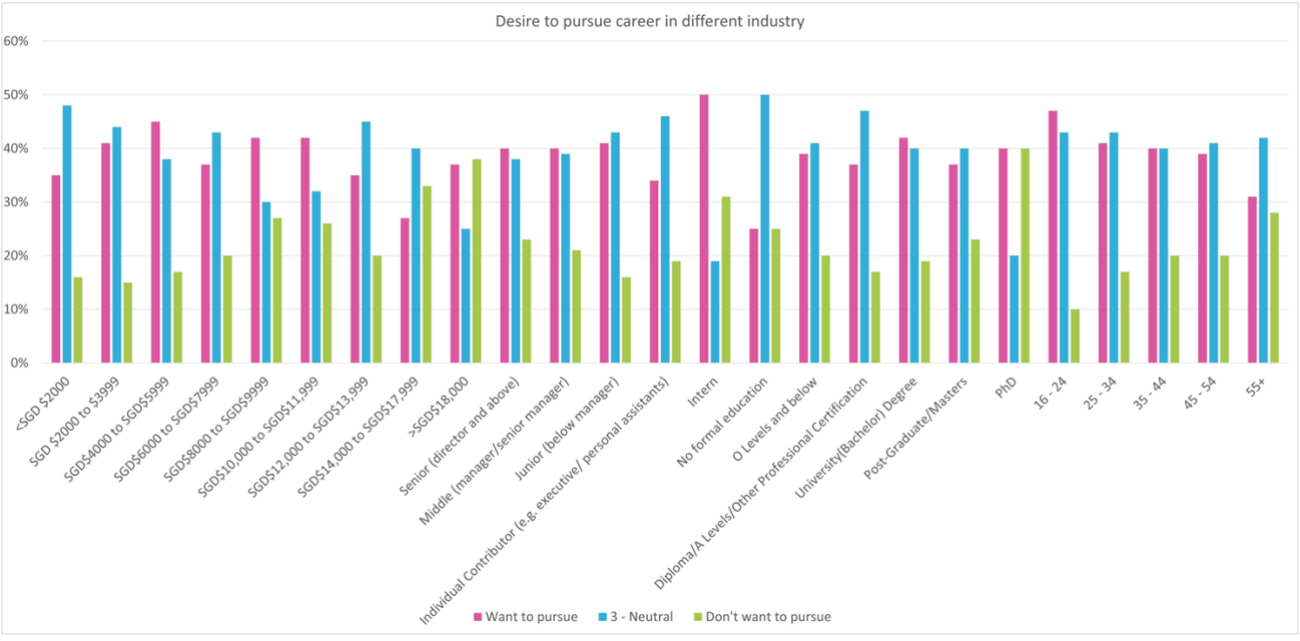


Figure 56: Desire of workers to pursue a career in a different industry, breakdown by demographics

Workers outside of manufacturing generally view the manufacturing sector as unappealing (62% negative vs 38% positive).

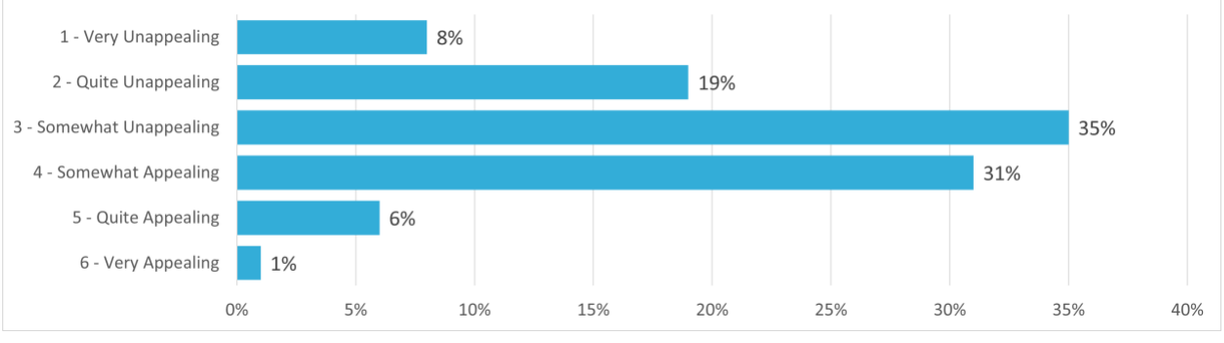


Figure 57: Appeal of working in the manufacturing sector for non-manufacturing worker

Younger workers tend to view manufacturing as less appealing compared to older workers.

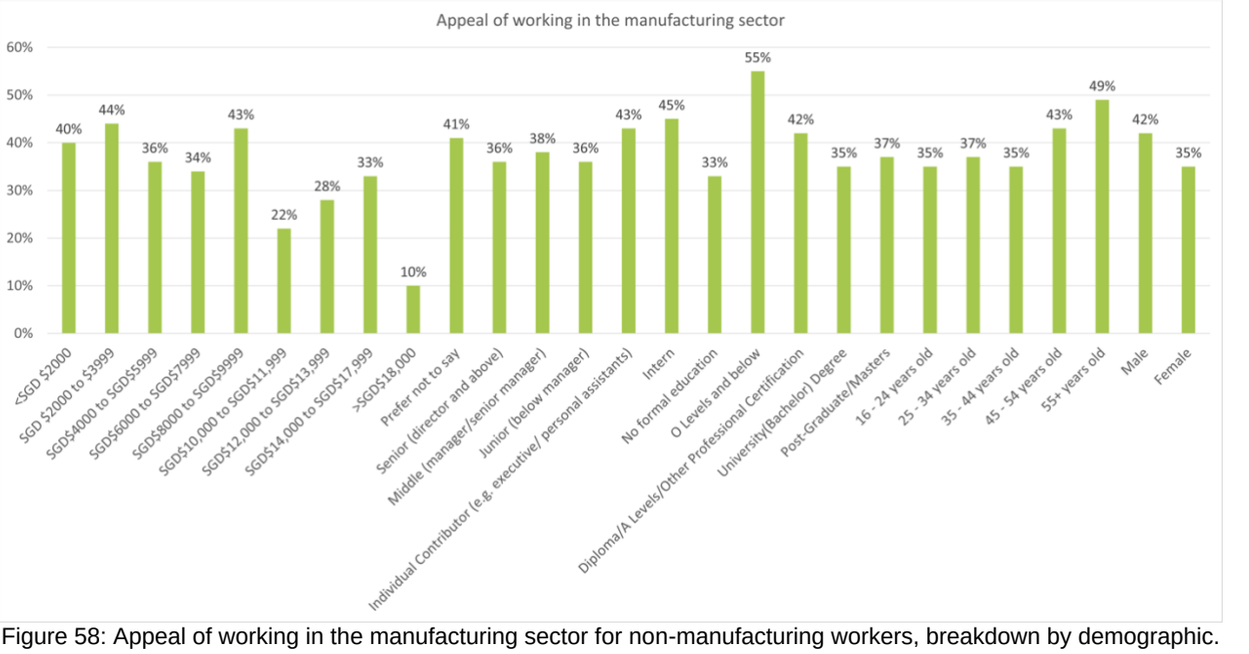


Figure 58: Appeal of working in the manufacturing sector for non-manufacturing workers, breakdown by demographic.

Among workers from other sectors, those in the Construction and the Transport/Logistics sector tend to have the most positive view of the manufacturing sector.

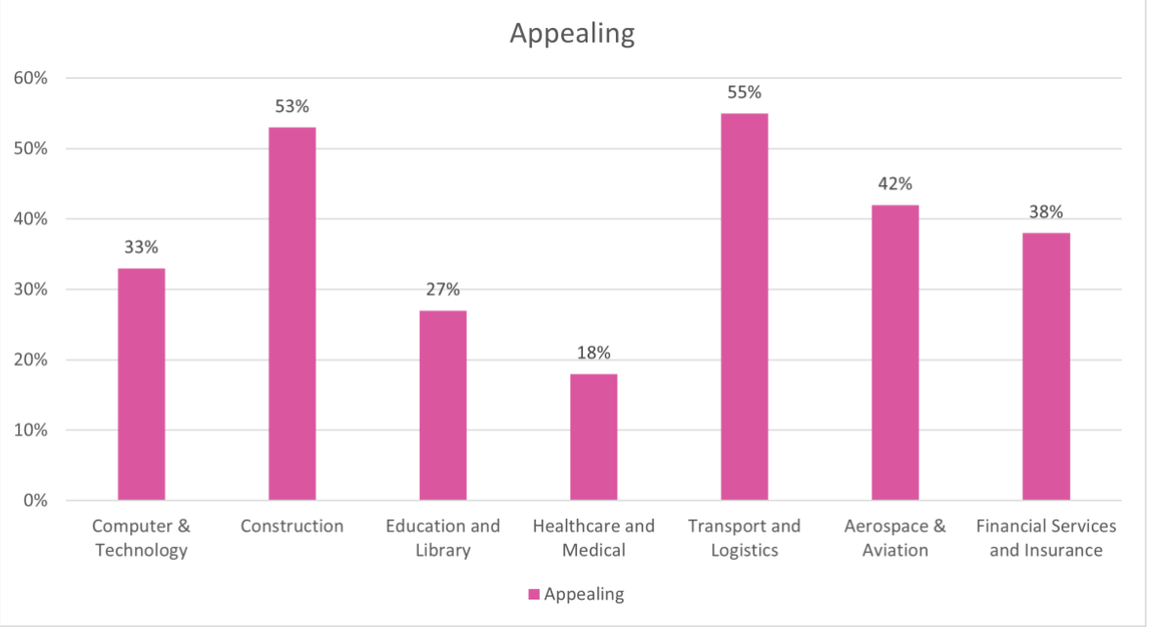


Figure 59: Appeal of working in the manufacturing sector for non-manufacturing workers, breakdown by sector

For workers who view manufacturing as “Appealing”, salary was cited as the biggest factor, followed by benefits, stability of industry, and suitability of skills.

For workers who view manufacturing as “Not Appealing”, work environment was cited as the biggest factor, followed by salary, suitability of skills, and working hours.

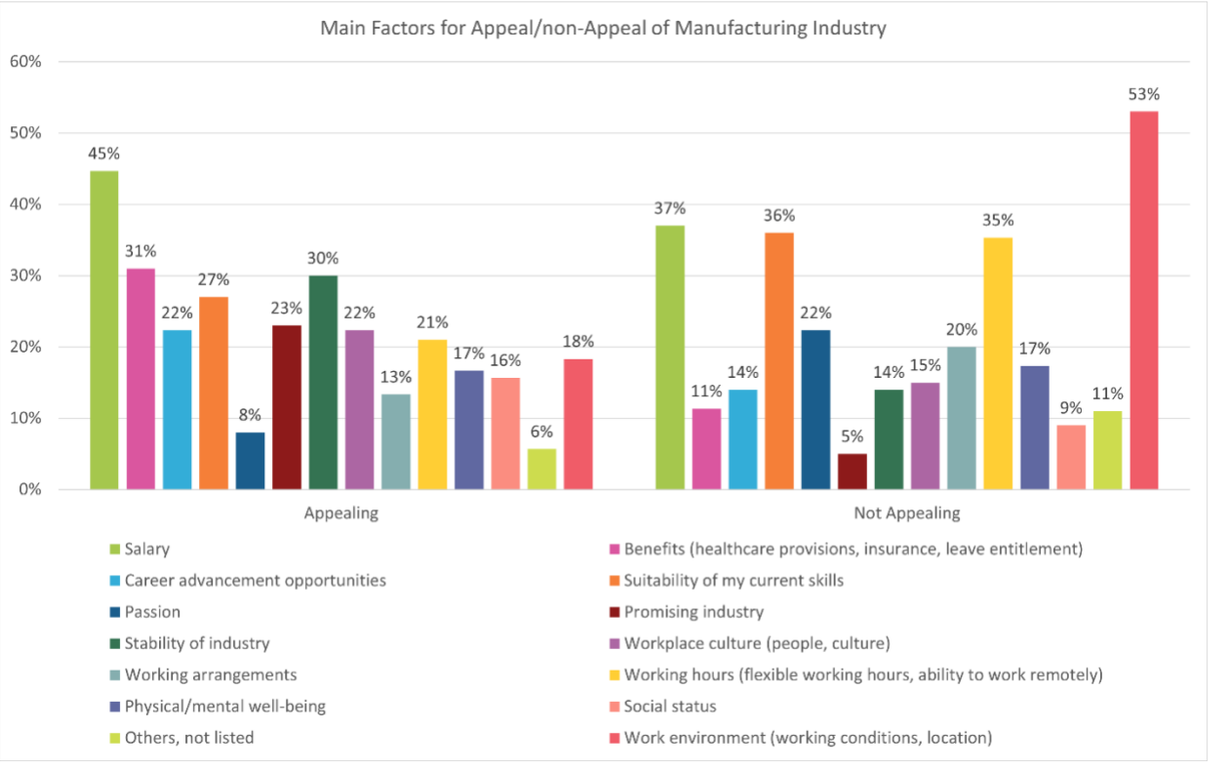
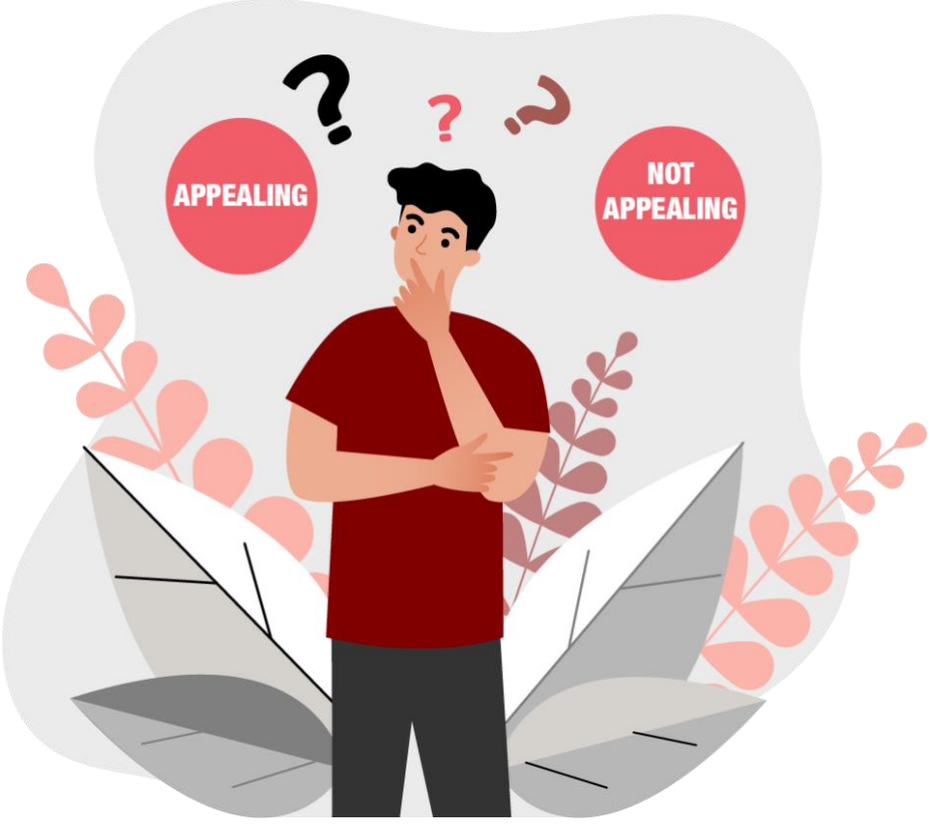


Figure 60: Main factors cited by non-manufacturing workers who view manufacturing as Appealing or Not Appealing.



Appendix D: Mastery in a Digital Age

Conventional conceptions of technology's impact on skills focus on how technology automates or augments humans (see Figure 61). This has led to a view that all that needs to be done is for each individual to become more skilled.

Our Mastery in the Digital Age research finds this limiting. It is limiting because unlike the above individual-centric view of upskilling, modern mastery demands an interactions-centric view.

This is because expertise is now distributed across people and technologies, and workers must build the meta-skills to access this distributed expertise through interactions within an ecosystem (see right portion of Figure 61).

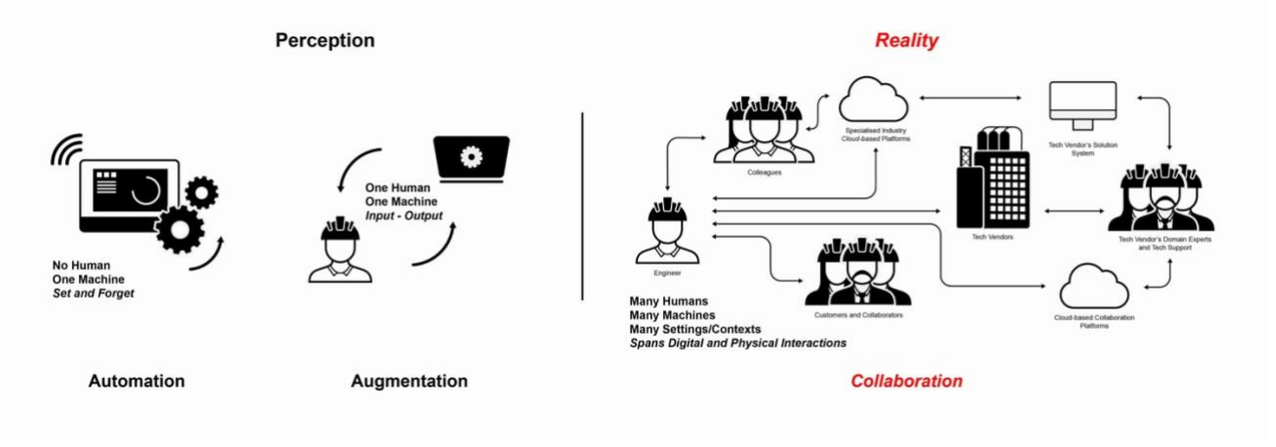


Figure 61: Perception VS reality diagram

There are three reasons for mastery to be distributed now.

Firstly, the expertise the person needs to accomplish his/her work resides across and between these multiple technologies and people.

Secondly, Distributed Mastery more accurately describes how work is now regionalised and globalised. How competitive a city's/country's workforce is depends on how well it harnesses global and regional expertise.

Thirdly, with AI computing power doubling every 3-4 months, the only way humans can keep up is when they draw on each other's collective expertise.

This is best illustrated in these two quotes that show how manufacturing workers undergoing digital transformation will need to draw on both what the younger professionals know (i.e. digital), and what older professionals are steeped in (i.e. the physical plant and which past iterations of technologies worked or did not work):

We call them Nintendo engineers. Because basically they are just playing, it's like playing a game right. *So, I don't know if I have a fully formed opinion about that, I see that, I see that they come in and they are the most comfortable with the technology and there is no question. They expect that it works this way. How could you have ever not? Of course, it works this way.*
(E&C Engineer)

But they [younger generation] don't know where these tools come from. In case anything goes wrong with the tool, they actually don't know how to do a lot of the troubleshooting. But for us, because we know how the tool was being made, the geometry that affects the machining, this and that, so when things go wrong, we have the opportunity or luxury because we're being trained, we have the knowledge to understand that. So, when it comes to some of the troubleshooting we're doing ourselves, it becomes more handy to do. So, we have the additional knowledge compared to today, these people are being trained.
(PE Technician)

Distributed Mastery Diagnostic Tool

We also developed a diagnostic tool which can be used to determine what workers and companies need to do to raise their level of Distributed Mastery.

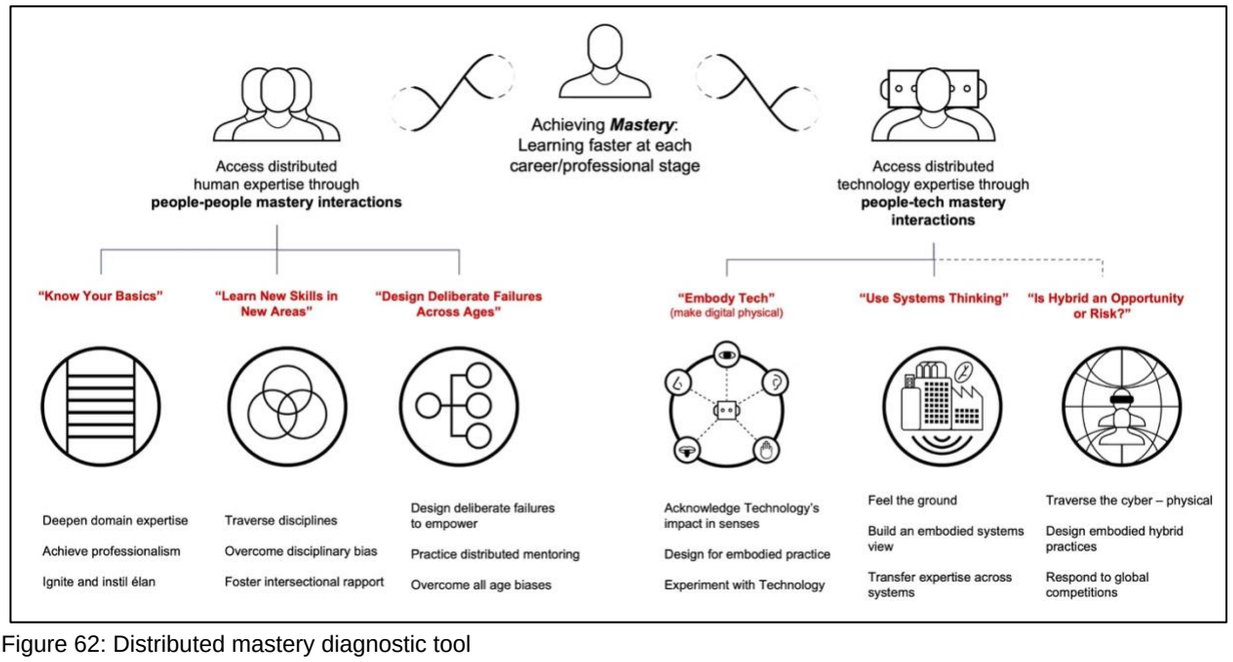


Figure 62: Distributed mastery diagnostic tool

Appendix E: How Fast is Skills Disruption Really When We Analyse Each Skill's Tasks

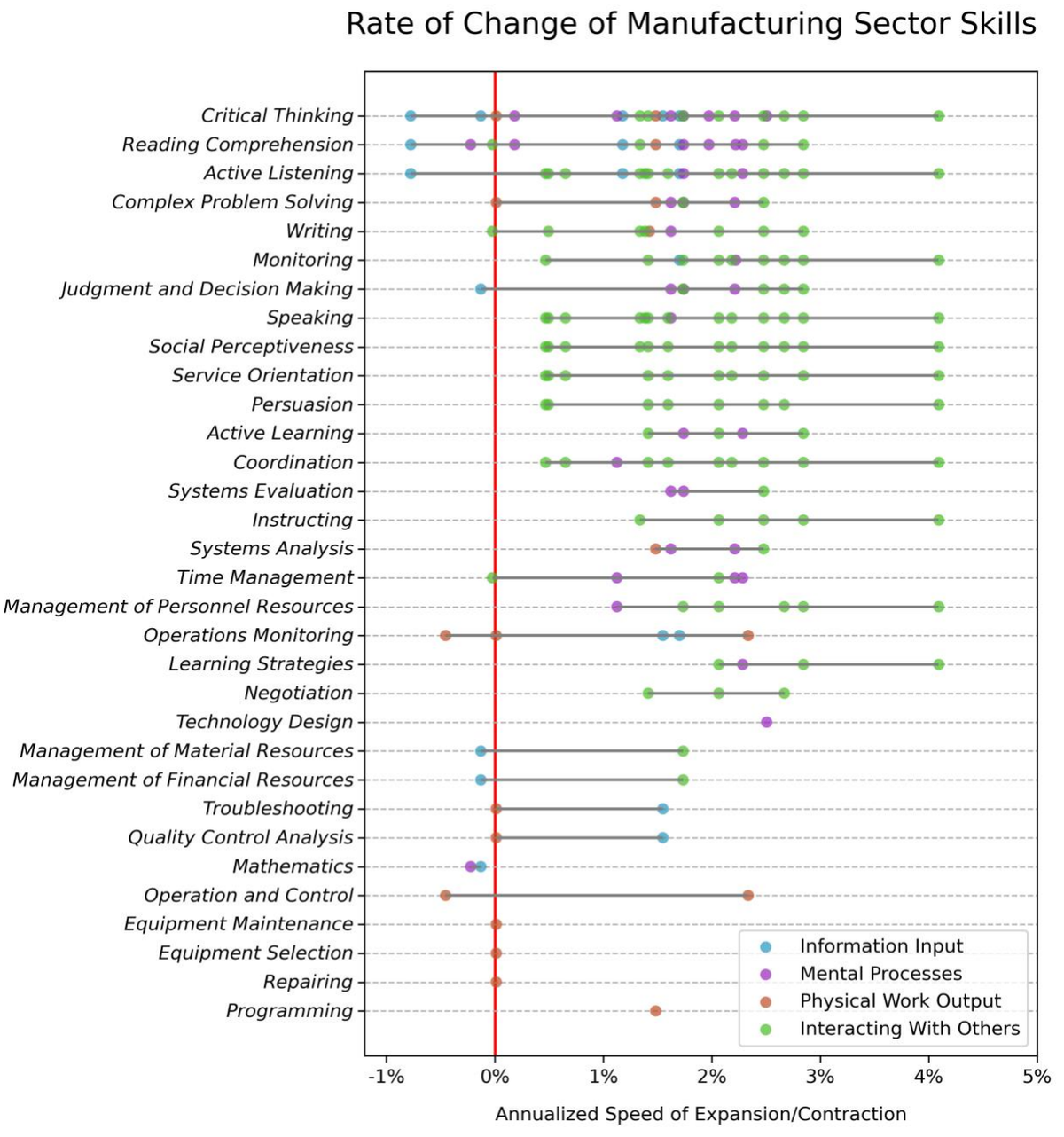


Figure 63: Rate of change of manufacturing sector skills

How to Read the Chart

These in-depth insights are only possible because we broke down skills into tasks for granular analysis by LKYCIC's algorithms as follows:

Breaking down and subsequently stacking official Singapore and global skills data to granular tasks

1) *The skills are ordered based on their prevalence in manufacturing occupations ('Critical Thinking' appears most frequently, 'Programming' least frequently).*
2) *We break each skill down into its tasks (using the idea of General Work Activities in labour economics research, i.e. tasks shared by a number of job families).*
3) *We also colour code for the type/nature of tasks.*

Predictions from multiple public sources

1) *Projections of each task's disruption speeds are compiled from consultancies, universities etc.*
2) *The grey lines show the range of disruption speeds for each of the tasks belonging to each skill.*
3) *The red line is placed at zero to show which skills have a mix of declining/emerging tasks.*
4) *The last few skills have no grey bars because they have only one corresponding task.*

Insights: What the Charts Tell Us

Contradicts dominant corporate voices on disruption

- The majority of tasks have positive rates of growth (i.e. they are on the right side of the red line of the chart). This contradicts the dominant narrative (see Executive Summary) that technology is an unstoppable wave that will disrupt workers. It is telling that many of the same voices who say tech is unstoppable are the same ones who predicted these positive rates of growth.

- The dominant narrative is also likely to have led many voices and decision makers to look at the small number of tasks that are disrupted (i.e. those left of the red line), and extrapolated similar disruption to the tasks on the right. The resultant pessimistic predictions contribute to outsized assumptions about how much tech can replace humans, and hence a disproportionate reduction in workers.

Disruption is from competition, and we must create value

- That the majority of tasks have positive growth rates is also consistent with what we heard from workers. They told us that they are already tech-intensive, and there are limits to further cuts to the workforce.

- In addition, if there are any further reductions in workers, it is likely due to outsourcing to another country, i.e. the tasks with positive growth are relocated to another country. And hence, the importance of ensuring we find ways for workers to create new value so that they create more value with the same tasks than anyone else in another country.

Appendix F: The Multivitamin Strategy

The Multivitamin Strategy is a recent research insight from LKYCIC's project on Designing Resilience Task-by-Task that was funded by SIMPDF. It is a new way of designing career experiences for individuals using AI and human insight. In the same way that taking a multivitamin offers resilience on multiple fronts, a career multivitamin offers resilience to workers by diversifying their pathways and increasing mobility between these pathways on the basis of shared tasks. As opposed to conventional methods of job transitioning/job search, the Multivitamin Strategy uses tasks because jobs are disrupted task-by-task, and not skill-by-skill.

Conventional hiring and skilling programmes tend to focus on single pathways. This requires workers and employers to put their bets on a single track, akin to a single vitamin:

Skills training ⟶ Direct role

A Multivitamin Strategy, on the other hand, lays out multiple pathways. Workers and employers can diversify their bets across multiple tracks:

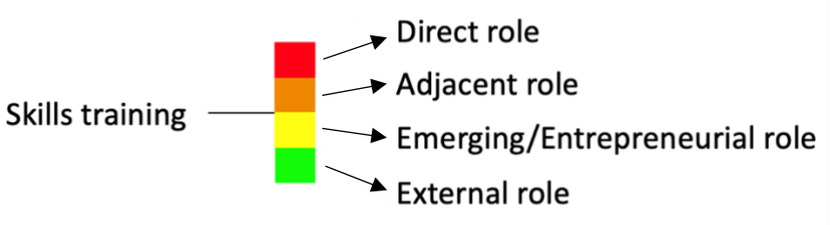


Figure 64: Multivitamin strategy

By encouraging them to diversify opportunities and risks, we raise the odds that they find suitable ones across new possibilities and networks. Moving opportunistically across multiple pathways creates fluidity, and this need for fluidity is consistent with the latest literature on career resilience from career scholars, publications, and organisations ranging from OECD[7] to Harvard Business Review:

- *"Don't marry a job before your first date"*—Trailblazing psychologist John Krumboltz and his Stanford colleague Ryan Babineaux (2013) believed we can be empowered to achieve satisfaction in life and work, especially when we intentionally incorporate unplanned events into our lives in what he calls "planned happenstance".
- *"Test and learn"*—Herminia Ibarra, an authority on leadership and career development, believes that successful change comes first from doing, then knowing.
- *"Multiple possible selves"*—Having only one shot at getting it right or having only one dream job raises the stakes and closes off opportunities to one's other "possible selves" (1986), a concept developed by pioneering social psychologists Hazel Markus and Paula Nurius.

[7] https://www.oecd-ilibrary.org/sites/4ce36128-en/index.html?itemId=/content/component/4ce36128-en#section-d1e11438

The Multivitamin Strategy has been tested and will continue to be developed with various groups of workers including gig workers, semi-stuck independent mid-career workers, workers with disabilities and older workers.

Two related concepts have arisen out of this research:

1. Career Insurance Planning: Like financial insurance planning, Career Insurance Planning done ahead of time provides a soft landing for unforeseen events and a bridge to alternative career options, thus reducing uncertainty for workers while enhancing their employability across different economies.

2. Career Investment Planning: Like financial investments, Career Investment Planning helps workers create a balanced and unique portfolio of career investments, allowing them to experiment safely with alternative career options, create job options that are more aligned with their life stage and personal values, and stand out to employers.

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