

HAPLOS: Human Population and Location Simulator

Emily Schmidt

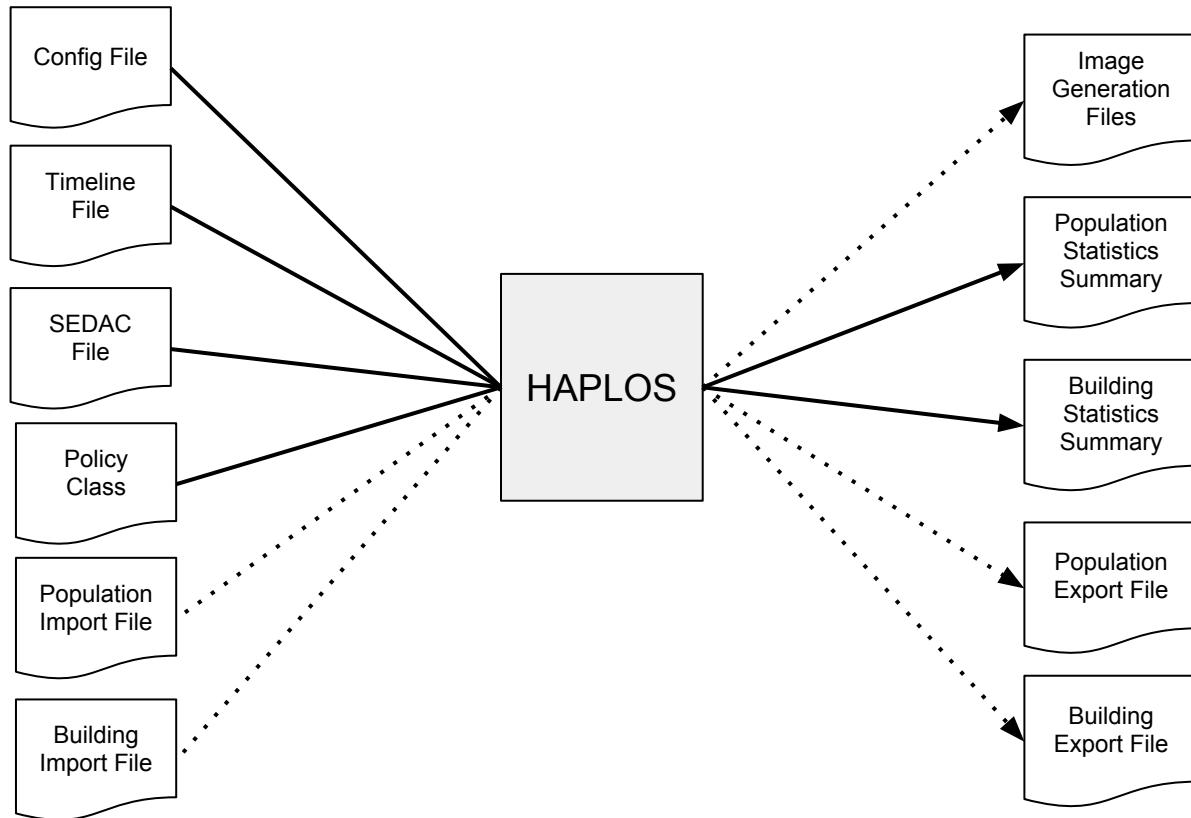
Motivation and Goals

- To model a human population behavior and movement realistically.
- To create a way in order to easily change out policy models without having to re-create the human model.
- Ability to quickly change out parameters and variables.

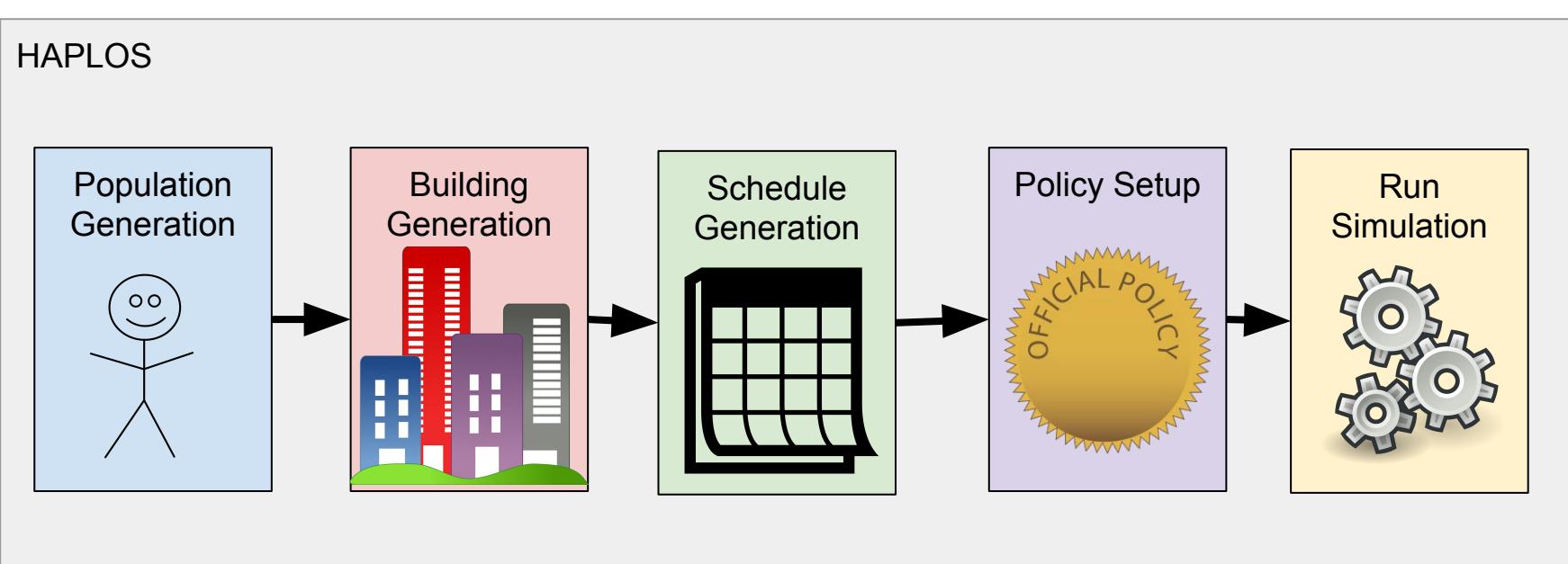
Overview

- System Overview
- Inputs
- Outputs
- Population Generation
- Building Generation
- Schedule Generation
- Policy Model
- Validation
- Summary

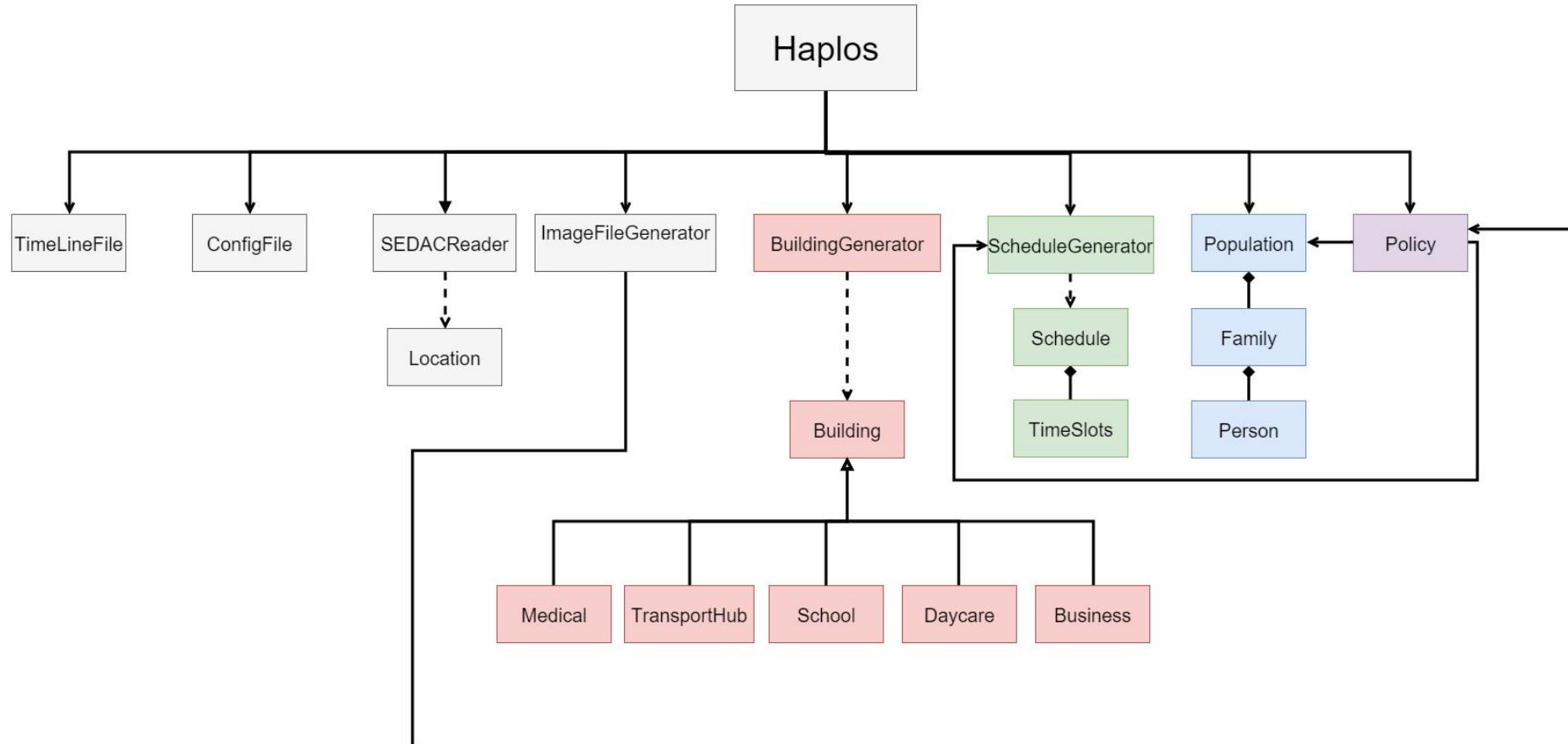
System Overview



HAPLOS Process Overview



Class Relationship Diagram



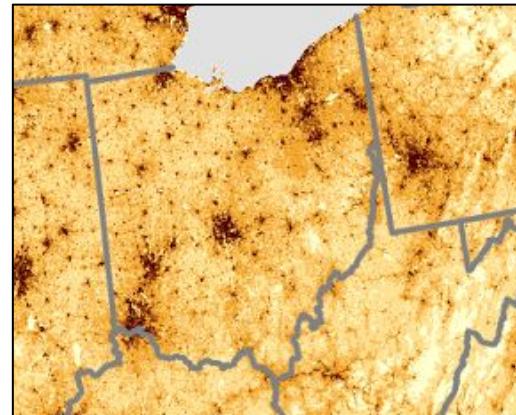
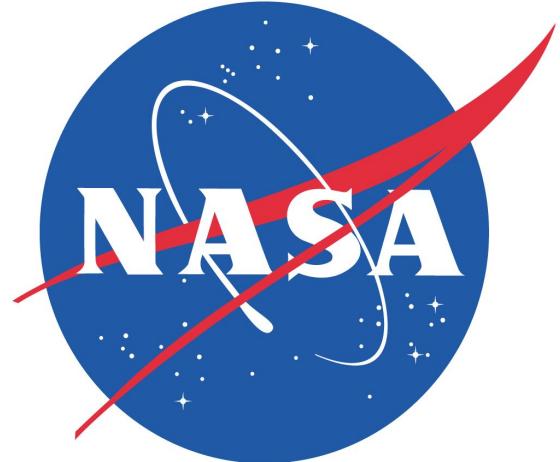
Inputs



SEDAC File

- NASA Socioeconomic Data and Applications Center (SEDAC).
- Data is retrieved using Satellites in order to estimate population density of a area.

```
ncols          10
nrows          10
xllcorner     -10
yllcorner      10
cellsize       0.0416666666667
NODATA_value  -9999
0 0 0 0 0 0 0 0 0 0
0 1 0 0 1 0 0 0 1 0
0 0 2 2 2 2 2 2 2 0
```



Configuration File

- Sets all parameters for the simulation.
- General Settings
 - Contains Other File Locations
 - Density Information, Timeline File, Output Directory, and Optional Building and Population Import.
 - Custom File Output Types
 - Geolocation information if applicable.
 - Cell Size, Lower Left Longitude and Latitude.
 - Length of Simulation in HAPLOS Time (1 HAPLOS Time = 10 minutes)
 - Population Configuration
 - Total Population in Density File
 - Population Seed (-1 for Random)
 - Total Population to Generate

Configuration File (Continued)

- Demographic Information
 - Gender Probability
 - Age Probabilities
 - Family size Probabilities
- Building Generation Information
 - Business Size Probabilities
 - School Size Probabilities
 - Daycare Size Probabilities
 - Medical Size Probabilities
- Transportation Information
 - Probabilities for Transportation Types
 - Speed in cells per 1 HAPLOS Time unit.
 - Max travel distance.
- Schedule Generation Information
 - Schedule Type Probabilities by Age
 - Travel radius limits by Schedule Type
 - Visitor Type Probabilities by Schedule Type

Configuration File Data Sources (Demographics)

Table 3. Projections of the Population by Sex and Selected Age Groups for the United States: 2015 to 2060

Sex and age	(Resident population as of July 1. Numbers in thousands)									
	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
BOTH SEXES	321,369	334,503	347,335	359,402	370,338	380,219	389,394	398,328	407,412	416,795
Under 18 years	73,635	74,128	75,015	76,273	77,446	78,185	79,888	81,087	82,309	
Under 5 years	19,965	20,568	21,010	21,178	21,268	21,471	21,775	22,147	22,499	22,778
5 to 13 years	36,874	36,624	37,116	38,322	38,848	39,097	39,389	39,690	40,527	41,193
14 to 17 years	16,196	16,730	17,000	17,427	17,746	17,854	18,061	18,268		
18 to 64 years	189,635	203,634	208,400	209,022	213,659	219,690	227,772	230,444	238,886	236,322
18 to 24 years	31,214	30,555	30,736	30,794	30,890	31,815	32,440	32,717	32,937	33,300
25 to 44 years	84,857	89,518	93,429	95,795	96,981	96,854	98,034	99,653	101,228	103,010
45 to 64 years	84,032	83,861	82,235	82,434	85,788	91,021	95,298	98,074	99,691	100,013
65 years and over	47,830	56,441	65,920	74,107	79,233	82,344	84,712	87,996	92,470	98,164
85 years and over	6,304	6,727	7,482	9,132	11,909	14,634	17,259	18,972	19,454	19,724
100 years and over	72	89	119	138	154	193	267	387	493	604
16 years and over	286,107	288,750	280,749	291,500	301,559	310,879	319,400	327,402	335,383	343,677
18 years and over	247,734	260,375	272,319	283,129	292,892	302,034	310,484	318,440	326,325	334,486
15 to 44 years	129,469	132,623	136,726	139,154	140,869	141,910	143,813	145,784	147,728	150,076

Population Projections 2014 US Census Table 3¹



Table 62. Households by Age of Householder and Size of Household: 1990 to 2010

[In millions (93.3 represents 93,300,000). As of March. Based on Current Population Survey; see headnote, Table 59]

Age of householder and size of household	2010				Non-Hispanic White				
	1990	2000	2005	Total					
				White	Black	Asian	Hispanic		
Total.....	93.3	104.7	113.3	117.5	95.5	14.7	4.7	13.3	83.2
Age of householder:									
15 to 24 years old.....	5.1	5.9	6.7	6.2	4.7	1.0	0.3	1.2	3.7
25 to 29 years old.....	9.4	8.5	9.2	9.4	7.4	1.3	0.4	1.5	6.0
30 to 34 years old.....	11.9	10.1	10.1	9.6	7.5	1.4	0.6	1.0	6.0
35 to 44 years old.....	20.6	24.0	23.2	21.5	16.8	3.0	1.1	3.3	13.7
45 to 54 years old.....	14.5	20.3	23.4	24.9	20.1	3.2	1.0	2.6	17.7
55 to 64 years old.....	12.5	13.8	17.5	20.4	16.9	2.4	0.7	1.6	15.5
65 to 74 years old.....	11.7	11.3	11.5	13.2	11.2	1.3	0.4	0.9	10.4
75 years old and over.....	8.4	10.4	11.6	12.1	10.7	1.0	0.3	0.6	10.2
One person.....	23.0	26.7	30.1	31.4	25.2	4.7	0.9	2.1	23.3
Male.....	9.0	11.2	12.8	14.0	11.2	2.0	0.4	1.1	10.3
Female.....	14.0	15.5	17.3	17.4	14.0	2.7	0.4	1.0	12.1
Two persons.....	30.1	34.7	37.4	39.5	33.4	4.0	1.3	3.0	30.6
Three persons.....	16.1	17.2	18.3	18.6	14.7	2.5	0.9	2.5	12.3
Four persons.....	14.5	15.3	16.4	16.1	12.9	1.9	1.0	2.6	10.5
Five persons.....	6.2	7.0	7.2	7.4	5.8	0.9	0.4	1.6	4.3
Six persons.....	2.1	2.4	2.5	2.8	2.1	0.4	0.2	0.8	1.4
Seven persons or more.....	1.3	1.4	1.4	1.7	1.2	0.3	0.1	0.6	0.7

¹ Includes other races, not shown separately. ² Beginning with the 2003 Current Population Survey (CPS), respondents could choose more than one race. The 2003 and 2010 data include persons who selected this race group only and exclude persons reporting more than one race. The CPS in prior years only allowed respondents to report one race group. See also comments on race in the text for this section. ³ Hispanic persons may be any race.

Source: U.S. Census Bureau, *America's Families and Living Arrangements*, Current Population Reports, P20-537, 2001, and earlier reports, "Families and Living Arrangements." See also <<http://www.census.gov/population/www/socdemo/hh-fam.html>>.

Households by Age of Householder and Size of Household 2010 Table 62¹⁹

Configuration Data Sources (Buildings and Transportation)

Number of Firms, Number of Establishments, Employment, Annual Payroll, and Estimated Receipts by Enterprise Employment Size for the United States, All Industries: 2012								
NAICS CODE		NAICS DESCRIPTION		ENTERPRISE EMPLOYMENT SIZE	NUMBER OF FIRMS	NUMBER OF ESTABLISHMENTS	EMPLOYMENT	ANNUAL PAYROLL (\$1,000)
...	Total	01: Total	5,726,160	7,431,808	115,036,468	5,414,250,995
...	02: Total	3,640,291	3,640,102	10,369,839	237,000,000
...	03: 5-9	1,652,241	1,652,241	6,527,943	75,438,268
...	04: 10-19	593,641	630,811	7,674,340	290,990,895
...	05: 20+	5,130,348	5,194,955	20,408,789	763,326,016
...	Total	06: 20-99	494,170	687,272	19,387,249	763,571,581
...	07: 100-499	1,618,223	1,600,223	16,380,837	2,287,530,861
...	08: 500+	5,707,441	6,622,434	66,062,863	3,146,720,114
...	Total	09: 500+	18,129	1,199,374	59,875,575	...
11	Agriculture, Forestry, Fishing and Hunting	01: Total	21,361	22,046	161,077	5,909,348
11	Agriculture, Forestry, Fishing and Hunting	02: 0-4	14,849	14,852	22,260	865,308
11	Agriculture, Forestry, Fishing and Hunting	03: 5-9	6,379	6,379	22,931	1,000,000
11	Agriculture, Forestry, Fishing and Hunting	04: 10-19	1,604	1,641	21,414	794,772
11	Agriculture, Forestry, Fishing and Hunting	05: 20+	19,953	19,968	66,252	2,456,101
11	Agriculture, Forestry, Fishing and Hunting	06: 20-99	1,087	1,185	38,955	1,505,858
11	Agriculture, Forestry, Fishing and Hunting	07: 100-499	220	480	31,948	993,734
11	Agriculture, Forestry, Fishing and Hunting	08: 500+	21,203	21,203	137,181	4,000,000
11	Agriculture, Forestry, Fishing and Hunting	09: 500+	91	433	23,922	968,857
113	Forestry and Logging	01: Total	8,591	8,727	53,515	2,126,056
113	Forestry and Logging	02: 0-4	5,192	5,193	9,244	307,167
113	Forestry and Logging	03: 5-9	1,948	1,948	12,230	441,522
113	Forestry and Logging	04: 10-19	932	932	12,471	492,292
113	Forestry and Logging	05: 20+	8,093	8,096	34,450	1,210,871
113	Forestry and Logging	06: 20-99	447	453	14,148	595,415
113	Forestry and Logging	07: 100-499	23	54	1,573	62,133
113	Forestry and Logging	08: 500+	8,591	8,601	90,171	1,920,000
113	Forestry and Logging	09: 500+	129	3,344	11,206	251,837
1131	Timber Tract Operations	01: Total	379	394	2,129	...
1131	Timber Tract Operations	02: 0-4	264	264	415	17,182
1131	Timber Tract Operations	03: 5-9	57	57	334	13,833
1131	Timber Tract Operations	04: 10-19	26	26	363	13,240
1131	Timber Tract Operations	05: 20+	347	347	1,112	44,255

Number of Firms, Number of Establishments, Employment, Annual Payroll, and Estimated Receipts by Enterprise Employment Size for the United States, All Industries, Establishments 2012²⁰

	United States	
	Estimate	Margin of Error
Total:	145,870,653	+/-134,123
Car, truck, or van:	125,006,865	+/-149,799
Drove alone	111,525,436	+/-151,310
Carpooled:	13,481,429	+/-74,789
In 2-person carpool	10,348,485	+/-65,136
In 3-person carpool	1,839,514	+/-25,873
In 4-person carpool	684,226	+/-15,888
In 5- or 6-person carpool	357,924	+/-10,822
In 7-or-more-person carpool	251,280	+/-9,477
Public transportation (excluding taxicab):	7,600,395	+/-44,154
Bus or trolley bus	3,879,331	+/-36,934
Streetcar or trolley car (carro publico in Puerto Rico)	83,015	+/-5,006
Subway or elevated	2,760,978	+/-24,395
Railroad	823,230	+/-12,902
Ferryboat	53,841	+/-3,889
Taxicab	165,977	+/-8,165
Motorcycle	285,407	+/-8,679
Bicycle	904,463	+/-17,061
Walked	4,011,094	+/-33,672
Other means	1,353,870	+/-19,754
Worked at home	6,542,582	+/-41,264

2014 Means of Transportation to Work Table: B08301²¹

Configuration Data Sources (Schedule)

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Labor Force Statistics from the Current Population Survey

HOUSEHOLD DATA ANNUAL AVERAGES										
3. Employment status of the civilian noninstitutional population by age, sex, and race (Numbers in thousands)										
Age, sex, and race	Civilians noninstitutional population	2014			Civilian labor force			Unemployed		
		Total	Percent of population	Total	Total	Percent of population	Number	Percent of labor force	Not in labor force	
TOTAL										
16 years and over	247,947	155,922	62.9	146,305	59.0	9,617	6.2	92,025		
16 to 19 years	16,633	5,654	34.0	4,548	27.3	1,106	19.6	10,979		
16 to 17 years	8,898	1,971	22.2	1,545	17.4	426	21.6	6,959		
18 to 24 years	77,735	3,683	9.7	3,051	38.8	800	18.7	4,052		
20 to 24 years	22,079	19,641	70.8	13,694	63.9	1,747	11.2	6,438		
25 to 54 years	124,511	100,767	80.9	95,497	76.7	5,270	5.2	23,744		
25 to 34 years	42,131	34,199	81.2	31,975	75.9	2,224	6.5	7,932		
25 to 29 years	21,230	17,091	80.5	15,868	74.7	1,223	7.2	4,139		
30 to 34 years	20,902	17,108	81.9	16,107	77.1	1,001	5.9	3,794		
35 to 44 years	39,565	32,506	82.2	30,966	78.3	1,539	4.7	7,059		
35 to 39 years	19,409	15,931	82.1	15,144	78.0	787	4.9	3,477		
40 to 44 years	20,156	16,574	82.2	15,822	78.5	752	4.5	3,582		
45 to 54 years	42,815	34,062	79.6	32,556	76.0	1,507	4.4	8,752		
45 to 49 years	20,521	16,638	81.1	15,889	77.4	749	4.5	3,882		

Employment status of the civilian noninstitutional population by age, sex, and race February 12, 2015²²

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Economic News Release

Table 4. Employed persons working and time spent working on days worked by full- and part-time status and sex, jobholding status, educational attainment, and day of week, 2014 annual averages

Table 4. Employed persons working and time spent working on days worked by full- and part-time status and sex, jobholding status, educational attainment, and day of week, 2014 annual averages
(Numbers in thousands)

Characteristic	Total Employed	Employed persons who worked on an average day			Employed persons who worked on an average weekday			Employed persons who worked on an average Saturday, Sunday, and holiday		
		Number	Percent of employed	Average hours of work	Number ⁽¹⁾	Percent of employed	Average hours of work	Number ⁽²⁾	Percent of employed	Average hours of work
Full- and part-time status and sex										
Total, 15 years and over ⁽³⁾	153,681	105,658	68.8	7.75	127,374	82.9	8.12	54,406	35.4	5.72
Full-time workers	120,531	87,562	72.6	8.18	106,795	88.6	8.57	41,951	34.8	5.80
Part-time workers	33,151	18,096	54.6	5.68	20,533	61.9	5.74	12,444	37.5	5.44
Men ⁽³⁾	82,273	57,877	70.3	8.14	68,861	83.7	8.54	31,787	38.6	6.06
Full-time workers	69,626	51,309	73.7	8.43	61,477	88.3	8.85	27,025	38.8	6.12
Part-time workers	12,647	6,568	51.9	5.86	7,350	58.1	5.89	4,765	37.7	5.77
Women ⁽³⁾	71,408	47,782	66.9	7.28	58,511	81.9	7.62	22,945	31.7	5.23
Full-time workers	50,905	36,254	71.2	7.82	45,319	89.0	8.19	14,958	29.4	5.23
Part-time workers	20,503	11,528	56.2	5.58	13,181	64.3	5.66	7,679	37.5	5.24
Jobholding status										
Single jobholders	139,983	94,548	67.5	7.71	114,854	82.0	8.07	46,845	33.5	5.65
Multiple jobholders	13,698	11,110	81.1	8.05	12,502	91.3	8.52	7,664	55.9	6.13
Educational attainment, 25 years and over										
Less than a high school diploma	8,384	6,085	72.6	7.84	7,532	89.8	8.02	3,355	40.0	7.05

Table 4. Time spent in primary activities for the civilian population by age, sex, race, Hispanic or Latino ethnicity, marital status, and educational attainment, 2014 annual averages²³

Partial Sample Configuration File

#Configuration File for MidWorld Data

#Data File Paths

Density_File=examples/data/MidWorld_22000.asc

Timeline_File=examples/timeline/MidWorld.tl

Output_Directory=output/

Building_Import=-1

Population_Import=-1

#Output File Parameters and Header Information

Custom_Output_Files=infectious,immune,exposed

Lower_Left_Longitude=0

Lower_Left_Latitude=0

Cellsize_Width=0.0416666666667

Cellsize_Height=0.0416666666667

Partial Sample Configuration File

##Schedules####

#Adult Schedules

Schedule_Employeed_Adults_18-24_Probablity=0.56674717

Schedule_Unemployeed_Adults_18-24_Probablity=0.43325283

Schedule_Employeed_Adults_25-44_Probablity=0.77042940

Schedule_Unemployeed_Adults_25-44_Probablity=0.22957060

Schedule_Employeed_Adults_45-64_Probablity=0.68965475

Schedule_Unemployeed_Adults_45-64_Probablity=0.31034525

Schedule_Employeed_Adults_65-Older_Probablity=0.17729487

Schedule_Unemployeed_Adults_65-Older_Probablity=0.82270513

Timeline File

- Designates what types Image Generation Files (IGF) should be generated at one points during the simulation.
 - Custom IFG types can be included in with the policy model to be generated.
- Repeatable File Generation
 - Generate on a set interval of time during the simulation
 - Days, Weeks (7 Days), Months (30 Days), Years (365 Days)
 - Files are generated at the start of the day
- Single File Generation
 - Files are generated once at a specific time during the simulation

```
#Produce File every 5 Days
D 5 infectious,immune,exposed
#Produce File every 2 Weeks
W 2 exposed
#Produce File every Month
M 1 population_density
#Produce file every year
Y 1 immune,homes

#Single Files
0 all_buildings,
10 medical_buildings,
business_buildings
123 school_buildings,homes
```

Policy Class

- Allows for customized policy model to be applied to the HAPLOS simulation.
- Required Methods:
 - `setupCustomAttributes (Population)`
 - Called at initial creation of the population, buildings, and schedules
 - `updatePopulation (Population, allBuildings, currentTime, scheduleGenerator)`
 - Called every time step after all other updates
 - `getCustomFileTypeData (Location, FileType)`
 - Returns information for a given location for a custom file type

Population/Building Imports

- It is optional to import a previous Population and Building set up created by a prior HAPLOS run.
- This will bypass the Population Generation, Building Generation and Schedule Generation processes of the program.

*S	Type	%31265	Family ID
31369	ID	-1	Assigned Daycare ID (-1 if None)
13	Max Employee	*21999	Person ID
180	Max Visitor Capacity	64	Age
81, 77	Location (X,Y)	m	Gender
0	School Type	4	Schedule Type
90	Max Student Capacity	#-1	Job Location (-1 if None)
43	School Start Time	31265, H, 91	Time Slot Elements (Building ID, Visitor Type, End Time)
87	School End Time		

Outputs



Statistics Summaries

- Contains basic information about population and buildings that were generated.
- Population Summary
 - Family Distribution
 - Gender Distribution
 - Age Distribution
 - Schedule Distribution
- Building Summary
 - Business, Medical, School, and Daycare Distributions.

Partial Population Statistic File

-----Family-----

Total Number of Families: 8825

Size 1:	2417	0.27388	(Expected 0.27000)
Size 2:	2944	0.33360	(Expected 0.34000)
Size 3:	1385	0.15694	(Expected 0.16000)
Size 4:	1258	0.14255	(Expected 0.14000)
Size 5:	521	0.05904	(Expected 0.06000)
Size 6:	196	0.02221	(Expected 0.02000)
Size 7:	104	0.01178	(Expected 0.01000)

-----Population-----

---Gender---

Males:	10873	0.49423	(Expected 0.49272)
Females:	11127	0.50577	(Expected 0.50728)

---Age---

Under Age 5:	813	0.03695	(Expected 0.06212)
Age 5-13:	1442	0.06555	(Expected 0.11474)
Age 14-17:	693	0.03150	(Expected 0.05226)
Age 18-24:	2008	0.09127	(Expected 0.09713)
Age 25-44:	5601	0.25459	(Expected 0.26343)
Age 45-64:	5636	0.25618	(Expected 0.26148)
Over Age 65:	5807	0.26395	(Expected 0.14883)
Total:	22000		

Partial Building Statistic File

-----Buildings-----

Total Buildings Generated: 31476

----Businesses----

Total Generated: 100

Employee Capacity 1-4: 79 0.79 (Expected 0.477556)

Employee Capacity 5-9: 10 0.1 (Expected 0.135235)

Employee Capacity 10-19: 11 0.11 (Expected 0.0848799)

Employee Capacity 20-99: 0 0 (Expected 0.0924771)

Employee Capacity 100-499: 0 0 (Expected 0.0484683)

Employee Capacity 500: 0 0 (Expected 0.161384)

Image Generation Files (IGF)

- Based on the Timeline file IGF will be created and placed in the OUTPUT_LOCATION/imageFiles/IMAGE_TYPE folder.
- These can be used to create image representation or import into other programs for analysis.
- Contains information about what is in a location cell.
- Default Provided IGF:
 - Current Population Density
 - All Buildings
 - Specific Building Types
 - Custom Image Generation Files can be set through the Policy Class and Configuration File.

Image Generation File Sample

```
0.000000,0.000000
0.041667,0.041667
10
0,4
0,0,0,0,1,0,0,0
0,0,1,0,0,0,0,0
0,0,0,0,0,4,0,0
2,0,0,0,0,0,0,0
0,0,0,2,0,0,0,0
```

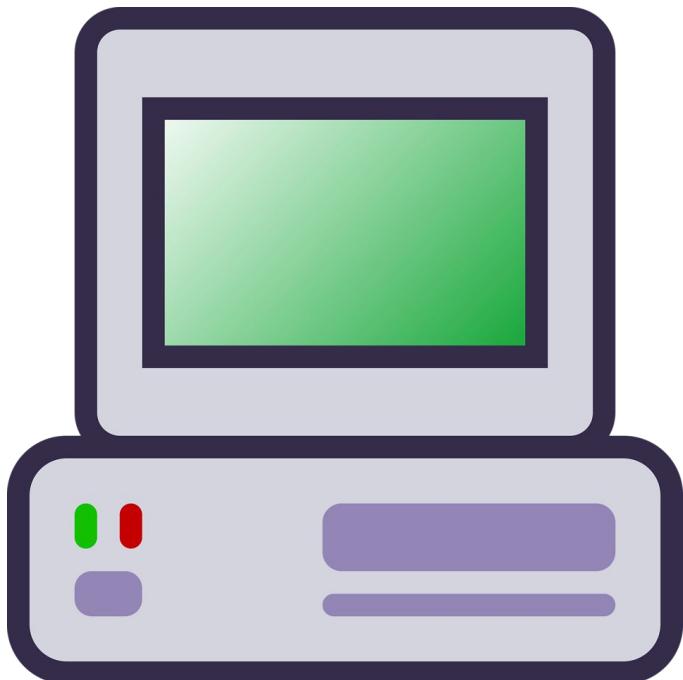
Lower Left Longitude/Latitude
Cell Size
Total Number
Min, Max Value

Population and Building Exports

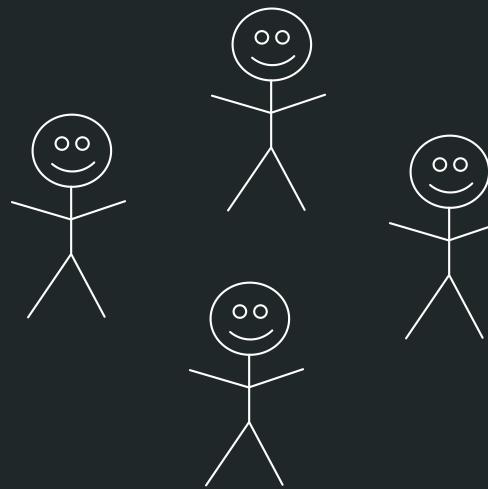
- These are exported after the Population, Building, and Schedule Generation phases and before the simulation begins.
- Can be used later to import the same population and building set up for a different execution.
- You cannot mix and match population and building exports.

Overview of HAPLOS Algorithm

- Load Configuration, SEDAC Files.
- If generating new population and buildings
 - Generate Population
 - Generate Buildings
 - Generate Schedules
 - Apply Policy Model
 - Run Simulation
- Else
 - Import Population
 - Import Buildings
 - Apply Policy Model
 - Run Simulation



Population Generation

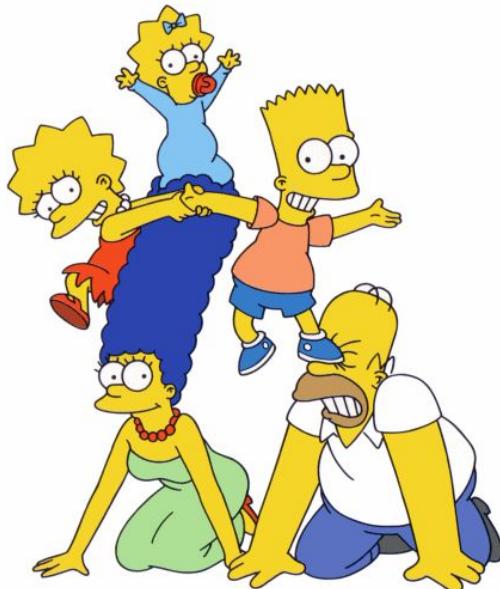


Population Generation Algorithm

- While `numberOfPeople < Population Size`
 - Determine Family Size
 - Generate Family
 - Force Generate 1 Adult, set as Child Care Adult
 - Generate rest of family.
 - Determine Demographic Information
 - Gender
 - Age
 - Schedule Type
 - All other demographic attributes need to be added as a custom attribute in the policy model

Family Generation Specifics

- Family sizes range from 1 - 7 individuals.
- Families must have 1 adult.
- 1 Adult is assigned as child care adult regardless of if there are children in the family.
 - Preference is given to Unemployed Adult if one is generated for the family.
 - Child modifications are only applied if there are children in the family.



Building Generation



Building Types

- **Business**
 - Visitor Types: Visitor, Employee
- **Medical**
 - Visitor Types: Visitor, Patient, Employee
- **School**
 - Three Types: Elementary (K-5), Middle (6-8), High (9-12)
 - Visitor Types: Visitor, Student, Employee
- **Daycare**
 - Visitor Types: Visitor, Child, Employee
- **Transport Hub**
 - Used as holding area for people between areas.
 - Visitors Types: Public Transport, Private Transport, Walking.
- **Building**
 - Used as general purpose building type and is used for homes
 - Visitor Types: Visitor, Employee



Building Generation Algorithm

- Based on Population Size and Demographics.
- Buildings are placed based on Population Density.
- Schools and Daycares are always generated based on the demographics of the area.
- All other buildings are generated based on number of remaining employed adults.

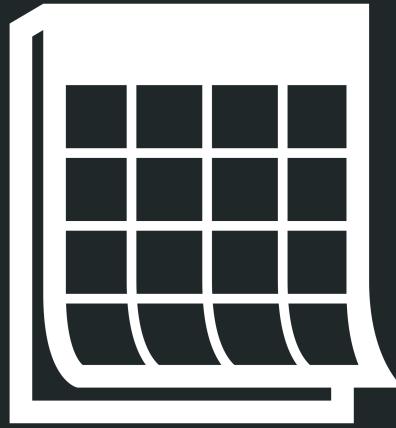


Building Type Generation Specifics

- Generate Transportation Hubs
 - 1 Transportation Hub per Location.
 - Private Transport are grouped together by Family members in the same hub.
- Generate Homes
 - 1 per Family
- Generate Schools
 - Generates enough schools in order to allow all kids to be able to attend.
- Generate Daycares
 - Generates enough daycares as needed by families who child care adult is employed.
- Generate Other Buildings
 - Generate any remaining buildings in order to assign job locations for remaining employed adults.
 - Can be Medical or Business.

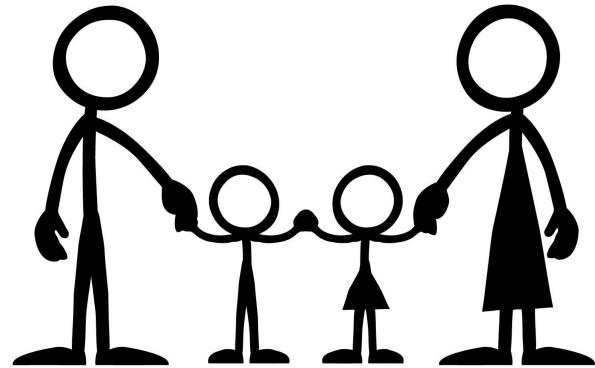


Schedule Generation



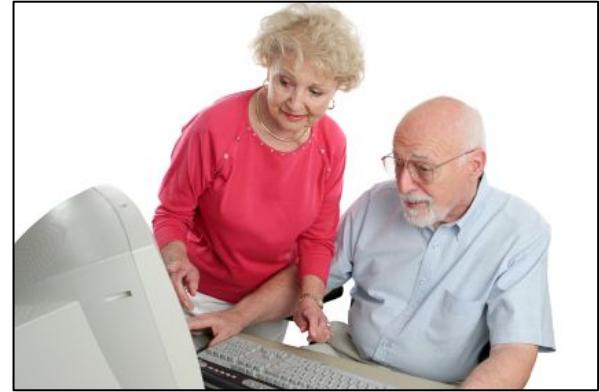
Schedule Generation Algorithm

- Generate schedule for Child Care Adult.
 - This is needed due to younger children schedules are based off the child care adult's schedule.
- Generate remaining family schedules.



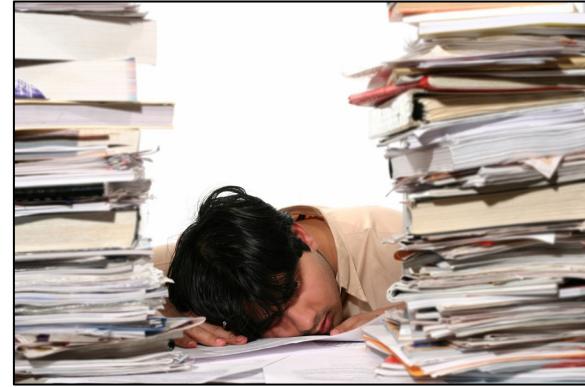
Adult Schedules Generation (Unemployed)

- If Child Care Adult
 - Determine start and end school times for children in the family.
 - Set Curfew to 20:00
- For 7 Days:
 - While !Curfew
 - Determine if Child Needs to be taken or picked up from school
 - Go to school location.
 - Else, Time Out ≥ 16 hours?
 - Go home
 - Else, pick a location based on probabilities
 - Go Home
 - Visit a Location
 - Current Time ≤ 144 (End of Day)
 - Yes, Go Home



Adult Schedules Generation (Employed)

- If Child Care Adult
 - Determine start and end school times for children in the family.
 - Set curfew to 20:00
- For 7 Days:
 - While !curfew
 - If Child Needs to be taken or picked up from school
 - Go to school location.
 - Else, Time Out ≥ 16 hours?
 - Child.currentLocation == Daycare?
 - Pick child up from daycare and Go home
 - Else Go Home
 - Else Never Been To Work && TimeLeft \leq RequiredTimeToWork && KidsAtSchool?
 - Drop kid off at daycare and go to work.
 - Else, pick a location based on probabilities
 - Go Home
 - Visit a Location
 - Go to Job
 - Current Time ≤ 144 (End of Day)
 - Go Home



Young Child Schedule Generation (0 - 4 Years)

- Is generated based off of the Child Care Adult's Schedule
- Stays with Child Care Adult at all times except when Adult is at work.
 - Child will be taken to a daycare facility prior to the adult going job location and picked up after their shift is over.



Young School Child Schedule Generation (5 - 13 Years)

- Attends School Monday - Friday.
- Is generated based off of the Child Care Adult's Schedule
- Stays with Child Care adult at all times except when at School.
- Curfew is 20:00



School Child Schedule Generation (14 - 17 Years)

- Attends School Monday - Friday.
- Schedule is independant of Child Care Adult for Schedule Generation
- Travel Radius Limit based on Age regardless of transportation method used.
- Curfew is 22:00

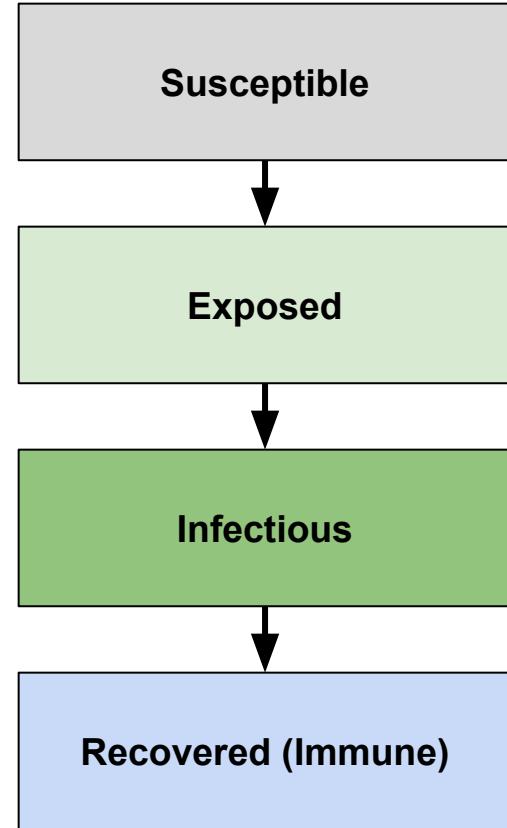


Policy Model



SEIR Model

- Simplest and most flexible model for disease spread.
- Model is based off of one created by Nsoesie et. al.² for Seasonal Flu Epidemic Models.
 - Note: their results assumed measures were taken to reduce the spread of the disease. This includes vaccinations.
- People can only contagious during the Infectious Stage.
 - During the infectious stage schedules are modified at 24:00 to mimic a person who is ill.
- 0-5 Contacts per 10 minutes
- Contact time ranges from 1 second to 600 seconds.
- Initial Exposed Population is 5

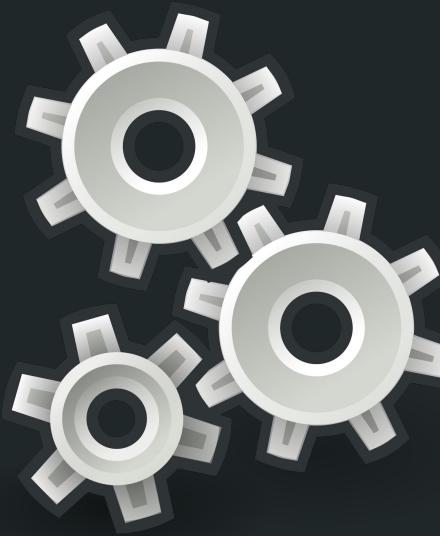


Transmission Rate Probability

$$\Pr(w(i, j)) = 1 - (1 - t)^{w(i, j)}$$

- i = Infected Person
- j = Susceptible Person
- $w(i, j)$ = contact that i has with j in seconds
- t = Transmission Rate

Validation

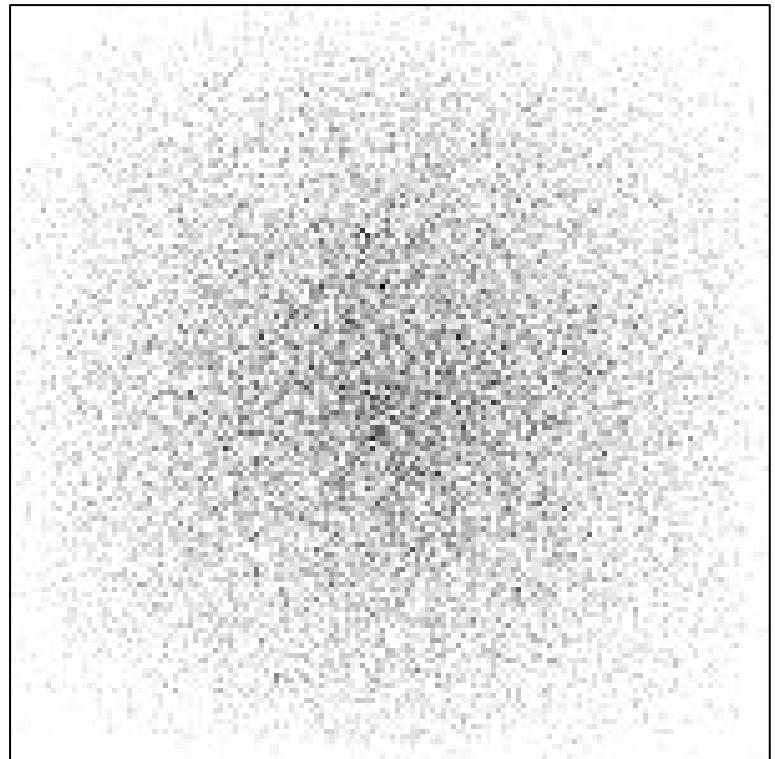


Sample Population (MicroWorld)

- Simulated a Very Small Town (104 Residents)
 - 10 x 10 Grid
 - SEDAC file was hand created to mimic a basic bullet style city density with variation.
 - This was mainly created for use with developing HAPLOS due to it was executed quickly and was easy to manipulate.

Sample Populations (MidWorld)

- Simulated City about the size of Oxford (22,000 Residents)
- 500 x 500 Grid
- Population is distributed based on a triangular distribution.
 - $a = 0$
 - $c = 250$
 - $b = 500$

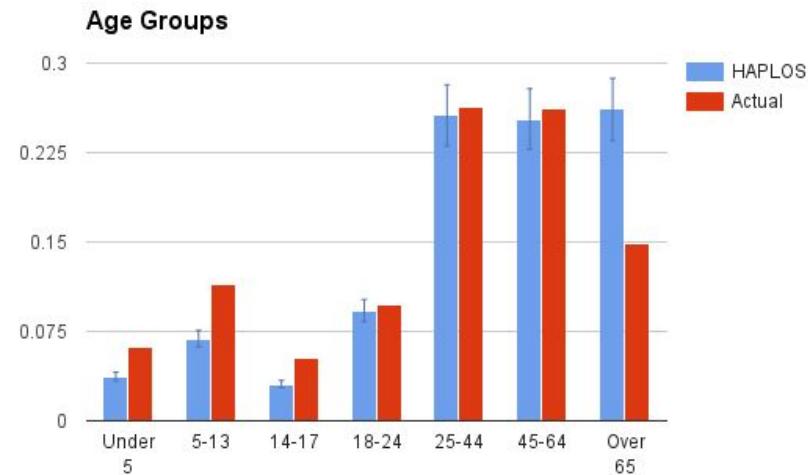
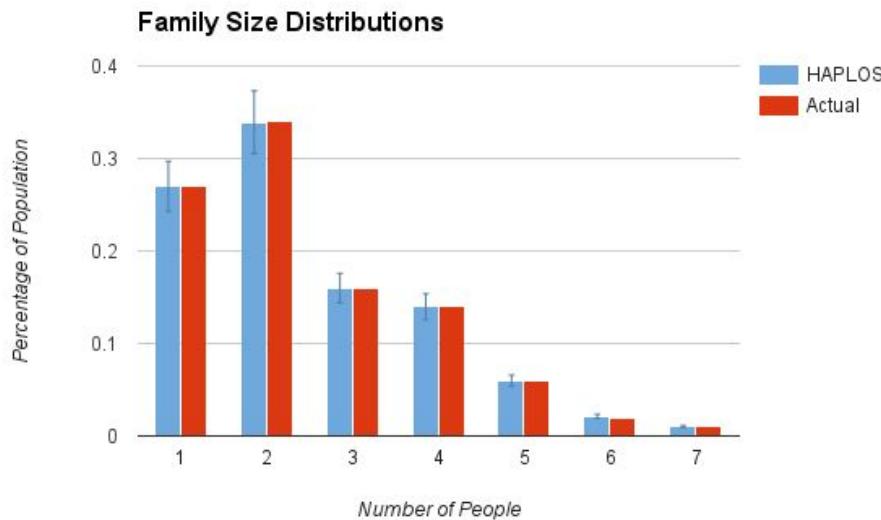


Sample Populations (Cincinnati Area)

- Population of 1,979,202
- 1440 x 960 Grid
- SEDAC File Provided by U.S. Census Grids (Summary File 3), 2000: Metropolitan Statistical Areas²⁵.
- Used for Building Generation Validation.

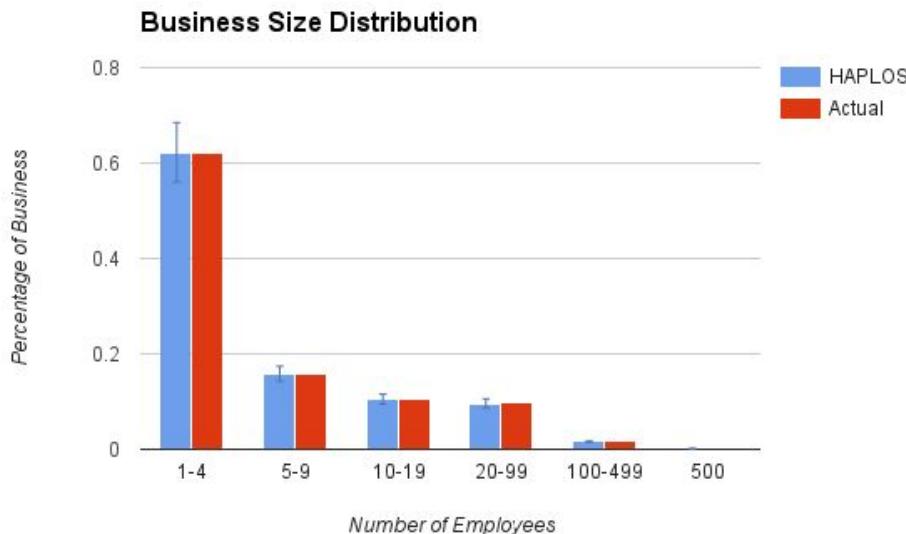


Demographic Validation

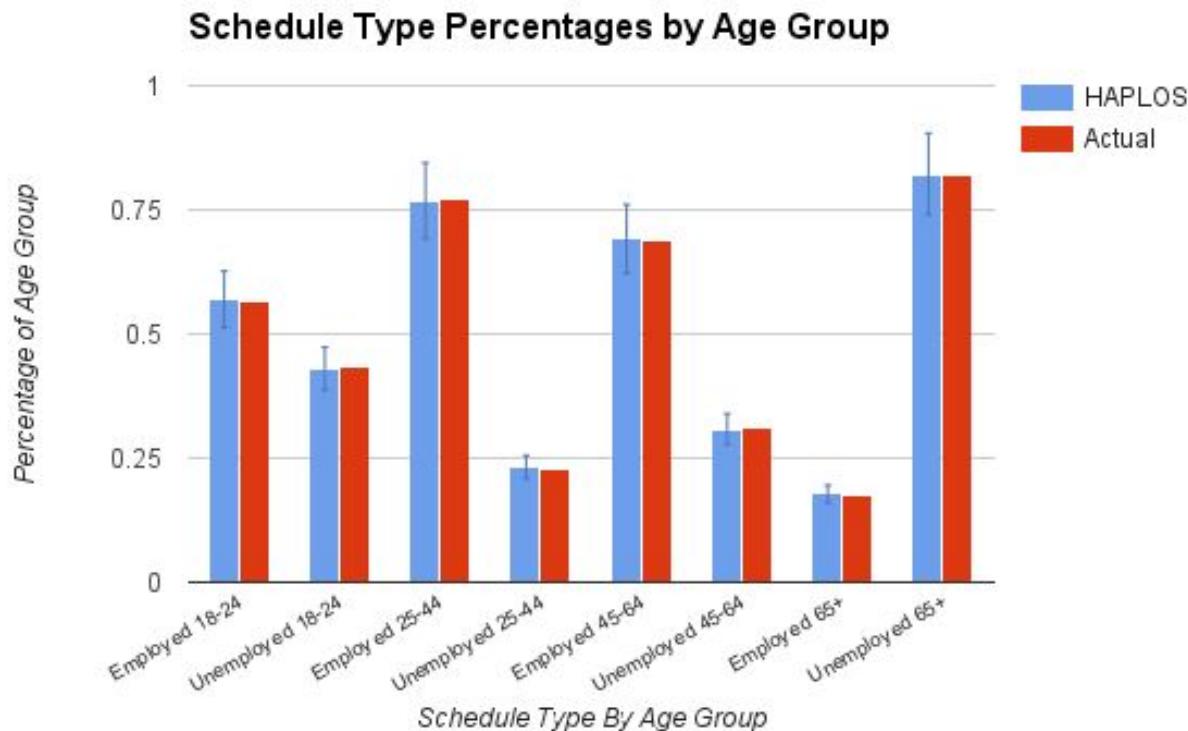


Building Generation Validation

- Due to how buildings are generated they will almost not always match the expected distribution in smaller data sets. Cincinnati sample was used for validation.



Schedule Assignment Validation



Schedule Generation Validation

- Unit Tests were created using Python in order to test the accuracy and viability of schedules created.
- Tests included:
 - School Child
 - Goes to School.
 - Goes to school only on weekdays.
 - Young School Child
 - Goes to School
 - Goes to school only on weekdays.
 - Follows Child Care Adult when not at School.
 - Young Child
 - Does not go to work.
 - Follows child care adult when not at day care
 - Employed Adult Tests
 - Goes to job at least once.
 - Unemployed Adult Tests
 - Does not go to job.
 - Family Specific Tests
 - Check for 1 Adult in Family
 - General Schedule Tests
 - At home for 8 hours every 24 hours.

Schedule Generation Test Results

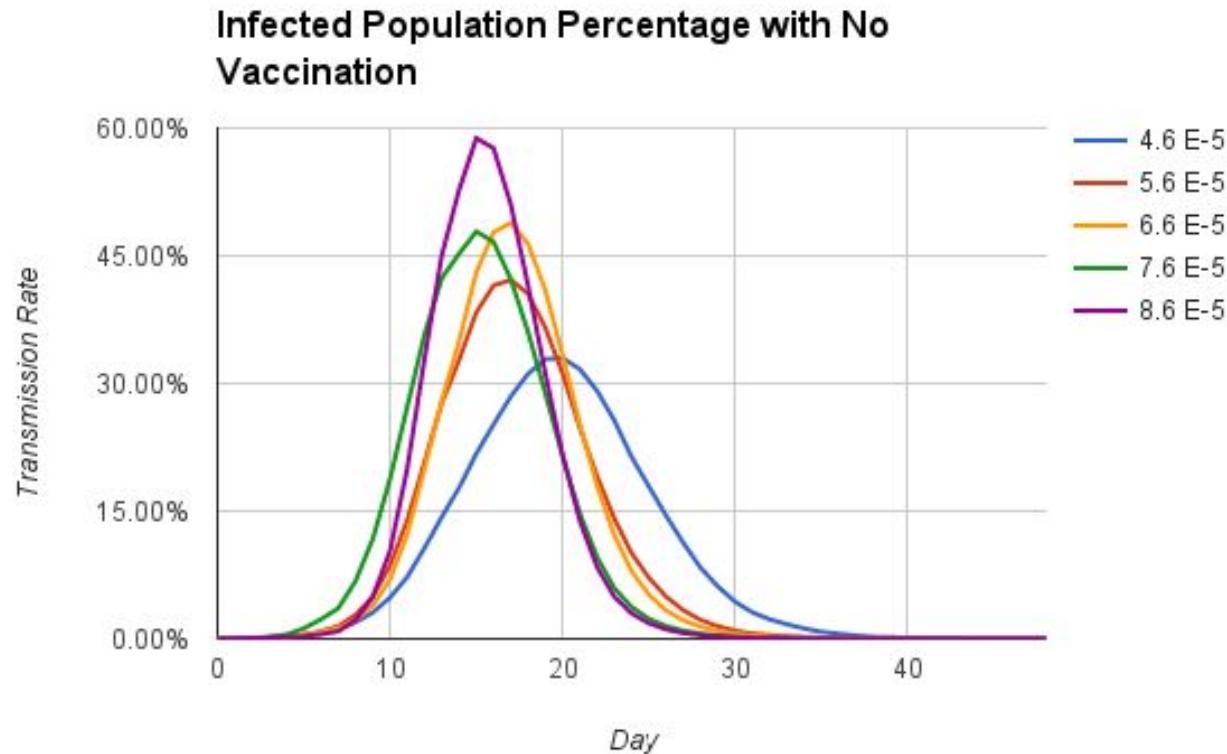
- HAPLOS was executed over 10 million times using the MicroWorld sample in which approximately 1.04 billion unique schedules were generated for approximately 280 million families.
- All successfully passed unit testing.



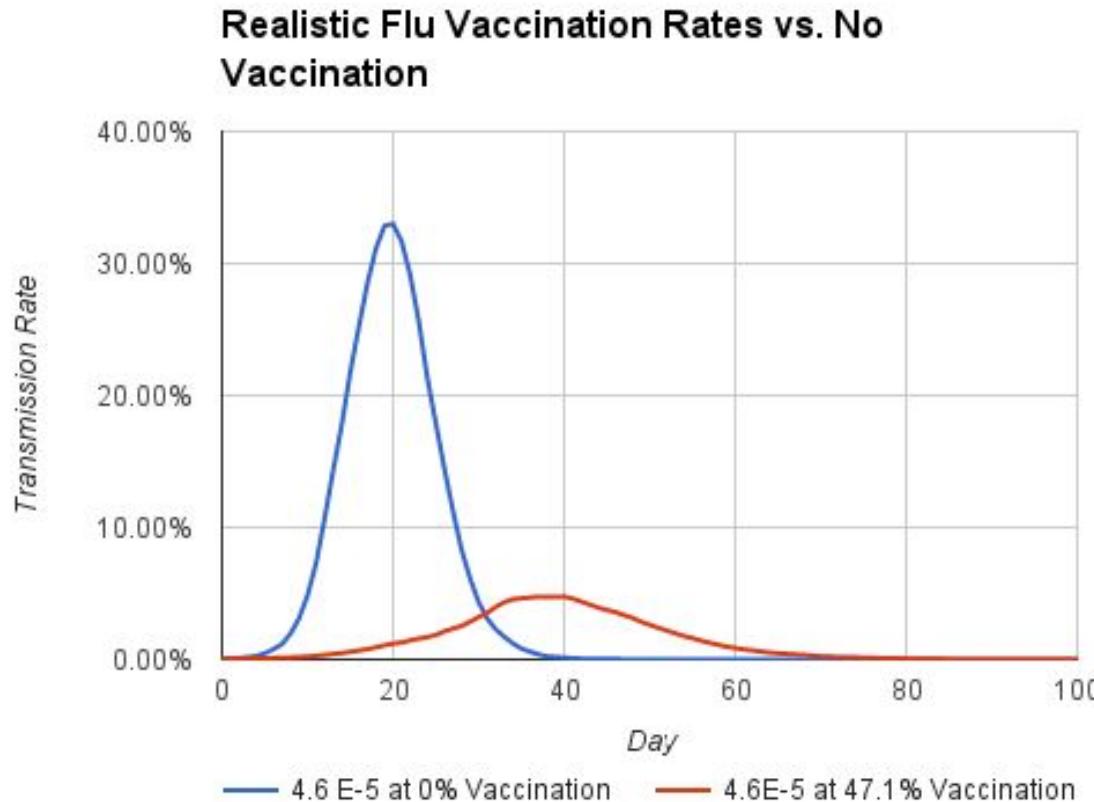
Policy Model Validation

- Ran MidWorld with 5 different transmission rates, 3 times per rate
 - 4.6 E-5
 - 5.6 E-5
 - 6.6 E-5
 - 7.6 E-5
 - 8.6 E-5
- Ran MidWorld with 2 different Vaccination rate, 3 times per rate.
 - No Vaccination.
 - Current Vaccination at 47.1%
 - Average US Vaccination Rate²⁶.

Infection Rates (No Vaccination)



Infection Rates (Current Vaccination 47.1%)



Summary

Trade Offs

- Allows for trade off of policy models without having to redo the entire simulation.
- Requires at least coding knowledge in order to use.
- Operates more like a library than a stand alone application.
- Time resolution becomes a problem with smaller areas due to transportation times become inaccurate.



Interplay with lab's efforts

- A key application area of my lab is macro epidemiological analysis

Forecasting Chikungunya

Forecasting Dengue fever

Analysis of Avian Influenza

- Epidemic models currently use abstract human populations

Modeled as overlapping circular regions of about 15 mile diameter

- This research aims to provide more detailed model for humans



Future Work

- Add in customizable time resolution.
- Improve overall performance.
- Create additional Policy Models for more types of scenarios, specifically evacuation.



Questions?

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