SIMULATING TRANSIT ACCESSIBILITY TO EARLY LEARNING CENTERS IN CHICAGO, ILLINOIS

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ABSTRACT

Accessing essential services like grocery stores, libraries, and schools via transit requires a system that makes them reachable in terms of space and time. Current research leverages the General Transit Feed Specification (GTFS) to analyze spatiotemporal access to essential services. Still, insufficient consideration has been given to early learning centers (ELCs), unique among essential services in that they are often an intermediate stop on a commute trip. This paper aims to assess if transit service adequately serves parents who escort their children to/from ELCs on their way to/from work, using the Chicago Transit Authority (CTA) as a case study. The overarching goal is to develop a method that can be used to identify areas of a city that may be underserved by transit and/or childcare services. A simulation model is presented that considers the temporal dimension of transit service through GTFS-based analysis and accounts for the random nature of ELC enrollment through 100 Monte Carlo simulations. The model results suggest that CTA transit services may be too infrequent to serve parents living in Far North Chicago, while parents in Central Chicago are also disproportionately affected with long commute times because of the high demand for childcare in that area. A key contribution of this paper is that the simulation model relies on open data sets and OpenTripPlanner (OTP), so it could be easily replicated in other American cities to assess transit access to childcare.

Keywords: families, children, childcare, early learning centers, GTFS, OpenTripPlanner, transit accessibility

INTRODUCTION

In the United States, parents often enroll their children in early learning centers (ELCs) that specialize in educating young children, typically between six weeks and five years of age. Unlike primary and secondary education, education from an ELC is not required. Thus, enrollment in ELCs does not parallel public primary schools that must accept all children within a prescribed municipal zone. Instead, ELCs can only extend offers for enrollment when they have a current vacancy, which is infrequent. Nationally, the average ELC has more than 230 young children waiting for care (*1*). Consequently, parents without childcare and on multiple waitlists will presumably accept the first offer for care they receive.

A family's first enrollment offer will likely come from a center other than the one closest to their homes or workplaces. Rational working parents will apply to several ELCs near their homes or work to increase the likelihood of admission to an ELC that conveniently fits their current commute patterns. Other essential services (e.g., grocery stores, libraries, and religious centers) are selected from a relatively small pool of choices, typically based on travel time or services offered. Conversely, ELC selection is more strongly influenced by factors outside the parents' control, such as the rate of child turnover. Therefore, traditional methods such as the two-step floating catchment area method may be challenging to use for accessibility analysis for childcare and have only been used in a very limited number of prior studies *(2,3)*.

The challenge of ELC enrollment is further exacerbated for transit-reliant parents, whose practical selections for ELCs are only those close to transit stops. Even if an ELC is near a transit stop, if its location requires indirect travel between home and work, transit riders may be disproportionately affected. Whereas drivers can more easily handle indirect travel routes, transit riders may experience excessively long commute times if travel is indirect. Single-parent households, who are more likely to be transit-reliant than two-parent households (*4*) may find it especially difficult to find care. Whereas households with two working parents have three viable regions for ELC selection (i.e., near home, near parent one's workplace, and near parent two's workplace), single-parent households may only have two viable regions (i.e., near home and work). This paper does not differentiate single-parent and two-parent households. For simplicity, all households are modeled as having one parent who escorts his/her child to an ELC during the parent's morning commute and picks the child up from the ELC during the parent's evening commute.

This paper aims to assess if transit service adequately serves parents who escort their children to/from ELCs on their way to/from work, using Chicago as a case study. The overarching goal of this research is to develop a method that can be used to identify areas of a city that may be underserved by transit and/or childcare services. The simulation model presented in this paper relies on open data sets and OpenTripPlanner (OTP), so it could be easily replicated in other American cities to assess transit access to childcare.

This paper proceeds as follows. First, a literature review on transit access to childcare is presented. After identifying gaps in the literature, the research questions are presented. This is followed by a detailed description of the simulation method used to analyze childcare access in Chicago. Finally, conclusions, areas for improvement, and suggestions for future research are presented.

LITERATURE REVIEW ON TRANSIT ACCESS TO CHILDCARE

A review of prior research was conducted specifically on transit access to childcare. A key finding from this review is that there is very limited literature on this topic from the United States, where the relatively small amount of literature on accessibility to childcare primarily focuses on travel via private vehicles - such as recent studies from Blumenberg et al. *(2)* and Hu et al. *(5)*.

Early transit accessibility studies concerning childcare often relied on survey data supported by ground truthing. Such was the case with a 2006 report from Syracuse, New York, which estimated that even though more than 90% of parents considered the nearest bus stop to be “close” to their childcare center, only 13% and 14% of parents in Syracuse used transit services to pick-up and drop-off their children, respectively *(6)*. Despite the small percentages of parents using transit, this study confirms that this mode should be considered for childcare accessibility; nearly one in six parents who think a transit commute is feasible either relied on it or chose it.

More recent studies on transit access to childcare have continued to use survey-based methods and also geographic information systems (GIS) to map the supply of and demand for ELCs. A 2016 report to Minnesota’s Twin Cities revealed a substantial discrepancy between the proximity of transit facilities to ELCs and parents’ perception of transit access to ELCs *(7)*. By overlaying ELC maps with transit maps, the study found that the highest concentrations of ELCs were near residential locations and business districts, and an even distribution of ELCs existed along transit routes. However, household surveys demonstrated that parents did not feel the transit schedule served them well, confirming a discrepancy between the previously accepted survey-based data and the GIS-based research.

More recently, a 2024 paper tested the relationship between childcare supply, a household’s use of care, and home-to-childcare travel distances in California *(8)*. The approach included a two-step floating catchment area (2SFCA) method to overlay the locations of childcare demand (i.e., where young children live) with the locations of childcare supply (i.e., where ELCs are). The authors then developed a binary logistic regression model using 2017 National Household Travel Survey data to assess if a household had made a home-to-childcare trip. The results revealed that nearly 90% of home-to-childcare trips were made by private vehicles, and none were made using public transit, highlighting the rarity of using transit to access childcare facilities in California *(8)*.

Last, a 2024 study assessed which census blocks in Nashville, TN adequately provide transit access to essential services, including childcare facilities and other services such as supermarkets *(9)*. The authors developed a five-step method to identify “essential service” deserts, which included creating a spatiotemporal transit supply index using General Transit Feed Specification (GTFS) data and evaluating transit dependency using data from the US Census Bureau. The results were used to identify areas of Nashville that may be “childcare deserts” for those who depend on public transit, such as car limited and/or low-income households. However, the authors did not explicitly consider the temporal nature of childcare facilities or that childcare drop-offs and pick-ups are typically conducted a part of a linked trip on the way to/from work.

Gaps in the Literature

As can be seen from this review of existing research, there is very limited prior research on transit access to childcare in the US. The few prior studies of access to childcare that explicitly consider transit service provision – such as the recent study of Nashville *(9)* – have not considered the temporal nature of ELCs or the time constraints of most jobs. This research seeks to address these gaps in the literature by explicitly considering the impacts on transit-based travel when multi-stop trip chaining is necessary between home, work, and ELC locations. To the best of the authors’ knowledge, no prior study has examined whether the span and frequency of transit networks sufficiently serve linked trips (i.e., from home to ELC to work, and vice versa).

RESEARCH QUESTIONS

This study seeks to answer two primary questions based on simulated results:

1) Do transit services in Chicago adequately serve parents escorting their children to ELCs before and after work?
2) Are any of Chicago's census tracts underserved for transit-reliant working parents who require childcare services?

METHODOLOGY

The methodology used in this research will be described in detail in this section. Figure 1 below provides a framework for the reader to reference as necessary. As shown, this research applies six steps to answer the two research questions outlined above.

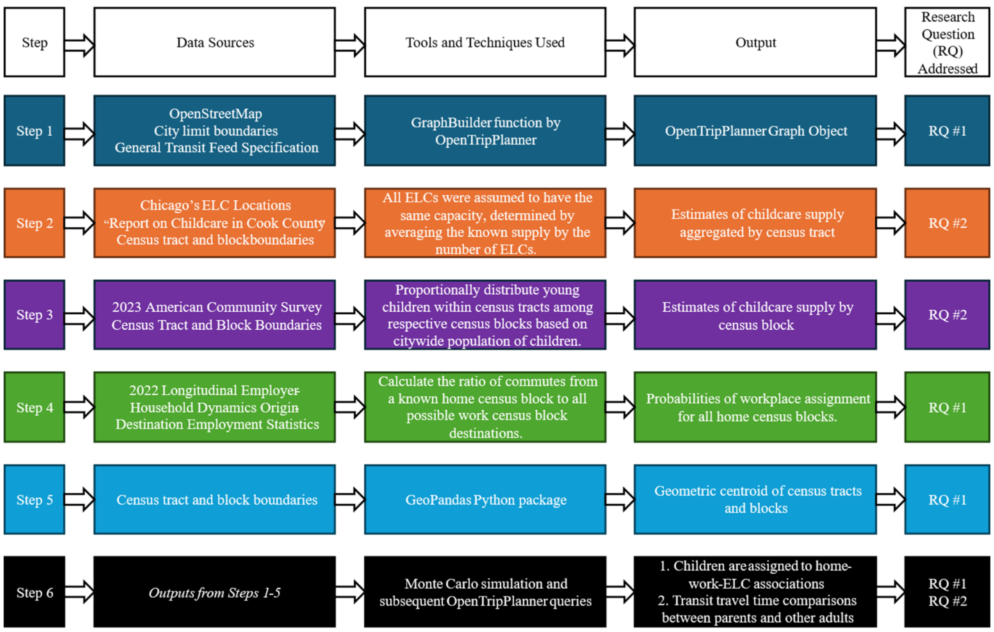

FIGURE 1 Framework of Methodology Applied

After initial data collection and preprocessing, this research simulates the probabilistic assignment of children to ELCs. The most common associations between home locations, work locations, and ELCs are queried in OpenTripPlanner (OTP) to determine the shortest morning and afternoon commute times for pedestrians and transit riders.

Data Collection and Preprocessing

Surface Network Construction

This research required the construction of an OTP graph that would later be queried for travel times among home, work, and ELC associations. Illinois's OpenStreetMap (OSM) file *(10)* was first trimmed to the bounds of Chicago's city limits, as defined in the Chicago Open Data Portal *(11)*. Using OTP's GraphBuilder function, the trimmed OSM file was joined with CTA GTFS data *(12)* to create the OTP graph representing Chicago's transportation surface network.

Childcare Demand and Supply Estimation

Chicago fully or partially funds 706 licensed ELCs *(13),* and the estimated total capacity of ELCs was 33,218 children in 2022 *(14).* The exact capacity of most centers is unreported, so this research presumes that the average capacity of 47 children is evenly spread across all centers. Using this initial estimation and the known location of all 706 centers, the estimated supply of young childcare can be aggregated to census tracts, as shown in Figure 2. In the figure, pink census tracts show areas of the city with high levels of childcare supply, whereas light blue census tracts have little to no childcare availability.

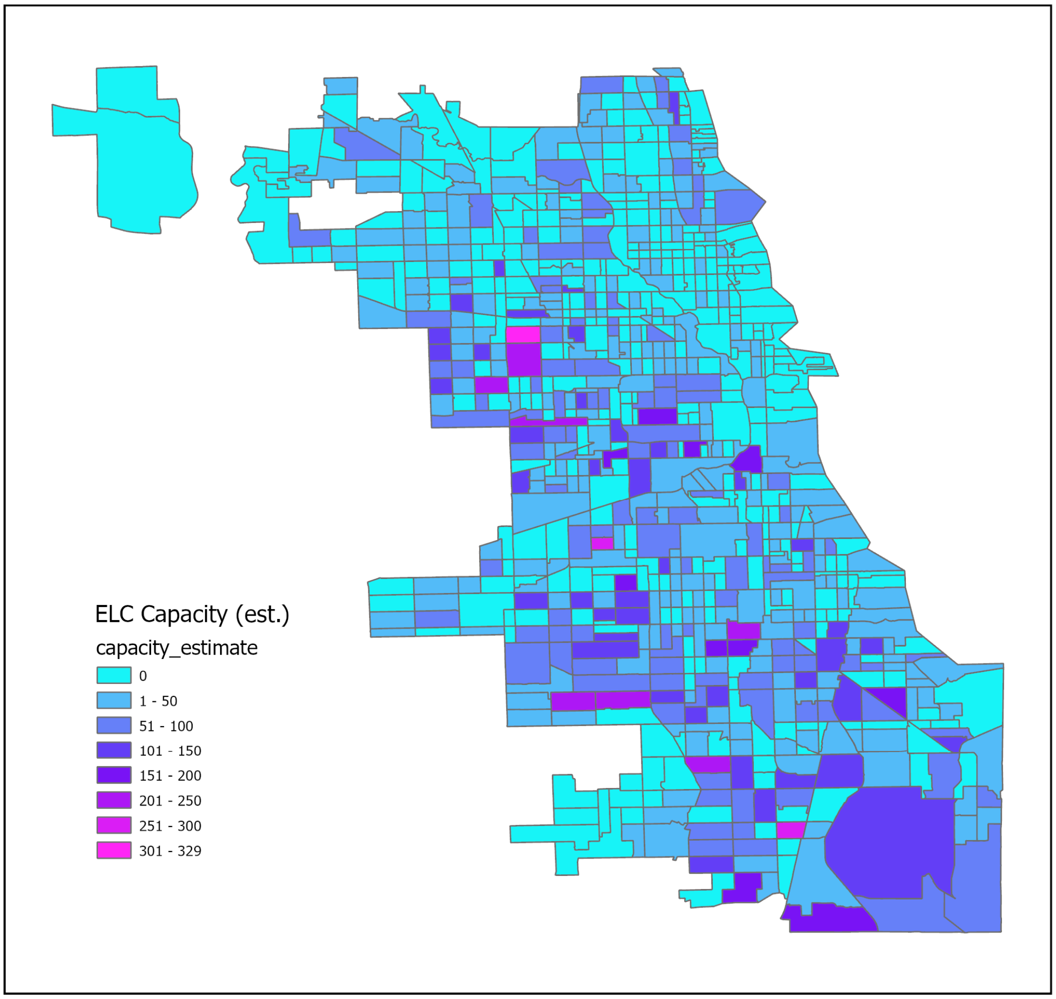

FIGURE 2 Capacity of Chicago's Early Learning Centers Aggregated by Census Tract

Chicago's ELCs do not currently satisfy the City's actual demand for childcare *(14),* with many young children presumably on waitlists for enrollment. This research does not explore ELC enrollment turnover or latent demand but assumes that demand and supply are in steady-state equilibrium. The 5-Year Estimates from the 2023 American Community Survey (ACS) approximate the young child population (<5 years old) of each census tract. To determine travel time to and from ELCs accurately, these estimates had to be adjusted to census blocks. Thus, census tract estimates were evenly distributed among the respective census blocks internal to each tract. Because the supply and demand of childcare in the city are assumed to be in equilibrium, the city-wide supply of childcare (33,218 enrollments) was proportionally distributed by census block, and those estimates were subsequently rounded to the nearest whole number. The result is that all census blocks within a census tract have an equal number of children who will be enrolled in an ELC, but this number varies between census tracts due to population-based weighting.

Table 1 shows this estimation process for census block 170311202001010 as an example. Based on population of young children in the tract, 3.536 children less than five years of age were initially presumed to live in this census block. Since 0.230% of the children in Chicago live in the entire tract, 0.230% of the available ELC enrollments (33,218) were presumed to be associated with the tract. Thus, while roughly four (3.536) children are estimated to live in census block 170311202001010, only one (0.787) of them is presumed to be enrolled in an ELC.

TABLE 1 Estimating the Population of Young Children in Census Block 170311202001010

Census Tract 17031120200	
ACS B01001 estimated population (<5yo) for this census tract	343
Share of city-wide child population in this tract	0.230%
Number of census blocks in this census tract	97
Census Block 170311202001010	
Estimated children (tract population / number of blocks)	3.536
Population of children scaled to ELC capacity (33,218)	0.787
Population of children rounded to the nearest integer	1*
*After rounding, 33,331 children were assigned across 32,431 home census blocks, a 0.34% error from the target population of 33,218 children.	

Census block estimates were used for analysis, but census tract estimates are shown in Figure 3 for visualization. Areas with the sparsest population of young children are shaded yellow, while those with the highest populations of children are shaded red. Although such a correlation is neither explored nor quantified in this research, visual comparison of Figure 3 and CTA transit maps reveals that the densely populated census tracts generally follow the pattern of "L" rail lines within the City of Chicago.

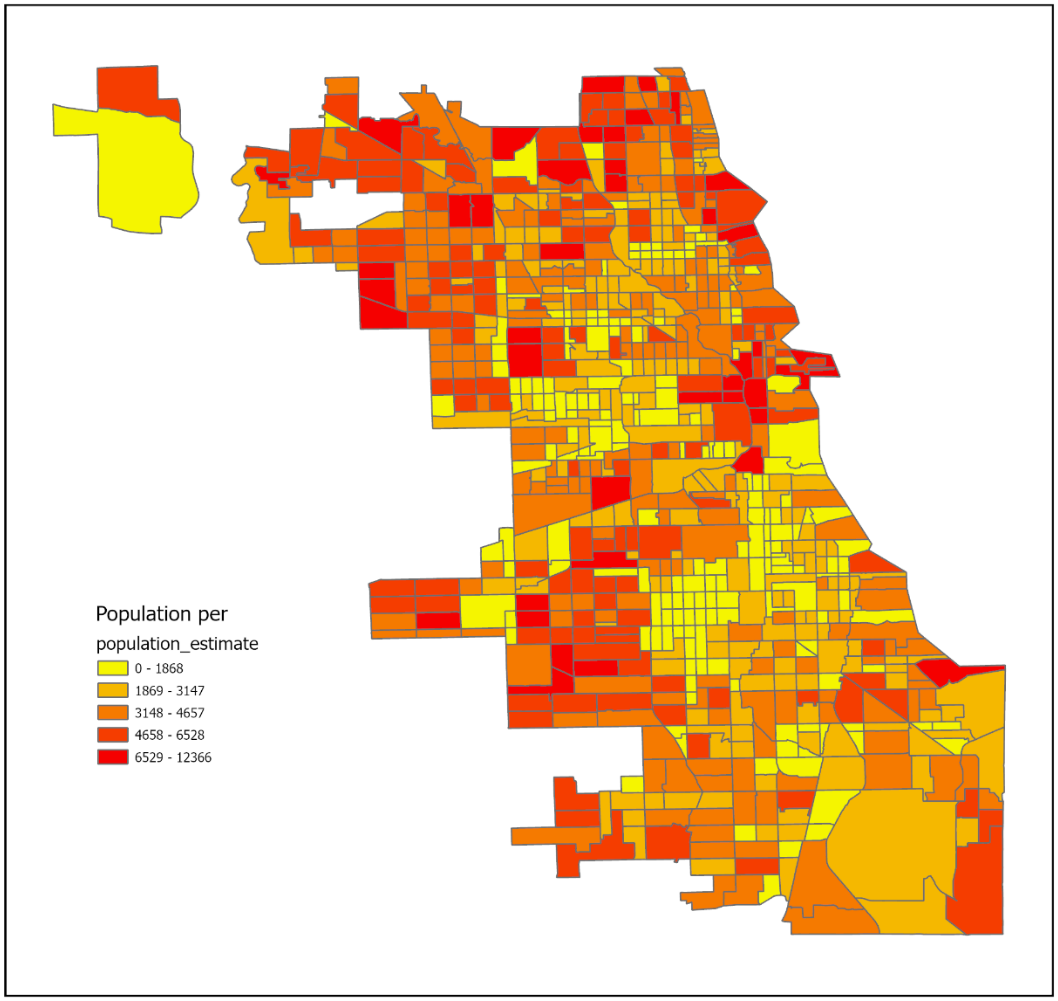

FIGURE 3 Demand for Childcare Aggregated by Census Tract

Home-Work Origin-Destination Pairing

This research assumes that parents whose children are in ELCs work a full-time job from 9 a.m. to 5 p.m. on weekdays. In the yearly Longitudinal Employer-Household Dynamics (LEHD) study, the U.S. Census Bureau reports known home-work origin-destination pairs in the LEHD Origin-Destination Employment Statistics (LODES) datasets. The 2022 LODES dataset for Illinois *(15)* was trimmed to exclude commuters who live or work outside the city limits, leaving 32,431 home census blocks and 12,782 work census blocks among commuters. 557,787 unique origin-destination pairs within the city limits remained in the dataset. From each home census block, the ratio of its workers was taken from the sum of all potential job destinations.

Table 2 provides an example using census block 170311202001010 (hereafter "block **1010") as the home census block. There are 15 census blocks which correspond to work locations for citizens living in block **1010. The number of jobs for each unique home-work pair is taken as a ratio for the total number of jobs from block **1010.

TABLE 2 Ratios of Job Commutes Originating from Census Block 170311202001010

Home Census Block	Estimated Children from this Home Census Block	Work Census Block	# Jobs	Ratio of Jobs from this Home Census Block
170311202001010	1	170310101001000	1	5.88%
		170310104003002	1	5.88%
		170310207021021	1	5.88%
		170310814031010	1	5.88%
		170311202004012	1	5.88%
		170312819003008	1	5.88%
		170317202003031	1	5.88%
		170318316004000	1	5.88%
		170318391001041	1	5.88%
		170318391001042	2	11.76%
		170318391001085	2	11.76%
		170318391001090	1	5.88%
		170318391002001	1	5.88%
		170318419001043	1	5.88%
		170319801001004	1	5.88%

Figure 4 shows the jobs by census tract. The shading of census tracts indicates the number of jobs generated within the tract's associated work census blocks. Census tracts with a relatively low number of jobs are shaded light blue, while those with a relatively high number of jobs are shaded dark blue. The City's highest concentration of jobs is in the central business district (CBD), which is served by the "L" rail loop. As with the population centers previously shown in Figure 3, the job locations shown in Figure 4 correspond to the location of CTA's "L" rail lines, although that is not explored further in this research.

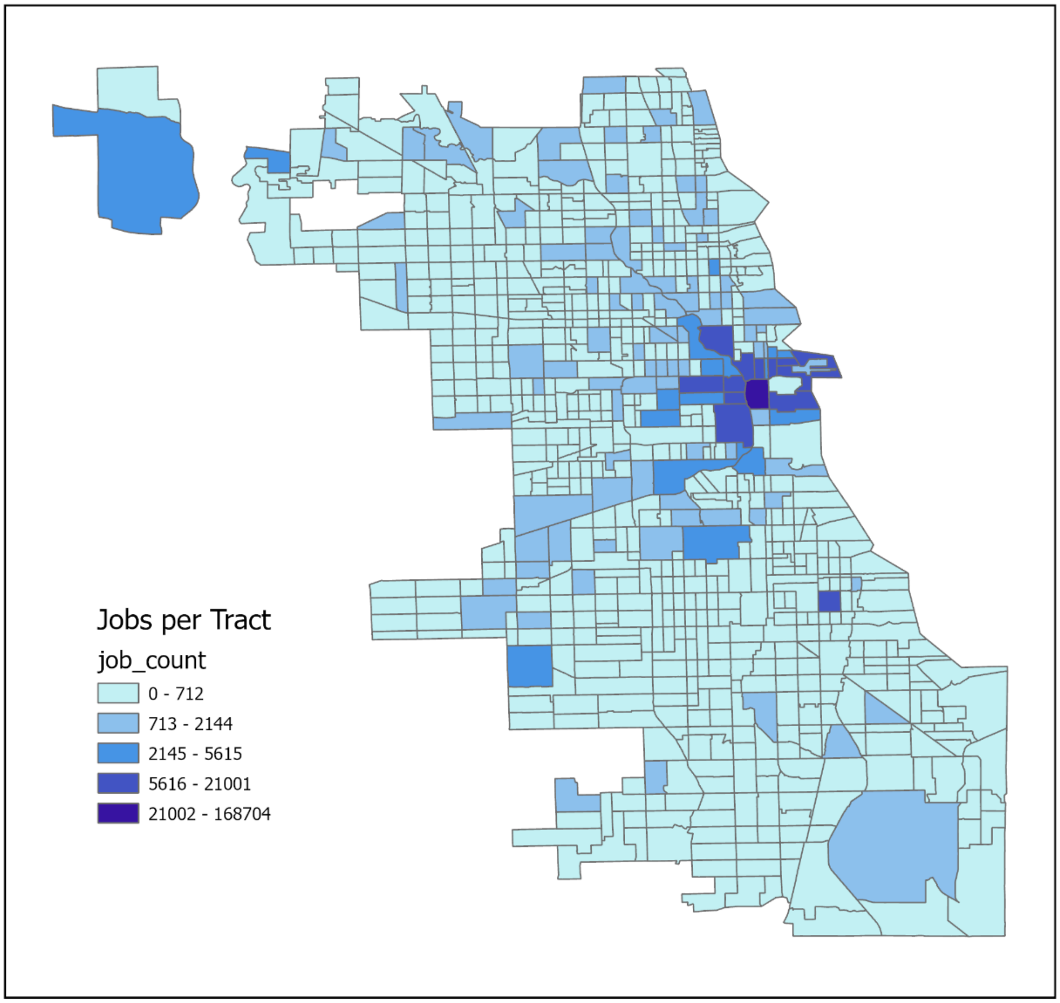

FIGURE 4 Jobs by Census Tract

Geometric Simplifications

This research presumes that all census block demand for childcare originates from the geometric centroid of the block. This research further assumes that commuting parents will consider ELC options close to home or work, but parents will not consider all 706 ELCs in the registry as viable mid-commute options. The Euclidean distance was calculated from each census block centroid to each of the 706 centers, and the 10 nearest centers were selected for consideration during simulations. Thus, a parent commuting on a known origin-destination pair could consider as many as 20 ELCs – 10 near home and 10 near work.

Simulations with Probabilistic Assignment

Sampling Travel Time to the Nearest ELCs

The 10 ELCs nearest to each census block were queried through OTP to determine a sample travel time duration. “WALK” and “TRANSIT” were permitted travel modes for a trip beginning at 7:30 a.m. on April 17, 2025. The two-stage filtering process is demonstrated in Figure 5: the images in the top row demonstrate geometric filtering to the 10 nearest ELCs to each census block centroid, while those in the bottom row represent the corresponding OTP travel time queries.

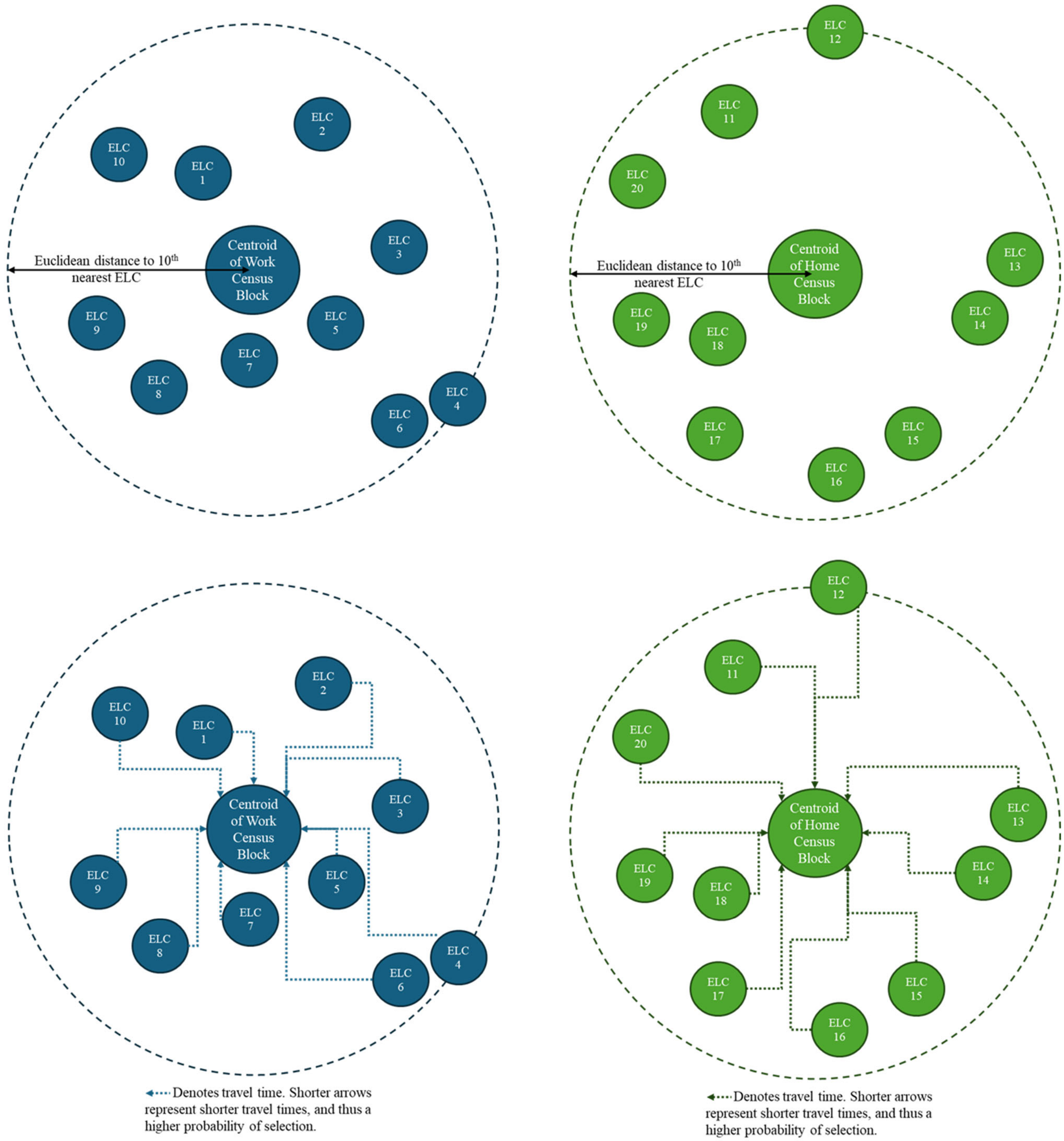

FIGURE 5 Two Step Travel Time Queries - Top: Nearest 10 ELCs by Euclidean Distance; Bottom - Travel Time Queries from OTP

Travel times determined from the sample query were used to develop a multinomial logit model for the assignment probability of children traveling along a specified origin-destination pair. The likelihood of selecting ELC i ($P_{ELC,\,i}$) is calculated using Equation 1, where TT is travel time, m is the number of ELCs (up to 20), and β is a constant (0.2 in this model). A sample of probability assignments is shown in Table 3 for the origin-destination pair between census blocks 170311202001010 and 170310104003002. Within Table 3, the travel time to the 10 nearest centers from each census blocks is provided in minutes, and the corresponding probability of ELC selection is shown as a percentage based on the calculation from Equation 1.

$$P_{ELC,i} = \frac{e^{-\beta * TT_{ELC,i}}}{\sum_{i=1}^{m} e^{-\beta * TT_{ELC,i}}} \quad (1)$$

TABLE 3 Probability of ELC Assignment for a Child Associated with a Sample Origin-Destination Pair

Census Block 170310104003002 (Work)			Census Block 170311202001010 (Home)		
Center ID	Travel Time (min)	Probability	Center ID	Travel Time (min)	Probability
734	11.9	34.188%	662	39.3	0.143%
326	13.4	25.327%	714	44.7	0.048%
938	17	12.328%	798	46.6	0.033%
984	18.6	8.952%	855	53	0.009%
786	21.8	4.720%	561	55.5	0.006%
701	22.1	4.445%	793	61.2	0.002%
866	23.1	3.640%	823	64.4	0.001%
391	23.9	3.101%	803	66	0.001%
284	25.2	2.391%	862	69	0.000%
313	31.6	0.665%	652	69.8	0.000%

Assigning Children to Origin-Destination Pairs

This research conducted 100 Monte Carlo simulations using a single Python script to identify the most common assignments of children to specific ELCs. The following list describes the sequence of each simulation:

1. The order of home census blocks was randomized.
2. Following randomization, the home census blocks were sequentially selected to assign children to ELCs.
3. 1–*n* children were sequentially selected, where *n* is the number of children living in the home census block.
4. For child *i*, an origin-destination pair was probabilistically selected based on the ratio of jobs associated with that origin-destination pair to the total number of jobs related to the home census block (e.g., the ratios shown in Table 2).
5. An ELC was probabilistically selected for the chosen origin-destination pair based on multinomial logit probabilities from sample travel time analysis (e.g., the probabilities shown in Table 3).
6. Update the selected ELC's enrollment volume.
    a. When 50 students had been assigned to a specific ELC, a "soft cap" was imposed, reducing the probability of selecting that ELC in future iterations by 90% (e.g., from 35.9% to 3.59%).
    b. When 75 students had been assigned to an ELC, a "hard cap" was imposed, reducing the probability of selecting that ELC in future iterations to 0%.

c. If the probability of all 20 ELCs was 0%, an ELC with available capacity was selected randomly (i.e., one of the 686 ELCs not initially identified as viable).

Figure 6 provides an example simulation sequence on the next page.

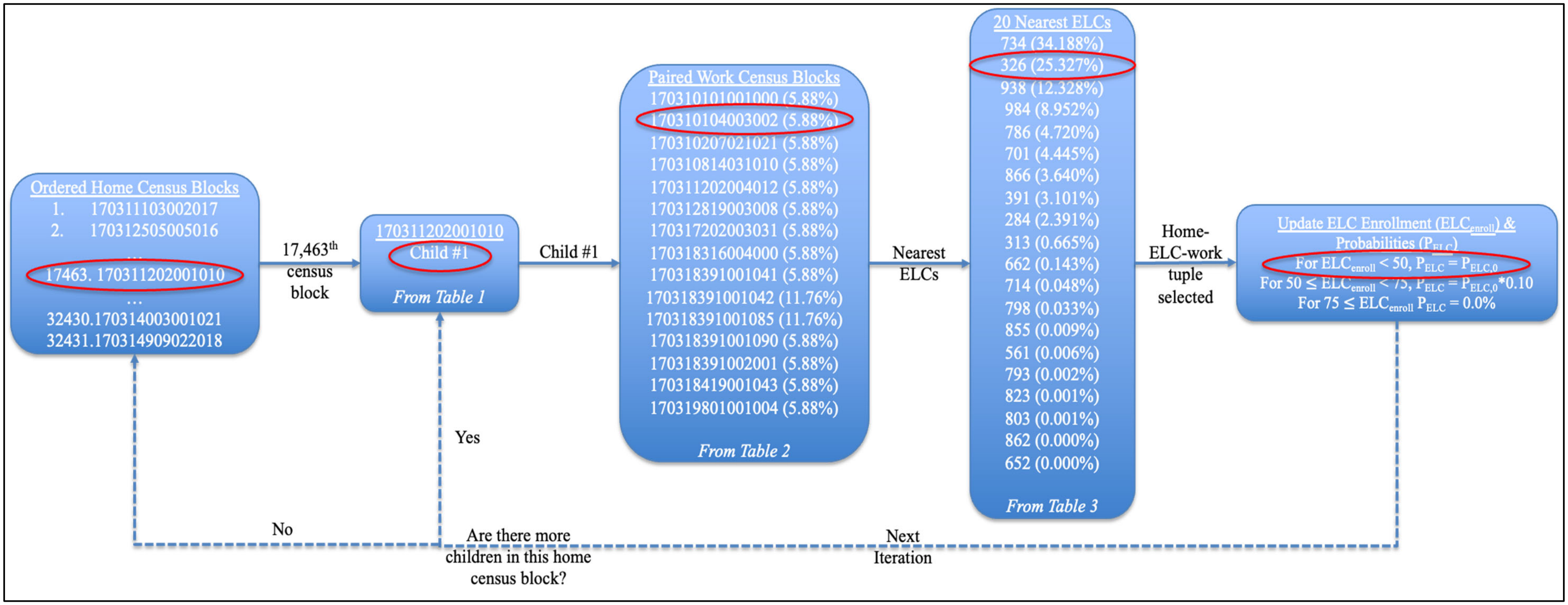

FIGURE 6 Example Simulation Sequence

Identifying the Most Common Home-ELC-Work Associations

The frequency of center selections for all home-work pairs was reviewed after all simulations. The most frequently selected ELC for each pair was identified, and this home-ELC-work association was retained in the dataset. If the two most frequently selected ELCs were selected an equal number of times, both corresponding home-ELC-work associations were retained in the dataset.

Trip Time Calculation

A 10% sample of home-ELC-work associations was selected from each census tract, not to exceed 50 total sample associations. The unsampled dataset included 557,416 associations, but the sampled dataset included 33,098, reducing computational power needed for OTP queries seventeenfold, while retaining enough home-ELC-work associations (30-50) per census tract to be representative. The selected samples were queried in OTP for the following trips:

- Multi-stop Trip 1: Home census block centroid to ELC to work census block centroid. Assumptions: employees must arrive by 9 a.m., and child drop-off time at ELCs is five minutes.
- Multi-stop Trip 2: Work census block centroid to ELC to home census block centroid. Assumptions: employees leave work at 5 p.m., and child pick-up time at ELCs is five minutes.
- Control Trip 1: Home census block centroid to work census block centroid. Employees must arrive by 9 a.m.
- Control Trip 2: Work census block centroid to home census block centroid. Employees must depart by 5 p.m.

The queried trips were on Friday, April 17, 2025, and considered representative of weekday commutes generated from home census tracts. The travel modes selected for the queried trips were walking and transit. Other modes like driving and cycling were not considered for parents or other commuting adults.

RESULTS

Compared to Control Trips 1 and 2, Multi-stop Trips 1 and 2 were notably longer from most census tracts, particularly in the Central and Far North Sides of Chicago, but also to a lesser extent in the central locations of West Side Chicago, including West Town, Near West Side, and Lower West Side. Figure 7 provides a visual contrast of the necessary arrival/departure times for parents and other commuting adults who must work from 9 a.m. to 5 p.m. The shading in each tract refers to the arrival/departure time for people who live in that tract (i.e., their home tract rather than their work tract). Green shading indicates shorter commute times in either the morning or evening, whereas red indicates extremely long commute times. For comparison, Figure 7a. is the morning control trip corresponding to a morning commute with an ELC stop in Figure 7b. Likewise, Figure 7c. is the afternoon control trip corresponding to an afternoon commute with an ELC stop in Figure 7d.

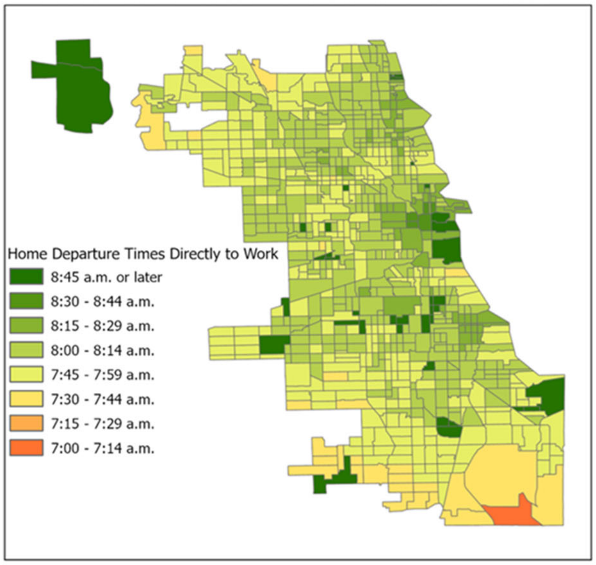

FIGURE 7a. Control Trip 1 – Home to Work

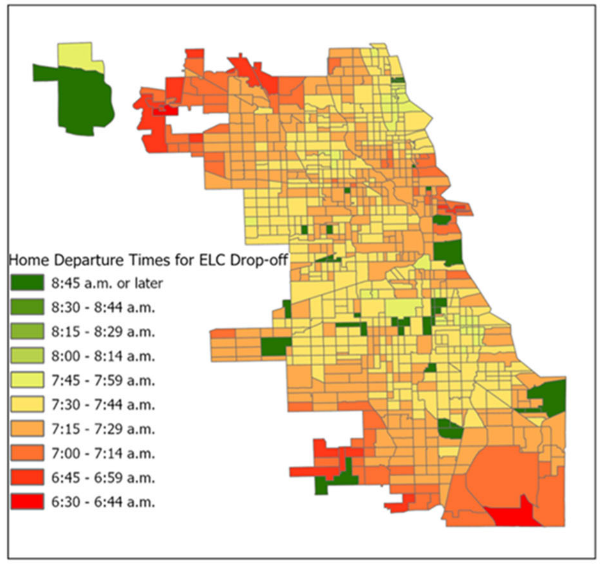

FIGURE 7b. Trip 1 – Home to ELC to Work

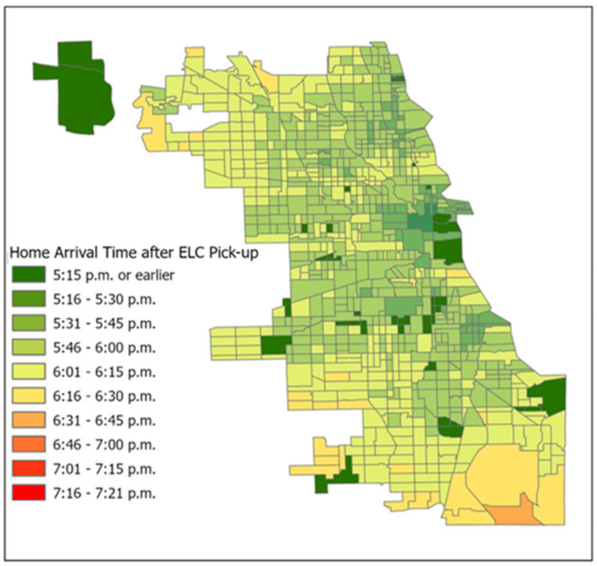

FIGURE 7c. Control Trip 1 – Work to Home

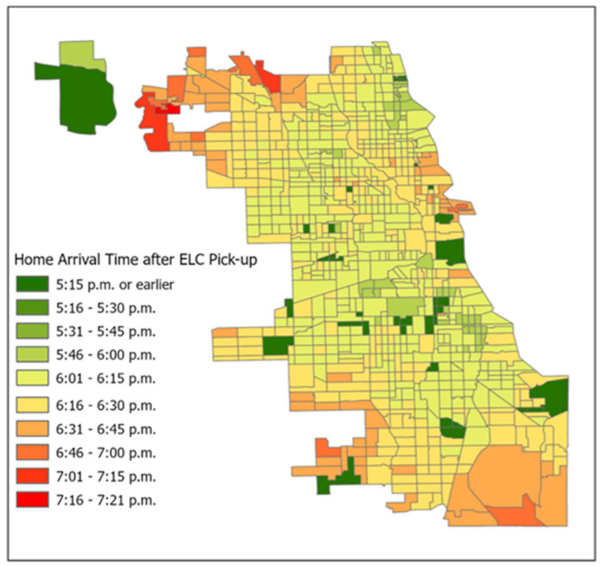

FIGURE 7d. Trip 2 – Work to ELC to Home

FIGURE 7 Estimated Departure and Arrival Times: Comparison of Parents Needing Childcare and Other Working Adults

Aside from the dramatically longer commutes observed in some census tracts of Central and Far North Chicago, the simulation results suggest that most working parents requiring ELC access are sufficiently served by the CTA. Citywide, the average increase in two-way daily commute time for parents of young children was 35.9 minutes compared to other working adults. Parents in 70% of census tracts (559 of 766) had a commute shorter than the 35.9-minute average, with nearly half of the city's parents (370 of 766 census tracts) experiencing a total daily commute increase of less than 30 minutes, while parents in 93% of census tracts (709 of 766) experience an increase of less than 60 minutes per day. Table 4 summarizes comparative statistics across the 766 census tracts included in the simulation. For both morning and evening commutes, the minimum and maximum increase in commute times for parents are provided, as well as the associated means and standard deviations for the dataset. The rightmost column outlines the range, mean, and standard deviation for the total daily commute time increase.

TABLE 4 Increases in Transit Travel Time (TT) Increase for Parents of Young Children Compared to other Working Adults

	9 a.m. commute TT Increase (Minutes)	**5 p.m. commute TT Increase (Minutes)**	**Total Daily TT Increase (Minutes)**
Minimum	5.13	4.40	13.73
Mean	18.52	17.33	35.85
Standard Deviation	9.57	9.31	18.76
Maximum	89.95	86.02	175.97

While most parents are adequately served by CTA, Table 4 above shows that some parents have widely varying experiences across the city. In the most extreme increase of commute times, census tract 17031770902, a neighborhood in the Far North Side, saw an increased daily commute time of almost three hours (175.97 minutes). Although the tract has an average number of children relative to much of the city, there are few jobs and few ELCs in Far North Side relative to its population. The probabilistic assignment of children to ELCs often required transit-reliant parents in the simulation to travel inefficiently across the city to an ELC before linking the trip to work. The simulation repeatedly determined that transit-reliant parents living in this census tract would have to resort to walking during several portions of their commute because of service times.

Areas of Central Chicago also experienced significant increases in travel time during the simulations. Although this area of the city is well-served by high frequency transit, the ELCs in that portion of the city rapidly reached their assumed maximum capacity. Per *(14)*, only 25% of Chicago's ELC capacity is located in Central and West Chicago, even though these areas create significant childcare demand. As a result, the simulations quickly filled the available centers while demand generated by home census blocks in those areas of the city was still high. Consequently, the simulation required many parents who live in Central Chicago to escort their children to ELCs in other neighborhoods before returning to the CBD for work. This indirect travel pattern caused a dramatic increase in travel time for those parents who live and work in Central Chicago but were assigned to ELCs elsewhere.

Conversely, parents in census tracts like 17031838700 in the North Lawndale neighborhood of the West Side experienced minimal delays when escorting their children to and from ELCs. The simulation determined that by using a mix of both walking and transit, parents and children living in this census tract could arrive home within 4.4 minutes of other adults living there, despite the parents' five-minute delay for pick-up time. This is because many transit-reliant commuters from this part of the city must make numerous connections; 20 percent of simulations found that commuters without children chose a combination of walking, riding the bus, and riding the subway for the shortest commute time. In these cases, parents more efficiently walked from work to the ELC and subsequently selected a more direct transit route.

Figure 8 demonstrates the increase in total daily commute time across the city when intermediate stops at ELCs are required. The light blue shading represents an increase of less than 30 minutes daily, while the dark blue shading represents an increase of up to 176 minutes. The most substantial increases in overall commute times were observed in Central Chicago (near the Loop) and the Far North Side of Chicago (near eastern O'Hare).

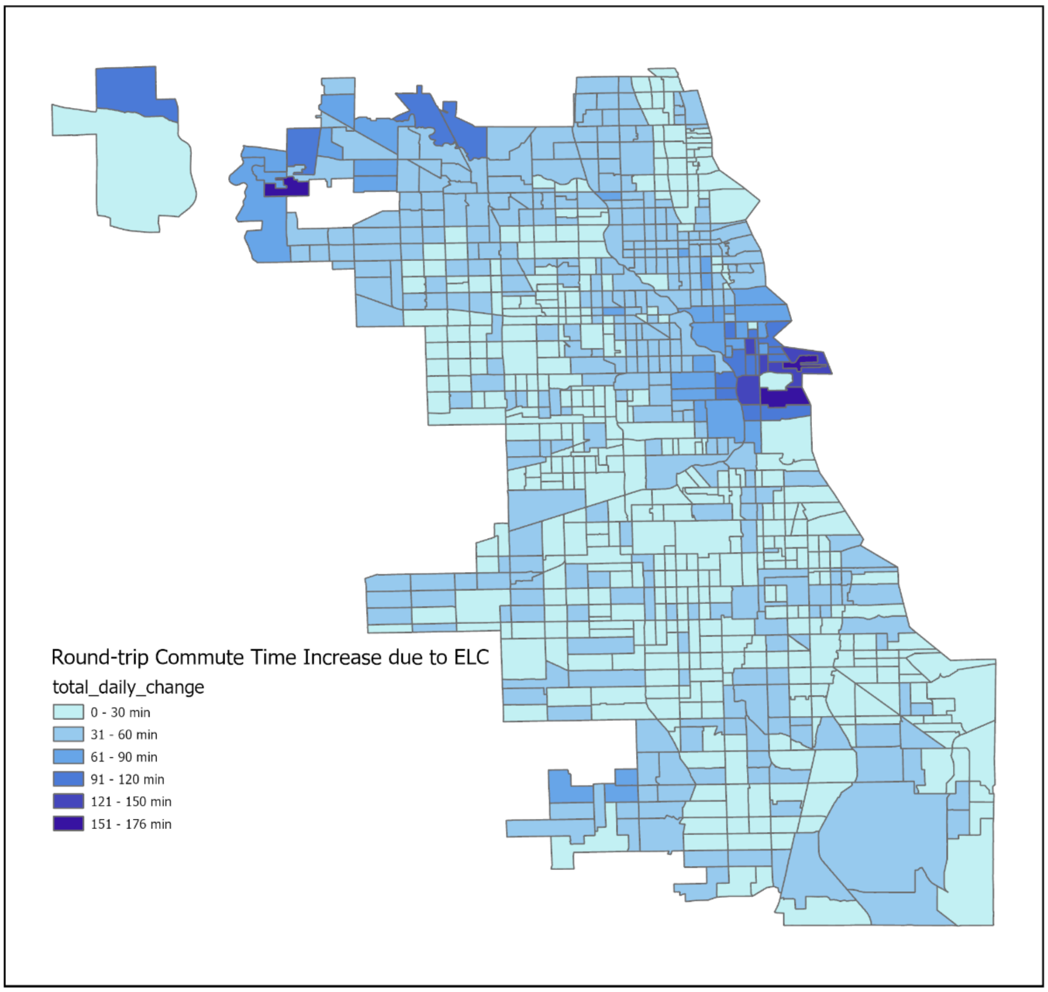

FIGURE 8 Total Estimated Travel Time Added to Daily Commutes by ELC Drop-offs and Pick-ups

A distinct pattern can be observed by comparing total daily commute times (Figure 8 above) to the travel mode split between walking exclusively and transit travel with walking (Figure 9 below). As travel schedules make parents more reliant on walking than transit, the disparity in overall travel times from home to work and vice versa, with intermediate stops at ELC, becomes notably more stratified.

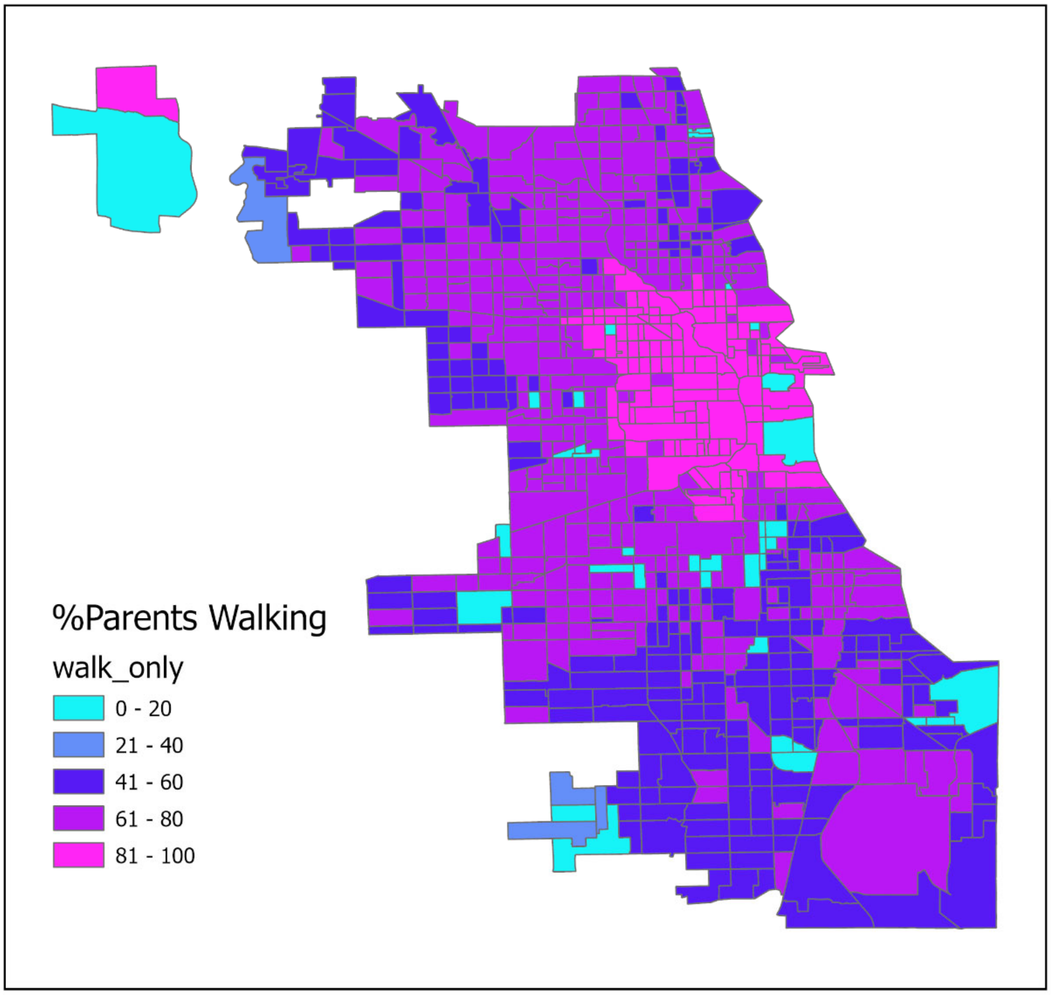

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FIGURE 9 Estimated percentage of Parents and Children Exclusively Walking During their Commutes

DISCUSSION AND CONCLUSIONS

This paper aimed to assess if transit services adequately serve parents escorting their children to/from ELCs on their way to/from work, using Chicago as a case study. The authors presented a novel approach to evaluate the availability of transit service for linked trips between home and work with intermediate stops at ELCs. Through this approach, the authors determined that transit-reliant parents stopping at ELCs incur an additional 35.85 minutes of daily travel time on average when compared to direct home-to-work and work-to-home commuters. However, the range of increased travel times varied widely, with parents in some census tracts incurring only a 13.73 minute-per-day travel time increase, while others incurred nearly three hours (175.97 minutes) of additional daily travel time.

To evaluate whether a given transit network is adequately serving working parents of young children, a two-fold approach is necessary. First, a system-wide evaluation should consider if the average additional daily travel time incurred by parents is acceptable. To set this metric, a sufficient citywide policy might read, “Our transit services shall seek to provide the frequency and span of service necessary to ensure that, on average, parents do not incur more than 30 minutes of additional daily travel time while escorting young children to/from early learning centers on the way to/from work." In the context of this specific case study focusing on Chicago, the CTA and associated stakeholders should identify the acceptable amount of additional commute time to be imposed on transit-reliant parents.

Separately, city policymakers should consider the actual capacity of individual ELCs to determine where ELC enrollment capacity must be increased across the city. In the example from this research, the elected officials of Chicago should decide whether additional ELCs are required in the Far North to prevent excessively long commutes of nearly three hours for parents of young children. Similarly, policymakers could consider restricting the enrollment of children into municipally funded ELCs, adopting a public school zoning model to level system-wide commute times and reduce inefficiency. Such a policy requires judicious application, but the results of this research demonstrated that parents and children living near Chicago's CBD could have the longest commute times due to a lack of zoning structure.

This study contributes to the literature by creating a method to identify areas of a city that may be underserved by transit and/or childcare services. The simulation model presented in this paper relied on open data sets (such as GTFS) and OpenTripPlanner (OTP), so it could be easily replicated in other American cities to assess transit access to childcare.

AREAS FOR IMPROVEMENT AND FUTURE RESEARCH

Several areas for improvement and future research emerged from this analysis. First, the simulation model presented in this paper relies on numerous assumptions that should be validated in future research. For example, the simulation model assumes that the drop-off time at ELCs on the way to work is only five minutes; this assumption could be validated by conducting real-world observations of drop-offs at childcare facilities. Additionally, ten ELCs nearest each home census block and another ten ELCs nearest each work census block were queried through OTP, implying that parents may consider up to twenty ELC locations for their child. This assumption should be validated in future research to understand the approximate number of ELCs that parents consider when placing their child on ELC waitlists. Likewise, travel times to ELCs were used in the multinomial logit model to determine the assignment probability of traveling along a specified origin-destination pair, which implies that travel time and/or proximity to ELCs is the most important factor in ELC assignment. However, other factors such as child turnover rate and individual ELC capacity were not considered because data was not available. In the simulation model, an average capacity of 47 children per ELC was assumed based on aggregate numbers from Chicago in 2022 *(14,15)*; this could be improved in the future by gathering real-world data on the number of children that attend each individual ELC to better understand capacity constraints.

There are many ways to extend the simulation framework presented in this paper. First, the model assumes that parents whose children are in ELCs work a full-time job from 9am to 5pm on weekdays; future research should consider work schedules outside of 9am to 5pm, such as shift work or part-time employment. Second, the modeling framework presented in this paper assigns each child in a census block to an ELC individually and does not account for siblings within the same household. Future research could consider alternative assignment approaches that group some children together, since siblings close in age often attend the same ELC. External factors not related to household demographics, such as scheduling delays and route reliability, could also be considered in future model improvements. The model presented in this paper uses scheduled GTFS data, but to accurately simulate such external realities, using archived GTFS data would be more appropriate.

Additionally, while the focus of the paper is on transit trips, the OTP query did allow for deviation into pure walking. Future research could apply a mandatory transit leg in the query to further identify areas where transit frequency and/or routes are lacking. Similarly, future research should compare trips with mandatory transit legs to private vehicle trips to determine where transit routes are too infrequent to provide reasonable commute times. Furthermore, whereas this work explored the aggregate increase in travel times, future work could also identify appropriate level-of-service (LOS) thresholds for multi-stop transit trips. Evaluating the number and location of census tracts which fall outside these LOS thresholds can inform transit authorities in making schedule changes which support more acceptable commute times.

Concerning ELC selection, the model presented in this work assumes that families are willing to accept the first available enrollment in geographic proximity to their home or work locations. It does not consider other factors like program quality, language, culture, or affordability. Future research could limit the number of possible assignments for a given household based on language and cultural fit, or explore the travel implications of selecting ELCs which may seem more desirable because of affordability or program quality. This work assumed that parents had limited flexibility to choose between multiple centers, so these considerations were not explored.

Last, this paper simulated transit trips to early learning centers, which are a common destination for caregivers of small children. Future research could include additional destinations – such as primary schools or grocery stores, or even multiple childcare centers in the case of households with multiple children– that are also common stops for caregivers along their commute trips. Since the literature on mobility-of-care often encompasses a broad range of trip purposes *(16),* additionally research is recommended for a wider range of destinations to provide a mobile holistic picture of care-related travel.

AUTHOR CONTRIBUTION STATEMENT

The authors confirm contribution to the paper as follows: study conception and design: Tyer, Brakewood; data collection: Tyer; analysis and interpretation of results: Tyer; draft manuscript preparation: Tyer and Brakewood. All authors reviewed the results and approved the final version of the manuscript.

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