The Logistics of the Covid-19 Vaccine

Professor John Manners-Bell, CEO, Ti

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The political imperative to develop a vaccine to mitigate the impact of the worldwide coronavirus crisis cannot be underestimated. A modern day 'space race' to develop, trial and produce a vaccine is underway with the prize of huge prestige for the country and company which is first to get to market.

Although the focus is, of course, on the science involved in inventing the drug, it seems that less thought has gone into how the vaccine would be stored and moved around the world, including its specific environmental needs. The storage and distribution of the vaccine have been secondary considerations although they are just as essential to the control of the global pandemic. For instance, at a time when the air cargo sector is under unprecedented stress due to the cessation of many air passenger services, will there be enough capacity and facilities to distribute chilled or even deep frozen product? Likewise, will there be enough cool chain warehousing capacity available not only in the markets in which the vaccine is being produced but in every country around the world where it is being distributed?

Although it is still too early to say where the vaccine will be produced or by which companies, this paper will identify many of the logistics opportunities and challenges involved in its distribution.

THE COVID VACCINE IN CONTEXT

The race to develop a Covid vaccine has become deeply entwined with politics – both domestic and international. In the US, a presidential election is looming and it will do Trump's chances no harm at all if he is able to claim that a US company was first to invent a vaccine. In Russia and China, the prize is that of international acclaim as well as the global projection of soft power which handing out 'free' doses of vaccine to countries in their sphere of influence would provide.

In the US, Trump has initiated a programme called 'Operation Warp Speed' whilst Russia's version has been dubbed 'Sputnik V'. The UK, China, France and Germany all have vaccines at various stages of clinical development. In total, there are more than 150 individual vaccines which may – or may not – be successfully brought to market.

The table below identifies some of those being developed by 'Big Pharma' companies, supported enthusiastically by their governments.

Table 1. Main Covid vaccine developers

Company	Country
Johnson & Johnson	US
Pfizer and BionTech	US/Germany
GlaxoSmithKline (GSK) and Sanofi	UK/France
Moderna	US
Novavax	US
Merck	US
Sinovac and Dynavax	China
AstraZeneca	UK
CanSino Biologics	Hong Kong

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There have already been pre-orders of millions of doses of the vaccines, even though success of the trials is not guaranteed.

- The UK has pre-ordered 340 million doses from GlaxoSmithKline, Sanofi, AstraZeneca/Oxford University, Johnson & Johnson and Novavax.
- EU has pre-ordered 400 million doses from AstraZeneca and 300 million from GSK/Sanofi; in addition, it is talking to Johnson & Johnson, Moderna and Pfizer/BioNTech which would see in total 1.3 billion doses.
- Canada has reserved 90 million doses
- The US government has pre-ordered 100 million doses of Moderna's vaccine and 300 million doses from AstraZeneca. In total, as of August 2020, it had ordered 800 million doses.
- Between them, the US and UK have pre-ordered about a quarter of AstraZeneca's estimated annual supply.

Outside of the major Western and Chinese manufacturers, Russia's vaccine, developed by Gamaleya National Center of Epidemiology and Microbiology in Moscow and financed by Russia's sovereign wealth fund, has apparently received requests for 1 billion doses.

In terms of numbers of people requiring the vaccine, a presentation by the Centers for Disease Control and Prevention (CDC) suggested that 20 million doses would be required initially for US health workers; 80 million for essential workers and 53 million for the over 65s. Each would require two doses of the vaccine.

To begin with shipped volumes are likely to be low and therefore focused on specific parts of society in various 'waves'. The CDC suggests that in order of priority the vaccine would be administered to:

- The most vulnerable 'at risk' from Coronavirus (those with medical conditions and the elderly)
- Health professionals
- Essential workers and teachers
- Working-age population (to maintain economic recovery)

Eventually, though, once (or if) vaccine production is up and running, the numbers of people which need to be reached will run into the billions. Adar Poonawalla, CEO of the Serum Institute, judged that in a best case scenario every member of the Indian population could be vaccinated – although not until 2024. This would mean 1.35 billion people and, if a booster is required (depending on the development of the vaccine), 2.7 billion doses in India alone.

It is not only the vaccine which will be required but the medical peripheries which are used every time a dose is administered. This will involve needles, syringes and swabs not to mention the vials and the containers in which the vaccine is held. They will be distributed through different, but existing, supply chains although the volumes required will be enormous.

There is considerable confusion over when doses of the vaccine will start to be shipped. Of course, if none of them passes the approval process, there will be no vaccine and success is by no means guaranteed, whatever the politicians may say. However, in the US the CDC has commented that 2 million doses might be available at the end of October 2020, with 20-30 million available by the end of the year. However, there are more conservative estimates suggesting that the vaccine would not be available to Americans until mid-2021.

This later date is probably more likely as the clinical trials process usually takes much longer than a few months (usually several years). Having said that, 'emergency' approval could be forthcoming if early results of the clinical trials are overwhelmingly positive. However, there are already concerns that corners may be being cut for political reasons and this could have a severe impact on the take up of the vaccine by the general public if there are worries about its safety.

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THE NEED FOR GLOBAL DISTRIBUTION

Whichever vaccine passes the approval stage, production will be concentrated on a small number of locations. It is likely that the vaccines will be produced in the same countries in which they were developed although with some exceptions. AstraZeneca has already entered into a licensing agreement with the Serum Institute of India for the production of its vaccine (see below).

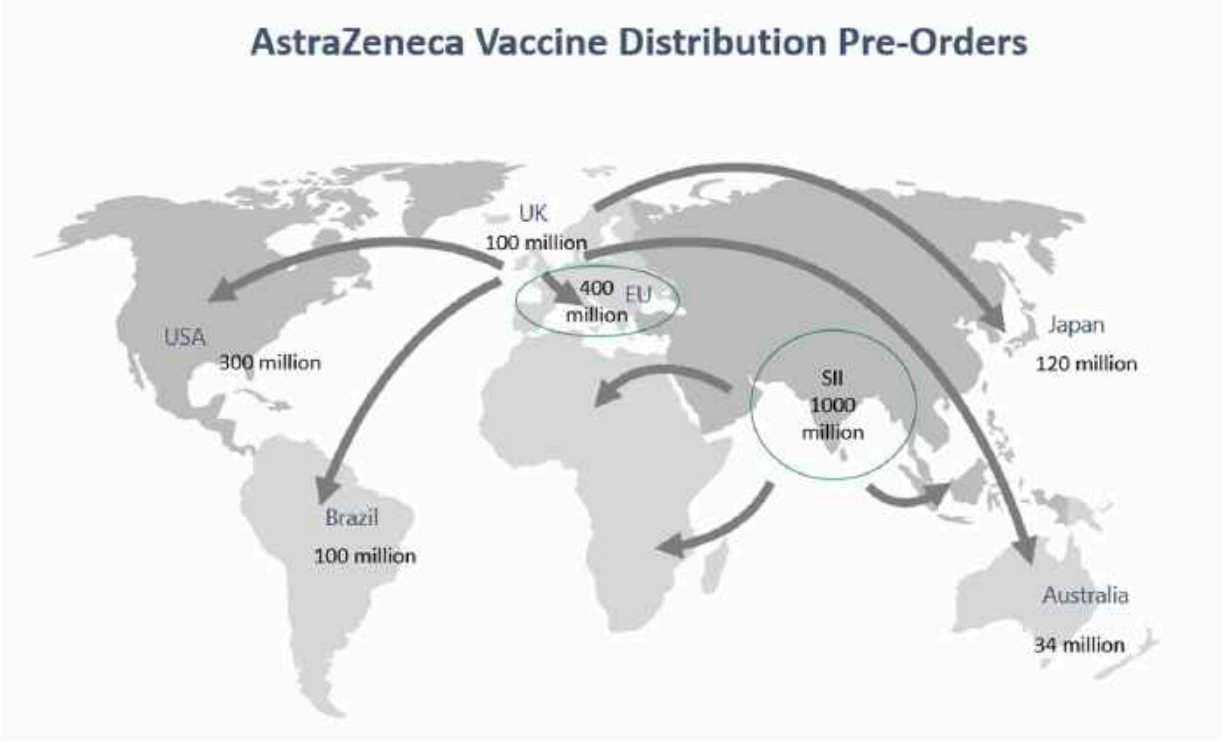
Given the existing pre-orders, the largest producers of vaccine are likely to be:

- UK
- USA
- China
- France
- Germany
- Russia

In terms of air cargo, this would mean significant volumes would flow through:

- London Heathrow (DHL, British Airways and multiple airlines), East Midlands Airport (UPS hub), Stansted (FedEx)
- Louisville (UPS), Memphis (FedEx), Philadelphia (American Airlines), Newark (United and FedEx)
- Shanghai and SAR Hong Kong (China hubs); Singapore (Asian air hub)
- Paris (Air France and FedEx hub)
- Frankfurt (Lufthansa)

In Europe, most of the vaccines would be moved by road and so it would seem the English Channel crossing may become very important. Given that the release of the vaccine may coincide with Brexit, there is a considerable risk that shipments may be held up in queues unless an agreement is reached between UK and the EU. If this is not the case, then air charter may be the only option.



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As the map indicates, roughly about half of the 1 billion pre-orders of doses placed with AstraZeneca will require air freighting. 100 million will be moved domestically around the UK and 400 million will require ground distribution throughout the EU. In addition, AstraZeneca has agreed a licensing deal with the Serum Institute of India (SII) to manufacturer 1 billion does of the vaccine which will then be distributed to low and medium income countries in developing markets such as Africa. Presumably a large proportion of this will also need air freight capacity.

THE ROLE OF AIR CARGO

It seems inevitable that due to the perishable nature of the vaccines being developed, air cargo will play an important role in their worldwide distribution. However, given that capacity in the industry has been so impacted by the cancellation of many air passenger services, how exactly the huge volumes of vaccine will be moved is difficult to assess. According to industry organization, IATA, providing a single dose to 7.8 billion people would fill 8,000 747 cargo aircraft (although in reality a significant proportion of this volume would be moved by road). DHL/McKinsey have estimated that there would be 200,000 movements of pallets on 15,000 flights over two years to enable global distribution.

Existing capacity in September 2020 was still a third below the previous year and organisations such as UNICEF have already warned that it has been difficult maintaining existing vaccine programmes in parts of the world, let alone fulfilling the requirements for a Covid vaccine.

IATA also highlighted a number of other challenges:

- Availability of temperature-controlled facilities and equipment - maximizing the use or re-purposing of existing infrastructure and minimizing temporary builds
- Availability of staff trained to handle time- and temperature-sensitive vaccines
- Robust monitoring capabilities to ensure the integrity of the vaccines is maintained
- Security arrangements making sure that shipments cannot be tampered with.

The fast processing of exports and imports will be fundamental to the efforts to the vaccination programme. The risk of the vaccine becoming ineffective increases significantly the longer the shipment is delayed at border crossings.

According to IATA, there are a number of issues which will need to be addressed in order to facilitate the cross-border movement of shipments of vaccine.

- Introducing fast-track procedures for overflight and landing permits
- Exempting flight crew members from quarantine requirements
- Supporting temporary traffic rights for operations carrying the COVID-19 vaccines
- Removing operating hour curfews for flights carrying the vaccine
- Grant priority on arrival
- Considering tariff relief to facilitate the movement of the vaccine.

The extent of the logistics challenges involved has encouraged some politicians to involve their military to ensure airlift. In the US, President Trump has committed the air force to move the vaccine around the country – although how exactly it will deal with the problems of refrigeration has not been revealed.

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THE IMPORTANCE OF THE COOL CHAIN

The specialised environmental conditions in which the vaccines need to be stored and moved is already resulting in a massive investment in cool chain facilities. There is only a very small tolerance in the allowable temperature range specific to each vaccine and this requires not only the equipment to maintain these levels but also the sensors to monitor the status and assure the integrity of the cool chain at every stage: from manufacturer through distribution centres to the hospitals or medical settings where the dose is to be administered. Not only this, but specialised containers and packaging will be needed when in transit, often using dry ice which itself may be in short supply. Shortages have meant that UPS and FedEx are both looking at investing in their own dry ice making capabilities.

Some of the vaccines will require what is called 'deep-frozen' storage at temperatures as low as -80 degrees Celsius (perhaps even as low as -180 degrees Celsius using liquid nitrogen). This is likely to be a hugely inhibiting factor in the distribution of the vaccine as very few freezers can reach this temperature. Whilst so much uncertainty exists over which vaccine will be authorized, there is reluctance on the part of governments and companies (with some exceptions – see below) to invest heavily in freezer capacity which may not be needed.

The vaccines of two leading pharma companies, Pfizer and Moderna, need to be stored at very low temperature in specialist freezers and vials. The doses then only have a short life at the temperatures found in refrigerators; perhaps 3-5 days at a higher temperature (say 5-8 degrees). However, this means that the clock is ticking very fast on the distribution of the vials and this will require a JIT approach to getting the vaccine to where its required as well as express transit times. This will have significant implications on the cost of the transport and would be highly dependent on the locations of the 'freezer farms' and the remoteness and density of the population being vaccinated. For example, if elderly care homes are a priority, small numbers of the dose will have to be delivered to a very high number of fragmented locations with more than one dose required. The administrative and logistics effort required to make this happen will be immense and the potential for doses to be wasted significant.

Quoted in the New York Times, Kathleen Dooling, an expert with the US Center for Disease Control and Prevention commented that the specific temperature requirements would "make it very difficult for community clinics and local pharmacies to store and administer." She also commented that the vaccine would likely need to be dispensed at centres which had a high throughput. This would make logistics much easier and cheaper, but as mentioned above, potentially exclude large sectors of the most vulnerable in society.

Employing a centralized approach to storage and distribution also has the problem that the 'freezer farm' hub may be located a long distance away from areas of infection. Many health professionals are suggesting that such hotspots should be prioritised, in which case a central hub would make targeting these locations highly problematic.

Despite these uncertainties, investment in specialised cool chain facilities and equipment has already started ahead of the hoped for roll out of a vaccine.

- UPS is building freezer farms at Venlo, Netherlands and at Louisville, Kentucky with more planned for UK, Germany and South America. The two existing 'farms' will hold 600 freezers each capable of storing 48,000 vials of the vaccine, prior to dispatch in dry ice. This capability would be required for the Moderna and Pfizer vaccines, but not many of the others which require refrigeration at 2-8 degrees but not freezing.
- FedEx has freezer facilities at its hubs in Memphis, Tennessee and Paris, France. It is adding refrigerated capacity in California and Texas.
- DHL has recently opened a life sciences centre in Indianapolis with capabilities of holding vaccines at various temperatures down to -20 degrees Celsius.

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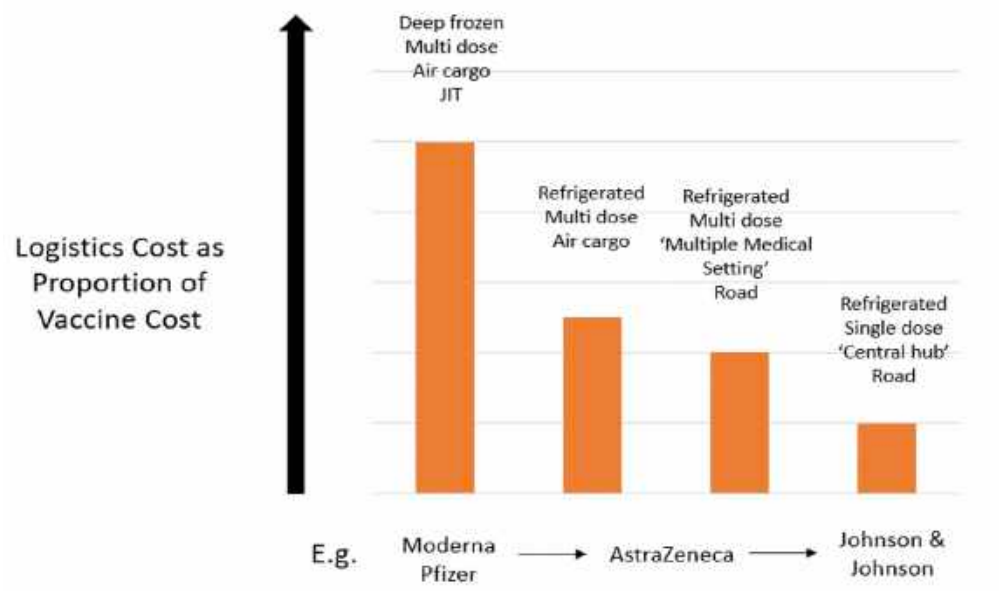
- Pfizer has invested in containers that will maintain a -75 degrees temperature for 10 days with dry ice. Each box contains 200 vials of 10-20 doses of the vaccine. They are GPS enabled with thermal sensors.

Of course, the challenges of distributing the vaccine in developing countries will be at an entirely different level. It will be very difficult to keep the vaccine at the very low temperatures required as freezing and refrigeration facilities are in short supply in large parts of Asia, Africa and South America. Consistency of electricity supply can also be problematic. These challenges, combined with a fragmented, rural population profile, will mean that it will be difficult to get the vaccine to the necessary medical setting whilst it is still within the appropriate temperature range.

LOGISTICS COST UNCERTAINTY

The cost of distribution will depend very much on the specific attributes of which vaccine is successfully trialled and brought into production.

- Does it need to be deep frozen or just refrigerated?
- What is its shelf life at warmer temperatures?
- Is it administered in a single dose or does it need 'boosters'?
- Can the vaccine be transported by road or does it need to be moved by air cargo?
- Will it be distributed through vaccination hubs or fragmented medical settings?
- Is it produced locally or sourced internationally?



For example, as previously mentioned, Pfizer's vaccine would need shipping and storing at -80 degrees; Moderna's vaccine will require shipping at -20 degrees; AstraZeneca's alternative will need to be kept cold but not frozen and so distribution would be much easier. However, it seems that all these vaccines would need an initial dose followed by a booster, whereas Johnson & Johnson's would only need a single dose and has the benefit of only requiring refrigeration rather than freezing. It needs just the single dose and can be stored in liquid form in refrigerators for three months, rather than a handful of days as is the case with some of its competitors.

If vaccines are administered through a centralized hub, this will make logistics costs even cheaper. In the UK the British Army may move shipments of vaccine to empty 'Nightingale' hospitals. These hubs would act as centres for storing and administering the vaccines, although this would not necessarily solve the problem of

reaching more vulnerable groups of society unable to travel to the hospitals.

With all these uncertainties it is very difficult to assess what the logistics spend on the vaccine will be. However, in the sector logistics costs can amount to 7-8% of the 'cost of goods sold' for pharmaceutical products[1]. AstraZeneca has announced that it would be selling doses of its vaccine at cost price which would be around $3 each. A simple calculation using the number of pre-orders it has received suggests that there could be a logistics spend of up to $0.5 billion for this company's vaccine alone. Obviously, this has multiple caveats depending on the variables outlined above.

The downstream logistics costs are likely to be paid by the government health services who are administering the vaccine program rather than the pharmaceutical companies. The US agency involved in coordinating the vaccine response has said that it will move the vaccine to distribution sites across the country within 24 hours of its approval using medical supply company McKesson as the main distributor.

CONCLUSION

Until one of the Covid vaccines being trialled gains approval from the statutory bodies tasked with overseeing safety it is impossible to identify the necessary logistics requirements for global distribution. Much will depend on the conditions in which the vaccine has to be stored and moved as well as its shelf life. However, what can be stated with more certainty is that if approval is forthcoming, the logistics resources required and their associated costs will be huge: from investment in freezer farms or chilled warehousing; the airlift; the refrigerated road freight movements; the last mile delivery to medical settings as well as the sensor and software technology to track and validate the integrity of the coolchain. On top of this there will be the distribution of medical peripheries needed to administer the doses: vials, syringes, needles, swabs etc, not to mention their secure disposal. Much of this capacity is already in short supply and will be in addition to important and on-going vaccination programmes (such as flu). Whilst this should be a major concern for many health authorities and buying organisations, it will provide a massive opportunity for those in the relevant sectors of the logistics industry.

Before getting too carried away, however, the pharma industry needs to develop a safe and effective vaccine – and this is by no means guaranteed.

1. https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/operations/pdfs/lean_and_mean-how_does_your_supply_chain_shape_up.ashx

About Ti

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