PROTECT
A COVID-19 National Core Study

An exploration of how 'Living with COVID' influences COVID-19 transmission risk, response and resilience in workplace settings: a Greater Manchester Case Study – Study 1

Prepared for
The PROTECT COVID-19 National Core Study on transmission and environment

Prepared 2023

First published 2023

The PROTECT COVID-19 National Core Study on transmission and environment is a UK-wide research programme improving our understanding of how SARS-CoV-2 (the virus that causes COVID-19) is transmitted from person to person, and how this varies in different settings and environments. This improved understanding is enabling more effective measures to reduce transmission – saving lives and getting society back towards 'normal'.

The aim of this study, together with the accompanying Case Study 2 (available on the PROTECT website) is to assess how will the 'Living with COVID' change in policy and guidance affect transmission risk, response and resilience in workplace settings in Greater Manchester. Study 1 aims to group, order, analyse and map, test and trace data by workplace across Greater Manchester to make recommendations for future pandemic response, policy and guidance.

Within this case study, researchers analysed aggregated testing data from Greater Manchester organised by occupation and location, and examined the ordinal ranking of likelihood of transmission in different sectors, and evaluated the multidisciplinary response to COVID-19 in higher education settings in Greater Manchester using a realist framework to identify what works, for whom, and in what circumstances. Researchers found that the combination of infection and locations visited produced pictures of individual and social behaviour, and constructed theories from the interviews with professionals to explain the response, needs and recommendations for future pandemic preparedness and response.

This report and the research it describes were funded by the PROTECT COVID-19 National Core Study on transmission and environment, which is managed by the Health and Safety Executive (HSE) on behalf of HM Government. Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect UK Government or HSE policy.

Research team:

[1]Eliza Varga, [1]Mark Johnson, [1]Michael Benson, [1]Arpana Verma

[1] University of Manchester

Acknowledgements

We would like to thank all the individuals and organisations who were involved in the research. We would like to thank Cath Lewis, Victoria Turner and Helen Kreissl for their help preparing the reports.

PROTECT (2023)
National Core Study Report

Work package 3 Study 1 Combined Report for the Greater Manchester Case Study

Contents

Short descriptive

The aim of these two studies is to assess how will the 'Living with COVID' change in policy and guidance affect transmission risk, response and resilience in workplace settings in Greater Manchester. We have two studies that investigate workplace settings in Greater Manchester as a case study. Study 1 aims to group, order, analyse and map, test and trace data by workplace across Greater Manchester to make recommendations for future pandemic response, policy and guidance. Study 2 aims to use Greater Manchester higher education institutions as a workplace setting to exemplify best practice, barriers, challenges and reflections using a realist evaluation approach for lessons learnt during the pandemic to reduce the risk of transmission.

Key Messages

- Local teams in public health and health protection know their areas
- Working actively together was the success factor in manging the pandemic
- Challenges of receiving timely and contemporaneous testing data for basing infection prevention and control strategies including outbreak planning and management was an issue
- Utilising new techniques in machine learning, artificial intelligence, mapping and analyses can help with future pandemic preparedness and management

Executive Summary

Report 1

We analysed aggregated testing data from Greater Manchester organised by occupation and location, and examined the ordinal ranking of likelihood of transmission in different sectors. While the dataset lacks individual level data, it is nevertheless possible to produce an analysis of the ordinality of likelihood of transmission in different occupations i.e. identify sectors and occupations in order of frequencies of cases which allows us to map of contingency in the data. Ranking in this way means that the resulting map contains ordinal information which reflects underlying patterns of virus transmission which in turn can inform approaches to COVID-19 controls in the era of "Living with COVID" by sectors. We found that the combination of infection and locations visited produced pictures of individual and social behaviour. We found utility in the information by the ranking of likelihood of infection by time, sector and geography. These data lead to the need of further hypotheses testing to ensure true associations can be demonstrated of individual level linked datasets.

We consider the ways in which these data might be improved, and make recommendations on how aggregated data received in timely contemporaneous way can lead to better decisions for infection prevention and control. We propose learning from the current pandemic response and the systematic analyses of these data by local public health teams facilitates better outcomes. Mapping contingencies provides a way of focusing inquiry and design of new interventions to deepen understanding of specific risks and take appropriate measures within different occupational contexts.

Report 2

We evaluated the multidisciplinary response to COVID-19 in higher education settings in Greater Manchester using a realist framework to identify what works, for whom, and in what circumstances. Using a before and after design we investigated best practice, barriers, challenges and reflections of the teams that were frontline and managing outbreaks in Greater Manchester. We constructed theories from the interviews of these professionals to explain the response, needs and recommendations for future pandemic preparedness and response. Local teams felt they worked well together providing the much needed advice, guidance and response in a timely way. The most challenging aspect remained the access to timely and contemporaneous data. The post “Living with COVID” period and loss of local teams to access testing data has resulted in concerns on being able to manage the infection prevention and control of COVID-19 effectively. Recommendations included ensuring that the lessons learnt from COVID-19 include access of these data by local teams trained in health protection and public health, who know their populations and are able to reduce the risk of transmission in workplace settings.

Report 1: An Analysis of Ordinal Information in Occupational COVID-19 Data

Johnson MW, Varga E, Benson MJ, Verma A

Division of Population Health, Health Services Research and Primary Care, University of Manchester.

Introduction

This report considers the potential utility of quantitative analysis of data about occupational settings in Coronavirus 19 disease (COVID-19) transmission from Enhanced Contact Tracing in Greater Manchester (UK Government, 2023). Several studies have explored the spread of the contingency in transmission data as it relates to occupational health (Dodson, 2020; Engelmann, Montgomery, Sturdy, & Moreno Lozano, 2022; Sartor & Hess, 2020; ONS, 2020). Given that all data concerning COVID-19 transmission is contingent to various degrees of uncertainty (Stoto, Woolverton, Kraemer, Barlow, & Clarke, 2022), understanding what datasets have the most useful utility for the local, national and international responses to prevent workplace transmission is essential in light of policy, guidelines and legislation. Policy measures to mitigate transmission have themselves followed the perceived shifts in contingency and risk throughout the pandemic (Bekker, Ivankovic, & Biermann, 2020; Zaki, Pattyn, & Wayenberg, 2022). Different measures have variously, and at different times, sought to minimise impact on vulnerable groups, health services, or the economy. Current measures around "Living with COVID" clearly emphasise the latter, while carrying the risk of creating data blind-spots which might not offer effective early-warning of a future viral threat. A better understanding of the spread of risk and contingency relating to occupational health and geography could produce more nuanced and balanced measures to monitor and control COVID-19 which focus resources on well-targeted areas of employment, socio-economic groups and geographical locations.

The aim of this report is to present the analysis and its results as a way of opening-up deeper questions about the relationship between risk, uncertainty and policy – particularly as it applies to the new phases of managing the pandemic. In the following sections, we explain the nature of the collected data, the rationale and method of analyses, the resulting spread of contingency represented in the data, and how this model might be refined with further data.

Methods

The dataset

Using a dataset derived from postcode coincidence of clusters of possible transmission during the Delta wave of COVID-19 (from June 2021 to February 2022), we show how data concerning employment sectors and locations alongside likelihood of infection can present a broad overview of the distribution of risk across geographies and employment sectors. This is a deficient model in many aspects because data are lacking with regard to socio-economic and demographic groupings of people, and the nature of the relationship between clusters of positive cases and specific sectors of employment or locations. Nevertheless, in the light of producing a crude model of likelihood of infection, the principal question arises: What if we had better data? This question we consider towards the end of the report and discuss the potential for future planning and policy with regard to maintaining a balance between management of the epidemic and cost-benefit analysis more refined approaches.

The dataset used for this analysis is derived from Enhanced Contact Tracing surveys between June 2021 and February 2022. It details clusters of positive cases against geographical area middle super output areas (MSOA) and employment sector. The dataset comprises postcode coincidence data and employment sector information for a period of 36 weeks from 20th June 2021 until 20th February 2022. Postcode coincidence data indicates clusters of infection. A cluster is defined as three or more cases where a location is mentioned by a participant as a place they visited up to seven days prior to testing positive. Locations were collected and coded initially as postcodes, and the dataset results from aggregation, whereby postcodes are collected as clusters within a "Middle Super Output Areas" (MSOA). For each cluster in each week, the employment sector is recorded. The dataset contains 474,704 records for the 36 weeks, where 32 employment sectors are reported against 346 MSOAs within Greater Manchester.

As part of Test and Trace, Enhanced Contact Tracing information was collected on household, workplace, education and activities in the 7-day period before symptom onset (or date of test). This dataset comprised two parts: a 'forward period' covered 2 days before symptoms (or test) to the date of exposure of subsequent contacts and backward contact tracing, which involved interviewing positive cases to ascertain possible sources of their infection. Since it is estimated that it takes between 2 and 7 days from the point of infection to the onset of symptoms, the backward tracing examines the period 2 to 7 days before onset of symptoms i.e., when it was possible the case could have been infected. Any place/event with two or more persons declaring the same postcode within seven days of each other gets identified as a "Common Exposure".

This “Common Exposure” dataset was available to local councils during the pandemic and provided detailed information about transmission. Since the pandemic, the only available datasets for analysis have been those aggregated from this original data. These are much less specific in terms of location, and demographics of participants. Regarding the location, the original “postcode coincidence” data has been aggregated under MSOAs categorised by employment sector. This aggregation makes it more difficult to differentiate between clusters within a particular MSOA – and impossible if there are multiple locations in the same employment sector within clusters. Furthermore, the data does not indicate where transmission occurs but “common exposures”: it could be purely coincidental that these places/events are in the list, and they may have had no role in the transmission of disease. Obviously, with a lack of demographic detail about participants, household transmission within a usual place of residence is not included.

There are also deficiencies in the original Common Exposure dataset in terms of clarity as to the relationship between a respondent and a particular location: there is no way of knowing if a person reporting a visit to a retail location is there as a worker or as a customer. This is compounded by uncertainty around the classification of occupations in the first place, and its relationship to actual behaviour. Despite this however, given the amount of data, the analysis is revealing of underlying trends which are reflected in the qualitative aspects of this research.

Analytical approach

Our analytical approach is to rank the data in terms of numbers of cases in different sectors and numbers of cases in different locations. This 2-dimensional ranking approach reveals ordinal information relating to the relative likelihoods of infection between different sectors and geographies which is otherwise obscured in analysis of sectors or geographies in isolation. Ordinal information influenced by Thurstone’s (1927) comparative judgement method has been advocated for qualitative measurement in health (Maydeu-Olivares & Böckenholt, n.d.) and education (Pollitt, 2011; Johnson et al, 2020) as well as new uses in machine learning and assessment (Johnson and Saleh, 2022). Here we consider how pairwise comparison of quantitative data can reveal deeper patterns within an apparently simple dataset where simple ranking by cluster numbers illustrates that ordinal information reveals not only the relative risk of infection, but also the relative degree of uncertainty, or the spread of contingency, associated with infection risk across sectors and geographies.

To say that classifiers in the data are contingent is to say that there is uncertainty as to what categorisations of employment sector or geography actually mean. There is contingency in data collection methods, veracity, consistency, cohesion and timeliness which contribute to systemic difficulties in being able to distinguish signal from noise (Sartor and Hess, 2020).

There is always uncertainty relating to any quantitative analysis of viral transmission, and there is rarely an even spread of contingency across a population. Some sectors and some locations have a higher risk of transmission with lower uncertainty than others; some sectors have a low risk of transmission with low uncertainty; other sectors have a low risk of transmission with high uncertainty. This is reflected in our dataset in terms of the demonstrable sensitivity of certain locations and certain occupations to the waves of the pandemic. Our method here has been to analyse the spread of contingency in sectoral and geographical data. Taking the unevenness of contingency into account raises important questions as to how the current policy of "Living with COVID" might best be approached if more accurate models of the spread of contingency across different employment sectors is considered.

Results

Through this process of analysis, we have created a model of likelihood of infection against each geography and each employment sector between June 2021 and February 2022. The construction of this model has entailed exploring the relationship between infection over the period of data collection against geographies (as MSOAs) and employment sectors. Since likelihood is a calculation based on the probability density, the principal aim of the analysis has been to explore how probability densities vary across the dataset. It can be seen from Figures 1 and 2 that the basic pattern of infection follows a similar trajectory over time with different degrees of amplification. Because of this we suggest that the time variable can regarded as the shared context within which these underlying patterns emerges. Whilst bracketing-out time in this way risks overlooking temporal events which are specific to certain sectors or geographies and not others (which we discuss in the limitations to this study), it has the advantage of facilitating an analysis of vulnerability of sectors and geographies against an underlying pattern of disease prevalence.

The following sections detail the exploration of the data with a view to creating a model which maps geography to employment sector on ranking scales of decreasing likelihood in the basic form:

Rank of sectors →

Rank of Geographies ↓

MSOA	Education	Retail	Transport	Distribution
MSOA1	1	4	5	9
MSOA2	2	2	5	7
MSOA3	0	4	6	8
MSOA4	1	6	8	10

Here the columns represent employment sectors ordered in terms of the likelihood of infection, and the rows indicate areas similarly ordered. The numbers in the cells represent the ranking of a particular sector in terms of the number of clusters, where a ranking of 0 represents the top sector for infection within a particular MSOA. Since geographies are listed in rank of decreasing likelihood, the lower down the table the fewer clusters there are, similarly, employment sectors within those geographies with lower likelihood of infection are listed towards the right of the table, but (as will be shown below), the basic sensitivity to the prevalence of disease maintains a general pattern, where there is a spike in infections towards Christmas 2021 in the wake of the Delta wave.

In the following sections, we discuss the variation in sensitivity to the Delta wave in terms of occupation, and then in terms of geography. After presenting the detail of the final model, we discuss some of the implications of the general approach in terms of how such a model might be used to target interventions – particularly in the light of "Living with COVID".

Time of data collection

The period of data collection from 20/6/21 until 20/2/22 corresponds with the Delta wave, the infections leading up to Christmas 2021, and the drop in infection following the introduction of new controls. In the context of the overall progress of COVID-19, this relates to the shaded area in graph below, with the graph of different occupations in Greater Manchester illustrated in Figure 1 below:

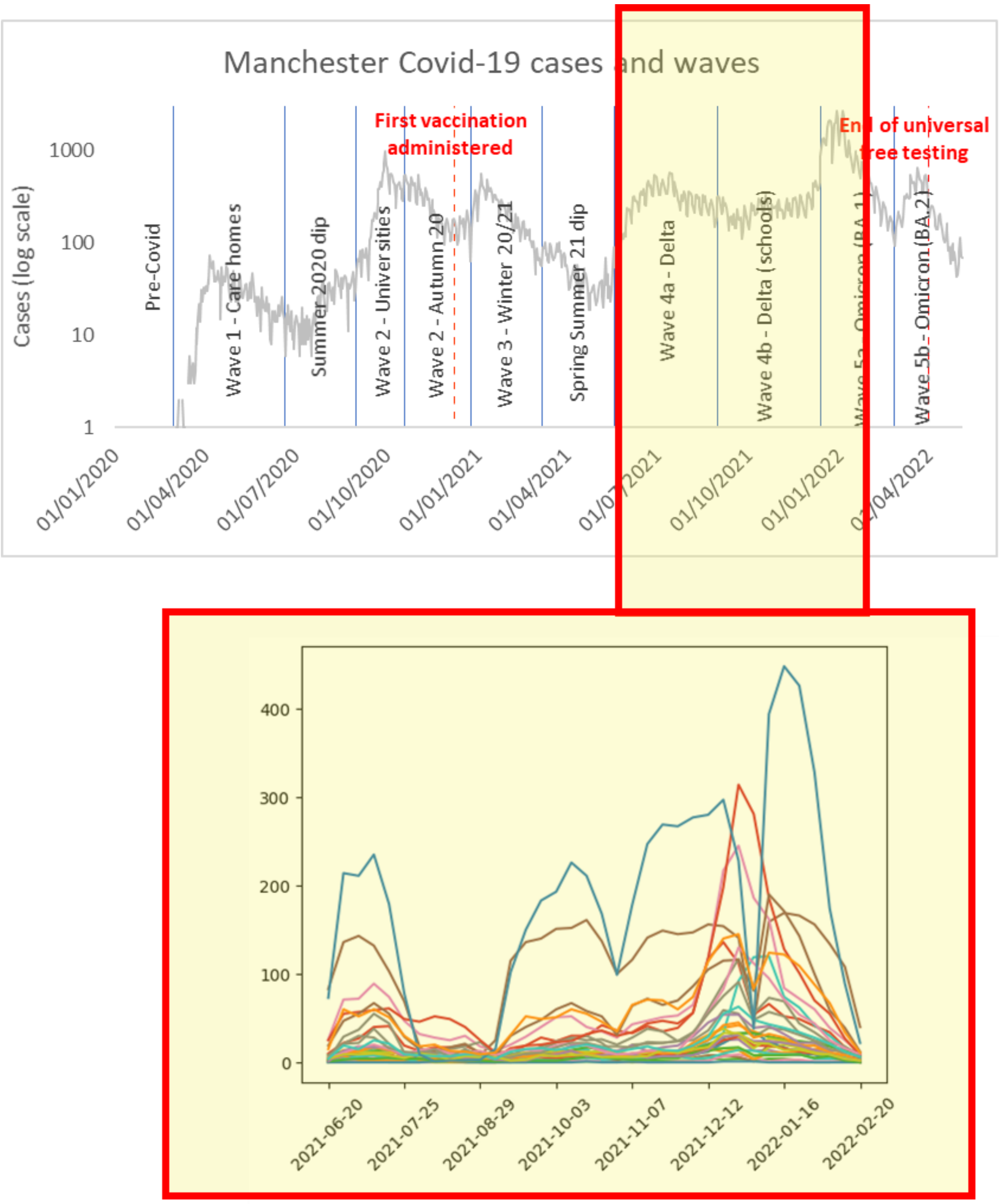

Figure 1 Time-scale of data collection and clusters by occupational setting compared to overall waves

Occupation and Infection

Examining the graph of occupational exposures in more detail reveals how all occupational exposure follows the general prevalence trend. There are 32 occupational categories represented in the graph at the bottom of Figure 1. There are very large numbers of clusters recorded in certain sectors, including Education and Retail. For most other categories (for example, Agriculture or Waste Management), there are relatively few clusters. This makes the table of all occupational clusters rather “noisy” (as in Figure 1), so it is more instructive to reduce the 32 clusters to 7 broad categories as shown in Figure 2.

The most dominant red line represents Services, which includes retail and accommodation, while the blue line next to it indicates Education (primary, secondary and university). In the categorisations in Figure 2, “Other” includes Agriculture, Waste Management, Utilities and Construction.

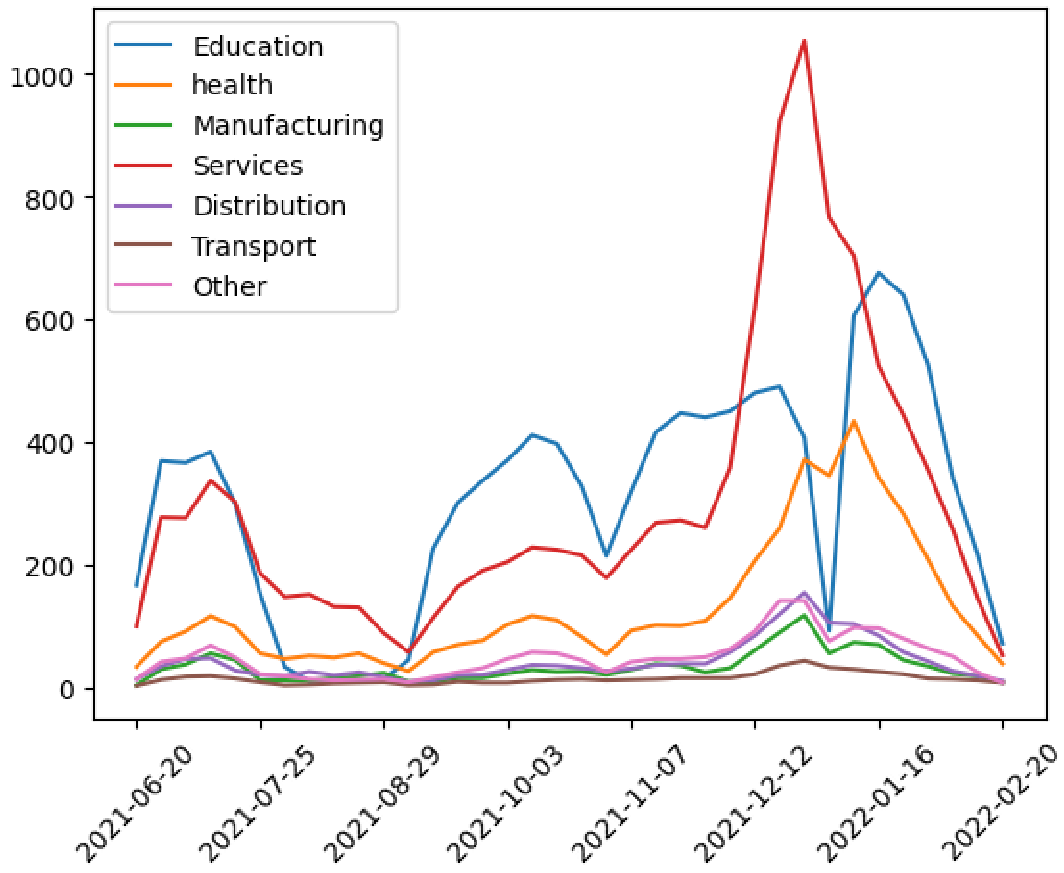

Figure 2 Broad Occupational Groups and Clusters over time period

While the peak value of clusters for Services in December 2021 is the highest recorded number of clusters in the dataset, the total clusters reveal that Education has the greatest number. Over the entire dataset, the numbers of clusters per employment sector are as follows, with a total number of clusters recorded across the entire dataset of 31,851.

industry	Clusters	%
Education - Primary education	6316	19.84
Education - Secondary education	3942	12.38
Services - Retail trade; except of motor vehicles and motorcycles	2436	7.65
Services - Accommodation and food service activities	2296	7.21
Human health and social work - Social work activities without accommodation	2229	7.00
Services - Administrative and support service activities	2107	6.62
Services - Professional, scientific and technical activities	1356	4.26
Manufacturing excl. food and beverage manufacturing	1168	3.67
Human health and social work - Medical (inc. GPs), dental practices and other human health activities	1046	3.29
Distribution and warehousing - Wholesale trade, excluding motor vehicles and motorcycles	884	2.78
Human health and social work - Residential care activities	832	2.61
Construction	751	2.36
Services - Arts, entertainment and recreation	717	2.25
Public administration and defence; compulsory social security	667	2.10
Human health and social work - Hospital activities	537	1.69
Services - Real estate activities	455	1.43
Services - Other service activities	463	1.45
Services - Wholesale and retail trade and repair of motor vehicles and motorcycles	438	1.38
Food and beverage manufacturing	396	1.24
Services - Finance and insurance activities	367	1.15
Distribution and warehousing - Postal and courier activities	324	1.02
Transport (non-passenger)	314	0.99
Distribution and warehousing - Warehousing and storage	296	0.93
Services - Information and communication excl. telecommunications	287	0.90
Education - Higher education	280	0.88
Education - Other education	254	0.80
Education - Pre-primary education	215	0.68
Utilities	183	0.57
Transport (passenger)	182	0.57
Waste management and remediation activities	60	0.19
Education - Educational support activities	46	0.14
Agriculture, forestry and fishing	7	0.02

Table 1: Number of Clusters by Sector

This data clearly says something about the “most likely” sectors for infection and the “least likely” sectors. However, the analytical challenge is to make finer-grained distinctions between clusters that are not at the extremes of this distribution.

To do this, it is possible to make repeated pairwise comparisons between different sectors. This enables the data to be organised in rank order of similarity of cluster numbers between sectors. There are a number of ways in which this can be done: for example, the means and standard deviations of data for different sectors can be used to calculate normal distributions and then compared to see how the normal distribution curves overlap in a way similar to Thurstone's Law of Comparative Judgement (1927).

However, simpler graphical comparisons can be made. For Figure 3, the graphs for Distribution and Warehousing looks similar to the graph for services, although services has a slightly lower peak in December:

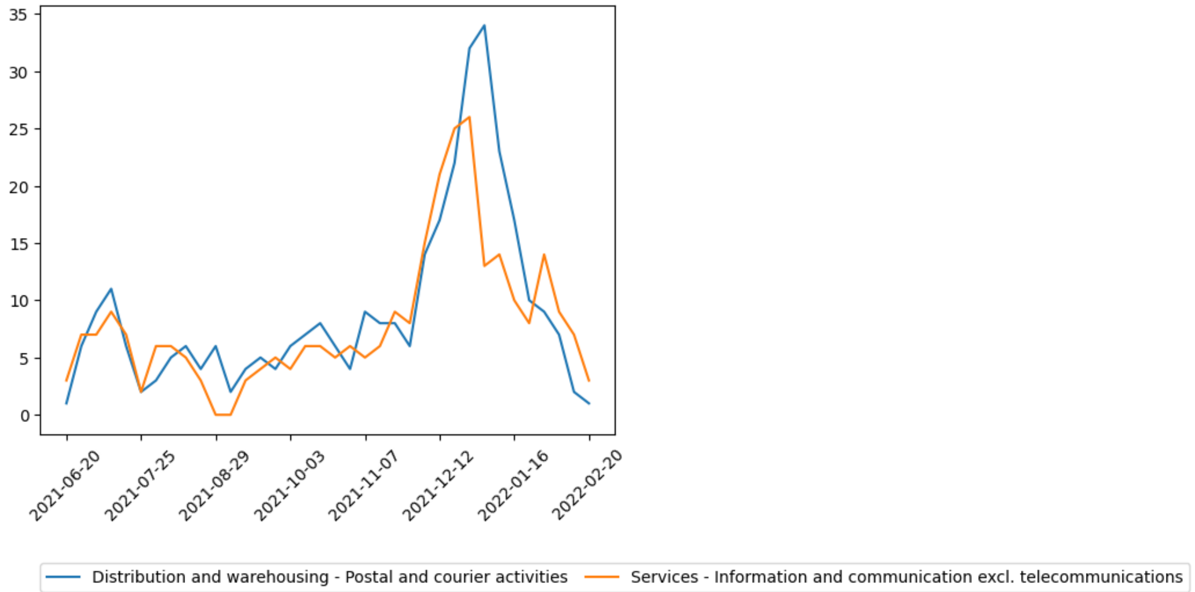

Figure 3 Comparison of Distribution and Warehousing vs Service - Information and communication

Some of the comparisons reveal greater differences which can then lead to further questions. For example, we might ask why the graph for construction against distribution and warehousing shows a number of peaks in June and October, while the graph for distribution and warehousing shows a lower level of incidence until December:

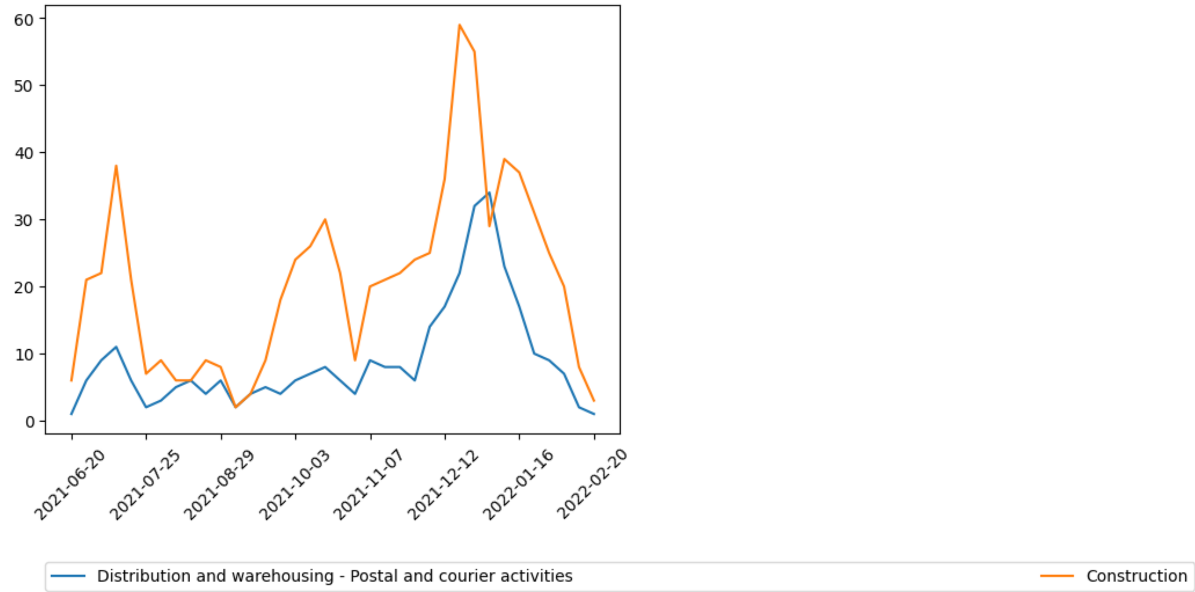

Figure 4 Comparison of Distribution and Warehousing vs Construction

Similarly, the relative infection between Higher Education and Postal Workers is interesting because of the dip that it shows education taking (presumably as universities closed in the light of rising infections and students returned home):

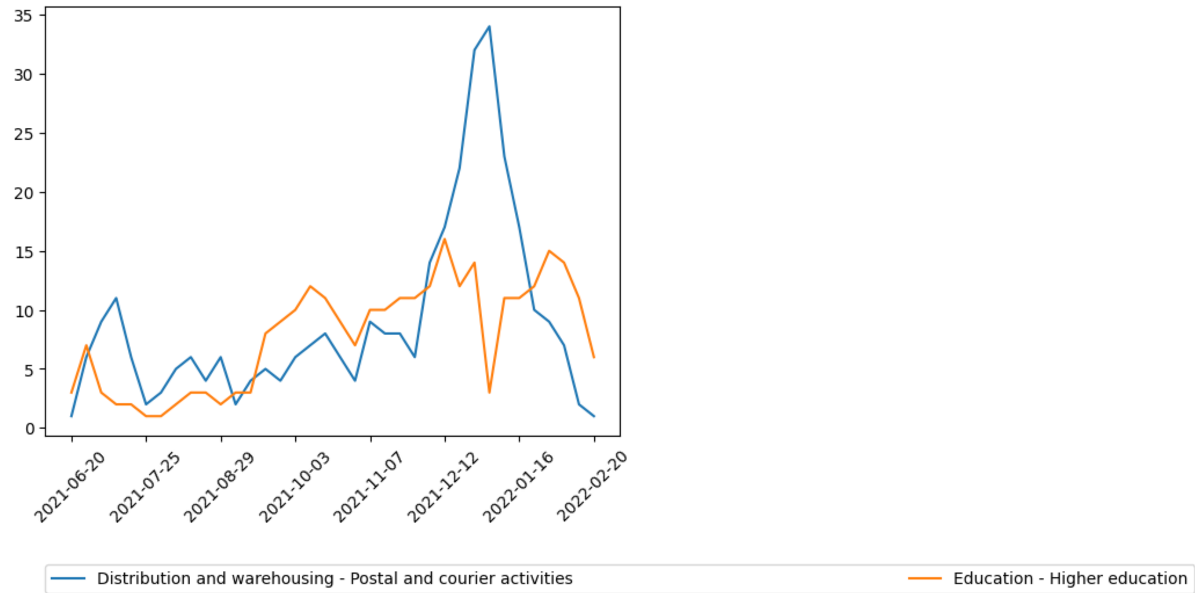

Figure 5 Comparison of Distribution and Warehousing (Postal) vs Higher Education

Further questions might be asked by comparing other sectors and asking questions about the differences between working practices and individual behaviours.

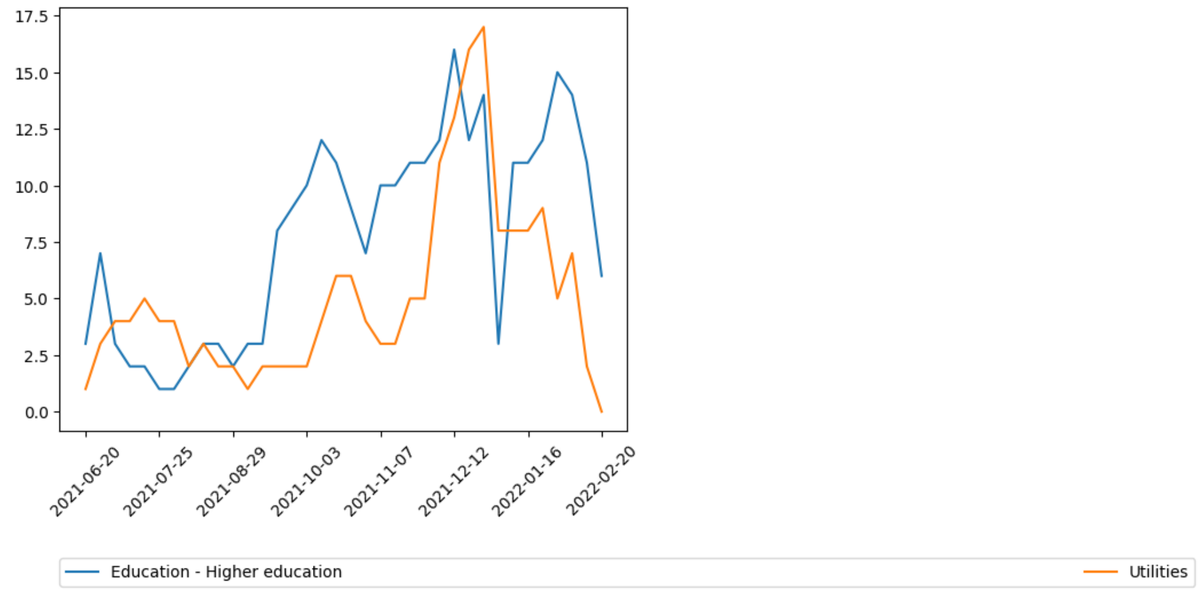

Figure 6 Comparison of Higher Education vs Utilities

With 32 employment sectors listed, the number of combinations of pairwise comparison is 496 and this will reveal an order of sensitivity to infection over the time period. As an approximation to this order, the simplest approach is to rank sectors by the number of infections using data shown in Table 1. This ranking can be used to organise the employment sector columns in the final model we produce. While not the most sophisticated approach to ranking, it serves the purpose of demonstrating how the ordinal information in the dataset can be useful in studying the distribution of risk and uncertainty around the likelihood of infection.

Geography and Infection

One of the key indicators from the qualitative survey is the disproportionate spread of infection on areas with high social deprivation. The quantitative data does not record the socio-economic group of participants, but rather those postcode locations where participation said they were present in the one week before infection. For this reason, it is not surprising to see that the geographical area with most infections is that area where there is the greatest concentration of visitors: central Manchester. The map below indicates the MSOAs with the intensity of infection throughout the time period of the dataset:

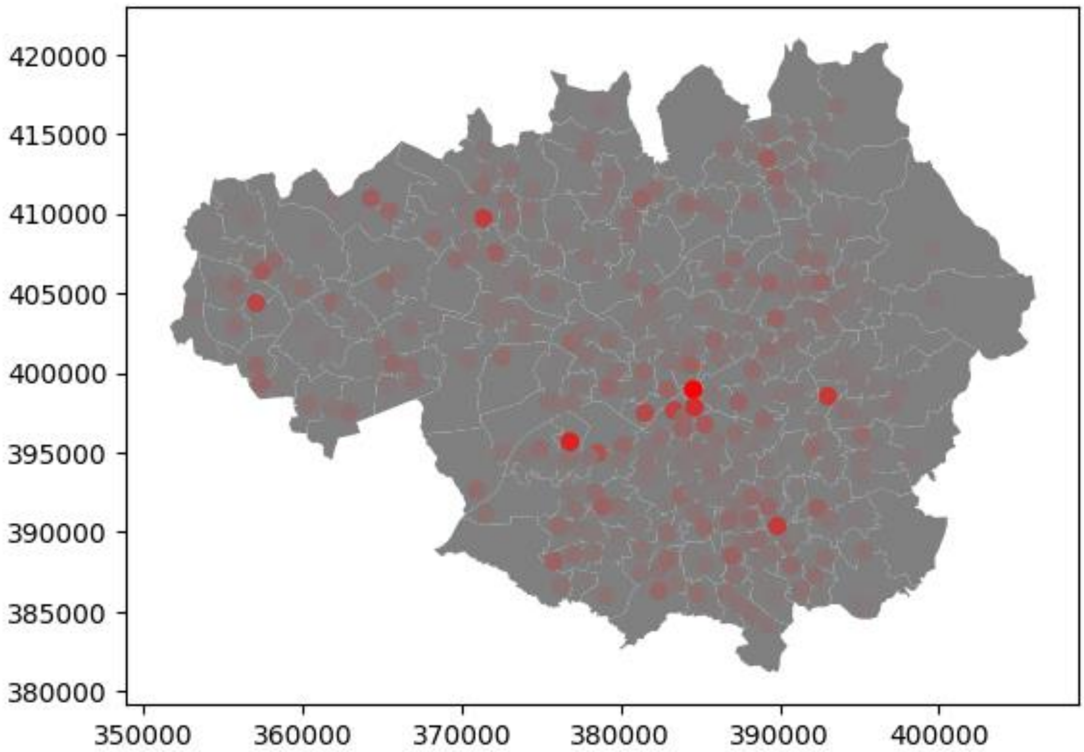

Figure 7 Geographical distribution of clusters in Greater Manchester

This can be represented in more detail as a heatmap against the different MSOAs. By mapping MSOAs to lower super output areas (LSOAs) and then estimating the average Social Deprivation Index, it is possible to order the table of clusters according to social deprivation. This is shown in Figure 2 below. In the heatmap, the red bars indicate hotspots of infection, but it is noticeable how these hotspots are distributed across the spectrum of Social Deprivation.

Just as with employment sectors, geographies can be ranked in terms of their sensitivity to infection waves. As with employment sectors, this can be done by simply ordering the number of cases across the period of the dataset for each MSOA. This enables us to create a ranking of MSOAs which can take the position of the columns in a model.

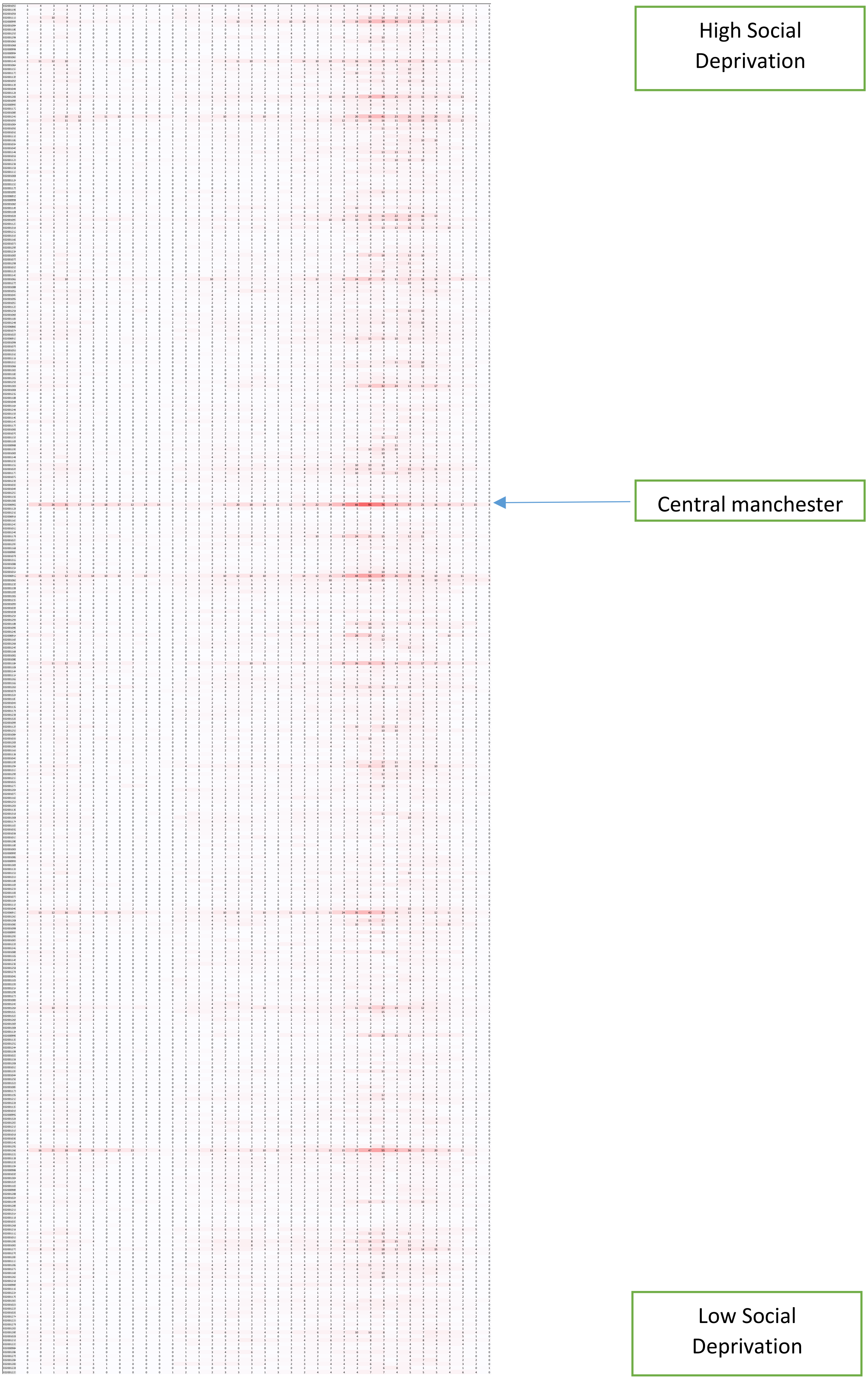

Figure 8 Social Deprivation and Infection

Assembling a Model of Geography and Employment

With ranking of MSOAs and infection forming the lookup columns of a model, and ranking of employment sectors forming the rows, we can use these ranking as an underlying guide with which to situate the specific employment sector/geography data.

This is done by repeating the ranking process but for each sector. With a given location and identification of employment sector, it is possible to establish the risk of infection based on the data by identifying the cell corresponding to the MSOA and sector. The cell indicates the rank of infections within that sector over the 36-week timescale. A rank of 0 indicates that a particular sector had the most infections of all sectors for that geographical area, while a rank of 32 indicates the least likelihood of infection. The likelihood of infection can be estimated by the vertical position of the MSOA in the table, which is ordered by the overall number of clusters per sector.

Figure 9 shows a sample of the dataset. It is colour-coded so that those cells which are the darkest red are those indicating the sector/geography with the highest rank (the highest being 0). By ranking sectors and geographies by their overall number of cases, the conformance with this rank with the actual recorded cases in specific sectors and geographies can be compared. Broadly, this means that the top-left of the table should contain the deepest red colour, and this should dissipate the further to the right, and the further down.

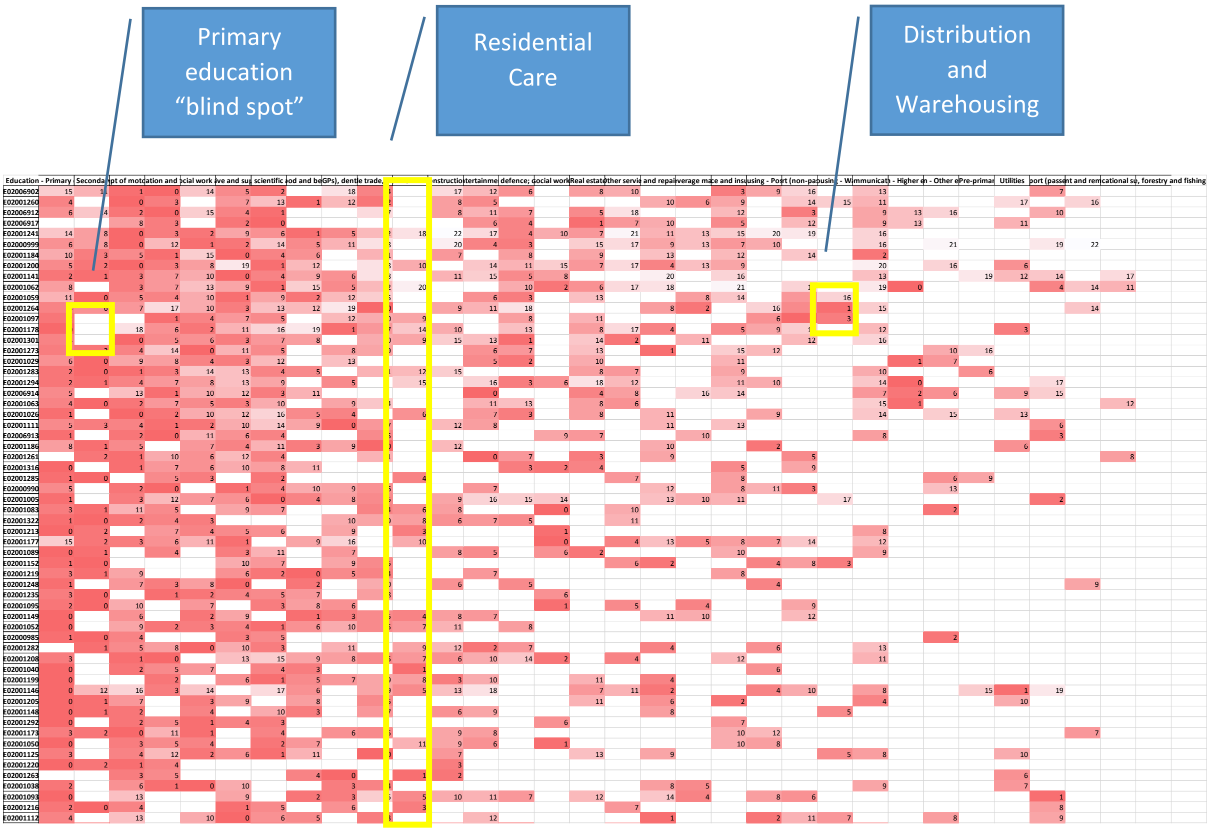

Figure 9 Sample of ranking dataset: employment sectors are across the top in rank order, MSOAs are on the left column in rank order

While the table in Figure 9 indicates the rank order of clusters within a particular area, a further table (Figure 10) can be produced which illustrates the actual number of recorded cases for each sector/geography. This shows a similar pattern to Figure 9, but provides more context to the ordinal information. This reveals the degree of difference between different sectors and geographies – particularly noticeable in selected red area in Figure 10, where the deep red colour indicates that retail in the MSOA E02001260 (which includes a large out of town shopping mall) had 189 clusters, with high clusters also recorded in central Manchester retail locations.

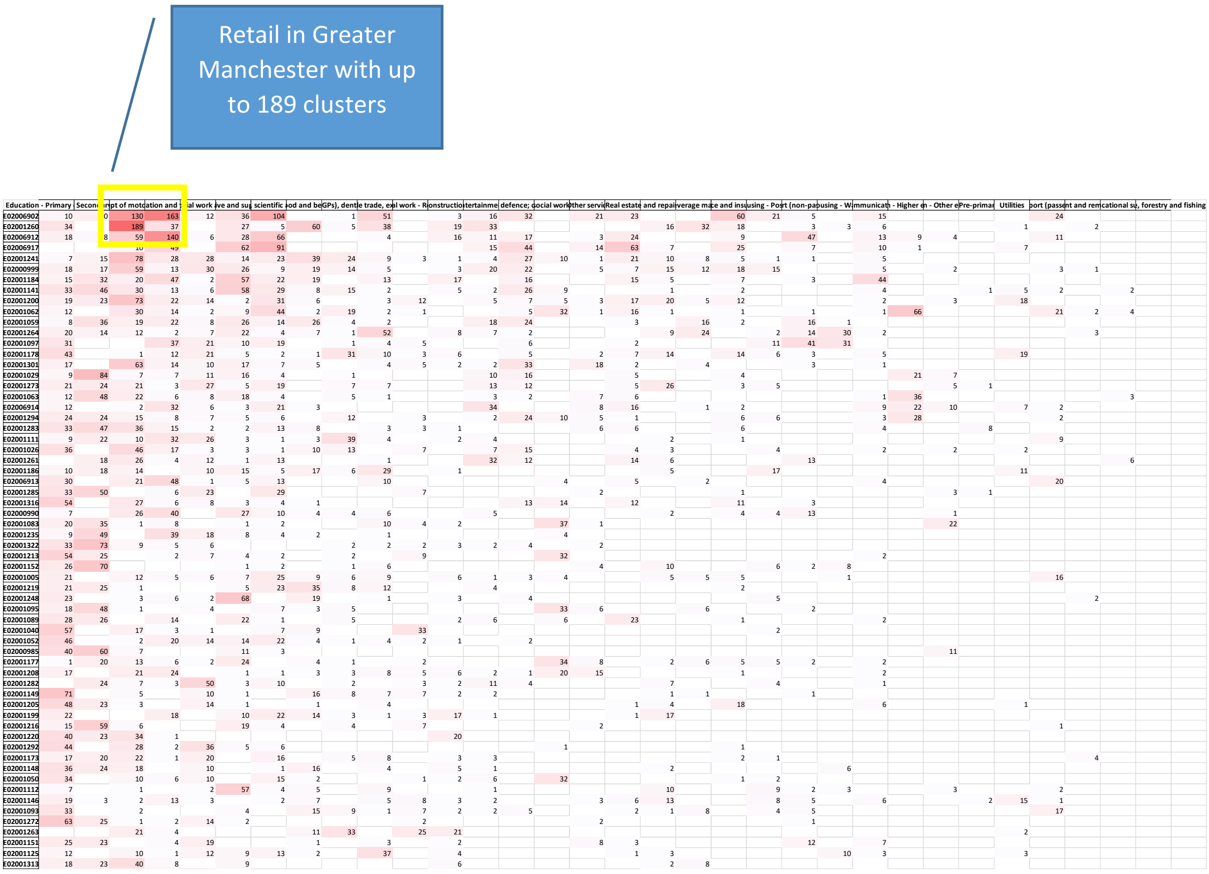

Figure 10 - Rank ordering of clusters by sector/geography

In both tables, the density of values decreases down the y-axis. While the rows at the bottom of the table still indicate a relative ranking of clusters for a particular MSOA, the total number of clusters is much lower. For example, from the table shown in Figure 10, the lowest MSOA has a total number of cases of 2 (recorded in residential care). Similarly for sectors of employment where there are few clusters recorded, the likelihood is much lower.

Likelihood relies on the probability density function, and this table represents different degrees of probability density from the top-left to the bottom-right. This reflects the number of cases in vulnerable sectors, which in turn affects the spread of data across different sectors.

The data clearly shows that the general pattern of education (the far left columns are Secondary and Primary) being a leading contributor to clusters is distributed across almost all MSOAs. Having said this, there are one or two gaps in the data, as for example highlighted in the second column in yellow. The highlights no cases in education in those particular geographies which would suggest either no schools in those areas, or a blind-spot in testing. A similar picture emerges of cases relating to residential care.

Figure 9 indicates that Residential care data is an example of an outlier example of where specific sectors of employment are located in specific locations. Residential care is also an outlier because although the total number of clusters recorded for this category is relatively high (737), which places residential care high up in the ranking of overall cases, these cases are distributed across a range of MSOAs more evenly than the distribution of cases for other categories with a standard deviation of 4.63.

Further examples of outliers include "Food and beverage manufacturing" and "Distribution and warehousing - Warehousing and storage". These, like Residential Care, stand out statistically because they do not follow the underlying pattern established in the overall ranking of clusters. By examining the data from the table shown in Figure 10, this may be partly because there are a relatively small numbers of cases in those sectors. However, within particularly locations, the number of cases is significant relative to other sectors in that particular area.

Discussion: Data, Decision and Contingency

The aim of this report has been to analyse the ordinal information contained in the COVID-19 dataset in Greater Manchester for the 36-week period during the Delta wave. The ordinal information contained in this data does appear to be illuminating of a number of aspects concerning the spread of COVID-19 across different sectors. By situating clusters on a matrix of location and sector, the approach is particularly notable for the ways in which data outliers provoke questions. These are generally of the form "given that there is a general high prevalence for sector a and location b, why does this sector/location have no/many clusters?" These question are powerful because they are a stimulus for further refinements and incremental improvement in analysis and further inquiry (both qualitative and quantitative) into specific locations and sectors.

Having said this, our dataset has some major deficiencies. There is therefore a legitimate question as to what could be done with better datasets that can be utilised contemporaneously by local and national public health teams to improve infection prevention and control in occupational settings. Identifying the sectors where greatest transmission exists within populations in a city region such as Greater Manchester, allows a unique opportunity to test hypotheses, work with the local public health teams. Study 2 of this work package investigates the higher education sector's response to COVID and it is clear the paucity of data prior to testing being made available and during Living with COVID has been challenging for the managing workplace outbreaks in this sector (Varga, Benson, Verma

2003). A companion report (Lewis et al, 2023) examined changes in how Greater Manchester workplaces were supported by local authority public health and environmental health teams during the course of the pandemic.

Having more data always becomes an important policy debate but it is intuitive i.e. the more data we have the better the model, the more we can deduce and hypotheses test. However, it is important to note that with any large datasets, with multiple hypotheses testing, we can misinterpret signals as being true associations leading to misleading results. Ensuring we utilise the analyses of these large datasets using the principle of hypothesis testing and epidemiological paradigms. To illustrate this, many of the debates around COVID-19 policy (for example, the wearing of masks) show that with highly complex and contingent data, it is theoretically possible to defend a wide range of potentially contradictory decision proposals (Martin, Hanna, & Dingwall, 2020). In such debates the desire for evidential data that eliminates contingency and makes particular policy choices immune is understandably strong. Not only is this desire illusory, it is also not possible to determine if “better data”, or simply “more data” will result in better decisions: the differences between competing positions are differences in judgement as to whether data is information, redundancy or noise, and which data falls into which category. Aggregated geographical data that are then analysed for signals need further hypothesis testing to ensure true associations can be described. It is also important to note, that looking at population level data, we cannot ascribe any portion of risk to an individual within that population i.e. ecological fallacy. Therefore, this study is hypotheses generating and lends itself to further studies where data linkage of individual data can then be performed.

The occupation classification within the dataset presents a case-in-point (Stoto et al, 2022). While these designations are classifications of particular settings, they are insufficient to describe the behaviour of individuals in those locations. Just as with the comparative analysis of transmission data, comparing sector definitions with one another can reveal deeper distinctions that be made between classifications. For example, to compare “Education” with “Retail” is to consider the range of likelihood in the differences in demography, behaviour, proximity, mobility, space and time. The underlying features may then be more useful in distinguishing the differences in settings.

Postcode coincidence data (itself also highly contingent) does however provide an outcome measure which arises through the complex interaction of many different variables. Some of the underlying differences between sectors of employment and geographical areas can be illuminated by examining the transmission and analysing the varying degrees of contingency in results. For those sectors of employment and geographies which have the highest number of clusters, there is far less contingency concerning the likelihood of transmission than there is with the employment sectors with low levels of transmission. Equally, different geographical locations display different degrees of contingency in their likelihood of transmission for different employment sectors, and this is demonstrated both in the differences in probability density for each location, and in the agreement between a particular location's clusters with the global ranking of different sectors.

Given this, it is important to consider that a "cluster" is the coincidence of location data given by a participant in response to the question "where did you go in the 7 days prior to testing positive?" The veracity of responses to this question cannot be ascertained, although given the size of the dataset, it may be possible to estimate that the eventual "signal" represented in the data is the result of sufficient redundancy of information (i.e. many people giving the same location) to be significant. However, this significance may result from other underlying complexities of the interview, for example, what people are prepared to say in response to the questions.

Having said this, one of the key features of our analysis has been to focus on the ordinal relationships between the data. An analogy helps to explain why this matters: the James Webb telescope sees more detail of the universe than the Hubble telescope, but the order of certainty about features (e.g. craters on the moon vs planets in Alpha Centauri) remains the same. By ranking cases and locations, ordinal information can present a simple question as to whether location x or location y presents a greater likelihood of infection. Irrespective of the uncertainties in specific measurements, the uncertainties of these comparisons reveals patterns of contingency which are likely to be repeated even with more data or "better data".

If other data were available, for example, demographic data then this too could be used as the basis for further analysis of risk which could be useful in targeting interventions both to collect further data or to target measures to mitigate transmission. For example, demographic data collection could focus attention on the habits of young people and the occupational sectors where they are most likely to be infected, or on people in residential care.

The dataset we analysed shows very clearly the differences in variation in sensitivity to waves of the virus across different occupations. It seems reasonable to ask if a new wave of the virus was to occur, would we expect there to be a difference in the relative sensitivity to infection across different sectors? If the same policies were adopted, would the pattern of distribution of differences in sensitivity to transmission be reproduced?

The pandemic's waves were mirrored by waves of policy initiatives worldwide (Bekker, Ivankovic, & Biermann, 2020; Zaki, Pattyn, & Wayenberg, 2022). The Living with COVID policy is the latest of these in the UK. Each policy initiative takes a different approach to the management of risk and contingency. A map of contingency in the sensitivity to a virus wave can be useful in this context because it pinpoints certain areas for data collection and analysis both as an early warning for a new threat, as well as a means of targeting measures to mitigate spread of the virus. In terms of monitoring, to concentrate data collection and analysis on those areas with greatest sensitivity to transmission. At the same time, risk "outliers" present opportunities to analyse in more detail why certain sectors appear safer than others.

In our analysis outliers can be both identified with regard to sectors (for example, forestry) and with regard to location. In many cases, sectors of occupation are sparse because they are associated with particular locations. In these cases, within specific locations, the likelihood of transmission is high. The strength of the analysis lies in the impetus that apparent "noise" in the data can provide for deeper inquiry and refinement of analytical techniques.

Many of the deficiencies in the present dataset relate to the way the data is classified and aggregated. The loss of demographic information which was present in the original Test and Trace survey is particularly notable. This means that analytic work focusing on issues around the connection between social deprivation and likelihood of infection cannot be considered in detail. Instead, we only have data about locations visited.

The exclusion of time as a variable in the analysis is a limitation. There are significant contingencies associated with time and coincident events and locations which can have a bearing on the risk of infection which is obscured both by the original data and by the analytical approach. A 3D mapping of time against location and sector is a possibility for further development of this analysis.

The aggregation of the dataset from postcodes in the original survey to MSOA clusters presents a further challenge. MSOAs are geographical areas with an average population of 7500. They are comprised of groups of LSOAs, each with a population of about 1500. Postcodes, by comparison, contain about 15 properties. Therefore it is easy to see how translating postcode information into MSOAs loses significant amounts of information. Furthermore, because this data concerns places visited, there is no reflection of the transient population in a particular MSOA. It is therefore to be expected that areas with highest numbers of visitors (for example, central Manchester) will be identified as hotspots for infection.

In the contact tracing interview, it is difficult to determine specific locations. For any MSOA, there can be a number of different locations which fit an occupational category (for example, “retail”). This means that the specific location of transmission of the virus cannot be pinned-down, limiting the study of the features of any particular location (e.g. architecture, ventilation, concentration of population, transience of population, time spent at the location, etc).

Conclusions

Test and Trace during COVID-19 can be seen as an exercise in the mass observation of movements of a population. The combination of infection and locations visited produced pictures of individual and social behaviour. The fact that some of these observations are much clearer than others is itself informative: there is information in the ranking of likelihood of infection which can be usefully analysed. Having a map of uncertainty in observation is useful because it allows for the concentration of scarce human resources on specific areas of inquiry and intervention where finer-grained distinctions need to be made.

The distinction between information, redundancy and noise in the data is critical in being able to use the data to act effectively. The COVID-19 data represented in the dataset we have analysed is informative, redundant and noisy. The information it contains lies not only in the case numbers for particular sectors, but in the ordered relationships between different sectors and geographies. This ordinal information can be useful in unpicking the apparently noisy aspects of the data for sectors where there does not appear to be much to distinguish patterns of infection across different employment sectors. Pairwise comparison provides a way of elucidating this.

The fundamental question is how to coordinate actions to monitor, analyse and control COVID-19 transmission given a map of contingency. Despite the deficiencies in the dataset, a map of contingency in the likelihood of transmission across sectors and locations can be useful in considering how the risks associated with the Living with COVID might be managed. The identification of those sectors of employment and geographical locations which are most sensitive to a new wave of the virus, with the least uncertainty in the data, can provide a foundation for less invasive monitoring strategies which could provide an early warning and foci for interventions.

The question over how differences between information, redundancy and noise in datasets can be determined lies at the heart of how better decisions for the management of the pandemic can be made. More data carries the risk of more noise, or more bias (or both) whilst also presenting deeper social and political concerns about surveillance. Focus on the contingencies in data, however, can be a spur to deeper inquiry: noise – as Von Foerster (2003) noted, can be an essential contributor of new development and self-organisation.

Recommendations

The recommendations of this report are:

1. Understanding uncertainty and contingency:

   It is important to understand uncertainty and contingency in collected data for mitigating risk in a post-pandemic world. Information contained in an ordinal ranking of uncertainty produces a map that can situate the relative risks of different occupational settings and locations which can guide new control measures to prevent transmission.

2. Public communication of uncertainty to engender greater public trust

   In the crisis situation of the pandemic, the need for clear political messaging overrode the articulation and communication of uncertainty. The distribution of contingencies in the data derived from COVID-19 remain in the era of "Living with COVID". These data mean that should a new threat emerge, those sectors which carry the least and greatest contingency can be distinguished and interventions tailored to particular circumstances in ways which were not possible in the early stages of the pandemic. Having clear ways of communicating uncertainty could provide a more sophisticated approach to managing social behaviour in a pandemic in ways which could encourage better-informed debate and greater public trust.

3. Developing ordinal models is a spur to deeper inquiry and incremental improvement in analysis and measurement

   The ordinal information of infection by sector and location provides deeper information as to the likely outcomes and contingencies associated with particular occupations. This information can be useful in driving deeper inquiry alongside creative and localised interventions to improve outcomes and mitigate risk.

4. Within contingencies are more contingencies: recursive patterns in the data may provide a foundation for more powerful analysis for asking "What if?"

   One of the advantages of concentrating on the ordinal information in the datasets is that ordinal information reveals recursive patterns: there is ordinal information in the global statistics for transmission, and there is ordinal information in the comparisons between different occupations, and there is ordinal information in individual sectors and locations themselves. This recursiveness reflects the recursive nature of risk and uncertainty in dealing with the virus itself, and provides a platform for inquiry as new challenges arise. These analyses are hypotheses generating and further data linkage of individual level data with personal, location, employment, occupational data can be utilised.

References for Report 1

Bekker, M., Ivankovic, D., & Biermann, O. (2020). Early lessons from COVID-19 response and shifts in authority: public trust, policy legitimacy and political inclusion. *European Journal of Public Health*, *30*(5), 854–855. https://doi.org/10.1093/eurpub/ckaa181

Cherrie, M., Rhodes, S., Wilkinson, J., Mueller, W., Nafilyan, V., Van Tongeren, M., & Pearce, N. (2022). Longitudinal changes in proportionate mortality due to COVID-19 by occupation in England and Wales. *Scandinavian Journal of Work, Environment & Health*. https://doi.org/10.5271/sjweh.4048

Dodson, T. B. (2020). Uncertainty and the Risk of Occupational Exposure to Severe Acute Respiratory Syndrome–Coronavirus-2. *Journal of Oral and Maxillofacial Surgery*. https://doi.org/10.1016/j.joms.2020.05.007

Engelmann, L., Montgomery, C. M., Sturdy, S., & Moreno Lozano, C. (2022). Domesticating models: On the contingency of Covid-19 modelling in UK media and policy. *Social Studies of Science*, 030631272211261. https://doi.org/10.1177/03063127221126166

Johnson, M., & Saleh, R. (2022). The guts of assessment: a digital architecture for machine learning and analogue judgement. *Interactive Learning Environments*, 1–15. https://doi.org/10.1080/10494820.2022.2135105

Johnson, M. W., Rodriguez-Arciniegas, S., & Kataeva, A. N. (2020). Comparative judgement and the visualisation of construct formation in a personal learning environment. *Interactive Learning Environments*, 1–20. https://doi.org/10.1080/10494820.2020.1799030

Lewis, C., Mann, C., Ubido, J., Farrell, B., Johnson, S. (2023) An exploration of how 'Living with COVID' influences COVID-19 transmission risk, response and resilience in workplace settings: a Greater Manchester Case Study – Study 2. PROTECT

Maydeu-Olivares, A., & Böckenholt, U. (n.d.). *Modeling Subjective Health Outcomes Top 10 Reasons to Use Thurstone's Method*. Retrieved from http://www.medicine.mcgill.ca/epidemiology/courses/EPIB654/Summer2010/WTP/Maydeu-Olivares%202008%20Med%20Care.pdf

Pollitt, A. (2011). Comparative judgement for assessment. *International Journal of Technology and Design Education*, *22*(2), 157–170. https://doi.org/10.1007/s10798-011-9189-x

Sartor, Z., & Hess, B. (2020). Increasing the Signal-to-Noise Ratio: COVID-19 Clinical Synopsis for Outpatient Providers. *Journal of Primary Care & Community Health*, *11*, 215013272092295. https://doi.org/10.1177/2150132720922957

Stoto, M. A., Woolverton, A., Kraemer, J., Barlow, P., & Clarke, M. (2022). COVID-19 data are messy: analytic methods for rigorous impact analyses with imperfect data. *Globalization and Health*, *18*(1). https://doi.org/10.1186/s12992-021-00795-0

Martin, G. P., Hanna, E., & Dingwall, R. (2020b). Urgency and uncertainty: covid-19, face masks, and evidence informed policy. *BMJ*, m2017. https://doi.org/10.1136/bmj.m2017

ONS. (2020, May 11). Which occupations have the highest potential exposure to the coronavirus (COVID-19)? - Office for National Statistics. Retrieved from www.ons.gov.uk website: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/articles/whichoccupationshavethehighestpotentialexposuretothecoronaviruscovid19/2020-05-11

Sartor, Z., & Hess, B. (2020). Increasing the Signal-to-Noise Ratio: COVID-19 Clinical Synopsis for Outpatient Providers. *Journal of Primary Care & Community Health*, *11*, 215013272092295. https://doi.org/10.1177/2150132720922957

Stoto, M. A., Woolverton, A., Kraemer, J., Barlow, P., & Clarke, M. (2022). COVID-19 data are messy: analytic methods for rigorous impact analyses with imperfect data. *Globalization and Health*, *18*(1). https://doi.org/10.1186/s12992-021-00795-0

Thurstone, L. L. (1927). A law of comparative judgment. *Psychological Review*, *34*(4), 273–286. https://doi.org/10.1037/h0070288

UK Government. (2023). Chapter 7: contact tracing and isolation. Retrieved January 24, 2023, from GOV.UK website: https://www.gov.uk/government/publications/technical-report-on-the-covid-19-pandemic-in-the-uk/chapter-7-contact-tracing-and-isolation

Varga E, Benson MJ, Verma A (2023) Workplace outbreak management in a Manchester higher education setting during the COVID pandemic: a before and after ‘Living with COVID’ study Report for PROTECT study Year 3 WP3 Study 1

Von Foerster, Heinz. (2003). “Self-Organising Systems and their Environments”, in Von Foerster, H *Understanding understanding : essays on cybernetics and cognition*. New York: Springer.

Zaki, B. L., Pattyn, V., & Wayenberg, E. (2022). Policy learning type shifts during creeping crises: A storyboard of COVID-19 driven learning in Belgium. *European Policy Analysis*. https://doi.org/10.1002/epa2.1165

Report 2: Workplace outbreak management in a Manchester higher education setting during the COVID pandemic: a before and after 'Living with COVID' study

Varga E, Benson MJ, Verma A

Division of Population Health, Health Services Research and Primary Care, University of Manchester.

Introduction

The study presented here is a realist evaluation conducted to identify the past and present transmission risk reduction practices implemented in a higher educational setting and describe the views and experiences of those public health professionals directly involved in the Coronavirus 19 disease (COVID-19) response. Below are summarised key events that occurred from January 2020 until the current 'Living with COVID' era of COVID-19, which will serve as the context for the evaluation.

Timeline

On 31 January 2020, the UK documented its first case of COVID-19, and by 11 March 2020, the WHO declared the novel coronavirus outbreak a global pandemic (IFG 2021a). During this time, no official testing existed; generally, little was known about the virus. On 23 March 2020, Prime Minister Boris Johnson announced an official UK lockdown, ordering people to stay at home (IFG 2021b). This came legally into force on 26 March 2020 (IFG 2021c). During this time at University of Manchester (UoM), staff were instructed to work off-site, remotely. Nationwide, key workers remained in the workplace at this time. As this was a period prior to testing, many challenges existed in managing outbreaks in the workplace.

On 23 April 2020, testing for essential workers was announced (DHSC 2020). Those included in the list of essential workers were those in schools and education. On 22 May 2020, contact tracing was announced to help identify and break the chain of transmission to help reduce the spread of COVID-19. On 27 May 2020, NHS Test and Trace was announced and went live the next day (Briggs et al., 2020). The service aimed to reduce transmission risk, especially in workplace settings, to identify potential contacts and advise them to test and self-isolate. Shortly after this, in July 2020, NHS Test and Trace began to share postcode-level data with local authorities(UKHSA 2021).

Throughout 2020, the UK faced rises and falls in the levels of transmission of COVID-19 and even saw local lockdowns enforced, such as those in Leicester on 4 July 2020. Prime Minister Boris Johnson announced a new three-tier system in England on 14 October 2020 (IFG 2021 d). Following these restrictions, England entered its second national lockdown on 5 November 2020 (IFG 2021d). This was followed by a third lockdown in January 2021, during which time University students would not return and instead have online tuition (IFG 2021). In addition, the university end-of-year exams were cancelled. In September 2021, the UK Health Security Agency (UKHSA) was formed (UKHSA 2023). The UKHSA published weekly statistics on NHS Test and Trace in England. This document primarily set out information on the data sources and methodology used to generate statistics for testing in England. These statistics included information on the number of people who tested for COVID-19, those who tested positive for COVID-19, as well as lateral flow device (LFD) tests reported linked to educational settings.

On 21 February 2022, the UK government introduced the COVID-19 response 'Living with COVID' (CO 2022). From 24 February 2022, the UK government removed the legal requirement to self-isolate following a positive COVID test. Any adult or child who tested positive was advised to stay home and avoid contact with other people. The government no longer asked fully vaccinated close contacts of positive cases or those under 18 to test daily for seven days and removed the legal requirement for those not vaccinated to self-isolate for seven days (PMO 2022). On 27 February, contact tracing ended as part of the 'Living with COVID' strategy. The aim of this period is for the UK to be able to manage COVID-19 like other respiratory illnesses and respond to new variants of the virus that could threaten to place the NHS under unsustainable pressure. However, without contact tracing, people will no longer be informed if they have come in to contact with anyone who has tested positive for COVID-19.

Additionally, from 24 March 2022, the COVID-19 provisions within Statutory Sick Pay and Employment and Support Allowance regulations ended (ACAS 2022). On 1 April 2022, the government decided to update the guidance setting out the ongoing steps that people with COVID-19 should take to minimise the threat to others. In addition, the government no longer required certain venues to use the NHS COVID pass (IFG 2022).

Background

Since the end of compulsory testing for people on 1 April 2022, the UK entered a new stage in the pandemic as we learned to 'Live with COVID-19' as laid out by PM Boris Johnson's government (UKSHA 2022). This new era has seen a lack of data sharing with local authorities. Universities were responsible for managing their responses throughout the pandemic by implementing up-to-date legislation, policies, and guidance in partnership with the local public health teams in local authorities and Public Health England (PHE), now UKHSA. Due to the current situation and lack of data sharing against the backdrop of a return to on-campus teaching and a rising student population, public health teams have been tasked with assessing the current situation in HEI regarding outbreak management and protecting students and staff from the risk of transmission of COVID-19. The methods they implemented in the workplace are essential in learning how to practice outbreak management for potential future pandemics.

Aims

To explore the risk management of COVID-19 transmission in a higher education setting, in Greater Manchester, before and after the ‘Living with Covid’ guidance.

Objectives

The objectives of our evaluation are:

- To report current workplace practices to reduce the risk of transmission in a higher educational setting, compared to previous policy decisions (local, national).
- To conduct a realist evaluation using qualitative methods with local Manchester public health professionals to evaluate their views on reducing the risk of transmission before and after the era of ‘Living with Covid’.
- To identify the challenges and barriers, public health professionals face in managing the risk of transmission in higher educational settings.
- To identify the facilitators and opportunities public health professionals experienced in managing the risk of transmission in higher educational settings.
- To construct recommendations for future pandemic preparation and deployment.

Methods

We used qualitative methods as a before and after study to evaluate the views and experiences of public health professionals involved in COVID-19 transmission risk reduction and workplace outbreak management at higher educational settings before and after the 'Living with COVID' guidance. The realist evaluation framework was selected to identify what works, for whom, and in what circumstances (Pawson et al., 1997)

Realist evaluation

Realist evaluations acknowledge that the observed outcomes of programmes and interventions in complex systems will depend on contextual factors. This method allows decision-makers and stakeholders to gain a deeper and richer understanding of complex local, regional, or national programmes and enables the continuous development of those (Pawson, 2005).

At the core of the realist methodology are the context, mechanism, and outcome (CMO) configurations (Pawson et al., 1997). These are a collection of theories that enable the untangling of complexities within programmes and interventions where multiple factors simultaneously assert their influence. Realist aims not to judge if something works but to identify "what works for whom in what circumstances?" through an iterative process of generating Middle Range Theories (MRT). MRTs are initial programme theories that describe how particular outcomes are achieved in a specific context through particular mechanisms (Roodbari et al., 2021).

Recruitment

We used purposive sampling through existing professional networks to recruit participants. All those invited were known to have been directly involved in managing workplace outbreaks and transmission in Higher Educational Institutions (HEI) and have supported the University of Manchester's response before and after the 'Living with COVID' guidance. Participants were invited via email. The data were generated from interviews. Data collection took place in January 2023. University of Manchester Research Ethics Committee reviewed the study and granted approval using the proportionate review process (Ref: 2023-16074-26806).

Data collection and Analysis

Two qualitative researchers (EV, MJ) conducted realist interviews with public health professionals in Greater Manchester to evaluate workplace COVID-19 transmission risk reduction and outbreak management practices, their barriers and facilitators, and their experiences since the 'Living with COVID' guidance. They reviewed the findings from Study 3 work package 3 interviews which were conducted in March 2022, immediately prior to implementation of the 'Living with COVID' policies were implemented.

The interviews were conducted online using Microsoft Teams. A topic guide was developed to probe participants' experiences of working in their roles before and after the 'Living with COVID' guidance – particularly concerning their experiences of workplace outbreak management in HEI. The researchers took handwritten notes of the key responses. Using the realist framework, notes were coded and thematically analysed. Then, contextual factors, and underlying mechanisms relevant to transmission risk management, were identified. NVivo 12 software was used to code the data and to locate the most vivid excerpts. The candidate context-mechanism-outcome theories were discussed at regular meetings between the researchers. The context-mechanisms-outcomes (CMO) configurations were translated into middle range theories (MRTs).

Results

The period of January – March 2020

Unknown risks

The participants highlighted that when COVID-19 emerged, there was very little information about the virus transmission, susceptibility, and risks. As there was no testing, they did not know the exact number of infections in the population and any pattern that might have been emerging. Public Health (PH) professionals had to rely on information and base pandemic response around risks of and susceptibility to other respiratory infections, resulting in a very high level/general understanding of the risk of transmission of COVID-19. Areas of high deprivation and setting such as care homes and nursing homes - known to be vulnerable to respiratory infections - were high on their analysis as at risk; however, universities did not flag up as particularly susceptible to outbreaks.

At that time, we didn't look at universities; they were not high on our risk analysis. We were looking at nursing homes and care homes. We didn't know where covid would be high risk.

Supporting people

The novel virus and unprecedented pandemic caused much anxiety among staff and students. People needed support and reassurance.

Disjointed working

The disjointed working between Health Protection Teams and other Public Health bodies represented a barrier in this phase of the pandemic, as communication was slow and collaborative working was not established yet. These siloed working conditions meant the response to the pandemic was not as efficient and quick as it could have been.

Before the pandemic, there was a lot of separation between health protection and bits of public health. There was not much connection with health protection from a surveillance point of view.

Table 1 - Candidate CMOs - The period of January - March 2020

The period of January – March 2020		
Context	Mechanism	Outcome
Unknown risks		
A novel virus, no pre-existing data	Stakeholders use information on susceptibility to other respiratory infections	Very high-level/general understanding about the risks of transmission

No testing, no available data	Stakeholders analyse patterns of other infections	Ineffective analysis- Universities are not flagged as high-risk settings
	Universities are not identified as high risk	Universities are not prioritised at a national level
Supporting people		
The novel COVID-19 virus- an unprecedented situation	Stakeholders establish a support network at HEI to reassure staff and students	People feel supported and reassured – anxiety is reduced
COVID-19 is spreading	Staff and students are impacted	People require extra support
Disjointed working		
The separation between Health Protection and other parts of Public Health	Different organisations do not communicate nor collaborate	Disjointed working – slow response to the pandemic

The first lockdown

Supporting people

During the first lockdown, supporting university staff was described as an essential task. Remote working was introduced, furlough was organised, and those who had to remain on site were provided extra protection and support to work in a safe environment and maintain transmission risk at the minimum. Staff was informed through direct messages and updates about what was happening. Those impacted by mortality, personal tragedies and the stress of homeschooling needed extra support to cope and process upsetting and stressful events.

> *Prior to the setting up of campus management group and testing sub-groups, this stage was about making sure the division was off campus, and on-site staff could do their jobs. Organising furlough for staff was important. […] It was an all-new situation for everyone. People were working remotely, high mortalities, personal tragedies, homeschooling and people's reactions to these. We had to deal with people's anxieties and had to be supportive of their needs.*

Quality of guidelines

Poor national guidance was highlighted as one of the main issues during this period. The information on protection and risk mitigation was poor and rapidly changing. People ended up misinformed or poorly informed.

We received poor information about protection, such as being told at one point that wearing a mask could lead to the possible increase of COVID-19 transmission.

Data availability

Any data that was available at this point was very minimal. While lobbying for more data, local PHP had to rely on generic, census-based information to assess risks, resulting in missing Universities as a potentially high-risk setting and, thus, a less effective pandemic response.

Most of our work were based on generic, area and census data. We were trying to work out where will it be most affected but did not have any data to back that up. We did high-level stuff, mapping and quantifying what and whom we thought might be at risk, but no data to demonstrate what was actually happening.

Don't recall universities being high on the list. Nobody said let's look at universities where a population might be at risk – until the big outbreak happened.

The lack of information on the virus meant that general transmission risk and outbreak management continued.

Table 2 - Candidate CMOs - The first lockdown

The first Lockdown		
Context	Mechanism	Outcome
Supporting People		
COVID-19 pandemic	Enabling remote working at HEI	Infection prevention – HEI staff are safe and supported
	Supporting on-site staff at HEI	
	Organising furlough for HEI staff	
	University stakeholders send messages to staff	Staff is supported and informed
Staff impacted by COVID-19	University stakeholders support people's individual needs	Staff is coping better with their personal experiences of the pandemic
Quality of guidelines		

Poor information on protection	People are being misinformed or badly informed	Increased risk of transmission, infection, and outbreaks
Data availability		
Only general data is available	Stakeholders lobby for more specific data	Data delayed- increased risk of transmission
	Stakeholders use generic area, census-based risk assessment	Crude risk assessment
	University deploys general infection prevention measures	Non-targeted management of transmission and infections risks
	Stakeholders analyse incomplete data on at-risk groups and settings	Increased risk of transmission, infection, and outbreaks
		Inadequate pandemic response
		HEI are missed as high-risk setting

The post- 1st lockdown period – before data was shared with LA

Quality of guidelines

The poor national guidelines and the government's handling of COVID-19 continued to be a problem in managing the risk of transmission in HE settings. The participants highlighted that the conflicting messaging created much apprehension, and the sudden guidance changes resulted in confusion among the staff and students. The changing guidance, often about the basics of transmission, resulted in people losing confidence in what campus management was advising them.

> *There was a lot of apprehension due to the conflicting messages coming from the government. Usually, after Boris's 7pm transmission – all hell broke loose. The advice suddenly changed, ranging from that on masks, public spaces, social distancing – the basics of transmission, our bread and butter.*

The Department for Education (DfE) directed and provided guidance to HEIs. This included the return to face-to-face teaching and withdrawing certain restrictions. This created a situation stakeholders described as challenging due to campus management not being able to assure staff and students that the premises were COVID-19 secure.

General mitigation measures

General mitigating measures were implemented due to the lack of data on virus spread and infection rates. The available data was national level only; thus, local, tailored, bespoke mitigating measures could not be implemented. In order to open campus safely and securely, weekly/twice weekly testing of students and staff was in place, personal protective equipment (PPE) such as masks (including suitable ones for those who lip read), hand washing and sanitising facilities were made accessible, ventilation was ensured, and social distancing was required. Putting these procedures and protective measures in place was a massive task.

UoM acquired a large stock of LFTs and distributed them at key strategic sites to increase the rate of testing and support monitoring. Those with disabilities or difficulties using LFTs were assisted, and thus exclusion and barriers to testing were reduced.

Data protection/Legal restrictions

The legal restrictions around data sharing were described as a hindrance to effecting transmission risk management. No data was given, which meant direct monitoring of what was happening in Greater Manchester regarding the spread of the virus was impossible.

> *We had no data during the first few months due to legal restrictions on data sharing, no individual, not even high level.*

Existing legal regulations made laboratories duty-bound to share positive test results but not negative ones; thus, they could not calculate the proportion of positive test results within the tested population. Due to the non-existent legal framework, a Control of Patient Information (COPI) notice was quickly put together, which created the legal base for laboratories to share data on everybody.

Campus Management Group (CMG)

Establishing a Campus Management Group was described as one of the most critical steps towards deploying an effective response to the pandemic. The Outbreak Planning Team was a subcommittee within the Campus Management Group. They worked collaboratively with institutions such as the Royal College of Music, Manchester Metropolitan University,

University of Salford, University of Bolton, and others such as Public Health England (now UKHSA). Regular meetings took place daily, often multiple times a day, to look at data from different sources and to work out actions to follow. Public Health experts participating in these meetings ensured that the response was evidence-based; their knowledge was greatly valued and described as crucial to effective transmission risk management and outbreak response during this period.

Collaborative working

Collaborative working between groups and organisations enabled data and knowledge sharing. The regular meetings meant they were more agile and could adapt quicker to the frequently changing guidelines. The communication team was closely involved and was able to disseminate up-to-date information effectively.

Other

Stakeholders highlighted that once people returned to work, cases went up. Although locally relevant data was kept from local authorities, there was some understanding of COVID-19 rates on a national level (table 3).

Table 3 - Candidate CMOs - Post lockdown, before data sharing

The post lockdown period – before data was shared with LA		
Context	Mechanism	Outcome
Quality of guidelines		
Government's COVID-19 response	Government releases conflicting and contradictory messages	Students and staff are apprehensive
New government announcement	Advice suddenly changes	Students and staff are confusion
	Advice changes on the basics of transmission	Student and staff lose confidence in what the HEI was advising
DfE releases HE guidelines	HEI follows direction to ease restrictions	The setting is no longer a COVID-19 secure environment
	HEI moves away from COVID-19 secure environment	Difficulties in reassuring staff and students about the level of infection risks
	HEI returns to face-to-face teaching	
General mitigation measures		
Data is not available to Local Authority	HEI implement general mitigation measure	Limited infection control
Data only available at a national level	Stakeholders do not know local level of infection	The risk of mismanagement and inadequate response is increased

Test and Trace	HEI acquires a stock of LFT	More people have access to tests
	More people test at HEI	More effective monitoring
HEI acquired LFTs	HEI distributes LFTs at key strategic points on campus	Testing rate increases
Students or staff with disabilities or difficulties using LFTs	Stakeholders assist people to use LFTs	The barriers to testing is reduced
Data protection/Legal restrictions		
Legal restriction on data sharing	Data is not shared	Stakeholders are unable to monitor and assess risk of transmission, infection and outbreaks
	COPI notice developed	Data sharing across organisations is made legally possible
	Laboratories only share positive test results	Stakeholders are unable to calculate what proportion of tests are positive
	Legal base created for laboratories to share all results	Broader view infection rates and what proportion of tests are positive
Campus Management Group (CMG)		
The Campus Management Group and the Outbreak Planning subcommittee are set up	Local experts are contributing to COVID-19 response	More effective infection control and outbreak management
	Group members meet regularly	Patterns, hotspots, links identified among students and staff
Data is available from different sources	Data collated and triangulated by CMG	Better monitoring of transmission, infections, and outbreaks in HEI
Collaborative working		
Groups and organisations work collaboratively	Members meet daily	Agility in adaptive action to changing guidance
	CMG works closely with the communication team at HEI	Reliable, up-to-date information is effectively disseminated
Other		
Students and staff return to campus	Transmission risk increases	COVID-19 level increases
Test and Trace restarted - without data sharing with LA	Asymptomatic people test	Increased understanding of virus spread on a national level

The period of data sharing with the local authority

Data availability

Participants stated that they needed accurate and timely data. When data was made available to local authorities, it was a "huge game changer" in understanding and responding to the spread of COVID-19 in Greater Manchester and, more specifically, in HEI according to participants.

Only approved people could access the data, as it was both negative and positive test results, identifiable and anonymised; thus, data security and maintenance of confidentiality were ensured. Due to the enhanced contact tracing, the data was very detailed about the movement and potential sites of infection, transmission, and potential contacts. Participants described how access to such detailed information generated a sudden clear understanding and "made everything easier".

> *Once we had the data, it went from 0 to 100 miles per hour, from having nothing to having an awful lot of data.*

Tailored, targeted, bespoke response

Access to data meant that resources were targeted more effectively, and the response was more targeted and bespoke.

> *We became better informed on where the issues were and the result of that was a to respond better and quicker.*

> *We were able to follow up individuals. It could mean a welfare call, asking if they had what they needed, supporting their wellbeing – it was very positive.*

The clinical population at the university particularly benefited from the comprehensive data. Some had academic and clinical roles, and as they worked in high-risk settings on the 'frontline', ensuring their and their student's safety was critically important. A medical risk assessment algorithm, ALAMA COVID age tool (https://alama.org.uk/covid-19-medical-risk-assessment/) was implemented by the Occupation Health Department, which enabled the calculation of each individual's risk of contracting COVID-19 and their likely response to it.

Universities held their own data, generating setting specific knowledge about particular sub-population clusters and outbreaks. When there was an outbreak, due to the availability of detailed information, they could respond to it in a more targeted manner.

Data Integrity

The reliability of the data was highlighted as something essential. Stakeholders highlighted that data integrity depended on how much people were willing to share and how able contact tracers were to elicit the truth during the enhanced contact tracing interviews. There could be many reasons why someone would not want to disclose locations they visited, such as fear of fines and penalties; they might not want their family or friends to be told to isolate; therefore, social desirability was a factor during these interviews.

Initially, the data was analysed based on age groups; however, not all 18-25 years old are enrolled in higher education. This resulted in the dilution of data on student infection rates by the broader age cohort and overlooking outbreaks and clusters occurring specifically within the student population.

> *The first big on [outbreak] came as a surprise to us, so I personally hadn't looked at that particular level of information.*

They reported issues with data collection and how to distinguish between students' home addresses, university addresses and their addresses based on their GP registration. Positive case assignment was based on their primary care records. Some students were registered at GPs back home, and when they tested positive in Manchester, they were nevertheless assigned to their home addresses. This greatly affected the integrity of the data on a national level. Due to these geographic misclassifications, stakeholders felt they could have missed outbreaks and not responded to them; thus, having the correct address was vital.

Data integrity was enhanced by bespoke testing at university halls of residence; this provided additional information to national-level data. Due to this bespoke testing, campus management was able to identify that the first significant outbreak was actually in halls of residence and not in the general student population. This also helped them recognise that they were "missing students" from their list. Establishing a definitive list of students was essential, as not all lived in halls on residences. The difference in accommodation meant different sets of exposures and ways of transmitting the virus to others; therefore, these cases required a different response.

NHS and staff supported

Supporting the already struggling NHS with the additional pressure of the pandemic was a priority for participants. The HEI teams worked hard to enable clinical staff to return to the 'frontline'. The ALAMA COVID age tool was used to assess individuals' risk age, and those classified as at low or moderate risk could return to work. The results were supplemented with data from the Office for National Statistics (ONS) and UKSHA on COVID-19 prevalence in different sub-populations, and they adjusted their recommendations accordingly. The vaccination programme was described as a "game changer". Adjusting to vaccination status, and matching that to prevalence rates, brought clinicians' COVID-19 risk age down, and they could return to their roles within the NHS.

Response groups

One of the critical steps towards effective response was setting up the campus management group and its sub-committee, the outbreak planning group. The groups were made up of locally available public health experts who implemented a system of mitigating measures and responses to outbreaks.

The Local Authority set up a network between the local universities, such as the Royal College of Music, Manchester Metropolitan University, the University of Salford, and the University of Bolton. A data-sharing agreement was signed between them, which enabled a closer collaboration.

> *The universities worked together as a team and generated an understanding of what was happening in shared halls. Prevention was the key, and outbreaks could be easily monitored.*

Once there was no further escalation in cases, the group was gradually deescalated; however, they maintained links to answer analytical and dashboard queries and alert each other about potential anomalies. This increased flexibility and adaptability, and overall resilience going forward.

Learning/Planning

Participants incorporated what they learned into planning for next year after the large outbreak at the University. They changed how students were assigned to an address; instead of using primary care records-based addresses, students were assigned to the location where they lived at the time of taking the test. Much work went into creating more resilience and generating a definitive list of students.

Quality of guidance

DfE was described as too slow to communicate, which impaired the response. Stakeholders felt government consultants had poor knowledge of transmission risk reduction and outbreak management, often gave inappropriate advice, and disseminated contradictory and misleading guidance. Their insistence on the return of face-to-face teaching was thought to have increased COVID-19 levels.

Collaborative working

Collaborative working was described as one of the most important aspects of the pandemic response during this period. Universities, the local authority and UKSHA's ability to work through barriers and work collaboratively was a critical strategic step. The university network continued during this period and made prevention and monitoring much more manageable. There are several shared halls where students from different universities live together; therefore, infection clusters in one institution could have been linked to one in another university. These cross-infections could be managed through collaboration between HEIs and information sharing on links between different student groups.

Lack of pre-existing infrastructure

The lack of pre-existing legal and technological infrastructure was a barrier to managing the pandemic. The IT system was challenging to set up, and the legal infrastructure allowing data sharing had to be quickly put together.

> *There were challenges around where the data will go and technically how can it be supplied, who will have access to it. Suddenly, ok here is a load of data.*

Table 4 - Candidate CMOs - Period of data sharing with authorities

Period of data sharing with local authority (LA)		
Context	Mechanism	Outcome
Data availability		
Data is shared with LA	Stakeholders analyse data	Stakeholders better understand virus spread
	Selected, approved list of people is accessing the data	Data security and confidentially ensured/maintained
Stakeholders better understand virus spread	Stakeholders adjust their response to new information	Pandemic response is easier and more effective
Selected, approved list of people is accessing the data	Stakeholders analyse individual level data sets	Clusters and outbreaks are management more effectively
Test and Trace	Enhanced contact tracing interviews conducted	More information is available on movement and potential site of infection/transmission
Tailored, targeted, bespoke response		
Accurate locally relevant data is shared with LA	Targeted bespoke response	Individual at HEI are followed up - welfare calls
	Stakeholders are able to target resources more efficiently	HEI resources are not overstretched
	Stakeholders analyse data provided	Clinical population at HEI is supported
		More efficient response to at risk sub-groups
HEI gathers its own data	HEI analyses its own data	Setting specific knowledge about particular populations
Potential outbreak	Stakeholders analyse data provided	Stakeholders are able to respond quicker and more effectively
Data Integrity		
Enhanced contact tracing interview	People are willing to share correct information	Reliable data
	People are unwilling to share correct information	Partial data
	Contact tracer is able to tease out correct information	Reliable data
	Contact tracer unable to tease out correct information	Partial data
Not all 10-25 yr. olds are in HE	Stakeholders look at age group level data	Stakeholders miss universities as high-risk settings
Students are not registered with a Manchester GP	Positive cases are assigned based on primary care records	Geographic misclassification of cases
Bespoke testing in HE halls of residence	Stakeholders compare bespoke data with national level data	The additional information generates a clearer understanding of local virus spread
		Outbreak is identified in specific sub-population of students
Large student body	Students live in rented accommodations, at home or in halls of residence	Students are exposed to different set of infection risks
Geographic misclassification of cases	Stakeholders are not aware of local outbreaks	Outbreaks are not responded to
NHS and staff supported		

Stretched, under-resourced NHS with the additional pressure of COVID-19	Stakeholders support staff with clinical and academic role	Clinicians return to 'frontline'
ALAMA covid age tool	Individual covid age risks are calculated	Clinicians return to 'frontline' quicker
	ONS and UKHSA data for prevalence in sub-populations is triangulated with available data	Stakeholders adjust recommendations – clinicians return to the 'frontline'
Vaccination programme rolled out	Vaccination reduced individuals' covid risk age	Student and staff can return to campus; clinicians can return to the 'frontline'
Stakeholders stayed on site at HEI	Stakeholders helps with the vaccination efforts	Pressure on NHS, risk of morbidity and mortality are reduced
Response groups		
Outbreak control team continue to operate	Implementing a system of COVID-19 response	Infection control and outbreak management continues
Universities network continue to operate	Members continue to meet	Knowledge and data sharing, triangulation continues
	Data sharing agreement put in place	Collaborative covid response – more effective response
	Stakeholders see no escalation in number of cases	Group is gradually deescalated
Group is deescalated	Stakeholders maintain links for analytical, dashboard queries, and alert for anomalies	Flexibility and adaptability is increased, resilience to future pandemic improved
Learning/ Planning		
The experience of a large outbreak	Increased planning for next academic year	Quicker, more effective response
Geographic misclassification of cases	Stakeholders change the way student are assigned to an area	Accurate on viral spread– more confidence in data
Large infection spike in students	Stakeholders work intensely to establishing accurate list of students	Definitive list of students compiled
Quality of guidelines		
DfE responsible for HE guidance	DfE slow to communicate	Transmission risk reduction is impaired
Government employs consultant with limited knowledge	Consultants unable to answer questions	People are misinformed, badly informed
Government insists on face-to-face teaching	Transmission risk increases	Increased rates of COVID-19 infections
Collaborative working		
COVID-19 pandemic	Collaborative working with universities, LA and UKSHA	Organisations work through barriers
Greater Manchester has many HEI	Universities Network set up	Data sharing between HEI
Universities Network collaborates	LA disseminates data	Prevention and monitoring are made easier
Students of different HEI share halls of residence	Universities network share intelligence and data	More information on transmission and links between different student groups is available
Lack of pre-existing infrastructure		
Unexpected pandemic	IT infrastructure does not exist	Barrier to data sharing

	Legal infrastructure does not exist	

"Living with COVID"

Unknown level of COVID-19 infections

Participants recalled that the transmission to the "Living with COVID" era was difficult and, similarly, having to rely on campus management to estimate COVID-19 levels is problematic. They felt this is incomplete data and an inaccurate view of what is occurring regarding transmission and outbreaks. Since the "Living with COVID" guidance, the lack of data and guidance from governmental organisations meant they have had to rely on their own judgement to mitigate risks. They found it challenging to do so without knowing which groups of people in what particular setting within the campus have COVID-19.

They mentioned that they felt blind and were worried that there were outbreaks they were not responding to. Without data, they are not only struggling to assess risk and outbreaks in the student population but in the general population of Greater Manchester as well. While there is some private testing, no national database registers those test results.

General/holistic response

Only general mitigating measures remain in place since all national restrictions were withdrawn. They now deploy a holistic approach to health protection. The focus shifted from COVID-19 to managing all other infections together.

Enhanced local powers

GM was the focus of interest because, at one point, having the highest rates of infection in the country. In order to manage the difficult situation, the Public Health Director at Greater Manchester was given additional powers to manage the pandemic response.

> *GM was of enhanced interest, this meant the local Director of Public Health had enhanced powers, over and above other Directors of Public Health. This meant if we needed to go over and above DfE advise, we could.*

Local experts

The public health specialists at University were valued for their expertise. They were able to provide reliable advice on how to manage the situation. In combination with the additional powers of Manchester's Director of Public Health meant that when the national guidance was given, and local experts disagreed with it, they could say no to easing the restrictions – ensuring people were not subjected to unnecessary risks.

Other

Participants mentioned a polarised risk perception amongst students and staff during this period. Some were very concerned about COVID-19 and the effect of easing restrictions, while others were not concerned at all.

Table 5 - Candidate CMOs - Period since the "Living with COVID" guidance

The period since the "Living with COVID" guidance		
Context	**Mechanism**	**Outcome**
Unknown level of Covid		
Test and Trace stopped	Stakeholders rely on campus management group data	Incomplete data is available
	Stakeholders are unaware of outbreaks	Outbreaks are not responded to
	People take private tests	Not registered anywhere
"Living with CCOVID-19"	Stakeholders receive no guidance	Uncertainty in mitigating risk
	Stakeholders receive no data	Unknown level of infection
	Test and Trace stopped	Stakeholders experience difficulty in transitioning to the new level of uncertainty
General/holistic response		
Restrictions withdrawn	HEI implement general mitigating measures	HEI deploys holistic approach to health protection
	Stakeholders shift focus from COVID-19	More general response- including against other infections
Enhanced local powers		
GM is of enhanced interest due to high infection rate	Director of Public Health is given additional powers	Stakeholders are able to go beyond DfE advice
Local experts		
Government makes contradictory announcements	Experts are in available at HEI	Reliable advice on reducing risk of transmission
Manchester has a high-density, high-risk population with high infection rates	HE experts suggest not to lower restrictions	Location specific measures deployed
Other		
"Living with COVID"	People exhibit polarised risk perception	Stakeholders have to accommodate different risk perceptions
	Additional cost of living crises	Increased number of winter illnesses

Facilitators

Enhanced infection control

Health and Safety legislation - already in place - duty bound HEIs to monitor risks and exposures; thus, these will continue to be adhered to. Students and staff conduct research on campus, and whether their experiments pose a health risk and potentially expose them to infectious agents are routinely assessed. The knowledge generated during the pandemic is retained, and in addition to the normal PPE, they kept certain mitigating measures such as HEPA filters in the ventilation system. They hope this will offer some protection to staff and students not only from COVID-19 but from other respiratory infections. While there are no longer any restrictions on a national level nor any rules on isolation after testing positive or displaying COVID-19 symptoms, the University continues to urge people to stay home if they feel ill.

Locally available experts

Having the expertise available at the University meant that the right people were making decisions at the right time. This increased people's confidence in the university's response and any advice coming from them. Utilising these experts was described as having made the situation more manageable.

Limited available data

Specific populations, such as NHS staff and nursing homes, continue to be tested. The data from these unique populations can be used as a proxy for the general population and estimate COVID-19 levels there.

Increased resilience

The COVID-19 pandemic was an "immense learning curve", and all who had been involved with the response gained invaluable expertise in managing such an event. They put this knowledge into planning for the next pandemic/epidemic, making the setting better prepared and more resilient.

Flexibility

Now that all restrictions have been withdrawn, there is more flexibility in working and studying at a university. Flexibility was a facilitator during the height of the pandemic when due to the emergency, much bureaucracy could be cut through and, thus, processes streamlined.

Table 6 - Candidate CMOs - facilitators of transition risk reduction

Facilitators		
Context	Mechanism	Outcome
Enhanced infection control		
Health and safety work legislation in place	HEI monitor risk and exposures to infections	Risk is reduced and controlled
Student/staff conduct research at HEI	HE stakeholders assess potential risk of infections	The risk to respiratory sensitisers is reduced
COVID-19 pandemic	HE stakeholders retain learning post pandemic	Normal PPE plus additional mitigations are kept in place
HE stakeholders retain learning post pandemic	Normal PPE plus additional mitigations are kept in place	Increased protection from COVID-19 and other respiratory pathogens
Restrictions are withdrawn	HEI urges people to stay at home if feel ill	Reduced risk of transmission of COVID-19 and other respiratory infections
Local experts		
Public health experts at HEI	Right people at right time are making decisions	Effective transmission risk reduction
	People with the right expertise in decision making position	Students and staff have confidence in HEI response and transmission risk management
Limited available data		
Specific populations are still tested	Stakeholders analyse limited available data	Some understanding of covid levels is developed
	Stakeholders use data as proxy for general population	Some understanding of covid level in the general population is developed
Increased resilience		
Stakeholders experienced the COVID-19 pandemic	Stakeholders gained valuable skills and knowledge	Stakeholders plan and prepare for next pandemic/epidemic more effectively
Flexibility		
“Living with COVID”	Restrictions withdrawn	More flexibility in HEI – less legal requirements
Emergency situation due to COVID-19	Stakeholders cut through bureaucracy	Stakeholders streamline processes

Barriers

Data availability

According to participants, assessing COVID-19 levels is now impossible, that testing and contact tracing have stopped. Stakeholders feel blind to what is currently happening regarding viral spread. Without access to the data, very little research is taking place; thus, the opportunities to learn are not fully exploited. This was highlighted as a considerable barrier to preparing adequately for the next pandemic. Without the ability to meaningfully study the data, participants could not identify where and what exact settings were COVID-19 hotspots, and which specific sub-groups of people were particularly vulnerable. The data that was made available was described as poor quality, and its analysis generated more questions than answers.

> *When the data was available, we didn't have time, now that we have time, the data is no longer available.*

No restrictions

The UoM has a large international student body. Without border restrictions and the requirement of a negative test, it is impossible to know international arrivals' COVID-19 status. Participants highlighted that there are a broad and diverse range of students currently studying at the university. Staff and students have now restarted travelling to areas with higher prevalence of COVID-19. Visitors are also back on campus. In light of the recent large outbreaks globally, the lack testing is concerning.

Bureaucracy

Large academic institutions were described as challenging to navigate and, therefore, slow to respond. This is not only an issue for an effective response to a potential future event but also in accessing and studying the data collected from the previous one.

Additional crises

Political instability and other crises can cause difficulties in managing and mitigating a pandemic. Politicians were slow to respond to the COVID-19 pandemic, the George Floyd murder and the consequent rise of the Black Lives Matter movement. Minorities already distrustful of the government and local authorities due to historical grievances were even less likely to trust these institutions. The current crises around the rising cost of living and energy prices are likely to worsen winter illnesses, potentially reigniting the spread of COVID-19 and other respiratory diseases.

Table 7 - Candidate CMOs - Barriers to transmission risk reduction

Barriers		
Context	Mechanism	Outcome
Data availability		
Test and Trace stopped	Positive tests are not reported	Unknown levels of COVID-19
	New data is not generated	Less prepared for next pandemic/epidemic
	Data is not studied	Infection hotspots are not identified
Data is not available to be studied	Infection hotspots are not identified	Unable to prepare/plan adequately for the next pandemic/epidemic
The available data is poor quality	Stakeholders analyse available data	Crude understanding is generated – more questions than answers
Strict governance structure at HEI	Stakeholders try to access data	Stakeholders struggle to access data
UKHSA takes strict legal perspective to data sharing	Stakeholders request data	Stakeholders are unable to access the data
Lack of border restrictions		
Diverse study body	COVID-19 status is not checked	Introduction of new variant
Staff, students and visitors have recommenced international travel		
Bureaucracy		
Large HEI	Stakeholders struggle to navigate existing bureaucracy	Slow response to ciris
Additional crises		
Additional crises	Government slow to act	Vulnerable communities lose faith in government

Recommendations

Learning

The central theme that emerged was learning from the experience of going through and responding to the pandemic. Participants felt that using the existing data would generate a tremendous amount of understanding about the nature of COVID-19 transmission. They recommended that relevant authorities release data to local authorities and academic institutions in anonymised or pseudo-anonymised form, without personal identifiers, even if the database is no longer updated, so types and points of transmission can be studied thoroughly. They explained that the knowledge gained during the pandemic helped them plan for future pandemics and epidemics. The university incorporated this new knowledge into its infectious disease policy and used it during the Monkeypox outbreak. All participants strongly advised that the lessons from the pandemic must not be forgotten.

> *Do not forget the lessons. With the future of UKHSA under question, all that knowledge and expertise could be lost.*

Timely data supply

In the event of a future pandemic or epidemic, participants recommended that national and local teams share their data with local authorities to generate location-specific, targeted interventions and implement bespoke outbreak management, thus, avoiding a national lockdown and the consequent economic downturn.

Timely response to vulnerable communities

Participants noted the government's slow response to the emerging evidence showing that Black and Asian communities were more vulnerable to the virus and suffered from disproportionate rates of morbidity and mortality. While academic institutions, such as UoM, tried to bring this to national attention, the government and PHE were slow to protect those communities.

Table 8 - Candidate CMOs - Reccomendations

Recommendations		
Context	Mechanism	Outcome
Learning		
Test and Trace data exist	Data is not being studied	Stakeholders are not able to learn from the data
HEI infectious disease policy is in place	COVID-19 lessons are added to the infectious disease policy	COVID-19 lessons are used during Monkeypox outbreak
Test and Trace data available	Stakeholders study the data	Sub-groups, vulnerable groups and key points of transmission are established
Data made available anonymised pseudo anonymised		The information enables enhanced planning, preparedness, resilience
Timely data supply		

Slow data sharing	Stakeholders are slow to understanding viral spread	Less effective management transmissions, infections, and outbreaks
		Nationwide lockdowns are implemented
Timely data sharing	Stakeholders deploy a targeted response to outbreaks	National lockdowns are not necessary
Timely response to vulnerable communities		
Minorities are more at risk of morbidity and mortality	Government and PHE overlook vulnerable minorities	Increased morbidity and mortality in vulnerable communities
	HEIs highlight vulnerable populations	Decrease morbidity and mortality in vulnerable communities

Middle Range Theory

Access to good quality and timely data

Mechanism – throughout the pandemic's course and need for effective testing, all personnel working together to prevent HEI workplace transmission have stated the need for timely access to useful and high-quality data that can be used for infection prevention and control, supporting students, staff and visitors on campus, and providing effective mechanisms to assure all stakeholders. The main outcome of when these data were not available e.g., at the beginning of the pandemic when testing was not available, and after Living with COVID when data sharing was no longer allowed, has caused stakeholders to not effectively manage the potential transmission of COVID-19 in HEI settings effectively. The outcomes include not having reliable case-based data, not able to do contact tracing, put in place effective measures such ventilation, mask wearing etc.

Effective working across all agencies and governmental departments

Mechanisms – due to the speed of the pandemic response, many non-expert "consultants" were brought in from non-health fields. This resulted in very confusing messages and not always correct advice from Governmental Departments. There was disjointed communications from all the departments who were involved in setting policies in HEIs and sometimes these contradicted each other. It was difficult to find a public health or epidemiology expert in the regular drop-in sessions and meetings. This meant that there was often confusion with the instructions, poor explanations for what was to be done, and on many occasions, "we will get back to you" which then never transpired. Outcomes of this was loss of trust, time, resources, and possibly poor advice/guidance.

Effective working locally

Mechanisms – many of the people who came together to form the local team to prevent transmission in HEIs in GM had already worked together, built trust and what was evident was the support from colleagues helped get through very difficult circumstances. Outcomes were very positive due the team working, effective communications, meetings and co-ordinated responses as things continually changed.

Conclusions and Recommendations

This evaluation aimed to explore the COVID-19 transmission risk management practices in a higher educational setting in Greater Manchester before and after the "Living with COVID" guidance. We reported previous and current infection reduction and outbreak management practices through periods defined by significant policy decisions. We conducted qualitative interviews with local stakeholders known to have been directly involved in deploying the COVID-19 pandemic response in higher educational settings. We evaluated their views and experiences throughout the pandemic following the "Living with COVID" guidance, with a particular focus on barriers and facilitators of transmission risk and outbreak management.

The strength of our work was interviewing stakeholders who were on the ground directly involved with the pandemic response in a higher educational context. Their lived experience of managing the risk of infections and outbreaks gives a deeper insight into what occurred during those significant months. The complexities of the pandemic response lent themselves well to the realist evaluation framework. This method and the consequent thematic analysis provided a detailed and rich description of stakeholder views and lived experiences. Through this analysis, we developed CMO configurations, later translated into MRT, summarising and distilling the essence of what stakeholders shared with us, providing the initial programme theory.

Similarly, to the other studies in workpackage 3 (Lewis et al., 2023, Johnson et al., 2023), we strongly conclude that the successes of reducing transmission in workplace settings can only be achieved through working as a multi-disciplinary team with timely and contemporaneous data that allows true hypotheses testing and a local infection prevention and control response.

While this study generated valuable insight into the potential underlying theories of transmission risk management in a higher educational setting, it was not without limitations.

Realist evaluations, similarly, to other theory-based evaluations, are time and resource-consuming (Mark et al., 1998) and often intellectually challenging (Greenhalgh et al., 2015, Salter and Kothari, 2014). This method does not involve strict methodological rules and predetermined steps; thus, investigators must rely on their best judgement on how to structure and conduct the evaluation. A further limitation of this methodology we experienced during data analysis was the difficulty in defining the CMOs and distinguishing between their components.

We used purposive sampling to recruit participants. Similarly, to other non-probability sampling techniques, this method can introduce research bias (Sharma, 2017). Our aim through this choice of sampling was to elicit public health professionals with lived experience of deploying the pandemic response at a higher educational setting; thus, the stakeholders invited were the only potential source of information on this matter.

The interviews were not audio/video recorded and transcribed; handwritten notes were taken of the key responses. While all efforts were made to write down everything essential shared by participants, it must be considered that some data might have been missed (Dong and Peng, 2013).

The most significant limitation during this evaluation was recall bias. We asked participants to recall events starting three years ago; likely, they did not remember everything and what they recalled might not be fully accurate. Some participants struggled during the interviews to recall the exact dates and which exact year a significant event happened.

Recommendations

Based on our findings, the critical success of a workplace, in this case HEI, response to mitigate and reduce risk of transmission is the availability of timely and contemporaneous data. These data's timely availability and integrity significantly contribute to effective, local, and targeted management of transmission risks and outbreaks. Stakeholders struggled during the initial phases of the pandemic without local knowledge of infection levels and the spread of the virus. Therefore, in future pandemics and epidemics, data should be shared with local authorities from the outset to enable them to deploy a targeted, bespoke, and tailored response to local clusters of infections and more significant outbreaks. This will require establishing permanent legal and technological structures that are maintained between emerging pandemics and epidemics, enabling the timely rollout of the local pandemic response based on up-to-date information and a clear understanding of hotspots and vulnerable population groups.

Additionally, to the timeliness, the integrity of the data emerged as critically important. Local stakeholders should ensure they obtain a definitive list of students and staff and that the differences between transmission risk those experience due to their varied living situations and demographic factors are thoroughly understood.

On a governmental level, the most detrimental effect stakeholders experienced were due to the rapidly changing guidance and contradictory messages. While it is acknowledged that the COVID-19 pandemic was an unprecedented event in modern history and a rapidly evolving situation, Governmental departments are recommended to deploy a more thorough vetting process when recruiting consultants to ensure that the best available experts advise those in decision-making positions with the most up to date and comprehensive knowledge on infection prevention and outbreak management. This will likely generate more consistency in national and local guidance and thus reduce apprehension and confusion in HEIs and the general public.

Local outbreak management based on local knowledge was crucial in effective pandemic response. The additional powers granted to Greater Manchester's Director of Public Health were described as advantageous as stakeholders could adapt their response specifically to the local situation rather than exclusively following the general, national guidelines. Therefore, the devolution of powers to local decision-makers in the field of Public Health is a critical step towards avoiding national lockdowns and the consequent economic downturn.

Local Public Health expertise should be valued and utilised. These individuals may form an invaluable part of outbreak response groups and networks set up to maximise the effectiveness of the pandemic response. These groups and networks were critical during the COVID-19 pandemic and should be a model to follow in future pandemics and epidemics.

Collaborative working across agencies and local and national government departments should be fostered. The initial disjointed working slowed down the deployment of the pandemic response; however, overcoming those boundaries and barriers were welcomed and described as making transmission risk reduction and outbreak management more straightforward. These links and networks should be maintained, and collaborative working continued to increase resilience and adaptability to future crises.

Knowledge, skills, and expertise gained while responding to the COVID-19 pandemic should be retained and incorporated into HEIs' infectious disease policy. Additional mitigating measures that are legally and ethically possible to maintain should remain in place as they are likely to protect against other respiratory illnesses and potential future novel pathogens.

The existing knowledge should be used to prepare for future pandemics, as those are predicted to appear in increasing frequency due to the increasingly globalised world. To expand on the current knowledge, using the existing data to probe further and study the nuances of infection risks, vulnerabilities, hotspots, and viral spread should be considered by those in decision-making positions on data sharing. However, the questions arise: what additional data are needed and how will that further our understanding? As the previous quantitative study described, additional data can be redundant, noisy, or may hold additional information. The data needs of researchers and local authorities should be specified, and the pros and cons of data sharing should be discussed to work through opposing views.

References for Report 2

BRIGGS, A., JENKINS, D., FRASER, C., (2020) available at:

https://www.health.org.uk/publications/longreads/nhs-test-and-trace-the-journey-so-far (Accessed 27/01/2023)

DEPARTMENT OF HEALTH AND SOCIAL CARE, DHSC (2020) 'On 23 April 2020

testing for essential workers was announced' available at: https://www.gov.uk/government/speeches/health-and-social-care-secretarys-statement-oncoronavirus-covid-19-23-april-2020 (Accessed 27/01/2023)

DONG, Y. & PENG, C.-Y. J. 2013. Principled missing data methods for researchers. *SpringerPlus,* 2**,** 1-17.

GREENHALGH, T., WONG, G., JAGOSH, J., GREENHALGH, J., MANZANO, A., WESTHORP, G. & PAWSON, R. 2015. Protocol—the RAMESES II study: developing guidance and reporting standards for realist evaluation. *BMJ open,* 5**,** e008567.

INSTITUTE FOR GOVERNMENT, IFG, (2021) 'WHO declared the novel coronavirus

outbreak as a global pandemic' , available at: https://www.instituteforgovernment.org.uk/sites/default/files/2022-12/timelinecoronavirus-lockdown-december-2021.pdf (Accessed 27/01/2023)

INSTITUTE FOR GOVERNMENT, IFG (2021) 'PM Boris Johnson announced an

official UK lockdown, ordering people to stay at home', available at:

https://www.instituteforgovernment.org.uk/sites/default/files/timelinecoronavirus-lockdown-december-2021.pdf (Accessed 27/01/2023)

INSTITUTE FOR GOVERNMENT, IFG (2021) 'legally in to force on 26 March 2020',

available at: https://www.instituteforgovernment.org.uk/sites/default/files/timeline-coronaviruslockdown-december-2021.pdf (Accessed 27/01/2023)

INSTITUTE FOR GOVERNMENT, IFG (2022), available at

https://www.instituteforgovernment.org.uk/article/explainer/covid-passports (Accessed 27/01/2023)

INSTITUTE FOR GOVERNMENT, IFG (2022), available at

https://www.instituteforgovernment.org.uk/article/explainer/covid-passports (Accessed 27/01/2023)

INSTITUTE FOR GOVERNMENT, IFG (2021) 'A new three tier system to start in

England on October 14, 2020' available at: https://www.instituteforgovernment.org.uk/sites/default/files/timeline-coronaviruslockdown-december-2021.pdf (Accessed 27/01/2023)

INSTITUTE FOR GOVERNMENT, IFG (2021) ''Timeline of UK government

coronavirus lockdowns and measures, March 2020 to December 2021', available at:

https://www.instituteforgovernment.org.uk/sites/default/files/timeline-coronaviruslockdown-december-2021.pdf (Accessed 27/01/2023)

JOHNSON, M. W., VARGA, E., BENSON M.J., VERMA, A. (2023) An Analysis of

Ordinal Information in Occupational COVID-19 Data. Report for PROTECT study Year 3 WP3 Study 2

LEWIS, C., MANN, C., UBIDO, J., FARRELL, M, JOHSNON, S. (2023)

An exploration of how 'Living with COVID' influences workplace transmission risk, response and resilience in workplace settings – a Greater Manchester Case Study: Study 2. PROTECT.

MARK, M. M., HENRY, G. T. & JULNES, G. 1998. A realist theory of evaluation practice. *New Directions for Evaluation,* 1998**,** 3-32.

PAWSON, R. 2005. Evidence-based policy: a realist perspective. *Making realism work.* Routledge.

PAWSON, R., TILLEY, N. & TILLEY, N. 1997. *Realistic evaluation*, sage.

PRIME MINISTER OFFICE, PMO (2022) 'The government no longer asked fully

vaccinated close contacts of positive cases or those under the age of 18 to test daily for 7 days and removed the legal requirement for those not vaccinated to self-isolate for 7 days' https://www.gov.uk/government/speeches/pm-statement-on-living-with-covid-21-february2022 (Accessed 27/01/2023)

ROODBARI, H., NIELSEN, K., AXTELL, C., PETERS, S. E. & SORENSEN, G. 2021. Developing initial middle range theories in realist evaluation: a Case of an organisational intervention. *International Journal of Environmental Research and Public Health,* 18**,** 8360.

SALTER, K. L. & KOTHARI, A. 2014. Using realist evaluation to open the black box ofknowledge translation: a state-of-the-art review. *Implementation science,* 9**,** 1-14.

SHARMA, G. 2017. Pros and cons of different sampling techniques. *International journal of applied research,* 3**,** 749-752.

THE CABINET OFFICE (2022)' COVID response 'Living with COVID' available at:

https://www.gov.uk/government/publications/covid-19-response-living-with-covid-19 (Accessed 27/01/2023)

THE ADVISORY, CONCILIATION AND ARBITRATION SERVICE, ACAS (2022)

available at: https://www.acas.org.uk/coronavirus/self-isolation-and-sickpay/sick-pay-for-selfisolation#:~:text=The%20rules%20around%20Statutory%20Sick,the%20first%20day%20of% 20absence (Accessed 27/01/2023)

UNITED KINGDOM HEALTH SECURITY AGENCY, UKHSA (2023) available at:

https://www.gov.uk/government/organisations/uk-healthsecurity-agency (Accessed 27/01/2023)

UNITED KINGDOM HEALTH SECURITY AGENCY, UKHSA (2021) available at:

https://www.gov.uk/government/publications/nhs-test-andtrace-privacy-information/test-and-trace-overarching-privacy-notice (Accessed 27/01/2023)