FORWARD PLANNING FOR THE NEXT PANDEMIC

ROCKLEY G. BOOTHROYD
Chartered Engineer, Queensland, Australia

ABSTRACT
This paper is mainly concerned with providing a safe workplace in future pandemics which are likely to be similar to the present COVID-19 crisis. It concentrates on methods to avoid expensive future lockdowns. More advanced air conditioners are considered which exclude the effects of dangerous viruses. Such designs which have these beneficial qualities depend on adequate basic data concerning viruses. This information is vital for adequate design of engineered equipment. These requirements are also specified here. The general insufficiency of this information is also examined. The airline industry faces a particularly complicated set of problems which are treated in more extensive depth with recommendations for an acceptable new system up to 2050. Our civil airline industry is probably the most vulnerable in a future pandemic. By exploiting the nature of modern industrial development, it is recommended that the economically destructive effects of extensive lockdowns can be largely avoided in modern economies. For want of a better name (ID-LID?), the recommended system is called ID-LIP which stands for: "inherently down-lockable industrial plant". This approach is advantageous for the Wholesale side of a nation's economy. However, because Retailing is associated closely with human sociability, which viruses also exploit, improving this commercial aspect requires different remedial methods. One of these is the more extensive use of on-line retailing.
Keywords: air travel; vaccines; virus bioaerosols; workplace health and safety

1 INTRODUCTION

In an earlier paper [1], methods were described which would achieve safer use of public transport especially for people needing public transport to travel to work in the time of a pandemic. Equally important, in this respect, is the need to provide a safe workplace where infection from future pandemics can be supressed. This is examined in the present paper.

It was also predicted in this earlier paper [1] that our experience in the present COVID-19 pandemic would eventually supply us with valuable statistical data. One such particularly useful example [2] of supplying statistical data has also emphasised the importance of finding alternative strategies to lockdowns. Lockdowns have resulted in catastrophic adverse effects on the economies of most nations together with significant social unrest.

COVID-19 has certainly brought it to our attention that the domestic economies of most present-day nations are very fragile in our internationally competitive world. Extended lockdowns are an expensive way of controlling pandemics. They work well but we need to find alternative forms of control. This explains the emphasis and direction in the present paper.

2 UPDATING THE GENERAL PRESENT SITUATION

Earlier suspicions that the COVID-19 virus was likely to be a devious enemy seem to have been confirmed [3]. Estimates vary but "long COVID" seems [3, 4] likely to infect about 10^5 victims in U.K. alone and many of them are young and were in the prime of life. The symptoms are many and varied and are described by terms such as 'brain fog' and chronic fatigue. These observations suggest that we may have to accept a long-term and expensive addition to social security benefits in our welfare state systems (also see Appendix A1.2 which also contributes to the same adverse effect).

© 2022 WIT Press, www.witpress.com
ISSN: 2398-2640 (paper format), ISSN: 2398-2659 (online), http://www.witpress.com/journals
DOI: 10.2495/EI-V5-N2-185-196

Medical experts seem to be perplexed by "long COVID". Is the near permanent damage to victims of COVID-19 due to the virus itself or is it a result of damage caused by our bodies fighting this nasty infection?

Due to "long COVID", the policy of relying on herd immunity in the future has been questioned [3].

In general, developing statistics indicate that accepted vaccination systems greatly reduce fatality figures and serious illness. However vaccinated people showing no symptoms can infect others. The same observation applies to patients who have recovered. The generally accepted goal is to strive for 100% vaccination of the world population. The enlarging world population results in more mutations which, fortunately, can be dealt with by adjustments which can be made with modern vaccine technology.

3 NEED FOR FAST ROLL OUT OF EFFECTIVE NEW VACCINES

It has to be admitted that the World was taken by surprise by the COVID-19 pandemic. Yet we had no excuse for being surprised. This follows because we had experienced and contained previous outbreaks of MERS and SARS which were strongly related to the present pandemic. Also, our experts in Epidemiology had given us plenty of warning of such future problems with pandemics.

References [5] and [6] describe the monumental and expensive task of large-scale and speedy manufacture of vaccines using new technologies without our having much previous experience. The virus vector (AstraZeneca, Johnson and Johnson) and messenger mRNA (e.g. Pfizer and Moderna) methods have demonstrated adequate vaccination efficacy and can be adapted to cope with emergent mutations. Other very novel and promising technologies are still at early development stages. Experience with mRNA, has also opened up other future medical advances [7] such as improved self-immunity treatment of cancers. mRNA vaccine technology has been described [6] as "uncomplicated" requiring 2 h for synthesis and 2 days to manufacture. mRNA is a method whereby our cells are triggered to produce their own relevant proteins to stimulate our own immune system. This is superior technology to our normal method of administering medicines externally. Although this mRNA approach seems to have wide application in medicine, the means by which it works is quite complicated.

Vaccine manufacture is a healthy and very competitive industry. Profits may be large but investments such a Pfizer's $2 billion low temperature manufacturing facility, which has potential for improvement, seem courageously reminiscent of the speedy technology advancement by combatants in later stages of World War II. The 'know how' expected in the confidential files of vaccine manufactures seems likely to inspire confidence in coping with future and different pandemics. This seems to favour us with less reliance on economically disruptive control methods such as lockdowns.

4 THE NEED FOR REVISED AIR CONDITIONING TECHNOLOGY

The World Health Organisation (WHO) has issued a roadmap of recommendations for the use of air conditioning in pandemics. They have also commissioned a committee of experts to review the subject. At present their recommendations are limited to conventional matters such as stricter maintenance of existing systems and the advice to always turn off air recirculation systems. In looking for further developments it seems appropriate to divide this subject into two sections:

4.1 Workshop safety in pandemics for large-scale manufacturing

The present author has not located any suitable references in this area. Consequently, a hypothetical case study is included in appendix A1.1 to demonstrate some methods which are likely to be used and recommended in the future. This leads to appendix A1.3 which recommends the use of ID-LIP which can be used to eliminate the need for lockdowns expected to apply to most manufacturing enterprises.

4.2 Premise safety during pandemics for small business

It is unlikely that smaller entities such as shops would be able to afford purpose-made air conditioners. In the future these smaller forms of business are likely to adhere to the following requirements in pandemics:

- Require all customers to either "log in" using their mobile phone so that they can be traced. Alternatively, they can identify themselves manually. This system is already in operation. It is likely and desirable that this process would include checking of appropriate certification of vaccination.
- Arrange their premises to have once-through ventilation. Normally fresh air would enter at the entrance to the premises and be fan-ejected to an open window at the back of the premises.
- Install the appropriate number of CO_2 monitors with wired-in audible alarms. It is found that air-borne pathogen levels correlate closely with CO_2 levels [8, 9].

5 THE RECURRENT PROBLEM OF POOR BASIC DATA FOR EFFECTIVE DESIGN OF ENGINEERED SYSTEMS

This problem was addressed in [1]. We know surprisingly little about how the virus exists in our own environment. Our experience is that the virus is unable to travel long distances from one region to another without exploiting the mobility of a person to carry the infection. Yet we have almost no accurate factual data of the natural environmental factors which kill the virus. Solar radiation, adverse humidity and temperature are all presumed to be involved. What we need is factual data of the half-lives of decay of the virus population, and mutated species, due to these environmental factors acting separately. Such data come from laboratory studies. Most earlier studies are for bacteria [10] and other higher pathogenic life forms. The study of viruses is much more problematical. Viruses can be killed easily by the sampling procedures we have, and we want our measurements to be able to discriminate between dead and live virions [11–21].

The best we can hope for is more progress in this ongoing field of study. Perhaps the resurrection of some old technologies [22] may help in a small way.

6 THE CIVIL AVIATION PROBLEM

Despite its economic importance, the information relating to the possibility of virus infection in aircraft is rather sparse. By way of trying to find an explanation for this is a paper [23] written in a reputable journal by three authors associated with the airline industry. Yet the paper is followed by 14 well-qualified critics raising several disputable issues. With few exceptions [24,25] it seems hard to reject the suspicion that the airline industry would prefer to avoid the problem. Curiously, in support of this belief, the present author has failed to find an instance where the airlines have tried to shift the blame for aircraft infections onto the air terminals themselves. Clearly all the relevant parts of the travel industry, tourism, airlines and terminals, are in this same mess together and have suffered enormously due to travel lockdowns. Therefore, it is reasonable to conclude that such a reserved attitude is the correct one. Shifting the blame does not solve, or even address, the many problems which have to be faced.

6.1 Air terminals

Most of us would probably agree that our overcrowded air terminals have been designed with scant regard for pandemic infections. The similarities with cattle sale-yard design seem obvious enough especially with the advent of later "add-on" facilities such as anti-terrorism 'carry on' baggage controls.

Yet to suggest that all our air terminals should be rebuilt is hardly reasonable in an industry which has struggled to survive an era of repeated lockdowns caused by a long-lasting pandemic. Perhaps adequate interim improvements can result from adopting a new "batch-wise" approach to passenger management? In this way it would be easier to identify and contain the occasional case of infection from a supposedly vaccinated and certified passenger.

In more detail, it is suggested:

1) Assemble all passengers on a particular flight in a comfortable lounge. If later experience suggests that personal contact is a significant cause of infection, passengers could even be re-clothed daily in inexpensive disposable paper garments. This system could also make passenger identification easier.
2) Process documentation of passengers in fully-assembled passenger batches. This seems preferable to the present system of documentation carried out collectively for several flights at the same line of desks.
3) Try to minimise the need for carry-on baggage, See item (4) below.
4) Try to minimise flights to a duration of 7 hrs rather than present-day 14 hr long hops. In this way passengers can be fed and rested in a hotel for breakfast and dinner. Only light refreshments in mid-flight would require mask (or more advanced protective headgear (fig. 1 in [1]) removal).
5) All interim and final disembarkation should use the "isolated passenger batch' approach to identify and contain the occasional incidence of an infected person.

Much of the detail of such suggested re-organisation relies on more accurate data concerning virus transfer to individuals (see section 5). Unfortunately, the airline industry faces other important problems, and these will inevitably take priority and must therefore be addressed in this paper.

6.2 The greenhouse gas footprint of air travel

It seems inevitable [26] that airlines worldwide will face limitations caused by greenhouse gases (both H_2O and CO_2) at 10 km altitude. At this height the atmosphere lacks adequate turbulence which would otherwise assist in transferring pollutants to ground level where they can be recycled more easily and correctly All nations can expect to face future penalties in proportion to their use of present-day air transport [26].

Future hydrogen-fuelled aircraft have been designed but there are doubts that they will become reality. It is planned to store hydrogen fuel within the fuselage in carbon-fibre tanks. Hydrogen is an odourless and very explosive gas noted for its ability to leak. Will hydrogen ever be sufficiently safe in this application?

The present author has faced such problems before [27]. This experience seems to be relevant and is summarised in Appendix A2.1. This appendix should be read in conjunction with Appendix A2.2 and ref. [28].

7 CHANGING AREAS OF COMMERCIAL IMPORTANCE IN THE PANDEMIC ERA

There will inevitably be winners and losers from the outbreak of any new pandemic.

Cruise ships were an early manifestation of the need to design air conditioning systems which were free from virus contamination. Fortunately, this seems easy to achieve. Like airliners the atmosphere in the direction of travel can be expected to be virus free because viruses do not survive well in the open atmosphere. As stated in [1] social activities on cruise ships need special consideration and are probably best avoided altogether. Much success has been achieved in other tourist areas by using the ship as a vehicle of travel to many different countries and allowing selected groups of patrons to choose optional coach trips inland and pick up the same ship at its next port of call. This form of surface travel has tourism advantages over air travel which only offers limited views at a height of 10 km. We might well expect the tourist ship industry to make a comeback, but it is essential to draw in fresh air for air conditioning from the front of the ship and anchor the ship to benefit from sea breezes flowing towards the bow of the ship.

8 THE CASE FOR COMPULSORY VACCINATION

Despite the surprising level of public antagonism to vaccination, the case for compulsory vaccination is not particularly strong in the fundamental sense. All democratic governments and, supposedly, all those which are not democratic, have a basic responsibility to legislate and act decisively on all matters of public safety. It is now abundantly clear that our travelling habits spread viruses and control of our movements is a matter for government control.

9 CONCLUSIONS

The conclusions of [1] still stand. In addition, it is concluded that in this paper that:

a) Economic disruption of a nation can be greatly reduced by using the system here referred to by the acronym ID-LIP which stands for "inherently down-lockable industrial plant". In monetary terms, this is by far the most important conclusion in the present paper. (The second most financially important conclusion is summarised in Appendix A2.2.)
The ID-LIP system is potentially of commercial benefit to the Wholesale activities of a nation's economy. In essence, ID-LIP is aimed at keeping the national manufacturing economy in a state of full operation so that it becomes independent of a virus pandemic. The retail side of business remains more vulnerable to future pandemics. Essentially this arises because retailing is strongly associated with the social aspects of human behaviour, which viruses also exploit so successfully. This suggests that on-line or remote retailing is preferable to conventional face to face trading.
b) The civil aviation industry is particularly vulnerable to other future demands and pandemics are only part of the story. We need to open our minds to alternative technologies and question some of the well-established methods we have been using in the past.

c) Future pandemics may limit the importance of some parts of our economy, but such limitations may open up new opportunities in other areas. For example, the present problem with virus contamination in cruise ships can be overcome with extra investment in better air-conditioning which can remedy past design mistakes. This form of mass tourism has the potential to compete more effectively with international air travel which has fundamental problems for which we still lack a solution.

d) The retail side of business also presents problems which remain with us to a large extent. Essentially this arises because viruses use their small size and relatively straightforward evolutionary skill to use our sociability as a means to improve their own reproduction. The COVID-19 virus has no brain and no soul and yet it has hijacked our human quality of sociability. We want our sociability back and fortunately we have our science to achieve this. Our sociability is essential for the evolutionary development of the human species. So many of our good qualities such as conscience, compassion, charity, co-operation and companionship derive directly from our sociability. Perhaps the greatest lesson we can learn from this COVID-19 experience is to treasure our sociability which is so precious to our human species.

REFERENCES

[1] Boothroyd, R.G., Retrofitting public transport systems to reduce health hazards from pandemics, *WIT transactions on Ecology and the Environment*, vol. 253, pp. 487–497, 2021.

[2] Haug, N., et al., Ranking the effectiveness of world-wide COVID-19 government interventions. *Nature Human Behaviour*, **4**, pp. 1303–1312, 2020. https:doi.org/10.1038/s41562-020-01009-0.

[3] Hamzelou, J., Symptoms that won't stop. *New Scientist*, **248**(3306), pp. 10–13, 2020.

[4] Vaughan, A., The spectre of long covid. *New Scientist*, **252**(3357), p. 21, 2021.

[5] Various Contributors, https://www.lek.com>insights>covid 19-vaccine-man… COVID-19 Vaccine Manufacturing: Challenges, Solutions and….. 15 Sept 2021. Accessed on: 1 Nov. 2021.

[6] Various Contributors, https://www.chemistryworld.com>news>4013429.article, Why manufacturing Covid vaccines at scale is hard business … , 23 Mar 2021.

[7] Le Page, M., The future of medicine unlocked. *New Scientist*, **252**(3356), pp. 38–42, 2021.

[8] Bazant, M.Z., Kodio, O., Cohen, A.E., Khan, K., Gu, Z. & Bush, J.W.M., Monitoring carbon dioxide to quantify the risk of indoor airborne transmission of COVID-19. *Flow: Applications of Fluid Mechanics*, **1**(E10), 2021. https://doi.org/10.1017/flo.2021.10

[9] Leung, N.H.L., et al., Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nature Medicine*, **26**, pp. 676–680, 2020. https://doi.org/10.1038/s41591-020-0843-2

[10] Le-Pan, Y., Kalume, A., Kinahan, S., Tezak, M. & Santarpia, J., Bioaerosol property and viability affected by various environmental factors. *International Journal of Environmental Impacts*, **3**(1), pp. 19–30, 2020. Doi :10.2495/EI-V3-N1-1930

[11] Haddad, G., et al., Rapid scanning electron microscopy detection and sequencing of severe acute respiratory syndrome Coronavirus2 and other respiratory viruses. *Frontiers in Microbiol*ogy, 19 November, 2020. https://doi.org10.3389/fmicb202.596180

[12] Santl-Temkiv, T., et al., Bioaerosol/field measurements: challenges and perspectives in outdoor studies. *Aerosol Science and Technology*, **54**(5), pp.520–546, 2019. https://doi.org/10.1080/02786826.2019.1676395.

[13] Shammi, M., Rahman, Md.M. & Tareq, S.M., Distribution of bioaerosols in association with particulate matter: A review on emerging public health threat in Asian megacities, *Frontiers in Environmental Science*, 20 Aug. 2021. https://doi.org/10.333389/fenvs.2021.698215.

[14] Sender, R. et al., The total number and mass of SARS-Cov2 virions. *Proceedings of the National Academy of Sciences,* **118**(25) e2024815118, 2021. https://doi.org/10.1073/pnas.2024815118.

[15] Kawasuji, H., et al., Transmissibility of COVID-19 depends on the viral load around onset in adult and symptomatic patients. *PLoS ONE*, **15**(12), e0243597, 2020. https://doi.org/10.1371/journal.pone.0243597.

[16] Bar-On, Y.M., Flamholz, A., Philips, R. & Milo, R., SARS-CoV-2(COVID-19) by the numbers. *eLife,* **9**, e57309, 2020. doi: 10.7554/eLife.57309

[17] Ratnesar-Shumate, S., et al., Comparison of the performance of aerosol sampling devices for measuring infectious SARS-CoV-2 aerosols. *Aerosol Science and Technology*, **55**(8), pp. 975–986, 2021. https://doi.org/10.1080/02786826.2021.1910137

[18] Rahmani, A.R., Leili, M., Azarian, G. & Poormohammadi, A., Sampling and detection of corona viruses in air: a mini review. *Science of the Total Environment*, **740**, pp. 140207, 2020. doi:10.1016j.scitotenv.2020.140207

[19] Kim, S.W., Ramakrishnan, M.A., Raynor, P.C. & Goyal, D.M., Effects of humidity and other factors on the generation and sampling of a corona virus aerosol. *Aerobiologia*, **23**, pp. 239–248, 2007. https://doi.org/10.1007/s10453-007-9089-9

[20] Goodman, J.R., A pandemic like no other. *New Scientist*, **249**(3316), pp. 38–41, 2021.

[21] Kakutani, K., et al, A simple electrostatic precipitator for trapping virus particles spread via droplet transmission. *International Journal of Environmental Research & Public Health*, **18**, paper 4934 (on-line), 2021. https://doi.org/10.3390/ijerph18094934

[22] Boothroyd, R.G., An anemometric isokinetic sampling probe for aerosols. *Journal of Scientific Instruments*, **44**, pp.249–253, 1967.

[23] Pombal, R., Hosegood, I. &Powell, D., Risk of COVID-19 during air travel. *JAMA,* **324**(17), pp.1798, 2020. doi: 10.1001/jama.202019108.

[24] Blomquist, et.al., Risk of symptomatic Covid-19 due to aircraft transmission: a retrospective cohort study of contact-traced flights during England's containment phase. *Influenza and other Respiratory Viruses*, **15**(2), pp.336–344, 2021. https:// doi.org/10.1111/irv.12846.

[25] Williams, G.H., et.al., SARS-CoV-2 testing and sequencing for international arrivals reveals significant cross border transmission of high-risk variants into the United Kingdom. *EClinical Medicine*, On-line 14 July 2021. https://doi.org/10.1016/j.eclinm.2021.101021.

[26] Vaughan, A., Good COP, bad COP. *New Scientist*, **252**(3357), pp.36–41, 2021.

[27] Boothroyd, R.G., A proposed extra international air transport corridor along the world's equatorial belt. *12th World Conference on Transport Research*, July 11–15, Lisbon, Portugal, paper 1069, 2010.

[28] Various authors from 24 corporate bodies from civil aviation, Hydrogen powered aviation: a fact-based study of hydrogen technology, economics and climate impact by 2050., Publication office of the European Union: Luxembourg, pp. 1 – 93, May 2020. Doi: 10.2843/47150

[29] Boothroyd, R.G., Nuclear power can be the answer. *International Journal of Energy Production and Management*, **2**(3), pp. 225–238, 2017.

[30] Jenness, B.L., Jenness, S. & Bohn, D.D., Wet scrubber for carbon dioxide collection, United States Patent Application Publication, Pub. no: US 2011/0011261 A1, Jan. 20, 2011.
[31] Higgins, C., et al., Carbon dioxide scrubbers for controlling the gaseous composition of spaceflight plant growth chambers-design trades and test results, SAE Technical Paper, 2005-01-2954, https://doi.org/10.4271/2005-01-2954.
[32] Quammen, D., How viruses shape our world. *National Geographic*, **238**(2), pp.41-47, 2020.

APPENDIX 1

A1.1 Outline of a future engineered system to ensure workplace safety

Figure A1 shows a proposed scheme for ensuring the safety of workers in a clothing manufacturing factory in Bangladesh. This is a place with a very concentrated human population. Consequently, it would be expected to have a dangerously high atmospheric level of virus contamination in a pandemic. On the other hand, one of the advantages of factories in this area is that workers also often live within their workplace. Consequently, they do not have the danger of catching the virus while travelling to their workplace and infecting other workers. It seems reasonable to conclude that such a factory could maintain full production throughout the worst of pandemics as there is no need to experience a lockdown.

Figure A1 shows a plan view of a suitable form of air-conditioning for this factory. Virus contaminated air is drawn in at a number of roof-top separated channels A_1 - A_n. These channels all have a baffle system which is only shown here for channel A_1. The purpose of this baffle system is to restrict mixing of the contaminated air which is heated by solar energy to about 30 °C, if laboratory tests show that this is the optimum temperature for the virus to become active. Water is sprayed into the air to achieve 100% humidity if, as expected, this also makes the virus particles most active. Air is drawn sequentially by a trapdoor system from each channel in turn and this active virus-laden air passes into the base of the disinfection system B. The dirty air is blown as small bubbles into the base of B. B contains ethyl alcohol at about 70% concentration in a viscous fluid such as glycerol. The purpose of the viscous fluid is to give the contaminated air bubbles sufficient "residence time' in the

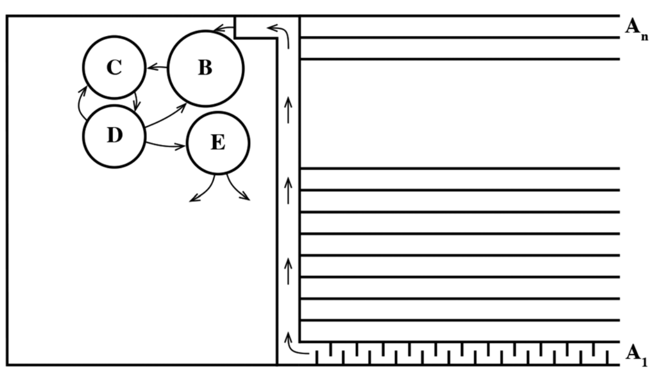

Figure A1: Air conditioning in factory in Bangladesh.

disinfector to kill the virus. The air then passes to the top of C which is a wet scrubber. The scrubbing water in C absorbs the "carry over" alcohol and then passes the water/alcohol mix to a fractional distillation unit D which separates the water from the alcohol. The alcohol is recycled to the disinfector B and the water is recycled to the wet scrubber C. The virus-free air is then passed to a conventional air conditioner E and thence to the workers who breathe the cleaned air. Coping with workplaces of different size would probably be most easily accommodated by having several identical units B, C and D working in parallel. This would also simplify servicing and repair work.

There are a number of permutations of this type of set-up. A more advanced technology was suggested in the oral presentation of [1] using a fogging machine and electrostatic precipitation of killed virus. A paste effluent of dead virus waste was to be used usefully to make cement building products such as wall planking.

The problem with choosing alternatives is the lack of basic knowledge (see section 5). Also, much of our research in handling viruses is at a very early stage of development (21]. Other alternatives exist such as using another type of scrubber [30], [31] to absorb CO_2 emitted by breathing and replacing this CO_2 with oxygen. This "make-up" oxygen can be obtained most conveniently by electrolysis of water. The hydrogen by-product can then be used for other purposes.

A1.2 Changing social developments significant to providing workplace safety in pandemics

The example in A1.1 refers to a situation where relatively cheap labour is available. Nevertheless, even cheap labour can become uncompetitive with today's technical developments in the use of automated machinery. A couple of locally observed examples clarify this point:

1) Traditionally Australian agriculture has relied on itinerant fruit pickers to help at harvest time. COVID-19 has produced problems limiting the supply of itinerant workers. To compound the problem, itinerant workers have recently been granted the right to a large wage increase which now guarantees them the minimum wage. These two factors will inevitably influence our farmers to invest more in engineered harvesting equipment as a more attractive alternative to an unreliable and prohibitively expensive workforce. This is an impending social problem of worldwide dimensions as higher wage expectations reduce the availability of semi-skilled employment. It is an increasing social problem which merits much greater attention than the limited consideration in the present paper.
2) A new local manufacturing facility to produce gluten-free processed food mainly for export requires an investment of about AU$ 10 million. Yet this plant will only employ about 50 people mainly to keep complicated machinery functioning correctly. This situation is typical these days. Hardly any local people are likely to find employment in this new plant. On the other hand, such modern industrial plant can be adapted more easily to cope with future virus pandemics. Older designs of production plant with a high manual labour payroll are likely to be ill-suited to this approach. This is all described in A1.3.

A1.3 ID-LIP: A method of eliminating the need for lockdowns in our major industries

It is certainly a matter of much social concern that industrial manufacturing technology is reducing the need for semi-skilled labour. Inevitably decisions will be based on purely economic grounds of operational efficiency. Yet, in the long term, we will have to consider the larger picture of the consequences of reduced semi-skilled employment opportunity within our future civilised society.

With regard to future pandemics however this trend can be exploited to considerable advantage. A large-sized industrial plant with a small workforce can easily be designed for contingencies where enclosed space can be adapted on a temporary basis to provide fully protective accommodation for its workforce. As in the case considered in A1.1, the workforce can be completely isolated from pandemic virus infection and the manufacturing plant can continue in a full production status until the pandemic has subsided. Much depends on agreed contractual relationships with individual employees. Most families when faced with the option of family separation but with a regular income and the alternative of no income and no separation would, most likely, choose the former option. Larger companies may even be able to design their own quarantine section to help alleviate these difficulties.

Incorporation of such contingency designs would require government certification. Each certification application would be unique and need to be submitted, examined and certified prior to a pandemic crisis. Such a system as ID-LIP (an acronym for "inherently down-lockable industrial plant") can be seen as a reversal of the "work from home" system which has been used, where possible, in the present pandemic.

It has been suggested that ID-LIP could be changed to ID-LID or Idlid which means "inherently down-lockable industrial design".

APPENDIX 2

A2.1 A civil aviation system which is free of virus contamination and greenhouse gas contamination.

This scheme [27] suggested using pilotless aircraft operating between 1,000 and 5,000 m altitude compared with 10,000 m altitude of today's aircraft. These aircraft were to be launched to cloud height by a ground-based towing cable. Initially these aircraft were proposed to provide an air cargo service along the World's equator. Most of their flight energy requirements would be derived from cloud hopping using their special radar systems to locate updraft in equatorial cumulus clouds. Two small hydrogen-fuelled gas turbines could be used intermittently for propulsion as required. The trailing edge of the strong delta wing would catch water droplets from the clouds and be used to generate hydrogen as required. The fuel source was plastic encapsulated sodium hydride which was available commercially in 2010. These capsules would, after slicing them open at a controlled rate, provide hydrogen fuel as needed using the reaction:

$$\mathrm{NaH} + \mathrm{H_2O} = \mathrm{NaOH} + \mathrm{H_2} \tag{1}$$

The sodium hydroxide was to be stored in the wings to be converted back to sodium hydride after landing.

In this particular case most of the energy requirements for launching aircraft and converting NaOH to NaH were to be obtained from algae grown in "racecourse" ponds adjacent to runways in normal airports. The nutrients from processed algae were to be recycled to the racecourse ponds. The racecourse ponds were themselves to be used for launching the aircraft which were amphibious so that they could also use sheltered seaways. The aircraft could land on these seaways to be reloaded and re-launched using the winch equipment fitted to some ships such as ferries.

The concept was limited in its value because almost all desired air corridors are North-South inclined and not East West. The main advantage of the proposed system was very low fuel cost and the only greenhouse gas emitted was H_2O and this would be automatically and quickly recycled as ordinary rain.

Perhaps the advantages of this proposed system can be reconsidered in the light of today's different requirements? An inexpensive transport system for damage-prone tropical agricultural products may well be needed. A regular diet of meat can be expected to become too expensive for most of us due to expected future restrictions on ruminant animals which emit potent methane greenhouse gas. It is suggested that access of this equatorial air corridor to European and North American markets could be achieved by high speed rail links passing beneath Gibraltar and through Panama respectively.

The Club of Rome, in decades past, has also long advocated the economic development of African countries. Their principal aim was to develop a natural large-scale source of solar-powered electricity which could be exported to Europe. Perhaps the problem of unwanted refugee migration into Europe can also be eased if such investments can be made to improve the economies of African nations?

A2.2 The need to rethink our fundamental needs in the future civil aviation industry

Whatever the future, if any, may be for the system described in appendix A2.1, it serves to suggest that radical redesign may be needed for the survival and necessary growth of our civil aviation industry which now emits 10^9 tonnes of CO_2 annually. Such revision will need all the resources we have from our major industries. The following suggestions are only the result of a number of "back of envelope' feasibility studies but they seem to point us in the right direction.

Advice from [28] points out that about 66% of our civil aviation GHG emissions stem from short and medium length flights and only about 34% can be attributed to intercontinental flights at the most efficient 10000m cruising altitude. Report [28] is emphatic that hydrogen is ill-suited to fuel long haul flights because of storage space but this is not the case for shorter flights.

If aircraft for short/medium haul trips could be just a bit slower perhaps they would not need their heavy turbofan engines but could be launched from suitable hillsides by an electric rail launcher. This form of launching is easy to power from solar or wind farm energy, perhaps even with nuclear power backup [29] thus eliminating our CO_2 emissions if hydrogen fuel is used only to power a pair of much smaller turbofan engines. These smaller engines might be rated as operating on 70% of their maximum thrust to maintain level flight. They might also be designed to operate between 1000 and 5000 m altitude thus relieving flight path congestion of future intercontinental flights. The air at these lower heights would also be equally free of virus contamination.

By redesigning our short/medium-haul aviation system we should have the time interval to find an answer to developing a less polluting intercontinental aviation system Also this would also allow all our present airliner fleet to live out their designed lifespan.

APPENDIX 3: THE VIRUS: IS IT OUR FRIEND OR IS IT A FOE? OR IS IT BOTH OF THESE?

In this reference [32] it is explained how the human species could not even exist without the past evolutionary effects of viruses. 8% of the tissue in our bodies was, in effect, placed there by "horizontal gene transfer" caused by viruses. Also, some of the most important human features of our advanced mammalian life form can be traced back to the benign effects of viruses.

All viruses are parasites of other higher forms of life. Normally they exist by exploiting a particular species. Very rarely are viruses able to jump across the species barrier to adapt themselves to life within another species. This is most likely to occur when a particular species suffers a population explosion. A population explosion of a species increases the number of virus mutations and thence a higher chance of the virus finding a new home. Viruses are a natural part of Nature's elaborate set of control systems and we need to limit our interference with the powers of Nature.