The Perfect Grid

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1 Introduction

Grids are among the most common forms of spatial organization used for planned urban expansion. Orthogonal subdivisions of streets, blocks and parcels have been adopted from Miletus to Barcelona, Buenos Aires to New York and Adelaide to Beijing. A gridiron organizations of urban space has proven to offer a number of benefits – grids are relatively easy and fast to survey on the ground (Chisholm 1911); they facilitate parcel amalgamations and subdivision as needs arise (Siskna 1998); they lend themselves readily to land market speculation (Hoyt 1933); they encourage rectangular building forms that are simpler to build than oblique building forms (Steadman 2006); they are easy to navigate and remember (Gell 1985; Sadalla and Montello 1989); they lend themselves readily to axial organizations of places of symbolic importance (Lynch 1984); and due to their substantial redundancy in travel paths, they are among the most accessible urban forms in terms of circulation efficiency (Sevtsuk, Mekonnen et al. forthcoming). These and other benefits have withstood the test of time under changing social order and technological needs, and continue to demonstrate the viability of grids in a number of contemporary cities. “It (the grid) is universal both geographically and chronologically”, argues Spiro Kostoff. “No better urban solution recommends itself as a standard scheme for disparate sites or as a means for the equal distribution of land or the easy parceling and selling of real estate.” (Kostof 1991, p. 95)

Given their universal adoption, it comes somewhat surprising that the literature on the dimensions of urban grids is relatively sparse (Marshall 2005; Figueiredo & Amorim 2007; Shpuza 2007). The effects of parcel, street and block dimensions on the performance of a grid have been a subject of some studies, and lot more assertion. Arnis Siksna (1998) has analyzed block dimensions in eight American and Australian gridded CBDs and found that block dimensions in cities adjust over time as the city’s land values change and built form densifies. Grids that start out with large blocks (e.g. an original Adelaide block measured 554x155m) are typically subdivided in the course of time to yield more direct circulation routes in higher-density CBDs. John de Monchaux, the lead design consultant for the new town of Milton Keynes outside of London, has argued that the design team at Llewellyn Davies’ office behind the project adopted a square ten-hectare grid, since the traffic calculations
suggested that the 330x330m block size “turned out to be the model that minimized total travel effort” under the predicted development density (DeMonchaux 2003).

A number of urbanists have advocated for smaller blocks based on seeming benefits observed in existing built examples. Leon Krier has argued that small city blocks generate more diversity and complexity in the urban scenery. “Urban blocks should be as small in length and width as is typologically viable; they should form as many as well defined streets and squares as possible in the form of a multi-directional horizontal pattern of urban spaces. (Krier 2007, p. 244)” Krier justifies his advocacy for small blocks by arguing that “Small blocks are the results of the maximum exploitation of urban ground caused by great density of activities, high cost of urban ground, and that a great number of streets on a relatively small area correspond to the maximum length of commercial façade”. (Krier, 2007, p. 245).

Jane Jacobs has also argued for small blocks in her famous book the “Death and Life of Great American Cities”. Critiquing one of the most celebrated grids in world, Jacobs suggested that the blocks of Manhattan are too long “Most blocks must be short; that is, streets and opportunities to turn corners must be frequent”. (Jacobs 1960) Shorter blocks would enable more encounter and interaction between the grid’s occupants, according to Jacobs. Allan B. Jacobs’ analysis of successful streets around the world has led him to suggest that particular configurational qualities of streets, such as the density of cross streets, contribute to the qualities of streets as hosts to diverse pedestrian friendly activities. “Streets with one entry for every 300 feet (90 meters) are easy to find, and some of the best streets approach that figure, …, but there are more entries on the busiest streets” (Jacobs 1993: 302).

Urban design debates about block sizes and grid dimensions contain more assertion than fact; we know relatively little about the comparative effects that different block and grid dimensions are likely to produce. This may be in part explained by the difficulty of identifying what these effects might be and how their performance could be captured. Further, an effect studied in one city, may not repeat itself in another, where climatic, cultural and economic circumstances differ. And a high performance
in any one indicators may inevitably come at the cost of another. The benefits of small blocks, for instance, can not be separated from the additional infrastructure costs they generate via a greater investment in streets. Yet even modest progress in understanding the effects of grid dimensions on urban life appears desirable for both the practice and study of city design.

In this paper we investigate how subtle differences in block sizes, parcel dimensions and street widths affect their users’ capacity to interact with each other by organizing land-ownership patterns at greater or lesser propinquities. In doing so, we do not observe actual interactions between the users of any particular city, but focus on the theoretical capacity of grids to generate pedestrian accessibility. We quantify how many neighboring parcels can be reached in a given walking radius in any direction around each parcel in a typical city block along the street network, and explore how such accessibility changes with different grid parameters. We analyze well-known grids in the US and Australia and additionally generate thousands of synthetic grids with variable dimensions on a computer, applying the same performance metrics on each. We use these investigations to demonstrate which combinations of grid dimensions maximize pedestrian accessibility to surrounding parcels and discuss how dimensional properties of parcels and streets impact the outcome.

The next section discusses the methodology. Section three illustrates the levels of accessibility in a number of existing grid layouts around the world. Section four discusses which parameters of grids impact accessibility and section five illustrates accessibility results from numerous simulated grid configurations. Section six provides practical examples of grids that maximize accessibility with realistic parcel dimensions for contemporary city design practice and section seven opens a discussion.

2 Capturing accessibility

In order to be able to compare pedestrian accessibility in multiple existing or imaginary grids, it is important to use a consistent performance metric that can be applied on grids of different size and configuration. And since urban grids are arranged around an orthogonal pattern of streets, it is also
important to measure accessibility under the spatial constraints of the actual street networks. We do so by utilizing the Reach metric from urban network analysis (Sevtsuk, Mekonnen 2011). Different specifications of an accessibility measure could be used (Bhat, Handy et al. 2000), but we chose the Reach metric as our yardstick since it offers an intuitive and easily interpretable output. The Reach of a given land parcel $i$ in a grid is defined as follows:

$$\text{Reach}_{i,r} = \sum_{j=1}^{n} w_r$$

, where $r$ is the search radius on the network for detecting neighboring parcels (in meters), $n$ is the total number of parcels in the system and $w_r$ represents a destination parcel $j$ that can be reached from an origin parcel $i$ within network radius $r$. Put alternatively, the index captures how many neighboring parcels can be reached if one walked in any direction along the street network from a given parcel $i$ until reaching the limit of the search radius (Figure 1).

![Figure 1. Illustration of the Reach metric on a grid. Parcel $i$ (highlighted in red) reaches 70 other parcels (hatched in gray) in a 100m network radius. All parcels are 8m wide and 16m deep, all streets are 10m wide.](image)

In order to count how many other parcels are reached, it is necessary to indicate a discrete entry point for each parcel. For simplicity, we use a single point denoting an entrance placed in the middle of each parcel’s frontage on the street. In Figure 1, the parcel highlighted in red reaches 70 neighboring parcels in a 100m walking radius. The walks are measured along the centerlines of streets, which as we shall demonstrate below, yields very similar results to constraining measurement to actual sidewalks and street crossings.
It is obvious from Figure 1 that the result of the Reach index at any parcel depends on the search radius used – parcel $i$’s Reach would increase if the search radius was expanded from 100m to 200m for instance. This raises an interesting question of what search radius best captures pedestrian access to destinations in the city? Figure 2 illustrates observed walking probabilities at different distances to bus stops in U.S. cities (TRB 2014). It shows how people’s likelihood to walk decreases with distance of the destination. While at short distances (e.g. 0-50m) most people choose to walk, less than 5% of people walk to destinations further than 600m. Similar empirical results have been found in other studies (Pushkarev and Zupan 1975; Handy 1997; Zacharias 2001). These findings suggest that measuring pedestrian access can be limited to a 600m range or shorter. Six hundred meters corresponds to roughly a 10-minute walk while two hundred meters to an approximately 3-minute walk.

Figure 2. Graph illustrates likelihood to walk to bus stops at different distances in North American cities. Source: TRB Transit Capacity and Quality of Service Manual—2nd Edition.

Many real-world grids are not large enough to allow us to measure access to surrounding parcels in a 600m range – grids merge with other street patterns and they may be asymmetric in different directions. We therefore implement our tests on idealized grids, where a typical block is repeated for at least 600m in each direction. This procedure allows us to investigate the pure effects of grid geometry on accessibility in a uniform, controlled environment.
3 Comparison of existing urban grids

In order to investigate how geometric configurations of urban layouts impact accessibility, we first studied the original grid layouts of nine cities from North America and Australia. We used the same cities as explored by Siksna (1998) – Portland, Perth, Melbourne, Indianapolis, Chicago, Brisbane, Adelaide – and added Manhattan and Savannah to this list to make the comparison richer. Sizes of these historic urban layouts range from Portland’s 61x61m blocks, consisting of 8 parcels, to the largest block in our samples – Adelaide with massive 518x156m blocks, containing 20 parcels each. The dimensions of each of these urban layouts are shown in Table 1. Table 1 also illustrates the Reach index measured to individual parcels in all of these cities in 600m and 200m walking radii. Since different parcels in the same city block can reach a different number of destinations in the same walking range depending on their location, we document the average reach value for a typical city block in each case. The comparison suggests that the grids of the nine cities produce remarkably different pedestrian accessibility to surrounding lots. Manhattan grid generates the highest level of access in a 200m and 600m analysis – 155 and 2,087 parcels reached respectively. The second most accessible grid after Manhattan is Portland with 858 parcels reached within in a 600m walk. In the original plan of Adelaide, on the other hand, a typical lot owner only reaches 89 parcels during the same walk, the lowest result in our comparison.

The variation in the number of parcels one can reach in a similar walking radius in Manhattan, Adelaide and the other cities, is explained by the geometric differences in these cities’ grids. Manhattan parcels, which are skinny and deep (8x24m), are packed densely along relatively lengthy block frontages. The layout of streets in Manhattan is rather economical, all parcels except for those on corners, are accessed from a single street. Savannah’s grid, on the other hand, has a greater density of streets, giving each parcel access from at least two different roads.

The very high result for Manhattan evokes a fascinating question – did the Commissioners who designed the plan intuitively achieve the most accessible grid possible? Given similar street and parcel dimensions, could shorter or longer blocks in Manhattan have led to even higher accessibility? We will return to these questions in section seven.
Table 1. 600m and 200m reach to neighboring parcels in selected North American and Australian grid patterns. The measurements were implemented in a uniform grids using identical blocks in each direction and parcels dimensions and observed street widths.

<table>
<thead>
<tr>
<th></th>
<th>Typical Parcel size</th>
<th>Number of Parcels in a row</th>
<th>Street Width (East-West, North-South)</th>
<th>Percentage under streets</th>
<th>Reach Mean (600m/200m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland</td>
<td>15m x 30m</td>
<td>4</td>
<td>24m/18m</td>
<td>44.6</td>
<td>85/87</td>
</tr>
<tr>
<td>Porth</td>
<td>31m x 121m</td>
<td>10</td>
<td>15m/15m</td>
<td>15.1</td>
<td>148.8/12.4</td>
</tr>
<tr>
<td>Melbourne</td>
<td>20m x 96m</td>
<td>10</td>
<td>30m/30m</td>
<td>28</td>
<td>253.8/33.4</td>
</tr>
<tr>
<td>Indianapolis</td>
<td>21m x 59m</td>
<td>6</td>
<td>30m/30m</td>
<td>41</td>
<td>149/35</td>
</tr>
<tr>
<td>Chicago</td>
<td>24m x 55m</td>
<td>4</td>
<td>25m/25m</td>
<td>37.8</td>
<td>329/30</td>
</tr>
<tr>
<td>Brisbane</td>
<td>20m x 45m</td>
<td>10</td>
<td>20m/20m</td>
<td>25.5</td>
<td>552.6/43</td>
</tr>
<tr>
<td>Adelaide</td>
<td>65m x 65m</td>
<td>8</td>
<td>26m/35m</td>
<td>21.9</td>
<td>89/11.5</td>
</tr>
<tr>
<td>Manhattan</td>
<td>8m x 24m</td>
<td>24</td>
<td>15m/27.5m</td>
<td>29</td>
<td>2097.2/155.2</td>
</tr>
<tr>
<td>Savannah</td>
<td>17.6m x 27.4m</td>
<td>5</td>
<td>24m/19m</td>
<td>53</td>
<td>630/61.3</td>
</tr>
</tbody>
</table>

4 Factors affecting access to surrounding parcels

The analysis of existing grids suggests that there are a number of parameters in any grid that affect how many neighboring parcels can be reached in a given walking radius (Table 2). We already saw in the case of Manhattan, that narrow frontages enable one to encounter a higher number of parcels. All else equal, parcel frontages need to be small in order to maximize accessibility. Parcel areas and street widths produce a similar effect – keeping all other parameters constant, smaller parcels and narrower streets put destinations closer to each other and yield more accessibility. Accessibility is also affected by the number of parcels arranged in a block, which determines the length of a block. For this parameter there is no obvious directional effect – if all other parameters are kept constant, how many parcels should be included in a block so as to maximize the reach to neighboring parcels? And how does this optimal number of parcels in a block, in turn, depend on the walking radius we assume? Would the most accessible block size for a 10-minute walk look any different from that for
a 3-minute walk? To find answers to these questions, we simulate synthetic grid layouts and test the effect of parcel count on accessibility while keeping other parameters constant. We repeat such tests with different walking radii and explore how the results change if the parameters for frontage, sizes and street widths are changed. The simulations were performed in Rhinoceros 3D software by automating the generation and measurement of girds with various input parameters.\(^1\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Expected effect if all else equal</th>
<th>Minimum dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parcel frontage</td>
<td>Narrower frontages yield more accessibility</td>
<td>8m</td>
</tr>
<tr>
<td>Parcel area</td>
<td>Smaller parcels yield more accessibility</td>
<td>(8mx8m) 64m²</td>
</tr>
<tr>
<td>Nr. of parcels in block</td>
<td>Unknown</td>
<td>unknown</td>
</tr>
<tr>
<td>Street widths</td>
<td>Narrower streets yield more accessibility</td>
<td>10m</td>
</tr>
<tr>
<td>Search radius</td>
<td>Larger search radii yield more accessibility</td>
<td>600m</td>
</tr>
</tbody>
</table>

Table 2. Critical grid design parameters affecting the reach to neighboring parcels and their expected effects.

All grids tested in this study use only bi-directional blocks, with parcels facing towards two opposing sides, as shown in Figure 1. This configuration can also be noted in six out of eight grids investigated by Siskna (1998). We did not model any grids with parcels facing towards four sides, as found for instance, in the Manhattan grid. This extension can be undertaken in future research.

5 Simulations

We start our experiment by setting the parcel frontage, area and street width parameters at reasonable constant minimum dimensions – 8m frontages, 64m² areas, and 10m wide streets. This allows us to test what number of parcels in a block maximizes the reach outcome, keeping other parameters constant. The constants are later relaxed and tested under different dimensions.

\(^1\) We opted for simulations rather than a pure mathematical solution in order to be able to rapidly test multiple different grid typologies and to develop a simulation framework that can later be scaled to more complex grid layouts.
Figure 3. Graph shows 600m reach values with a different number of parcels in a row, keeping parcel frontages at 8m, areas at 64m$^2$ and street widths at 10m in each direction. The number of parcels in a row designates a single sided count, it has to be multiplied by two to get the number of parcels in the block. MMR point shows at what number of parcels the most neighbors are reached. The values on the right-hand-side vertical axis also show what percentage of ground is covered under streets (as opposed to parcels) in each case.

Figure 3 illustrates the relationship between the number of parcels in a block (by row) and 600m reach values, keeping parcels frontages at 8m, areas at 64m$^2$ and street widths at 10m. The graph shows that the highest number of neighboring parcels – 6,000 – is reached when 20 parcels are arrayed in a row (40 in a double-sided block). This is around three times more parcels reached than in the Manhattan grid, because we are using 8x8m parcels, which are considerably smaller than the 8x24m parcels used in the original Manhattan grid. At the 600m radius, the mean value curve is relatively flat at its peak. If the maximum reach target is lowered by only a 1%, than the result can be achieved by 12-25 parcels in a row. This suggests that the precise number of parcels in a row required to achieve the near maximum reach result is not a sharp important absolute – there are a range of configurations that can achieve almost equal accessibility with a different number of parcels.
We can also read from Figure 3 that at the peak accessibility with 20 parcels on each frontage, around 42% of land is devoted to streets.

As a theoretical exercise, we also determined the absolute maximum reach values in a scenario where street widths are reduced to zero, covering all land with parcels. Though this configuration is of course impossible in reality due to lack on streets, the exercise gives us a theoretical ceiling, where the 600m reach equals 11,317. Beyond this, no grid with parcel fronts of 8m of wider and areas of 64m$^2$ or higher can reach any more neighbors. In this hypothetical configuration, the optimal number of parcels per row is only one, having streets around every pair of back-to-back parcels.

In the following comparisons, we use the term Maximum Mean Reach or “MMR” to denote the combination of parameters, where the average reach value amid all parcels in a typical block is at its achievable maximum. As in Figure 3, all the MMR curves that follow were determined via simulations, where only the top performing configurations are shown. The concept of MMR is quite useful in allowing us to investigate what number of parcels arrayed in a row achieves the highest accessibility with variable frontage, parcel area and street-width dimensions.

5.1 Walking distance effects

How many parcels are reached in the surrounding blocks usually depends on how far we walk. By keeping parcel frontages constant at 8m, areas at 64m$^2$ and streets at 10m as above, we can explore what the maximum accessibility value for a typical block is at different walking radii. Correspondingly, we can also determine how many parcels would need to be arrayed in a row to achieve these MMR values. We obtain these results by simulating city blocks with the given constant parcel parameters, but a variable number of parcels in a row, and filtering out only the highest results for every search radius (Figure 4). Every point displayed on the graphs in Figure 4 thus illustrates the achievable maximum reach values under different walking radii.
Figure 4. The blue curve shows Maximum Mean Reach values at different walking radii, using 8m frontages, 64m areas, and 10m street widths. The red curve shows respectively how many parcels need to be arrayed in a row to achieve the MMR results. Area between the dotted upper and lower red lines corresponds parcel count with -1% difference in MMR.

The figure shows that walking radius has an exponential effect on accessibility – doubling the walking radius more than doubles the reach result. In a 300m walking radius, for instance, up to 1,500 neighbors can be reached. We can read from the graph how many parcels in a row this result requires by moving up on the vertical axis at the 300m search radius mark. The configuration that yields this maximum result has 11 parcels in a row, or 22 back to back in a block. In a 600m radius, the maximum achievable MMR goes up to 6,000 neighbors and achieving this requires arranging 20 parcels in a row on each block frontage. However, just 1% lower MMR can be achieved with 15-23 parcels in a row, as shown with the 1% upper and lower intervals.

For urban design practice, these findings point back to the question evoked above – which walking radius to design urban layouts for? We know that the majority of walks in a city range between 0-600m. Should grids be designed to maximize accessibility for an average walk of 300m? Or are
shorter walks more likely to take place anyway, and should urban design cater to the longer walks that are less likely to occur unless they yield perceivable benefits? We think that a 600m range offers a reasonable upper bound yardstick to use, but also show some of the results with a 300m radius for clarity below.

We also tested how the analysis results differ when measured along sidewalks as opposed to road centerlines. In case of sidewalks, we assume that each block is surrounded by a sidewalk and that road crossings only occur at around intersections, as in the Manhattan grid for instance. The maximum achievable reach values, shown in Figure 5, suggest that the results are almost identical – almost the same number of parcels is reached at different search radii whether the analysis is performed along sidewalks or road centerlines. The minor differences in the number of destinations reached is shown on the right-hand-side vertical axis. Note that the similarity is smaller at shorter walking radii, where the sidewalk limitations for accessing parcels on the opposite side of the street take effect. At a 200m radius, for instance, analysis along road centerlines reaches on average, 2.2 destinations more than the equivalent analysis along sidewalks because parcels on both sides of a road connect directly to the same centerline.

Figure 5. Comparison of MMR results at different walking radii along road centerlines versus sidewalk centerlines.
5.2 Parcel area effects

In the next set of experiments we explore the effect of changing parcel areas on the average accessibility values in a block. To do this, we now keep the search radius constant at 300m, the parcel frontage at 8m and street widths at 10m. Increasing parcel area while keeping frontages at 8m effectively makes each parcel deeper and the blocks thicker. We test increasing parcel areas at 10m² steps and for each of the areas tested we find the corresponding achievable MMR (blue line in Figure 6) and the number of parcels in a row required to reach this MMR (red line in Figure 6).

Figure 6. Comparison of MMR results at different parcel areas. The blue curve shows Maximum Mean Reach values at different parcel sizes, using 8m frontages, 10m street widths and a 300m walking radius. The red curve shows respectively how many parcels need to be lined in a row to achieve the MMR results. Area between the dotted upper and lower bounds corresponds to a parcel count with ±1% difference in MMR.

All else equal, the maximum mean reach of neighboring parcels varies considerably with larger parcels. While with 64m² parcels (8m deep) around 1,400 neighbors can be reached, with 224m² parcels (24m deep) only around 500 neighbors can be reached. The number of parcels in a row needed to achieve these maximal results is 11 in both cases. This number of parcels required to
achieve MMR fluctuates between 10 and 16. Within a 1% drop in MMR, between 8 and 18 parcels need to be arranged along each block frontage.

The results also vary by search radii. Figure 7 illustrates the MMR at different parcel sizes for three separate search radii: 100m, 300m, and 500m. Following the example from above, the MMR at a 500m walking radius for 64m² parcels goes up above 4,000, and for 224m² parcels up to around 1,750 neighbors. While it is clear that smaller parcels achieve higher accessibility. The results here allow us to detect how many parcels should be arranged in a typical block in order to achieve highest pedestrian accessibility, which might be required by building sizes and development codes.

Figure 7. The effect of search radius on the MMR results at different parcel areas.

5.3 Street width effects

The number of neighboring parcels one can reach within a given grid layout also depends on street widths. The wider the streets, the longer it takes to cross roads and the less parcels are reached within a given radius. Figure 8 illustrates the simulation results for MMR under different street widths. For these tests we keep the search radius at 300m, parcel frontages at 8m and areas at 64m² and varied the street widths at 2m steps. The results show that street widths and accessibility are negatively
correlated; while with 10m-wide streets one can arrive at over 1,400 neighboring parcels within a 300m walk, with 30m-wide streets the number drops by a half, to around 700 neighbors. The number of parcels in a row that are needed to reach the maximum neighbors (MMR) is again shown on the right-hand-side vertical axis. The 1% fluctuations are smaller in this case – in order to reach an average of 700 neighbors in a 300m walking range in every block with 30m wide streets, 8m frontages, 64m$^2$ areas, we need to have no less than 15 parcels and no more than 17 parcels on block frontages.

![Graph](image)

**Figure 8.** Comparison of MMR results at a 300m walking radius (blue curve) with different street widths. Red curve presents the corresponding number of parcels in a row on each side of the block needed to achieve MMR. Parcel frontages are kept constant at 8m, and areas at 64m$^2$.

6 Sample grids with different building types

Exploring the isolated effects of the search radius, parcel area and street width parameters on our main question variable – the maximum reach to surrounding parcels (MMR) – has provided an understanding of how each parameter alone affects the outcome. In practical settings, however, the planning of grids often starts with some parcel and street dimensions in mind. Different parcel sizes are suitable for accommodating different building types. Likewise, different street widths are needed
in order to accommodate the predicted traffic flow under given development densities. In this section we describe five prototypical parcel sizes and associated street dimensions that may correspond to different developer intentions. The examples shown in Table 3 and Figures 9-14 are intended to provide a practical guide to maximizing accessibility to surrounding parcels with the given parcel and street parameters. For each, we provide the MMR at different walking radii, which could be used to adjust the number of parcels per block under various climatic and cultural settings, depending on people’s walking habits.

<table>
<thead>
<tr>
<th>#</th>
<th>Building types</th>
<th>Parcel and dimensions</th>
<th>Street dimensions</th>
<th>Maximum Mean Reach (MMR)</th>
<th>Parcel count per frontage at MMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shop-houses</td>
<td>8x16m</td>
<td>12.5m, 12.5m</td>
<td>3,400</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Walk-ups</td>
<td>16x32m</td>
<td>12m, 12m</td>
<td>930</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>Office buildings</td>
<td>64x32m</td>
<td>12m, 12m</td>
<td>200</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Office buildings 2</td>
<td>32x64m</td>
<td>12m, 12m</td>
<td>440</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Mixed-use complexes</td>
<td>64x128m</td>
<td>12m, 12m</td>
<td>65</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 3. Sample grids with prototypical parcel and street dimensions.

Table 9. Sample parcels with prototypical street dimensions.
Figure 10. Maximum achievable mean reach results (MMR blue line) for parcels with 8m frontage and 16m depth under different walking radii. Red line shows the corresponding required number of parcels side by side on each side of the block as well as 1% upper and lower bounds.

Figure 11. Maximum achievable mean reach results (MMR blue line) for parcels with 16m frontage and 32m depth under different walking radii. Red line shows the corresponding required number of parcels side by side on each side of the block as well as 1% upper and lower bounds.
Figure 12. Maximum achievable mean reach results (MMR blue line) for parcels with 64m frontage and 32m depth under different walking radii. Red line shows the corresponding required number of parcels side by side on each side of the block as well as 1% upper and lower bounds.

Figure 13. Maximum achievable mean reach results (MMR blue line) for parcels with 32m frontage and 64m depth under different walking radii. Red line shows the corresponding required number of parcels side by side on each side of the block as well as 1% upper and lower bounds.
Figure 14. Maximum achievable mean reach results (MMR blue line) for parcels with 64m frontage and 128m depth under different walking radii. Red line shows the corresponding required number of parcels side by side on each side of the block as well as 1% upper and lower bounds.

7 Discussion

Generating access and encounter between the residents of a city is one of the fundamental goals of good city design. Even though a part of this task in contemporary cities is fulfilled by mechanical systems that move people and goods as well as electronic systems that transfer information and enable communication, some of the most valued interaction still occurs in person in buildings, streets and public spaces. Understanding how the geometric configuration of these spaces could foster more encounters is important to every city designer.

In this paper we have explored the grid as a common typology of urban layouts and studied how particular parameters that determine a grid affect its ability to generate access to surrounding destinations. These parameters include 1) parcel frontages, 2) parcel sizes, 3) street widths and 4) the number of parcels assembled in a single block. While the former three parameters have
predictable effects on accessibility – smaller is usually better – the latter does not. We have thus focused most of our analysis on understanding how the number of parcels in a block, which also determines the length of a block, affects accessibility. Using simulations, we have found the maximum possible access results to neighboring parcels for different grid parameters and determined what particular parcel aggregations deliver these results.

The simulation results have shown that if the optimal parameters were used in real city layouts, then substantial improvements to pedestrian access could be gained. While it may not be possible to have great flexibility in adjusting parcel sizes, frontages and street widths due to engineering constraints, the number of parcels in a block is a variable that can be controlled relatively well in a city design process. If for instance, if the designers of Portland had laid 13 parcels in a row, instead of the current four, then an average landlord could walk to 1,023 neighboring parcels in a ten-minute walking range instead of the current 858. The potential gains of such optimization are shown for all the different grids studied by Siskna (1998) in Table 4. Between all the seven grids in the table, the original parcel layouts on average achieve 87% of the maximum possible reach results at a 600m radius with the given parcel and street dimensions.

<table>
<thead>
<tr>
<th>#</th>
<th>City</th>
<th>Parcel count per frontage</th>
<th>Mean Reach 600m</th>
<th>Maximum Mean Reach (MMR) 600m</th>
<th>Parcel count per frontage at MMR</th>
<th>% MMR achieved in original layout</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Portland</td>
<td>4</td>
<td>858</td>
<td>1023</td>
<td>13</td>
<td>83%</td>
</tr>
<tr>
<td>2</td>
<td>Perth</td>
<td>10</td>
<td>149</td>
<td>164</td>
<td>5 or 9</td>
<td>90%</td>
</tr>
<tr>
<td>3</td>
<td>Melbourne</td>
<td>10</td>
<td>254</td>
<td>270</td>
<td>16 or 7</td>
<td>94%</td>
</tr>
<tr>
<td>4</td>
<td>Indianapolis</td>
<td>6</td>
<td>349</td>
<td>391</td>
<td>13</td>
<td>89%</td>
</tr>
<tr>
<td>5</td>
<td>Chicago</td>
<td>4</td>
<td>329</td>
<td>379</td>
<td>8</td>
<td>86%</td>
</tr>
<tr>
<td>6</td>
<td>Brisbane</td>
<td>10</td>
<td>55</td>
<td>645</td>
<td>9</td>
<td>85%</td>
</tr>
<tr>
<td>7</td>
<td>Adelaide</td>
<td>8</td>
<td>89</td>
<td>109</td>
<td>3 or 4</td>
<td>82%</td>
</tr>
</tbody>
</table>

Table 4. Comparison between actual mean reach in a 600m radius and parcel count and maximum mean reach and parcel count in seven US and Australian grids.
The one grid that outperformed all others in our comparisons in section three above, was Manhattan. We can now return back to the question of whether the Commissioners of Manhattan intuitively achieved a “perfect grid” that maximizes access to surrounding parcels or could the Manhattan blocks also have been improved for greater accessibility? Our simulations results that address this question are not completely comparable to Manhattan since we only modeled blocks with parcels on two opposing sides, while Manhattan also has parcels facing avenues on the shorter sides of each block (Figure 15).

Figure 15. Manhattan comparison. Top: typical Manhattan block. Bottom: synthetic block.

However, if we simplify the picture and assume that those parcels that face the avenues may be turned 90 degrees and counted as part of the street parcels in a row, then Manhattan blocks would have 24+8=32 parcels in a row on each block frontage\(^2\). We took the same parcel and street dimensions as the original Manhattan plan (8x24m parcels, 15m streets, 27m avenues) and tested what number

\(^2\) The original plan has 24 parcels on a street frontage and 8 on an avenue frontage.
of parcels yields the highest average reach result to surrounding parcels. The result is shown in Figure 16. At a 600m walking radius, the maximum mean reach was 2,000 parcels, which required 27 parcels on each block frontage. But the average 600m reach on the original Manhattan grid is 2,087 (Table 1), one percent more than our simulation.

![Graph showing reach vs. search radius](image)

**Figure 16.** Manhattan comparison. Using 8x24m parcels, 15m east-west streets and 27m north-south avenues (same as real Manhattan).

This difference is explained by the parcels facing avenues in Manhattan, which generate higher results than the parcels facing streets. The simulation result also shows that within a 1% difference interval, the maximum reach to neighbors in a 600m walking radius can be achieved with 23-32 parcels. We are thus left to conclude that the Manhattan grid is either perfectly calibrated to maximize access to surrounding parcels, or very close.

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1 Since Manhattan blocks actually have a narrow alley in the middle of the block behind rows of parcels (see Figure 15), we stretched the parcels in the simulation to also account for the spacing of this alley and produce blocks that have the same block thickness.
Accessibility is certainly not the only performance indicator that should drive grid design in practice. Grids may be also configured to yield a greater variety of access characteristics among parcels in a block (Anderson 1993), greater equality, greater profitability, and their dimensions may be adjusted to cultural and climatic constraints. It would be indeed fascinating to investigate which grid configurations generate the greatest variety of access conditions on different land parcels so as to incentivize a variety of uses and users in each city block. This will have to remain the subject of future research.

8 References


Hoyt, H. (1933). One Hundred Years of Land Values in Chicago, 1830-1930. Chicago, IL.


