Quantifying the impacts of social infrastructure on human networks

Introduction

At the end of 2020, the COVID-19 pandemic has pushed additional 88 million people into extreme poverty and caused some form of school closures for at least 1.5 billion children and youth from more than 160 countries (World Bank). To assist the nation's recovery from this catastrophic, 2.57 trillion in new budgetary resources and two-year over billion tax relief have been approved by US congress, as of October 1, 2020 (https://datalab.usaspending.gov/federal-covid-funding). Up to 4 May 2021, more than 150 million people get infected in this global pandemic, including 3 million deaths (World Health Organization). Therefore, how to conquer the difficulties and resume the vigorous of society after the disaster setting becomes a thriving topic.

In sociology, a rich literature claims that social capital plays a more valuable role than physical infrastructure by driving more flexible communities' resilience under a disaster setting(Kirmayer & Whitley, 2009); Metaxa-kakavouli et al., 2018). Community resilience refers to a concerted ability of residents to defy or efficiently recover through cooperation and mutual help from or after disaster strikes(*Disaster Risk Reduction for the Built Environment | Wiley*, n.d.). Fran Norris proposed that community resilience flourished from four fundamental adaptive capacities - Economic Development, Social Capital, Information and Communication, and Community Competence. For building a more consolidate local resilience, she suggests engaging the social activities to strengthen the community linkages(Norris et al., 2008). More practical instance from the U.S. Federal Emergency Management Agency's National Disaster Recovery Framework, a disaster management sector, who advised that responders should build and maintain partnerships with each other by increasing the opportunities for social interaction and activities (*FEMA*, 2011).

While extensive research distinguishes physical infrastructure and social interaction to compare the impact from them and declares the effects of latter outperformance than the former, I assume that the built environment provides the context and foundation for social activities. For instance, you cannot place a formal business negotiation on a crowded street. You also cannot hold an academic conference in a fitness room or around with a swimming pool. There is a voice in your mind warning you, they are not the "right" place to do so. As such, the appropriate "collocating" between built environment and social activities suggests the correlation between them in the actual world.

Despite it is clear to conclude the logical relationship between the physical environment and human activities, we still lack data and methods that explicitly link each other and verify how strong the association is and explore how it transmits and variates across space and time. Without a clear understanding of how the built environment facilitates social events occurrence, we are not able to answer simple questions, such as, what is the best investment to community aftermath? how to draw a reasonable city planning to promote the residents' communication contributing to a solid social network and flexible resilience?

In this study, we ask the following research question: Does the built environment have spatial associations with social events? If so, how to quantitatively measure it. We plan to employ POI data from Safe Graph to describe the site characteristics and utilize the social events records from the online platform to address the spatial association between human activities and surrounding physical facilities. Borrowing the concepts from the association rule-based approach and bootstrap aggregating and data simulating, we can test the significance of the relationship between POIs and social events.

Intellectual Merit and Broader Impacts

Although extensive studies addressed the effectiveness of social relationships and communities' resilience, disaster management has not fully embraced it due to the hardness of estimating and promoting (Aldrich & Meyer, 2015). Our research fills the need of measuring the relationship by providing quantitative approaches to address the association between the physical environment and social events, which implies an alternative way to fortify local resilience. Also, the approach used in this study remains suitable for exploring spatial association rules among varied objects. With data simulating and generation process, we are capable to test the significance of the association rule we detected. This approach is capable to capture correlation from multiple spatial scales and temporal intervals, which gives us the ability to investigate how the relationship transmits and variates across space and time.

We assume that (1) POIs could be used to describes the characteristics of different place; (2) Different types of POI affords for different types of social events by providing diverse services and attractions; (3) we lack an approach, methodology to quantitatively measure the relationships among POIs and Social events. Our study was founded by studies confirming the social events take support from the built environment, the traits and natures of the built environment also associate with human networks (Boessen et al., 2018;Cao et al., 2020) .However, Current studies about human networks and built environment makes efforts on either spatial or social patterns but lack a framework to integrate quantitative analysis of the association between them (Ye & Liu, 2018).

This study will advance knowledge about place-marketing, urban planning, social capitals, and community resilience. The result of our research would provide the association rule about specific combinations of POI and Social events. For example, you may find the "public library" is highly collocated with "writing, reading, learning" types of social events, which may bring more informal social ties among residents to develop the bridging social capitals.

Also, a fully understand the role of the built environment plays in human activities helps us answer the question of why are people doing this here? It also helps us to address how the connections within humans transmit and change by surrounding facilities. Both the methods and the case study can serve as decision references for situational awareness and city management.

Methodology

The Apriori algorithm is one of the most popular approaches to finding association patterns in big data, which have been utilized in multiple domains, including marketing analysis, natural disaster prediction, traffic accidents modeling, etc. It treats data as a set of attribute-value pairs, or items, and concludes association rules which satisfy two requirements: minimum support and minimum confidence. Support is the indicator to describe how often the selected item appears in the dataset (Agrawal et al., 1993), which is defined as

$$Support(X) = \frac{Number\ of\ transactions\ in\ which\ X\ appears}{Total\ number\ of\ transactions} = P(X)$$

And confidence represents when transactions have item X, what is the proportion of them also contain item Y (Agrawal et al., 1993)? It could also be interpreted as the conditional probability

$$Confidence(X \rightarrow Y) = \frac{Support(X \cap Y)}{Support(X)} = P(Y|X)$$

Therefore, we applied Apriori algorithm to find association pattern $POI \rightarrow Social\ events$.

Finding and Contribution

We have discovered 35 rules from our data, the popular lift measure in the literature suggests that 29 of them are significant (which have lift values larger than 1.2). The lift evaluates the observing probability of rules against the independence assumption, the equation is

$$Lift\{X \rightarrow Y\} = \frac{Support(X,Y)}{Support(X) * Support(Y)} = \frac{Cof(X \rightarrow Y)}{Sup(Y)}$$

POI		Social events	support	confidence	lift	count
{Business}	=>	{Tech}	0.0131	0.2259	3.803	110
{Finance, Party, Shopping}	=>	{Arts}	0.0105	0.1082	3.4051	88
{Appearance, Finance, Party}	=>	{Arts}	0.0114	0.1005	3.1625	95
{Education, Finance}	=>	{Learning}	0.0176	0.1061	2.3922	147
{Finance, Party, Shopping}	=>	{Dance}	0.0127	0.1304	2.3718	106
{Education, Finance, Shopping}	=>	{Dance}	0.0118	0.12	2.183	99
{Parking}	=>	{Health&Wellness}	0.0136	0.2036	2.17	114
{Medical}	=>	{Health&Wellness}	0.0188	0.199	2.1212	157
{Food, Shopping}	=>	{Dance}	0.0214	0.1108	2.0162	179
{Entertainment}	=>	{Dance}	0.0345	0.1105	2.0104	289
{Hotel}	=>	{Health&Wellness}	0.02	0.1813	1.9329	167
{Appearance, Finance}	=>	{Dance}	0.0182	0.1059	1.9269	152
{Hotel}	=>	{Career&Business}	0.0201	0.1824	1.8962	168
{Education, Party}	=>	{Dance}	0.0177	0.1027	1.8684	148
{Car}	=>	{Dance}	0.0151	0.1021	1.8575	126
{Appearance, Party, Shopping}	=>	{Social}	0.0136	0.1019	1.8216	114
{Appearance, Party, Shopping}	=>	{Dance}	0.0134	0.1001	1.8208	112
{Education, Finance, Party}	=>	{Tech}	0.011	0.1059	1.7825	92
{Car}	=>	{Health&Wellness}	0.0246	0.1669	1.7795	206
{Party}	=>	{Health&Wellness}	0.0441	0.1538	1.6396	369
{Food}	=>	{Sci-Fi&Games}	0.0314	0.1227	1.4755	263
{Appearance}	=>	{Career&Business}	0.046	0.1247	1.296	385
{Education, Shopping}	=>	{Sci-Fi&Games}	0.025	0.1065	1.2801	209
{Car}	=>	{Beliefs}	0.0163	0.1102	1.2651	136
{Education}	=>	{Health&Wellness}	0.0507	0.1186	1.2646	424
{Car}	=>	{Sci-Fi&Games}	0.0151	0.1021	1.2276	126
{Entertainment}	=>	{Health&Wellness}	0.0359	0.1147	1.2229	300
{Finance}	=>	{Career&Business}	0.0376	0.1174	1.22	315
{Party}	=>	{Career&Business}	0.0333	0.1163	1.2089	279
{Food}	=>	{Career&Business}	0.029	0.1134	1.1787	243
{Food}	=>	{Health&Wellness}	0.028	0.1092	1.164	234
{Entertainment}	=>	{Career&Business}	0.0344	0.1101	1.1448	288
{Finance}	=>	{Health&Wellness}	0.0338	0.1054	1.124	283
{Appearance}	=>	{Health&Wellness}	0.0379	0.1027	1.0943	317
{Shopping}	=>	{Career&Business}	0.0431	0.1035	1.0762	361

We made a parallel plot for those rules, the width of arrow stands for support (0.01-0.05), and color stands for confidence (0.1-0.22).

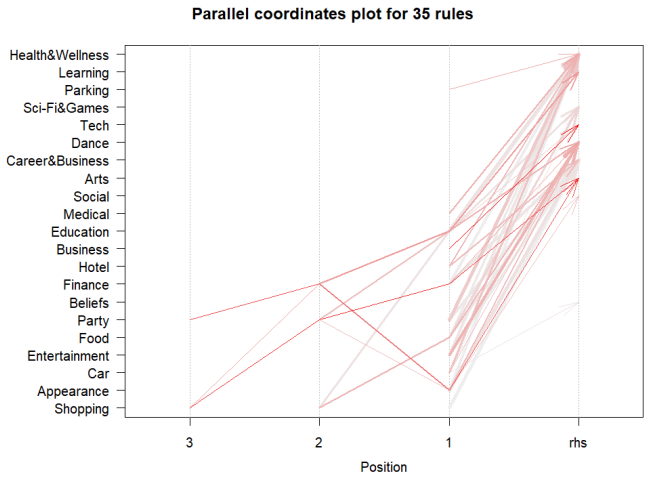


Fig.1. Parallel plot for 35 rules

From the graph and table, we conclude that the occurrence of social events may require the collective service from different types of POI due to the lift measure. And some specific types of POI, like food and shopping related place, are more active for social events supporting. Our finding can be used as a supplementary for urban planning.

ESRI technology and Web application

We publish a webpage to introduce two essential datasets in our research, POI and social events, the link of our webpage is https://experience.arcgis.com/experience/bf9393441c8445f681035d7d4e320185. And the design diagram as shown below.

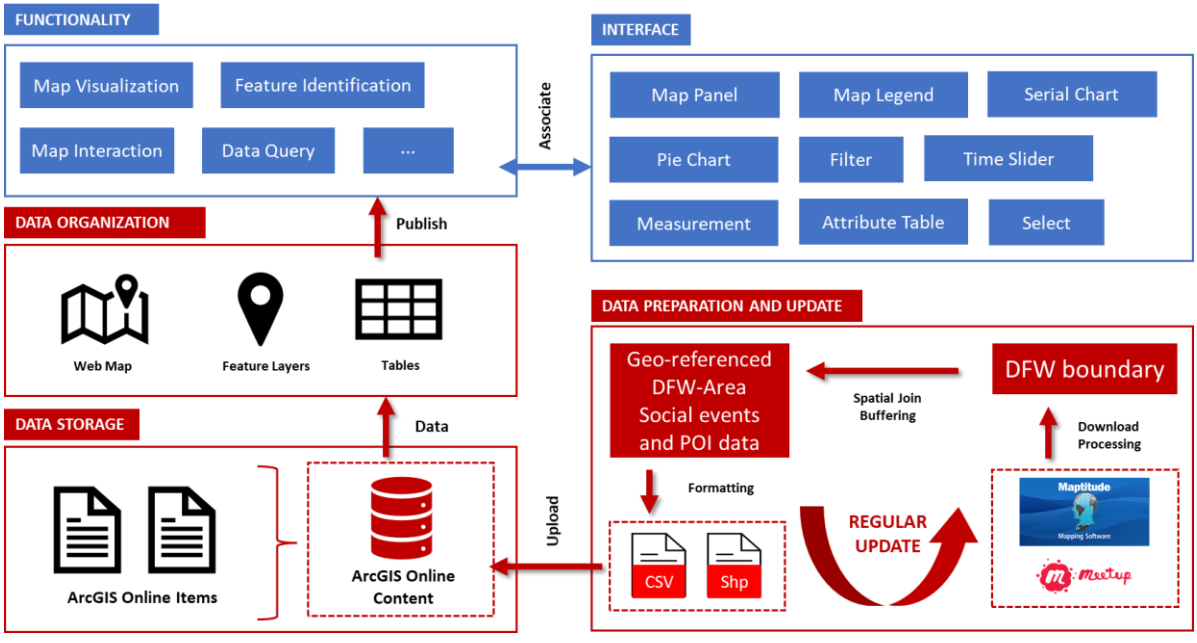
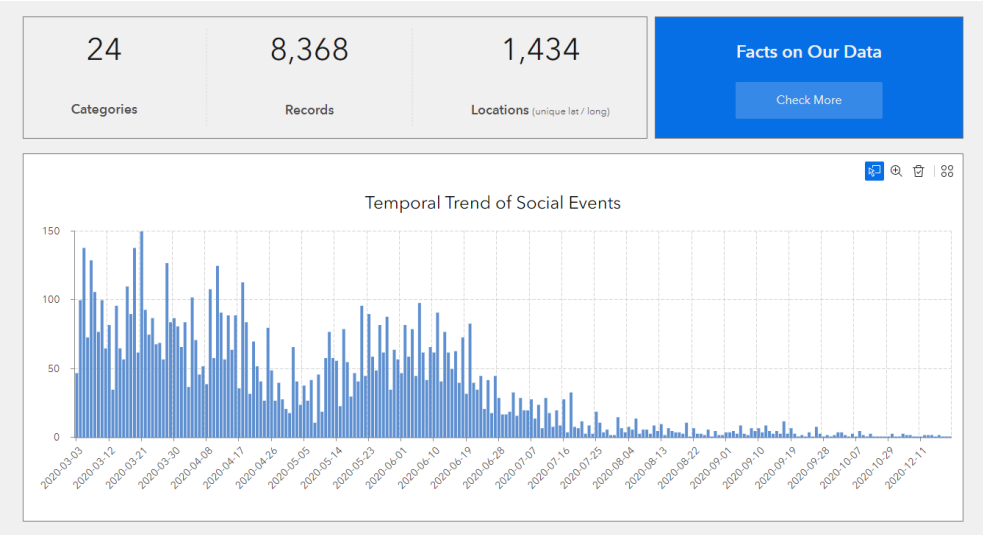


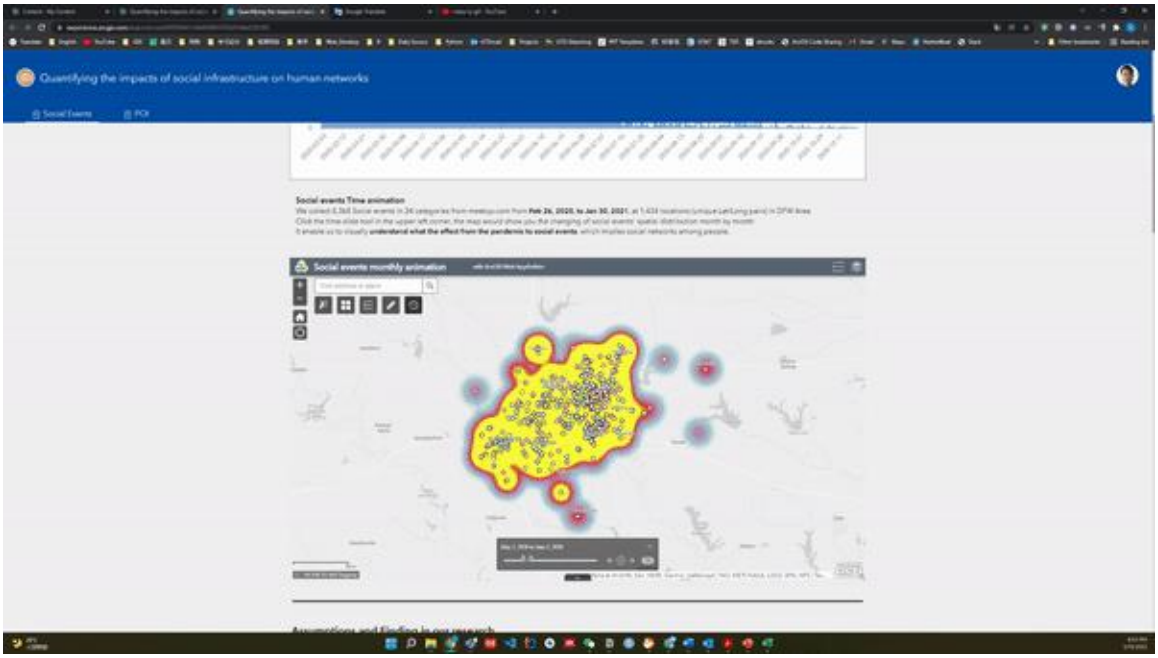
Fig.2. System Design Diagram

All the database Server, interface Server and methods Server are hosted by ESRI. In our web application, user can

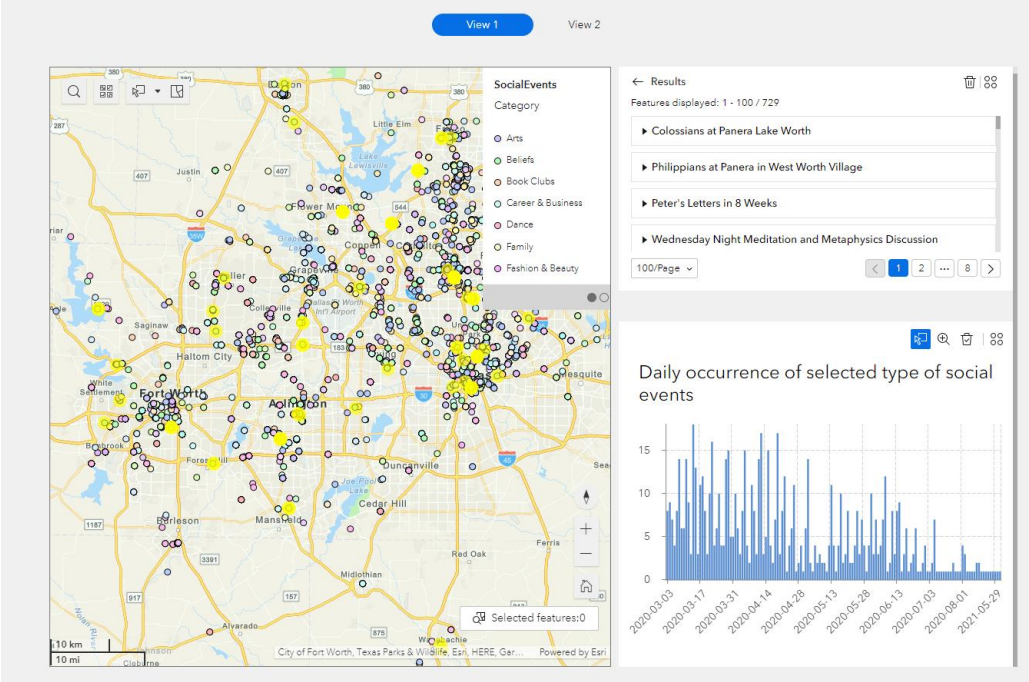
1. View the temporal trend of our social events data



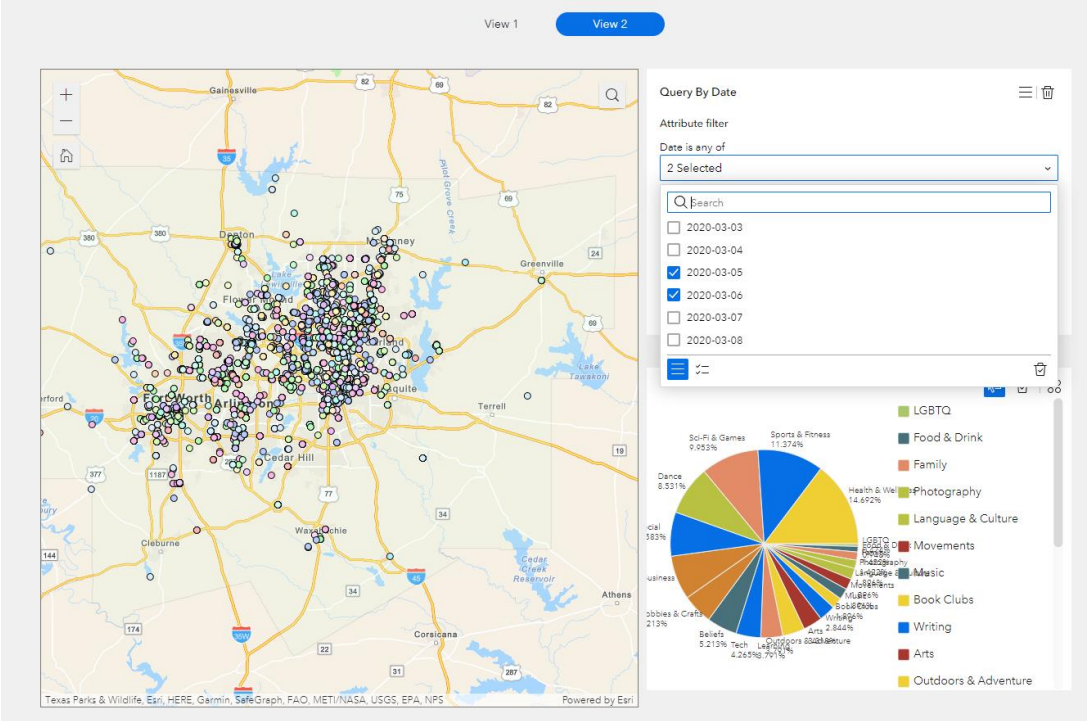
2. Check the time animation of social events to see the effects from pandemic



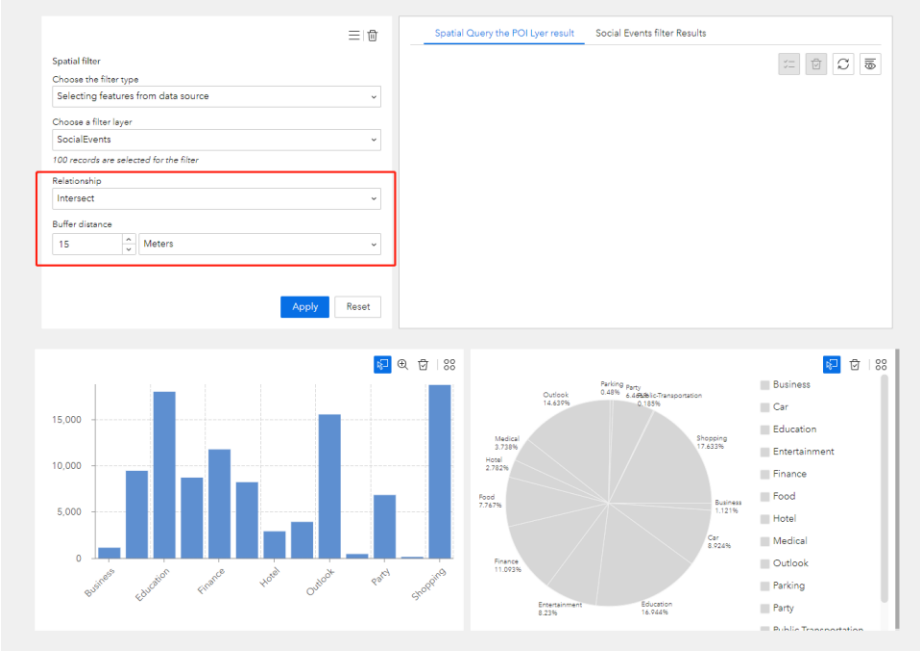
3. Check the daily occurrence of selected type of social events



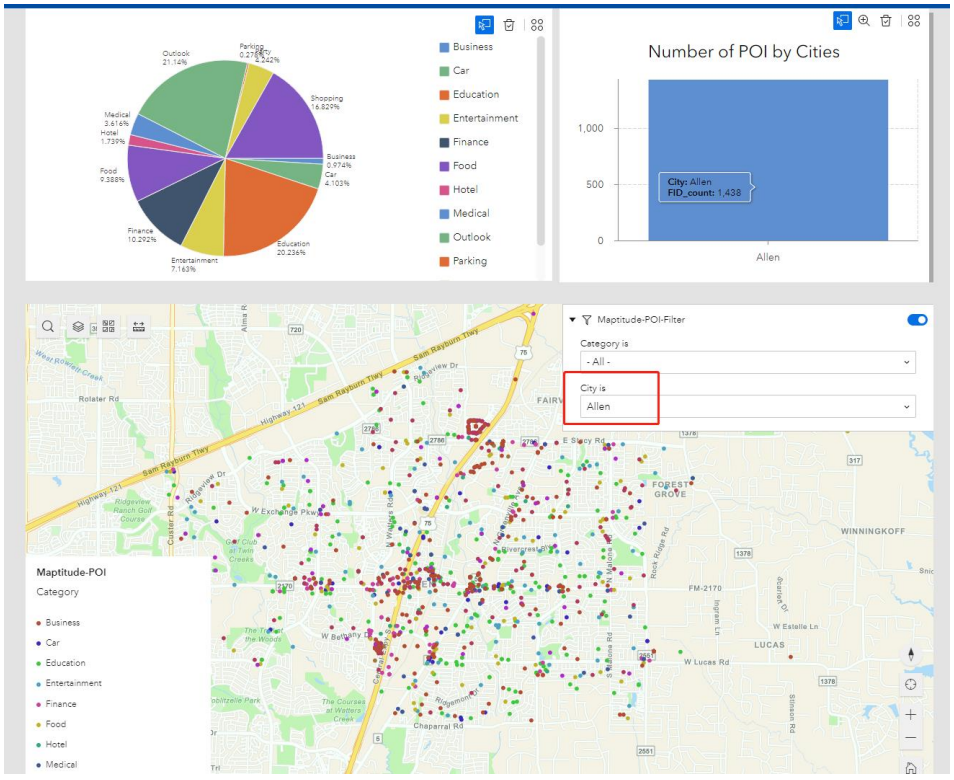
4. Check the social events happened in selected date



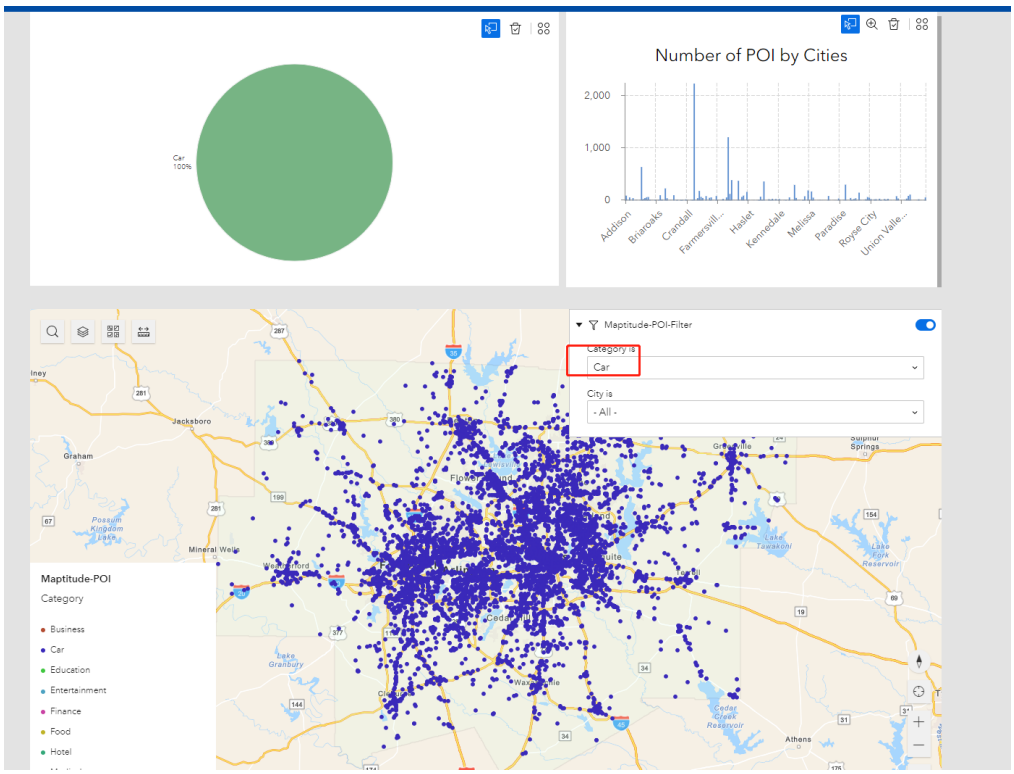
5. Check the POI within a certain distance from the selected type of social event



6. Check the distribution of POI in selected city



7. Check the number of the selected type of POI in each city



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