FEATURE COVID AND LOPA



LOPA Versus Covid

Ali Mokhber, Christopher Ross, and Pablo Garcia-Trinanes describe how layers of protection analysis might be applied to the coronavirus

HEN the International Electrotechnical Commission conceptualised IEC 61511 at the turn of the century to protect people from industrial process accidents, they could hardly have imagined that in the years ahead the methodology might be adapted to protect people in a global virus pandemic.

From a chemical engineering point of view, transmission of the SARS-COV-2 virus is a process, and the disease Covid-19 can be managed like any other process hazard. There have already been attempts to do this, eg the bowtie and Swiss cheese models (*see Figure 1*). These are useful in identifying the pathways of infection and potential interventions.

LOPA (layer of protection analysis) can take this further, by performing a semi quantitative risk assessment, which enables evaluation of the relative probabilities of virus transmission, infection, and death.

Thus, we have adapted LOPA and are developing it as a **management tool** that can evaluate, compare and improve the steps that users – such as process plant management, offices

and university HSE managers, hospitals, care homes, and social venues – could take to reduce the risk of infection and of death.

This project has been developed as part of the volunteer work undertaken by the University of Greenwich and IChemE's Covid-19 Response Team. The aim is to help HSE professionals and chemical engineers evaluate workplace risks and highlight safety measures they can consider to lower them. For example, the method could be used as risk reduction metrics to assess the degree of compliance of office workers to the barriers to spread the virus when they return to work after lockdown.

We're currently further developing this tool and talking to industry about implementing and commercialising.

LOPA INPUT DATA FOR COVID-19 RISK MODELLING

LOPA is a semi-quantitative risk assessment methodology. Safety integrity level (SIL) analysis and LOPA methodology were formalised in IEC 61508 & IEC 61511, adapted by AIChE CCPS (Centre for Chemical Process Safety) for process industry use. It requires valid input data, which is well established for process industry use, but more challenging to apply for a pandemic.

LOPA requires three main inputs:

- risk tolerability criteria;
- initiating event frequency; and
- probability of failure on demand (PFD) for independent protection layers (IPLs) and condition modifiers.

For Covid-19, the risk tolerability criteria is taken as a comparison of the annual frequency of death due to Covid-19 and that of seasonal flu.

The initiating event is the frequency of encountering a person infected with the virus; and the independent protection layers are: social distancing; free air movement (ventilation and open space); face mask; hand hygiene; and the condition modifier for the vaccine efficacy.

For LOPA modelling, independent protection layers are used as barriers to virus spread with specific probability of failure on demand. A probability of failure on demand is a probability between almost 0 and 1.0. 1.0 means no independent protection layer is present (or 100% failure), decreasing as the probability of failure of an element decreases.

Thus, for social distancing, we could take an exposure risk of 0.16 (PFD = 0.84), considering the infection risk source is the centre of any of the six positive and negative cartesian coordinates. If not social distancing, an exposure risk is 0.5 (PFD = 0.5) where the source is near enough at two coordinates only. For face mask/visors/fixed barriers and vaccines, the manufacturers specify the efficiency of their products. For open air and closed space (if there are high efficiency particulate air, HEPA, filters), we could use a very low PFD of 0.05

FIGURE 1: THE SWISS CHEESE MODEL OF PANDEMIC DEFENCE

HAND HYSICAL RESPIRATORY MASK VENTILATION VENTILATION or 0.1, otherwise larger PFDs need to be used. A PFD for hand sanitisation has to be selected illustratively, as it depends on compliance.

INITIATING EVENT

Covid-19 is atypical of process hazards, as it is pervasive and often carried by asymptomatic individuals. However, we can evaluate the frequency of an "initiating event", ie "effective" contact with an infected person, as follows:

- 1. Local rolling infection rates eg the UK coronavirus interactive map.
- 2. Potential effective contacts per event.
- 3. Number of events per year.
- 4. Adjust for any confounding factors which tend to magnify and multiply the effect of the infected contacts. This includes poor ventilation systems, cramped enclosed space, and excessive crowding. These should be taken as a prompt to improve the situation, maybe with expert help. Other factors to account for are not quarantining, and the presence of asymptomatic infected individuals.
- 5. If there is a suitable testing regime, it is then possible to account for this and adjust accordingly.

These factors are all used in a simple calculation to evaluate the number of effective infection encounters per year, which is the initiating event in the LOPA calculation. (*See Table 1*)

LOPA ASSESSMENT TOOL

Two parallel infection pathways have been identified: direct transmission from an infected person to the target individual via droplets and aerosols carrying the virus, and indirect transmission, where infected droplets land on a surface, and are then picked up by the yet-uninfected public.

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The method takes the frequency of the initiating event and multiplies this by the PFDs of the independent protection layers, with the result being the risk of infection/year for that pathway, summing these for the pathways to give an overall risk of infection. This is then computed with the probability of death for the infected individual (see *Table 2*) to give the overall risk of death per year for that individual.

We calculated this risk of death per year using the annual flu death rate to evaluate the improvement index – similar to the risk reduction factor commonly used in process safety LOPA risk applications.

TABLE 1: CALCULATION OF INFECTION ENCOUNTER RATE PER YEAR INPROCESS PLANT (INFECTION ENCOUNTER RATE IS THE INITIATING EVENTRATE PER YEAR)

CASE	1
Location	Chemical works
Upper tier local authority (UTLA) selected	North Lanarkshire
Date	4 Jan 21
1. Rolling infection per 100,000	423.6
Rolling infection rate as decimal (per individual)	0.004236
2. Number of encounters per shift	40
3. Number of events per year	146
4. Modifier for testing regime	0.25
5. Modifier for high risk setting	1.25
Infection encounter rate per year	23.19

COLOUR KEY

- = USER INPUT
- = CALCULATION OUTPUT
- = INPUT FROM OTHER SOURCES (RELEVANT WEBSITES)
- = CHANGE VARIABLE

UTLA obtained from https://coronavirus.data.gov.uk/details/interactive-map

IMPACT ON INDIVIDUALS - RISK OF DEATH

The impact of infection on the death rate of infected persons is obtained from the ALAMA (Association of Local Authority Medical Advisers) calculator, which, given inputs on the age, sex, ethnicity, BMI, and various co-morbidities, indicates the probability of death of an infected person. This can be run for typical and vulnerable individuals.

CASE STUDY

Table 1 illustrates a hypothetical process plant where upper tier local authority data gives 423.6 cases of Covid-19 per 100,000

TABLE 2: CALCULATION OF DEATH PROBABILITY FROM ALAMA DATA

and considers a hypothetical chemical factory. For a base case of 25% personnel tested with a frequent highly-effective test, an infection encounter frequency rate of 23.19/year is obtained. This would mean that for an individual with 40 encounters per shift (handovers, management, other team members and maintenance contacts) on a 5-shift system, 12-hour shifts, commuting from North Lanarkshire for a total of 146 encounter events per year, there is a likelihood of 23.19 Covid-19 positive contacts per year.

Table 2 is then used to calculate the probability of death from ALAMA data, which illustrates two cases A and B, of similar age, ethnicity and gender but differing in the health status and body mass index (BMI). ALAMA data gives the Covid age with upper and lower fatality limit. For the LOPA, the geometric mean is calculated as a suitable average for distributions with large fluctuations.

OUR LOPA TOOL GIVES THE USER A FEEL FOR WHAT STEPS COULD BE MADE TO IMPROVE THE SITUATION. THEY MIGHT BE ABLE TO IMPROVE THE INFECTION ENCOUNTER RATE BY REDUCING THE NUMBER OF CONTACTS, AND/OR EVENTS, OR SETTING UP A SUITABLE TESTING SYSTEM

Table 3 (the base case) is the LOPA table for the infection rates for poor social distancing, ventilation, and mask compliance with no vaccine, and 25% testing. When the risk of death for the individuals is taken into account, A and B show a marked difference in improvement factors of 158.65 and 9,725.58, respectively. This suggests improvements are required, especially for B.

A sensitivity analysis was carried out, changing variables as follows: *Table* 4 shows the LOPA for improving the PFDs for social distancing and for ventilation to 0.5 and 0.1 respectively, with the resulting improvement factors over the base cases. *Figure* 2 summarises the change in improvement factors for A and B for testing regimes of 25% (base), 50%, and 75% uptake.

Figure 3, beside summarising the changes in improvement factors for social distancing and ventilation, also covers changes to the PFD for face masks (0.05) and hand hygiene (0.3) and for vaccines at various efficacies of 0.7 and 0.9 (PFDs = 0.3 and 0.1).

BASE CASE	ACTUAL Age	FLU DEATH RISK FOR ALL AGES (Many Younger People Work in Process Plants)	SEX	ETHNICITY	BMI	HEALTH STATUS	COVID Age	LOWER Fatality Limit	UPPER Fatality Limit	GEOMETRIC MEAN of Fatality for 1 Person
A	40	1.87E-04	м	White	30-34.9	Good	40	0.5	1.9	9.75E-04
В	40	1.87E-04	м	White	40+	Asthma, Type 2 Diabetes	85+	30	119	5.97E-02

Table 2 is obtained from https://alama.org.uk/covid-19-medical-risk-assessment

TABLE 3: LOPA IPL AND BASE CASE

BASE CASE	INFECTION Encounter Rate Per Year	tion Inter Pathway	INDEPENDENT PROTECTION LAYERS (IPL)						DEATH Probability	RISK OF		T FACT OR
			SOCIAL Distancing	VENTILATION/ Outside	FACE MASK/ Visors/ Fixed Barriers	HAND Hygiene	VACCINE	RATE PER Year	FOR 1 Infected Person	DEATH PER Year	DEATH RATE	IMPROVEMEN
	23.19	Direct	0.90	0.90	0.90	0.90	1.00	15.22				
A	23.19	Indirect	0.90	0.90	0.90	0.90	1.00	15.22				
		Total						30.43	9.75E-04	2.97E-02	1.87E-04	158.65
В	23.19	Direct	0.90	0.90	0.90	0.90	1.00	15.22				
	23.19	Indirect	0.90	0.90	0.90	0.90	1.00	15.22				
		Total						30.43	5.97E-02	1.82E+00	1.87E-04	9725.58

TABLE 4: LOPA IPL SENSITIVITY ANALYSIS

CASE (SOCIAL Distancing ipl to 50% & Ventilation ipl to 10%)	INFECTION	ssion Ay	INDEPENDEN	T PROTECTION LA	YERS (IPL)	DEATH Infection probability	RISK OF	FLU	T FACTOR			
	RATE PER YEAR	TRANSMIS	SOCIAL Distancing	VENTILATION/ OUTSIDE	FACE MASK/ Visors/ Fixed Barriers	HAND Hygiene	VACCINE	RATE PER Year	FOR 1 Infected Person	DEATH PER Year	ANNUAL Death Rate	IMPROVEMEN
	23.19	Direct	0.50	0.10	0.90	0.90	1.00	0.94				
A	23.19	Indirect	0.50	0.10	0.90	0.90	1.00	0.94				
		Total						1.88	9.75E-04	1.83E-03	1.87E-04	9.79
В	23.19	Direct	0.50	0.10	0.90	0.90	1.00	0.94				
	23.19	Indirect	0.50	0.10	0.90	0.90	1.00	0.94				
		Total						1.88	5.97E-02	1.12E-01	1.87E-04	600.34



FIGURE 2: CHANGE IN THE IMPROVEMENT FACTORS FOR CASES A & B

FIGURE 3: CHANGES IN THE IMPROVEMENT FACTORS FOR SOCIAL DISTANCING AND VENTILATION, FACE MASKS, HAND HYGIENE AND FOR VACCINES AT VARIOUS EFFICACIES



WHERE DOES THIS LEAVE US?

Effective quarantining has the potential to remove the symptomatic infections from the encounter rate.

A significant proportion of Covid-19 cases are asymptomatic for part or all of their infectious period, and are an important factor in transmission.

The testing factor we used was the proportion of staff covered by the testing. The test will not be 100% accurate and frequency of testing also matters. Rapid testing, ie lateral flow tests, tends to give true positives, but false negative results, because they skip the viral RNA amplification step. Lack of practical data has been major obstacle to more accurately model the virus spread, however it is hoped that later versions of the tool could incorporate these factors.

Ventilation can be a protection against spread of the virus, when outdoors, or recycling air through HEPA filters. But for ventilation that moves air around without filtering it can positively assist the spread of the virus.

Our LOPA tool gives the user a feel for what steps could be made to improve the situation. They might be able to improve the infection encounter rate by reducing the number of contacts or events, or setting up a suitable testing system. There may be individuals who need special protection due to a combination of age, ethnicity, or BMI. They might be able to improve PFDs, either by physical improvements or encouraging compliance.

It is important to understand the ventilation system and its maintenance status, as this has the potential to be a factor in virus spread. If necessary, seek expert assistance from qualified personnel from CIBSE (Chartered Institute of Building Services Engineers) or REHVA (Federation of European Heating Ventilation & Air Conditioning Associations).

The tool allows the user to evaluate what they are currently doing, and to evaluate the relative effects of various improvements as part of a cost benefit analysis.

Vaccines are included as an independent protection layer in the LOPA. Once an individual is properly vaccinated then they can be considered protected to the efficacy of the vaccine. Eventually, vaccinations should reduce the infection rates, thus reducing the encounter rates and the overall risk.

LOPA is an established tool that supports reducing risk via the design of safety instrumented systems, but we believe it can be adapted in certain circumstances to contain the spread of this pandemic.

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ATTRIBUTIONS

1. https://alama.org.uk/covid-19-medical-risk-assessment 2. https://coronavirus.data.gov.uk/details/interactive-map (contains MSOA names ©Open Parliament and database right 2020; contains Ordnance Survey data ©Crown and database right 2020; contains Royal Mail data ©Royal Mail and database right 2020; contains Public Health England data ©Crown and database right 2020; Office for National Statistics licensed under the Open Government Licence v.3.0).

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