Syracuse University
Center of Excellence in
Environmental & Energy Systems

Research Brief #4
May 4, 2021

How Should We Set Pandemic Capacity Limits for Restaurants & Bars?

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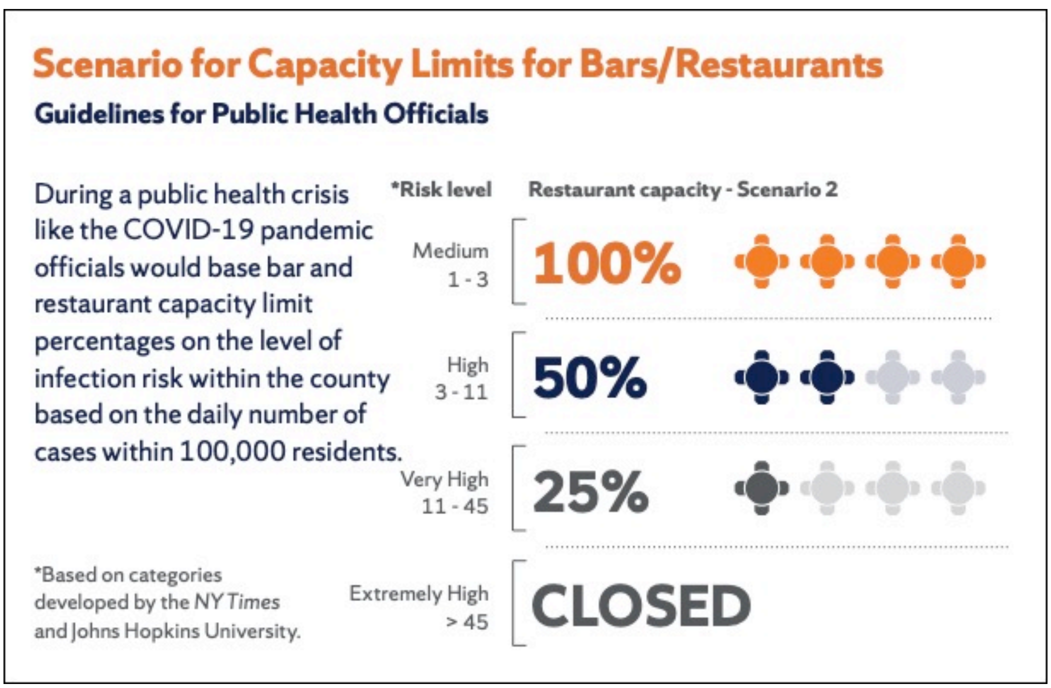
Restaurants and bars are places where airborne diseases like COVID-19 are easily transmitted from one patron to another. To reduce the number of infections during the pandemic, public health authorities have often shuttered them. When re-opening is allowed, restaurants and bars are known to add significantly to new infections.

To moderate the number of infections from bars and restaurants, health authorities are experimenting with reducing their capacity limits. We have made calculations of these limits based on the principle of limiting COVID-19 cases from restaurants and bars to a specific, low rate. The calculations are based on the daily rate of new infections in a county. They use the corresponding risk categories developed by the *New York Times* and Johns Hopkins University. As shown in the graphic below, in one scenario officials would reduce capacity to 50% when the county moves from the medium to the high-risk category. If the very-high-risk category is reached, restaurants would be limited to 25% capacity. With these specific capacity reductions, the number of restaurant and bar-related COVID-19 cases will be similar in all three categories. Without them, the number of cases rises sixteen times before the extremely-high-risk risk level is reached.

The full article also describes a more aggressive scenario and a less aggressive one. It outlines how capacities could be increased for facilities with superior indoor ventilation systems. This could encourage restaurateurs and bar owners to improve the systems. Finally, it provides details of the calculations and discusses the underlying assumptions.



Introduction

In March 2021, the U.S. Centers for Disease Control (CDC) released a study of transmission of COVID-19 associated with restaurants and bars. It showed that re-opening of restaurants and bars after a shutdown noticeably increases the weekly count of COVID-19 cases. For the average US county there was an additional 7% increment to the week-to-week growth of cases.[1] To envision this, imagine that a shutdown of workplaces and public facilities has stabilized a county's weekly count of new cases. The weekly growth rate is thus 0%. As a first concession, restaurants and bars are re-opened. The weekly growth rate typically increases to 7% - and the weekly count of new cases will double over the next 9 weeks.

One tactic for counteracting this effect, and that still allows restaurants and bars to operate, is to limit the indoor capacity of patrons to a percentage of the maximum originally set by a building inspector. For example, in June 2020, following a shutdown, New York State set the maximum capacity of restaurants and bars to 50%.[2] As we show here, this reduction in capacity is predicted to reduce the restaurant/bar-related cases to about 25% of the number of cases with full capacity.

In this article, we first propose a process for calculating capacity percentages based on the incidence of disease in a county. A key input is judgment by public health authorities about how high the daily case count can be before they need to act. If restaurants and bars are not a major contributor to the county's caseload, patronage may be left as a personal decision. If health care facilities are stressed, reducing the case load becomes urgent.

Because airborne transmission of COVID-19 indoors is common, improved ventilation and purification of indoor air reduces this transmission risk. When there is an infected person – presumably asymptomatic – in the facility, the person's breathing steadily adds virus particles to the indoor air. These particles need to be removed or de-activated by ventilation systems or other measures. In the second section of this article, we illustrate how capacity percentages can be increased for restaurants and bars with superior systems for lowering the virus concentration in the air. The ultimate goal is to provide a financial incentive for facilities to document and to upgrade these systems. One way this could be implemented would be to include it in retrocommissioning projects. This offers an additional incentive by way of increasing energy efficiency. A 2011 review paper calculated that the average payback time for retrocommissioning of existing buildings was 1.1 years due to reduced energy usage.[3]

County risk categories and capacity restrictions on restaurants and bars

We use a published set of five COVID-19 risk categories - low to extremely high - for a county. These categories were proposed by scientists at Johns Hopkins University, and the *New York Times* has been posting the changing risk categories for every county in the United States. The categories are based on the daily counts of new infections in a county averaged for two weeks. The average is then normalized by the population of the county, so the final result is the average number of new cases each day per 100,000 county residents.[4]

In Table 1, the left-hand column shows the five categories of infection risk and the associated ranges of averaged daily case numbers per 100,000 residents. 1.00 cases per day per 100,000 residents is the largest value for the "low risk" category. 3.00 cases per day per 100,000 residents is the largest value in the "medium risk" category. Without intervention, we expect that disease transmission in restaurants and bars will be 3 times faster when the county's case rate is at the top of the medium risk category than when it is at the top of the low-risk category. Transmission is 45 times faster when the county is at the top of the "very high" category.

Table 1: Proposed pandemic capacity limits for restaurants/bars			
County risk level (case rate*)	Scenario 1	Scenario 2	Scenario 3
Low (0.00 - 1.00)	100%	100%	100%
Medium (1.01 - 3.00)	60%	100%	100%
High (3.01-11.00)	30%	50%	100%
Very high (11.01-45.00)	15%	25%	50%
Extremely high (>45.00)	closed	closed	closed

*Cases per day per 100,000 residents - 14 day average

The column labeled Scenario 1 in Table 1 shows the proposed maximum capacity percentages if a county chooses to act when the threshold to medium risk is reached. The capacity reduction at the “medium” risk level keeps new, restaurant-related cases in the same range that occurred for full capacity at the “low” risk level. We present the calculations in a later section. Note that capacity percentages have been rounded to multiples of 5%. Further reductions in capacity again match the ranges of new cases at the “very high” and “high” risk levels to the range for the low risk level. Despite the increase in the county risk level, new cases due to restaurant and bar patronage don’t rise above the values at the “low” risk level.

For Scenario 2, we assume that public health officials decide not to intervene until the “high” risk category is reached. The capacity percentages listed then match the ranges of new, restaurant and bar-related cases each day at the “high risk” and “very high risk” categories to the range at the “medium risk” category. Scenario 3 is the least restrictive. It introduces capacity limits when the community case rate enters the “very high” risk category and matches the range of new cases to the “high risk” category. For all scenarios, when the “extremely high” risk category is entered we assume that public facilities such as restaurants and bars will be ordered to close.

The decision by public health officials about which scenario to use is difficult. Choosing a scenario implicitly accepts some number of new cases each day from bar & restaurant patronage. Once the decision is made, the present analysis suggests capacity percentages that will limit the number of new cases to whatever level has been chosen.

Capacity restrictions and ventilation levels in restaurants and bars

Ventilation inside buildings affects the likelihood of airborne disease transmission when an infected person is present. The widely used “Wells-Riley” model predicts that the likelihood of disease transmission to uninfected persons in the same indoor space as an infected person is inversely proportional to the rate at which outdoor air (or its equivalent) replaces the infected indoor air.[5] We show the related calculations in the next section.

Ventilation rates with outdoor air were measured in a study of 150 bars and restaurants in Minnesota. The study found that the median ventilation rate was about 0.08 cubic feet per minute per square foot of the room (cfm/sf).[6] This median rate is about 45% of the default rate of 0.18 cfm/sf recommended by the ASHRAE society.[7] The ASHRAE level was set primarily to control the level of carbon dioxide in the indoor air. Carbon dioxide is exhaled by occupants and builds up in indoor spaces unless outside air is brought in by a ventilation system (or by opening windows).

The capacity limits in Table 1 neglected the wide range of ventilation levels in bars & restaurants, and thus implicitly assume the same ventilation level applies to all restaurants. In the Minnesota study, the ventilation levels in the bars and restaurants varied widely. About 10% of the facilities had ventilation rates that were three or more times larger than the median. These facilities are predicted by the Wells-Riley model to be three or more times safer against disease transmission than a facility with the median rate.

We argue that restaurants and bars should be encouraged to improve ventilation systems to be more resilient during pandemic times. In particular, when the ventilation system of a restaurant or bar has been documented and confirmed to be substantially better at disease reduction than the median, it is reasonable to allow increased capacity. The corresponding adjustments will encourage both documentation of a facility's ventilation system and its improvement.

Table 2 presents a proposal for how this can be done for Scenario 2, which calls for capacity reduction when the "high" county risk level is reached. The problem of preventing the buildup of airborne virus differs somewhat from carbon dioxide buildup, which is caused collectively by all the room's occupants. The buildup of indoor virus can be caused by a single diseased individual. For this reason, the ventilation system is rated in terms of "air changes per hour" (ACH) in the room instead of "cubic feet per minute per square foot" of outdoor air. Air changes per hour encompasses a much wider range of systems. One example is ultraviolet irradiation, which cleanses virus from the air but has no effect on the carbon dioxide buildup.

We propose that restaurants be invited to apply for a rating as silver, gold, or platinum for their ventilation systems' effectiveness in reducing disease transmission. As a first proposal, restaurants are divided into four categories with increasing ACH. (i) "normal" - undocumented ventilation system, or rate less than 1.5 ACH, (ii) silver (1.5-2.9 ACH), (iii) gold (3.0 - 5.9 ACH), and (iv) platinum (>6.0 ACH). For comparison with the previous Minnesota and other ventilation studies, the corresponding outdoor rating in cfm/sf is given in the notes for an 8-foot room.

Table 2: Pandemic capacity restrictions for bars/restaurants with varying ventilation systems (risk level restricted to "medium")

County risk level (case rate*)	normal	Silver	Gold	Platinum
Low (0.00 - 1.00)	100%	100%	100%	100%
Medium (1.01 - 3.00)	100%	100%	100%	100%
High (3.01-11.00)	50%	79%	100%	100%
Very high (11.01-45.00)	25%	40%	56%	79%
Extremely high (>45.00)	closed	closed	closed	closed

*Cases per day per 100,000 residents - 14 day average
normal: < 1.5 ACH (<0.20 outdoor cfm/sf - 8 foot ceiling)
Silver: 1.5 - 2.9 ACH (0.20 - 0.39 cfm/sf)
Gold: 3.0-5.9 ACH (0.40 - 0.79 cfm/sf
Platinum: >6.0 ACH (>0.80 cfm/sf)

The column labeled "normal" is the same as the column for Scenario 2 in Table 1. Because of their larger numbers of air changes per hour, silver, gold, and platinum restaurants and bars are permitted larger capacity percentages. For the "high" county risk level, gold and platinum facilities can operate at full capacity, whereas the normal and silver facilities operate at reduced capacity percentages. Tables for Scenarios 1 & 3 are included as an appendix. With the indicated capacities, the airborne disease transmission rates for the silver, gold, and platinum facilities are always lower than that of the median restaurant. We discuss possible elaborations of the rating system at the conclusion.

Calculation of capacity percentages

There is a proportionality the mean number of disease transmissions each day C_i for a particular facility i and the county case rate C_{cty} (as defined previously).

$$C_i \propto \left(C_{cty} p_i O_i\right) \times \left(p_i O_i\right) \times \left(\frac{1}{ACH_i \times V_i}\right). \qquad (1)$$

Here O_i is the room's maximum occupancy as designated by the building inspector, p_i is the capacity percentage, V_i is the volume of the dining room or barroom, and ACH_i is the outdoor-equivalent air-changes in the room per hour. It's assumed that the facility is operating at the permitted capacity p_i. The first term in parenthesis is proportional to the likelihood that there is a disease spreader in the room. The second term is the number of patrons who may get infected by the spreader. Here we are assuming that the fraction of vaccinated or otherwise immune persons is small. The third term is based on the Wells-Riley model for airborne disease transmission.[5] For the present calculation, the model predicts that the chance of a particular patron catching the disease is inversely proportional to the product of the room's volume and the rate at which the indoor air is replaced by outdoor or "disinfected" air. This version of the Wells-Riley model makes the simplifying assumption that airborne, disease-carrying particles are distributed uniformly throughout the volume of a room. "Disinfected air" is recirculated air that has been disinfected by filtration, ultraviolet radiation, or other methods.

Table 1 assumes that the capacity percentage for any restaurant p_i is set from the county risk category has the same value p for all restaurants. It is convenient to recast equation (1) to show the dependence on p more clearly:

$$C_i \propto C_{cty} p^2 \times \left(\frac{O_i^2}{ACH_i \times V_i}\right) \qquad (1a)$$

This proportionality implies that the total number of restaurant & bar-related cases C_{rb} in a given risk category is proportional to the product $C_{cty} p^2$. Summing over all the restaurants and bars operating in the county yields:

$$C_{rb} \propto C_{cty} p^2 \qquad (2)$$

In Scenario 1, the capacity percentages in the low and medium categories were $p_{low} = 100\%$, and $p_{med} = 60\%$. These values were chosen to equalize the number of restaurant & bar-related cases at the tops of the low and medium risk categories, where C_{cty} is 1 and 3 daily cases per 100,000 residents, respectively. Thus $p_{med} = \sqrt{1/3}$; note that the numerical values in the tables have been rounded to the nearest multiple of 5%. At the top of the high-risk category, $C_{cty} = 11$ cases per 100,000 residents. Thus $p_{high} = \sqrt{1/11}$. The lowering of the capacity in each category means that restaurant and bar-related cases don't exceed the number of cases at the top of the low-risk category. Scenarios 2 & 3 were calculated using the same process but using the case level at the top of the medium and of the high-risk categories, respectively.

Vaccination and ventilation effects

The likelihood of an infected person being a patron is assumed to be proportional to the daily case rate C_{cty}. C_{cty} is affected both by vaccination and by residual immunity of persons who've recovered the disease. The risk calculation for an individual, susceptible patron is unaffected. However, the number of patrons who are susceptible to infection is reduced. If the fraction of restaurant and bar patrons who are not susceptible to infection is denoted f_{vac}, equation (2) for the total number of cases becomes:

$$C_{rb} \propto C_{cty}(1 - f_{vac})p^2. \qquad (2a)$$

We don't recommend any change in the capacity calculations as the fraction of vaccinated/immune persons increases. As herd immunity approaches, and case growth rates decline, public health officials could change the scenario selected in Table 1, or abandon capacity restrictions altogether, to accommodate the improved conditions.

We now consider the option of allowing some restaurants with better than median ventilation rates to have larger capacities than unrated restaurants. We rewrite equation (1a) to emphasize the ventilation-related parameter:

$$C_i \propto O_i\left(C_{cty}p^2\right) \times (O_i/V_i) \times (1/ACH)\,. \qquad (1b)$$

For Table 2, the capacity percentages for the silver, gold, and platinum restaurants and bars were increased beyond the normal level based on the increased air changes per hour: $ACH_{silver} = 1.5$ and $ACH_{gold} = 3.0$ as well as the inferred median $ACH_{median} = 0.6$ (based on 8 foot ceilings). Thus $p_{silver} = \sqrt{1.5/.6}\,p_{normal}$ and $p_{gold} = \sqrt{3.0/0.6}\,p_{normal}$. Of course, the maximum capacity percentage is 100%. Despite the increased capacity, patronage of the higher rated restaurants and bars still has a lower risk of disease transmission than for a facility with the median level of ventilation.

Beyond Air Changes per Hour

Development of a complete rating system will need to encompass filtration and disinfection systems for recirculated air in addition to replacement of indoor air with outside air. Filtration is done both by central ventilation systems as well as room systems. Disinfection is typically done by ultraviolet irradiation systems. The efficacy of these systems depends on the particular airborne disease.

In addition, we have neglected architectural features that are likely to affect disease transmission in a given space. One example is the ratio of full occupancy O_i to room volume V_i. While this ratio wouldn't change dramatically between restaurants, facilities with very high ceilings are better than those with low ceilings. In addition, the complete mixing approach to infection risk is simplified. Displacement ventilation systems are likely superior to conventional mixing systems. These architectural features could be included in a more sophisticated rating system.

As is evident, the complications suggest that a licensed professional will be needed to establish the ultimate rating of a facility. One possibility is to integrate this analysis into an established program such as certification as a "Building Commissioning Professional".[8]

The author thanks Charles Bertuch (Bergmann Associates) and William Chadwick for conversations and critical reading of the manuscript. The information, data, or work presented herein was funded in part by an award from the New York State Department of Economic Development (DED) to the Center of Excellence in Environmental & Energy Systems (SyracuseCoE) at Syracuse University. Any opinions, findings, conclusions or recommendations expressed are those of the author(s) and do not necessarily reflect the views of the DED.

Appendix

Table A-1: Pandemic capacity restrictions for bars/restaurants with varying ventilation systems (risk level restricted to range at "low" risk)

County risk level (case rate*)	normal	Silver	Gold	Platinum
Low (0.00 - 1.00)	100%	100%	100%	100%
Medium (1.01 - 3.00)	60%	95%	100%	100%
High (3.01-11.00)	30%	45%	65%	95%
Very high (11.01-45.00)	15%	25%	35%	45%
Extremely high (>45.00)	closed	closed	closed	closed

*Cases per day per 100,000 residents - 14 day average

Table A-2: Pandemic capacity restrictions for bars/restaurants with varying ventilation systems (risk level restricted to range at "high" risk)

County risk level (case rate*)	normal	Silver	Gold	Platinum
Low (0.00 - 1.00)	100%	100%	100%	100%
Medium (1.01 - 3.00)	100%	100%	100%	100%
High (3.01-11.00)	100%	100%	100%	100%
Very high (11.01-45.00)	50%	80%	100%	100%
Extremely high (>45.00)	closed	closed	closed	closed

*Cases per day per 100,000 residents - 14 day average

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