ENVIRONMENT AND MODELLING GROUP

Risk Estimation to inform risk assessment

(Based on available evidence up to 05/05/20)

Executive Summary

- Structured, pragmatic risk estimation should be used as part of the assessment of the relative risks associated with contracting and transmitting SARS-CoV-2 which focuses on the risk of exposure from surfaces, from people and from the air; this applies both at national level, and at the level of employers;
- Ideally, this should be quantified, but the data is not yet sufficient, and it will be too complex for many organisations. However, a framework based on factors that influence exposure can be used to evaluate risk in a structured way;
- The approach to controlling risk should be based on the hierarchy of control; mitigation measures that are implemented at a system or organisational level should be applied as far as possible before those that rely on personal compliance;
- We propose that assessment of risk should be based on the exposure during different job activities carried out over a work day, rather than considering by location, organisation or industry sector;
- Data collection should be built into any risk reduction interventions using a "mitigate, monitor, modify" strategy to adapt to changes in evidence;
- We strongly recommend that national surveillance systems and research programmes are set up to collect data on occupation and location of positive COVID cases in order to identify those roles and environments where controls are effective and where they can be improved (e.g. hospital admissions, test-track-trace);
- At national level, the likely impact on the whole system risk of any individual work sector should be taken into account (e.g. implications for transport, system of opening schools);
- It is important that vulnerable groups as well as equality and accessibility are considered throughout the risk assessment process;
- Risk assessments should be completed by those people responsible for managing the risk within an organisation to an agreed and documented approach.

Background

Risk has two dimensions: the likelihood and the severity of harm. Risk assessment comprises **risk estimation**, '*how big is the risk of what to whom?*', and **risk evaluation**, '*are the risks tolerable?*' Risk estimation can be qualitative, semi-qualitative, or quantitative: the appropriate approach depends on the nature of the risk, the degree of uncertainty in evidence about that risk, and who is doing the risk assessment. Whichever approach is taken, risk estimation should be structured and systematic.

Understanding risk is going to be a significant part of enabling people to go back to work and wider societal activities to restart. This will need to include consideration of how to protect workers from catching the infection as well as how to prevent spread from infected workers to colleagues or the public. It is important that the assessment of risk considers the potential for exposure to the virus in the context of the transmission routes, and hence develops a mitigation strategy that is related to these risks.

This will be bespoke, not just to a workplace environment but to the people and activities within it. It will be critical to understand the relative risks of the various activities that make up either a job, or a "user journey". Each work activity or element of a user interaction will involve a number of potential exposure routes and risk factors which need to be understood to enable effective control measures to be put in place.

Each employment sector, job or user experience is also part of the wider national system. Changes affecting workers in one work activity, may affect the level of transmission nationally. (For example, if transmission of SARS-CoV-2 can be controlled effectively in many office spaces, this might lead to an increase in commuting by office workers which might significantly increase the likelihood of transmission through the transport system). Therefore, there will be a need for monitoring and review at a national level.

Each job or user (customer, pupil, etc) experience is also part of a wider system. Changes to one job, may affect the ability of the wider system to manage the overall risk effectively (e.g. if risk can be managed effectively in office spaces, the increased commuter numbers which may result, could significantly increase the risk of transmission of SARS-CoV-2 through the transport system). The people best placed to assess the risks in any situation are the organisations which are required to manage the risks (e.g. the employer). However, there will be a role for Central and local government to review activity as a whole at a national/local level particularly in the context of the impact individual decisions have on the wider system.

Estimation of Relative Risk of Transmission for Exposure to SARS-CoV-2

When estimating the risk posed from SARS-CoV-2 in any work activity or user journey, the following principles provide a systematic approach.

1. Identify the Hazards and Exposure:

In the case of SARS-CoV-2 the hazards fall into the following key areas:

a. Exposure to SARS-CoV-2 from surfaces (contact transmission);
b. Exposure to SARS-CoV-2 from people (short range droplet transmission);
c. Exposure to SARS-CoV-2 from the air (aerosol transmission);

For all these routes the risk of infection is determined by the amount of viral exposure and the dose-response. In the future we anticipate this could be quantitatively modelled for a particular scenario as further data emerges on the virus and the transmission routes, as detailed in Annex 1. While this can't be done at the moment, the factors that influence the risk can be identified and these can therefore be used to identify appropriate mitigations that will address one or more of the transmission routes.

2. Identification of Risk

To identify where these hazards might be encountered in any given situation, it is important that any job or user journey is broken down into its constituent activities, and the potential for each of the hazards to occur should be considered for each of the activities. This will identify the risks for an individual worker and/or customer/user being exposed to the hazard. In considering the risk, it is important to consider both the frequency and duration of the exposure to SARS-CoV-2. Furthermore, the scale of the risk will vary in different situations. For example, activities which involve contact with the public will have a bigger risk than activities involving contact with a team of the same group of work colleagues only. Activities that interact across a wide geographic area will have a bigger risk than those that are within a contained local network. More detail is provided in annex 1, and some worked examples are provided at annex 2.

3. Identification of Controls

Once the risk estimate has been identified for each work activity, consideration should be given to the controls that need to be implemented to reduce the risk. The controls should be based on an understanding of the transmission routes, the hierarchy of control (figure 1), and the best available evidence[1].

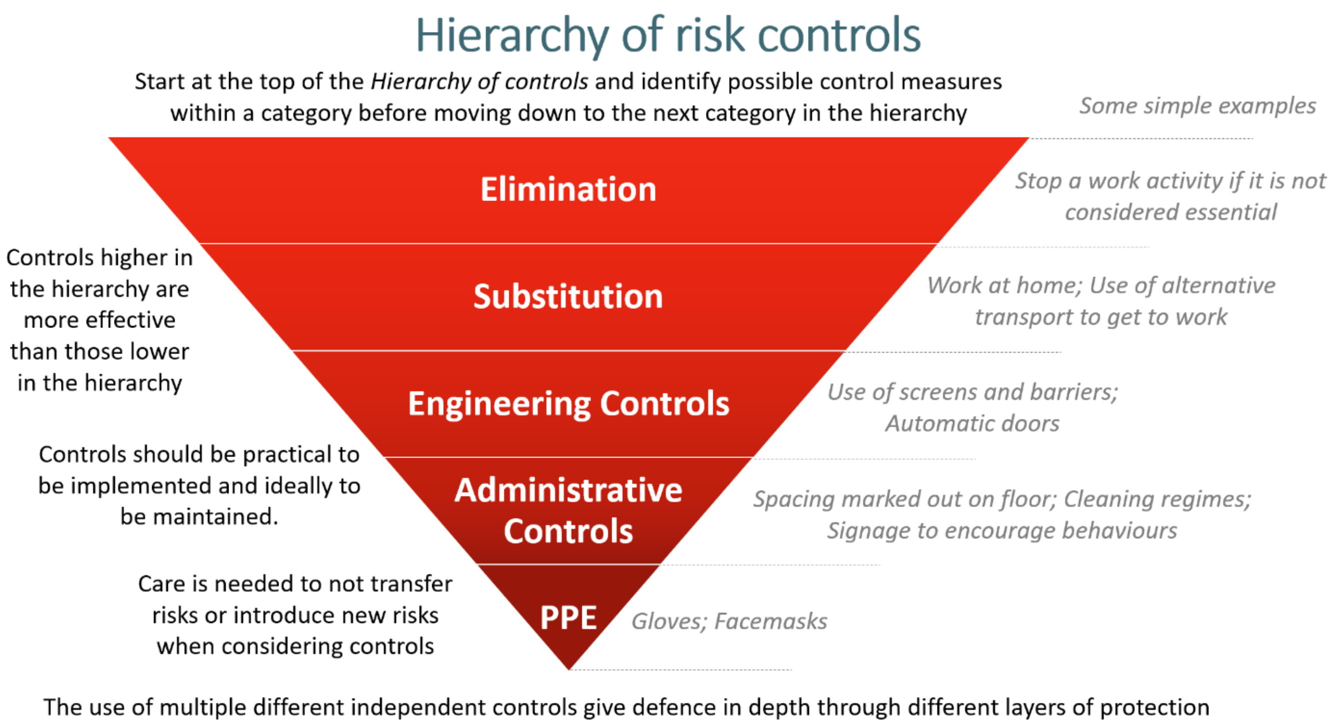

Figure 1: Hierarchy of control model including some simple examples of control that might be used for SARS-CoV-2.

Given the nature of SARS-CoV-2, it is important that any controls are regularly and critically reviewed to take account of the evolving evidence base so that continuous learning and improvement is built in. In addition, consideration should be given to the routine collection of data to increase the knowledge base regarding control measures, this should include a, “Mitigate, Monitor, Modify” strategy where the efficacy of planned interventions is properly evaluated.

A hierarchy of controls is a way to prioritise risk control measures based on how effective different types of control are in reducing risks. Risk reduction measures should be assessed in order of the priority given in the hierarchy; it is not a case of simply jumping to the easiest control measure to

[1] HSE, What is a hierarchy of control, www.hse.gov.uk/risk/faq.htm#hierarchy . Accessed 05/05/2020 .

implement from the list. This is because it is recognised that the types of control higher up in the hierarchy (Table 1) are more effective at reducing the risks than those lower down the list.

Controls should be practical to be implemented and, ideally, should be able to be maintained easily over time. It might be necessary to monitor control effectiveness on a regular basis. Care is needed to not transfer risks or introduce new risks when considering controls measures. The use of multiple different independent controls give defence in depth through different layers of protection.

TABLE 1: Detail regarding the hierarchy of control.

Hierarchy of risk controls

1. Elimination

Redesign the activity such that the risk is removed or eliminated.

E.g. Stop a work activity if it is not considered essential. This may be just one part of a job (e.g travelling to meetings in another part of the country), but other aspects could continue where the risk is acceptable.

2. Substitution

Replace the activity with an activity that reduces the risk. Care is required to avoid introducing new hazards from the substitution.

E.g. Work at home; Use of alternative transport to get to work; online meetings

3. Engineering Controls

Design measures that help control or mitigate risks, such as barriers, guards, etc.
Priority should be given to measures that provide collective protection rather than those that just protect individuals or a small group of people.

E.g. Use of screens and barriers; Automatic doors; effective ventilation and sanitation systems

4. Administrative Controls

Identifying and implementing the procedures to improve safety, such as undertaking risk assessments, preparing and communicating mitigating procedures, and increasing signage.

E.g. Spacing marked out on floors; Cleaning regimes; Signage to encourage behaviours; provision of hand wash stations

5. PPE

Personal Protective Equipment: local kit to mitigate the risks to those exposed to the hazard. People must be familiar with the function and limitation of each item of PPE for this to be an effective measure. Ideally, PPE is only considered after all previous measures higher in the hierarchy are identified as not being fully effective in controlling the risks.

E.g. Gloves; Facemasks.

It will only rarely be feasible to eliminate the risk completely. The combination of controls introduced should aim to reduce the risk to as low as reasonably practicable prioritising structural, environmental interventions over individual level ones. If any residual risk is judged to remain after this process is completed (including consideration of “layered controls” [2]) then the hierarchy of control would suggest that appropriate PPE would need to be used to remove exposure. It is likely that, from a practical perspective, the hierarchy of control won’t always be used in a traditional sense; multiple different layers of control will have to be adapted going as high up the hierarchy as possibly but PPE will likely remain on the table no matter what – partially for reassurance to people and partially to provide some level of defence in depth.

(4) Actions to Maintain Controls.

Where appropriate, systems would need to be implemented to ensure that controls remain in place until other more permanent mitigation becomes available. This might include increased maintenance checks, repeated communication campaigns, enforcement activities, training programmes etc. In addition, the use of statistical data to identify at risk population groups as they emerge would be critical to gather information on the efficacy of control measures, both within an organisation and as part of a national data collection. Of particular importance would be the routine collection of occupational data at every opportunity (e.g. as part of hospital admission, under “test, track and trace”, and through the NHS-App). This type of data is crucial to understand where controls are working effectively, and if there are any strategies, environments or job roles where controlling transmission is a greater challenge and needs further intervention.

(5) Other Considerations

System issues: the implementation of controls at the component level would need to be reviewed in the context of the whole system, Experience suggests that if systems thinking is not applied to the whole work situation, then issues can arise at the interfaces between the components e.g. “bonding” activities at the end of a shift. Systems may also change in other ways, for example with adaptations in response to interventions. It is important to identify potential unintended consequences to allow mitigation or reinforcement of them.

Actions to maintain control: these would need to be kept under review as new approaches come on line e.g. antibody testing, new technological solutions (wearable devices to monitor physical distancing)

At-risk groups: the process described above provides a “population” based approach to assessing risk. However, there are a number of individual susceptibility issues which would need to be considered at the organisational and national level to ensure that any at risk groups are effectively protected.

Accessibility and equality: There is already evidence that COVID-19 has disproportionate impacts on certain societal groups. It is important to consider equality and accessibility throughout the process to ensure that mitigation strategies do not further marginalise any groups.

[2] Reason JT. Managing the risks of organizational accidents. Aldershot: Ashgate Publishing; 1997.

(6) Issues

The nature and novelty of the virus is such that there are many gaps in our understanding, and therefore in our ability to access an evidence base on a wide range of potential controls. In mapping the current controls, the majority sit within the “administrative” band of the hierarchy of control. There is a need to develop a wider range of elimination, substitution and low cost engineering controls which meet the requirements of specific control needs.

Approaches to control risk through the duration and frequency of exposure should be calculated. For example; could the relative risks of standing within 1m of an asymptomatic individual for 15mins on a tube journey whilst both parties were wearing face coverings be sufficient to control exposure to an acceptable degree? This should be linked to the nature of the contact e.g. with a small group of the same people, with other teams or with members of the public.

The risk estimation approach should be discussed with individuals who may be exposed to it so that all options for control can be explored and considered. Comparison of levels of risk to accepted within cultural norms (e.g. driving or supermarket shopping during the current situation) may be helpful comparators).

Behavioural factors will influence many of the measures, and in some situations, negative behaviours may result in a failure of control. For example, in the transport sector, intoxication and school traffic have all been highlighted as concerns.

Risk communication should be a way of empowering individuals to make informed decisions about their own protection as well as well as the protection of others. If they understand the principles by which risk can be controlled then they may be able to support the process through a dynamic individual assessment of their personal risk in any situation. However, there a need for caution with this as there is evidence that the more agentic an intervention is, the greater the risk that it may widen health inequalities.

Consideration will need to be given to any potential inequality issues which may arise from the implementation of control measures, and how best to mitigate them.

System issues need to be considered. A positive action in one part of the system may lead to negative consequences in other components of that system. For example, if schools return there will be increased pressures on the public transport system, which may lead to the inability to maintain controls for other travellers.

The use of test, track and trace approaches with accompanying advice to individuals may enable risk to be controlled at the individual level. This would be particularly true once antibody status can be reliably determined. This could lead to the development of appropriate health surveillance systems for workplaces.

There should be a systematic process for capturing data as lockdown is eased. This includes quality statistical information regarding any emerging occupational risk factors. Learning from industries which have continued to operate (chemicals industry, refineries, some retail) is critical, and the opportunity to collect occupational data at any point should be encouraged. Targeted data collection could be considered to address evidence gaps, including regular testing of people and workplaces during any return to work activity. “Mitigate, Monitor, Modify” could be used as a strategy to target resources to fill evidence gaps.

The information collected through these activities will help to inform the formal risk assessments which will need to be completed by the risk owners.

ANNEX 1: Developing an approach for quantitative microbial risk assessment (QMRA) for COVID-19

We consider the factors that determine the exposure risk via each of the transmission routes in order to put together a framework for evaluating the risk of infection and the impact of mitigation measures.

QMRA

QMRA is a well-established methodology for assessing exposure to pathogens, using a probabilistic modelling approach to estimate the transfer of pathogens to people with data on dose-response to calculate risk. The approach is widely applied to water and food borne pathogens [1][2][3], and there is some precedent for application to respiratory pathogens [4], [5][6]. The approach has four stages:

- Hazard identification – which microorganisms and what diseases they cause
- Exposure Assessment – quantification of the amount of virus the individual is exposed to, which depends on the amount in the environment and the route of exposure
- Dose-response – model for the response to a particular dose (possibly for a particular route)which relates the amount of virus an individual receives to the probability of infection
- Risk characterisation – brings together the exposure and the dose-response to predict likelihood of infection (as a probability). In simple terms this can be expressed as *Risk of infection = Exposure x Dose-response*

It is also feasible to use this to then estimate the impact at population level or within a group using the concept of *Impact = Number exposed x Risk of infection x Vulnerability*. Vulnerability here could be the probability of infection translating to either a case requiring hospitalisation or resulting in death (or both). The impact in that case would be the number with that outcome. While this looks brutal it would be helpful for weighing up costs and benefits of mitigation measures. The limitation with this approach is that it does not account for the potential for feedback or cross-transmission into other activities. However, this could be addressed by combining impact assessments for different scenarios.

Exposure Assessment

The primary focus of this paper is to establish the factors that underpin the exposure assessment for the COVID-19 transmission routes, and consider potential mitigations based on the factors. Throughout the exploration of mitigations we consider the well-established *Hierarchy of Risk* framework:

- Elimination/substitution (work from home, self-isolation)
- Engineering/environment controls
- Administrative controls
- PPE/individual behaviour controls

In considering exposure, time is a factor. We are here considering that exposure can be treated as cumulative over a short period of time (a few hours) but not over days. This would assume that someone needs to have sufficient exposure in a relatively short period of time to become infected, and we assume that small doses over a long period (say a week or more) would not lead to infection.

Contact exposure

Contact exposure is assumed to be determined primarily on the amount of contamination on someone's hand. This can be assessed using the Pathogen Accretion Model defined in [7]

Hand contamination = amount on surface x number of contacts x area of contact x transfer efficiency x (1-hand hygiene efficiency)

Hazard = amount of virus on surface
Dose = number of contacts x area of contact x transfer efficiency x (1-hand hygiene efficiency)

Hand contamination leads to inoculation through touching face, which requires data on hand-face touching behaviour.

Amount on surface	Increases with occupancy (more sources), increases with number of different occupants (higher change of a source), increases in high touch environment (more touches moves it around), decreases with cleaning frequency, adjusted for material, adjusted for indoor/outdoor, adjusted for temp & RH & UV, surface type, decreases with time since first contamination and last occupation.
Number of contacts	Increases with number of different surfaces/objects touched, increases with frequency of contact.
Area of contact	Varies from whole hand (grab handle) to finger (button). The contact pressure may also be an influence.
Transfer efficiency	Two efficiencies, one for pick up and one for put down, Depends on pathogen, pathogen suspension fluid, surface material, temp/RH, whether hand is gloved or bare. Transfer efficiency is determined experimentally in small scale laboratory conditions for different pathogens/surfaces.
Hand hygiene	Increases with frequency, increases with effectiveness, depends on method.

<u>Mitigating factors for contact transmission</u>

- Frequency and effectiveness of cleaning of surfaces – changes amount on surfaces (Hazard – admin)
- Provision of sanitizer/increased hand wash – increases hand hygiene (Dose - admin)
- Use of gloves – treat as very high hand hygiene? (Dose – PPE/personal)
- Outdoor – decays quicker so reduces amount on surfaces? Doesn't necessarily mean lower touch frequency (Hazard – eng/environ)
- Sunlight – UV light is an important element in reducing amount on surfaces (Hazard –eng/ environ)
- Surface material – increases decay rate so changes amount on surfaces (Hazard –eng/ environ)
- Low (or no) touch devices – reduces number of contacts (Dose – eng/environ)
- Shift patterns – reduces number of contacts, may also reduce amount on surface (Hazard/Dose – subs/elimin)
- Behaviour – reduced surface contact (use elbows), reduced face touching (Dose – PPE/personal)

Short Range Respiratory exposure

Short range respiratory is assumed to be the immediate exposure that someone would experience while face-to-face with an infected person. This is taken as the exposure through droplets that land on the mucous membranes, plus aerosols that are inhaled. Contact through surfaces is not included – this is under contact transmission above.

Amount of virus = droplet deposition onto persons face + short range aerosol inhalation

= (droplet generation + (aerosol generation x breathing rate)) x time x (distance relationship) x face-to-face factor

Hazard = droplet + aerosol generation
Dose = breathing rate x time x (1/distance) x face-to-face factor

Viral load	The more virus load, the more likelihood that a particle will contain virus. There may be a relationship between viral load in nasal/throat swabs and droplet/aerosol generation rate
Spray factor	Measure of aerosolisation potential = AC (aerosol/droplet concentration (pfu/m^3)/VT (viral titre (pfu/ml)
Aerosol /droplet gen	Probably increases with loudness of sound, increases with coughing, increases with sneezing, varies between people but can't factor this in. May also vary between languages and even words used.
Breathing rate	Increases with activity, varies between children/adults and with health
Time	iIncreases with both susceptible and infectors duration in the same location
Distance	eExposure decreases with distance, assumed up to 2m
Face-to-face factor	highest for face-to-face, lowest back-to-back, partial risk side to side as people will move their heads, partial risk front-back. May be influenced by relative height of people.

<u>Mitigating factors for short range</u>

- Increase distance – reduce concentration exposed to (Dose- admin)
- Face coverings on infectors – decreases generation rate (Hazard – PPE/personal)
- Face coverings on susceptible – reduces effective breathing rate (Dose – PPE/personal)
- Screens – physical barriers to block droplets (Dose – environ/eng)
- Change in job role to reduce duration of exposures (Dose – admin)
- Auto systems (e.g. for paying to remove face to face interactions (Hazard – environ/eng)
- Orientation of people – (Dose – admin/PPE)
- Shift patterns – reduces number of interactions (Hazard/Dose – subs/elim, admin)
- Behaviour – reduced face touching, eye rubbing etc (Dose – PPE/personal)
- Changes in amount of speaking and volume – no singing (Hazard – admin)

Airborne exposure

Airborne transmission is regarded as that which is caused by fine aerosols (< 5μm) which are inhaled at a distance of more than 2m - aerosols that are in the bulk air of an environment rather than at close range.

Amount inhaled = number of infectors x aerosol generation rate x breathing rate x time x (1/(ventilation rate) + other losses)

Hazard = number of infectors x generation rate
Dose= breathing rate x time x (1/ventilation rate)

Number of infectors I	increases with occupancy (more sources) ,increases with number of different occupants (higher change of a source)
Breathing rate	Increases with activity, varies between children/adults and with health
Time	Increases with of both person and infectors duration in the same location
Ventilation rate	Depends on design of system, for natural ventilation may depend on the weather
Ventilation distribution	Level of air mixing between zones, layout and mixing devices (e.g. fans, A/C splits). Only influences >2m transmission
Losses	Loss due to deposition and decay rate of virus in air. May be affected by flow patterns, temperature, humidity, UV, pathogen suspension fluid
Viral load	The more virus load, the more likelihood that a particle will contain virus. There may be a relationship between viral load in nasal/throat swabs and droplet/aerosol generation rate
Spray factor	Measure of aerosolisation potential = AC (aerosol/droplet concentration (pfu/m^3)/VT (viral titre (pfu/ml)
Aerosol /droplet gen	Probably increases with loudness of sound, increases with coughing, increases with sneezing, varies between people but can’t factor this in. May also vary between languages and even words used.

Mitigating factors for airborne

- Ventilation rate – higher rate reduces concentration, closed windows/vents increases concentration (Dose – environ/eng)
- Ventilation pattern (prevention of stagnant zones, flow between zones) – local extract, mixing devices, pressure controls (Dose – environ/eng)
- Local control devices – limit aerosol generation due to procedures (e.g. hospital, dental) or contain procedures in a particular room (Hazard – environ/admin)
- Air cleaning devices – removal from the air through purpose devices or filters on recirculating systems (Dose – environ/eng)
- Lower occupancy – less chance of an infector, less people to infect (Hazard – admin)
- Face coverings on infectors – decreases generation rate and reduces exposure of those nearby by changing flow patterns (Hazard – PPE/personal)

- Face coverings on susceptible – reduces effective breathing rate, small effect (Dose – PPE/personal)
- Lower activity levels – reduces generation rate and breathing rate (Hazard/Dose – admin)
- Shift patterns – reduces time for both infector and susceptibles (Hazard/Dose – subs/elim, admin)

Dose-Response

The exposure assessment alone can enable an understanding of relative effects of mitigation measures, however to understand infection risk and hence predict the likely impact of changes it is necessary to have data on dose-response. This is a relationship that describes the likelihood of infection from exposure to a particular dose, and can be constructed from data from animal models, human trials and past outbreaks. The dose-response is commonly described with an exponential or beta-Poisson relationship [5]. It is possible that the dose-response will vary with transmission route – for example a disease could need a higher or lower dose to cause infection when delivered as fine particles to the lungs than course particles to the nose. For most diseases this level of detail is not known.

There is not yet a dose-response relationship for SARS-CoV-2, however there is a curve for SARS-CoV-1 [8] which follows an exponential relationship. For airborne transmission the Wells-Riley model [9] is commonly used which is an exponential relationship using a term "quanta" to represent the infectious dose and this has been applied to an airborne outbreak of SARS-CoV-1 [10]. While this is cruder than a dose-response model, it is a way to estimate risk of infection based on past outbreak data.

We would also have to consider how combine the risks through different routes, and whether we could assume the same dose-response relationship for different transmission routes. Research modelling the virus within thehuman body may support this question in the longer term.

References

[1] C. N. Haas, "Microbial dose response modeling: Past, present, and future," *Environmental Science and Technology*, vol. 49, no. 3. American Chemical Society, pp. 1245–1259, Feb. 03, 2015, doi: 10.1021/es504422q.

[2] G. Medema, "Quantitative microbial risk assessment," *Routledge Handb. Water Heal.*, pp. 558–569, 2015, doi: 10.4324/9781315693606.

[3] B. Stephens, P. Azimi, M. S. Thoemmes, M. Heidarinejad, J. G. Allen, and J. A. Gilbert, "Microbial Exchange via Fomites and Implications for Human Health," *Curr. Pollut. Reports*, vol. 5, no. 4, pp. 198–213, 2019, doi: 10.1007/s40726-019-00123-6.

[4] M. Nicas and R. M. Jones, "Relative contributions of four exposure pathways to influenza infection risk," *Risk Anal.*, vol. 29, no. 9, pp. 1292–1303, Sep. 2009, doi: 10.1111/j.1539-6924.2009.01253.x.

[5] R. M. Jones and Y. M. Su, "Dose-response models for selected respiratory infectious agents:, group a, rhinovirus and respiratory syncytial virus," *BMC Infect. Dis.*, vol. 15, no. 1, pp. 1–9, 2015, doi: 10.1186/s12879-015-0832-0.

[6] A. Carducci, G. Donzelli, L. Cioni, and M. Verani, "Quantitative microbial risk assessment in occupational settings applied to the airborne human adenovirus infection," *Int. J. Environ.*

Res. Public Health, vol. 13, no. 7, 2016, doi: 10.3390/ijerph13070733.

[7] M. F. King, C. J. Noakes, P. A. Sleigh, and M. A. Camargo-Valero, “Bioaerosol deposition in single and two-bed hospital rooms: A numerical and experimental study,” *Build. Environ.*, vol. 59, pp. 436–447, Jan. 2013, doi: 10.1016/j.buildenv.2012.09.011.

[8] T. Watanabe, T. A. Bartrand, M. H. Weir, T. Omura, and C. N. Haas, “Development of a dose-response model for SARS coronavirus,” *Risk Anal.*, vol. 30, no. 7, pp. 1129–1138, 2010, doi: 10.1111/j.1539-6924.2010.01427.x.

[9] C. J. Noakes and P. Andrew Sleigh, “Mathematical models for assessing the role of airflow on the risk of airborne infection in hospital wards,” *J. R. Soc. Interface*, vol. 6, no. SUPPL. 6, 2009, doi: 10.1098/rsif.2009.0305.focus.

[10] H. Qian, Y. Li, P. V. Nielsen, and X. Huang, “Spatial distribution of infection risk of SARS transmission in a hospital ward,” *Build. Environ.*, vol. 44, no. 8, pp. 1651–1658, 2009, doi: 10.1016/j.buildenv.2008.11.002.

Annex 2: Worked Example

A Workshop was held with key representatives from the Transport Sector on 1st May 2020. This included involvement from Bus, Train and Tube operators as well as the British Transport Police.

For each transport area, the key work activities were identified and then discussed in the context of the risk factors. The risk factors were then scored for each work activity by frequency of exposure (0= no exposure; 1=limited exposure; 2=some significant exposure, 3=significant exposure) and duration of exposure (0= no exposure; 1=infrequent; 2=intermittent, 3=frequent) without control. Potential control measures were then discussed, and each work activity was then rescored with achievable controls in place.

Risk factors: add or take away

Worked Examples reviewing risk factors by work activities for (a) Tube drivers and (b) passengers with and without controls

TUBE DRIVER WORK ACTIVITY	RISK FACTORS (score by frequency, duration) – without control																	
	Interactions with direct colleagues (small)	Interactions with other teams	Interactions with same customers	Interaction with public (local)	Interaction with public in wider geographic areas	Contact with surfaces (personal)	Contact with surfaces shares with colleagues	Contact with surfaces shared by regular group	Contact with surfaces shared by the public	Working in one location	Working in multiple locations on one site	Working at multiple location across sites	Use of shared social facilities with team	Use of shared facilities with a wider group	Toilets/changing shares with team	Toilets/changing shares with wider group	Toilets/changing shares with public	
Arrival at depot	2, 1	1,1	0,0	0,0	0,0	1,1	1,1	1,1	0,0	1,1	0,0	0,0	2,1	0,0	2,1	0,0	0,0	11
	2	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**2**	**0**	**2**	**0**	**0**	
"Book on"	1,1	0,0	0,0	0,0	0,0	1,1	1,1	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4
	1	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Drive train	0, 0	0,0	0,0	0,0	0,0	3,3	1,1	0,0	0,0	3,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	18
	0	**0**	**0**	**0**	**0**	**9**	**1**	**0**	**0**	**9**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Breaks	1,1	3,1	0,0	0,0	0,0	1,1	1,2	1,1	0,0	1,1	0,0	0,0	1,1	0,0	2,1	0,0	0,0	12
	1	**3**	**0**	**0**	**0**	**1**	**2**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**2**	**0**	**0**	
	4	**4**	**0**	**0**	**0**	**12**	**5**	**2**	**0**	**12**	**0**	**0**	**3**	**0**	**4**	**0**	**0**	

CONTROL MEASURES

Risk Factor	Mitigation	Feasibility	Hierarchy of control
Interactions with direct colleagues (small)	(1) Social distancing at 2m	1	Admin
	(2) Administrative control of interactions with other teams (e.g. scheduling of shifts etc)	1	Admin
Interactions with other teams	(1) Social distancing at 2m	1	Admin
	(2) Administrative control of interactions with other teams ((e.g. scheduling of shifts etc)	1	Admin
Contact with surfaces (personal)	(1) Cleaning of drivers cab before entry	1	Admin
	(2) Administrative control e.g. (e.g. specific driver allocated to a single train for whole shift)	1	Admin
Contact with surfaces shares with colleagues	(1) Regular cleaning of surfaces	1	Admin
	(2) Effective personal hand hygiene	1	Admin
Contact with surfaces shared by regular group	(1) Regular cleaning of surfaces	1	Admin
	(2) Effective personal hand hygiene through provision of appropriate facilities and materials	1	Admin
Working in one location	(1) Administrative control (e.g. specific driver allocated to a single train for whole shift)	1	Admin
Use of shared social facilities with team	(1) Social distancing at 2m	1	Admin
	(2) Regular cleaning of surfaces	1	Admin
	(3) Effective personal hand hygiene	1	Admin
	(4) Administrative control (e.g. limiting occupancy of social facilities	1	Admin
Toilets/changing shares with team	(1) Social distancing at 2m	1	Admin
	(2) Regular cleaning of surfaces	1	Admin
	(3) Effective personal hand hygiene	1	Admin
	(4) Administrative control (e.g. limiting occupancy of toilet facilities		Admin

1= straightforward; 2=difficult; 3=very difficult

TUBE DRIVER WORK ACTIVITIES	RISK FACTORS– with control																	
	Interactions with direct colleagues (small)	Interactions with other teams	Interactions with same customers	Interaction with public (local)	Interaction with public in wider geographic areas	Contact with surfaces (personal)	Contact with surfaces shares with colleagues	Contact with surfaces shared by regular group	Contact with surfaces shared by the public	Working in one location	Working in multiple locations on one site	Working at multiple location across sites	Use of shared social facilities with team	Use of shared facilities with a wider group	Toilets/changing shares with team	Toilets/changing shares with wider group	Toilets/changing shares with public	
Arrival at depot	1, 1	1,1	0,0	0,0	0,0	1,1	1,1	1,1	0,0	1,1	0,0	0,0	1,1	0,0	1,1	0,0	0,0	**8**
	1	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	
"Book on"	1,1	0,0	0,0	0,0	0,0	1,1	1,1	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**4**
	1	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Drive train	0, 0	0,0	0,0	0,0	0,0	1,1	1,1	0,0	0,0	1,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	**3**
	0	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Breaks	1,1	1,1	0,0	0,0	0,0	1,1	1,1	1,1	0,0	1,1	0,0	0,0	1,1	0,0	1,1	0,0	0,0	**8**
	1	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	
	3	**2**	**0**	**0**	**0**	**4**	**4**	**4**	**0**	**4**	**0**	**0**	**2**	**0**	**2**	**0**	**0**	

TUBE PASSENGER ACTIVITY	RISK FACTORS (score by frequency, duration) – without control																	
	Interactions with direct colleagues (small)	Interactions with other teams	Interactions with same customers	Interaction with public (local)	Interaction with public in wider geographic areas	Contact with surfaces (personal)	Contact with surfaces shares with colleagues	Contact with surfaces shared by regular group	Contact with surfaces shared by the public	Working in one location	Travelling to multiple locations on one site	Travelling to multiple location across sites	Use of shared social facilities with team	Use of shared facilities with a wider group	Toilets/changing shares with team	Toilets/changing shares with wider group	Toilets/changing shares with public	
Arrival at station	0,0	0,0	0,0	3,2	0,0	1,1	0,0	0,0	2,2	0,0	0,0	3,2	0,0	3,2	0,0	0,0	1,2	22
	0	**0**	**0**	**6**	**0**	**1**	**0**	**0**	**4**	**0**	**0**	**6**	**0**	**6**	0	0	**2**	
Purchase ticket	0,0	0,0	0,0	3,2	0,0	1,1	0,0	0,0	1,2	0,0	0,0	0,0	0,0	3,2	0,0	0,0	0,0	15
	0	**0**	**0**	**6**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**6**	0	0	**0**	
Transit to platform	0, 0	0,0	0,0	3,2	0,0	2,2	0,0	0,0	2,2	0,0	3,2	0,0	0,0	3,2	0,0	0,0	0,0	**26**
	0	**0**	**0**	**6**	**0**	**4**	**0**	**0**	**4**	**0**	**6**	**0**	**0**	**6**	0	0	**0**	
Wait on platform	0,0	0,0	0,0	3,2	0,0	1,2	0,0	0,0	1,2	0,0	0,0	0,0	0,0	3,2	0,0	0,0	1,2	**18**
	0	**0**	**0**	**6**	**0**	**2**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**6**	0	0	**2**	
Board/Alight tube	0,0	0,0	0,0	3,2	0,0	**1,2**	0,0	0,0	**2,1**	0,0	**2,2**	**2,2**	0,0	3,2	0,0	0,0	0,0	**24**
	0	**0**	**0**	**6**	0	**2**	**0**	**0**	**2**	**0**	**4**	**4**	0	**6**	0	0	0	
Seated Journey	0,0	0,0	0,0	3,2	0,0	**1,1**	0,0	0,0	**1,2**	0,0	0,0	0,0	0,0	3,2	0,0	0,0	0,0	**15**
	0	**0**	**0**	**6**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**6**	0	0	0	
Standing journey	0, 0	0, 0	0, 0	3,2	0, 0	**2,3**	0, 0	0, 0	**2,3**	0, 0	0, 0	0, 0	0, 0	3,2	0, 0	0, 0	0, 0	**24**
	0	**0**	**0**	**6**	**0**	**6**	**0**	**0**	**6**	**0**	**0**	**0**	**0**	**6**	0	0	0	
	0	**0**	**0**	**42**	**0**	**17**	**0**	**0**	**14**	**0**	**10**	**10**	**0**	**42**	**0**	**0**	**4**	

CONTROL MEASURES

Risk Factor	Mitigation	Hierarchy of control	Feasibility
Interaction with public	(1) Restriction on passenger numbers (e.g. promote working from home, alternative travel arrangements)	Substitution	2
	(2) Social distancing at 2m	Admin	3
	(3) Administrative control of interactions (e.g. marking of platforms, advice on social distancing)	Admin	1
	(4) Use of face coverings for all passengers	PPE	2
Contact with surfaces (personal)	(1) Effective personal hand hygiene through provision of appropriate facilities and materials	Admin	2
	(2) Administrative control e.g. (advice to public regarding the need for effective hygiene which is well communicated)	Admin	1
Contact with surfaces shared by the public	(1) Restriction on passenger numbers (e.g. maintain need for office workers to work from home)	Substitution	2
	(2) Administrative control e.g. (advice to public regarding the need for effective hygiene)	Admin	1
	(3) Regular cleaning of all surfaces	Admin	1
Travelling to multiple locations on one site	(1) Restriction on passenger numbers (e.g. promote working from home, alternative travel arrangements)	Substitution	2
	(2) Social distancing at 2m	Admin	3
	(3) Administrative control of interactions (e.g. marking of platforms, advice on social distancing)	Admin	1
	(4) Use of face coverings for all passengers	PPE	3
Travelling to multiple location across sites	(1) Restriction on passenger numbers (e.g. promote working from home, alternative travel arrangements)	Substitution	2
	(2) Social distancing at 2m	Admin	3
	(3) Administrative control of interactions (e.g. marking of platforms, advice on social distancing)	Admin	1
	(4) Use of face coverings for all passengers	PPE	2
Use of shared facilities with a wider group	(1) Restriction on passenger numbers (e.g. promote working from home, alternative travel arrangements)	Substitution	2
	(2) Administrative control e.g. (advice to public regarding the need for effective hygiene)	Admin	1
	(3) Regular cleaning of all surfaces	Admin	1

	(4) Use of face coverings for all passengers	PPE	2
Shared public toilets	(1) Restriction on passenger numbers (e.g. promote working from home, alternative travel arrangements)	Substitution	2
	(2) Social distancing at 2m	Admin	3
	(3) Administrative control of interactions (e.g. advice on effective hand hygiene)	Admin	1
	(4) Effective and regular cleaning routines	Admin	1

1= straightforward; 2=difficult; 3=very difficult

TUBE PASSENGER ACTIVITY	RISK FACTORS- (frequency/duration) WITH CONTROL																	
	Interactions with direct colleagues (small)	Interactions with other teams	Interactions with same customers	Interaction with public (local)	Interaction with public in wider geographic areas	Contact with surfaces (personal)	Contact with surfaces shares with colleagues	Contact with surfaces shared by regular group	Contact with surfaces shared by the public	Working in one location	Travelling to multiple locations on one site	Travelling to multiple location across sites	Use of shared social facilities with team	Use of shared facilities with a wider group	Toilets/changing shares with team	Toilets/changing shares with wider group	Toilets/changing shares with public	
Arrival at station	0,0	0,0	0,0	1,2	0,0	1,1	0,0	0,0	1,2	0,0	0,0	1,2	0,0	1,2	0,0	0,0	1,1	22
	0	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**2**	**0**	**2**	0	0	**1**	
Purchase ticket	0,0	0,0	0,0	1,2	0,0	1,1	0,0	0,0	1,2	0,0	0,0	0,0	0,0	1,1	0,0	0,0	0,0	15
	0	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**1**	0	0	**0**	
Transit to platform	0, 0	0,0	0,0	1,2	0,0	1,1	0,0	0,0	1,2	0,0	1,2	0,0	0,0	1,2	0,0	0,0	0,0	**26**
	0	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**0**	**2**	**0**	**0**	**2**	0	0	**0**	
Wait on platform	0,0	0,0	0,0	1,2	0,0	1,1	0,0	0,0	1,2	0,0	0,0	0,0	0,0	1,1	0,0	0,0	1,1	**18**
	0	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**1**	0	0	**1**	
Board/Alight tube	0,0	0,0	0,0	1,2	0,0	**1,1**	0,0	0,0	**2,1**	0,0	**2,2**	**2,2**	0,0	1,2	0,0	0,0	0,0	**24**
	0	**0**	**0**	**2**	0	**1**	**0**	**0**	**2**	**0**	**4**	**4**	0	**2**	0	0	0	
Seated Journey	0,0	0,0	0,0	1,2	0,0	**1,1**	0,0	0,0	**1,2**	0,0	0,0	0,0	0,0	1,2	0,0	0,0	0,0	**15**
	0	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**2**	0	0	0	
Standing journey	0, 0	0, 0	0, 0	1,2	0, 0	**1,1**	0, 0	0, 0	**1,2**	0, 0	0, 0	0, 0	0, 0	1,2	0, 0	0, 0	0, 0	**24**
	0	**0**	**0**	**2**	**0**	**1**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**2**	0	0	0	
	0	**0**	**0**	**14**	**0**	**17**	**0**	**0**	**14**	**0**	**10**	**10**	**0**	**42**	**0**	**0**	**4**	