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COVID-19 – Lessons from the US in the Second World War

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Executive Summary

This document studies the rapid expansion of industrial capacity in the US during the Second World War to derive lessons for India's response to the COVID-19 pandemic in 2020. It provides insights on ramping up manufacturing capacity for goods required to fight the pandemic, and set the economy on the path to recovery and mass manufacturing to take advantage of the long-term reorientation of global supply chains away from China.

The analysis shows that a combination of government incentives and private initiatives can address these challenges at scale. These include models of state financing, ideas on enabling IP transfer and innovation, and ideas on developing and incentivising the labour force. Key recommendations include a national and state-level reserve for PPE and treating healthcare equipment and personnel as strategic assets in terms of development and deployment. This document suggests ways to leverage private sector capacity to bolster and expand public healthcare, rather than nationalisation. It also suggests that governments could facilitate licensing agreements and ease regulatory requirements to leverage expertise across sectors, and enter advance purchase agreements to incentivise the private sector to proceed with the high capital investment required to build up manufacturing capacity.

Introduction

This document aims to draw lessons from history to inform India's response to the COVID-19 pandemic. It looks at the most transformative years of the previous century in order to do so, specifically the Second World War. The case study chosen is the US ramping up its manufacturing capabilities on a war footing through the late 1930s and early 1940s.

Pandemics such as the Spanish Flu or outbreaks of the plague in colonial India, are deliberately not part of this study. This is due partly to our vastly expanded understanding of epidemics today - the public health responses to the outbreak of a disease are well-understood, and humanity's collective scientific knowledge and resources are enormously advanced in comparison to where they were a century or two ago. Many countries have already reopened their economies in some form after the initial wave of COVID-19 infections.

After discussing the historical and present-day context, we provide a four-factor model for ramping up manufacturing capacity. We then show how state intervention tackled each of these factors in the Second World War, and how these examples can guide contemporary India's response to the challenges and opportunities presented by the COVID-19 global pandemic.

The Second World War and the COVID-19 pandemic

The Second World War was one of the most catastrophic events in 20th century. The war directly involved more than 100 million people in more than 30 countries and led to about 70–85 million fatalities from military activities, food shortages, and famine. We can derive some similarities between the challenges of responding to the COVID-19 pandemic and the Second World War.

As the war broke out, the dual crises, military crisis as well as humanitarian forced the major players to ramp up their economic, industrial, and scientific capabilities to gain leverage over their rivals. Furthermore, all major powers during this period were still struggling with the aftermath of the Great Depression. This gave each country little time to prepare for a massive capacity build-up, but the risks of war made doing so an absolute imperative. The results can be seen in Figures 1, 2 and 3.

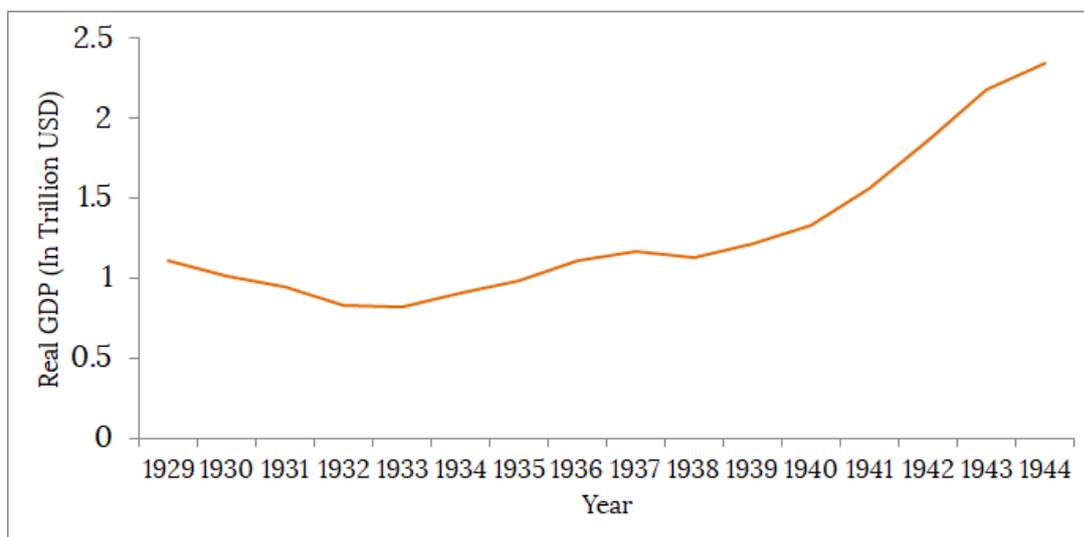


Figure 1. Real GDP (in Trillion USD) of the United States of America, 1929–1944. Observe the dip due to the Great Depression, the gradual increase after President Franklin D. Roosevelt’s New Deal in 1933, and the steady increase after the outbreak of the Second World War in 1939 and the US’s entry to the war in 1941¹.

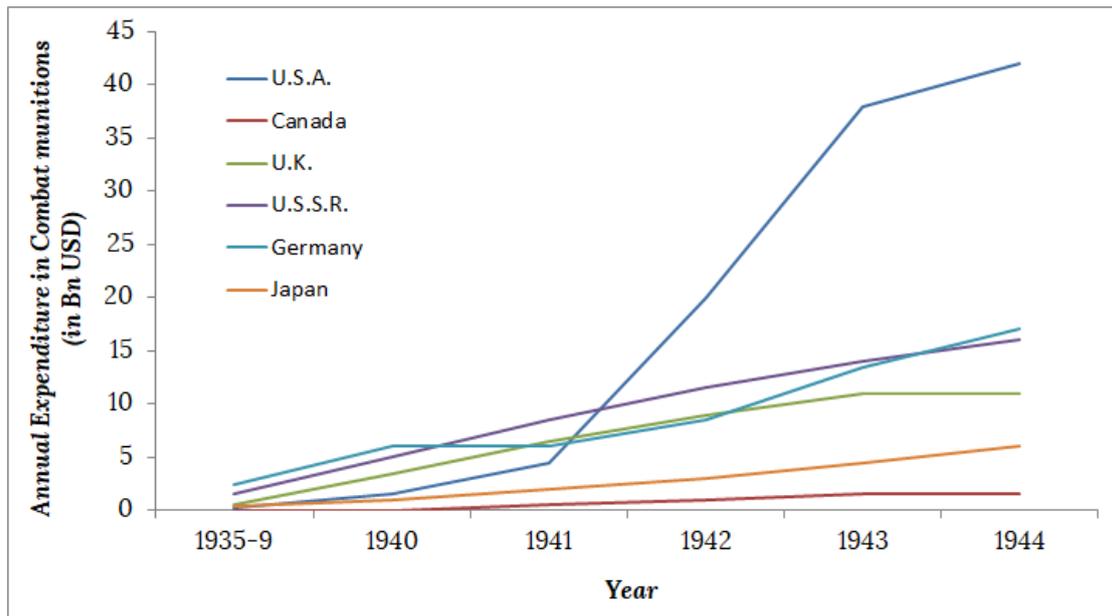


Figure 2. Annual expenditure in combat munitions in billion USD for major participants in the Second World War².

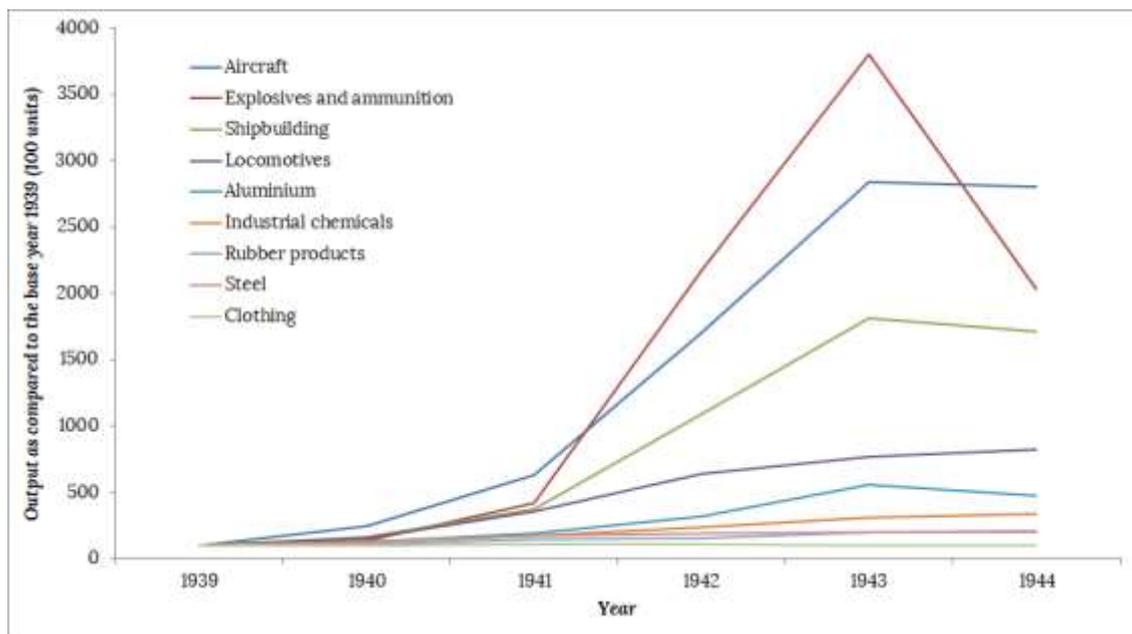


Figure 3. Federal Reserve Indexes of output of certain manufacturing industries in the United States, 1939-44 (1939 is the base value of 100, and subsequent years show output as a proportion of the base value)³.

Today, nation-states are faced with a similar challenge. The COVID-19 pandemic, in very few months, has infected nearly 6.5 million people in over 200 countries⁴. With over 350,000 deaths, the outbreak has crippled the healthcare systems of even the most advanced economies. Enforced lockdowns and quarantine measures have wreaked havoc on employment, investment, and supply chains. There is no vaccine for the virus at present, and the world continues to face shortages of medical equipment and safety gear.

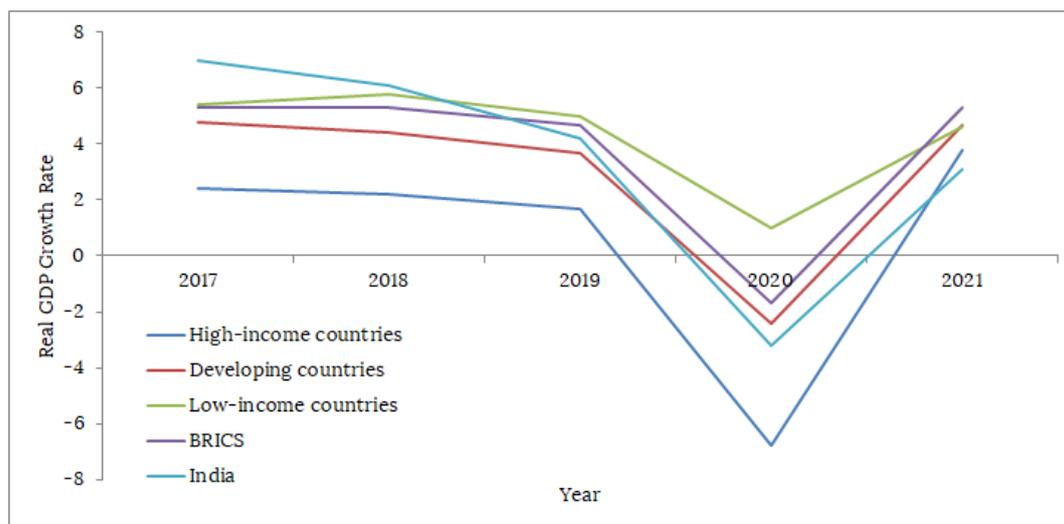


Figure 4. Real GDP growth rates of countries (2017-2020, forecast for 2021). Observe the sharp dip in output after the imposition of lockdowns in early 2020⁵.

To deal with the pandemic, nation-states must ramp up their capabilities in developing vaccines and drugs, manufacturing both medical equipment (such as ventilators, and defibrillators) and safety equipment (such as N95 masks, and coveralls). This ramping up is the only way to contain the spread of the virus, to get their economy going with social distancing measures, and to deal with further waves of infection as lockdowns are lifted. This necessity can be analogous to the demand for arms, ammunition, steel, and other wartime material for nation-states in the Second World War.

With a number of dense population clusters and an economy heading towards recession, ramping up domestic capacity for the above is of the utmost priority to India. There are also compelling strategic reasons for doing so. Many parts of the developing world are struggling with the load on their healthcare systems, and will require affordable pharmaceuticals, medical equipment, and safety equipment. Meanwhile, the developed world is increasingly realising the risks of overdependence on Chinese manufacturing and investment as the People's Republic has adopted a bellicose stance against criticism on its handling of the pandemic and arm-twisting its trading partners to change the narrative⁶.

India is in a position to take advantage of these trends and put its economy on the path to recovery and wide-scale industrialisation. Over the coming decades, this can help pull Indian households out of poverty, tackle the unemployment crisis, and boost domestic consumption – analogous to the US’ economic trajectory during and after the Great Depression and the Second World War (Figure 1)⁷. This can help understand how India can harness similar policies to the ones adopted by the US to advance its own national interest.

But before outlining the lessons we can draw from the US during the Second World War, it is important to highlight the two caveats that shaped this “American model” of increasing innovation and manufacturing capacity.

First, the US was a late entrant to the War, and slowly built up its manufacturing capacity up till then – largely owing to contracts coming from Western Europe. Indeed, the assistance provided to Britain and France in the early years of the war helped boost American post-recession economic recovery.

Second, even after entering the war at the end of 1941, American factories and critical support infrastructure remained largely unaffected by enemy attacks as the US was geographically insulated from the ongoing war in Europe. Nonetheless, the US manufacturing sector was underprepared for the scale of production required to sustain a war effort.

In 2020, India faces a similar situation, with its manufacturing sector and institutional mechanisms unprepared for increasing capacity to manufacture goods essential to counter the coronavirus, but also remains largely insulated from security threats. Therefore, a case study of the ramping up of American manufacturing capacity can offer useful lessons to tackle the COVID-19 pandemic.

A model is presented in the next section which explores how the procurement of raw materials, the role of labour policies, incentives to innovate, financing from private individuals and public institutions, and direct intervention from the government all contributed to increasing manufacturing capacity during the time of war, and shows how these can be applied to India today.

Ramping Up Manufacturing Capacity: A Model

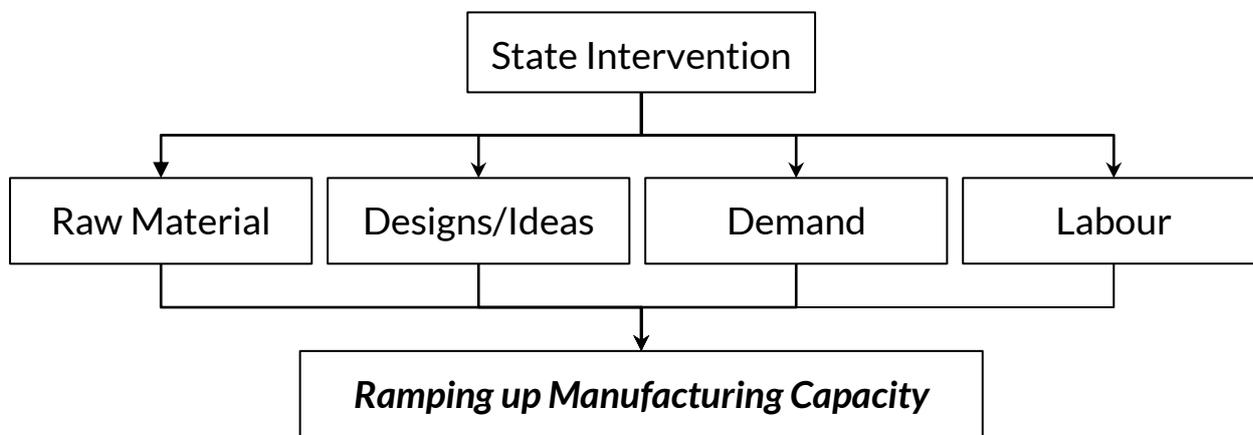


Figure 5. Factors required to ramp up manufacturing capacity.

This model is a functional representation of what is needed for a nation-state to ramp up its manufacturing capacity, based on our study of the Second World War and the present day.

First, raw materials are essential for any form of production activity. Supply chains for the procurement of raw materials must work. There must be a consistent labour supply, skilled and deployable as per the requirement. New designs and ideas are required to respond to new challenges or existing designs and ideas need to be cross-pollinated, replicated, and scaled up. None of this is possible without signals to manufacturers from the market, in the form of demand.

Governments have a significant role to play during times of crises and can create enabling conditions that allow these other factors to feed into ramping up manufacturing capacity.

We now discuss what the role of the government can be for each of these factors.

Raw Materials

Recommendations:

1. The Union government should announce R&D grants to incentivise production of scarce inputs or the development of alternative inputs.
2. The Union and state governments should enter into advanced purchase agreements to ensure production of critical equipment.

The onset of the Second World War led to supply chain disruptions for natural rubber due to the Japanese conquest of much of Southeast Asia. The supply to the US was cut off by 90percent⁸. This impacted the production of tyres for military trucks and aircraft. The US had a stockpile of 1 million tonnes of natural rubber, with a consumption rate of 600,000 tonnes per year⁹. Synthetic rubber was not being manufactured commercially. A rubber reserve company was established in 1940, which called for creation of synthetic rubber¹⁰.

As the manufacturing situation became critical, US President Franklin D. Roosevelt appointed a Rubber Survey Committee in August 1942, headed by financier Bernard Baruch, including scientists from institutions like Harvard and the Massachusetts Institute of Technology. The committee recommended the appointment of a rubber director who would have complete authority over rubber supply and use. It also recommended immediate construction of factories to produce monomers and polymers required for synthetic rubber production. While government agencies, universities, and private companies participated in the research efforts, the government provided the capital. In 1942, four plants in the US produced 2,241 tonnes of synthetic rubber. By 1945 they were producing 920,000 tons per year¹¹.

India faces similar challenges. Supply chains for various medical and health safety equipment have been disrupted. India needs N95 masks for its health workers, but these masks are not readily available. One of the major bottlenecks is the lack of availability of nonwoven polypropylene fibre used in the production of these masks¹². The machines used for producing masks are also in short supply.

China used to produce half the world's masks and was a leading producer of the fabric before the emergence of the novel coronavirus¹³. The containment measures to deal with the viral outbreaks led to suboptimal factory production. Also, the increase in COVID-19 cases worldwide led to massive spikes in demands, and Chinese production was not able to keep up. India needs to develop the capacity to manufacture these masks at competitive prices and quality and should aim to become a global supplier.

Currently, India has just 3-4 manufacturers of N95 masks and is dependent on imports for the melt woven fabric¹⁴. To meet demand and to maintain stocks for future waves of infection, it needs to ramp up production capacity for the fibre or develop substitutes for the fibre. Industry and academia need to be brought

together to develop indigenous capacities. The government needs to incentivise these players to meet the demand and ensure that regulatory roadblocks are minimised. Aside from the declaration of adequate quality standards, facilitating interaction between these actors, and declaring research grants for alternative fibres or manufacturing processes, it should not interfere in the supply side of this process. On the demand side, the government can incentivise manufacturers through the creation of a strategic stockpile for PPE at the national and state levels and entering into advance purchase agreements¹⁵. This is detailed in the “Demand” section below.

A similar process could be followed to increase India’s capacity to manufacture testing kits. As India has now substantially lifted movement and travel restrictions in many parts of the country, increasing the risk of community transmission of COVID-19, continuous ongoing testing of random samples of the population will be the only way to track the spread of the disease¹⁶. As with N95 masks, the rest of the developing world can be a major market for cost-effective testing kits.

Industry collaborations can also be an effective way to address shortages of raw materials. Before the war, aircraft manufacturers in the US were fierce competitors. As of 1942, the top nine manufacturers had a backlog of \$9 billion worth of orders due to a low manufacturing capacity¹⁷. Since there was a shortage of skilled labour and aircraft parts, they often poached employees and competed for aircraft parts.

In April 1942, eight West Coast manufacturers joined hands to coordinate production know-how, share materials and deal with common challenges. The Aircraft War Production Council was set up¹⁸. Under the coordination of Donald Douglas (the founder of Douglas aircrafts), these aircraft manufacturers shared parts, blueprints, and workers amongst themselves. This ensured optimum utilisation of scarce resources and continuity in supply chains. The B-17 bomber, which dropped more bombs than any other US aircraft, was a result of this coordination.

Returning to the present, manufacturing a ventilator requires more than 1,000 parts¹⁹. One of the bottlenecks in the production of ventilators is the limited supply of components, leading to higher prices, making it risky for manufacturers to purchase them – especially if demand is inconsistent²⁰. Learning from the example above, it is evident that supply chain coordination between manufacturers can be very useful for production of such complex equipment. This coordination is needed for parts as well as for designs. In the US, during the Second World War, it was the backlog in order fulfilment which drove the manufacturers to work together to ensure supply chain coordination. At present, some Indian manufacturers have shown interest and are collaborating to manufacture ventilators. Advance purchase agreements with these manufacturers will signal consistent demand and provide liquidity. This can further incentivise them to find ways to ensure efficient utilisation of

resources. In the long term, this can lay the foundation for globally competitive medical equipment manufacturing that can meet demands from developing nations, especially in Africa and West Asia.

Designs and Ideas

Recommendations:

1. The Government should reduce entry barriers to industries in order to leverage manufacturing expertise between sectors. If, for example, a manufacturer who does not normally produce healthcare equipment is facing difficulties in securing designs or in securing accreditations, the government must identify and reduce the bottlenecks.
2. The Government can promote cross-pollination of expertise between sectors by facilitating approvals/licenses for a fixed duration.

By the end of the Second World War in 1945, the US had produced 300,000 aircrafts – of which 95,000 were manufactured in a single year²¹. In 1939, it had manufactured just 6,000 aircrafts (see Figure 3 above)²². Resolving the supply chain of inputs was just one enabling factor.

During the Second World War, the US had companies like Pratt and Whitney which had the designs and knowledge to manufacture aircraft. But they lacked assembly line capacities required to scale up production. This is where automobile manufacturers like Ford Motor Co. and General Motors had the comparative advantage. The government provided licenses to them to manufacture aircraft or to act as subcontractors to aircraft manufacturers. Automobile manufacturers were able to deliver on their promises²³. But it should be noted that the conversion process from automobile to aircraft manufacturing was slow²⁴.

The present situation seems familiar. India faces shortages of ventilators and other ICU equipment like defibrillators²⁵. We have a few healthcare equipment manufacturers, but they are not enough to meet the present demand²⁶. Also, medical devices manufacturing takes more time, due to the adherence to stringent norms: Factors like biocompatibility have to be ensured²⁷. Specific risk management and quality protocols must be followed. The packaging material needs to be sterile. The medical devices need to have high levels of precision and reliability. Because of the above reasons, it might be difficult for non-healthcare manufacturers to start manufacturing medical devices at short notice.

If low production capacity of these facilities is the bottleneck, automobile manufacturers can be incentivised to pitch in. India needs to find ways to leverage both the experience and quality procedures of healthcare equipment manufacturers, and the assembly line capacity of automotive manufacturers. One way in which it can do this is by providing short-term licenses to automobile manufacturers to manufacture devices under the aegis of a

healthcare manufacturer. Should India be able to do this at scale and with high quality, COVID-19 offers a great chance for the country to become a major global manufacturing hub for healthcare equipment.

Demand

Recommendations:

1. Governments should develop estimates of the extent of medical equipment and PPE required at the state and district level. These should be used as an indicator to enter into advance purchase agreements with manufacturers for medical equipment and PPE supplies
2. A strategic stockpile of medical equipment and PPE supplies should be created at the Union level, with storage facilities across India to ensure quick distribution in case of a public health emergency. The strategic stockpile will only be used to supplement the state and local supplies. States are free to procure their own supplies as per their assessment of their needs.

During the Second World War, the US Army Services Force was tasked with providing supplies and equipment for the Army²⁸. It had to determine detailed requirements, secure raw materials, industrial facilities, and manpower. It had to oversee that items were produced as per schedules, stored, and delivered.

Before the attack on Pearl harbour, the G-4 division of War Department General Staff used to merely indicate the quantities procurable under different budgetary allocations²⁹. The data was inadequate for production planning. There was a requirement for long range estimates of military needs which can be used to estimate demand for raw material and facilities. This led to the creation of the first army supply program in April 1942³⁰. But time and again, it faced constraints in estimating the total requirements. The Army Supply Program was continuously revised depending on the situation: for example, the needs of the army in Europe and Pacific increased in 1944-1945. In the first phase the Program focused on providing initial equipment. After the first two years of war, it focussed on determining the replacement requirements for ongoing operations. Gradually a supply control system was established which brought into a single form data for each item, allowing for review and critical analysis. Monthly computations were made for 1900 principal items.

For estimating operational supplies, the Army Services Force faced major difficulties in the early stages of the war as the strategic plans at the highest levels were constantly changing³¹. Therefore, for the first 18 months, it made logistic plans in consonance with plans under the consideration of Joint and Combined Chiefs of Staff. Had this not been done, the Allies would have faced a shortage of weapons. By June 1943, theatre commands and staff started submitting estimates required for their operational requirements. Sometimes

the Army Services Force used different proxies, such as the combat experiences of allies, to estimate their own needs.

The present situation poses similar challenges. To contain the spread of the infection and to ensure the continuation of economic activities, India must ensure a steady supply of PPE. Since the risks faced by different individuals vary, the requirements for different types of PPE will be different – such as N95 for health workers, surgical masks for others. Apart from PPE, testing kits are required to contain the viral outbreak to identify and quarantine asymptomatic carriers and to locate hubs of community transmission. The total demand for PPE and testing kits will vary due to a number of social and environmental factors. And the supply chain needs to meet not only the initial requirement but also the replenishment of all these. Apart from PPE, there is also a need for more medical devices (ventilators, defibrillators, etc.) to assist hospitalised patients. Predicting these as part of a coherent ongoing disease control strategy will be difficult, and India will also face challenging uncertainties and difficulties in procuring data.

To win the situation, India needs to have mechanisms in place which can make these estimates and guide acquisition by governments. This can ensure a sufficient demand for manufacturers to plan a systematic increase in capacity. This should ideally be done by an agency at the Union level - estimating it at the local level might lead to losing out on the larger picture of pandemic response. It might also be difficult to shift supplies from one region to another if situations change.

The agency must constantly revise its estimates based on empirical evidence. It must leverage the experience of other countries. The estimates of the agency should be used to create a strategic stockpile for PPE and medical equipment at the Union level and be used by states to independently secure their own supplies. The Union stockpile could be stored in facilities across the country and used to supplement state and local supplies in case there is a second wave of infection or for other public health emergencies.

Labour

Recommendations:

1. Frontline healthcare workers should be thought of as strategic assets and receive protections as well as monetary and non-monetary benefits.
2. Extended health coverage and higher salaries must be provided to workers manufacturing PPE and other essential goods.

The Second World War required millions of people to fight at the front. The Selective Training and Service Act was enacted in 1940 to establish the first peacetime military conscription in US history³². Thousands upon thousands of men were trained and deployed for the war. A balance between industrial and military needs was also maintained: an offer of deferred conscription was

provided to college students, educators, scientists, and those involved in agriculture and military industry³³.

During certain crises – like the Second World War and the COVID-19 global pandemic – the manufacturing sector is under pressure to increase production of essential goods. Such demand creates pressures on the labour force to work overtime, beyond normal requirements. Workers may be forced to work long hours without additional wages. However, during the Second World War, the US strengthened labour laws rather than diluting them, ensuring that workers were highly incentivised to provide support on the factory floor.

For example, the National Labor Relations Act of 1935 was strengthened in order to protect members of unions from being removed by the employer for any activity related to union work. At the same time, the National Defense Mediation Board was established in March 1941 to ensure that disputes between labourers and management could be settled easily and quickly during wartime. These measures bolstered the confidence of factory workers, incentivising them to work beyond the required hours during the crisis.

Of course, while these measures suited the US in the Second World War, they are not necessarily applicable to India. The key lesson we can take from this is that it is crucial to recruit, maintain, and motivate the workforce in a moment of crisis.

Some insights can also be gleaned from the US's recruitment of doctors and nurses for the war effort. During and after the Second World War, the US Army considered doctors to be a “force multiplier” due to their potential in reducing casualties due to combat activities as well as disease³⁴. High military rank was provided to qualified professionals as an incentive³⁵. Recently-qualified and early-career doctors were recruited, with incentives such as allowing them to complete their internships through service in military hospitals, and allowing them to follow less stringent regulations than those followed by troopers. Similarly, nurses were recruited in massive numbers by providing them free education, as well as “officers' commissions and full retirement privileges, dependents' allowances, and equal pay”³⁶. Medical service provided a means to new career paths, as well as to an honoured position in postwar society, to many small-town Americans.

In India today, healthcare workers (doctors, nurses, paramedics etc.), law enforcement officials, security personnel, delivery executives, and other essential service providers such as grocery store workers are at the frontline of tackling the pandemic. The amount of risk faced varies with occupation, but they are the ones ensuring the containment of the virus and continuance of economic activities. They need to be treated as strategic assets and incentivised to serve “tours of duty”, as it were, in designated COVID-19 hospitals – just as in a war. These could be new facilities, refurbished public facilities, or specially-leased private facilities. Doctors, nurses, and cleaning staff who serve there

must be provided appropriate safety gear on top priority, perhaps using the strategic stockpile of PPE discussed in the previous section. They should also receive benefits such as healthcare and family health insurance. Early-career professionals could be incentivised to serve through scholarship programmes, while late-to-mid-career specialists could be incentivised through a system of honours and attractive salary packages.

The rest of the labour force, especially those working in factories and large air-conditioned office complexes, run the risk of contracting the novel coronavirus and turning these economically productive hubs into disease hotspots. At the same time, reopening the economy is crucial to ensuring that citizens can earn a living. Further complicating the matter is the fact that strengthening India's Byzantine labour laws to incentivise the industrial workforce might disincentivise foreign firms from setting up facilities in India, just when capital is exiting China. Other ways must thus be found to incentivise the workforce.

To balance the risks to lives and livelihoods, governments should provide health insurance to workers in the most crucial economic sectors. More private hospitals should be brought on board existing health insurance schemes to ensure that low-income households can also get treatment.

Conclusion

The COVID-19 pandemic is a crisis, but it is also an opportunity. Even before its onset, India's economy was slowing down. The onset of the pandemic, with its disruption of supply chains and labour networks, may well push the country into a recessionary spiral: but this is all the more reason for India to invest in building a solid industrial backbone and build up capacity to restore the economy and become a manufacturer for the world. The flight of global capital away from China and the demand for healthcare equipment and pharmaceuticals in much of the developing world – especially countries where India has strategic interests, like West Asia – offer an unprecedented opportunity for India to do so. This document has discussed how the US in the Second World War offers some lessons to India today.

These are summarised below:

1. Improve the availability of raw materials:

- a. The Union government should announce R&D grants to incentivise the production of scarce inputs or the development of alternative inputs.
- b. The Union and state governments should enter into advanced purchase agreements to ensure the production of critical equipment.

2. Ensure the circulation and development of designs and ideas:

- a. The Government should reduce entry barriers to industries in order to leverage manufacturing expertise between sectors. If, for example, a

manufacturer that does not normally produce healthcare equipment is facing difficulties in securing designs or in securing accreditations, it must identify and reduce the bottlenecks.

- b.** The Government can promote the cross-pollination of expertise between sectors through facilitating approvals/licenses for a fixed duration.

3. Create and maintain demand:

- a.** Governments should develop estimates of the extent of medical equipment and PPE required at the state and district level. These should be used as an indicator to enter into advance purchase agreements with manufacturers for medical equipment and PPE supplies
- b.** A strategic stockpile of medical equipment and PPE supplies should be created at the Union level, with storage facilities across India to ensure quick distribution in case of a public health emergency. The strategic stockpile will only be used to supplement the state and local supplies. States are free to procure their own supplies as per their assessment of their needs.

4. Incentivise the workforce:

- a.** Frontline healthcare workers should be thought of as strategic assets and receive protections as well as monetary and non-monetary benefits.
- b.** Extended health coverage and higher salaries must be provided to workers manufacturing PPE and other essential goods.

References

- ¹ Kimberly Amadeo. “An Annual Review of the U.S. Economy Since 1929,” February 6, 2020. <https://www.thebalance.com/us-gdp-by-year-3305543>.
- ² Mark Harrison. “Resource Mobilization for World War II: the U.S.A., U.K., U.S.S.R., and Germany, 1938–1945 1.” *Economic History Review* 41, no. 2 (1988): 171–92.
- ³ Alan S. Milward. *War, Economy and Society 1939-1945*. University of California Press, 1979.
- ⁴ “Coronavirus Cases:” Worldometer. Accessed June 12, 2020. <https://www.worldometers.info/coronavirus/>.
- ⁵ “Global Economic Prospects, June 2020.” *World Bank Group*, 2020. <https://doi.org/10.1596/978-1-4648-1553-9>.
- ⁶ Small, Andrew. “The Meaning of Systemic Rivalry: Europe and China beyond the Pandemic.” ECFR.EU, May 13, 1970. https://www.ecfr.eu/publications/summary/the_meaning_of_systemic_rivalry_europe_and_china_beyond_the_pandemic.
- ⁷ Pranay Kotasthane, Anirudh Kanisetti, and Anupam Manur. “Takshashila Discussion SlideDoc: India in the Post COVID-19 World Order.” The Takshashila Institution, May 20, 2020. <https://takshashila.org.in/takshashila-discussion-slidedoc-india-in-the-post-covid-19-world-order/>.
- ⁸ “U.S. Synthetic Rubber Program - National Historic Chemical Landmark.” American Chemical Society. Accessed June 12, 2020. <https://www.acs.org/content/acs/en/education/whatischemistry/landmarks/syntheticrubber.html>.
- ⁹ Ibid.
- ¹⁰ “Technical Reports and Standards.” Technical Reports and Standards (Science Reference Services, Library of Congress). Accessed June 12, 2020. https://www.loc.gov/rr/scitech/trs/trschemical_rubber.html.
- ¹¹ Mallard Creek Polymers. “A Brief History of Styrene Butadiene Emulsion Polymers Through 1945.” Mallard Creek Polymers, October 23, 2017. <https://www.mcpolymers.com/library/brief-history-of-styrene-butadiene-emulsion-polymers-through-1945>.
- ¹² Graham Kates. “N95 Mask Shortage Comes down to This Key Material: ‘The Supply Chain Has Gotten Nuts.’” CBS News. CBS Interactive, April 9, 2020. <https://www.cbsnews.com/news/n95-mask-shortage-melt-blown-filters/>.

¹³ Keith Bradsher and Liz Alderman. “The World Needs Masks. China Makes Them, but Has Been Hoarding Them.” The New York Times. The New York Times, March 13, 2020. <https://www.nytimes.com/2020/03/13/business/masks-china-coronavirus.html>.

¹⁴ Bidya Sapam. “Retailers Scramble to Stock up on N95 Masks amid Spurt in Demand.” Livemint, February 12, 2020. <https://www.livemint.com/news/india/retailers-scramble-to-stock-up-on-n95-masks-amid-spurt-in-demand-11581528552147.html>.

¹⁵ Shambhavi Naik, Sunil Dixit, Anirudh Kaniseti, and Sarthak Pradhan. “Takshashila Policy Advisory - COVID-19: Healthcare Measures to Tackle a Second Wave in India.” The Takshashila Institution, May 20, 2020. <https://takshashila.org.in/takshashila-policy-advisory-covid-19-healthcare-measures-to-tackle-a-second-wave-in-india/>.

¹⁶ Takshashila Working Group. “Takshashila Policy Advisory - Covid-19: Towards a National Reopening Strategy for India.” The Takshashila Institution, May 20, 2020. <https://takshashila.org.in/takshashila-policy-advisory-covid-19-towards-a-national-reopening-strategy-for-india/>.

¹⁷ Ethan Ilzetzki and Hugo Reichardt. “Ramping up Ventilator Production: Lessons from WWII.” Ramping up ventilator production: Lessons from WWII | VOX, CEPR Policy Portal, April 17, 2020. <https://voxeu.org/article/ramping-ventilator-production-lessons-wwii>.

¹⁸ Donald M. Pattillo. *Pushing the Envelope: the American Aircraft Industry*. Ann Arbor: University of Michigan Press, 2000.

¹⁹ PTI. “Ready to Help India to Procure Ventilators, but Scaling-up Production a Challenge: China.” The Economic Times. Economic Times, April 1, 2020. <https://economictimes.indiatimes.com/news/politics-and-nation/ready-to-help-india-to-procure-ventilators-but-scaling-up-production-a-challenge-china/articleshow/74933098.cms?from=mdr>.

²⁰ Viswanath Pilla. “Coronavirus Pandemic: Dwindling Inventory, Supply Chain Disruption - India Faces Shortage of Ventilators.” Moneycontrol. MoneyControl, March 23, 2020. <https://www.moneycontrol.com/news/business/companies/coronavirus-pandemic-dwindling-inventory-supply-chain-disruption-india-faces-shortage-of-ventilators-5063851.html>.

²¹ Karl G. Harr, Jr. “Industry and World War II.” Air Force / Space Digest, September 1965. <https://www.aia-aerospace.org/wp-content/uploads/2016/06/INDUSTRY-AND-WW-II.pdf>.

²² “The American Aerospace Industry During World War II.” Centennial of Flight . Accessed June 12, 2020. https://www.centennialofflight.net/essay/Aerospace/WWII_Industry/Aero7.htm.

²³ Ward Carroll. “How GM's Divisions Tackled the War Effort.” Military.com. Accessed June 12, 2020. <https://www.military.com/veteran-jobs/career-advice/military-transition/how-gm-divisions-tackled-war-effort.html>.

²⁴ Ethan Ilzetzki and Hugo Reichardt. “Ramping up Ventilator Production: Lessons from WWII.” Ramping up ventilator production: Lessons from WWII | VOX, CEPR Policy Portal, April 17, 2020. <https://voxeu.org/article/ramping-ventilator-production-lessons-wwii>.

²⁵ Stephanie Findlay. “Ventilator Shortage Threatens to Cripple India's Coronavirus Response.” Subscribe to read | Financial Times. Financial Times, April 7, 2020. <https://www.ft.com/content/b53066d1-bf31-4bff-9666-09e7a548228e>.

²⁶ P. B. Jayakumar. “Indian Ventilator Makers Plan 50,000 Units by May with Auto Majors' Help.” Business Today, March 31, 2020. <https://www.businesstoday.in/current/corporate/indian-ventilator-makers-plan-50000-units-by-may-with-auto-majors-help/story/399776.html>.

²⁷ Peter Ogrodnik. “Ventilators: Why It Is so Hard to Produce What's Needed to Tackle Coronavirus.” The Conversation, May 7, 2020. <https://theconversation.com/ventilators-why-it-is-so-hard-to-produce-whats-needed-to-tackle-coronavirus-135895>.

²⁸ “Logistics in World War II: Final Report of the Army Service Forces.” Washington, D.C.: United States Government Printing Office, 1948.

²⁹ “Forecasting War Requirements for Quartermaster Supplies.” US Army TS Quartermaster 1 Org, Supply, Services 1: Chapter 6: Forecasting War Requirements for Quartermaster Supplies, November 10, 2016. <http://tothosewhoserved.org/usa/ts/usatsq01/chapter06.html>.

³⁰ “Logistics in World War II: Final Report of the Army Service Forces.” Washington, D.C.: United States Government Printing Office, 1948.

³¹ “Forecasting War Requirements for Quartermaster Supplies.” US Army TS Quartermaster 1 Org, Supply, Services 1: Chapter 6: Forecasting War Requirements for Quartermaster Supplies, November 10, 2016. <http://tothosewhoserved.org/usa/ts/usatsq01/chapter06.html>.

³² David Vergun. “First Peacetime Draft Enacted Just Before World War II,” April 7, 2020. <https://www.defense.gov/Explore/Features/Story/Article/2140942/first-peacetime-draft-enacted-just-before-world-war-ii/>.

³³ “Conscription, World War II.” Americans at War. [Encyclopedia.com](https://www.encyclopedia.com/defense/energy-government-and-defense-magazines/conscription-world-war-ii), June 8, 2020. <https://www.encyclopedia.com/defense/energy-government-and-defense-magazines/conscription-world-war-ii>.

³⁴ Charles Van Way. “War and Trauma: A History of Military Medicine - Part II,” 2016. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6139825/>.

³⁵ Edgar Jones. “Doctors at War.” *The Lancet* 371, no. 9625 (2008): 1658–59. [https://doi.org/10.1016/s0140-6736\(08\)60714-x](https://doi.org/10.1016/s0140-6736(08)60714-x).

³⁶ Gordon R. Sullivan. “The Army Nurse Corps in World War II.” The Army Nurse Corps, October 3, 2003. <https://history.army.mil/books/wwii/72-14/72-14.HTM>.