Introduction

The industrial revolution has had immense impacts on global economies. One significant consequence is that the revolution has reshaped human geography—forming cities. Even developing countries today are experiencing urbanization. How did the industrial revolution affect where people choose to settle and live?

Model

We are concerned with the geographic distribution of workers, so we can model our land as a grid. **Workers** live in each cell of our grid, and multiple workers can live in each cell. There are also **workplaces** on our grid where each worker works.

There is a **cost of living**: workers need to pay rent and need to pay for transportation to work. For a box with more workers living on it, there is an increased cost of rent due to an increased demand (workers trying to rent a home) for a fixed and scarce supply (amount of land available). For our model, rent is equal to the number of people living in a certain box in dollars, this is equivalent to real estate prices in the real world.

Likewise, the distance a worker has to travel to reach their workplace determines the cost of transportation. Again, for the purposes of our model, we let this be the *taxicab distance* (only counting vertical and horizontal moves) between the worker and the workplace.

Example: here's our grid, the factory denotes the workplace, and 5 workers live on our grid at boxes A, B, and C. Their costs are as follows:

A. The person living in box A pays 1 dollar in rent as there is only one person living on that box, but they have to pay 4 dollars in transportation to the workplace (2 boxes to the right and 2 boxes down). Total cost: 1 + 4 = **5 dollars.**
B. The person living in box B also pays 1 dollar in rent, and pays 2 dollars in transportation. Total cost: 1 + 2 = **3 dollars.**
C. The people living in box C pay 3 dollars in rent and only need to pay 1 dollar in transportation. Total cost: 3 + 1 = **4 dollars.**
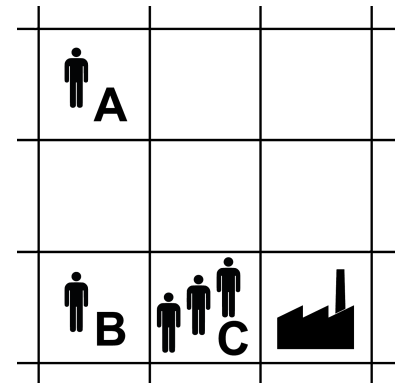
We can hypothesize the following empirical chain of reasoning that leads to urbanization:
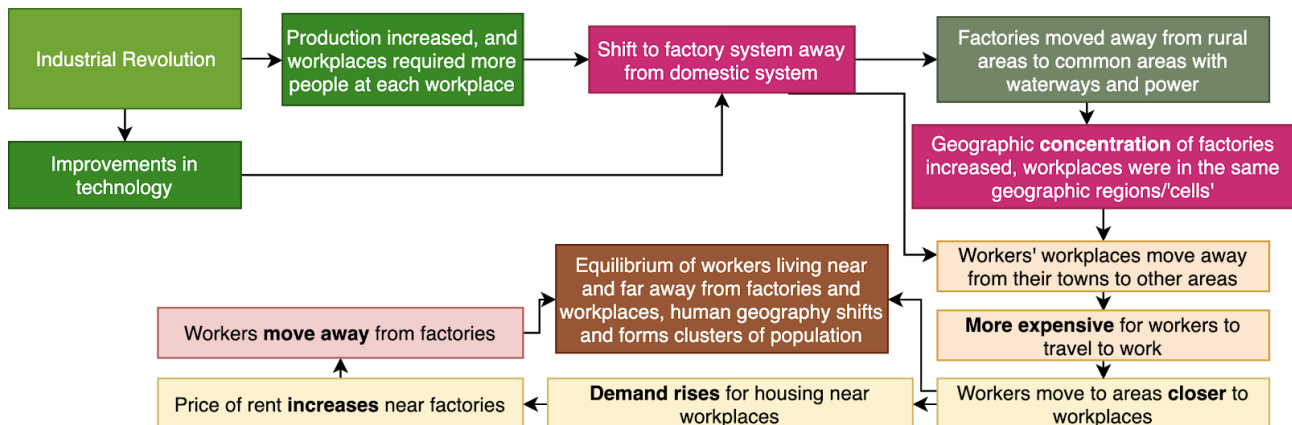
Making economically motivated decisions, workers would 'move around' the grid in search for a better box with net positive economic rent, which means that moving to this box will reduce their cost of living (rent + travel), giving the worker more surplus.

The industrial revolution implicated the shift from the domestic system to the factory system. This meant a shift from rural workplaces to workplaces that are more concentrated in certain areas, due to access to waterways (for power) and a demand for more workers per factory as the marginal product of labor was increasing due to innovation. (*Ency. Britannica*) We model this by increasing the capacity of each factory which decreases the number of factories, *ceteris paribus*. We want to know **how the number of workplaces** (the independent variable) affects **the densities of housing** (the dependent variable) if workers are allowed to freely move around to better locations.

We can scale this analogy to a much larger grid with more workers that represent a larger geographical landscape by running computer simulations on a 20 by 20 grid of 400 workers by letting them relocate many times to find better cells to live in.

Analysis

We can compare how workers move to locations nearer to their workplaces. Two trials comparing a region with 20 workplaces against 5 workplaces showcases the effects of decreasing workplaces and increasing concentration of labor *(Fig. 1)*. The left shows spots where the factories are located. After workers have had a chance to move around the grid, we can see that the locations with a higher density correlate to locations where there is a workplace (right). We can quantify how dense a population is by calculating the average density of all occupied boxes (boxes with > 0 workers).

20 workplaces
Average Density: 1.47

5 workplaces
Average Density: 1.94
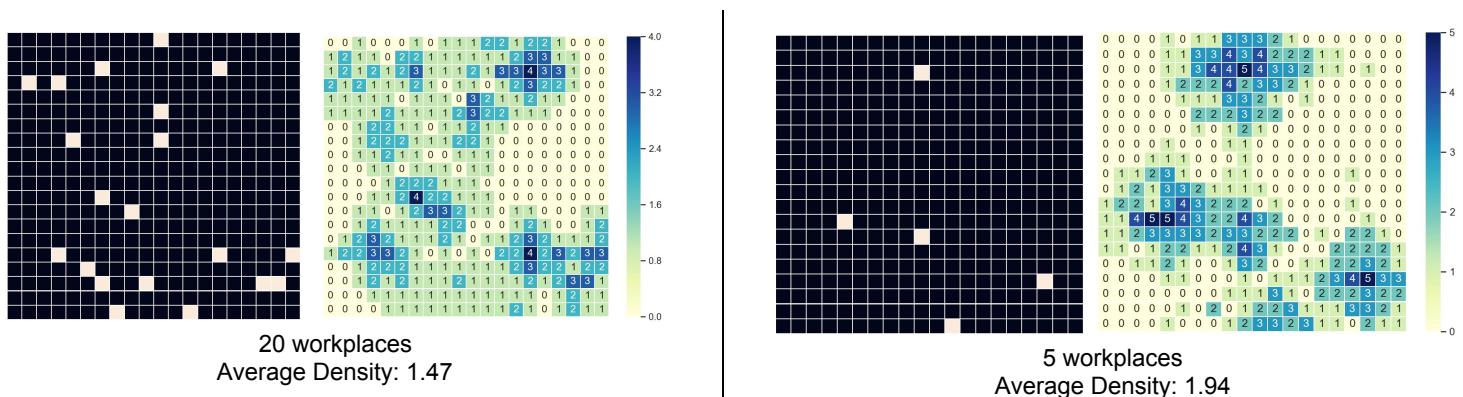
Fig. 1: Maps configured with 20 and 5 factories respectively, and their distribution of workers after movement.
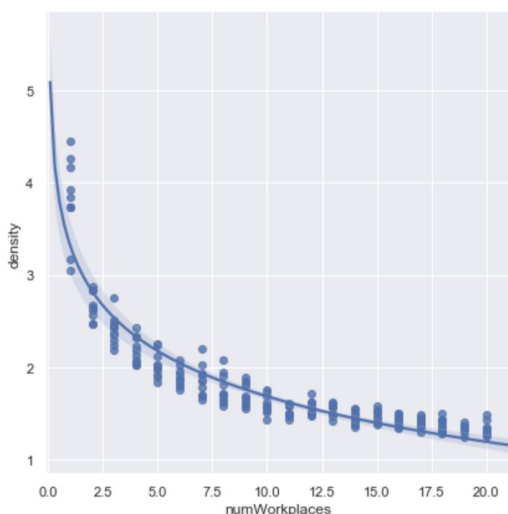
By varying the number of workplaces from 1 to 20, we plot each average density on a scatter plot (left). There is a trendline that as the number of workplaces decreases (the concentration of labor), the density of cells increases. This confirms our hypothesis that a decrease in # of workplaces leads to clustering and urbanization.

Conclusion/Future Investigation

This was all that was possible within the constraints of this paper. But by varying some of the constants in this simulation, we can gain more insightful observations and trends concerning the movement of populations as living & working conditions change.

<u>Works Cited</u>

"Factory System." *Encyclopædia Britannica*, Encyclopædia Britannica, Inc.,
https://www.britannica.com/topic/factory-system.