

Article

Lockout, Lockdown and Land Use: Exploring the Spatio-Temporal Evolution Patterns of Licensed Venues in Sydney, Australia between 2012 and 2021 in the Context of NSW Public Policy

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Abstract: The hospitality industry in Sydney, Australia, has been subject to several regulatory interventions in the last decade, including lockout laws, COVID-19 lockdowns and land use planning restrictions. This study has sought to explore the spatial implications of these policies in Inner Sydney between 2012 to 2021. Methods based in spatial analysis were applied to a database of over 40,000 licensed venues. Point pattern analysis and spatial autocorrelation methods were used to identify spatially significant venue clusters. Space-time cube and emerging-hot-spot methods were used to explore clusters over time. The results indicate that most venues are located in the Sydney CBD on business-zoned land and show a high degree of spatial clustering. Spatio-temporal analysis reveals this clustering to be consistent over time, with variations between venue types. Venue numbers declined following the introduction of the lockout laws, with numbers steadily recovering in the following years. There was no discernible change in the number of venues following the COVID-19 lockdowns; however, economic data suggest that there has been a decline in revenue. Some venues were identified as having temporarily ceased trading, with these clustered in the Sydney CBD. The findings of this study provide a data-driven approach to assist policymakers and industry bodies in better understanding the spatial implications of policies targeting the hospitality sector and will assist with recovery following the COVID-19 pandemic. Further research utilising similar methods could assess the impacts of further COVID-19 lockdowns as experienced in Sydney in 2021.

Keywords: lockout laws; COVID-19 lockdowns; spatio-temporal patterns; space-time cube; venue distribution; land use planning; hospitality industry; spatial analysis



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1. Introduction

Australia has a well-established drinking culture [1], as defined by norms and practices followed by a large proportion of its citizens [2]. This goes back to the very beginnings of British Colonial settlement [3], with much of the historical national identity in Australia tied to the consumption of alcohol [4]. The industry itself plays a crucial role in supporting business and employment, contributing upwards of 6% to the New South Wales (NSW) economy [5]. Notwithstanding this, alcohol consumption in Australia has been linked to poor public health outcomes and increases in physical violence [6]. The location where alcohol is consumed can affect the amount people drink [7], with increased density of venues shown to be correlated with an increase in violence resulting from alcohol consumption [8].

Politicians and policy makers are faced with the task of balancing pressure to uphold historical norms of Australian culture and the need to support the hospitality industry with the need to protect public health and safety. Largely, it is state-enacted legislation and policy guidance which are used to enact changes in the drinking patterns of Australians in order to achieve this balance.

In recent times, three policies targeted at regulating the hospitality industry have stood out for the media attention they have attracted and for the perceived impact they have had on the industry. These include: (1) The lockout laws; (2) COVID-19 lockdowns; and (3) Local Government land use planning regulations. Research has explored the effectiveness of these policies and sought to understand their overall impact. However, no study has been undertaken exploring the spatial implications of these policies on the hospitality industry.

This study has sought to fill this gap, using methods of spatial analysis to explore how these policies relate to and have impacted the spatial distribution of licensed venues in Inner Sydney between the period of 2012 to 2021.

1.1. A History of Alcohol Regulation in NSW

Sydney, NSW, has a long and complicated history with alcohol and the law. Following British occupation of the Australian continent, the newly established colony of New South Wales was somewhat reliant on alcohol as a form of illegitimate currency [9]. On 26 January 1808, an uprising occurred partly in response to then-Governor William Bligh's stifling of the rum trade, resulting in the Government being overturned and the New South Wales Corps assuming control of the colony, lasting for a period of two years [10].

The mid 1800s were characterised by relatively loose liquor restrictions, with the end of the century turning toward a more conservative approach to alcohol regulation [11]. This was a result of the temperance movement gaining traction in Australia. This movement sought to curb the drinking of alcohol for moral reasons and saw the 'Six o'clock swill' enacted in NSW in 1916, which restricted the sale and supply of alcohol by requiring hotel bars serving alcohol to close at six o'clock in the evening. The policy was targeted at reducing the amount of liquor consumed by patrons [12]. This was repealed in mid-1954, with the laws subsequently relaxing over the following half century. Indeed, with the subsequent licensing reforms of the following decades, in the words of Kirkby, " . . . the 'Australian pub' turned from a local drinking den to a stylish venue offering sophisticated food in ambient surroundings." [13] (p. 44).

This characterisation of Australian drinking culture speaks to a broader change in the hospitality industry in Australia, which has grown significantly in the 21st century and makes a significant contribution to the Australian economy [14].

1.2. Current Policy Setting

There exist many levers available to policymakers by which to aid in controlling alcohol supply and consumption. These can be broadly defined in two categories: restricting physical availability or restricting economic availability [7,15,16].

In NSW, such policies are set by the State and Local Governments, with Liquor and Gaming NSW operating as the regulatory agency responsible for enacting and enforcing these policies [17]. A major function of the agency includes the issuing of 'licences', which gives permissions to 'licensees' to sell alcohol to the public, with permissions varying depending on licence type [18].

One of the more recent policy interventions in the hospitality industry in Sydney that sought to restrict the physical availability of alcohol was the lockout laws. The lockout laws refer to legislation and policy changes enacted in January of 2014 and:

- Were only applicable to venues within the Sydney CBD precinct and Kings Cross precinct, two adjacent areas located in the inner-city area of Sydney LGA;
- Required bars, pubs and clubs to refuse people entry past 1:30 a.m.;
- Restricted the sale of last drinks to 3:00 a.m.;
- Gave the NSW Government greater powers to impose conditions on licensed premises [19].

These policy reforms were in response to intense public pressure and media attention [20], described by some as a 'moral panic' [21], following violent attacks causing the deaths of two young men in the precincts in 2012 and 2013.

In the two years immediately following the reforms there was a statistically significant and substantial reduction in assaults within the precincts [22]; however, the immediate benefit became less apparent over time [23], with research indicating that assaults were occurring earlier in the evening and in surrounding areas [24].

An interim review of the laws led to a slight easing of restrictions in 2016 [25], and in the years that followed, growing public concern and political pressure [26] ultimately led to the laws being lifted for the CBD precinct in 2020 and Kings Cross precinct in 2021 [27].

Despite the policy being somewhat successful at reducing crime, research and media outlets argued that it was unfairly restricting the night-time economy and live music industry [21] and was resulting in a reduction in patronage numbers [28], with research showing people to be moving away, thus affecting rental prices [29], and ultimately leading to the closure of venues [30,31] and loss of identity [32].

There has, however, not been substantive research undertaken exploring the spatial aspect of the impact lockdowns have had on the industry. This is pertinent given that the lockdown laws were geographically restricted.

In addition to the lockdown laws, at the very end of 2019 and in the early months of 2020, a newly emerged novel coronavirus disease named COVID-19 began spreading around the world [33]. In response to expert health advice and growing public concern surrounding the disease, governments at both the state and federal levels in Australia introduced 'lockdowns' which restricted people's movement and were aimed at reducing the spread of the disease. Among other things, the lockdowns:

- Enforced social distancing requirements;
- Restricted the number of people who could attend specific venues;
- Required some businesses to cease operations temporarily, including most types of licensed premises (except for allowing some take-away services to occur) [34,35].

These measures were strict during the first few months of the pandemic in early 2020, but they gradually eased throughout the year to early 2021. Notwithstanding this, snap lockdowns and some level of restrictions have remained in place to the time of writing, with restrictions increasing in mid-2021 due to a recent outbreak in the city.

Whilst succeeding at slowing the spread of the disease, the policies have had the effect of significantly impacting the revenue of the hospitality industry both in Australia (showing an approximate 13% contraction) [36] and globally [37], with media outlets and research suggesting that the industry was facing mass closures [38–40] despite receiving a financial stimulus from all levels of government [41,42].

Data taken from Google Trends and anecdotal evidence in the media have suggested that the impacts of lockdowns are concentrated spatially, with the data indicating that there was a dramatic drop in pedestrian mobility within the Sydney CBD area in the months during and following lockdowns [43–45]. This was in comparison to suburban areas, which experienced a strong bounce-back of visitors following the easing of lockdowns according to the data. This reduction in people visiting the CBD has contributed to a drop in revenue for businesses in the area [46,47].

No research has yet been undertaken with respect to how such revenue loss may be resulting in the permanent closure of businesses, including licensed premises, or whether they are relocating to other areas. This gap is particularly pertinent given the spatial aspect to the decline in pedestrian mobility and presents a relevant concern for authorities when providing targeted stimulus to these businesses.

In addition to the policies set at the state level, land use restrictions at the local government level further seek to regulate the hospitality industry. The framework for land use planning in NSW is set by the NSW Government to regulate permitted uses within specific 'zones' [48]. However, it is largely the responsibility of local councils to dictate zoning at a local level, along with assessing applications for development within these zones.

The City of Sydney recently undertook a comprehensive review of its policies to better support the hospitality industry, including allowing later trading hours for certain

‘entertainment’ areas [49]. Similar reforms regarding the night-time economy [50] and commercial land zoning [51] at the state government level are in various stages of completion. Notwithstanding this, there is limited research which has sought to explore the relationship between land use zones and licensed venues.

1.3. Spatial Analysis

Spatial analysis was chosen as the appropriate tool for undertaking the analysis. Spatial analysis refers to methods that enable the exploration, manipulation and display of spatial data and falls within the category of exploratory spatial data analysis (ESDA) [52,53]. With its beginnings in epidemiology [54], such analysis often reveals patterns previously unseen by utilising traditional methods, highlighting its value across a broad field of topics.

There exists a growing body of research utilising such methods to explore and better understand spatial elements of the hospitality industry and, in particular, hotel and venue locations. Broadly speaking, the existing research can be grouped into two areas: studies utilising methods of point pattern analysis and data agglomeration, and those utilising methods of spatial statistical significance.

Jing et al. explored the spatiality of ‘leisure venues’ in Wuhan, China, using the data visualisation method of kernel density estimation (KDE) to determine venue clusters [55], a commonly used method when applied to point pattern analysis [56]. Whilst allowing for the display of data, such methods are not statistically significant and they make it difficult to determine patterns from random noise [57].

Cui et al. [58] undertook a similar analysis of the distribution of karaoke bars in Nanjing, China, albeit with a more blended approach utilising methods of point pattern analysis along with Ripley’s K [59] and Local Moran’s I [60,61] for spatial statistical significance.

These methods of spatial statistical analysis can reveal significant venue clustering, referred to as spatial autocorrelation, which is the tendency for sites that are close together to have similar values.

Fang et al. followed a similar approach to Cui, applying the Local Moran’s I method looking at the distribution of hotels in the Guangdong region in China. They found hotel locations showed a high level of spatial autocorrelation, reflecting the phenomenon that hotels are known to cluster for mutual economic benefit [62]. This aligns with Chhetri and Chhetri’s work observing the spatial clustering of tourism and hospitality employment areas in Melbourne, Australia [63], and speaks broadly to the basic economic principle that specialised industry will agglomerate within a geographic area, as originally conceptualised by Alfred Marshall [64].

Sánchez-Martín et al. undertook a study looking at the grouping of rural accommodation in Extremadura, Spain. What is unique about the study is that they utilised both the Local Moran’s I and Getis–Ord G_i^* methods to undertake spatial autocorrelation analysis on hotel locations, with a view to drawing comparisons between the two methods. The study identified difficulties in using both techniques, in particular establishing spatial relationships between points of interest and identifying appropriate distance parameters when assessing such relationships [65].

When considering the existing literature, it is evident that studies involving both point pattern analysis and spatial statistical analysis yield the most comprehensive results. This study has sought to employ these methods, focussing on simple data display along with the Getis–Ord G_i^* method, following closely the approach undertaken by Sánchez-Martín et al.

1.4. Spatio-Temporal Analysis

Considering the study aims, it was necessary to examine the temporal aspect of the spatial distribution of venues. Similarly to the literature discussed above, the existing research can be broadly defined in two groups: those utilising methods point pattern analysis and data agglomeration, and those utilising methods of spatial statistical significance. The difference being that these methods were employed over time.

Parsa et al. undertook a study exploring restaurant failure rates in Denver between 2007–2013, utilising yearly choropleth maps of agglomerated data to compare changes over time [66]. Other studies have used similar methods, including the work undertaken by Moghadam et al. investigating the spatio-temporal changes in major activity centres in the Sydney metropolitan area over 25 years [67], and by Taylor examining the changing distributions of licensed venues and electronic gaming machines in Sydney between the late 1980s and mid-2000s [68]. These methods, whilst useful in the first instance, are simplistic in their output and can make it difficult to determine with confidence any significant changes that have occurred over time.

Kim et al. employed spatial statistical analysis on hotel locations in the United States across a 30-year period through applying the Local Moran's I method to each time period, then comparing the outputs to observe changes across time [69]. Whilst being statistically robust and thus more reliable than those discussed above, the study is similar in that it requires comparison between yearly results.

A more advanced method of undertaking statistically significant spatio-temporal analysis is by utilising the space-time cube (STC) method, which works by integrating spatial patterns over a nominated time-series. The space-time cube allows for results to be displayed in a 3D format, making it easier to interpret results across different time periods. First introduced in the early 1970s [70], the method has been employed across numerous industries, including studying vehicular accidents in Western Australia [71] and fire patterns in NSW [72].

Qin, Qin et al. utilised the space-time cube method in their paper looking at the evolution patterns of hotels in China between 1978–2018, coining the term 'Exploratory Spatial-Temporal Data Analysis (ESTDA)' as a way of categorising the method [73]. In consideration of the superior display of results when compared to other methods, this study has sought to employ a similar approach to this paper, albeit applying it to a smaller regional scale.

Extending from the space-time cube method is emerging hotspot analysis, which builds upon the functionality of STC and extends beyond ordinary hotspot analysis by way of identifying trends in the clustering of point densities in the STC. Whilst not having been utilised with respect to research on the hospitality industry or for venue analysis, the method is well known and has been used by both Gudes et al. [71] and Visner et al. [72] to great effect, in particular when utilised in conjunction with the 3D visualisation of STCs [71]. This study has also used the method of emerging hotspot analysis to identify how concentrations of venues may be changing over time in the study area.

1.5. Online Display

Methods of making the results interactive and publicly available were explored with respect to the study. The first option identified was a digital dashboard medium, with the second being an online 'data journalism' blog in the ArcGIS StoryMap environment [74].

Dashboards allow for the digital display of data, often in real-time, and encourage user interaction [72,75]. On the other hand, 'Storymaps' facilitate the construction of a narrative alongside the data and are better suited to communicating complex messages [76].

These two methods are not mutually exclusive and indeed operate well in unison. In consideration of the benefits of both platforms, the StoryMap format was chosen due to the ability to add substantial context to the display, which was considered to better align with this study and the intended message. The results of the study were uploaded onto a StoryMap for public access.

1.6. Research Aim

This study has sought to fill the research gaps identified above through exploring the spatial implications of public policy on the hospitality industry in Inner Sydney between the period of 2012 to 2021. The analysis has been divided into two sections. The first focusses on licensed venues as they are in 2021, identifying spatially significant clusters of

venues as relating to local government land use planning policies. The second explores the spatio-temporal patterns of licensed venues in Sydney across the time period in the context of the lockout laws and COVID-19 lockdowns. An interactive online display of the results has also been created, providing broader scope to the study.

This research is timely for the following reasons:

- The NSW Government earlier this year repealed the lockout laws entirely. As such, it is necessary to explore the full impact of the policy to assist policymakers, government regulators and industry bodies in better understanding the spatial implications of such policies targeting the hospitality sector.
- With the pandemic still underway, there is a need to better understand the effect of the COVID-19 lockdowns to assist the government in providing targeted stimulus to businesses recovering from the COVID-19 pandemic.

Based on the aim of the research, the investigation will seek to answer the following questions:

1. What is the spatial distribution of licensed venues in Inner Sydney? How does this relate to local government areas (LGAs) and land use zones?
2. How have these spatial patterns changed between 2012 and 2021?
3. Do these changes correspond with the introduction of the lockout laws and COVID-19 lockdowns?
4. How can the data of this study be visualised in a way that allows the audience to interactively explore the results?

2. Materials and Methods

This project has sought to explore land use planning restrictions, the 'lockout laws' and COVID-19 'lockdown' policies on the hospitality industry using methods based in geographical information science (GIS). Initial analysis focussed on visualising and summarising the data, with an emphasis on location relative to the variables of land use zone and local government area (LGA). Further analysis utilised methods of spatio-autocorrelation to explore the statistical significance of the venue data. Finally, the methods of emerging hotspot analysis and space-time cube visualisation were used to capture spatio-temporal patterns associated with the licensed venues. Results have been displayed online in the Storymap format to allow audience interaction. The methods described above were undertaken using the ArcGIS Pro desktop platform [77].

2.1. Study Extent

The project focusses on 13 local government areas (LGAs) within close proximity to the Sydney CBD (Figure 1). This area is referred to as 'Inner Sydney' throughout this study. The LGAs chosen are listed below:

- Bayside, Burwood, Canada Bay, Hunters Hill, Inner West, Lane Cove, Mosman, North Sydney Council, Randwick, Sydney, Waverley, Willoughby, Woollahra.

Furthermore, additional focus has been given to the Sydney CBD area, which includes the CBD and Kings Cross precincts, both of which were subject to the lockout laws. This acts as a case study and has been compared to the broader study area.

Study Extent

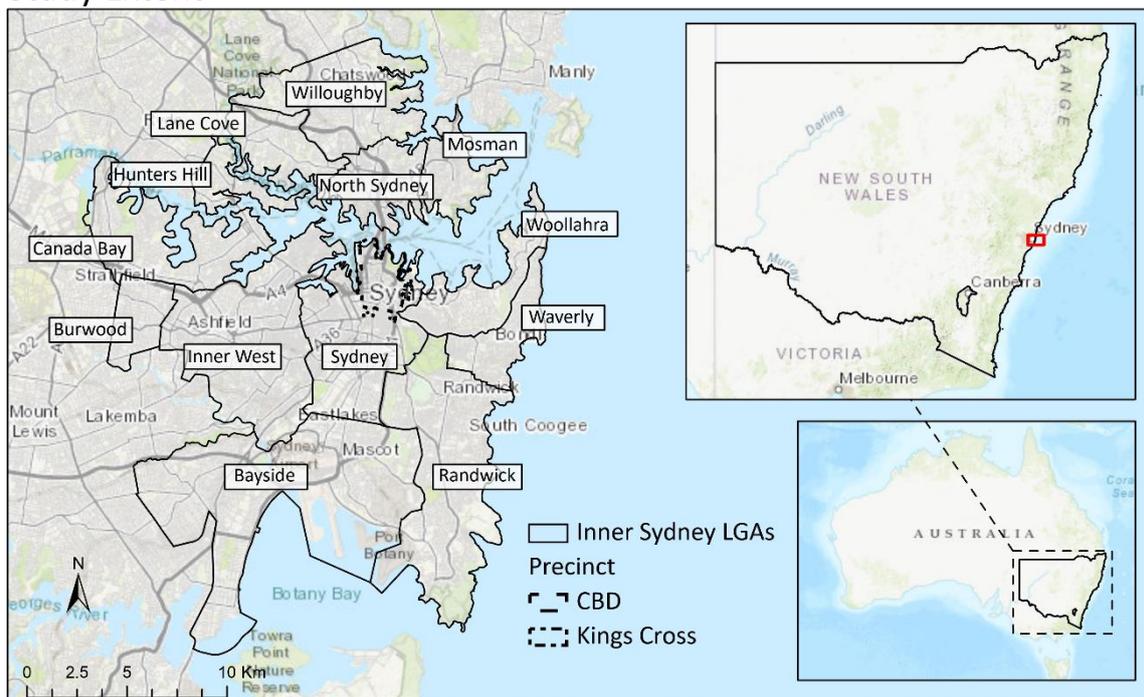


Figure 1. Study Extent.

2.2. Data

The primary source of data underpinning the study is a list of all licensed premises in NSW (17,000+), which is updated monthly by Liquor and Gaming NSW [78]. In this instance, a dataset from January of every year between 2012 and 2021 (inclusive) was used. For the purposes of this study, analysis was undertaken only on the following five licence types:

- Club Licence, Hotel Licence, On-Premises Licence, Limited Licence, Small Bar Licence.

In addition to licensed venue data, polygon boundaries of the CBD precinct and Kings Cross precinct were obtained to allow analysis on the precinct-specific level. More information on the licence types and precinct areas can be found on the Liquor and Gaming NSW website [18].

Additional spatial data were taken from several sources to assist with analysis and visualisation. This data includes:

1. *NSW Administrative Boundary Data*, which consists of a collection of legislative, regulatory, political, maritime and general administrative boundaries sourced from local and state boundary datasets within NSW [79].
2. *NSW Land Zoning Data*, which identifies land use zones and the type of development that is permitted or prohibited in each zone on any given land as designated by the relevant NSW environmental planning instrument (EPI) under the Environmental Planning and Assessment Act 1979 [80]. More information on the different land use zones can be found on the NSW Government Legislation Website [81].
3. *Australian Bureau of Statistics (ABS) Geography Standard Data*, which includes small-sized general-purpose area polygons, employed by the ABS to assist in the collation of census and other data [82].

2.3. Data Preparation

The venue data were downloaded from the Liquor and Gaming NSW website in XLSX format, which was then converted to CSV format to be used in the ArcGIS environment. Small alterations were made to the lists, including the addition of a 'state', 'postcode' and

‘year’ column, to allow for geocoding to occur. The venue data were added to ArcGIS Online and were geocoded automatically by the program. The data were then exported into a shapefile (SHP) format. It is noted that there existed a few minor errors in the geocoding, with some venues being mislocated by a few metres. For the purposes of this study, given the size of the datasets and the small percentage of errors, these were not corrected and do not have a significant bearing on the results. The venue data were added to the ArcGIS Pro map and each yearly list was combined into one large dataset to reduce the complexity of the analysis. All other datasets were added to the map. Finally, all data were ‘clipped’ to fit within the study extent area.

2.4. Spatial Analysis

2.4.1. Point Pattern Analysis

Both the LGA and land use zone layers are in polygon format, with the venue data being in point format. A spatial join was undertaken with the 2021 venues and LGA polygons to capture venue data per LGA, allowing for multivariate analysis to occur. This step was repeated for 2021 venues and land use zones. A bar chart was created showing the breakdown of the number of different venue types per LGA. This was repeated for land zoning. This was also displayed in table format and on a map giving spatial perspective to the relationship. Individual location maps were made for each venue type.

2.4.2. Spatial Autocorrelation: Getis–Ord G_i^*

Following the above step, it was necessary to undertake statistical analysis on the venue data to observe any statistically significant clustering that may be occurring. The Getis–Ord G_i^* method was chosen in this instance to undertake the analysis. The method, developed by Getis and Ord in their 1992 paper, measures the spatial autocorrelation of a variable and makes it possible to evaluate the spatial association of a variable within a specified distance of a single point [61,83]. The method works by calculating the sum of weighted points within a defined area (referred to as a ‘neighbourhood’) minus the mean, normalised by the standard deviation and corrected for neighbourhood weights. This is summarised by the formula below [61,83]:

$$G_i^* = \frac{\sum_{j=1}^n w_{i,j} x_j - \bar{X} \sum_{j=1}^n w_{i,j}}{S \sqrt{\frac{n \sum_{j=1}^n w_{i,j}^2 - \left(\sum_{j=1}^n w_{i,j}\right)^2}{n-1}}}$$

where x_j is the attribute value for feature j , $w_{i,j}$ is the spatial weight between feature i and j , and n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^n x_j}{n}$$

$$s = \sqrt{\frac{\sum_{j=1}^n x_j^2}{n} - (\bar{X})^2}$$

In this study, the feature j refers to a licensed venue, i refers to a neighbouring venue and the attribute value x_j is equal to 1, as the analysis focusses on location alone and does not consider weighted attributes.

This method, when applied across the entire map, reveals neighbourhoods that are statistically significant relative to other neighbourhoods on the map. It is considered to be a ‘local’ analysis in that it calculates a statistic for each location in the data set. It is noted that it was necessary to determine the parameters of the ‘neighbourhood’ when undertaking the analysis. Sánchez-Martín et al. determined that the ‘fixed distance’ method was most appropriate for venue locations and best captured the spatial relationship of such features,

also identifying an optimal neighbourhood distance of 6 miles, while noting that this was for rural areas with spread-out features [65].

In this instance it was left to the program to determine the optimum neighbourhood size, which resulted on average in a size of approximately 3 km (approx. 1.8 miles) for each venue type. This fits well within the distance defined by Sánchez-Martín et al., noting that this study focusses on a much smaller scale.

The points were agglomerated to an overlaying polygon to allow for analysis to occur, with SA1 regions being chosen for the overlay due to their appropriate size for the study extent, being approximately 1 km or less in width [72,84].

2.5. Spatio-Temporal Analysis

In order to understand how the distribution patterns of licensed venues have been changing over time, it was necessary to undertake spatio-temporal analysis of the data. The methods used have been discussed in detail below.

2.5.1. Space-Time Cube

To begin with, all venue data from 2012 to 2021 were combined into the one dataset. Following this, the *Create Space Time Cube By Aggregating Points* tool was used in ArcGIS Pro to explore the spatio-temporal patterns. The tool works by summarising a set of points into a Network Common Data Form (net-CDF) data structure by aggregating them into 'space-time bins' arranged both horizontally and vertically (Figure 2) [85]. In this instance there were 10 'bins' making up the vertical axis, one for each year starting at 2012 and going until 2021. Within each bin, the points are counted and the trend for bin values across time at each location is measured using the Mann–Kendall test [86,87]. The Mann–Kendall test uses the following statistic:

$$S = \sum_{i=1}^{n-1} \sum_{j=k+1}^n \text{sign}(x_j - x_i)$$

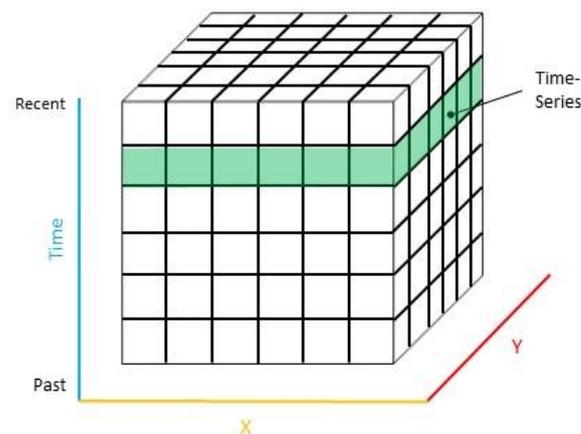


Figure 2. A space-time cube.

The statistic works by comparing the bin value for the first time period with the bin value for the second and so on up until the final bin. If the first is smaller than the second, the result is +1. If the first is larger than the second, the result is −1. If the two values are equal, the result is zero. Based on these trends an expected value is calculated for all bins, with differing results indicating statistically significant trends. Ultimately, if $S > 0$, then later observations in the time series tend to be larger than those that appear earlier in the time series, while the reverse is true if $S < 0$.

The variance of S is given by:

$$var = \frac{1}{18} \left[n(n-1)(2n+5) - \sum_t f_t(f_t-1)(2f_t+5) \right]$$

A ‘hexagon grid’ was used to agglomerate the points on the map, with a width of 400 m per cell. This size was chosen because it closely replicates the SA1 polygons, with the hexagon shape being chosen because it fits better to the undulating coastline and LGA boundaries in the study area.

2.5.2. Emerging Hotspot Analysis

As shown in Figure 3, following the creation of the space-time cube, the emerging hotspot analysis tool was used to identify hotspot and coldspot trends over time. The tool works by analysing values in the net-CDF input space-time cube using a space-time implementation of the Getis–Ord G_i^* statistic on each ‘bin’, then using the Mann–Kendall trend test to evaluate the emerging trends. Finally, each bin is categorised according to the trend it is presenting, with the main categories being new, consecutive, intensifying, persistent, diminishing, sporadic, oscillating, and historical hotspots and coldspots [88]. These have been defined in Appendix B.

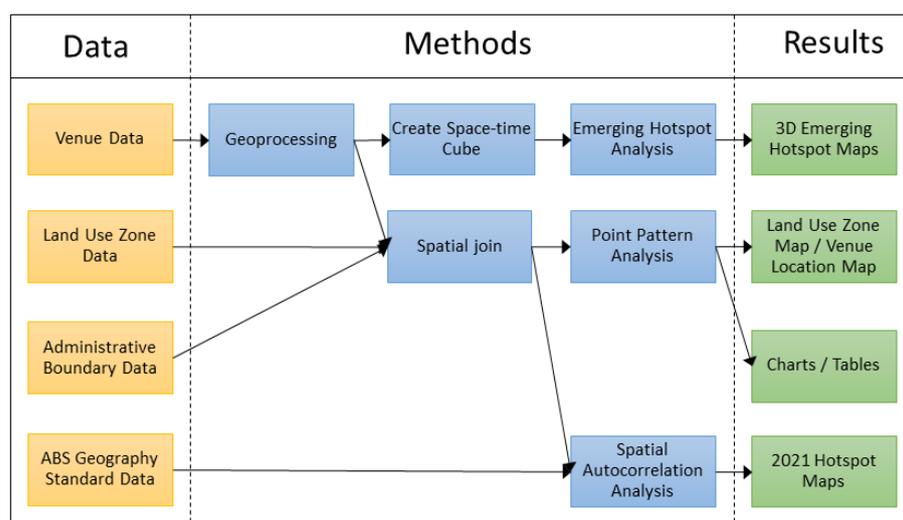


Figure 3. Methodological framework used for the main analysis.

As undertaken in the method described in Section 2.4.2 of the paper, in this instance it was left to the program to determine the optimum neighbourhood size for undertaking the Getis–Ord G_i^* calculation, which resulted on average in a size of approximately 3 km for each venue type. This is consistent with the earlier method and was considered to be appropriate for the space-time method.

Finally, the space-time cube was visualised in 3D format, showing changing hotspots and coldspots over time. This allowed for further detailed analysis beyond the 2D emerging hotspot output and provided additional understanding to the emerging hotspot analysis method. Further information on each type of hotspot can be found on Esri’s website [88].

2.6. Venues Temporarily Ceased Trading

The methods described above were undertaken based on licensed venue lists released by Liquor and Gaming NSW. It is noted however that the presence of a liquor licence does not necessarily indicate that a venue is actively trading. Whilst not available in previous lists, in June of 2020 a new column was added to the dataset showing the ‘trading status’ of a venue. This refers to whether a venue is operating or is temporarily closed.

Noting this additional data, a separate analysis was undertaken looking at the number and spatial distribution of licensed venues listed as ‘temporarily ceased trading’ in 2021. However, this was not incorporated into the core analysis. This was done to better determine the spatial impact that COVID-19 lockdowns may be having on licensed venues at the time of the study, something which may have gone unnoticed given that the dataset was limited to only recording whether a licence existed and not whether it was actively in use. The Getis–Ord G_i^* technique was applied to the data as described under Section 3.4 of the methodology. The results have been described in detail in the following sections.

2.7. Interactive Display

The results of the study were published online using The ArcGIS Storymap format [74].

3. Results

3.1. Data Summary

3.1.1. Licensed Venues per LGA

Figure 4 shows the locations of each licensed venue type in January of 2021. Each venue type is uniquely dispersed; however, there can be seen a general trend of increased density of most venue types in the CBD area, excluding limited-licence venues. On-premises venues cover most of the study area and, as shown in Table 1, are by far the most prolific licence type, there being 3358 on-premises venues. Hotels have a more central dispersion pattern, with small bars showing a distinct north-east to south-west alignment spanning from the CBD through to the southern area of the Inner West. Both clubs and limited-licence venues display a more evenly dispersed pattern across the entire study area.

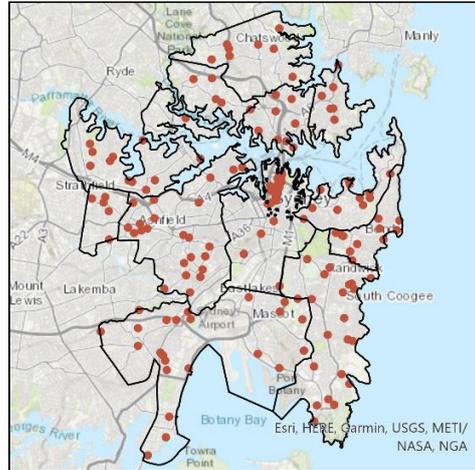
As seen in Figure 4 and confirmed by Figure 5 and Table 1, Sydney LGA has the most licensed venues at 2147, with Inner West housing the second highest number at 476 and Hunters Hill the lowest at 25 venues. It is noted that Hunters Hill is the smallest LGA and thus it would be expected for there to be a smaller number of licensed venues when compared to larger LGAs. Every LGA has at least one of every venue type excluding small bars, which are only present in Sydney, Inner West, North Sydney, Bayside and Waverly LGAs.

Table 1. Licensed venues per local government area (LGA).

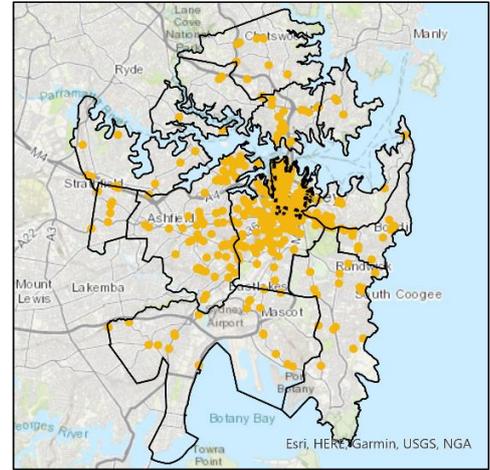
LGA	Club Licence	Hotel Licence	Limited Licence	On-Premises Licence	Small Bar Licence	Total
BAYSIDE	23	20	9	119	2	173
BURWOOD	5	8	1	63		77
CANADA BAY	11	9	8	147		175
HUNTERS HILL	1	2	1	21		25
INNER WEST	23	79	17	343	17	479
LANE COVE	4	4	3	39		50
MOSMAN	6	3	2	46		57
NORTH SYDNEY	9	22	3	271	2	307
RANDWICK	21	16	12	181		230
SYDNEY	23	337	15	1685	77	2137
WAVERLEY	12	13	4	177	1	207
WILLOUGHBY	8	7	3	155		173
WOOLLAHRA	10	22	6	106		144
Total	156	542	84	3353	99	4234

Venue Locations in 2021

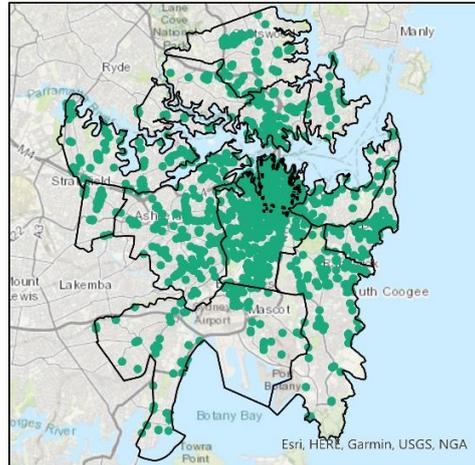
Clubs



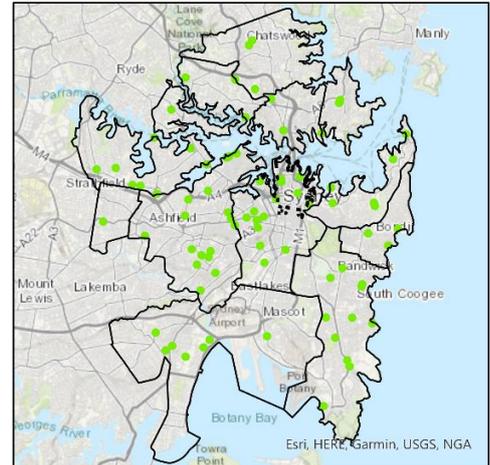
Hotels



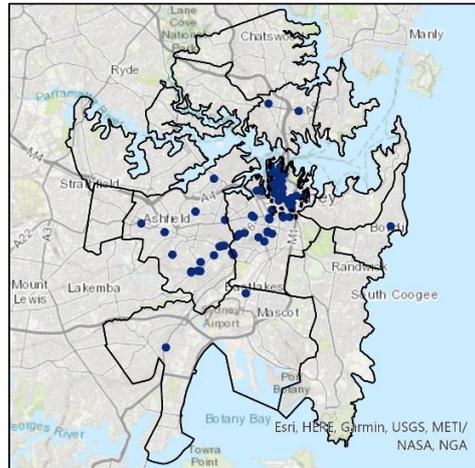
On Premises



Limited Licence



Small Bars



Licence Type

- Club licence
- Hotel licence
- Small bar licence
- On-premises licence
- Limited licence

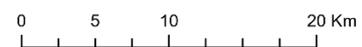


Figure 4. Venues displayed by type and LGA.

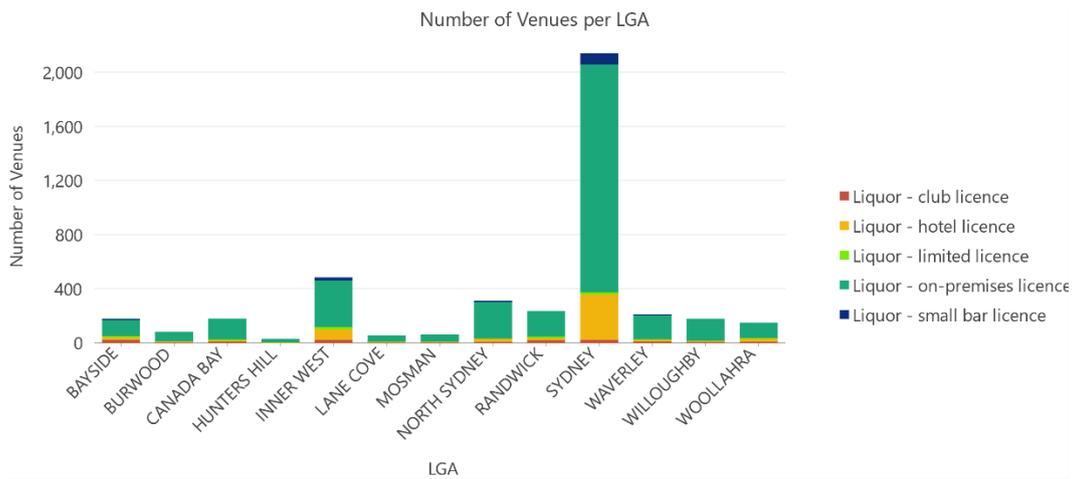


Figure 5. Number of venues per LGA.

3.1.2. Licensed Venues per Land Use Zone

Figure 6 shows the dispersal of land use zones within the study area. Sydney LGA includes a large swathe of ‘B—Business’ zones, with most other LGAs consisting of various residential zones complemented by small business areas and some industrial pockets. This is not surprising, considering the role of the CBD in acting as the commercial centre of Sydney. Bayside LGA includes Sydney Airport and Port Botany, which are represented by ‘S—Special use’ zones. It is noted that ‘IN2—Industrial’ zone is similar in colour to the ‘R1—General Residential’ zone, which may cause confusion when looking at the map and as such should be read with caution.

2021 NSW Land use Zones

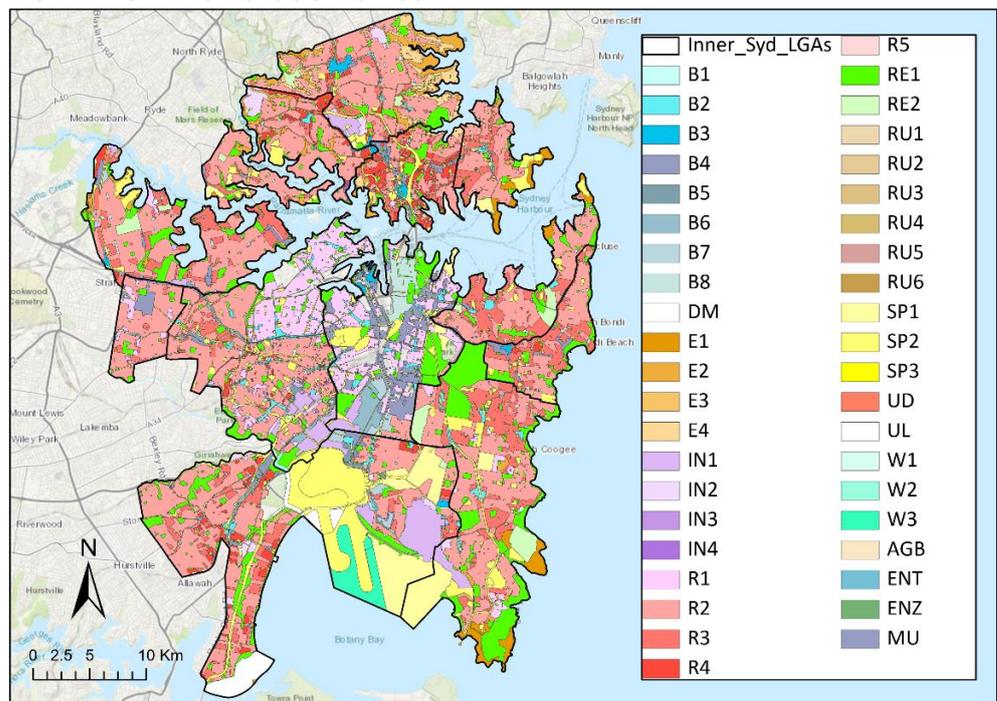


Figure 6. NSW Land use zones in 2021.

Figure 7 and Table 2 show that most venues are located within the ‘B—Business’ zones, with ‘R—Residential’ zones containing the second highest number of venues and the ‘RE2—Private Recreation’ and ‘SP2—Infrastructure’ zones also showing higher numbers

of venues. Proportionally the residential and recreation zones show a higher number of club licences when compared with B zones. This reflects the fact that these licensed clubs generally play a role in supporting communities (RSL 2021), be it sporting clubs, such as bowling clubs, or cultural clubs, such as Retired Service League (RSL) venues, and are often located in residential areas, where they are closer to their client base.

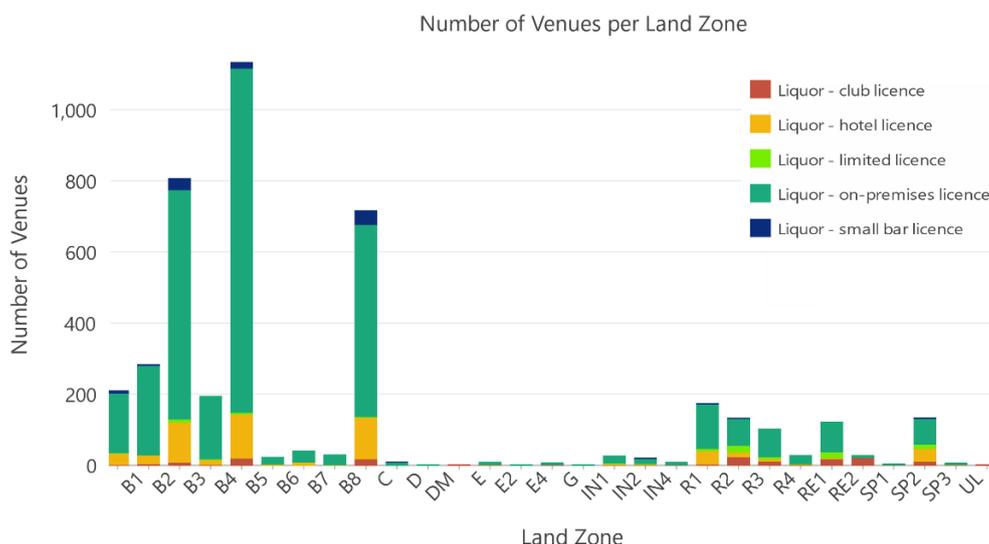


Figure 7. Number of venues per land zone.

Table 2. Licensed venues per land use zone.

Zone	Club Licence	Hotel Licence	Limited Licence	On-Premises Licence	Small Bar Licence	Total
	2	32	1	168	6	209
B1	4	25		252	2	283
B2	8	113	9	644	31	805
B3	2	14	2	176		194
B4	20	124	5	965	16	1130
B5		3		19		22
B6		9		31		40
B7		1		28		29
B8	18	117	2	540	39	716
C				8	1	9
D				1		1
DM	1					1
E	1	1		6		8
E2				1		1
E4	2			5		7
G				1		1
IN1	1	3	2	20		26
IN2	1	2	2	14	1	20
IN4	1			7		8
R1	3	38	6	125	1	173
R2	24	13	19	75	1	132
R3	12	6	6	77		101
R4	2	1	1	23		27
RE1	18	3	17	83		121
RE2	22			5		27
SP1	1			3		4
SP2	11	36	12	72	1	132
SP3	1	1		4		6
UL	1					1
Total	156	542	84	3353	99	4234

3.2. Spatial Autocorrelation

The results in sections below show the outputs of the Optimised Hotspot Analysis, which relies on the Getis–Ord G_i^* statistic, and shows statistically significant spatial clustering of venues.

3.2.1. Hotspot Analysis

Figure 8 indicates four relatively dispersed hotspots across multiple LGAs, with the largest being the northern area of the CBD precinct. One is located in the suburb of Marrickville, which is known to be home to numerous cultural and sporting clubs. Another hotspot is identified near the southern end of the Randwick LGA, with the final hotspot located in the Rose Bay area, likely reflecting several sailing clubs located on the harbour.

Club Licence 2021 - Hotspot Analysis

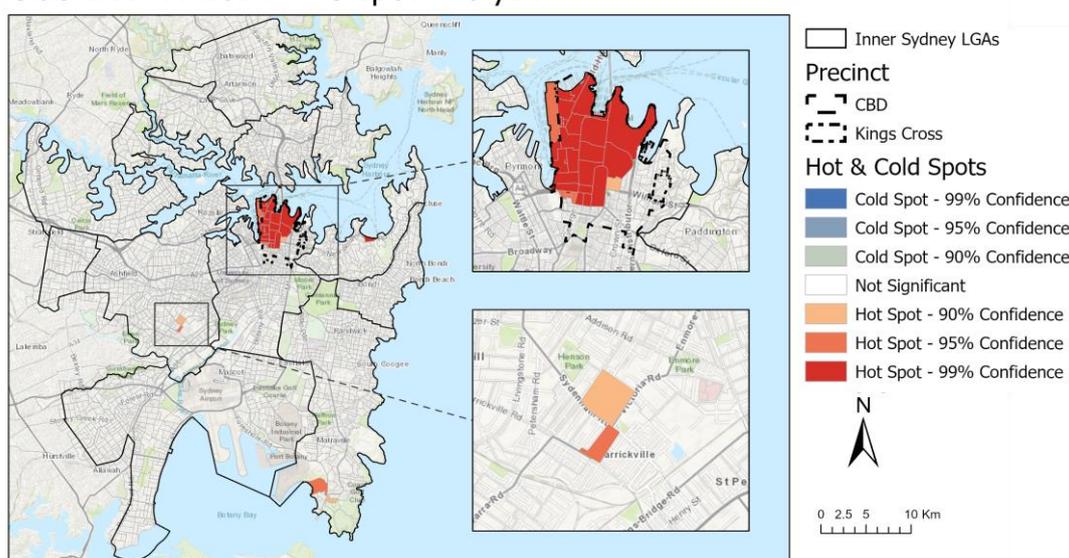


Figure 8. Licensed club hotspots 2021.

Figure 9 shows a large, centrally located hotspot encompassing most of the CBD and Kings Cross precincts, extending south to the suburb of Alexandria, east into the suburbs of Darlinghurst and Paddington and west toward Pyrmont and Glebe. There also exists a south-western tail to the main hotspot, extending through the suburbs of Chippendale and Darlington into Newtown and Camperdown skirting the border between Sydney and Inner West LGAs.

Figure 10 shows six clearly defined hotspots, with the largest located within the CBD precinct, noting that the Kings Cross precinct is not at all covered by the hotspot. Other hotspots are located in the Surry Hills area, around Glebe and Sydney University, at the northern end of King Street in the suburb of Newtown and in the suburbs of Enmore and Marrickville. These hotspots follow a north-eastern to south-western alignment and travel from the CBD to the ‘inner-west’ area, known for its small bar scene (Kelly 2021).

Figure 11 shows two hotspots, the largest of which is located in the CBD and Kings Cross precincts extending to adjoining suburbs and follows a similar pattern to those seen shown by hotel licences in Figure 11. The second hotspot is seen on the northern edge of the study area close to Chatswood train station and business area.

Hotel Licence 2021 - Hotspot Analysis

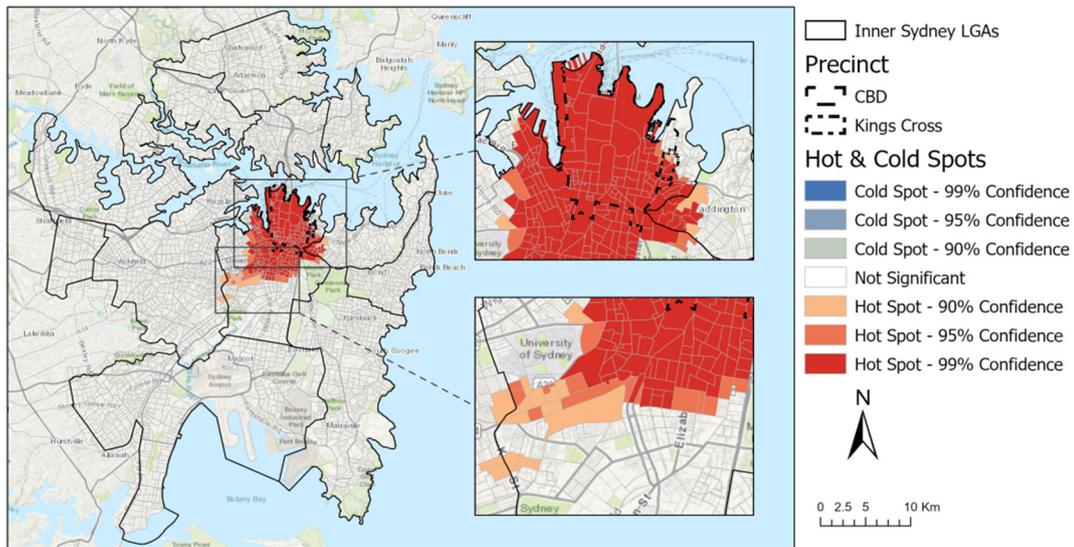


Figure 9. Licensed hotel hotspots 2021.

Small Bar Licence 2021 - Hotspot Analysis

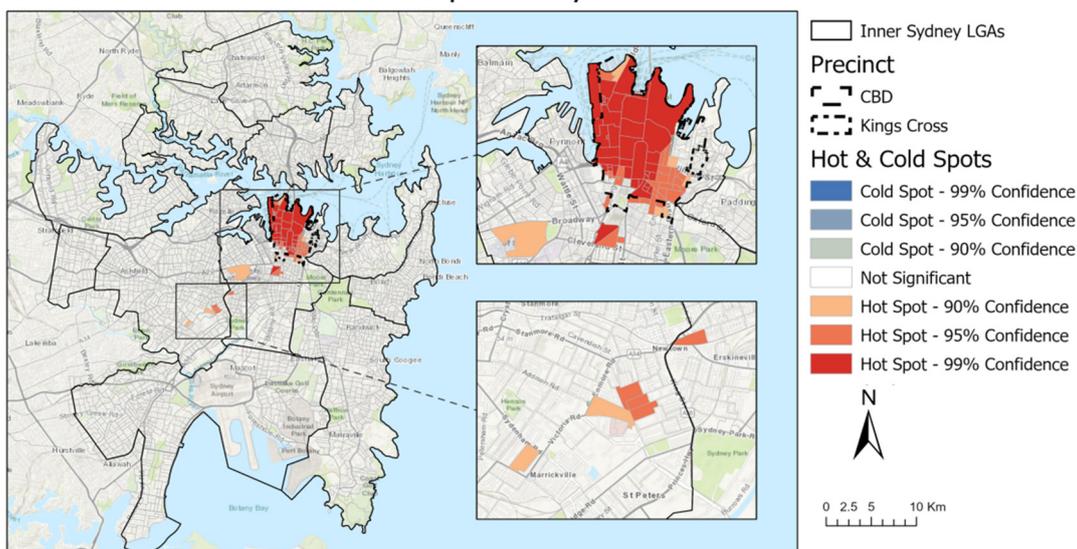


Figure 10. Small bar licence hotspots 2021.

Figure 12 shows a hotspot pattern of limited-licence venues, which differ significantly from other venue types, there being no hotspot identified in the CBD area. There exist two statistically significant hotspots, one located in Marrickville and the other in the Rockdale area. Limited licences cover a range of different uses and are restricted at the number of times they can be ‘used’ per year. The hotspot locations in this instance speak to this, with hotspots being in areas not traditionally associated with hospitality activity.

When considering the hotspots of each venue type, as seen in the previous figures, excluding limited licences, it is apparent that the northern section of the Sydney LGA encompassing the CBD precinct, Kings Cross precinct and surrounding suburbs ranks consistently as a hotspot area. This is re-enforced by Figure 13, which shows a large hotspot encompassing the northern part of the Sydney LGA. This is to be expected and reflects the role of the CBD as an economic and entertainment hub.

On-Premises Licence 2021 - Hotspot Analysis

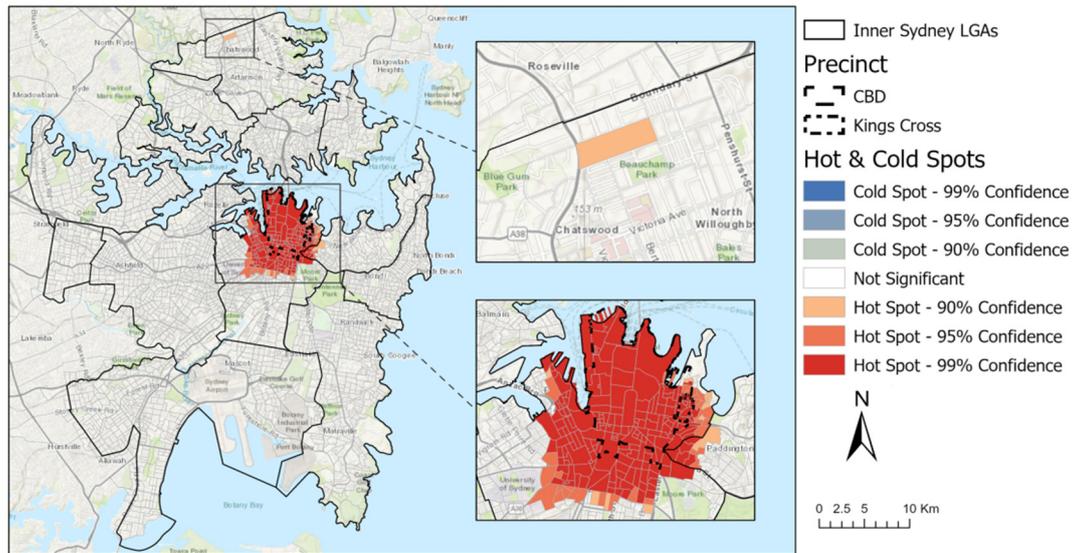


Figure 11. On-premises licence hotspots 2021.

Limited Licence 2021 - Hotspot Analysis

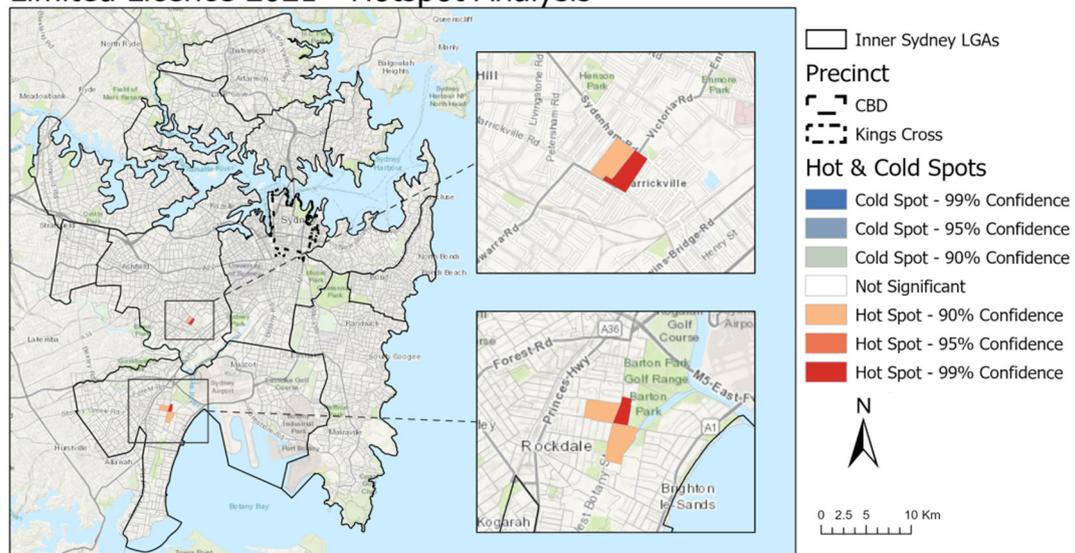


Figure 12. Limited licence hotspots 2021.

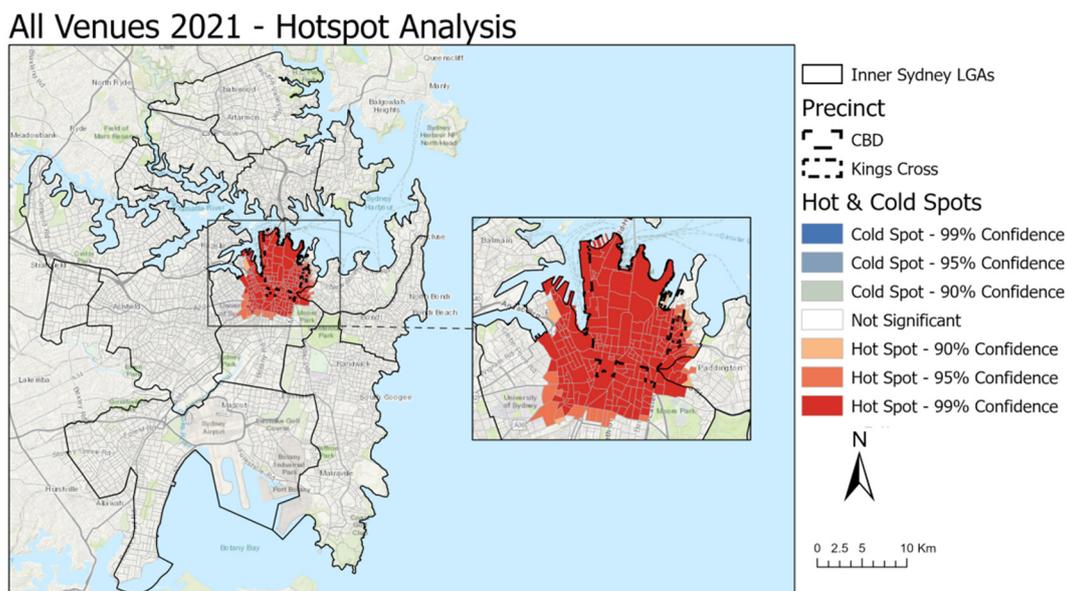


Figure 13. All venue hotspots 2021.

3.3. Spatio-Temporal Analysis

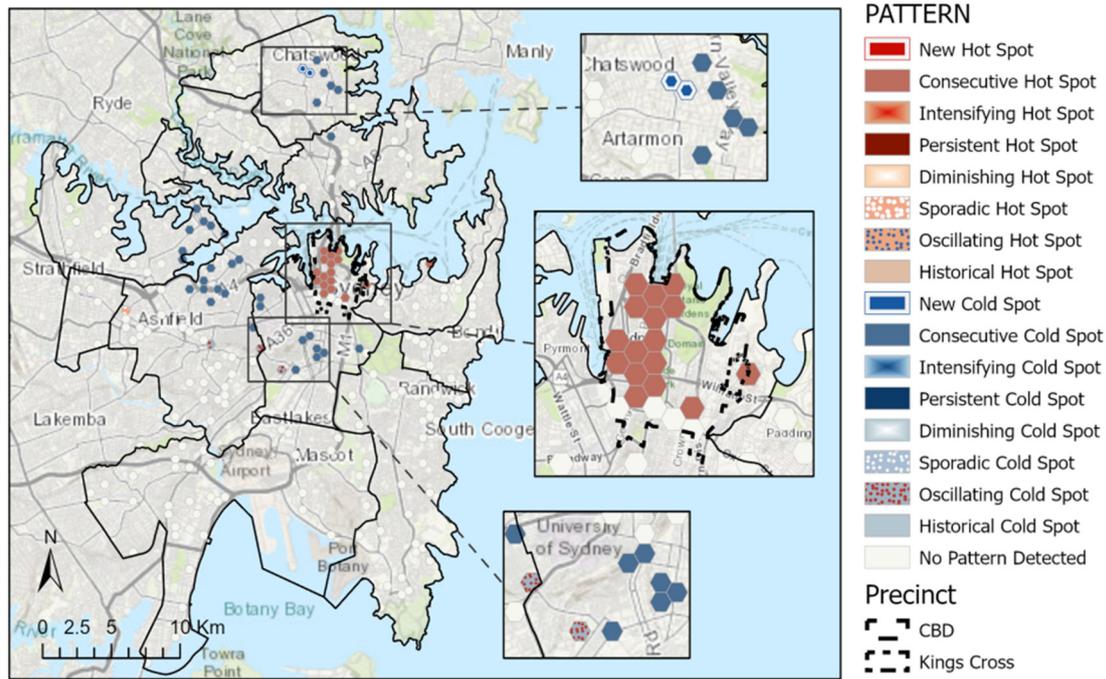
The results in the sections below show the outputs of the space-time cube and emerging hotspot analysis relying on the Getis–Ord G_i^* formula and the Mann–Kendall statistic and show statistically significant spatial clustering of venues over time. Detailed results of the space-time cubes can be found in Appendix A. Definitions of hotspot categories can be found in Appendix B.

Space-Time Cube and Emerging Hotspot Analysis

The results in Figure 14a show a consecutive hotspot area within the CBD and Kings Cross precincts, with the suburbs immediately to the south and west of the CBD showing consecutive coldspots. An emerging coldspot is seen in the Chatswood area, with Figure 14b confirming that the coldspots have strengthened over time with more emerging. Figure 14d shows a somewhat similar pattern occurring in the Redfern and Alexandria areas, showing oscillating coldspots increasing in strength over time. Figure 14c shows that the southern end of the hotspot is somewhat diminishing in significance, with only the northern CBD area remaining consistently as a hotspot throughout the time period. Overall, there is a general trend over time showing a decline in licensed clubs throughout the study area, particularly in the LGAs of Inner West, Canada Bay and Willoughby.

Figure 15a reveals that licensed hotel locations have remained relatively consistent across the time period, maintaining a strong hotspot area in the CBD and Kings Cross precincts and adjoining suburbs. The results show pockets of intensifying hotspots in the northern CBD area and near central station. Figure 15c shows high confidence in the hotspot status, with some undulation around the periphery of the central area. A consecutive coldspot has been identified in the suburb of Dover Heights, while an emerging coldspot has been identified in the suburb of Annandale and Leichardt within the Inner West LGA, shown in Figure 15d. Broadly speaking, the locations of hotels when compared to club licences have remained somewhat stable, there being a consecutive or persistent hotspot remaining in the CBD with some consecutive and emerging coldspots identified in outer suburbs.

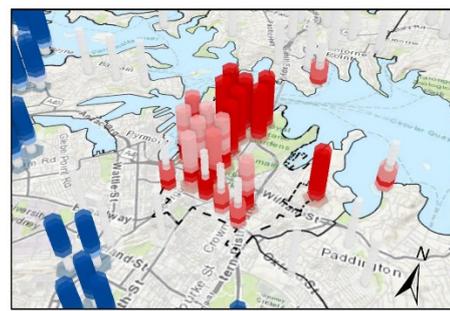
Clubs - Emerging Hotspot Analysis & 3D Visualisation



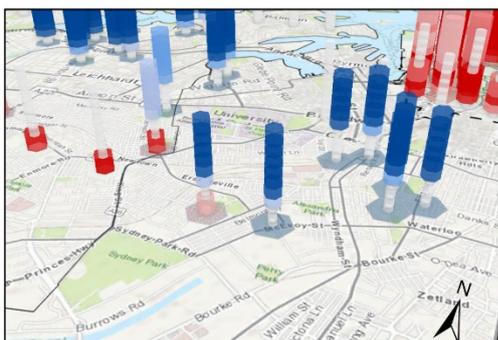
(a)



(b)



(c)



(d)

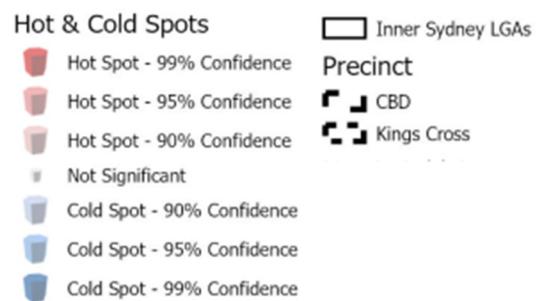
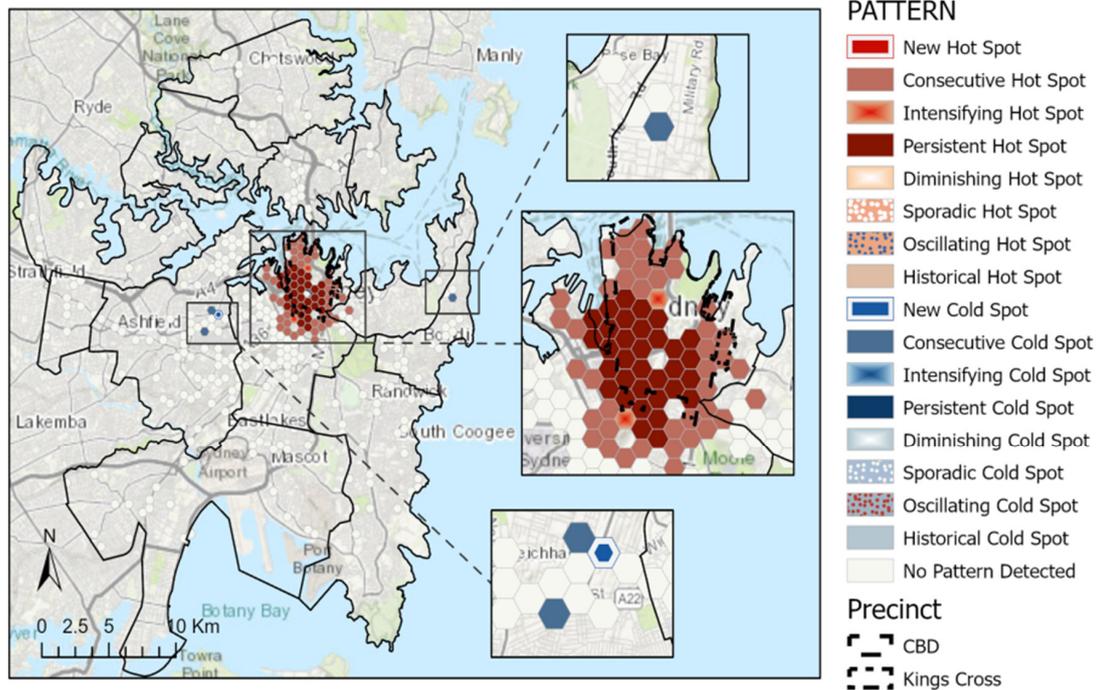


Figure 14. (a) Licensed club spatio-temporal analysis 2012–2021; (b) Club space-time cube 3D visualisation northern section; (c) Club space-time cube 3D visualisation CBD section; (d) Club space-time cube 3D visualisation southern section.

Hotels - Emerging Hotspot Analysis & 3D Visualisation



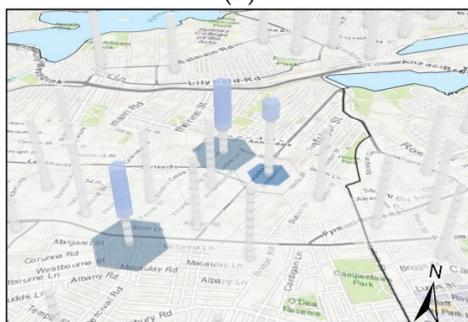
(a)



(b)



(c)



(d)

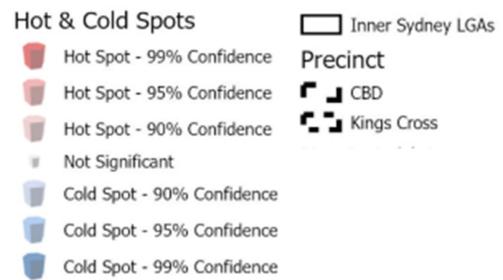
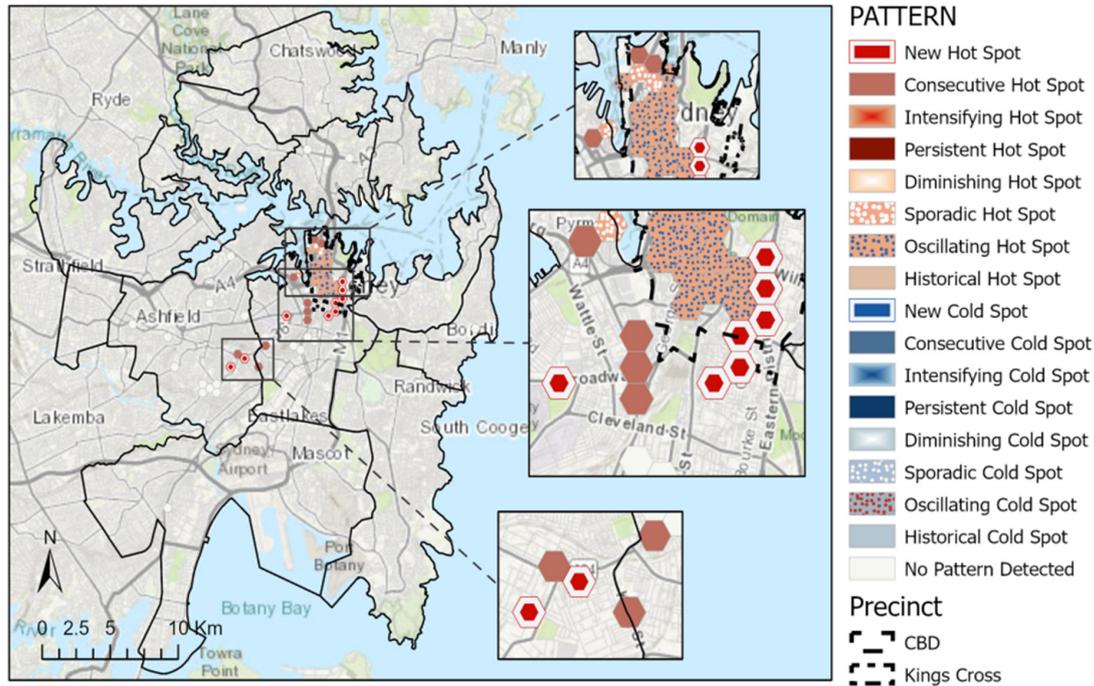


Figure 15. (a) Licensed hotel spatio-temporal analysis 2012–2021; (b) Hotel space-time cube 3D visualisation eastern section; (c) Hotel space-time cube 3D visualisation CBD section; (d) Hotel space-time cube 3D visualisation western section.

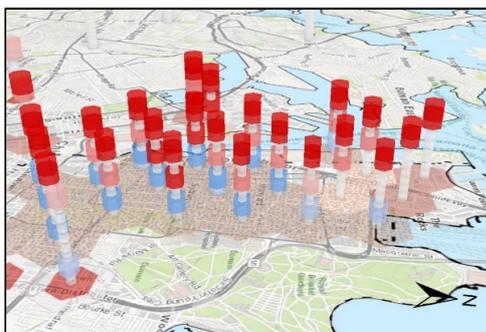
The results shown in Figure 16a indicate that the small bar scene in Inner Sydney is dynamic, undergoing significant changes in intensity and hotspot locations across the time period, with an overall trend showing strong increases in small bars across the northern portion of the Sydney LGA and part of the Inner West LGA. Figure 16b,c indicate that the CBD precinct was originally a coldspot in the period around 2014 (when the small bar

licence type was introduced), indicating slow uptake in this area. This has now changed, indicating strong growth of numbers in this region. The eastern area of the CBD precinct through the suburbs of Darlinghurst and Surry Hills shows the area to be an emerging hotspot for small bars, a trend also seen in the area along Enmore Road and Addison Road in the Inner West LGA.

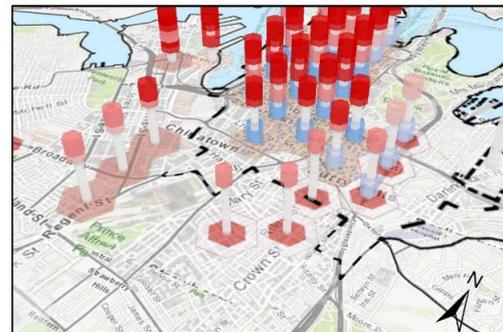
Small Bars - Emerging Hotspot Analysis & 3D Visualisation



(a)



(b)



(c)



(d)

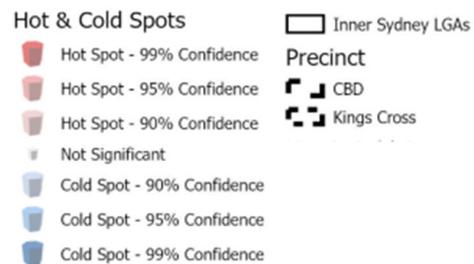
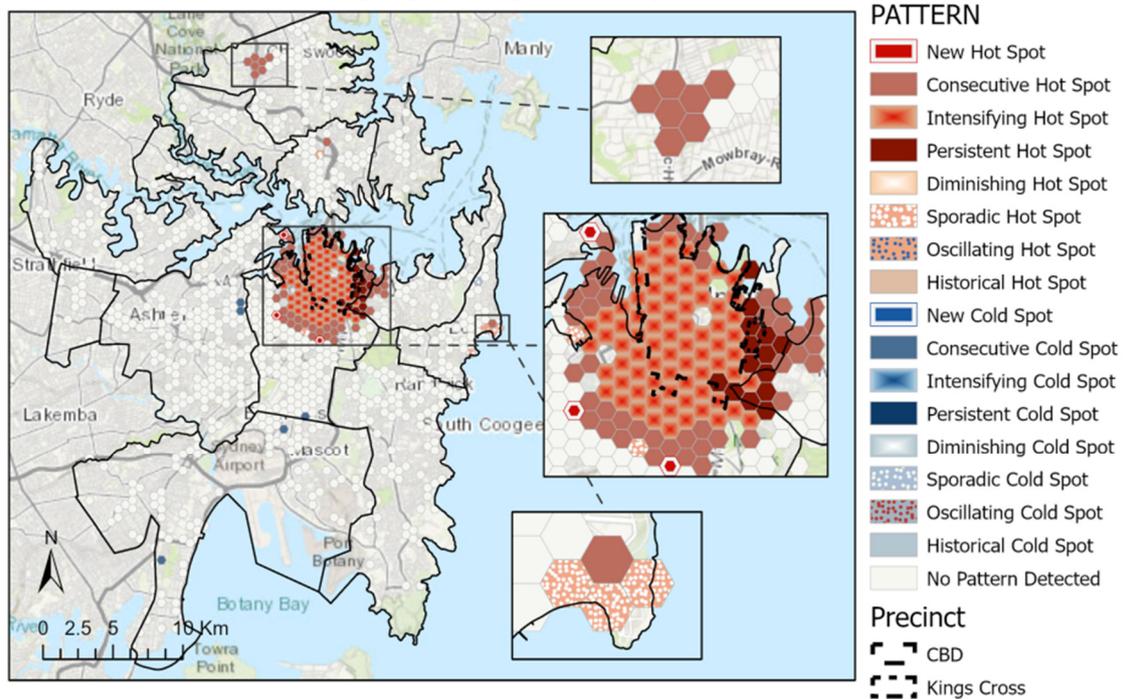


Figure 16. (a) Small bar spatio-temporal analysis 2012–2021; (b) Small bar space-time cube 3D visualisation northern CBD; (c) Small bar space-time cube 3D visualisation southern CBD; (d) Small bar space-time cube 3D visualisation western section.

Figure 17a indicates that on-premises licences are spatially dispersed across the study area, there being multiple hotspot locations. The CBD is classified as an intensifying hotspot area, indicating that the number of on-premises licensed venues is increasing in this location. There is a more stable pattern of either consecutive or persistent hotspots surrounding the CBD precinct, with Kings Cross precinct remaining a consistent hotspot. Around the periphery of the large areas one can see emerging hotspots, indicating that the area as a whole is growing in the number of on-premises licensed venues. Another hotspot is identified Figure 17b in the Chatswood area, with North Sydney in Figure 17b showing an area of oscillating hotspots indicating a state of flux for hospitality venues. Coldspots are located to the south and west of the CBD, as seen in Figure 17c, with the consecutive coldspot identified in the Mascot region possibly a result of recent redevelopment in the area resulting in the loss of licensed premises.

On-Premises - Emerging Hotspot Analysis & 3D Visualisation



(a)

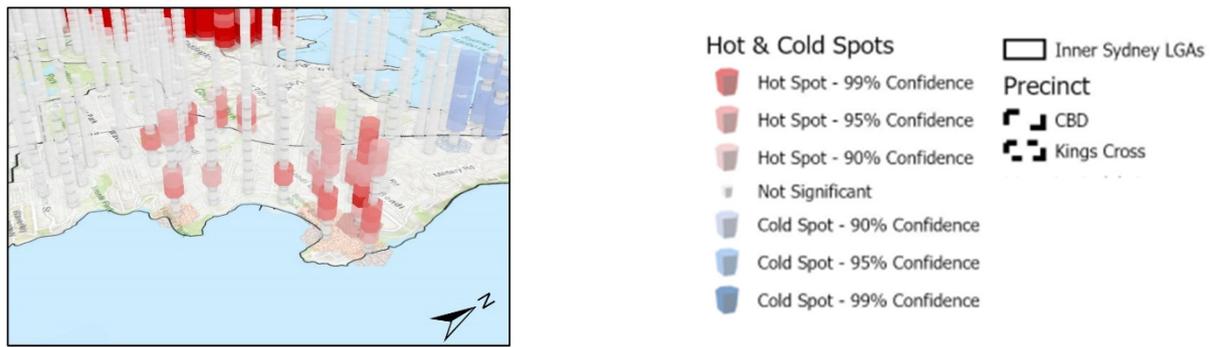


(b)



(c)

Figure 17. Cont.

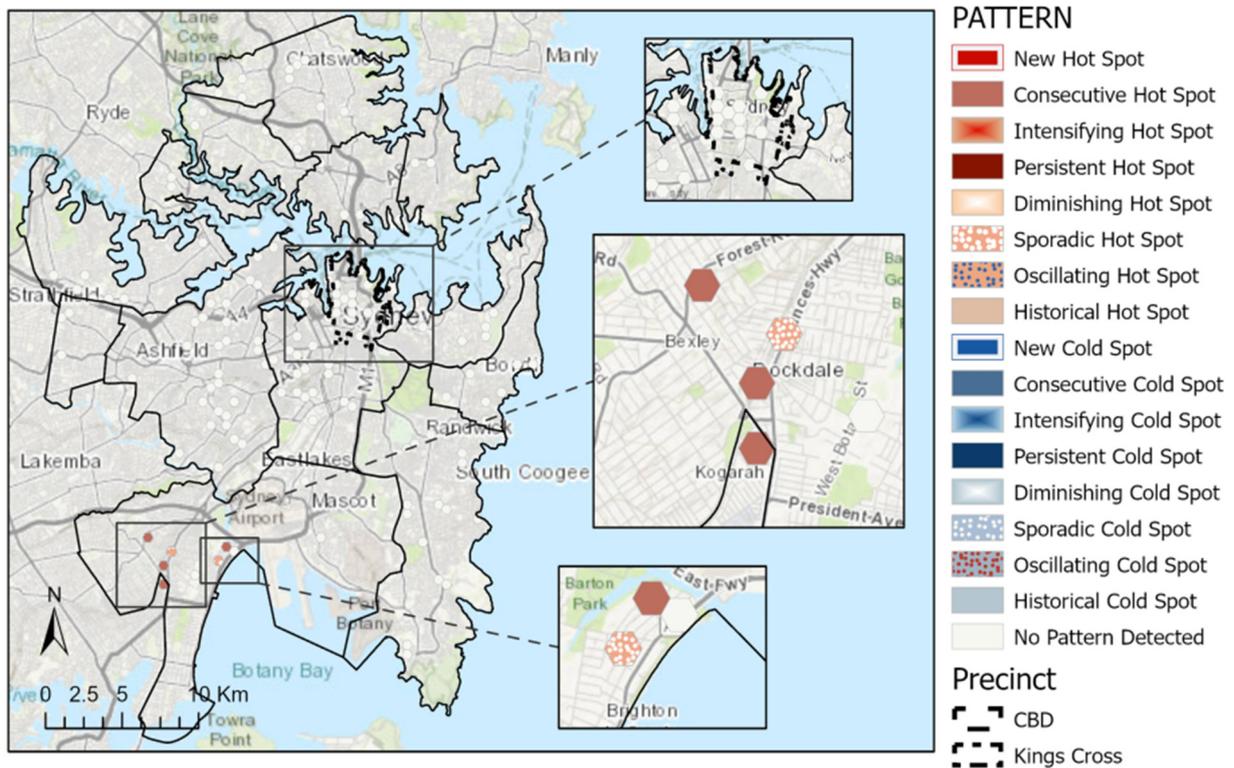


(d)

Figure 17. (a) On-premises spatio-temporal analysis 2012–2021; (b) On-premises space-time cube 3D visualisation northern section; (c) On-premises space-time cube 3D visualisation CBD section; (d) On-premises space-time cube 3D visualisation eastern section.

The analysis results looking at limited-licence venues in Figure 18a show a pattern of spatial distribution differing significantly from that of other venue types. No hotspots have been identified within the CBD or Kings Cross precincts, with two hotspots identified in the Bayside LGA. The first is located in the Kogarah and Rockdale areas, with the area showing an oscillating pattern in the earlier years of the time period, as seen in Figure 18d. The second hotspot is located close by in the suburb of Brighton-Lee Sands and shows a similar pattern, having emerged more recently as a hotspot area, as seen in Figure 18c. Limited licences often apply to celebratory venues used for weddings and parties, which are often located in scenic locations such as on the waterfront. These results support this assumption, there being a hotspot along the Cooks River.

Limited Licence - Emerging Hotspot Analysis & 3D Visualisation



(a)

Figure 18. Cont.

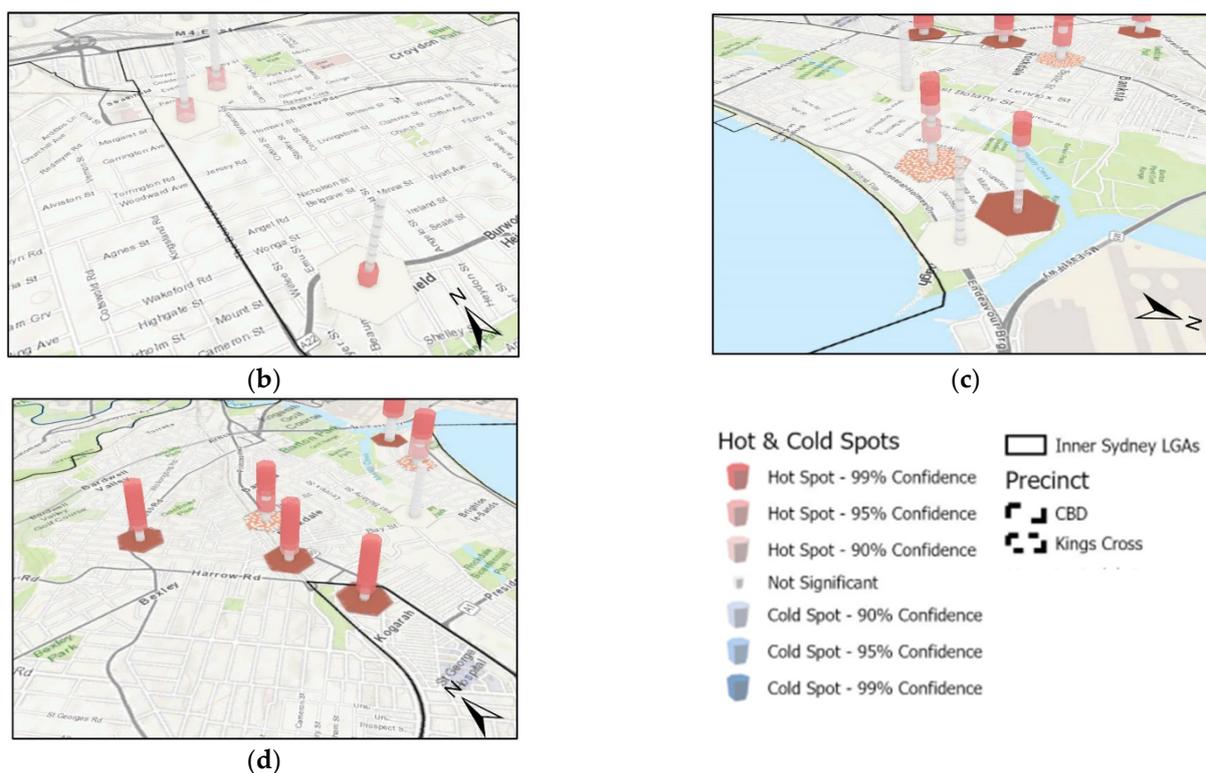
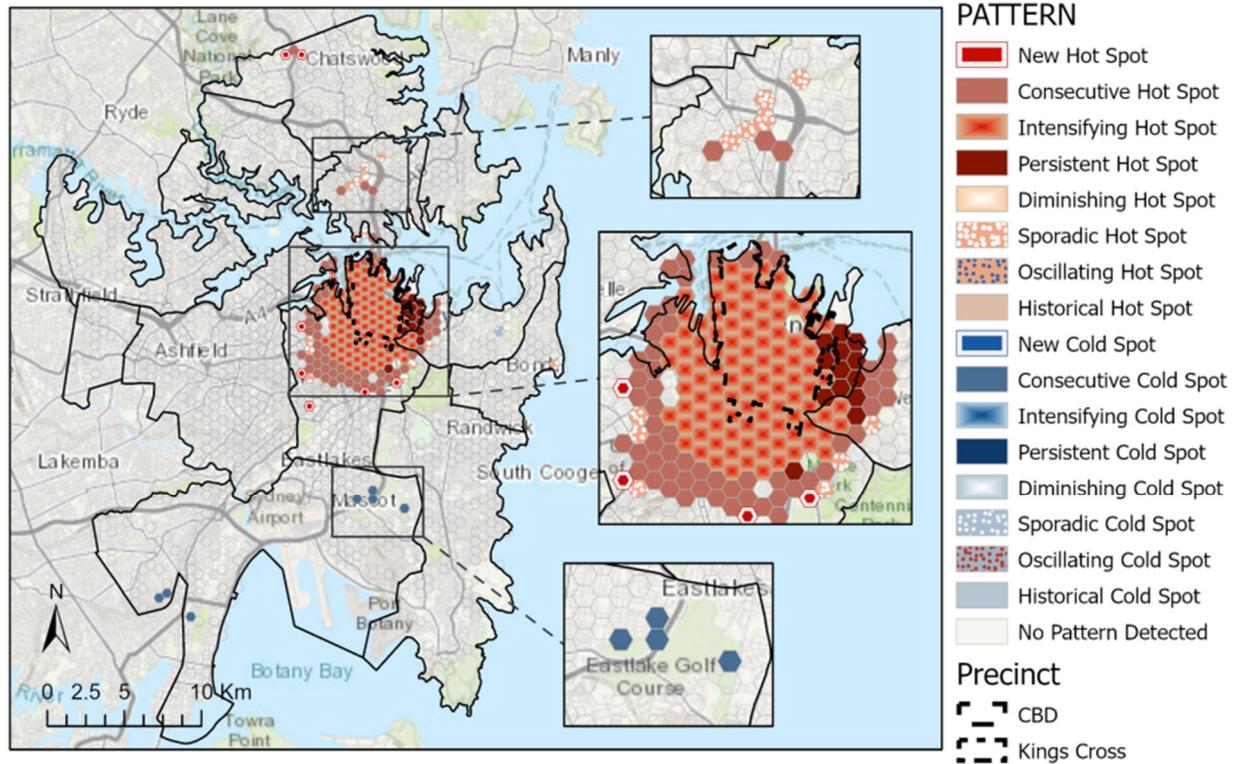


Figure 18. (a) Limited-licence spatio-temporal analysis 2012–2021; (b) Limited-licence space-time cube 3D visualisation northern section; (c) Limited-licence space-time cube 3D visualisation south-western section (1); (d) Limited-licence space-time cube 3D visualisation south-western section (2).

Generally speaking, the pattern of distribution over time of all venues collectively most reflects the spatial arrangement of on-premises licensed venues, given that these make up the largest proportion of venues observed in the study. This includes an intensifying hotspot area in the CBD precinct, with a more stable pattern of either consecutive or persistent hotspots surrounding the CBD precinct, with Kings Cross precinct remaining a persistent hotspot. Around the periphery of these areas one can see a number of emerging hotspots, indicating that growth is occurring at the boundaries. The area north of Chatswood appears as an emerging hotspot, with North Sydney in Figure 19b showing an area of oscillating hotspots indicating a state of flux for all venues. A pronounced coldspot is located south in the Mascot and Eastgardens regions shown in Figure 19d; another is in the Rockdale area. Overall, the results indicate that the inner-city area of Sydney LGA has remained a hotspot of hospitality venues, with outlying hot and coldspots appearing in outlying centres.

Figure 20 below shows the total number of venues by type within the study area for each year between 2012 to 2021. There was a large jump in the number of licensed venues between 2013 and 2014, led by a strong increase in the number of on-premises licences being issued. Also of note is the growth in small bar numbers, which have grown consistently since their introduction in 2014. It is noted that there has been a small reduction in the number of licensed clubs across the study period.

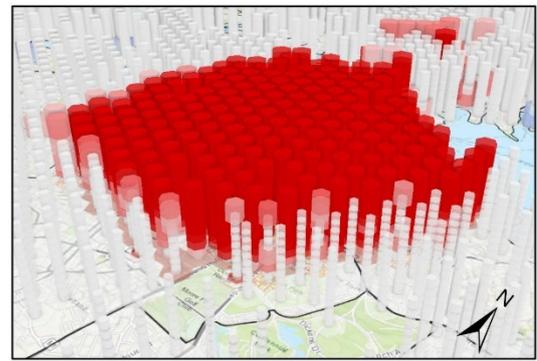
All Venues - Emerging Hotspot Analysis & 3D Visualisation



(a)



(b)



(c)



(d)

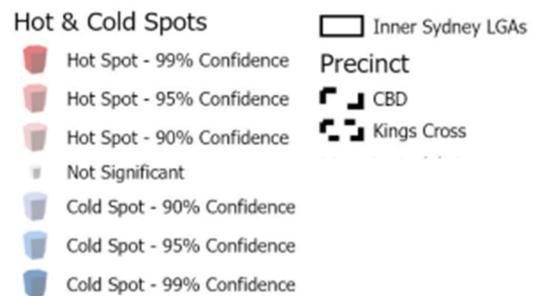


Figure 19. (a) All venues spatio-temporal analysis 2012–2021; (b) All venues space-time cube 3D visualisation northern section; (c) All venues space-time cube 3D visualisation south-western section (1); (d) All venues space-time cube 3D visualisation south-western section (2).

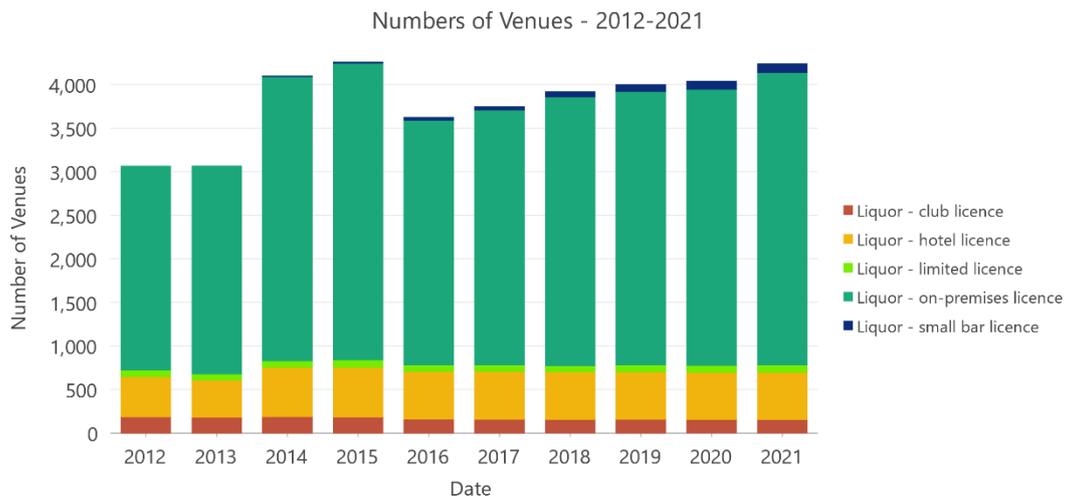


Figure 20. Number of venues by type for the entire study area 2012–2021.

Of particular interest is the large drop in the number of on-premises licensed venues between 2015 and 2016, with a less pronounced drop in hotel numbers in the same period. It is not abundantly clear why this drop occurred; however, it is noted that it happened 2 years after the introduction of the lockout laws. Following this drop, there is observed to be a steady increase in on-premises and small bar licences. There has been no discernible drop in venue numbers following the introduction of COVID-19 lockdowns. A similar pattern is followed by venues in the CBD precinct (Figure 21), showing a significant drop in venues followed by a steady increase following 2016. When looking at Figure 22, it is apparent that venues in the Kings Cross precinct observed a similar drop; however, these have not recovered since, with numbers staying stagnant between 2016 and 2021.

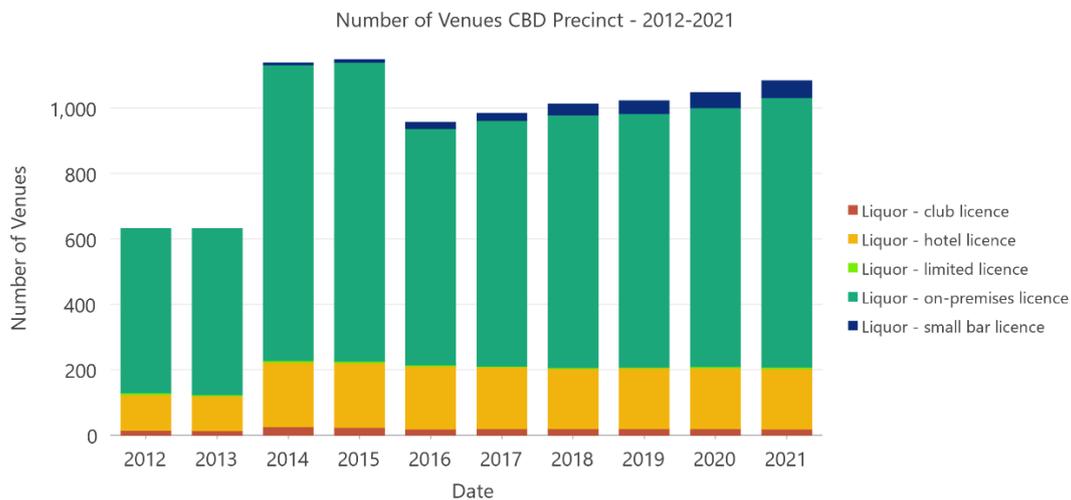


Figure 21. Number of venues by type 2012–2021 in CBD precinct.

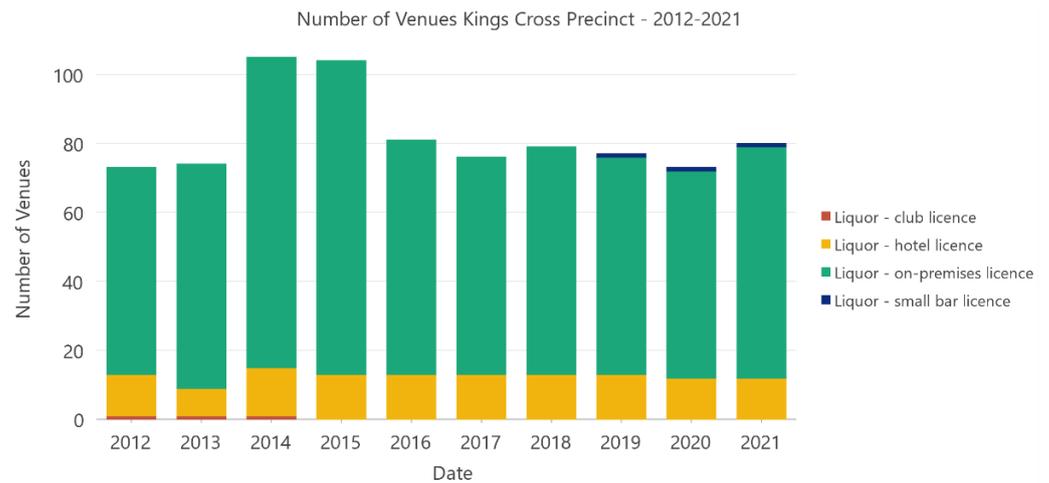


Figure 22. Number of venues by type 2012–2021 in Kings Cross precinct.

3.4. Venues Ceased Trading

As described in the methodology, a separate analysis was undertaken looking at venues listed as ‘temporarily ceased trading’ in 2021. The results can be seen in Figure 23 below.

As seen in Table 1 in Section 3.1.1, there were 4234 licensed venues listed in the 2021 dataset. Of these venues, only 4061 were listed as ‘trading’, with the remaining 174 venues listed as ‘temporarily ceased trading’. Figure 23a shows the spread of the venues across the study area, with Figure 23b revealing a statistically significant cluster in the CBD and Kings Cross precincts and surrounding suburbs. Figure 23c shows that Sydney LGA has the largest number of venues having temporarily ceased trading, followed by North Sydney.

Venues Temporarily Ceased Trading - 2021

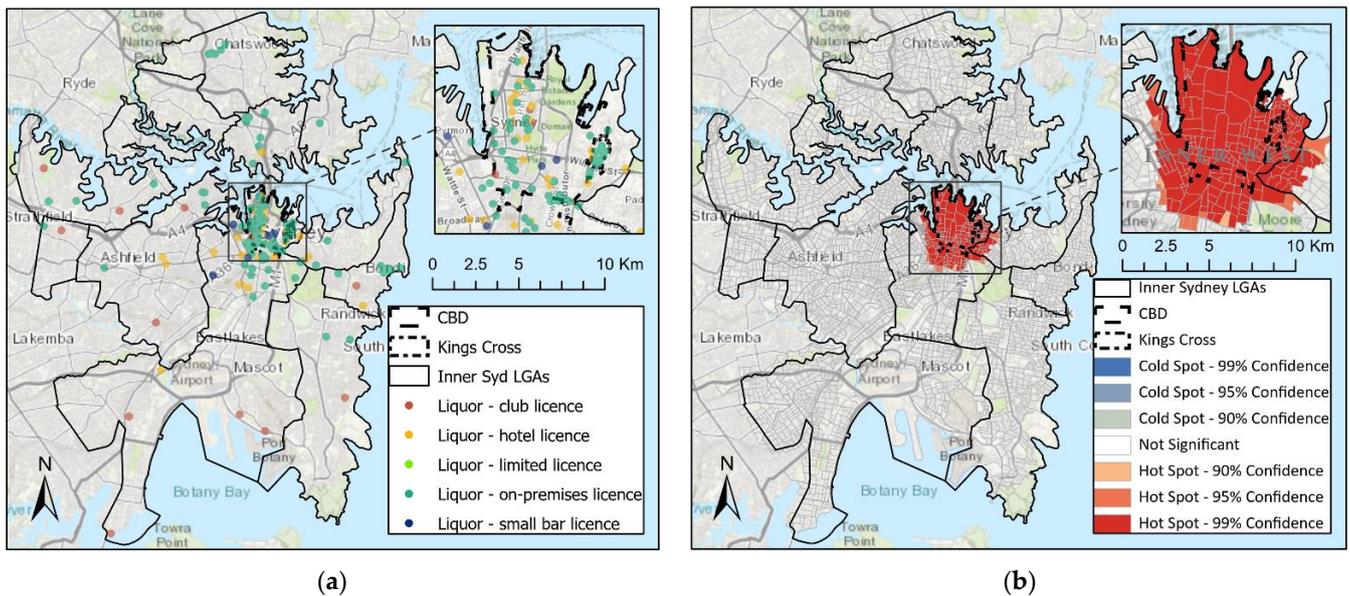


Figure 23. Cont.

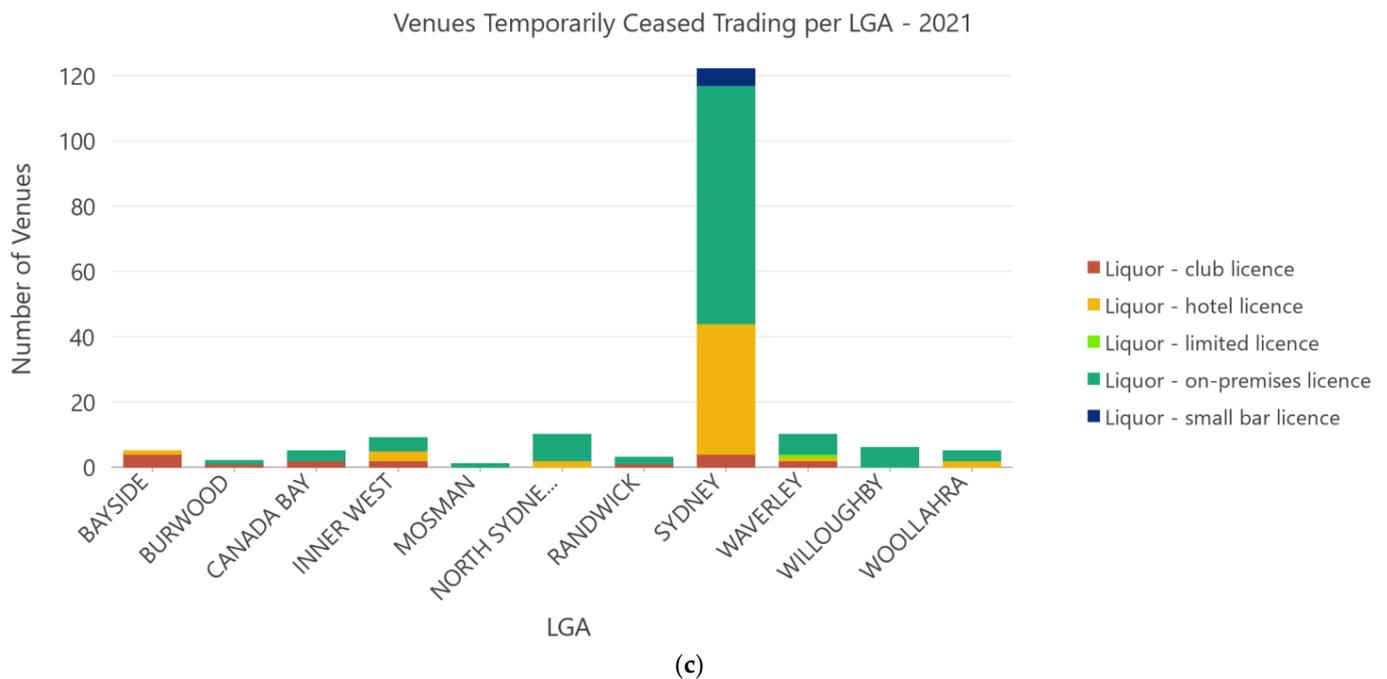


Figure 23. (a) Venues listed as having temporarily ceased trading in 2021; (b) Hotspot analysis of venues having temporarily ceased trading; (c) Number of venues listed as ‘temporarily ceased trading’ by type and LGA 2021.

When comparing Figure 23c to Figure 5 in Section 3.1.1 of the report, it is noted that there is a disproportionate number of hotels, clubs and small bars that have ceased trading when compared to on-premises licensed venues, particularly in Bayside, Sydney and Inner West LGAs. This may be due to the nature of the lockdowns, which sought to limit public movement and stop people from attending most hospitality venues, while allowing takeaway sales of food and alcohol. On-premises licences often apply to restaurants and as such it is likely that more remained open for takeaway business, with the other venue types choosing to suspend trading due to a close-to-total loss of business.

3.5. Online Storymap

The results of this study were uploaded online to Esri’s Storymap platform. Figure 24 demonstrates the capabilities of the Storymap platform, which allows users to interact with the data using pop-ups. This is publicly available and can be viewed at: <https://storymaps.arcgis.com/stories/5e649205813348faa59eb2f5efd855e2> (accessed on 1 October 2021).

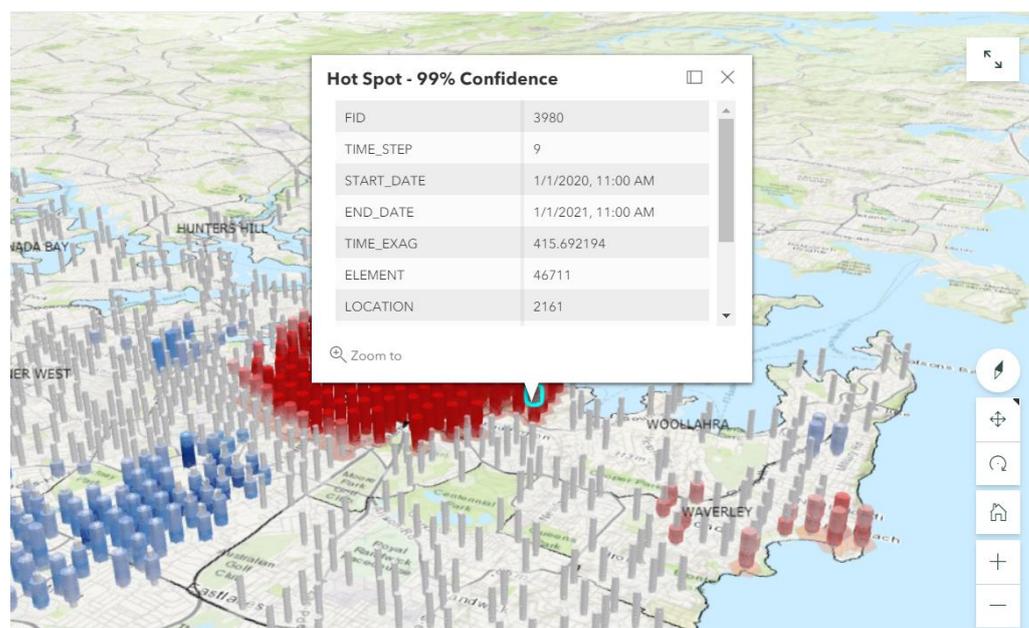


Figure 24. Storymap user interface.

4. Discussion

4.1. Research Findings

4.1.1. Spatial Distribution of Venues and Relationship to LGA and Land Use Zone

The literature exploring venue distribution patterns suggested that venues tend to cluster spatially [55,58,62,63]. The results of this study concur with these findings, indicating that venues in Inner Sydney are spatially clustered, with most statistically significant clustering occurring in the inner-city CBD area and outlying clusters occurring in surrounding areas such as the Inner West, North Sydney, Bondi, Rockdale and Chatswood depending on venue type. Utilising the optimised hotspot method, the neighbourhood bandwidth parameter chosen through the optimisation process was consistent with the literature outlining the appropriate distance for venue analysis utilising the Getis–Ord G_i^* technique [65], which supports the validity of the method undertaken.

The results from the study show that the Sydney local government area (LGA) is home to the largest number of licensed venues in the study area, far exceeding the number within other LGAs. This is somewhat expected given Sydney’s status as a global city, where such industries tend to cluster around the city centre. It may also be a result of the progressive approach Sydney LGA has adopted toward supporting the hospitality industry and the night-time economy [49]. Inner West and North Sydney LGAs were second and third in terms of venue numbers (Figure 5).

With respect to land use zoning, most venues are located within the ‘B–Business’ zones, with others in residential, recreational or special use zones. This reflects the pattern of zoning in the city, with most business zoning occurring in the CBD area, which is home to the largest number of venues. There exists an obvious relationship between venue numbers and business zoning (Figure 9), which re-enforces the function of land use planning as a city-shaping tool [89]. This information is helpful for councils when deciding how they zone land, particularly if they intend to encourage growth in the hospitality sector in their area. Further research across the time period looking at development applications would reveal application hotspots and would assist in further understanding the impacts of zoning on development and industry.

4.1.2. Trends over Time: 2012–2021

Acknowledging these spatial patterns, this study sought to identify trends in spatial distribution occurring over a 10-year timeframe between 2012 and 2021. The space-time

cube and emerging hotspot methods were used to explore this question, following a similar approach to other research identified in the literature [71–73], noting that no such study has been undertaken using these methods with reference to licensed venues in Sydney, Australia, during the time period.

The results, when compared to previous papers using traditional hotspot methods, provide greater insight into how changing patterns may be defined, such as emerging hotspots or consecutive coldspots as an example. The explanatory nature of the emerging hotspot method and results support its use in future studies. Across the time period, the results indicate that the Sydney LGA, in particular the CBD precinct and surrounds, has remained a consistent hotspot area in some form, whether this be consecutive, persistent, sporadic, oscillating or emerging. Conversely to this, the Mascot and Rockdale areas in Bayside LGA have been identified as coldspot areas for most venue types. This may be due to the fact that these areas are largely zoned as residential areas (Figure 6). Other areas including Randwick, Waverly and Woollahra LGAs in Sydney's east, LGAs further west such as Burwood and most LGAs on the northern side of the harbour show either no hotspots or no coldspots, with only North Sydney and Willoughby LGAs showing hotspots depending on venue type. Absence of hotspots or coldspots over time does not necessarily indicate that there has been no change in venues numbers in these areas. However, it does indicate that these areas do not have a statistically significant concentration of venues (or lack thereof) to constitute a hotspot or coldspot. It is noted that results vary between individual venue types.

Hotel licences show little variation across the time period, with the inner-city area identified as a persistent hotspot. An emerging coldspot is identified in the Inner West LGA (Figure 16). On-premises licensed venues followed a similar pattern (Figure 19), with much of the CBD being identified as an intensifying hotspot, Chatswood in Willoughby LGA identified as a consecutive hotspot and coldspots being identified in Annandale in the Inner West LGA and Mascot in Bayside LGA.

Such hotspots strengthen the inner city's reputation as a cultural precinct, with hotspots in Chatswood speaking to the emerging food scene in the area [90]. The coldspots identified in the south-east, including the Mascot and Rockdale areas, may be a result of the development cycle currently underway, with Mascot and to some degree Rockdale having undergone a period of significant re-development over the 10-year period [91], which may have resulted in the loss of venues.

Small bar licences have shown strong growth over the time period, with consecutive or emerging hotspots occurring in the CBD precinct, Surry Hills and in the Inner West areas of Newtown, Enmore and Marrickville (Figure 18). Conversely, excluding in the CBD precinct, licensed clubs have been seen to decline, particularly in the areas surrounding the CBD and to the north in Willoughby LGA (Figure 16). This speaks to the declining role clubs play in NSW [92], with many being redeveloped for other uses [93]. It is noted that, by comparison, many of the areas identified as consecutive or emerging coldspots for clubs have been identified as consecutive or emerging hotspots for other venue types, indicating the continuation of the cultural shift away from traditional drinking establishments toward more modern venues, as identified in the literature [13].

Limited licence venues showed a distinct pattern differing from other types, showing hotspots in the Bayside LGA (Figure 20). This is different from most other venue types and speaks to the variation in restrictions placed on this licence type when compared to other licences. It could be argued that this type of licence does not operate within the same 'specialised industry' as other venues in this study, instead offering alternative uses, and thus does not follow similar patterns of conglomeration [63,64].

4.1.3. Impact of Lockout Laws and COVID-19 Lockdowns

Previous research and media attention suggested that the lockout laws targeting the CBD and Kings Cross precincts had a negative impact on the area, resulting in the closure of venues [21,26,30,31]. However, no such study had been undertaken looking at the

impacts from a spatio-temporal perspective. This study sought to fill this gap through spatio-temporal analysis methods.

The results reveal there was a significant drop in the number of licensed venues in the CBD and Kings Cross precincts between the years of 2015 and 2016 (Figures 21 and 22), occurring within two years after the introduction of the lockout laws. These results are supported by economic analysis undertaken by the City of Sydney, which indicates that the policies have led to a potential opportunity cost of 2202 jobs and \$1.4 billion in turnover during the period [94]. However, when compared to results showing the drop of venue numbers across the whole of Inner Sydney (Figure 20), it is apparent that the drop in venue numbers within the precincts was proportional to the drop across the entire study area. This is contrary to what was expected from the literature and media discourse.

It is unclear what may have caused this reduction; it is possible that the lockout laws had some impact. However, the results indicate that it was not localised to the precincts subject to the lockout laws. The spatio-temporal analysis supports this, with the CBD precinct and to a lesser degree the Kings Cross precincts having been consistently identified as hotspot areas across the time period when compared to the broader study area, contrary to what was expected.

In the period following this drop, the CBD precinct saw growth in venue numbers (Figure 21) following a trend similar to that in the broader study area (Figure 20). However, the Kings Cross precinct has not experienced any growth in new venues during this period (Figure 22). This indicates that the precinct has not recovered as well as the CBD or larger study area, somewhat reinforcing reports that the area has lost its identity [32]. It is evident that the geographical nature of the lockout laws has had direct spatial implications on the distribution of venues, with the Kings Cross precinct struggling to recover following their cessation. However, it is interesting to observe that the Sydney CBD precinct, also the target of the laws, has not been similarly affected. Further research may seek to understand why Kings Cross has struggled to recover from the laws when compared with the CBD precinct and broader study area.

With respect to the COVID-19 lockdowns, research and media attention similarly suggested that venues were being impacted or were closing as a result of these measures [36–38]. In particular, reports suggested that this impact may have been greater in the CBD area [45–47]. Our results indicate otherwise: there has been no discernible drop in the number of licensed venues following the introduction of lockdowns in 2020 (Figure 23), nor has there been any significant changes to the spatial distribution of venues in the study area, with the CBD area appearing as an intensifying hotspot for all venues (Figure 23).

Notwithstanding this, it is noted that analysis of the data revealed that 174 venues were listed as ‘temporarily ceased trading’ in the 2021 dataset. While it is not possible to compare these results with those from previous years because the datasets did not list the trading status of venues, it is thought that the high number of venues listed as having temporarily ceased trading may in fact be related to the COVID-19 lockdowns. The impact has been felt disproportionately in the Sydney LGA, with hotel licences being overrepresented compared to other venue types (Figure 23). Economic data confirm this trend across NSW [95] and in particular the Sydney CBD area [96]. Spatial analysis shows that these venues are clustered in the CBD and Kings Cross precincts and surrounding inner-city areas. As such, whilst these results are not definitive, in some respect the previous research and data [45–47] suggesting that hospitality businesses in the CBD area are being particularly impacted by the lockdowns has been confirmed.

It can therefore be concluded that, whilst not targeted geographically, the lockdowns have also had spatial implications on venue distributions, with the CBD suffering particularly more than other areas. This, when the lockout laws and their impacts are also taken into consideration, indicates that the geographical application of policies is not solely responsible for their impact, but rather that it is the nature of the policies themselves and the underlying restrictions that will impact different areas in different ways.

Further research is needed to determine whether the pandemic-induced lockdowns will have a lasting impact or whether they will only represent a temporary response to the lockdowns.

4.1.4. Storymap Display

One aim of the study was to identify how the results of the study could be visualised in a way that allows the audience to interactively explore the results. Figure 24 demonstrates the result of uploading the study to the Storymap platform [74], with interactive displays allowing viewers to directly query and explore the data and results. The type of display will facilitate better interaction between industry and government bodies and the results of this study, facilitating greater interaction between industry and research and the communication of results, as suggested in the literature [76]. Future research could add dashboard capabilities to the research to allow further interaction to occur [75].

4.2. Limitations and Further Research

Some limitations were identified in the research and have been addressed below. This study has described the spatio-temporal evolution of the hospitality industry in Inner Sydney and has drawn parallels to relevant policy timelines. However, it has not quantitatively demonstrated a connection to these variables. The development of a future framework, as suggested by Qin, Qin et al. [73], would assist in providing greater assurance to the results of this study.

Numerous factors can influence venue locations, including population [58], agglomeration benefits [63] and transport infrastructure [55]. It is noted that Liquor and Gaming NSW have complete control over the issuing of liquor licenses and possess the ability to restrict the number of licences that are issued, including the ability to place a freeze on the issue of licences in the Kings Cross and CBD precincts [17]. It may be that this freeze was the main contributor to the reduction in licence numbers following the lockout laws. Furthermore, working-from-home policies enacted by non-government employers may have resulted in fewer people working in the CBD during the pandemic, which has likely indirectly affected the revenues of venues in this area and resulted in temporary closures. Future research may seek to conduct interviews with the Liquor and Gaming authority along with CBD employers to further explore this process and its effect on venue locations.

It is possible that the conclusions drawn in this study relating to LGAs and land use zones may also be the result of an unidentified variable.

More in-depth, statistically robust multi-variate analysis looking at many factors would provide greater context and understanding to the question why venues in Inner Sydney locate where they do. Such a method that may be used could be geographically weighted regression (GWR) at the static time scale [97] or geographical and temporal weighted regression (GTWR) across a time series [98,99].

Different approaches analysing the impact of lockout laws and COVID-19 lockdowns on the hospitality industry may include looking at alcohol expenditure in the region using methods similar to Leung et al. 2019 [100], or using pedestrian mobility trends [43] to understand pedestrian movement in these areas. Further research may also be undertaken following an approach similar to that in this paper, but which instead looks specifically at 'live-music venues' and builds upon the previous research in this space [21,68].

This study has used licensed venue data to identify venue locations, with the assumption that they are operational. However, it is clear that some venues may have temporarily ceased trading without relinquishing their liquor licence. Given that the datasets prior to 2021 did not include this information, it is impossible to discern with accuracy whether there were other venues which were 'temporarily closed' in previous years. This should be noted when interpreting the results.

It is noted that the 2021 dataset also included information on the number of patrons, closing times and number of electronic gaming machines. Further detailed analysis could

be undertaken with respect to these phenomena, which would significantly enrich the analysis undertaken in this study.

By restricting the study extent to thirteen LGAs within close proximity to the Sydney CBD, venue data from surrounding outer-ring LGAs was excluded from analysis and thus the results toward the edges of the study area may not be entirely accurate, an occurrence often referred to as the edge effect [57]. Future research undertaking analysis across the entire city would show trends occurring across outlying LGA areas and would have broader application across a range of policy settings not addressed in this paper.

The study results indicate that the COVID-19 lockdowns have impacted the hospitality industry, though it is too early to determine the extent of impacts with conviction, noting that Sydney is experiencing additional lockdown measures in 2021 at the time of writing [101]. Future research may seek to follow the method employed in this study to confirm the results when enough time has passed since the pandemic.

When selecting the data, study extent and method parameters, care was taken to base these choices on evidence and previous work [102,103]. Notwithstanding this, it is possible that if different choices had been made during the study, the results may have been slightly different [104]. Future studies may use alternative parameters to compare results.

5. Conclusions

This is the first study to use GIS methods to investigate the spatio-temporal patterns of licensed venues in Sydney in the context of the policies addressed above. The results of this study build upon previous research exploring the lockout laws, COVID-19 lockdowns and land use planning, and will assist in framing the discussion surrounding the geospatial impacts of the aforementioned policies on the hospitality industry. Furthermore, the paper is unique in that it introduces the space-time cube (STC) method to venue distribution research in Australia. The application of this methodology on a small-scale area and with the associated parameters used in the method is novel to the field and provides a framework for future studies to follow.

From a practical perspective, the findings of this study will assist policymakers, government regulators and industry bodies in planning for the spatial implications of future policies targeting the hospitality sector. For example, local governments may use the results to encourage hospitality investment in coldspot areas, through changing zoning rules or through the provision of grants. The results will assist the government in providing targeted stimulus to areas that are showing a reduction in venue numbers as a result of the COVID-19 pandemic. The separation of venues by type allows for a nuanced approach, specific to each type of venue. Hotel companies could use this information to seek gaps in the market where they may construct additional venues. Finally, the methodology itself could be repeated in the future by agencies to ensure that they keep abreast of any spatial changes that are occurring in the industry.

This aim of this study was to explore the effect of public policy on the hospitality industry in Sydney, Australia. This was approached from a spatial perspective, looking at the geographical distribution of licensed venues across Inner Sydney as they have changed between the period of 2012 to 2021. To achieve this aim, the study sought to answer four research questions. The first explored the spatial distribution of venues in Sydney, looking at how this related to LGA and land use zones; the second examined how these patterns had changed over a 10-year period; the third sought to identify whether any changes identified corresponded with the introduction of the lockout laws or COVID-19 lockdowns; the final question sought to explore how the results could be visualised online for audience interaction.

The results show that:

- Most venues were located in the Sydney CBD on business-zoned land and showed a high degree of spatial clustering. This clustering was consistent over time, with variations between venue types;

- Venue numbers declined following the introduction of the lockout laws, with numbers steadily recovering in the following years;
- There was no discernible change in the number of venues following the COVID-19 lockdowns; however, economic data suggest that there has been a decline in revenue. Some venues were identified as having temporarily ceased trading, with these clustered in the Sydney CBD.

The results of the study were displayed online in Storymap format public access, addressing the research aim which sought to identify how the research paper could encourage public interaction.

Ultimately, this study has filled the research gaps identified in this paper. Additionally, it has provided a foundation for further research to build upon these results.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Space-Time Cube Logfiles

```

----- Space Time Cube Characteristics -----
Input feature time extent      2012-01-01 00:00:00
                               to 2021-01-01 00:00:00

Number of time steps           10
Time step interval             1 year
Time step alignment            End

First time step temporal bias   100.00%
First time step interval       after
                               2011-01-01 00:00:00
                               to on or before
                               2012-01-01 00:00:00

Last time step temporal bias    0.00%
Last time step interval         after
                               2020-01-01 00:00:00
                               to on or before
                               2021-01-01 00:00:00

Cube extent across space       (coordinates in meters)
Min X                           16819259.1792
Min Y                           -4030001.6419
Max X                           16841198.4895
Max Y                           -3999801.6419
Rows                             75
Columns                          63
Total bins                       47250

----- Overall Data Trend - COUNT -----
Trend direction                 Decreasing
Trend statistic                 -3.1431
Trend p-value                   0.0017

```

Figure A1. Club licence space-time cube logfile.

```

----- Space Time Cube Characteristics -----
Input feature time extent      2012-01-01 00:00:00
                               to 2021-01-01 00:00:00

Number of time steps           10
Time step interval             1 year
Time step alignment            End

First time step temporal bias   100.00%
First time step interval       after
                               2011-01-01 00:00:00
                               to on or before
                               2012-01-01 00:00:00

Last time step temporal bias    0.00%
Last time step interval        after
                               2020-01-01 00:00:00
                               to on or before
                               2021-01-01 00:00:00

Cube extent across space       (coordinates in meters)
Min X                           16818317.6097
Min Y                           -4024660.2037
Max X                           16840949.7403
Max Y                           -4000460.2037
Rows                             60
Columns                          65
Total bins                       39000

----- Overall Data Trend - COUNT -----
Trend direction                 Not Significant
Trend statistic                 -0.6286
Trend p-value                   0.5296

```

Figure A2. Hotel licence space-time cube logfile.

```

----- Space Time Cube Characteristics -----
Input feature time extent      2014-01-01 00:00:00
                               to 2021-01-01 00:00:00

Number of time steps           10
Time step interval             9 months
Time step alignment            End

First time step temporal bias   67.15%
First time step interval       after
                               2013-07-01 00:00:00
                               to on or before
                               2014-04-01 00:00:00

Last time step temporal bias    0.00%
Last time step interval        after
                               2020-04-01 00:00:00
                               to on or before
                               2021-01-01 00:00:00

Cube extent across space       (coordinates in meters)
Min X                           16822783.9058
Min Y                           -4022570.2657
Max X                           16840219.8840
Max Y                           -4005170.2657
Rows                             43
Columns                          50
Total bins                       21500

----- Overall Data Trend - COUNT -----
Trend direction                 Increasing
Trend statistic                 2.6043
Trend p-value                   0.0092

```

Figure A3. Small bar licence space-time cube logfile.

```

----- Space Time Cube Characteristics -----
Input feature time extent      2012-01-01 00:00:00
                               to 2021-01-01 00:00:00

Number of time steps           10
Time step interval             1 year
Time step alignment            End

First time step temporal bias   100.00%
First time step interval       after
                               2011-01-01 00:00:00
                               to on or before
                               2012-01-01 00:00:00

Last time step temporal bias    0.00%
Last time step interval        after
                               2020-01-01 00:00:00
                               to on or before
                               2021-01-01 00:00:00

Cube extent across space      (coordinates in meters)
Min X                          16818261.0162
Min Y                          -4029419.1207
Max X                          16841239.5570
Max Y                          -3999219.1207
Rows                           75
Columns                        66
Total bins                     49500

----- Overall Data Trend - COUNT -----
Trend direction                Increasing
Trend statistic                1.9677
Trend p-value                 0.0491

```

Figure A4. On-premises licence space-time cube logfile.

```

----- Space Time Cube Characteristics -----
Input feature time extent      2012-01-01 00:00:00
                               to 2021-01-01 00:00:00

Number of time steps           10
Time step interval             1 year
Time step alignment            End

First time step temporal bias   100.00%
First time step interval       after
                               2011-01-01 00:00:00
                               to on or before
                               2012-01-01 00:00:00

Last time step temporal bias    0.00%
Last time step interval        after
                               2020-01-01 00:00:00
                               to on or before
                               2021-01-01 00:00:00

Cube extent across space      (coordinates in meters)
Min X                          16819301.1854
Min Y                          -4026593.8937
Max X                          16840894.0855
Max Y                          -4000793.8937
Rows                           64
Columns                        62
Total bins                     39680

----- Overall Data Trend - COUNT -----
Trend direction                Not Significant
Trend statistic                1.0820
Trend p-value                 0.2793

```

Figure A5. Limited-licence space-time cube logfile.

```

----- Space Time Cube Characteristics -----
Input feature time extent      2012-01-01 00:00:00
                               to 2021-01-01 00:00:00

Number of time steps          10
Time step interval            1 year
Time step alignment           End

First time step temporal bias  100.00%
First time step interval      after
                               2011-01-01 00:00:00
                               to on or before
                               2012-01-01 00:00:00

Last time step temporal bias   0.00%
Last time step interval       after
                               2020-01-01 00:00:00
                               to on or before
                               2021-01-01 00:00:00

Cube extent across space      (coordinates in meters)
Min X                          16818292.4462
Min Y                          -4029973.5927
Max X                          16841270.9869
Max Y                          -3998973.5927
Rows                            77
Columns                         66
Total bins                      50820

----- Overall Data Trend - COUNT -----
Trend direction                Increasing
Trend statistic                2.1466
Trend p-value                  0.0318

```

Figure A6. All venues space-time cube logfile.

Appendix B. Emerging Hotspot Analysis Categories

Source (Esri, 2021-<https://pro.arcgis.com/en/pro-app/latest/tool-reference/space-time-pattern-mining/learnmoreemerging.htm> (accessed on 20 June 2021)).

Symbol	Category	Definition
	No Pattern Detected	Does not fall into any of the hot or cold spot patterns defined below.
	New Hot Spot	A location that is a statistically significant hot spot for the final time step and has never been a statistically significant hot spot before.
	Consecutive Hot Spot	A location with a single uninterrupted run of statistically significant hot spot bins in the final time-step intervals. The location has never been a statistically significant hot spot prior to the final hot spot run and less than ninety percent of all bins are statistically significant hot spots.
	Intensifying Hot Spot	A location that has been a statistically significant hot spot for ninety percent of the time-step intervals, including the final time step. In addition, the intensity of clustering of high counts in each time step is increasing overall and that increase is statistically significant.
	Persistent Hot Spot	A location that has been a statistically significant hot spot for ninety percent of the time-step intervals with no discernible trend indicating an increase or decrease in the intensity of clustering over time.
	Diminishing Hot Spot	A location that has been a statistically significant hot spot for ninety percent of the time-step intervals, including the final time step. In addition, the intensity of clustering in each time step is decreasing overall and that decrease is statistically significant.
	Sporadic Hot Spot	A location that is an on-again then off-again hot spot. Less than ninety percent of the time-step intervals have been statistically significant hot spots and none of the time-step intervals have been statistically significant cold spots.
	Oscillating Hot Spot	A statistically significant hot spot for the final time-step interval that has a history of also being a statistically significant cold spot during a prior time step. Less than ninety percent of the time-step intervals have been statistically significant hot spots.
	Historical Hot Spot	The most recent time period is not hot, but at least ninety percent of the time-step intervals have been statistically significant hot spots

Figure A7. Hotspot categories.

Symbol	Category	Definition
	New Cold Spot	A location that is a statistically significant cold spot for the final time step and has never been a statistically significant cold spot before.
	Consecutive Cold Spot	A location with a single uninterrupted run of statistically significant cold spot bins in the final time-step intervals. The location has never been a statistically significant cold spot prior to the final cold spot run and less than ninety percent of all bins are statistically significant cold spots.
	Intensifying Cold Spot	A location that has been a statistically significant cold spot for ninety percent of the time-step intervals, including the final time step. In addition, the intensity of clustering of low counts in each time step is increasing overall and that increase is statistically significant.
	Persistent Cold Spot	A location that has been a statistically significant cold spot for ninety percent of the time-step intervals with no discernible trend, indicating an increase or decrease in the intensity of clustering of counts over time.
	Diminishing Cold Spot	A location that has been a statistically significant cold spot for ninety percent of the time-step intervals, including the final time step. In addition, the intensity of clustering of low counts in each time step is decreasing overall and that decrease is statistically significant.
	Sporadic Cold Spot	A location that is an on-again then off-again cold spot. Less than ninety percent of the time-step intervals have been statistically significant cold spots and none of the time-step intervals have been statistically significant hot spots.
	Oscillating Cold Spot	A statistically significant cold spot for the final time-step interval that has a history of also being a statistically significant hot spot during a prior time step. Less than ninety percent of the time-step intervals have been statistically significant cold spots.
	Historical Cold Spot	The most recent time period is not cold, but at least ninety percent of the time-step intervals have been statistically significant cold spots.

Figure A8. Coldspot categories.

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