Medical Research Archives

ESMED
European Society of Medicine

OPEN ACCESS

Published: October 31, 2022

**Citation:** Richard C. Jones, 2022. Spatial diffusion of Omicron in Texas: Predictable or Random?, Medical Research Archives, [online] 10(10). https://doi.org/10.18103/mra.v10i10.3166



DOI
https://doi.org/10.18103/mra.v10i10.3166

ISSN: 2375-1924

RESEARCH ARTICLE

# Spatial diffusion of Omicron in Texas: Predictable or Random?

**Richard C. Jones, Ph.D.***[1]

[1]Professor of Geography and Environmental Sustainability Coordinator, Geography Program, Department of Political Science and Geography, The University of Texas at San Antonio, One UTSA Circle, San Antonio TX 78249-0648

* richard.jones@utsa.edu

ABSTRACT

The impacts of Covid-19 on society and the environment have now, three years from its first appearance, ballooned across the scientific literature. But our knowledge of where it originated, and why it spread as it did, has advanced much more slowly. Models of spatial diffusion at national level have been applied to past pandemics with some success, but not yet to Covid-19. One exception is a study of the spread of the original strain of Covid-19 in Texas between March and September 2020. This spread adhered to spatial diffusion theory: first hierarchical, that is into metropolitan areas in proportion to their population sizes; later contagious, that is into adjacent towns based on their proximity to metropolitan areas to which they were tributary; and finally hierarchical once more, into the most isolated towns based on their urban/ rural status. This process took six months. By contrast, the Omicron variant, in less than two months (December 2021 and January 2022), reached case levels three times those of the original Covid surges. The current study focuses on how Omicron diffused across Texas over the period November to February 2021-22. Daily case numbers for Covid-19 were available for all 254 counties from the Texas Department of State Health Services over this period, and the Omicron variant was identifiable from these data. This analysis will reveal whether the Omicron spread across the counties of Texas was predictable, partially predictable, or unpredictable, based on county population, distance to their regional metro, or the gravity concept (the ratio between the two). These insights will be of value if other such variants appear on the horizon for the US and Texas, enabling local health officials to anticipate the onset in their communities.

**Keywords:** covid-19; Omicron variant; spatial diffusion; gravity model; Texas

> We were just about done with Covid. Then we were blindsided by Omicron. Do you know that covid spelled backwards is divoc? As in 'what divoc is happening?' (Anonymous)

## 1. Introduction

Disease spread is one form of *spatial diffusion*, defined as the systematic spread of technology, beliefs, innovations, news, migrants, diseases, etc., from origins to destinations over time. A number of epidemics and pandemics have occurred over the past two centuries, including cholera in the 1800s, the Spanish flu of 1918-1919, the Asian flu in 1957-1958, the Hong Kong flu of 1968-1970, AIDS in the 1980s and 90s, cholera in 1991-1994, SARS in 2001-2002, and the Swine flu in 2009-2010. Much has been written on the impact of these health crises, but much remains to be understood concerning their origins, spatial reach, and duration. The same can be said concerning Covid-19, a virus originating in China in late 2019. Its specific micro-origins are unknown, but more importantly its spread across the earth has seemed unpredictable and its duration (has) proven exasperatingly perpetual.

This article proposes that the spatial spread of a pandemic is not necessarily unpredictable. A closer reading of the literature on the pandemics just mentioned shows that after the initial case has appeared in a country, there are models that can predict its spread in that country. The *gravity model* is one such model. It can predict with some accuracy the arrival date of a virus at a particular place within the country as a function of two factors: the population size of the place itself; and its distance from other places of sufficient size that they are likely to have the virus. This model has seldom been applied at the state level, but one exception was an article by Jones,[1] for Texas. In that article, the gravity model predicted, with a substantial degree of accuracy, the number of days after its initial appearance (in Houston in early March 2020) for it to appear in each county in the state over the subsequent six months (until early September 2020), at which time all but three counties were infected. The relative importance of hierarchical and contagious processes was such that early on population dominated (hierarchical); later on, distance to regional metros dominated (contagious); and finally, population dominated once again (hierarchical). The Omicron variant, of course, has been a different beast. In less than two months (December 2021 and January 2022) it surged and peaked at new case levels three times those of the initial Covid-19 strain; since then it has persisted a lower levels. It is unproven whether Omicron will lend itself to prediction to the degree of earlier Covid-19 variants. During its surge it seemed to appear everywhere at once, infecting those who were vaccinated as well as those who were not. This article provides evidence to address the predictability of spread of the Omicron variant.

The study proceeds in several steps: (1) I review spatial diffusion studies and how well they have been able to predict the past spread of diseases. (2) I discuss my study design, define my data more closely, and state two hypotheses relating the "surge" (first significant escalation of new cases) of the Omicron variant in a Texas county to measures of population, distance, and the combination of the two (the gravity index) in that county. (3) I apply statistical routines (correlation, difference of means, tabular and graphic analysis) to the data and come to conclusions concerning the hypotheses. (4) Finally, I discuss the results in light of the literature, summarize my conclusions, and consider the utility of the model in the event of subsequent variant outbreaks in Texas and elsewhere.

### 1.1 Spatial Diffusion Theory

*Expansionary diffusion* involves the expansion of an item (innovation, belief, attitude, behavior, disease, etc,) from an initial entry point into a space until that space is saturated. Expansionary diffusion is further divided into hierarchical and contagious diffusion. *Hierarchical diffusion* means that the item locates initially in places atop (or more rarely, at the bottom of) some spatial hierarchy. The position in this hierarchy can be based on population size, economic importance, political or cultural hegemony, or other measures of importance. From there the item moves down the hierarchy to less important places. *Contagious diffusion,* by contrast, adheres to the principle of *distance decay*---places closer to other places that already have the item (regardless of size) will get it sooner than places farther away.

Spatial diffusion theory, as applied to disease, owes its concepts and models to early scholars such as Hagerstrand,[2] who developed a stochastic model for predicting the spread of bovine tuberculosis control in Sweden; Pyle,[3] who pioneered the idea that contagious and hierarchical spread of a disease operate at different historical periods, and applied it to cholera in the US in the 1800s; and Haggett,[4] who followed up on Pyle's research to show that both types of spread may operate over the course of a given disease outbreak, in this case measles in southwest England.

### 1.2 Case studies

As mentioned above, Pyle[3] first showed that contagious and hierarchical processes may operate at different times in the spread of a particular disease. In the US in 1832, cholera followed a largely contagious rather than hierarchical process. At that time the US was a frontier nation, and towns were connected by slow water transportation; cholera spread from town to town in linear contagious fashion along rivers. After 1850, the development of a definite urban hierarchy coupled with dramatic improvements in transportation (steamships, locomotives, automobiles, airplanes) fostered rapid movement into large cities, followed later by filtering into smaller cities and rural areas. Cholera followed human movement in a hierarchical pattern of spread in this later period.

The Spanish flu of 1918-1919 offered diffusion scholars another opportunity to study hierarchical and contagious processes, this time within a given pandemic. This flu made its way across the Atlantic to the British Isles, carried by American troops serving in WWI. Smallman-Raynor et al.[5] found that index cases occurred simultaneously in large coastal and interior cities; they were followed by contagious patterns that alternated between north-south and south-north over the remainder of the war. Nunes et al.[6] found the same basic sequence in regards to the Spanish flu in Portugal.

Finally, the AIDS pandemic, diffusing within Africa as early as the 1960s and then leapfrogging globally, captured the attention of geographers (Shannon and Pyle;[7] Gould[8]). In the late 1980s the disease, while staying with an "island" pattern (Haggett[4]) in Africa, underwent hierarchical diffusion to primate cities including Nairobi, Johannesburg and Abidjan (Ivory Coast). At various points Francophone natives and expatriots fled conflicts in West Africa, carrying the virus into French-speaking Europe. From there it spread to Port-au-Prince, Haiti, and finally to New York City, San Francisco/Los Angeles, and Miami. Its final act was contagious spread into the exurbs of these cities (Gould[8]). From South Africa HIV spread to Anglophone Asia and Australasia.

Large cities today are infected with diseases before smaller cities, owing to their population size and density, attractiveness to outsiders, and tendency of their residents, who are educated and well-off, to travel outside their city and country and then return. A city's population size is a stand-in for many factors related to entry of disease agents from outside. Likewise, the proximity of a smaller place to a large city is a stand-in for factors connecting the place to the city, such as commuting, shopping, business ties, school ties, social and family ties, all of which may be related in turn to disease transmission.

Although these case studies are instructive, investigations of the diffusion patterns of Covid-19 over time have been rare. It has not been ascertained whether the spread of the initial virus or its variants such as Delta, Omicron, and BA5, have been hierarchical or contagious, both, or neither. Nor have the separate roles of population and distance, and their sequencing in the diffusion process, been established. Temporal data by county in Texas offer a unique opportunity to examine the latest major variant, Omicron.

## 2. Study Design and Methods

The Texas Department of State Health Statistics[9] tracks confirmed Covid-19 cases and deaths by day individually for the 254 counties in the state. These data are downloadable from their website in Excel format. They are easily converted to SPSS, although some data transformation and formatting is necessary. Similarly, demographic data from the US Census and Department of Agriculture are available and downloadable (see below).

The goal of this study is to address two basic questions. First, were a county's population size and the distance to its major regional city able to predict the day of first entry of the virus into the county? Second, over time was the pattern of spread hierarchical followed by contagious, or the reverse, or neither?

The variables in this study, along with their accompanying definitions, are as follows:

**Table 1. Variables in Omicron analysis**

| Conceptual variable: | Operational Variable (definition) |
|---|---|
| *Dependent* | |
| Time of first entry of Omicron into a county | Proxy: Number of days from index case(es) in Texas (Nov. 29, 2021), to date of pronounced uptick in new Covid-19 cases in the county (TDSHS 2021-2[9]) |
| *Independent* | |
| Population size of county | Number of inhabitants in the county (US Census 2020[10]) |
| Distance from major city | Road distance from county seat to major regional city to which the county is tributary (USDA[11]) |
| Gravity index | Number of inhabitants in county divided by road distance to this major city |

NOTE: To reduce the effect of extreme cases, in the analyses below the base 10 logarithm of all variables is used.

A few pointers on interpreting the proxy for time of first entry are in order. Texas Covid-19 data are not broken down by variant. On Thanksgiving, 2021, Delta was still the variant of concern in Texas; however, it had been in decline since September. Pronounced upticks in Covid-19 after Thanksgiving of 2021 must have been due to a new variant, and indeed, wastewater samples from plants in the Houston area detected the first evidence of Omicron in the state at that time (Harper[12]; Packard et al.[13]). Texas health officials identified these upticks as the Omicron variant, based on genetic sequencing as well as information on its rapidity of spread in South Africa. In addition, the sequencing of upticks in cases of Covid-19 in the TDSHS data corresponds closely with the reports on confirmed cases of Omicron in the media (Harper[12] on Houston; Maddox[14] on Dallas; and Quinlan[15] on Austin). Without a doubt, the virus surges in late November and early December of 2021were owing to the new variant, Omicron, and they were due to community spread. Officials with TDSHS have substantiated these conclusions, and noted that 90% of Covid cases in Texas were Omicron before the 2022 New Year (Uchida[16]). Thus I was able to identify the onset of Omicron in a county by the date of a Covid case uptick, judged from visual inspection of each county's new cases after November 29, when both Montgomery County (Houston metro area) and Jefferson County (Beaumont metro area) had pronounced surges in Covid-19.

The following *hypotheses* are advanced:
H1: The gravity model (population of a county divided by the distance to the major regional city to which the county is tributary) will explain a high percentage of the variation in counties' date of surge in the Omicron variant.

H2: Early in the process of disease spread, hierarchical patterns will predominate; later on, contagious patterns will predominate; finally, hierarchical patterns will predominate once more.

## 3. Results

Table 2 reveals that population and distance to their major regional city predicted the surge of the Omicron virus across the counties of Texas during November to February of 2021-2022. Overall, a substantial negative correlation (Johnson[17], 142) was recorded for population (-.531**), and a similarly strong correlation for the gravity model (-.505**), with distance playing a lesser role.

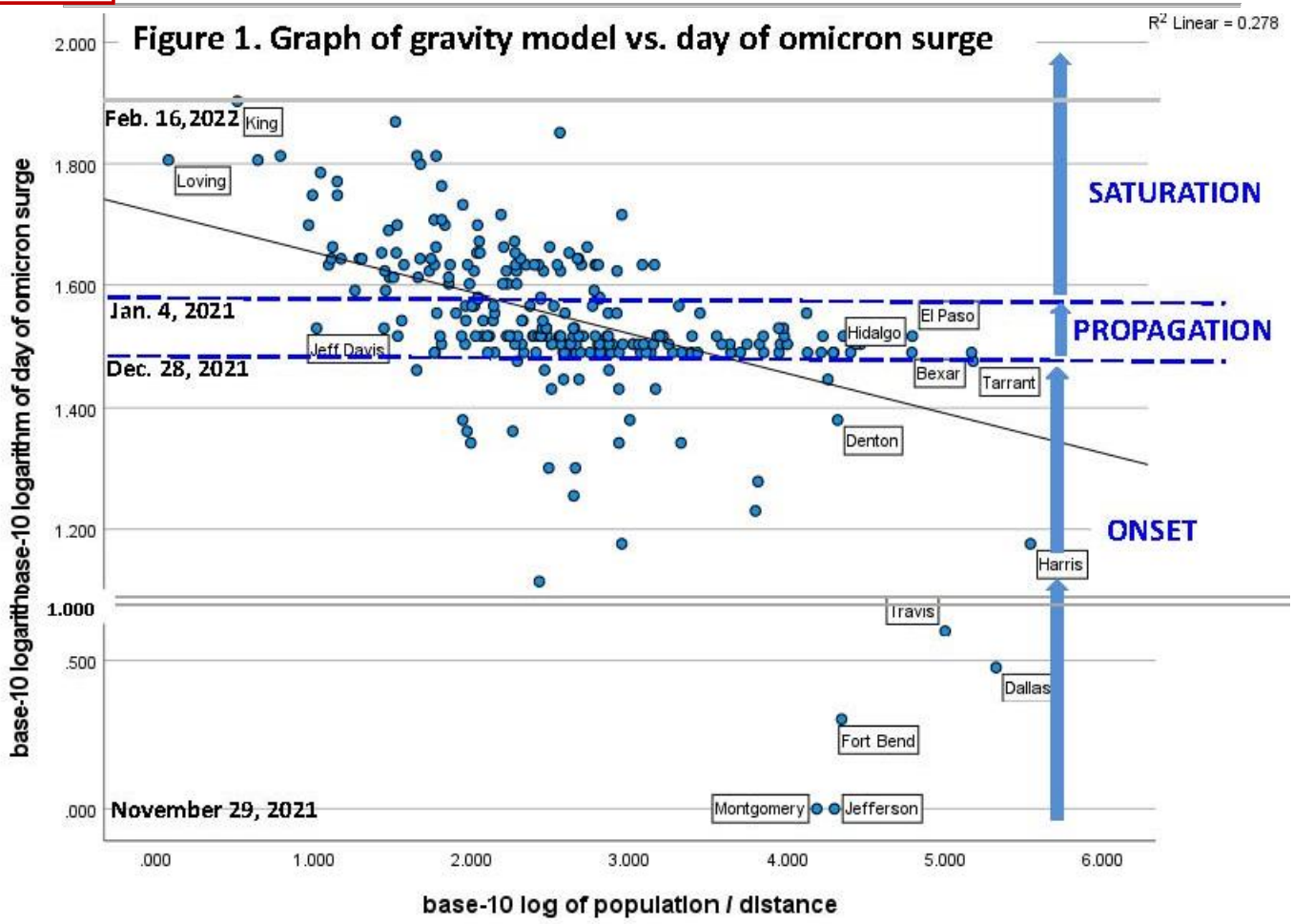
Table 2 also shows the relationship between the Omicron surge and the gravity model for three phases of the diffusion process, defined here as ***Onset*** (November 29 to December 28), ***Propagation*** (December 29 to January 4), and ***Saturation*** (January 5 to February 16). The boundary dates for each of these phases are a function of clear breaks in the frequency data, in which the new case numbers jumped dramatically on December 29 and fell markedly on January 5th. In each of these phases, the model was predictive, but unevenly so. During Onset and Saturation the gravity model and its components (population and distance) were more predictive than during propagation. That is to say, when the surge was most rapid was when it was least predictable. From December 29 to January 4 (7 days), 137 counties (53.9%) recorded their first surge in Omicron. During this period the Pearson correlation dropped to -.322 from -.520 in the previous period, before it recovered to -.456 in the final period. It cannot be said that the process was hierarchical, then contagious, and finally hierarchical once more. Hierarchical forces dominated in every period.

**Table 2. Relationship between Omicron's surge in a county vs. population and distance**

| base-10 log of day of Omicron surge, overall and by Phase: | base-10 log of population 2020 | base-10 log of distance to major regional city | base-10 log of population÷distance (gravity model) |
|---|---|---|---|
| Overall (n=254): 11/29/21 – 2/16/22 | -.531** | .290* | -.505** |
| ***Phase 1: Onset*** (n=32) 11/29 – 12/28 | **-.518**** | **.384*** | **-.520**** |
| ***Phase 2: Propagation*** (n=137): 12/29 - 1/4 | -.360** | .156 | -.322** |
| ***Phase 3: Saturation*** (n=85): 1/5 – 2/16 | -.451** | .237* | -.456** |

**[a]Pearsonian correlations; ** indicates significant at .01; * indicates significant at .05.**

Figure 1 offers a finer-grained analysis of how the gravity model predicted surges in Omicron across the counties of Texas. In the lower right of the graph are counties associated with major metropolitan areas of east Texas that were the first to exhibit surges, namely Montgomery, Fort Bend, and Harris (Houston), Dallas (Dallas), and Jefferson (Beaumont). The dominance of Houston suggests correctly that is where the variant entered the state, just as in the case of the initial Covid-19 strain nearly two years before (Jones[1]). On the other hand, rural, isolated ranching and oil mining counties of far west Texas such as King, Loving, and Jeff Davis were among the last to exhibit surges. This suggests a wave of infection generally proceeding from east to west. Note also the trending of the points from upper left to lower right within the Onset and Saturation periods. It is these trends that drove the trend in the overall pattern. In the propagation period, the trend is present, but much less evident.




## 4. Discussion

Regarding H1---the hypothesis that addressed the predictability of spread of the Omicron variant with just county population and distance from major cities---it is accepted. Although overall only a quarter of the variation in new cases can be explained, the correlation is still substantial (-.505) and somewhat remarkable given the short time frame involved (two and a half months) and the fact that over half the counties were infected over a span of seven days. Given the statistical results from Jones (2021) it is unsurprising that population alone was the dominant causal factor. The present study reiterates the strong metropolitan-rural divide on which so much else pivots in Texas, including disease susceptibility. Rural Texans are older and poorer and less-educated, and this estranges them from the types of outside travel that bring disease agents into their communities. They tend to be "Anglo" (a broad term that refers today to direct European ancestry) with limited contact with other ethnic groups. Many are retired, and thus do not come into contact with working environments (assembly-line manufacturing, meatpacking, etc.) or congregate living environments that are associated with community spread.

In addition to the metropolitan-rural divide there is another, spatial, divide revealed by the data. Of the first ten counties to get the Omicron variant, all ten were east of the Balcones Escarpment (and its northward extension, the Whiterock Escarpment), a north-south line of hills that separates east from west Texas. Of the last ten to get the variant, all but one (Kenedy County, in far south Texas) were west of this line. This verifies the spread of the variant from east to west. Interestingly, King County (east of Lubbock) was the last county to get the Omicron variant, just as it was the last to get the original Covid-19 strain (Jones[1]). King, like so many sparsely-populated and isolated counties in West Texas, had an invisible defense against the virus. It consisted of elderly population, population decline, loss of professional jobs and tax base, lack of business vitality, limited incoming and outgoing travel. These factors were an antidote to covid-19.

But in another sense, they were and have been indicators of the region's economic demise.

Regarding H2---the hypothesis that predicted phases in which hierarchical diffusion would be the rule initially, followed by contagious diffusion and then hierarchical again at the end---this hypothesis is only accepted in part. Although hierarchical diffusion does precede contagious diffusion as argued in much of the literature, and it is found to be substantially predictive at the beginning and the end, distance was less predictive at all phases including the middle phase. Three possible explanations for the lack of importance of regional interactions in the propagation phase come to mind. First, seven days (December 29 to January 4) was too short a time to flesh out a surge/regional interaction correlation. Second, these seven days were occupied with such a crush of cases that an orderly spatial process could not unfold. Finally, this phase coincided a time of heavy holiday travel to visit family---travel that was extra-regional as opposed to within a tributary region defined by commuting, shopping, and economic ties.

## 5. Conclusion

It is enlightening that so simple an index (the gravity model) can explain disease spread, because population data are readily accessible to urban planners and health officials and practitioners everywhere. Increasingly this is true of disease data. In fact, researchers at Johns Hopkins University have developed a daily database of Covid-19 cases for all the counties of the United States. It turns out that Texas is not the only state with a dense array of counties. This is true of Kansas, Oklahoma, Arkansas, Missouri---that combined, have more counties, 371, than Texas, facilitating spatial analysis. These states exhibit an urban-rural divide similar to that in Texas. It would be interesting to know whether the spread of Omicron and other variants was as predictable for these states as for Texas. More importantly, this would theoretically allow researchers to trace Covid-19 spread across state lines. Diseases, like health care, wildlife corridors, traffic accidents, immigrants, etc., do not stop at state borders. Coordination between states is therefore necessary to deal with them.

**References**


1. Jones, R. The spatial diffusion of Covid-19 in Texas. *The Social Science Journal*. 2021. https://doi.org/10.1080/03623319.2021.1926148
2. Hagerstrand, T. *Innovation Diffusion as a Spatial Process. Lund, Sweden: University of Lund.* English translation of Innovations förloppet ur korologisk synpunkt, with afterword by A. Pred. C.W K. Gleerup, Lund, and University of Chicago Press, Chicago. 1953.
3. Pyle, G. F. Diffusion of Cholera in the United States. *Geographical Analysis* 1969; 1, 1, 59-75.
4. Haggett, P. *Geography: a Modern Synthesis*. New York: Harper and Row. 1972.
5. Smallman-Raynor, M., Johnson, N., and Cliff, A. D. The spatial anatomy of an epidemic: Influenza in London and the county boroughs of England and Wales, 1918–1919. *Transactions of the Institute of British Geographers,* 2002; NS 27, 452–470.
6. Nunes. B., Silva, S., Rodrigues, A., Roquette, R., Batista, I., and Rebelo de Andrade, H. The 1918–1919 influenza pandemic in Portugal: A regional analysis of death impact. *American Journal of Epidemiology*, 2018; 187, 12, 2541–2549.
7. Shannon, G. and Pyle, G. F. The origin and diffusion of AIDs: The view from medical geography. *Annals of the Association of American Geographers*, 1989; 17, 1, 1-24.
8. Gould, P. *The slow plague: A geography of the AIDS pandemic*. Cambridge, MA: Blackwell Press. 1993.
9. TDSHS, the Texas Department of State Health Statistics. COVID-19 total cases & new cases by county, 3/4/2020 - 08/15/22. 2020. Retrieved from https://www.dshs.state.tx.us/coronavirus/additionaldata/.
10. US Census, 2020. *Quick facts on counties,* Retrieved from https://www.census.gov/quickfacts/fact/table/.
11. USDA, The U.S. Department of Agriculture, Economic Research Service. *Urban influence codes*, 2013. Retrieved from https://www.ers.usda.gov/data-products/urban-influence-codes.aspx.
12. Harper, K. B. Texas reports its first case of the omicron COVID-19 variant. *Texas Tribune*, Dec. 7, 2021.
13. Packard, S., Gutierrez, F., and Villareal, P. Omicron variant detected in Houston's wastewater. *Houston Health Dept. Reports*, December 6, 2021.
14. Maddux, W. Dallas prepares for Omicron, which has been found in Frisco. *Dallas Magazine*, Dec. 9, 2021.
15. Quinlan, M. Omicron detected in Travis County, Austin Public Health says. *Community Impact Newspaper,* December 13, 2021.
16. Uchida, A. Harder to detect 'stealth omicron' confirmed in Texas. *News4San Antonio*. January 19, 2022.
17. Johnson, A. G. *Statistics*. New York: Harcourt, Brace, Jovanovich. 1988.