Abstract
Adopting an agent-based approach, this paper explores and models the topological evolution of the Minneapolis Skyway System from a microscopic perspective. Under a decentralized decision-making mechanism, skyway segments are built by self-interested building owners locating in different blocks. We measure the accessibility of the blocks in downtown Minneapolis from 1962 to 2002 using the size of office space in each block as an indicator of business opportunities. By building skyway segments, building owners desire to increase their buildings’ value of accessibility, and thus potential business revenue. The skyway network in equilibrium generated from the agent model displays similarity to the actual skyway system. Our results disclose that the accessibility-based agent model can provide unique insights for the dynamics of the growth of skyway networks.

Facts about the Minneapolis Skyway System:
• It is the longest skyway system in the US (9,713 meters);
• The first segment started in 1962, connecting the NorthStar Center and the Northwestern National Bank;
• The flourishing construction period lasted from 1973 to 1985;
• The system was financed by private investors.

Modeling the Minneapolis Skyway System
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Why build skyways?
Relieving downtown congestion
Enhancing the profitability of downtown businesses by providing better visibility for office buildings’ second floors.

The evolution of degree centrality for the actual skyway network from 1963 to 2005 and the simulated network.

The evolution of degree centrality for the actual skyway network from 1963 to 2005 and the simulated network.

The evolution of betweenness centrality for the actual skyway network from 1963 to 2005 and the simulated network.


The model
A link (skyway segment) is defined as a physical connection between two adjacent blocks. There is a building in each block, which is owned by an individual business owner. The value of a block is determined by its accessibility to other blocks (buildings). Building owners build links to increase the accessibility of their own buildings (and thus increase business opportunities). Further, skyway construction is presumably irreversible, meaning that once a link is built, it cannot be severed. Multiple iterations are run until a stable skyway network pattern emerges (i.e., no new links are built).

Building owner $m$ builds road link $k$ (in iteration $t$) to maximize the value of its building. The marginal profit for block $j$ to build segment $k$ in road set $R$ equals the extra value with link $k$ introduced minus the construction cost of link $k$, which can be represented as:

$$\Delta p_k = (A(R \cup \{k\}) - A(R)) - c_k.$$  

Where $A(R)$ is the shortest path travel cost between parcel $i$ and parcel $j$, $A(R)$ is interference function, in this case a gravity relationship, represents the decay parameter; $c_k$ refers to the value of accessing parcel $j$, which takes on a predetermined value.

Conclusions
The Minneapolis Skyway System, the longest skyway network in North America, exhibits interesting pattern and order over its course of development. An agent model is developed to model the growth of Minneapolis Skyway System.

We argue that the Minneapolis Skyway System has the property of self-organization and evolution. Even without a central authority or following an optimal design, interesting network patterns emerge out of individual building owners’ profit-maximizing behavior. When certain economic conditions are met, segments are first built to connect important blocks (measured by the size of office space), and then gradually cover the blocks on the periphery. When the general economic values of blocks are low, the tree-like (non-redundant) structure centering on important nodes is the emergent topological characteristic. When the value increases, the network not only reaches other blocks farther from the center, but also provides multiple paths for already-connected blocks. Meanwhile the value of the whole network for each block increases.