LIVE | WORK | CHOICE

Walter Zesk, Carolina Fonseca, Xuan Liu, Chunfeng Yang

GOALS

Research suggests that high-density neighborhoods in which the residents live **and** work, dramatically reduces the carbon footprint of the city by eliminating commuting related emissions [UK Department for Business, 2019]. In addition to the environmental benefits, the commingled density offers provides social benefits by increasing the intensity and variety of human interaction.

Achieving this dense, “live-work balance” in Kendall Square represents a transformation from the current state -- a migration embodied in a multitude of individual choices. This investigation seeks to enhance our understanding of the relationships between:

- The ideal migration in terms of impact on carbon footprint
- The underlying choices constituting this migration
- Changes required in the city to influence those chosed and accomodate the result
- The future form of the live-work balanced city

KENDALL SQUARE TODAY

Kendall Square is one of the commercial districts of Cambridge, Massachusetts. It used to be a former industrial district and is now one of the leading centers for biotech research and innovation. The Square accommodates the MIT community and has experienced a transformative change as of late.

According to a report prepared by the Community Development Department of the City of Cambridge in 2021, Kendall Square’s population within a 0.5 mile radius is 8,866 people (**Figure 1**), and has the following age stratification (**Figure 2**).

TOTAL	.5 MILE RADIUS	1 MILE RADIUS
Population	8,866	35,376
Ages 0-14	13%	9%
Ages 15-24	20%	21%
Ages 25-34	29%	30%
Ages 35-44	14%	13%
Ages 45-64	16%	16%
Ages 65+	8%	10%
Median Age	30.4	31.1

Figures 1 and 2 – Map of 0.5-mile walkshed and Demographics

Source: Community Development Department calculations are based on data from ESRI Community Analyst Tool which forecasts data from the U.S. Census Bureau. Additional data comes from the MBTA and data gathered by Community Development Department.

In the same report, Kendall Square's households is the following (**Figure 3**):

HOUSEHOLDS

TOTAL	.5 MILE RADIUS	1 MILE RADIUS
Households	3,564	14,687
1 Person	33%	38%
2 Person	35%	35%
3+ Person	32%	27%
Average HH Size	2.21	2.13

Figure 3 – Demographics (Estimated Data) - Households

Source: Community Development Department calculations are based on data from ESRI Community Analyst Tool which forecasts data from the U.S. Census Bureau. Additional data comes from the MBTA and data gathered by Community Development Department.

In 2020 the Cambridge Community Development Department released a study called *Moving Forward – Cambridge's Journey to Work*, which "provides an overview of current commuting patterns of the Cambridge workforce, labor force and resident force…". Some of their findings are very relevant to understand who are today's total workers in Kendall Square and their behavior.

According to their report, the total number of workers in Kendall Square/MIT is 43,000 workers, and 12.1% of them live in Cambridge. The commuting mode split of these workers is: 40% of the workers Drove Alone, 33% uses

Public Transit, 13% Walked, 7% used their Bicycle, 6% used Carpool, and the other 1% is divided between Worked at Home and Other (see **Figure 4**).

17,200 workers drive alone to work at Kendall Square, and their commuting mode has the most impact on CO_2 emission. To reduce carbon emission in Kendall Square through live/work symmetry these workers should be attracted to move to the area and stop driving alone to work.

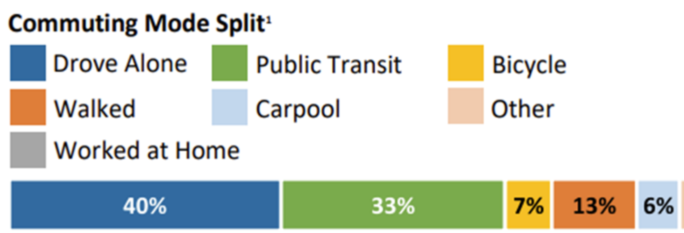


Figure 4 – Commuting Mode Split

Source: City of Cambridge Moving Forward Report 2020 ([1] Data derived from Census Transportation Planning Products, based on 2012 2016 5-year American Community Survey estimates).

Another interesting finding from that report is the annual household income by means of transportation and number of workers (**Figure 5**).

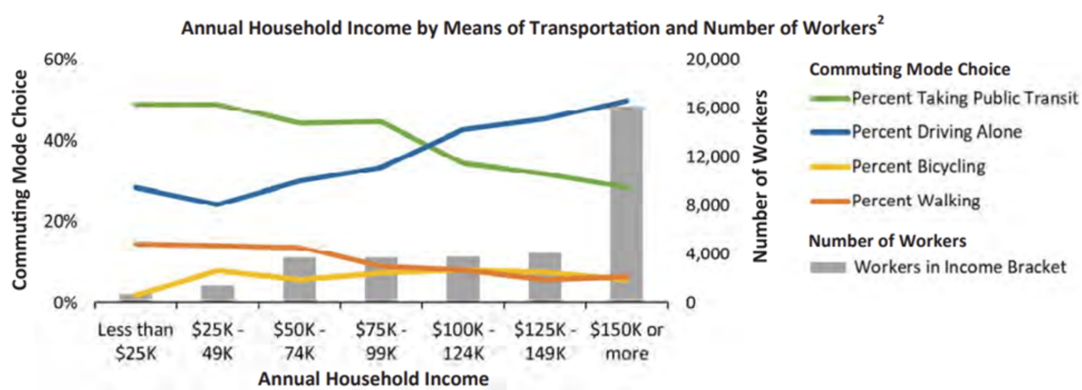


Figure 5 – Annual Household Income by Means of Transportation and Number of Workers

Source: City of Cambridge Moving Forward Report 2020 ([2] Excludes workers who do not live in households (i.e. students living in dormitories, etc.).

We observe, from this data, that a big parcel of the population who work in Kendall Square has an annual household income of $150K or more and is also the majority who drives alone as a commuting mode choice. If we extract the data of the two most used commuting mode choice per annual household income, we have approximately the following:

- 41% (17,000 workers) - $150k or more - 50% driving alone; 28% public transit
- 14% (4,500 workers) - $125k – 149k - 45% driving alone; 30% public transit

- 13% (4,500 workers) - $100k – 124k - 42% drivingalone; 32% public transit

- 12% (4,500 workers) - $75k – 99k - 33% driving alone; 44% public transit

- 12% (4,500 workers) - $50k – 74k - 30% driving alone; 44% public transit

- 5% (2,150 workers) - $25k – 49k - 23% driving alone; 50% public transit

- 2% (860 workers) - less than $25k - 28% driving alone; 50% public transit

We conclude that approximately 12,500 workers who commute by driving alone have an annual house income of more than $100k.

We also found some data on the top employer industries in Kendall Square (**Figure 6**).

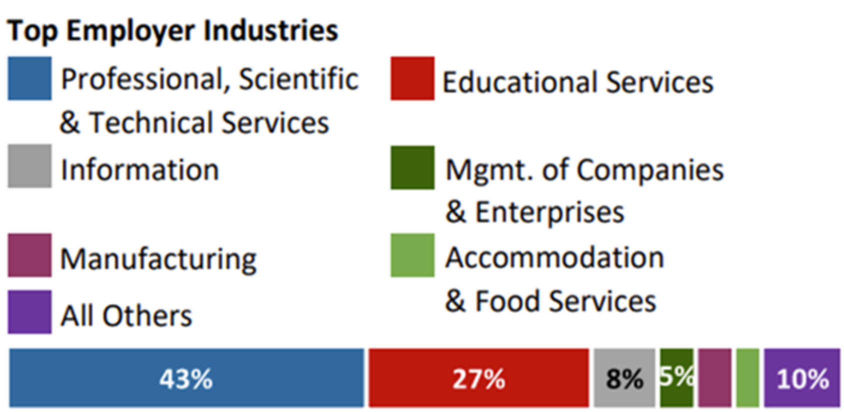


Figure 6 – Top Employer Industries

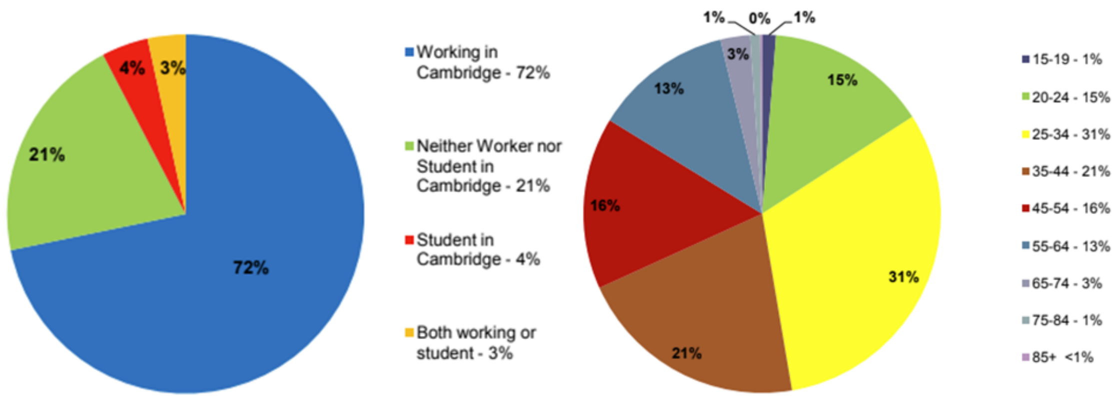
Source: City of Cambridge Moving Forward Report 2020 (LEHD OnTheMap origin destination analysis, current as of 2017).

From this data, and with the annual household income data, we will assume that most of the workers can work at home at least 2 times a week, which will reduce their commuting time per week, reducing CO_2 emission. We will assume it because most of the workers who commute have a higher annual household income, and most of the employer industries are industries that is feasible to work at home.

A survey made with customers at Kendall Square in 2011, *Kendall Square Customer Intercept Survey Summary Report*, revealed that 75% of the 640 respondents work in Cambridge. This survey also revealed that 52% of the 560 respondents (80 respondents did not answered this part of the survey) have age between 25 and 44 years old

(**Figures 7 and 8**). We will be considering this data as the data of the workers who commute to Kendall Square, since we could not identify specific data for that region.

The analysis of the age stratification is important because it identifies the population who is more likely to move (we will analyze this later in this paper).



Figures 7 and 8 – Respondents by Worker/Student and Respondents by Age

Source: Kendall Square Customer Intercept Survey Summary Report 2011, Cambridge Community Development Department, Economic Development Division.

With all the collected data four possible scenarios were created to address the impact of commuting to work in Kendall Square regarding the emission of CO_2 (**Figure 9**).

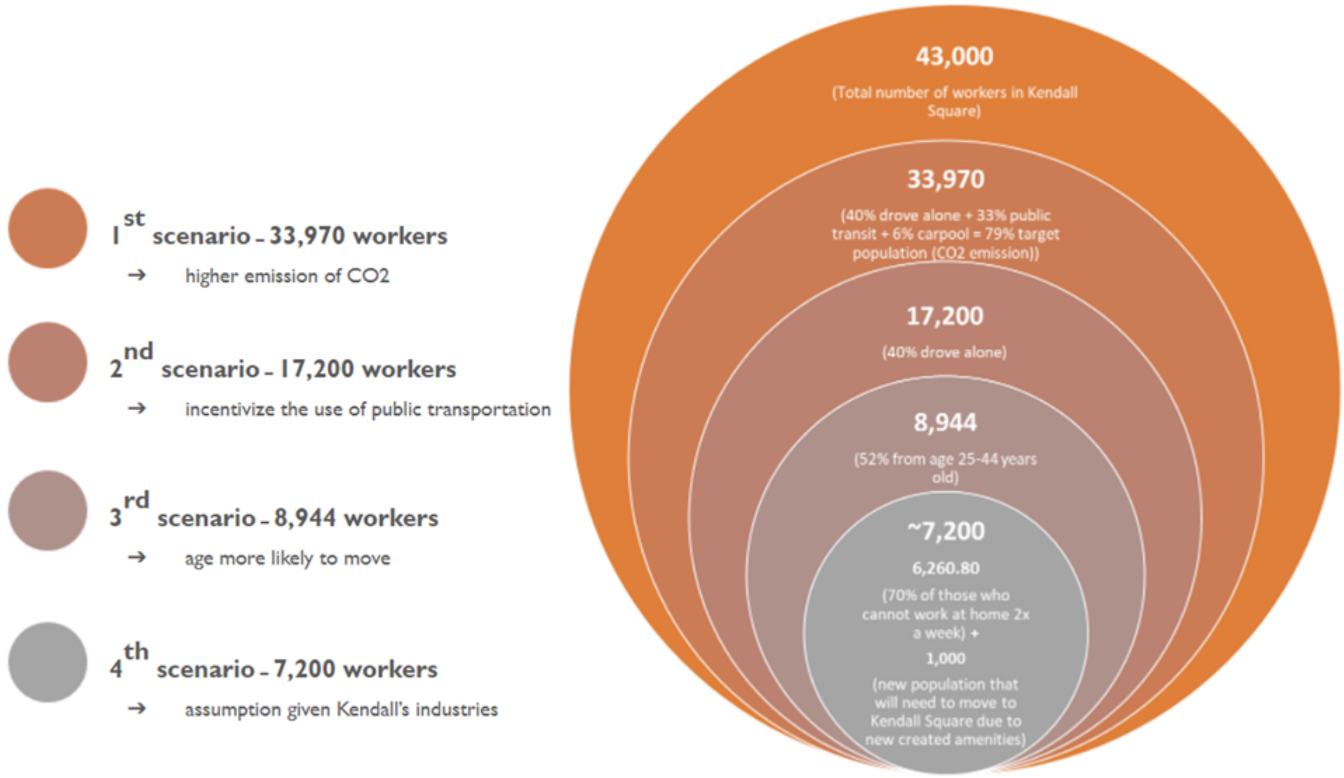


Figure 9 – Scenarios of targeted population to move to Kendall Square

In the 1st scenario we will be targeting 33,970 workers who drive alone, take public transit, and utilize carpool. To bring all these workers to Kendall Square might not be viable right now. It would be necessary a lot of land to develop high rise apartment buildings for living.

In the 2nd scenario we would be targeting only the workers who drive alone, 17,200 workers. This scenario is a great alternative, and if policies to take public transit are implemented, it will help the whole system – more money will be spent in public transit and therefore more investments can be spend in public transit, reinforcing the system.

In the 3rd scenario we would be targeting 52% of the workers who drive alone, 8,944 workers. We are assuming that 52% of that population are between 25 to 44 years old and therefore have more willingness to move.

In the 4th scenario we would be targeting approximately 7,200 workers, who are 70% of those who cannot work from home 2x a week (this is an assumption), commute by driving alone, and are between 25 to 44 years old. We add to those 1,000 workers who will be added because of the new population moving to the area. They will be working at the new facilities created to serve the new population.

We conducted some experiments to test our scenarios with the Net Zero Energy tool. The results are as follow:

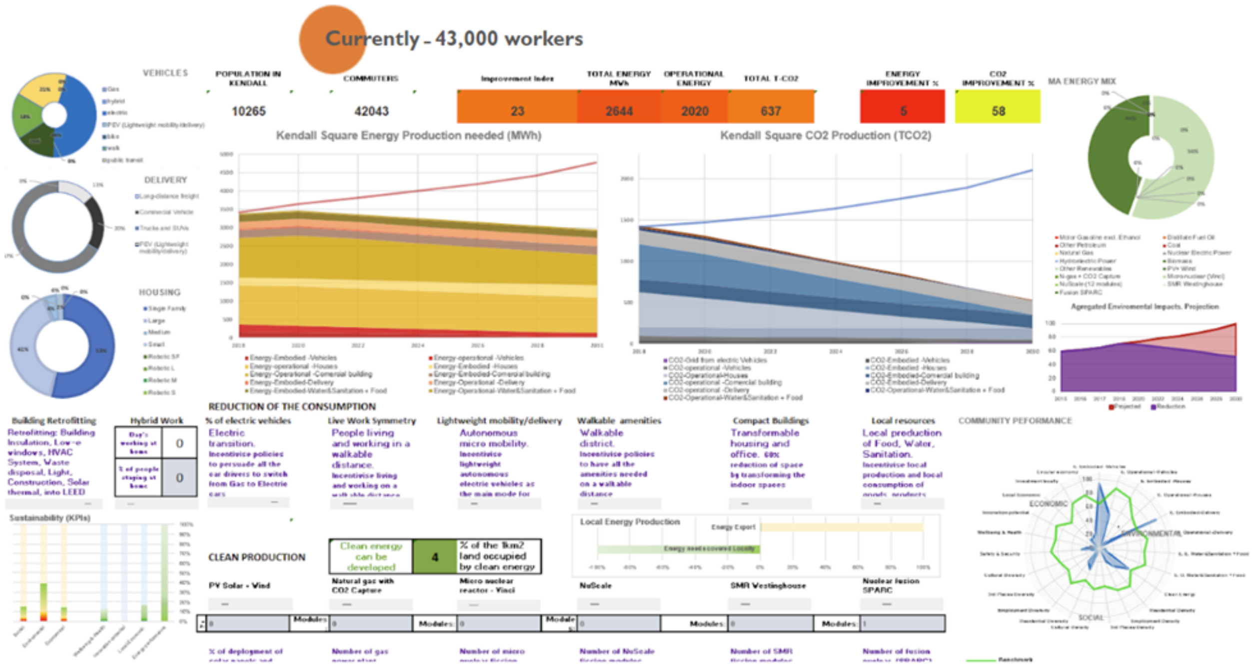


Figure 10 – Current scenario

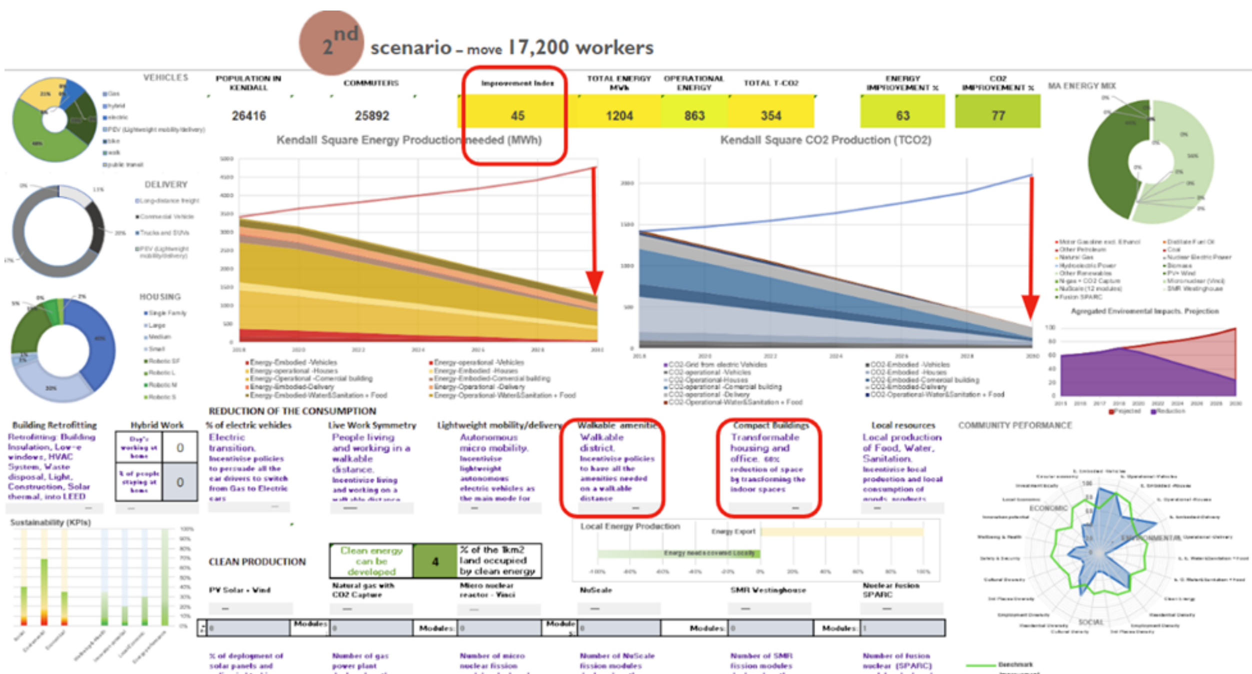


Figure 11 – 2nd scenario

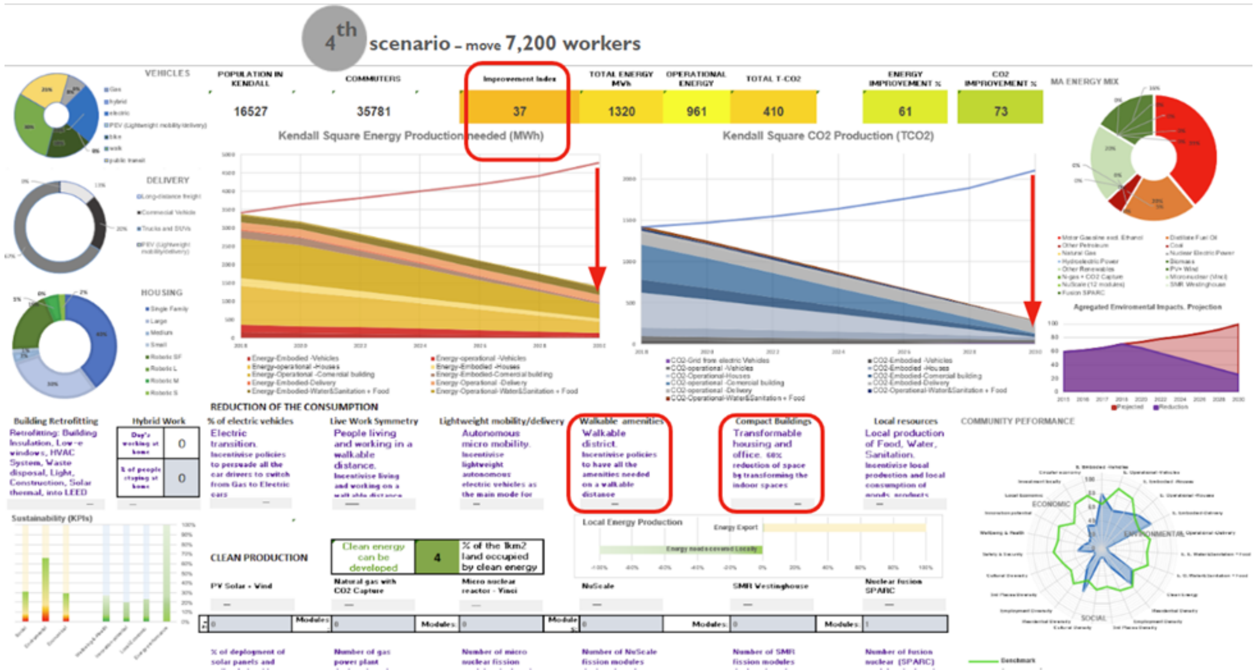


Figure 12 – 4th scenario

In **Figure 11** the $C0_2$ improvement went from 58% (**Figure 10**) to 77%, and the Improvement Index went from 23 to 45. The total energy went from 2644 MWh to 1204 MWh.

The 4th scenario has some improvements as well with 73% improvement of CO2, 37 at the Improvement Index, and 1320 MWh in total energy.

MIGRATION PROFILES

The transition from the current state to a state of greater live-work balance in Kendall Square or in any community, requires migration, job change or both. In Kendall specifically, the employed polulation far exceeds the residential population so migration is required. An intervention intended to promote live-work balance in Kendall must, as a first step, influence the decisions of those working but not living in Kendall, focusing on the highest impact commuters identified above.

There are a variety of ways to incentivize migration, including both carrots and sticks. Commuting could be penalized through mechanisms like:

- Tolls increases

- car tax increases
- gas price increases

Penalty interventions like these would increase the cost of the commute, increasing the comparative benefit of migrating to live-work balance. Alternatively live-work balance could be rewarded through mechanisms like:

- Tax credits
- Subsidized housing
- Benefits funneled through employer/salary
- Family benefits like school access

These would similarly increase the comparative benefit of migrating to live-work balance.

Each intervention would carry a **cost per migration-decision influenced**. The penalizing interventions could increase revenue for the city, but because they are costs to the individuals, they would decrease the value of **working** in Kendall. This ultimately would impact the ability to attract the best workforce, creating a cost increase for employers. In turn, the reward interventions would carry a more easily measured direct cost to the city or to employers. The most efficient policy would have the lowest cost per migration-decision influenced, basically:

$$\frac{\textit{net cost of policy}}{\textit{total number of commuters} * \textit{percentage convinced to move} * \textit{subsequent years of residence}}$$

Efforts to optimize incentives typically focus on comparing the equation numerators -- comparing the net cost of the policies with the assumption that the denominator remains basically the same. Extensive research into how age and life events drive migration suggests that this is not the case; instead finding:

> *"The evolution of a human population undisturbed by emigration or immigration is determined by the fertility and mortality schedules it has been subject to. If such a "closed" population system is disaggregated by region of residence, then its spatial evolution is largely determined by the prevailing schedules of internal migration."* [Rogers and Castro 1977]

Migration, particularly local migration, follows a consistent schedule, which can be represented as a profile of the relationship between age and likelihood of migration:

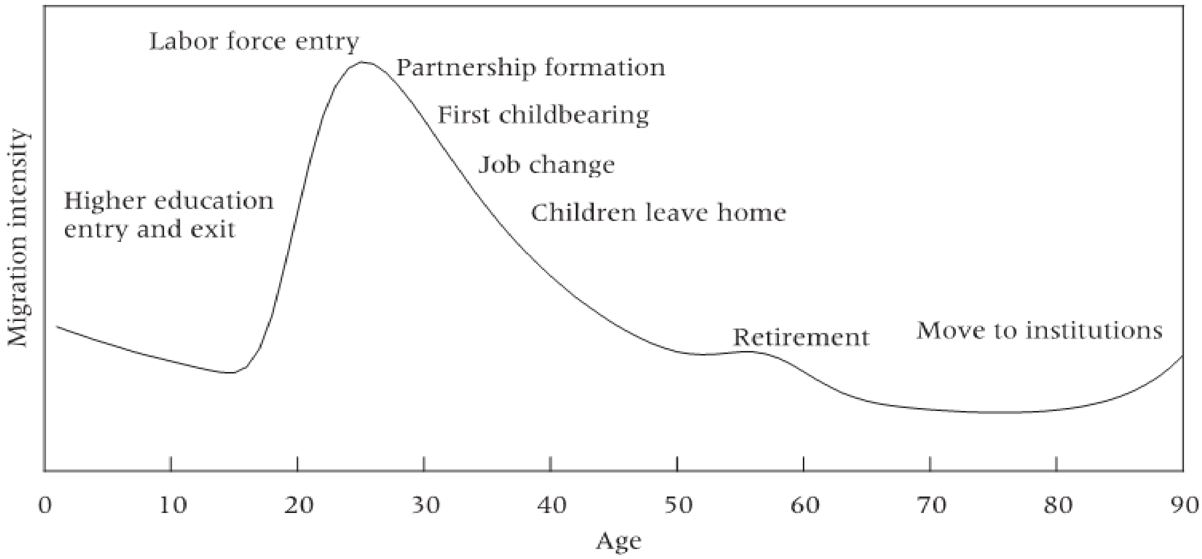


Figure 13 *Typical migration profile [Bernard, Bell and Edwards 2014]*

This profile provides a lens through which to focus any migration incentive policy. It is particulary impactful because it influences two different parts of the equation denominator:

$$\frac{\textit{net cost of policy}}{\textit{total number of commuters} \; * \; \textit{\textbf{percentage convinced to move}} \; * \; \textit{\textbf{subsequent years of residence}}}$$

If you can target an age range that is highly mobile, but will soon transition into a less mobile life phase, you are increasing both the success rate of your incentive (***percentage convinced to move***) and the impact of those decisions (***subsequent years of residence***).

EXPERIMENT: AGENT BASED MODEL

A simple agent based model was used to test this hypothesis. The "NetLogo Urban Suite - Economic Disparity model" [Felsen, M. and Wilensky, U. (2007)] is a simple and canonical model of urban dynamics, illustrating how an simple hedonic mobility decision making can drive patterns of segregation in a city. This model provided an ideal base environment to test the effects of a age based mobility profile because it already has agents moving within a grid in response to incentives (jobs/services).

As a first step, the new model extends Felsen, M. and Wilensky by:

- Added age as a property of agents within the model
- Removing the "poor" agents from the simulation

- Normalizing the value of cells within the model at each round (so location desirability is always relative)
- Adding tenure as a property of agents -- how long they have been in one place
- Allowing agents to move around continuously (not only when they are created)

Next, the age profile was incorporated into the agents decision making process. At each step, the agents “look around” to see if there are better locations to reside. The agents compare the benefits of moving against their desire to remain stationary using the following process:

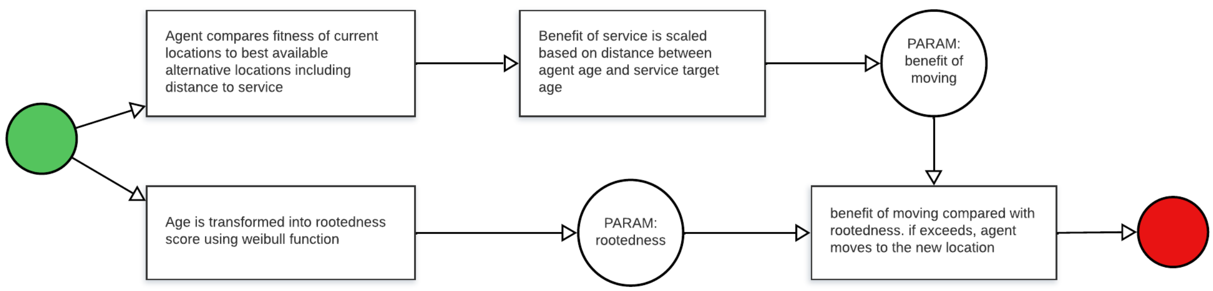


Figure 14

The agents “rootedness” or desire to remain stationary is calculated as a function of their age using a Weibull function that roughly approximates the typical age mobility profile:[1]

$$\textbf{Rootedness} = 6.6 * normalized\_age * exp\,(-(normalized\_age * 3\,)2)$$

Services are assigned an age target and the attractiveness of the service is weighted using:

$$\frac{1}{\textit{Normalized difference between agent age and service age target}}$$

With these changes to the model, initial simulations showed that services targeting an ideal age of 25, (right before rootedness starts to increase) were found to increase the average agent tenure by 25% when compared to services that targeted the oldest agents. This average tenure increase suggests that policy interventions designed to influence decisions made near that ideal age range could be significantly more efficient than age indiscriminate incentives.

As a next step, the model was further extended to simulate competing incentives. The simulation creates two randomly located services, one targeting the ideal age range, the other targeting very old or very young agents. In

---

[1] As Implemented: wy (2.2 * (gamma / 2) * ((wx * 3) ^ (gamma - 1))) * (exp (- ((wx * 3) ^ gamma)))

this version of the simulation, the age targeted service attracts a greater percentage of agents initially, but the effect vanishes as the simulation matures and more agents are added. It is possible that the targeting effect is undermined as all high value locations are occupied once the number of agents reaches a certain threshold because they can no longer find a “better” location to move to.

A next step would be to let the model increase density in response to demand to alleviate the location based scarcity, adding supply dynamics. Due to the complexity of implementing supply side decision making realistically in an agent based model, these relationships within the system were subsequently modeled separately as a stock and flow model.

INCENTIVES

The insight that migration decisions are most efficiently influenced at a certain point along the age migration profile has value only if targeted incentives can be created that appeal specifically to individuals at that age. In the literature, The age migration profile is attributed to critical life-course events or transitions. These drive of decision making:

> *Since life-course transitions act as an intermediary between contextual factors and migration outcomes, we refer to them as proximate determinants. This framework…permits comparative analysis of the drivers of age-related migration across space and time.* [Bernard, Bell and Edwards 2014]

If these life course transitions or events are the “intermediary” between context and migration outcomes, than changes in context (interventions) should be able to to target specific life events. In fact research into these decision making processes suggest that mobility decisions made at a specific age can be incentivized or “caused” by anticipated future benefits [Wang, Rasouli,Timmermans & Shao, 2018].   This suggest incentive need not specifically target life events typically occurring at age twenty five, rather they should target perceived future needs (like schools for planned children).

MARKET DYNAMICS

Though age targeted amenities suggest a more efficient way to incentivize migration, one of the greatest migration incentives, employment, exist already for the commuters to Kendall Square. They already work in Kendall so a strong incentive exists. In this instance, it might be more useful to think about removing barriers to their migration than creating incentives.

The most significant barrier for most are the intertwined problems of astronomical price and low supply. The current[2] average price/sqft in Cambridge is more than **$1300**[3]. In Providence, a short train ride from Cambridge, that average price drops to **$450**. These price disparities create a huge cost for migration, a cost paid in rent, mortgage or as a sacrifice of living space. At the heart of this pricing barrier are the broken market dynamics of real estate. To give a sense of the scale:

> *"(from 2019 to 2021), Americans who own their homes have gained more than **$6 trillion in housing wealth**…The cumulative effects figure to be sweeping, and divergent: This period of rising equity will enable some families to create intergenerational wealth for the first time. It will force other families to delay homeownership for years."* [Bui, 2022]

Skyrocketing home prices created a $6 trillion surge in equity for home owners in just two years. This problem, in part, has emerged out of broken feedback mechanisms in the market. Demand and price should have a stabilizing relationship. As demand goes up, price rises, lowering demand.

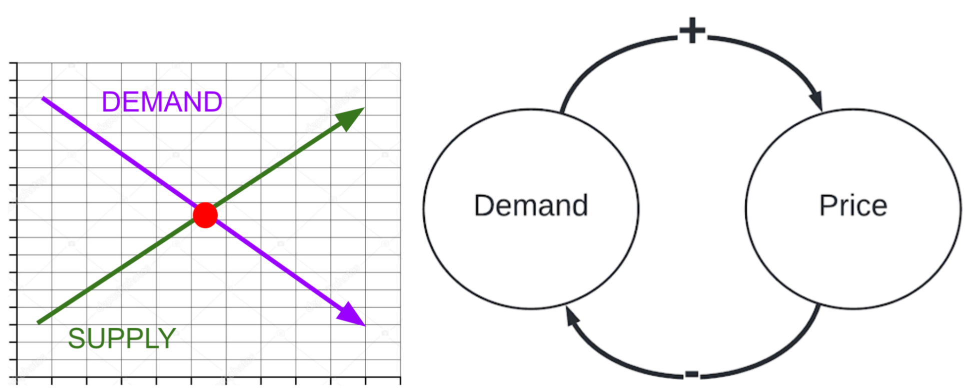


Figure 15

In real estate though, consistent growth in value over time has caused investors to assume continued growth. That anticipated future growth reduces the stabilizing effect of price increases:

2 May, 2022

3 https://www.numbeo.com/property-investment/in/Cambridge-MA

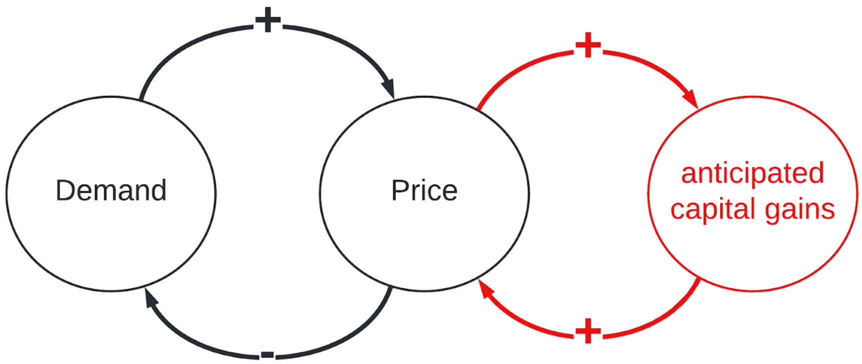


Figure 16

Further, this effect is amplified by favorable mortgage rates. The mortgage cushions the perceived cost in the short term and the assumed growth in value cushions the perceived cost in the long term:

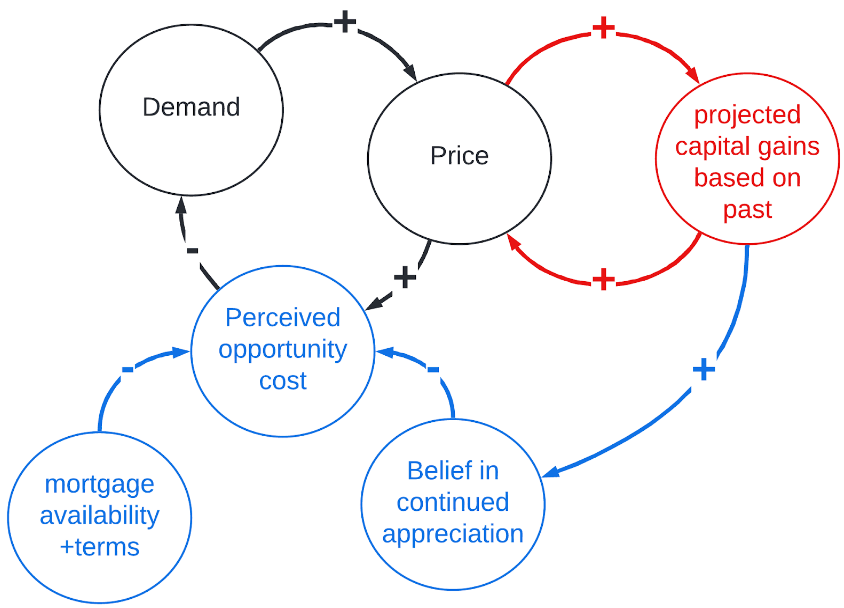


Figure 17

Alongside this price inelasticity of demand, we have similar undermining of the system dynamics on the supply side. In an ideal market, demand would increase price which in turn would rapidly drive an increase in supply (bring the price back down).

> *"The fundamental premise…is that…rents must adjust so that demand equals the existing stock. Such a simple principle sets the stage for identifying and forecasting time paths for not only rents or prices but also new construction"* [DiPasquale and Wheaton, 1996].

This, again, can be illustrated as a simple stabilizing loop:

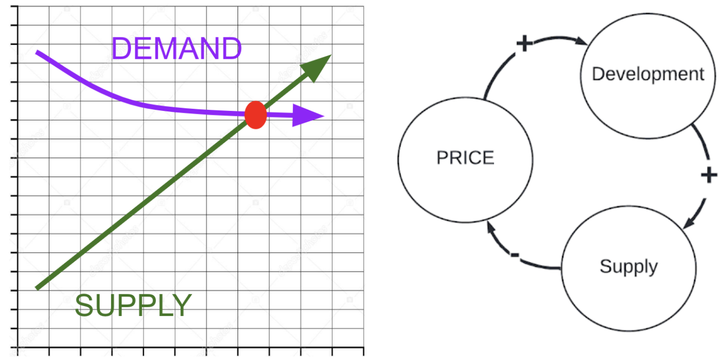


Figure 18

In real estate, particularly in cities with greater density, these supply side dynamics are undermined by risks and associated with market volatility and delays associated with permitting and the cost of construction. These create long delays in the supply response to pricing illustrated below:

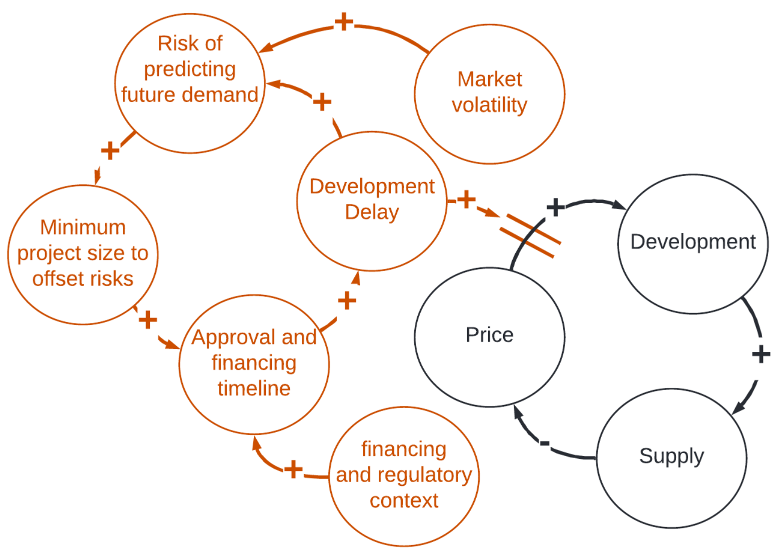


Figure 19

Improving these market dynamics, on both the demand and supply side must address the following leverage points:

- Increase demand price sensitivity (create some pressure to pull prices back down)
- Reduce minimum project size (by reducing project risk)
- Reduce regulatory and construction delays

These correspond roughly to typical real estate market inefficiencies as identified by [DiPasquale and Wheaton, 1995]:

- *Lack of information*
- *Construction lags*
- *Long-term leases*

EXPERIMENT: SYSTEM DYNAMICS MODEL

A simple system dynamics model was used to test the impact of adjusting these parameters:

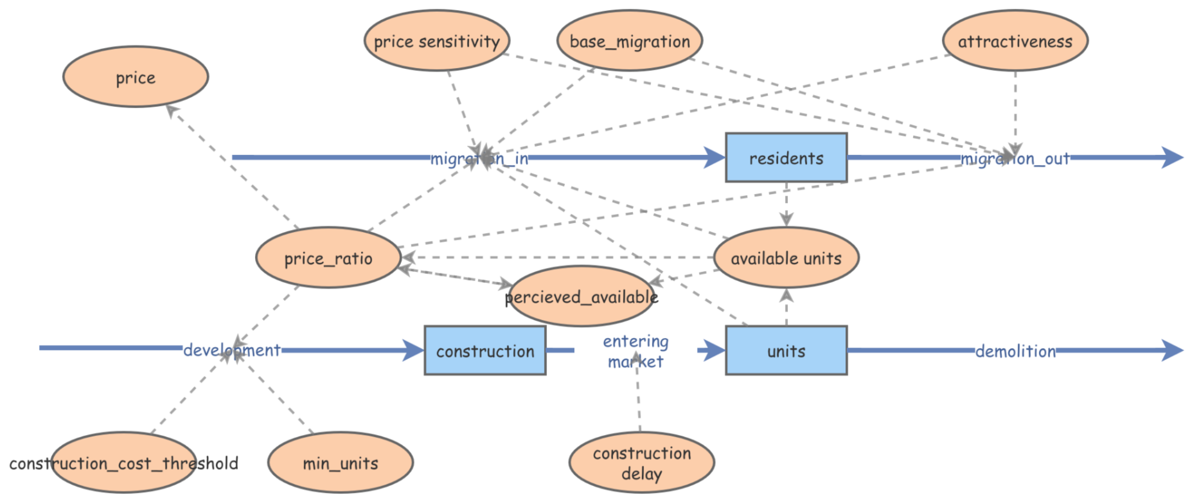


Figure 20

The model exposed the following default input parameters for adjustment, corresponding with the leverage points identified above:

Critical Inputs Parameters	
price sensitivity	**Value: 0.1**
min_units	**Value: 10**
construction_cost_threshold	**Value: 2.7**
construction delay	**Value: 3**

With those default values, this rough model demonstrates dramatic, long term price fluctuations (reminiscent of what we see in Boston):

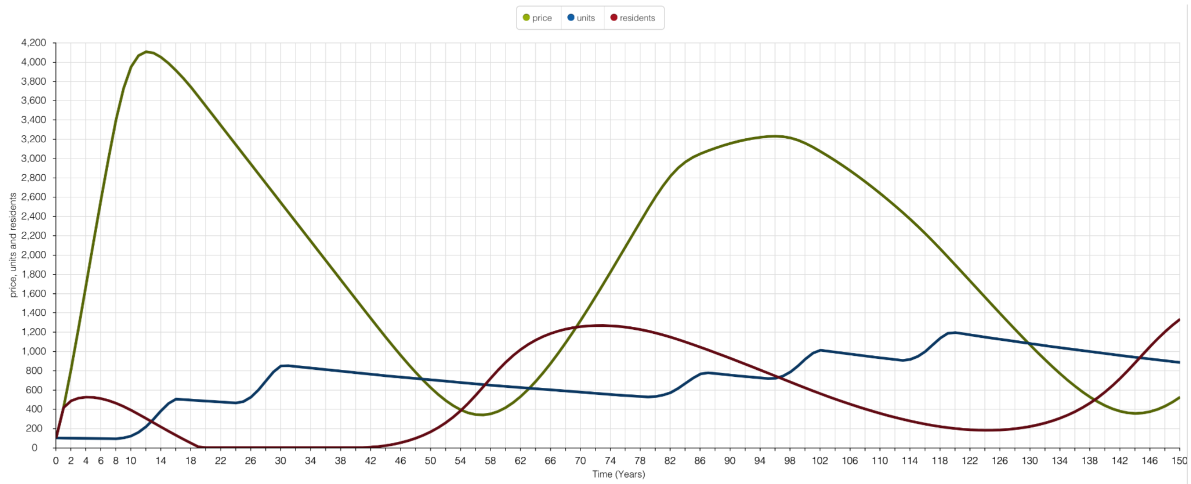


Figure 21

To simulate potential intervention, the price sensitivity, the minimum project size, the supply side price sensitivity and the construction delay were adjusted:

Critical Inputs Parameters	
price sensitivity	**Value: 0.6**
min_units	**Value: 1**
construction_cost_threshold	**Value: 0.1**
construction delay	**Value: 1**

Resulting in the following change in the system behavior:

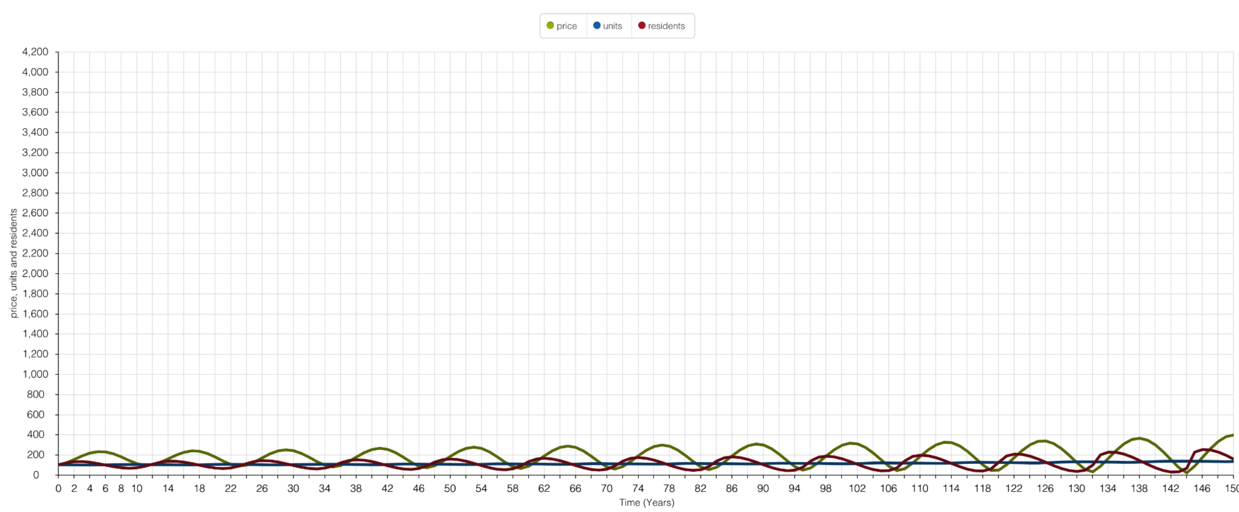


Figure 22

The price fluctuations are reduced by an order of magnitude. The remaining cyclical fluctionates can be attributed to the whiplash effect from the short delay between price change and supply response. Though this model is a gross oversimplification of urban real estate market dynamics, it suggests that changes to these parameters:

- Price sensitivity of demand
- Price sensitivity of supply
- Delay of supply response
- Minimum size of supply response

could dramatically improve the fundamental dynamics of the market, resulting in more responsive development, appropriate increases to density and moderate prices.

INTERVENTIONS: HAVE A C.A.O.

These problematic market dynamics are not new or unique to Cambridge. It would be reasonable to worry that all potential interventions have already been attempted. The difference today however, may be the emergence of blockchain technology to support truly decentralized decision making and value exchange. Decentralized autonomous organizations are systems controlled through large scale group decision making, tracked and managed on the blockchain to ensure transparency and trust. A community based D.A.O. or **C.A.O.** system, represents an opportunity for responsive local management of the real estate system and provides a novel access point to the critical market parameters identified above in the system dynamics model.

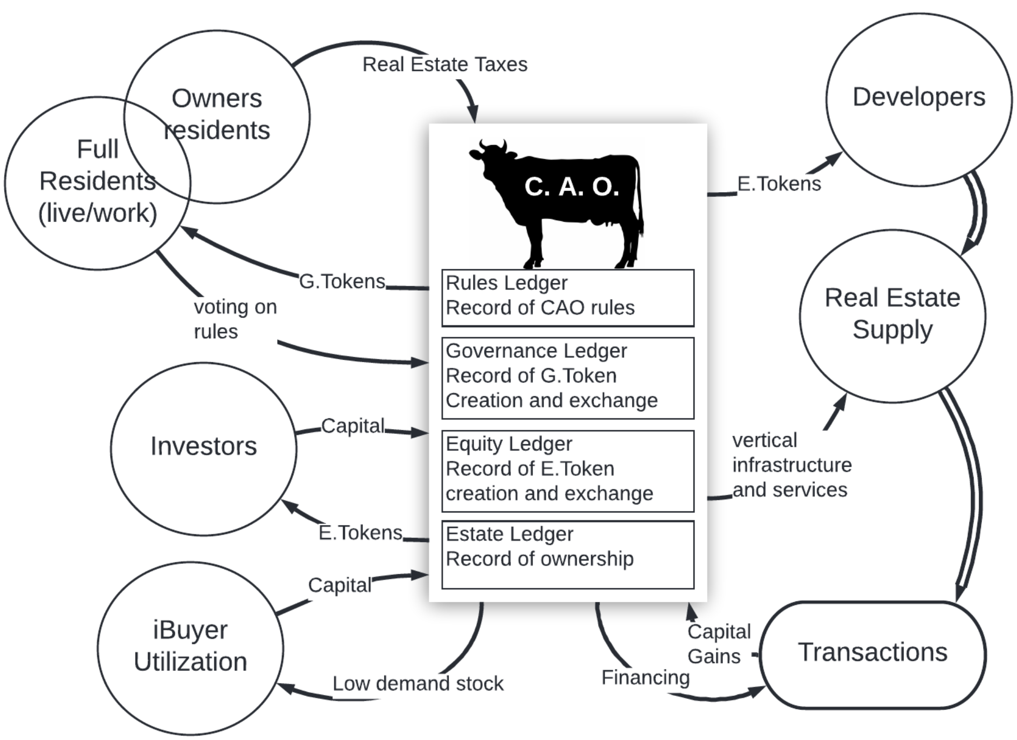


Figure 23 *Schematic C.A.O. model intended to improve local real estate market dynamics*

C.A.O. FEATURES

At its core the CAO consists of a set of immutable, public ledgers along with an investment fund allowing it to engage in real estate transactions. The ledgers include:

- A value token ledger, similar to typical crypto currency. This ledger enables rules based and market based value creation and exchange.
- A governance token ledger to sequester decision making from capital. The the second token ledger is important because it allows a different set of rules for governance tokens (which equate to an individual's control over the system) and value tokens which operate more like conventional currency.
- A rules ledger to record the ever adapting rules of the CAO system as determined by holders of governance tokens.
- An estate ledger to record actual real estate transactions and ownership.

To ensure the system best reflects the needs of Full Residents(residents living in live-work balance), full residents accrue Governance tokens each year. Governance tokens represent voting shares and can be exchanged earned or forfeited as determined by the rules ledger. These Full Residents determine the rules of the CAO, in particular determining systems of token exchange and distribution. Full residents transfer or forfeit their tokens upon migration or death per the rules ledger

The other specific features of the CAO are adaptive and determined by token holders. To have the intended impact, the CAO system would need features that modify the critical parameters in the market so we wil consider potential CAO features in terms of their contribution to these market parameters.

Price sensitivity of demand is primarily undermined by the anticipated returns from increased equity and the cost cushioning provided by the mortgage system. To improve price sensitivity, all Real Estate is taxes at an elevated rate to directly fund the CAO, with rates adjusted for assessed per/sqft and for prosocial program as determined by the Rules ledger. (basically a superchained capital gains tax)

Price sensitivity of supply is primarily determined by the marginal gain of adding density through construction. To improve those gains, the CAO subsidized high value/pro-social development as determined in the Rules Ledger. Additionally that gain is increased through the tax mechanism above because it reduces the ability to use price in lieu of density to increase revenue on a property.

Delay of supply response is reduced by reducing the complexity of zoning and permitting processes while transitioning all new construction to be engineered for the target vertical height with vertical structure and vertical circulation specifically subsidized by the CAO (similar to horizontal circulation in existing cities). In addition, as an investment fund, the CAO would be able to provide development financing directly. This would eliminate another source of delay from the process.

Minimum size of supply response will be reduced with pre-engineer vertical circulation and structure because owners can sell their roofs for development and developers can effectively build one story at a time.

In addition to these features targeting the critical parameters identified in the system dynamics model, it is important to also consider the **market dynamics when demand and prices fall.** To create a price floor, the CAO would also operate as a community iBuyer of last resort. Similar to existing iBuyer businesses like OpenDoor, the CAO would commit to buying any property within the community at a reduced market price and partner with businesses to create alternative uses for the space until demand and price recover. This mechanism would rapidly transition depressed areas within a community to alternative functions and then transition them back as the market rebounds creating an elastic price floor, cushioning market volatility.

External investors play a huge part in reducing price elasticity of demand in communities, but they also provide a powerful benefit, funneling capital to fund development. In a community controlled via a CAO, external real estate investors are strongly disincentivized against investing in specific properties because they receive no governance tokens and their capital gains is taxed aggressively. As an alternative, they are strongly incentivized to buy E.Tokens backed by shares in the CAO. **These are investments in the community,** not specific properties, that more appropriately match how value actually grows.

Returning to the **initial migration target group in Kendall Square**, the CAO rules ledger may additionally provides a mechanism to:

- test age targeted incentives rules,
- drive development of age targeted amenities
- penalize excessive car ownership via parking access
- Align new development to varied income groups through building form and financing opportunities

URBAN FORMS | SCENARIOS

What forms with these scenarios take in the city? What will Cambrige look like with these interventions?

Quantifying the qualities of urban spaces and acknowledging social needs is often a difficult and intangible process. There exist several successful precedents attempting to create a more holistic approach to the planning process. In *METRICITY*, the research focused on dissecting the changing needs of users. Four types of factor were identified: socioeconomic, social demographic, political, and technological. These have further informed the creation of four urban density principles which are: Intensity (use classification), Amenity (dwelling per hectare metric), Autonomy (zoning), and Frequency (occupancy). Another example derives from the research of Gensler. In this research, it emphasizes on shaping the nature of urban life, while the degree to which cities mix uses and integrate green space ultimately impacts density, efficiency, wellness, and sustainability. The prototypes evolve from 1) single-zoned neighborhood (users are separate from each other), to 2) mixed-zoned neighborhood (users are adjacent and connected, reducing the overall footprint), and to 3) mixed-use, compact neighborhood (users are mixed, ground floor is activated, overall footprint and building heights are reduced, and additional public space is created in a vertical fashion). Inspired by these two case studies, we experimented with our physical interventions by building the interface.

In our experiment, the overall strategy is to use Spacemaker (an online tool to do generative design), to implement 1) site explore based on Machine Learning to find the optimal results of neighborhood layout, 2) massing design based on user profile, and 3) environmental attribute analysis. In step 1, the main input are building properties, including FAR (floor area ratio), GFA (gross floor area), and BC (building coverage). In step 2, first, different functions are distributed, with residential taking account for almost 65%, and the rest consisting of amenities, commercial, and office. Second, within residential, five type of units are further classified, with the area of 0-400, 400-600, 600-800, 800-950, 950+ft2. Smaller units tend to take more priority due to our user profile. In step 3, several environmental attributes are analyzed to evaluate the living quality within the neighborhood. The major attributes are solar radiation, daylight autonomy, wind flow, wind comfort, energy production by using solar panels, etc. After these three steps, we integrated all the information above into an interactive interface to mock up the three development phases in Kendall Square.

For a short conclusion, our three development phases approached optimal results. The first phase located at Volpe site accomplished 7,272 total units, satisfying the 4th scenario (7,200 workers, assumption given Kendall's industries). The second phase extends to the surrounding areas with 17,493 units, satisfying the 2nd scenario (17,200 workers, incentivize the use of public transportation), while the third phase fulfills the whole Kendall square with 46,288 units, not only satisfying the 1st scenario (33,970 workers, higher emission of CO2), but also accommodating all of the workers in Kendall square – 43,000 workers.

For future improvement, economic factors could be applied. Apart from built form, income and costs could both be further explored. Potential income indicators could include total potential apartment rent, total retail potential rent, retail vacancy, apartment vacancy factor, expense ratio, apartment rent, retail rent, and NOI. Potential costs indicators could include hard costs, financing costs, soft costs, developer fee, and contingency.

CONCLUSIONS

Though more work is needed, initial results are compelling. We found that a small subset of the total commuters working in Kendall Square are responsible for a disproportionate portion of the emitted carbon, allowing us to focus our efforts into generating a smaller more realistic migratory transformation. Further, we found that decisions to move are concentrated within certain life phases, enabling use to focus on incentives that appeal to those particular phases. Our analysis suggests that price is the single more important barrier to this migration, which could be lowered by fixing broken real estate market dynamics. We explore the possibility of using a Decentralized, Autonomous Organization to implement these market fixes. Finally, we find that we can achieve the density needed to support this focused migration without dramatically degrading other aspects of the built environment in Kendall Square.

References

LEHD OnTheMap origin-destination analysis, current as of 2017

Census Transportation Planning Products, based on 2012 2016 5-year American Community Survey estimates.

Community Development Department calculations are based on data from ESRI Community Analyst Tool which forecasts data from the U.S. Census Bureau. Additional data comes from the MBTA and data gathered by Community Development Department

Cambridge Community Development Department, Economic Development Division, December 2011, Kendall Square Customer Intercept Survey Summary Report

Carbon Footprint by Mode: UK Department for Business, Energy & Industrial Strategy. Greenhouse gas reporting: conversion factors 2019. *Note: Data is based on official conversion factors used in UK reporting. These factors may vary slightly depending on the country, and assumed occupancy of public transport such as buses and trains.*

Bernard, Aude & Bell, Martin & Charles-Edwards, Elin. (2014). **Life-Course Transitions and the Age Profile of Internal Migration**. Population and Development Review. 40. 10.1111/j.1728-4457.2014.00671.x.

Rogers, Andrei and Luis J. Castro. 1979. "**Age patterns of migration: cause-specific profiles**," Research Report RR-79-065/. Laxenburg, Austria: International Institute for Applied Sys- tems Analysis.

Rogers, Andrei and L. J. Castro. "**Model migration schedules.**" (1981).

Bruch E, Swait J. **Choice Set Formation in Residential Mobility and Its Implications for Segregation Dynamics**. Demography. 2019 Oct;56(5):1665-1692. doi: 10.1007/s13524-019-00810-5. PMID: 31435838; PMCID: PMC6800645.

Wang, B., Rasouli, S., Timmermans, H., & Shao, C. (2018). **Relationships between consecutive long-term and mid-term mobility decisions over the life course: a Bayesian network approach**. Transportation Research Record, 2672(47), 159-170. https://doi.org/10.1177/0361198118777604

Felsen, M. and Wilensky, U. (2007). **NetLogo Urban Suite - Economic Disparity model**. http://ccl.northwestern.edu/netlogo/models/UrbanSuite-EconomicDisparity. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL

Wilensky, U. (1999). **NetLogo**. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL

Parlapiano, Solomon, Ngo and CowleyMarch **Where $5 Trillion in Pandemic Stimulus Money Went,** 11, 2022
https://www.nytimes.com/interactive/2022/03/11/us/how-covid-stimulus-money-was-spent.html

Badger, Bui. **The Extraordinary Wealth Created by the Pandemic Housing Market,** May 1, 2022

https://www.nytimes.com/2022/05/01/upshot/pandemic-housing-market-wealth.html?smid=url-share

11.433J / 15.021J **Real Estate Economics Fall 2008**, MIT OpenCourseWare. http://ocw.mit.edu

DiPasquale, Denise, and William Wheaton. **Urban Economics and Real Estate Markets**. Upper Saddle River, NJ: Prentice Hall, 1995. ISBN: 9780132252447.

Dixit, A. K. and R. S. Pindyck. 1994. **Investment under Uncertainty**. University Press: Princeton, NJ.

DiPasquale, D. and W. Wheaton. 1996. **Econometric Analysis of Office and Industrial Markets**. Chap. 12 in Urban Economics and Real Estate Markets. Englewood Cliffs, NJ: Prentice Hall

Wheaton, W and R. Torto. 1990. **An Investment Model of the Demand and Supply for Industrial Real Estate**.

AREUEA Journal, 18:4, 530-547.

Commuter Carbon Weighting Worksheet

		total	drive alone	public transit	bicycle	walk	carpool			
		100.00%	40.00%	33.00%	7.00%	14.00%	6.00%			
all ages	100.00%	43,000	17,200	14,190	3,010	6,020	2,580		33,970	
0-24	16.00%	6880	2752	2270	482	963	413	6880		
25-34	31.00%	13330	5332	4399	933	1866	800	13330		
35-45	21.00%	9030	3612	2980	632	1264	542	9030		
45+	32.00%	13760	5504	4541	963	1926	826	13760		
			17200	14190	3010	6020	2580			
	Average Carbon		237.50	35.00	0.00	0.00	79.17			
	Total Carbon		4085000	$496,650.00	0	0	204250		Total Carbon	4785900
		logic for carbon estimate:	average of large car, medium car	light rail	no carbon	no carbon	car average divided by 3		Divided by people:	140.8860
		total	drive alone	public transit	bicycle	walk	carpool			
			85.35%	10.38%	0.00%	0.00%	4.27%			
all ages	100.00%	43,000	36,703	4,462	0	0	1,835			
0-24	16.00%	6880	5872	714	0	0	294	6880		
25-34	31.00%	13330	11378	1383	0	0	569	13330		
35-45	21.00%	9030	7708	937	0	0	385	9030		
45+	32.00%	13760	11745	1428	0	0	587	13760		
			36703	4462	0	0	1835			
		commuters 25-45 actual drivers:	8944	if we increase density in kendall it reduces available parking, increasing percentage of public transit, lets say that adds 20% impact?						
		commuters 25-45 weighted equivalent drivers:	19085	Focusing incentives on drivers by appealing to high income and to families both correlated with driving vs public transit?						

System Dynamics Model: Parameters

Critical Inputs Parameters	
base_migration	**Value: 20**
attractiveness	**Value: 1.58**
price sensitivity	**Value: 0.6**
min_units	**Value: 1**
construction_cost_threshold	**Value: 0.1**
construction delay	**Value: 1**

Dependent Variables	
available units	**Value: ([units]-[residents])/[units]**
percieved_available	**Value: Delay([price_ratio],1, 1)-[available units]**
price_ratio	**Value: [percieved_available]**

Model Flows	
demolition	**Rate: Round([units]*.01)**
development	**Rate: (Floor(([price_ratio]-[construction_cost_threshold])/[min_units])*[min_units])**
entering market	**Rate: Delay([construction], [construction delay], 0)**
migration_in	**Rate: [base_migration]*(1/([price_ratio]*[price sensitivity]))*[attractiveness]**
migration_out	**Rate: [base_migration]*([price_ratio]*[price sensitivity])*(1/[attractiveness])**

Existing iBuying and DAO Systems of Exchange

crowd based real estate fund: https://www.crowdstreet.com/

Klima eco-DAO example: https://app.klimadao.finance

Carbon dao example: https://www.carbon-dao.com/

Carbon dao example: https://www.co2dao.org/

eco-DAO example: https://ipci.io/

Kima token model: https://carboncredits.com/carbon-crypto-guide-klimadao-carbon-nfts-and-carbon-tokens/

Why DAO for ecoresources:
https://medium.com/@antongalenovich/decentralized-solution-for-pricing-the-priceless-cd781746acdc

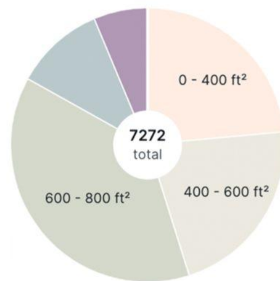
Why DAO for eco-agreements: https://ipci.io/wp-content/uploads/2018/06/Blockchain-Climate-Standard.pdf

Development Scenarios

Scenario planning

- 1st scenario - 33,970 workers
  → higher emission of CO2
- 2nd scenario - 17,200 workers
  → incentivize the use of public transportation
- 3rd scenario - 8,944 workers
  → age more likely to move
- 4th scenario - 7,200 workers
  → assumption given Kendall's industries

Unit distribution (RA)



Number of living units 7272

Site area

FAR (Floor Area Ratio)
14.66%

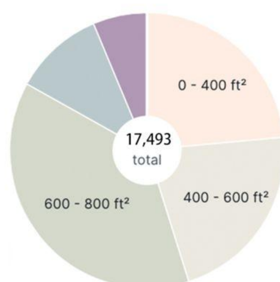
GFA (Gross Floor Area)
8,065,941 ft2

BC (Building Coverage)
282,893 ft2

Scenario planning

- 1st scenario - 33,970 workers
  → higher emission of CO2
- 2nd scenario - 17,200 workers
  → incentivize the use of public transportation
- 3rd scenario - 8,944 workers
  → age more likely to move
- 4th scenario - 7,200 workers
  → assumption given Kendall's industries

Unit distribution (RA)



Number of living units 17,493

Site area

FAR (Floor Area Ratio)
14.66%

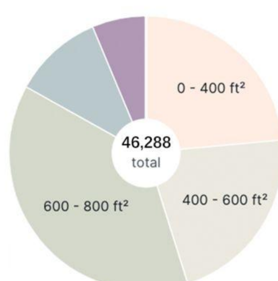
GFA (Gross Floor Area)
32,339,348 ft2

BC (Building Coverage)
1,134,508 ft2

Scenario planning

- 1st scenario - 33,970 workers
  → higher emission of CO2
- 2nd scenario - 17,200 workers
  → incentivize the use of public transportation
- 3rd scenario - 8,944 workers
  → age more likely to move
- 4th scenario - 7,200 workers
  → assumption given Kendall's industries

Unit distribution (RA)



Number of living units 46,288

Site area

FAR (Floor Area Ratio)
14.66%

GFA (Gross Floor Area)
85,570,482 ft2

BC (Building Coverage)
3,003,529 ft2

Development Progression