Assessing Polling Place Accessibility in Milwaukee County

Using a Spatial Database for Walkability Analysis

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Background Information

When assessing elections, the state of Wisconsin provides a unique case study. While often the focus has been on how continually competitive the state's elections have been on the national level for many years, the actual structure of how elections are administered is also worth examining. In the vast majority of states, counties are in charge of running elections, but only a small few are by smaller governmental agencies. In fact, Wisconsin is the most decentralized election system in the country.

Each town, village and city clerk in the state is in charge of establishing their specific election processes (Foley, Huefner and Tokaji, 2007) While there are many state statutes that govern these processes, there are considerable variations throughout the state, in many cases due to municipality size alone. The Village of Big Falls in Waupaca county, for instance, only had 61 total residents in the 2010 Census, while the City of Milwaukee had 594,833 (Wisconsin LRB, 2019). The difference in scale results in many differences in how election roles are delegated, but one consistent role local clerks have is assigning polling place locations for their citizens.

Though absentee voting has been rising in recent years (and especially in this year's spring primary election due to the COVID-19 public health crisis), voting at the polling place on election is still an important civic choice for Wisconsinites, especially given residents' option to register at the polling place on election day before voting. As a result, finding polling places that are convenient for voters is very important, even if the options for clerks to choose are sometimes limited. For example, schools have traditionally been a very popular polling place, but with school safety a much bigger consideration for local officials, many of those polling places have moved elsewhere.

Finding suitable locations takes on even greater importance given how Wisconsin's election laws are written. The state of Wisconsin is broken into specific voting precincts areas, which are referred to as wards. Residents within those wards are assigned a specific polling place and in many cases, these polling places will host voters from multiple wards (Wisconsin LRB, 2018). These polling places can be changed depending on the type of election, but the wards will almost never change between census periods (outside of annexations of land). As a result, depending on which locations are available for that specific election, voters' polling place may not necessarily be the closest one to their physical residence, due to municipal or ward lines. In smaller places, these locations may not change often (residents in townships most frequently vote at the town hall, for example), but those decisions can be very important in providing good access to voters, especially in places where transportation options are limited.

In order to look at some of these accessibility issues, we chose Milwaukee County for a case study. In addition to having the large City of Milwaukee, the county also includes cities and villages of different shapes and sizes that are adjacent to each other and may provide contrasting approaches to polling place placement. These decisions may be driven by different factors, such as availability of private or public transportation, or as stated above, availability of locations to host election day activities. Another reason we chose Milwaukee County is because there have not been large changes in the municipal lines in the county due to annexation since 2010, the county allowed for a relatively stable voting district dataset.

Milwaukee County also includes both highly urbanized and suburban populations and has a wide variation in household income levels. We believe these would also provide some interesting insight into how polling place locations can affect and/or cater to different types of populations and voters.

Application

Keeping these ideas in mind, we will build a spatial database that will assist in analyzing accessibility to polling places in Milwaukee. Using ward, census and road data, we can use a walkability analysis to determine the following research questions. Though access to polling places is dependent on a number of factors (access to private and public transportation, namely), we decided to use a walking score to provide a consistent look across different areas. Our main research questions are:

- Which wards have the lowest average distance to travel for voters to get to their polling place?
- How would lack of access to private or public transportation adversely affect voters? Do lower income voters have longer walk times than those with higher income?
- Which polling places are expected to host the most potential voters?

Though initially we were planning on looking only at one election to answer these questions, we decided to compare the 2018 General Election to more recent data, based on the State of Wisconsin holding their presidential primary and spring election in 2020 during the COVID-19 pandemic. As many municipalities were forced to move and consolidate polling places based on the availability of poll workers and other logistical factors, it provided a real-life test example of how polling place locations may change access for voters.

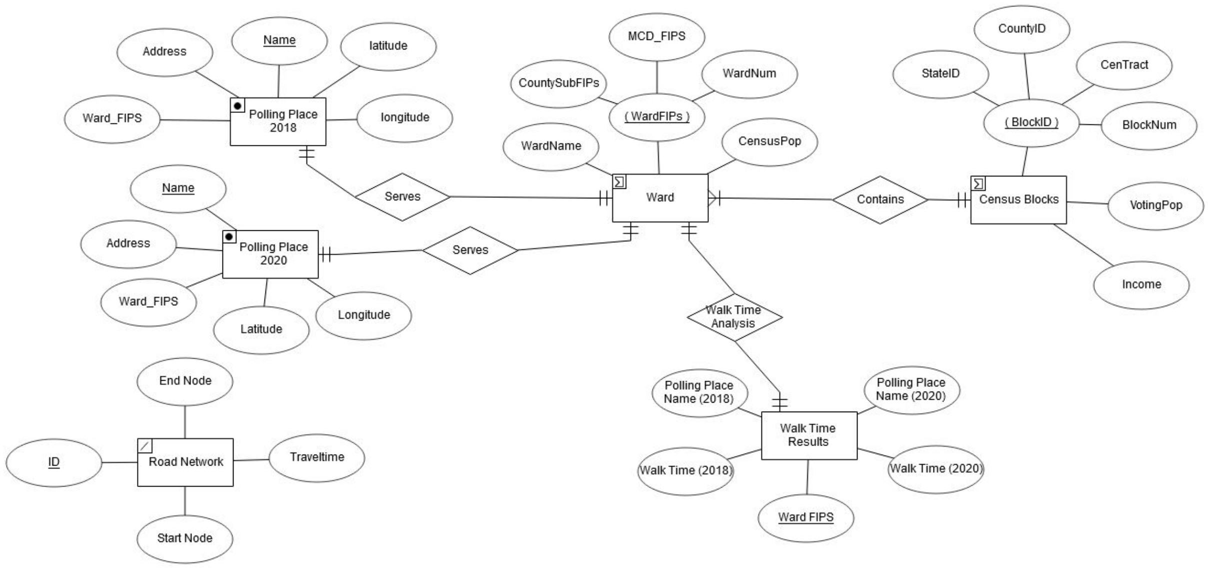
Objective

Determine which polling places in Milwaukee County are the most walkable by creating a database that links transportation, census, and election data. By combining these elements, we can determine how well polling places serve citizens on election day.

Datasets

- Tract and block data is from the U.S. Census Bureau. Tract data is the smallest data level household income is available for and will be translated to the block data.
- 2011 election ward data is from Wisconsin Legislative Technology Services Bureau. Wards were built from census blocks during the 2011 redistricting period.
- Polling Place Data is from Wisconsin Elections Commission. Found in tabular form for the 2018 General Election and 2020 Spring Election.
- Road network data is from Milwaukee County.
- A Walkability table will be created using ward, polling place and road network data.

ER Diagram



Database Design

Feature Class	**Field name**	**Field type**	**Length**	**AliasName**	**Description**
Wards	Ward_Fips	Text	16	Ward FIPS	Ward FIPS code – combination of state, county and ward number
	Name	Text		Ward Name	Text Description municipality, type and ward number
	Persons18	LI		Voters Over 18	Number of Eligible Voters after the 2010 Census
	ppname18	Text		Polling Place 2018	Name of the Polling Location in 2018 associated to the Ward
	ppname20	Text		Polling Place 2020	Name of the Polling Location in 2020 associated to the ward
Blocks	blockID10	Text	15	Block Number 2010	Block ID Code – combination of state, county, tract and block number
	Ward_Fips	Text	16	Ward FIPS	Ward FIPS code – combination of state, county and ward number
	pop10	Float		Block Population 2010	Population of the census block after the 2010 census
	hhinc18	Double		Avg Household Income 2018	Census Tract Average Household Income – Spatial Joined to block data
PPName18	Muni	Text		Polling Place 2018	Municipality of polling place
	ppname	Text		Polling Place Name	Name of the Polling Location
	ppadd	Text		Polling Place Address	Address of Polling Location
	latitude	Double		Latitude	Latitude Coordinate
	longitude	Double		Longitude	Longitude Coordinate

PPName20	Muni	Text		Polling Place 2018	Municipality of polling place
	ppname	Text		Polling Place Name	Name of the Polling Location
	ppadd	Text		Polling Place Address	Address of Polling Location
	latitude	Double		Latitude	Latitude Coordinate
	longitude	Double		Longitude	Longitude Coordinate
Walk_Time	Ward_Fips	Text	16	Ward FIPS	Ward FIPS code – combination of state, county and ward number
	ppname18	Text		Polling Place 2018	Name of the Polling Location in 2018 associated to ward
	walk_time_2018	Double		Walk Time 2018	Walkability Score for 2018 polling place in Minutes
	ppname20	Text		Polling Place 2020	Name of the Polling Location in 2020 associated to ward
	walk_time_2020	Double		Walk Time 2020	Walkability Score for 2020 polling place in Minutes
Network	id	Int		id	A unique ID for each road segment.
	source	Int		source	Segment source node
	target	Int		target	Segment target node
	traveltime	Double		Travel Time	Time in minutes it takes to walk from the source node to the target node along the line geometry at 3.1mph.

Why Walkability Analysis

In order to measure the accessibility of a given polling place to its low income voters, it is helpful to understand how difficult it is to reach the polling place by foot. A walkability score can be created for each voting ward that measures how easy it is for a voter to walk to their polling place. This score can then be compared to income and demographic data to help measure the accessibility of a polling place for people of various income levels.

Creating a walkability score can be a very complicated process that takes into consideration factors such as sidewalk availability, road conditions, the amount of traffic, and even the weather and time of year. For the purpose of this project, the walkability score will simply be measured as the average amount of time it takes for a voter to walk to their assigned polling location along the road network for each ward, assuming an average walking speed of 3.1 mph.

Process of Calculating Walkability

Creating the walkability score required the use of pgRouting, an extension that adds geospatial routing functionality to PostGIS. The first step was to prepare the road network dataset for analysis. PgRouting requires each segment of the road network to have an associated begin and end node as well as a travel time field. The nodes were created with the help of Chris Koher's tutorial. The travel time (in minutes) for each road segment was calculated by dividing the segment length by the assumed walking speed of 3.1mph (16,368 feet per hour) and multiplying by 60. The DDL used to prepare the road network is found in Appendix A-1.

Once the routable network was created, we had to calculate the walkability scores by completing the following tasks for each polling place:

1. Find the nearest network node to the polling place from which the travel time analysis will begin.
2. Run the travel time analysis for each polling place.
3. Clip the results by each voting ward that is assigned to that polling place.
4. Calculate the average travel time for each clipped result. This will be the average walking time to the polling place for each ward.

Such a process requires multiple steps to automate. In order to make the code for the scoring process more readable and maintainable, we decided to create functions to facilitate the process. The full code for each function is located in Appendix A.

- **find_nearst_node(name varchar)** - Appendix A-2 - Task 1 is accomplished with this function, which finds the node closest to the input polling place location. This will identify the node from which the travel time analysis will begin. The function measures the distance to each node within a 1500' buffer of the input polling place and returns the node id with the lowest distance value. Creating a GIST index on the polling place geometry improved the speed of this step by a factor of 3.
- **generate_walking_analysis_view(node int, ward_fips varchar)** - Appendix A-3 - Task 2, running travel time analysis, is accomplished with this function. The output is a new view that shows how long it takes to walk from the input begin node to every other node in the network. The view will be used both to calculate the average walk time in each ward and create isochrone maps.
- **avg_travel_time(ward_fips varchar(16), ppName varchar(254))** - Appendix A-4 - This function calculates the average travel time from all nodes within a ward to the ward's assigned polling place. This output is considered the ward's walkability score for the purpose of this project.

The SQL used to run through each of the tasks using these functions is presented in Appendix A-5. The results of the queries were a new view for each polling place showing the results of the walkability analysis for that polling place as well as the walking_time_analysis_results table. The table is a sample of the walking time results for each polling place in both the 2018 and 2020 elections.

	ward_fips character varying (16)	ppname18 character varying (254)	walk_time_2018 double precision	ppname20 character varying (254)	walk_time_2020 double precision
1	55079530000323	MODRZEJEWSKI_PLAYGROUND_FIE...	11.8993639960533	SOUTH_DIVISION_HIGH_SCH...	23.7916328345848
2	55079530000134	MARYLAND_AVENUE_MONTESSORI...	7.39462707624295	RIVERSIDE_HIGH_SCHOOL	10.9246889312632
3	55079530000310	SHOLES_EDUCATION_COMPLEX	15.3608286962729	HAMILTON_HIGH_SCHOOL	91.3458330814304
4	55079530000320	LONGFELLOW_SCHOOL	9.74742322674406	SOUTH_DIVISION_HIGH_SCH...	16.4873266406887
5	55079273000021	SAINT_MARTIN_OF_TOURS_CHURCH	46.3992419373679	SAINT_MARTIN_OF_TOURS_C...	46.3992419373679
6	55079530000191	MARQUETTE_UNIVERSITY_ALUMNI_...	6.54487565810426	SOUTH_DIVISION_HIGH_SCH...	37.2203561268127
7	55079530000182	CHARLES_ALLIS_ART_MUSEUM	6.00013060537916	RIVERSIDE_HIGH_SCHOOL	29.1571209928764
8	55079530000154	WASHINGTON_HIGH_SCHOOL	10.6854721126822	WASHINGTON_HIGH_SCHOOL	10.6854721126822
9	55079530000228	LONGFELLOW_SCHOOL	7.1485978955563	SOUTH_DIVISION_HIGH_SCH...	12.2177779649608
10	55079530000255	KOSCIUSZKO_COMMUNITY_CENTER	11.7070724905065	SOUTH_DIVISION_HIGH_SCH...	16.8033384048146

Bringing It All Together

In order to perform our final analysis, we needed to bring together the data from the census blocks, the wards, and the walkability analysis. This could be done by joining each of these tables by ward id (ward_fips). The ward id of each census block was identified by intersecting the centroid of the block geometry with the ward geometry. The centroid was used rather than the block polygon to avoid any issues with the boundaries between the two layers not aligning perfectly.

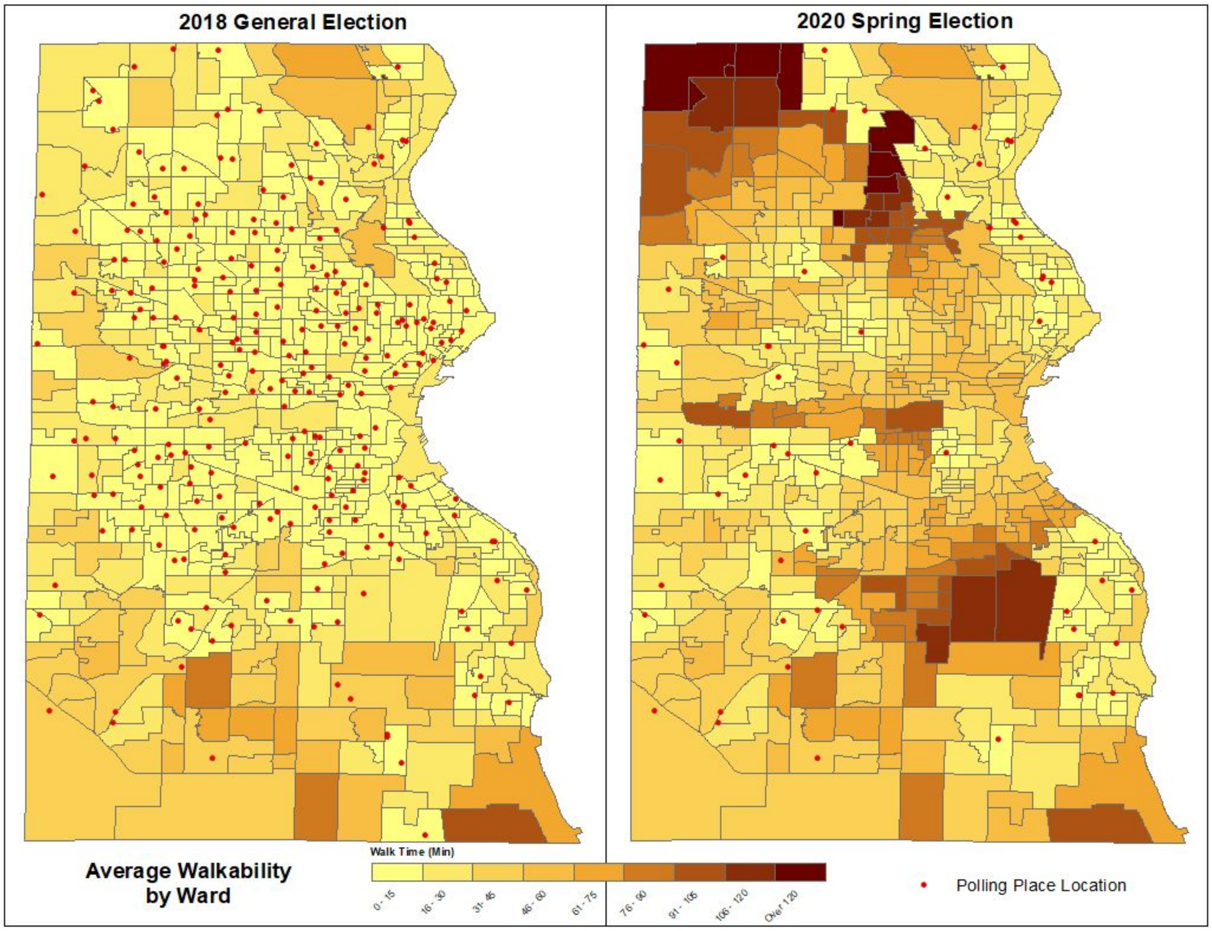
```
-- Add ward_fips field to blocks
alter table blocks
add column ward_fips varchar(16);

-- Update ward_fips values from wards layer using blocks centroid
update blocks
set ward_fips = (select w.ward_fips
                     from wards w
                     where st_intersects(st_centroid(blocks.geom), w.geom));
```

Finally, the ward_analysis table, holding all of the needed data, was created by joining the three tables together:

```
drop table if exists ward_analysis;
create table ward_analysis as (
select
    wta.ward_fips, wta.ppname18, wta.walk_time_2018,
    wta.ppname20, wta.walk_time_2020,
    w.persons18, w.white18, w.black18, w.hispanic18,
    w.asian18, w.amindian18, w.other18,
    b.housing10, b.pop10, b.hhinc18,
    w.geom
from
    walk_time_analysis_results wta,
    wards w,
    (select ward_fips,
              round(sum(housing10)) housing10,
              sum(pop10) pop10,
              round(avg(hhinc18)) hhinc18
     from blocks
     group by ward_fips) b
where w.ward_fips = wta.ward_fips and w.ward_fips = b.ward_fips);
```

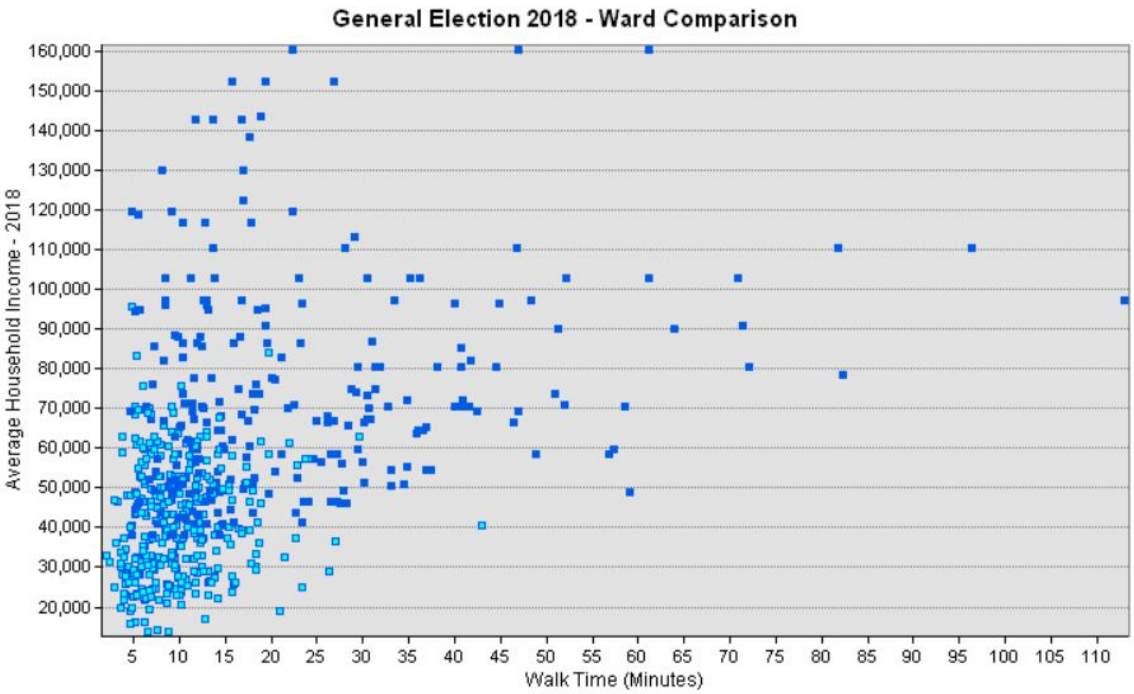
Results

In order to find out which wards had the best access to their associated polling place, the ward and polling places were joined together with the walkability analysis results. A map could then be created to show the walkability across the county in 15 minute increments for both the 2018 General Election and 2020 Spring Election:

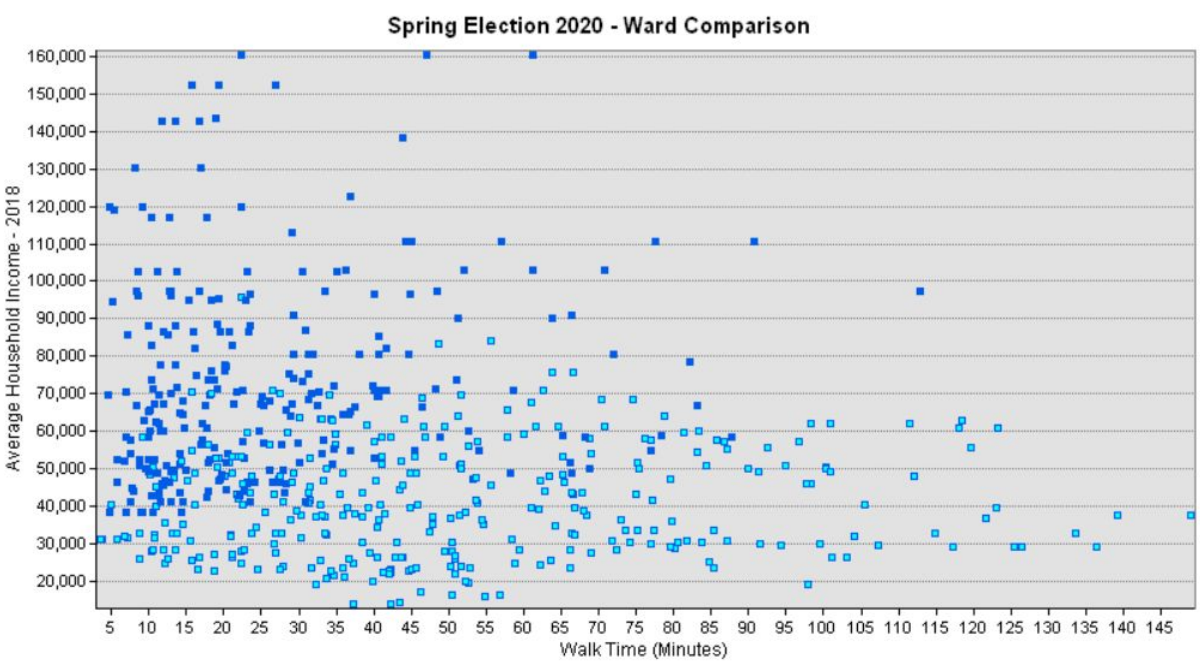


During a normal presidential election, most polling places are reachable with less than a 30 minute walk. Only in the areas of Milwaukee County that are less urban does the distance reach more than an hour. However, the impacts of polling place closures can begin to be seen in the 2020 map, especially with the City of Milwaukee having only five voting locations. Residents of some of the more outlying areas would have more than a two hour walk. Even though some of those areas are close to a polling place, because they are in a different city or village, they would not be able to vote in those locations, according to state law.

The second research question concerns looking at income levels for voters and whether that has an impact on their ability to reach their assigned polling place. For the 2018 General Election, those voters with lower income levels generally had shorter distances, with the majority having to walk less than 20 minutes. All of the areas with a walk over an hour had household income levels over $70,000 a year. The cyan squares below indicate wards in the City of Milwaukee and blue squares represent wards in other Milwaukee county municipalities:



For the 2020 Spring Election, greater polling place consolidation had a significant impact. This scatterplot shows how lower income residents would have had a lot of difficulty reaching a polling place in a reasonable time period. All of the longest walks would be for voters in wards averaging household income levels under $40,000 per year (Cyan are City of Milwaukee wards, blue are wards for other municipalities in Milwaukee County):



For the third research question, in order to find the polling place that can host the most voters, we can run a query that sums the voting population of all of the wards that are associated with that polling place. For the 2018 General Election, the top eight polling places that host the most voters are not in the City of Milwaukee, but in surrounding municipalities. For the 2020 Spring Election, because of the COVID-19 pandemic, many municipalities were forced to consolidate polling places, as Oak Creek went down to just one location (from 6) and Greenfield went to just two (from 6). However, the City of Milwaukee saw the biggest consolidation as its 180 polling places went down to just 5, as over 100 wards were relocated to larger high schools. Theoretically, these places could have needed to each host over 80,000 voters:

Query Editor Query History

```
select
    ppname18,
    sum(persons18)
from ward_analysis
group by ppname18
order by sum(persons18) desc limit 10;
```

Data Output

	ppname18 character varying (254)	sum numeric
1	MILWAUKEE_COUNTY_SPORTS_COMPLEX	8711
2	HART_PARK_RECREATION_BUILDING	7726
3	FRANK_P_ZEIDLER_MUNICIPAL_BUILDING	6317
4	HALES_CORNERS_VILLAGE_HALL	6090
5	GENERAL_MITCHELL_SCHOOL	5991
6	GREENFIELD_COMMUNITY_CENTER	5973
7	GLENWOOD_SCHOOL	5905
8	WHITNALL_HIGH_SCHOOL	5787
9	MARQUETTE_UNIVERSITY_ALUMNI_UNION	5675
10	BOYS_AND_GIRLS_CLUB_MILWAUKEE	5643

Query Editor Query History

```
select
    ppname20,
    sum(persons18)
from ward_analysis
group by ppname20
order by sum(persons18) desc limit 10;
```

Data Output

	ppname20 character varying (254)	sum numeric
1	RIVERSIDE_HIGH_SCHOOL	93272
2	SOUTH_DIVISION_HIGH_SCHOOL	89281
3	HAMILTON_HIGH_SCHOOL	87642
4	MARSHALL_HIGH_SCHOOL	83017
5	WASHINGTON_HIGH_SCHOOL	80274
6	OAK_CREEK_HIGH_SCHOOL	26319
7	GREENFIELD_COMMUNITY_CENTER	16851
8	HART_PARK_RECREATION_BUILDING	14806
9	WHITNALL_HIGH_SCHOOL	13417
10	MILWAUKEE_COUNTY_SPORTS_COMPLEX	8711

Summary Conclusions

After looking at walkability analysis in Milwaukee County for both the 2018 General Election and the 2020 Spring Election, it becomes clear how important polling place locations are for voters, especially those without access to transportation. In a normal election, polling places are fairly well-distributed, especially in lower income areas. Outside of a few outlying cases, most low income voters would be able to reach their polling place in under 30 minutes. In addition, the amount of voters who are assigned to each polling place is also low, which limits the amount of waiting voters would need to do once at their polling location.

However, with the chaotic 2020 Spring Election, lack of available poll workers caused significant issues for citizens who wanted to vote on election day. In many places, a polling place that once was normally a 15-20 minute walk could become an hour or longer. The consolidation of wards into a smaller number of polling places significantly increased the possibility those places could become overcrowded.

With additional time and data, it would also be interesting to look at private and public transportation to see what effects those variables would have on access.

Appendix A - Additional SQL and PL/pgSQL

Small clips of code are provided throughout the main portion of the paper, but larger blocks of code are contained in this appendix.

1. The following DDL is used to prepare the road network data for use in pgRouting's travel time analysis function.

```
-- Delete node and network tables if they already exist
drop table if exists node, roads_vertices_pgr, network cascade;

-- Create topology
select pgr_createTopology('roads', 0.001, 'geom', 'id');

-- Create node table
CREATE TABLE node AS
   SELECT row_number() OVER (ORDER BY foo.p)::integer AS id,
       foo.p AS geom
   FROM (
       SELECT DISTINCT roads.source AS p FROM roads
       UNION
       SELECT DISTINCT roads.target AS p FROM roads
   ) foo
   GROUP BY foo.p;

-- Create routable network
CREATE TABLE network AS
   SELECT a.*, b.id as start_id, c.id as end_id
   FROM roads AS a
       JOIN node AS b ON a.source = b.geom
       JOIN node AS c ON a.target = c.geom;

-- Create network nodes view
CREATE OR REPLACE VIEW network_nodes AS
SELECT foo.id,
 st_centroid(st_collect(foo.pt)) AS geom
FROM (
  SELECT network.source AS id,
       st_geometryn (st_multi(network.geom),1) AS pt
  FROM network
  UNION
  SELECT network.target AS id,
       st_boundary(st_multi(network.geom)) AS pt
  FROM network) foo
GROUP BY foo.id;

-- Add travel time field to network
ALTER TABLE network ADD COLUMN traveltime double precision;

-- Calculate travel time based on an average walking speed of 3.1mph.
UPDATE network SET traveltime = (st_length(geom) / 16368) * 60;
```

2. **find_nearest_node()** finds the node closest to the input polling place by measuring the distance to each node within a 1500' buffer of the input polling place and returning the node id with the lowest distance value.

```
create or replace function find_nearst_node(name varchar(254)) returns int as
$$

begin
    raise notice 'Finding nearest node for polling place %', name;

    if exists (select * from pp_2018General where pollingpla = name)
    then
        --Search in 2018 PP
        return (
                select
                        node.id
                from
                        PP_2018General pp,
                        network_nodes node
                where pp.pollingpla = name and
                        node.geom && st_expand(pp.geom, 1500)
              order by ST_Distance(pp.geom, node.geom) asc limit 1
                        );
    else
        --Search in 2020 PP
        return (
                select
                        node.id
                from
                        PP_2020Spring pp,
                        network_nodes node
                where pp.pollingpla = name and
                        node.geom && st_expand(pp.geom, 1500)
              order by ST_Distance(pp.geom, node.geom) asc limit 1
                        );
    end if;
end
$$ language plpgsql;
```

3. **generate_walking_analysis_view()** creates a view that shows the travel time analysis from the input node id value. The view will be used both to calculate the average walk time in each ward and create isochrone maps.

```
create or replace function generate_walking_analysis_view(node int, ward_fips
varchar(16)) returns void as
$$

begin
    raise notice 'Generating walking analysis view for %.', ward_fips;

    execute 'CREATE OR REPLACE VIEW v_'|| replace(ward_fips, ' ', '_') ||' AS
        SELECT di.seq,
                    di.id1,
                    di.id2,
                    di.cost,
                    pt.id,
                    pt.geom
        FROM pgr_drivingdistance(''SELECT
                id AS id,
                Source AS source,
                Target AS target,
                Traveltime AS cost
                     FROM network'', ' || node || ',
```

```
                100000, false, false)
                di(seq, id1, id2, cost)
        JOIN network_nodes pt ON di.id1 = pt.id';
        return;
end;
$$ language plpgsql;
```

4. **avg_travel_time()** returns the average walking time in minutes within a given ward to the ward's assigned polling place.

```
create or replace function avg_travel_time(ward_fips varchar(16), ppName
varchar(254)) returns double precision as $$

declare
       vName varchar := 'v_' || replace(ppName, ' ', '_');
    avg double precision;
begin
       raise notice '====';
    raise notice 'Looking for %', vName;
    raise notice 'Created from %', ppName;
    if exists (SELECT *
                    FROM information_schema.views
                    WHERE table_schema = 'public'
                           AND table_name = lower(vName))
    then
        execute '
                select
                       avg(n.cost)
                from
                       ' || vName || ' n,
                       wards w
                where w.ward_fips = ''' || ward_fips || ''' and
                st_intersects(n.geom, w.geom)' into avg;

        return avg;
    else
        return -1;
    end if;
end;
$$ language plpgsql;
```

5. **Walkability_analysis.sql** uses the polling place data, the Milwaukee road network, and the functions defined above to create a walking time analysis for each of the polling places in Milwaukee County in both the 2018 General and 2020 Spring elections.

```
-- Create tables holding nearest node for each polling place.
-- One for 2018 and one for 2020.
drop table if exists polling_place_nearest_nodes_2018;
create table polling_place_nearest_nodes_2018 as (
    select
       pollingpla,
       find_nearst_node(pollingpla) as node
    from pp_2018general
);


drop table if exists polling_place_nearest_nodes_2020;
create table polling_place_nearest_nodes_2020 as (
```

```
        select
           pollingpla,
           find_nearst_node(pollingpla) as node
        from pp_2020spring
);


-- Create views representing the walkability analysis for each polling place
-- eg The view 'v_RIVERSIDE_HIGH_SCHOOL' will be created for polling place
'RIERSIDE_HIGH_SCHOOL'
-- 2018:
select generate_walking_analysis_view(node, pollingpla) from
polling_place_nearest_nodes_2018;

-- 2020:
select generate_walking_analysis_view(node, pollingpla) from
polling_place_nearest_nodes_2020;

-- Create walkability results table
drop table if exists walk_time_analysis_results;
create table walk_time_analysis_results as (
        select
            WARD_FIPS,
            ppname18,
            avg_travel_time(WARD_FIPS, ppname18) as walk_time_2018,
            ppname20,
            avg_travel_time(WARD_FIPS, ppname20) as walk_time_2020
        from
            wards
        );
```

Sources

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