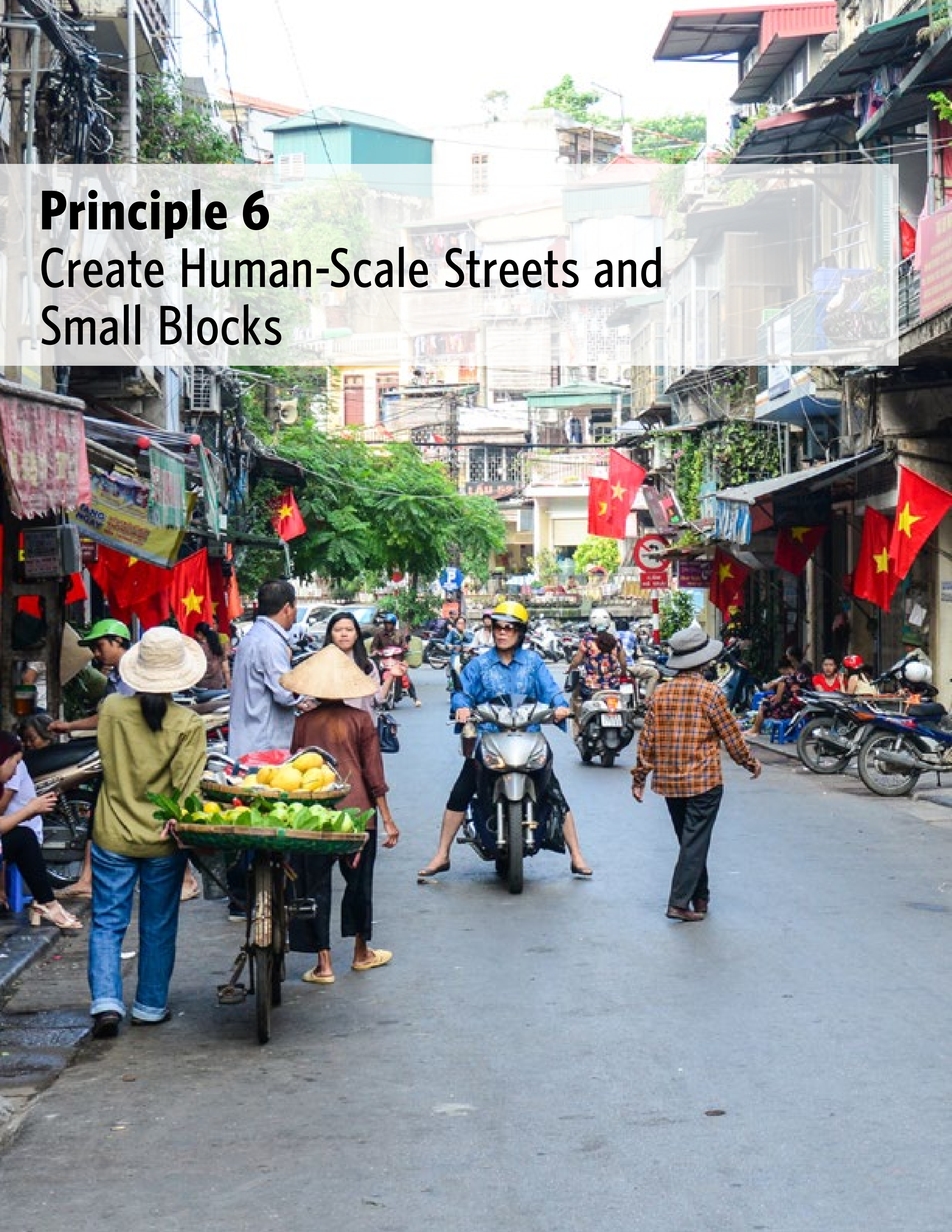
# Principle 6
Create Human-Scale Streets and Small Blocks




ĐẠI LÝ
GẠO CÁC LOẠI
ĐT: 04.39231662

# Principle 6
## Create Human-Scale Streets and Small Blocks

Increase density of road networks with small blocks and human-scaled streets

## GOALS

**6A Create human-scale blocks and streets**

**ACTION 1:** Develop blocks with perimeter buildings to provide shared interior courtyards and active sidewalks

**ACTION 2:** Reshape existing superblocks and cul-de-sac subdivisions with pedestrian passages

**6B Disperse traffic over narrow, parallel routes with a grid of varied street types**

**ACTION 3:** Locate larger expressways and highways at the district edge

**ACTION 4:** Limit major through street widths by substituting with one-way street couplets

**6C Establish car-free corridors that accommodate dedicated and connected biking and walking paths, which may include transit lanes**

**ACTION 5:** Auto-free streets should provide shopping and services at the building ground level

**ACTION 6:** Connect auto-free streets to trails and paths within major open spaces

## METRICS

**6.1 Block Size**

Ensure that at least 70 percent of blocks in residential areas are 1.5 hectare or less and commercial blocks in non-industrial areas are 3 hectare or less

**6.2 Setbacks**

Decrease setbacks to a maximum of 1 meter for retail, 3 meters for commercial, and 5 meters for residential

**6.3 Street Size**

No street should be more than 40 meters in non-industrial districts

**6.4 Auto-Free Streets**

Create auto-free streets for any combination of pedestrian, bike, or transit at an average spacing of 1 kilometer

## RATIONALE & CHALLENGES

Human-scale streets and small blocks are the essential elements of an effective urban transportation network and human-scaled neighborhoods. They create a dense mesh of narrower streets and paths that are more intrinsically pedestrian-friendly, helping shift people away from cars and improve air quality. At the same time, they can help optimize the flow of traffic for remaining cars by creating dispersed, parallel routes. Small blocks also allow a greater variety of public spaces, architectures, and activities, thus increasing the vibrancy of the neighborhood.

In new high-rise areas, superblocks have been a dominant planning paradigm due to the convenience it affords construction, parking, and infrastructure. Ironically, the large arterial streets that result from superblock development constrict auto flow compared to a denser network of smaller streets. With superblocks, all traffic is concentrated on a few main avenues with large and slow intersections. The net result is traffic congestion and barriers to pedestrian and bike movement, thus encouraging more people to drive.

The concept of small blocks and human-scaled streets is not an innovative idea. In fact, they are common features of cities around the world built prior to WWII. The legacy of these older urban forms is still prominent in central cities today, not only contributing to the diversity of cityscape but also providing a possibility to explore and contrast impacts of urban form on household travel behavior and transportation energy use.

Traffic engineers have focused on auto mobility by laying out grids of arterials and allowing few through streets within them—effectively creating superblocks of gated subdivisions or high-rise buildings. A similar outcome results in much of the Global South where local roads often sprout from highways but do not connect through. This creates complex dead-end street networks without the connectivity of a classic urban grid of small blocks.

In China, building 400-meter superblocks dates back to the Revolution with the idea of single-block enclaves containing complete communities of factories, housing, schools, and services generating blocks of over 16 hectares. These self-contained urban elements were created well before the problem of the automobile in the city became endemic. As factories grew larger and needed segregation, the superblock remained as the basis of their urban grid.

Similarly, in Europe after the war, a modernist vision of 'towers in the park' took hold and became the model for isolated residential blocks in new towns. This standard became a self-justifying framework. As the blocks grew in size, the streets became larger and inhospitable to housing and pedestrian-oriented shops. This, then, created inward-looking, gated developments with shops relegated to remote centers. Home buyers in most sprawling areas are now used to gated housing blocks with large setbacks along pedestrian-hostile arterial roads, reinforcing the use of cars and the demise of street life.

## BENEFITS

### ECONOMIC

**Saves costs on infrastructure:** Based on planning and development costs studies, a 30 percent reduction in roadway infrastructure costs is realized due to savings from pavement, curbs, drainage, streetlights, and trees for dense urban networks in contrast to superblocks.[1]

**Decreases energy use:** Small blocks contribute to energy savings due to less travel demand by supporting increased use of non-motorized travel modes and transit.[2]

**Increases retail space:** Small blocks create more sidewalks, which naturally means more retail space for developers to sell.[3]

**Attracts talent:** Small blocks lay the foundation for interesting, vibrant places, which in turn can attract diverse human talent to the local workforce.[4]

**Increases flexibility in land development financing:** Developments can be financed in smaller phases, meaning less capital must be raised at any given time.[5]

### ENVIRONMENTAL

**Reduces energy used for travel:** Superblock residents use more energy to satisfy their transportation needs compared to residents of other types of neighborhoods.[6]

**Reduces congestion:** Small block urban networks decrease traffic delays by 25 percent because traffic flow is more efficient. For example, congestion and environmental damages have reduced Beijing's economic output by 7.5 percent to 15 percent.[7]

### SOCIAL

**Increases pedestrian accessibility and safety:** The elderly and children can more easily navigate areas with small blocks. A dense street network with short and frequent pedestrian crossings greatly enhances pedestrian safety and reduces jaywalking.

**Increases driver accessibility and safety:** Cities with small blocks are safer for drivers.[8] A dense street network can also add resilience to the transportation system by providing many alternative routes for ambulances and fire trucks in emergencies.[9]

**Enhances sense of community:** Small residential blocks with more defined space shared by fewer residents create a suitable social scale where everyone knows each other, thus nurturing a sense of belonging for the community.

**CASE STUDY**

# Pearl District, Portland, Oregon, USA

Portland's Pearl District went through an extraordinary redevelopment in the mid-1990s after a series of plans culminating in the River District Urban Renewal Plan of 1998. The existing rail yard became a successful, walkable, mixed-use neighborhood that is built on small blocks. In general, the development has blocks that are no more than 67 meters by 67 meters; 84 percent of these small blocks have complete sidewalks.[10] Retail fronts on many of the blocks improve the walking experience of these small blocks, which makes walking more interesting, increases economic vitality, and creates local business opportunities.

Another key lesson from the Pearl District is the benefit gained from putting small blocks and one-way couplets together. One-way couplets allow roads to be narrower, which improves the pedestrian's ability to walk across roads while also improving traffic flow. Most of the local streets in this area also have a speed limit of less than 32 kph. As a result, the planning of the Pearl District is successful because small blocks were implemented along with narrow roads, good walking spaces, traffic calming devices, active frontage, and mixed-use.

The district has continued to grow economically. By 2006, 51 percent of the households in the River District Area (3,769 units), which is primarily comprised of the Pearl District, had an income higher than the median family income, as compared to 24 percent of households in 1999 (787 units) and two percent in 1994 (27 units).[11]

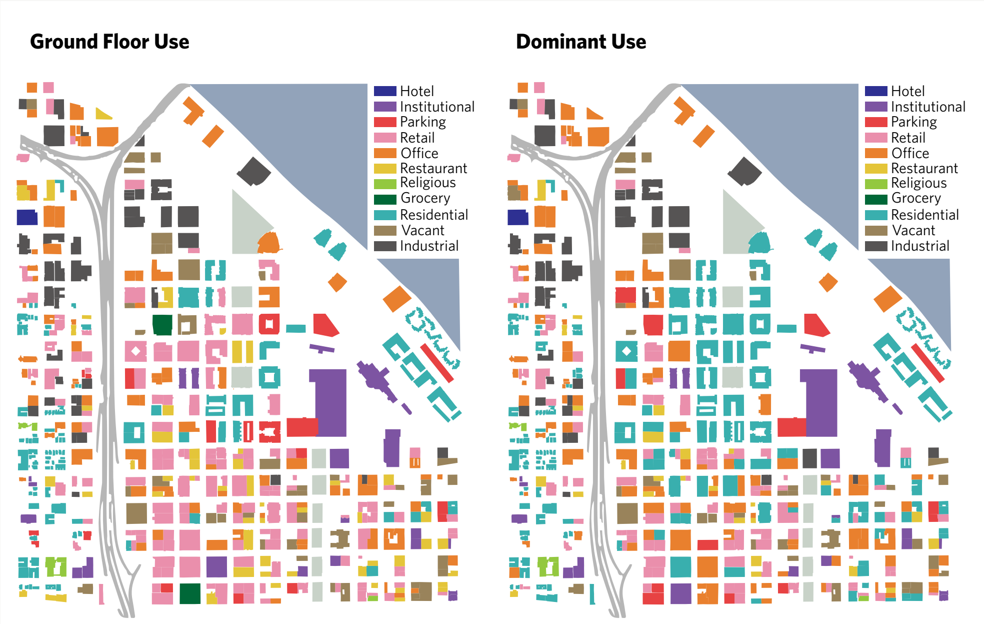



**Figure P6-4:** Predominant ground floor and building uses within each block in the Pearl District (Source: Portland Metro; www.portlandoregon.gov/transportation/article/306707)

**CASE STUDY**

# Jinan Urban Form and Travel Behavior Study

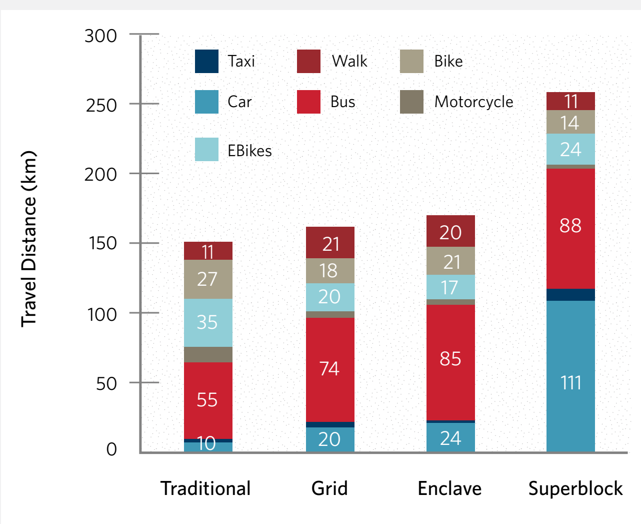
The travel mode impact of superblocks has been studied throughout the world. For example, in an extensive survey of travel behavior in Jinan, China, household transport energy uses were derived via weekly travel diaries. The analysis reveals that the superblock is associated with the highest per capita transportation energy use—two to five times as high as that of other neighborhood forms. (See Figure P6-2.) Comparing the mode share, there is also a large difference in car use between the superblock areas and the more traditional small block districts. In the superblocks, about 33 percent of trips are made by car, whereas the shares in other neighborhood types are lower than eight percent. Regarding walk trips, the shares in the traditional neighborhoods exceed 40 percent, much higher than walk shares in the superblock.

In summary, empirical analysis in the Jinan study confirms that superblock households consume more transportation energy than those living in other neighborhood types as they tend to travel longer distances and more likely by car. The same is true for gated subdivisions in developed countries. The analysis suggests neighborhood forms should move toward a combination of small blocks, mixed-use, and pedestrian-friendly street design.

| TYPOLOGY | TRADITIONAL (BEFORE 1920S) | GRID (1920-30S) | ENCLAVE (1980-90S) | SUPERBLOCKS (-2000S) |
|---|---|---|---|---|
| BUILDING/ STREET/ FUNCTION | 1-3 story courtyards; fractal /dendritic fabric off a main shopping street, on-site employment | Block structure with different building forms contained within each block, retail on connecting streets | Linear mid-rise walk-ups; housing integrated with communal facilities (kindergartens, clinic, restaurants, convenience shops, sports facilities, etc.) | Towers in park with homogeneous residential use |
| ACCESS/ PARKING | No cars | Easy access; cars on-street; some parking lots | Moderately gated (walls, fences and sometimes security guards at entries); Scarce on-courts parking lots | Completely gated; sufficient parking lots (underground, surface, etc.) |
| NEIGHBORHOOD CASES | 1. Zhang-Village | 2. Old Commercial District | 3. Wuying-Tan<br>4. Yanzi-Shan<br>5. Dong-Cang<br>6. Foshan-Yuan | 7. Shanghai-Garden<br>8. Sunshine 100<br>9. Lv-Jing |

**Figure P6-1:** Summary of form features across four main neighborhood typologies and nine neighborhood cases (Source: Yang Jiang)


**Figure P6-2:** Average household annual transportation energy consumption by development type (Source: Yang Jiang, "Does Energy Follow Urban Form? An Examination of Neighborhoods and Transport Energy Use in Jinan, China." Master theses, 2010, Massachusetts Institute of Technology)




Average households weekly travel distance (km)
across the four neighborhood typologies (Source: Yang Jiang)

**Figure P6-3:** Average households weekly travel distance (km) across the four neighborhood typologies (Source: Yang Jiang)

## GOAL 6A:
### Create human-scale blocks and streets

Small block zoning is an essential element of good urban design. In contrast to the superblock system, small blocks create a human-scaled environment and a fine-grained network of public space around the blocks, while also supporting a greater land-use mix in a smaller area. This generates multiple social, economic, and environmental advantages.

The social scale of small blocks are more convivial than superblocks. The typical small block should have dimensions of approximately 100 to 200 meters per side, making an area of one to two hectares. This area will result in 100 dwellings in low-density areas and up to 700 in high-rise environments, housing on average around 750 people. This number is small enough for most people to recognize one another and establish strong social connections. In contrast, superblocks easily contain 5,000 people, a scale at which many people become anonymous and children are more frequently exposed to strangers.

Another advantage of small blocks is their ability to mix uses at a walkable scale. The mixed-use quality can be achieved by combining different uses side by side. Rather than large commercial blocks isolated from local residential areas by massive arterials, small block zoning allows some separation of uses but with easy pedestrian access. Residential blocks can have small local corner shops while commercial blocks can create “main street” ground-floor shopping areas nearby. This provides a full range of services and shops with a lot of street life. In addition, small blocks naturally create a more varied skyline. In a small block, building heights change more frequently with orientation and placement. Each block can contain a variety of building configurations dependent on solar orientation and street frontage.

Overall, small block zoning creates development that is more varied and human-scaled while allowing smaller developers to participate in city building. Of course, multiple blocks can be combined to accommodate larger development plans. Multiple small blocks can be aggregated for sale to one large developer with the requirement that the local street network between the blocks is maintained as a public right-of-way.

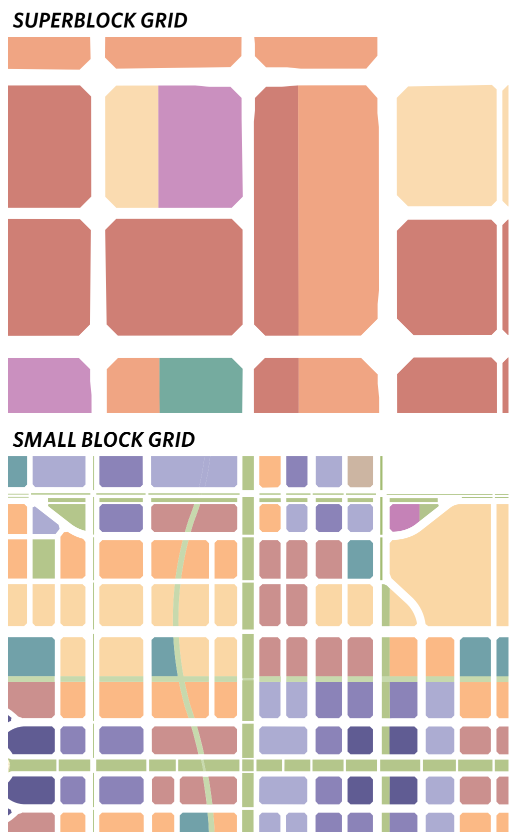



**Figure P6-5:** A superblock grid (top) is compared to an urban network of smaller blocks and narrow streets (bottom). Small blocks provide a human-scaled environment with greater variety in built form and more flexibility in planning land uses. (Source: HDR | Calthorpe)


**Figure P6-6:** Comparing superblock grids (before) versus an urban network of smaller blocks and narrower streets (after) in the master plans for Capital Steel, Beijing and Yuelai Eco-city, Chongqing (Source: HDR | Calthorpe)

**CASE STUDY**

# Small Blocks

**1. Mixed-use adds street-side retail where possible.** This can reinforce the pedestrian realm with easily accessible convenience activities and local shops. Lining the street with active uses and multiple entries add life and safety to the sidewalk.

**2. Mix building scales, configurations, and heights within each block.** Rather than repeating one or two identical building forms, a variety of building forms and heights adds to the identity of each place and provides more residential choices within one community.

**3. Respect southern orientation and solar access.** Even on small blocks, the vast majority of units can and should face south and building height can be adjusted to accommodate appropriate shadow setbacks.

**4. Develop private courtyard configurations.** By closing all sides of the blocks with retail and/or low-rise residential buildings, a semiprivate courtyard develops a distinct and useful identity. Transparent but secure fences can complete the block's perimeter.

**5. Carefully mixing high-rise and low-rise buildings can increase density.** Mixing building types and placing tall buildings on the south side of a block can significantly increase the development density per residential block from the norm. At the same time, human-scale is maintained through the placement of low-rise buildings.

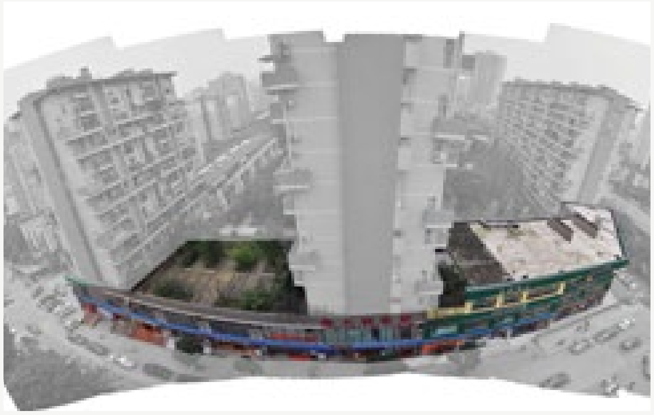


**Figure P6-7:** In Ren He Tian Di, Chongqing, a mid-rise residential small block, illustrates how street-side commercial anchors the project to its context while creating a lively pedestrian environment. (Source: HDR | Calthorpe)


**Figure P6-8:** Solar orientation and spacing standards can be achieved even in small blocks as illlustrated here. (Source: HDR | Calthorpe)

**ACTION 1:**

Develop blocks with perimeter buildings to provide shared interior courtyards and active sidewalks

With small block zoning, high quality design is key. Urban design controls that focus on creating lively and walkable street frontages are needed. Each small block has a central courtyard that is private in residential blocks and public in commercial blocks. This courtyard pattern recalls the city forms from the historic Mediterranean cities to the Chinese Hutong. In all cases, it provides the same urban layering, from public street to semi-public courtyard to private home. By closing all sides of the blocks with retail and/or residential buildings, the semi-private courtyard provides a distinct and communal identity. Transparent but secure fences can complete the block's perimeter.

The advantage of this configuration is that the common area is directly visible and accessible to all housing. In fact, in most cases all the units have a street view and a courtyard view along with cross-ventilation. This makes the common area more visible, safer and has more of a community focus. In the superblock configurations, many units are placed in parallel rows with no visual or direct connection to the larger common open space areas.

Finally, perimeter buildings in small blocks increase the opportunity for street-side shops and local services, which results in few dwelling units that have to be located on the ground floor, an undesirable living location for most even on the interior of a superblock. The ground floor naturally provides valuable commercial and civic opportunities that enhance the street life of the neighborhood. Amenities that contribute to a lively street atmosphere are needed to complete the design of an active block; benches, outdoor cafés, kiosks, and other street furniture that allow people to gather, relax and enjoy create street-life and stimulate local business. Street-level shops unify and activate the pedestrian environment while the floors above provide a balance of housing or jobs for the district.

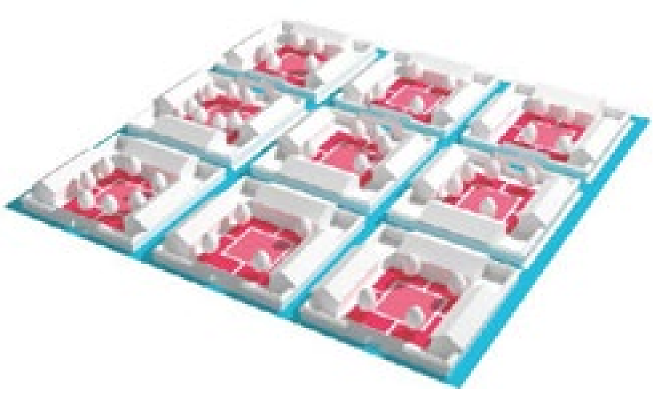


**Figure P6-9:** Traditional Chinese neighborhoods feature blocks with private interior courtyards. (Source: HDR | Calthorpe)

**Figure P6-10:** This traditional courtyard pattern can be reinterpreted at a scale that is more suitable to today's density requirements. (Source: HDR | Calthorpe)

**Figure P6-11:** Externally, small blocks create vibrant, human-scaled streets with ground floor shops and services that reinforce the pedestrian realm. (Source: HDR | Calthorpe)

**Figure P6-13:** Internally, small blocks provide a private space where residents can gather, relax, and play in a safe environment within close proximity to their homes. (Source: HDR | Calthorpe)

**Figure P6-12:** Rendered view of block with interior courtyard in a residential block. Courtyards provide the advantage of a shared space that is visible to all thereby improving overall safety. (Source: HDR | Calthorpe)

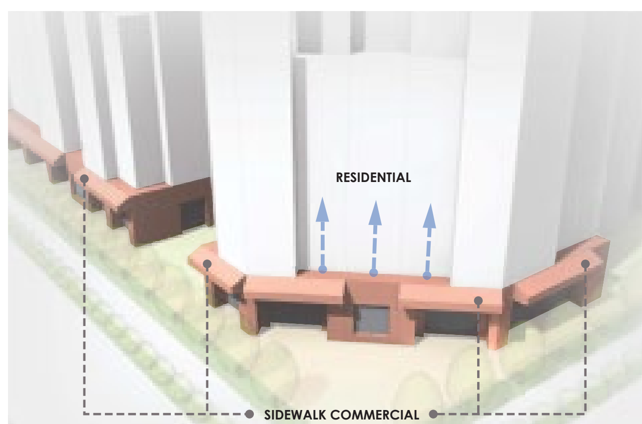



**Figure P6-14:** Providing street-side shops and local services at the ground level of residential blocks have multiple advantages, including eliminating the need for residential units at this undesirable location and strengthening the pedestrian experience. (Source: HDR | Calthorpe)

**ACTION 2:**
Re-shape existing superblocks and cul-de-sac subdivisions with pedestrian passages

It is possible to redesign existing superblocks by opening some interior roads and cul-de-sacs to slow traffic, pedestrians, and bikes. The example below shows typical superblocks with arterial streets in Chenggong, China compared to a more desirable urban network of smaller blocks and a dense network of narrower streets. Existing superblocks were made more human-scale and walkable by introducing auto-free streets to create more direct routes and improve pedestrian safety. Arterial-dominant superblock networks prioritize cars over people and impede pedestrian activity. A recommended urban network of smaller blocks prioritizes people over cars and supports pedestrian and economic activity.

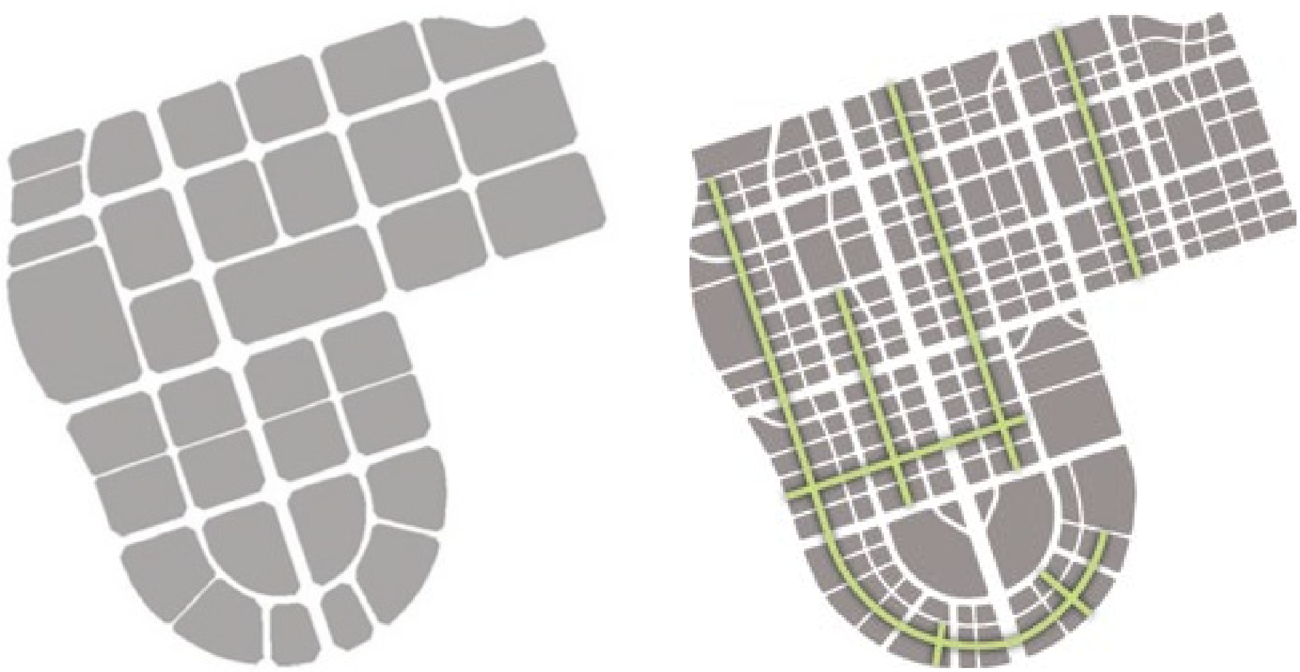


**Figure P6-15:** Existing superblocks are converted into small blocks by introducing interior roads and public passages (highlighted in green) in Chenggong, China. (Source: HDR | Calthorpe)

## GOAL 6B:
## Disperse traffic over narrow, parallel routes with a grid of varied street types

In order to develop more sustainable, low-carbon cities, a new circulation strategy that complements mixed-use developments is necessary. Such a network will balance the needs of pedestrians, bikes, transit, cars and trucks in a system of multi-modal rights of way. A grid that increases the number of through roads and thereby disperses traffic is key to the system. Foremost, the circulation system must encourage and support alternate modes to the auto by making transit ubiquitous, walking and biking safe and convenient, and bringing destinations closer to home and transit stations.

Once a reasonable mode share to autos is attained through land-use and design strategies, a more robust street grid has been shown to handle traffic more effectively than coarser arterial systems. For example, in Beijing, the superblock system has been incapable of handling the volumes of traffic that such a high-density city generates. Even with 8- and 10-lane arterials, congestion often results from delays at slow, complicated intersections and, given a lack of alternative routes, massive delays from accidents. In fact, the system generates its own debilitating feedback loop. The large street sections discourage pedestrian, biking, and transit mobility, which leads to more vehicle traffic and, therefore, wider streets. This results in an environment even more inhospitable to alternate travel modes. Note that a city or district level plan will employ both systems. The transition from one system to another is important and is illustrated below.

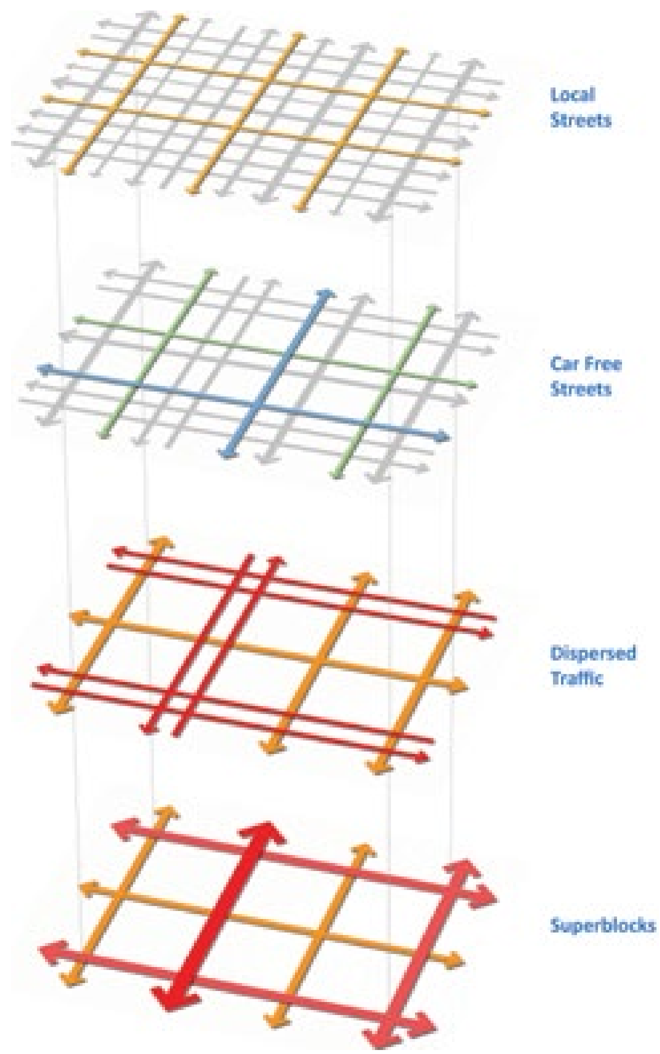



**Figure P6-16:** A superblock arterial network is converted into a denser grid of narrower streets and smaller blocks without compromising road lane capacity. (Source: HDR | Calthorpe)

**DEVELOPING AN URBAN NETWORK**

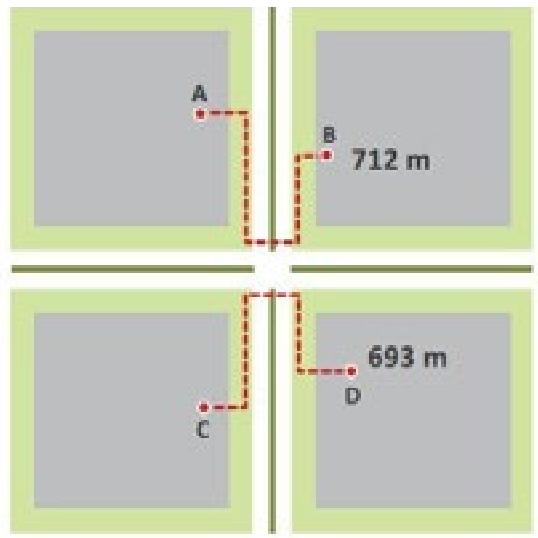
The 'urban network' is built out of a range of street types and produces a relatively small block pattern.

- Major through-traffic is handled with multiple minor arterials called 'avenues' of no more than 40m or 50m right-of-way width, or by pairs of one-way streets called 'couplets.'
- Special transit boulevards would provide space for dedicated-lane transit systems.
- Auto-free streets that accommodate bikeways, pedestrian shopping areas, and dedicated transit lanes complement the through-streets.
- Finally, a network of local streets providing local access to parcels with generous sidewalks completes the network.

The advantages of the urban network are as follows:

- The network disperses traffic over multiple routes reducing loads and pedestrian crossing dimension on most streets.
- It allows short trips more direct routes on local roads with mid-block left-turns into parcels.
- In case of blockage or emergency, traffic can be easily diverted to alternate routes.
- With more frequent intersections and shorter street crossings pedestrians have shorter, safer routes.
- Smaller street sections make transit systems more accessible to pedestrians.
- Smaller blocks provide for more adaptable urban forms, more flexibility of use, and opportunities for smaller developers.
- Emergency vehicles have multiple means of access to any destination.
- One-way couplets eliminate left-turn phases allowing signal synchronization and optimal traffic 'platooning.'

***Superblock Grid***




***Urban Network Grid***

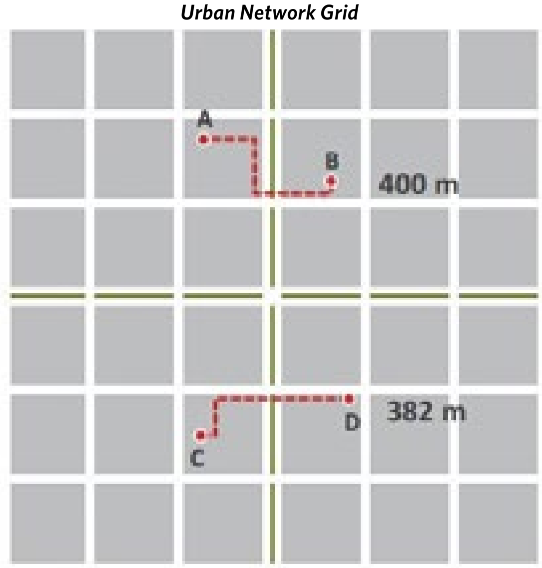
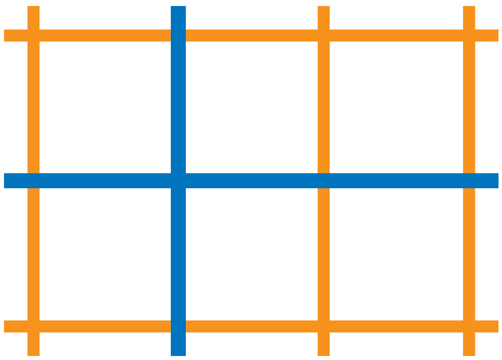



**Figure P6-17:** Urban network grids with small blocks allow for shorter trips with more direct routes on local roads. These diagrams show a comparison of pedestrian travel distance in a superblock grid (500 m) and an urban grid at the same scale. Lack of street permeability, fewer pedestrian crossings and wider intersection-crossing distances in a superblock result in the pedestrian having to walk almost twice the distance to get from one point to another in comparison to the urban grid. (Source: HDR | Calthorpe)





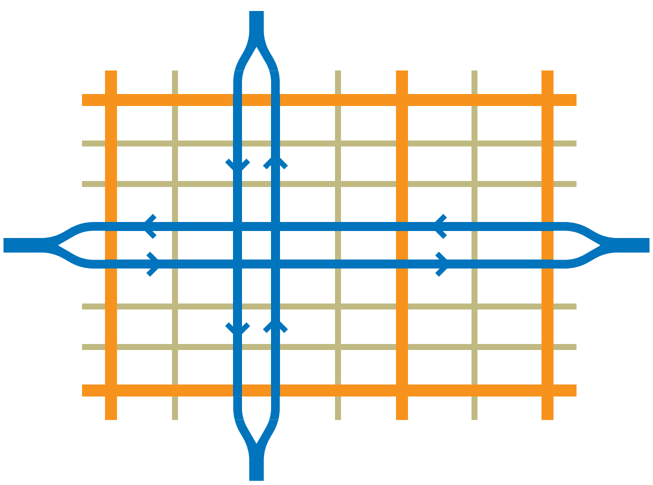




**Figure P6-18:** Process of transforming a superblock grid to a fine-grained urban network with couplets, instead of major arterials. The above comparison shows that the urban network provides more land capacity than the superblock system.(Source: HDR | Calthorpe)

The urban network requires narrow street sections that enhance pedestrian access. Narrow streets do not necessarily diminish network capacity as shown in Figure P6-23. The strategy to maintain through-traffic volumes is simple; a six-lane major arterial can be diverted to two three-lane one-way streets that actually have more capacity because they have the advantage of no intersection delays for left turn movements. Additionally, the six-lane arterial traffic could be accommodated by two four-lane minor arterials closely spaced. In the Urban Network system, major and secondary arterials are replaced by narrower 'couplets' and 'avenues'.

## ACTION 3:
Locate larger expressways and highways at the district edge

A city or district level plan will employ both urban network and the superblock systems. The urban network is appropriate for mixed-use and dense residential and commercial districts, while the superblock system is appropriate for large areas of manufacturing, industrial, warehousing or institutional use. Both systems must be supported by adequate expressways and highways that should be located at the district edge.

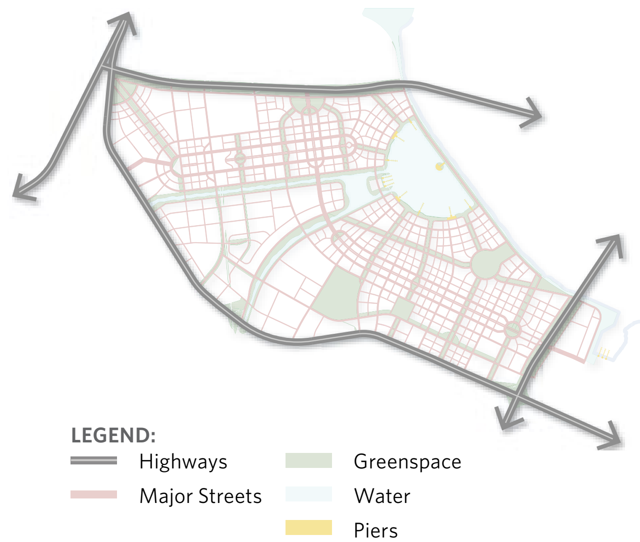



**Figure P6-19:** This diagram emphasizes the placement of major expressways and highways on the outer edge of the district in North TOD Plan for Zhuhai, China (Source: HDR | Calthorpe)

**Figure P6-20:** The major highway in Yuelai Eco-city, Chongqing is set at the edge of the development. (Source: HDR | Calthorpe)

**ACTION 4:**

Limit major through street widths by substituting with one-way street couplets

A key element of the Urban Network is the use of one-way streets in pairs to move high volumes of traffic without creating pedestrian barriers. These 'couplets' are typical in city centers throughout the world when suburban arterials and freeways enter urban grids. It is a traffic strategy that has been extensively tested and analyzed in many situations. The potential benefits of implementing one-way couplet streets and reduced block sizes in mixed-use developments or redevelopment areas are identified in a study described in the following pages. The intent is not to show that this street type should completely replace all arterial roadways. The results simply indicate that one-way couplets can achieve operational and safety benefits that make them a very viable alternative to the current development pattern of large roads and superblocks. The study includes a detailed description of one-way couplets and their general benefits as well as a computer-simulated operations analysis comparing conventional boulevards to couplets.

**Figure P6-21:** Original circulation diagram before the introduction of one-way couplet streets within the Yuelai Eco-City, China (Source: HDR | Calthorpe)

**Figure P6-22:** Circulation diagram after the introduction of one-way couplet streets within the Yuelai Eco-City, China (Source: HDR | Calthorpe)

## What are One-Way Couplets?

One-way couplets are parallel one-way roads with opposing traffic flow. Often inserted in a downtown street grid, each one-way street in the couplet is separated by a block length that varies from 100m to 200m. Although one-way couplets serve many different areas including higher-density commercial, mixed-use town centers, and residential uses, they are used primarily to improve traffic flow in densely developed areas. One-way couplets are widely regarded by transportation specialists as a proven solution benefitting pedestrians, bikes, transit as well as automobiles.

One-way couplets have been widely used in many cities in the United States and Canada including San Francisco, New York City, Vancouver, Toronto, Seattle, and Denver, as well as many cities in Europe and Asia. In China, couplets are used in Guangzhou and in Beijing near Olympic Park. Downtown San Francisco has more than a dozen pairs of one-way couplets, with two to four travel lanes in each direction along with on-street parking and bike lanes on one or both sides of the roadway. Typically, each lane serves 600 to 700 vehicles during peak hours. The relatively short block lengths create an attractive pedestrian environment while still adequately serving peak vehicle demand. As described later, shorter block lengths and more frequent traffic signals can be accommodated with the simpler signal operation at each intersection and signal coordination along corridors, only effective with couplets

Overall, a system of one-way couplets would result in:

- Improved traffic flow with less delay
- Smaller streets with increased walk and bike use
- Enhanced transit service
- A safer environment for all transportation modes
- More net land area available for development
- Reduced fuel consumption and greenhouse gas emissions

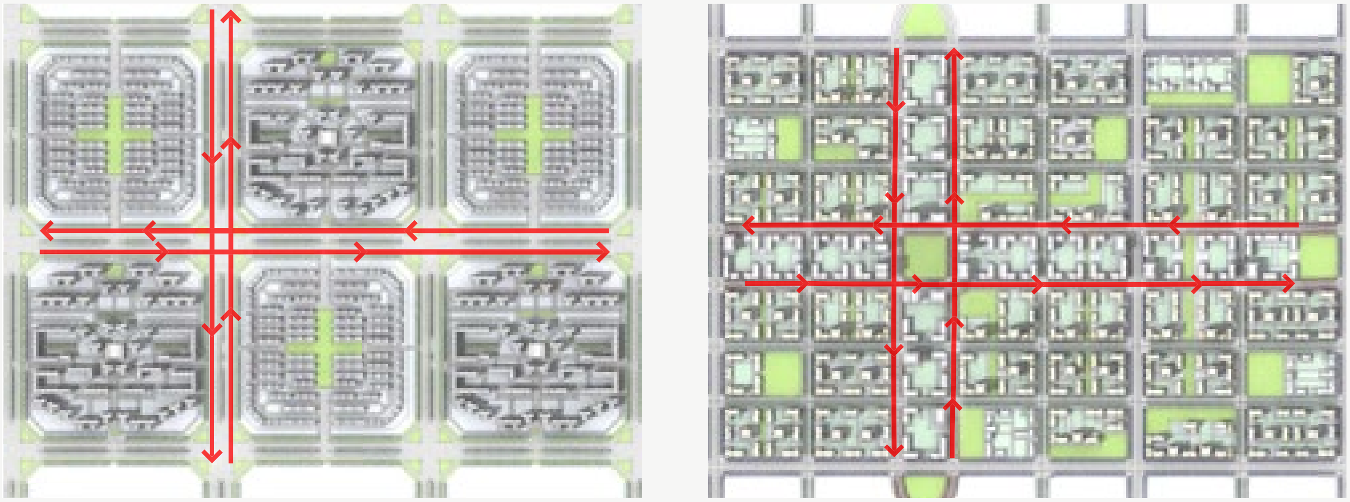


**Figure P6-23:** Comparison study of traffic operations in a typical superblock grid with conventional arterials (left) and an urban network with one-way couplets (right). Narrower one-way streets have fewer signal phases and reduce wait time at traffic lights, and also allow traffic signal coordination. (Source: HDR | Calthorpe)

## TRAFFIC BENEFITS

One-way couplets are designed to have higher intersection capacity than an equivalent two-way roadway due to fewer signal phases, less loss time between phases and more 'green' time for vehicle movements. Specifically, shorter crossing distances require less time for pedestrians and allow additional time for traffic to move unimpeded, which leads to better pedestrian compliance with the traffic control. Also, overall signal cycle lengths can be shorter resulting in less overall vehicle delay. The higher capacity results in better overall intersection operations and level of service (LOS). Even with high directional volumes, and most of the intersections along couplets operate at a level of service C or better during peak periods.

One-way couplets serve directional traffic and have fewer conflict points, which allows for improved signal coordination between adjacent intersections along the couplets, as well as on cross streets. In contrast, signal coordination for the conventional arterial or boulevard is more complicated by having to coordinate two directions of travel on the same street. In addition, more widely spaced intersections allow platoons to disperse and efficient signal coordination is more difficult to achieve.

The reduced number of conflict points with one-way couplets also reduces the potential for collisions between vehicles and bicyclists and pedestrians, thus improving overall traffic safety at intersections. Overall travel times to and from local land uses are reduced because access is more direct with implementation of a couplet system and shorter block lengths. In many cases, driveways to and from fronting uses can be accessed without crossing opposing traffic.

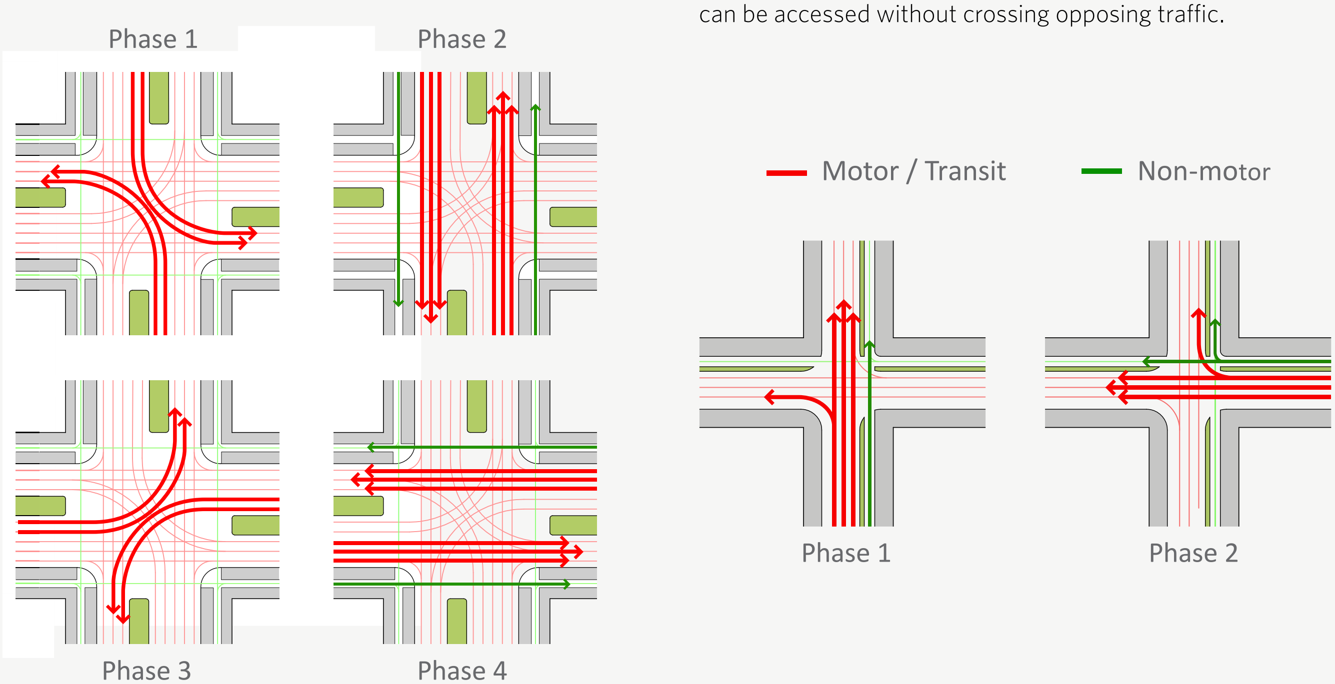



**Figure P6-24:** Comparison study of traffic operations at intersections in a superblock grid with conventional arterials (left) and an urban network with one-way couplets (right) (Source: HDR | Calthorpe)

## TRANSIT BENEFITS

Bus transit operations are also improved due to overall improved traffic flow along one-way couplets due to the increased roadway capacity. This consequently reduces delay for buses and improves reliability of transit services. With improved signal progression and reduced traffic congestion, the existing bus queuing problem at transit stops would be relieved. Also, shorter signal cycle lengths will facilitate bus services with high frequencies (with dispatching headways equal to or less than the cycle length) and improved headway regularity. In addition, the improved walking and biking environment, and enhanced connectivity between land uses in an urban network, increases the transit catchment area and potentially increases overall transit ridership and mode share.

## PEDESTRIAN AND BIKE BENEFITS

One-way couplets are designed to have narrower roadway cross-sections with fewer travel lanes and consequently shorter crosswalks for pedestrians. Compared to an equivalent two-way roadway, the required pedestrian clearance time for one-way couplet intersections is shorter by at least 50 percent. With traffic likely to be dispersed to parallel roadways in the grid-like urban network, one-way couplets have lower number of turning vehicles at each location. This creates a safer environment for pedestrian and bike users to cross streets at intersections. In addition, if the pedestrian and bike activity is significant, a protected pedestrian/bike phase could be provided without causing significant delays to turning traffic. With shorter block lengths and improved signal progression, traffic on one-way couplets can be maintained at reasonable travel speeds. This provides a more pedestrian- and bicycle-friendly setting and enhances safety for all roadway users. The shorter blocks that are possible with couplets and signal progression also reduce the distance for pedestrians to walk in order to reach signal-protected crossing locations. This can reduce the tendency for pedestrians to cross at unsafe mid-block locations.

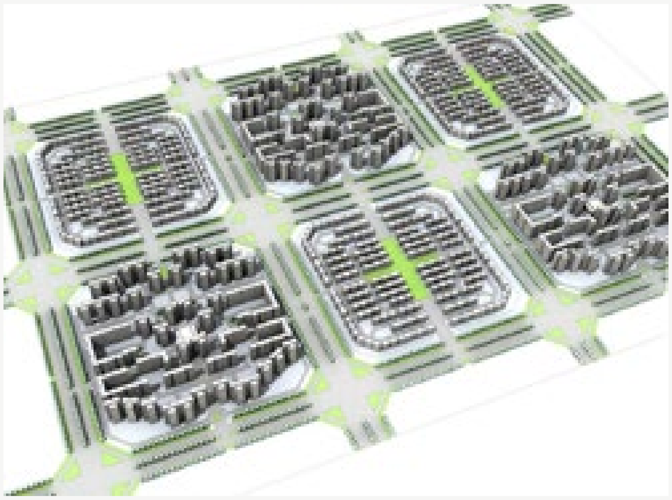


**Figure P6-25:** Typical building massing within a superblock system (left) and an urban grid network (right). Couplets are most effective when block lengths are short. (Source: HDR | Calthorpe)

## URBAN DESIGN BENEFITS

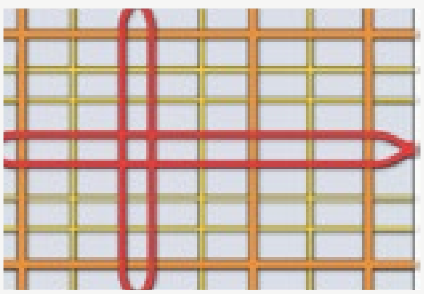
HDR | Calthorpe performed a right-of-way (ROW) area comparison between the superblock and couplet with grid systems (Figure P6-26). The superblock calculation assumes that there would be some internal circulation roadways to provide access within the superblock area. Their analysis shows that the couplet system would require less ROW for roads (66ha versus 85ha) than the superblock system for the same study area when local access roads within a typical superblock are included.

### SCENARIO 1.1

| Travel from A to B | *Superblock Grid* | *Urban Network* |
|---|---|---|
| Number of turns | 4 | 3 |
| Travel distance within study area | 2,400 m | 1,400 m |
| Length of travel on arterial streets | 2,400 m | 850 m |

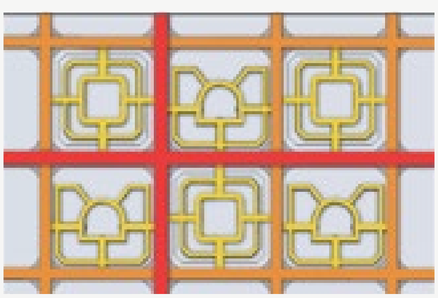
### SCENARIO 1.2

| Travel from A to B | *Superblock Grid* | *Urban Network* |
|---|---|---|
| Number of turns | 2 *(Including U-Turn)* | 1 |
| Travel distance within study area | 1,350 m | 900 m |
| Length of travel on arterial streets | 1,350 m | 100 m |



**Urban Network with One-way Couplets**

Arterial ROWs = 20 Ha   Boulevard ROWs = 26 Ha
Local Street ROWs = 20 Ha   TOTAL = 66 Ha



**Superblock with Conventional Arterials**

Arterial ROWs = 24 Ha   Boulevard ROWs = 32 Ha
Local Street ROWs = 29 Ha   TOTAL = 85 Ha

**Figure P6-26:** Comparison of the area used for streets in a superblock and an urban network

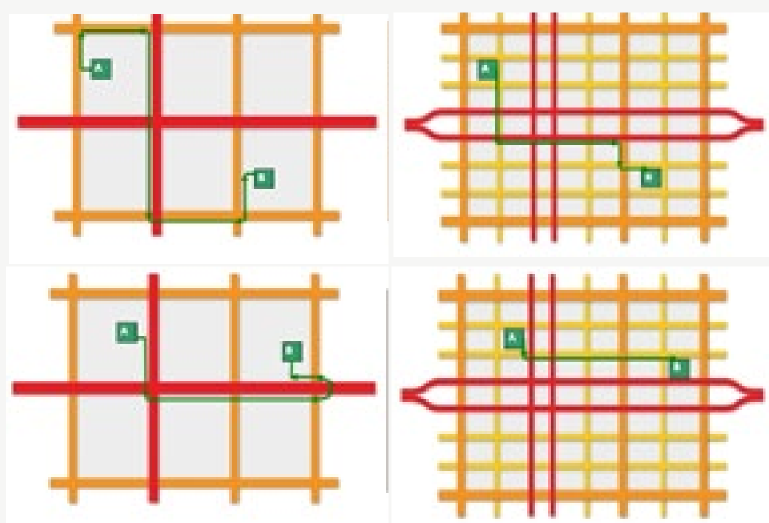


**Figure P6-27:** Travel distance comparison between conventional arterials and one-way couplets. Note: For superblocks, it is assumed that only right-turn-in/out is allowed for driveways along arterials.

## VEHICLE TRAVEL DISTANCE EVALUATION

Other issues to consider and compare between the two roadway configurations include the difference in travel distance and number of turns required to travel between various points within the overall network. The concept of the one-way couplets and its support of a highly connected urban roadway network is known to reduce, rather than increase, vehicle miles traveled and travel times. Compared to the superblock system, destinations are better accessed by more parallel streets in the highly connected grid system so drivers can drive shorter routes.

Fehr and Peers compared the shortest travel distances between the superblock and couplet systems for four different origin-destination (O-D) pairs, which are shown in Figure P6-28. As shown in three out of the four cases, the shortest travel distance in the couplets system is 150 to 1,000 meters shorter than the superblock system. For the case that the couplets system requires a longer travel distance, the difference is only 150 meters. Although traveling on the couplets is approximately eight percent greater in distance (150m / 1,850m) in this one case, the travel time along the couplets corridor is estimated to be approximately 10 to 15 percent less than the superblock system.

Compared to the superblock system, the one-way couplets system would provide more opportunities for drivers to choose and change alternative travel routes; however, this does not necessarily result in more turns. As shown in the four figures in Figure P6-28, the number of turns under the couplets system is less than the superblock system for two out of the four O-D pairs and is same as the superblock system for one O-D pair. For the last O-D pair, the couplets system would include one more turn than the superblock system. In this case, a driver may have to make one or two additional turns but they would be low-conflict turns and entail shorter travel distance and travel time than would be the case with attempting to make U-turns at widely-spaced, high-volume, and high-conflict intersections in the conventional superblock network configuration.

**SCENARIO 2.1**

| Travel from A to B | *Superblock Grid* | *Urban Network* |
|---|---|---|
| Number of turns | 2 | 2 |
| Travel distance within study area | 1,800 m | 1,650 m |
| Length of travel on arterial streets | 1,800 m | 1,250 m |

**SCENARIO 2.2**

| Travel from A to B | *Superblock Grid* | *Urban Network* |
|---|---|---|
| Number of turns | 1 (U-Turn) | 2 |
| Travel distance within study area | 1,850 m | 2,000 m |
| Length of travel on arterial streets | 1,850 m | 1,900 m |

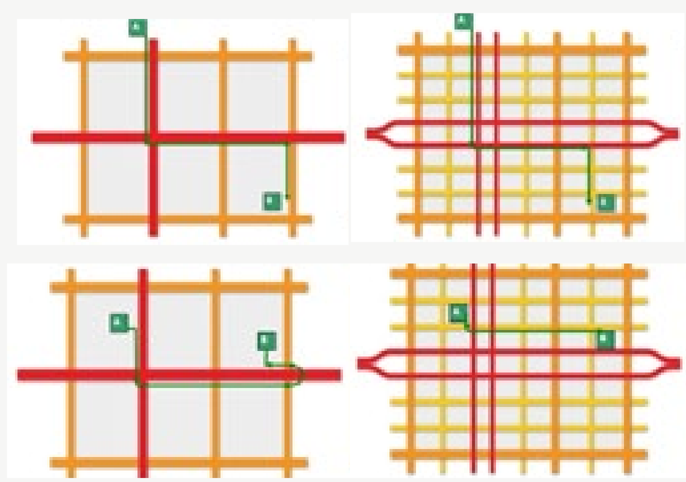


**Figure P6-28:** Travel distance omparison between superblocks and couplets.

## GOAL 6C:
### Establish car-free corridors that accommodate dedicated and connected biking and walking paths, which may include transit lanes

Unsafe biking and walking environments discourage non-motorized transit. Protected lanes for bikes and comfortable sidewalks must be incorporated into every major street. In addition, a certain number of auto free streets must allow for exclusive walking and biking. These auto-free streets are unique in that they not only allow a mix of pedestrian and bikes but can incorporate transit systems such as BRT where needed. Auto-free streets that incorporate transit—'Transit Boulevards'—should have clear separations for bikes, pedestrians, and transit. Such auto-free corridors should be established across the city grid at regular intervals to provide a seamless network. This network can supplement the non-motor lanes provided in the regular streets and should connect all important employment, civic, recreational and transit nodes. Integrating bike and walking paths with public transit is one of the hallmarks of a successful transit system.

**Figure P6-29:** Chenggong Auto-free Network will supplement the non-motor lanes provided in the regular streets; and connect all important employment, civic and recreational nodes. The network includes auto-free streets, trails and easements within open spaces, as well as a new Transit Boulevard aligned with the high speed rail station. (Source: HDR | Calthorpe)

**Figure P6-30:** A car-free streetscape concept that provides dedicated bike lanes and safe sidewalks, while also allowing dedicated lanes for public transportation. Well-designed landscaping and tree lines enhance the walking and biking experience. (Source: HDR | Calthorpe)

**ACTION 5:**
Auto-free streets should provide shopping and services at the building ground level

Auto-free streets can easily become vital shopping streets, either for local shops and destinations in residential areas or as a pedestrian walk of a commercial area lined with regional retail. It is important that, when possible, these pedestrian-only commercial shopping streets be directly connected to transit stations and the surrounding street networks rather than parking lots. This ensures the synergy found in enhancing the commercial viability of the retail and providing convenient services to those going to or from transit.

**Figure P6-31:** A rendered image of an auto-free street in the Zhuhai North TOD study area. The auto-free street runs through the heart of the urban core and is lined with high density mixed-use development that provides a thriving retail environment at the ground-level. (Source: HDR | Calthorpe)

**ACTION 6:**
## Connect auto-free streets to trails and paths within major open spaces

Where possible, auto-free streets should connect directly to trails and bikeways within major open space elements of a community. The trails within regional parks, riverfronts, linear parks, and community buffer areas should connect directly to the auto-free street network. They can also serve as greenway connections, providing a major bike and pedestrian route to key destinations. In special cases, they can be used in steep areas, employing escalators and stairways to provide direct access where cars cannot go.

**Figure P6-32:** Dedicated bike and pedestrian paths connect the Regional Plan for Jinan's development to its open space systems. (Source: HDR | Calthorpe)

**Figure P6-33:** Rendering depicting bike and pedestrians paths connecting the city to the open spaces in the Regional Plan for Jinan, China (Source: HDR | Calthorpe)

## METRIC 6.1:
### Block Size

Ensure that at least 70 percent of blocks in residential areas are 1.5 hectares or less and commercial blocks in non-industrial areas are 3 hectares or less

Small blocks not only create a denser street network that enhance the pedestrian realm, but they also have social benefits. They provide a more livable environment by creating a social scale that strengthens interactions and improves security. To ensure that the advantages of the small block zoning is achieved, it is important that, at a minimum, 70 percent of blocks in residential areas are 1.5 hectares or less and that 70 percent of commercial blocks in non-industrial areas are three hectares or less.

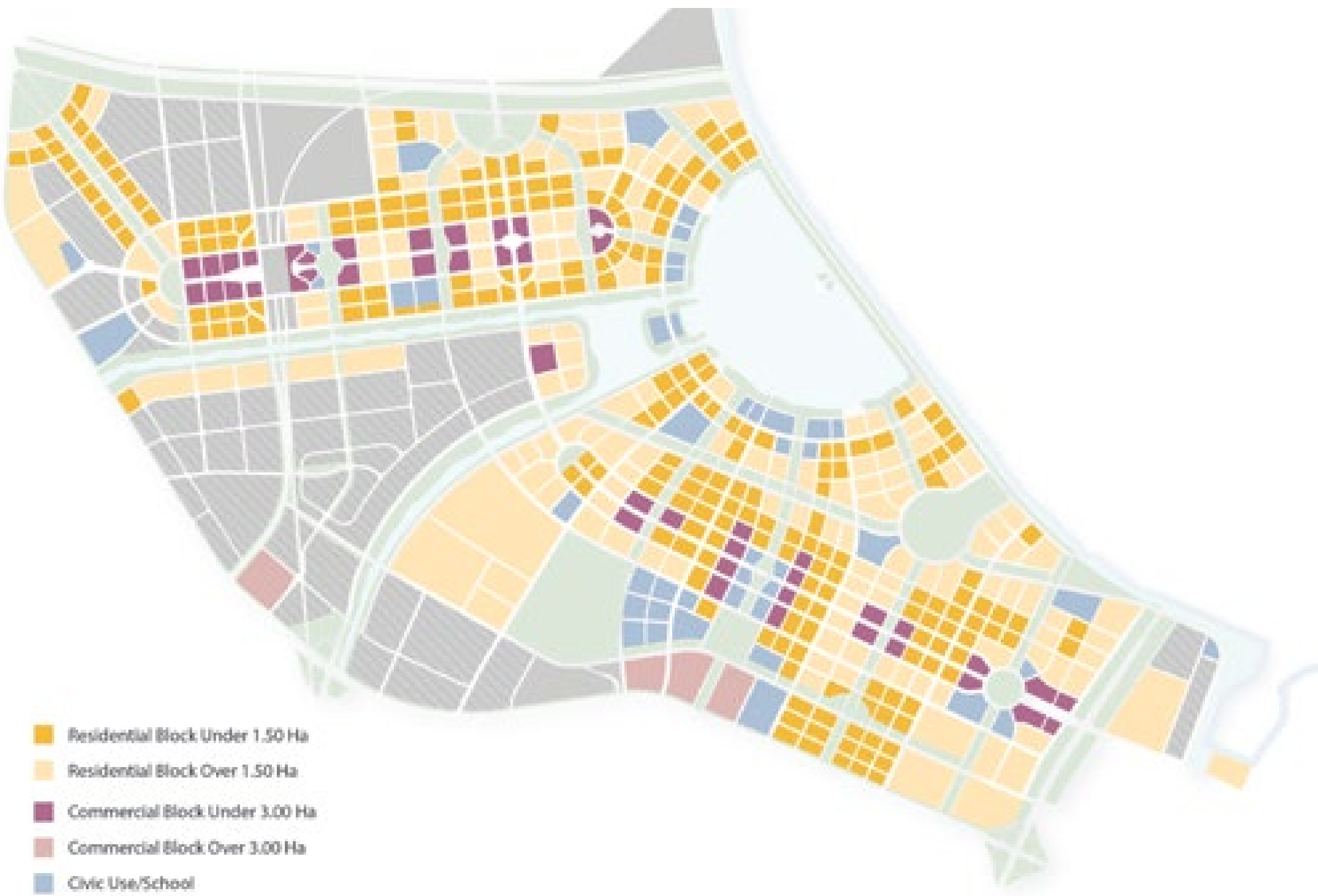



**Figure P6-34:** This map of North TOD Plan, Zhuhai separates blocks into categories by area. Blocks shaded in dark yellow are residential blocks under 1.5 hectares, light yellow are above 1.5 hectares, dark purple are commercial blocks under 3.0 hectares, and light purple are over 3.0 hectares; 74 percent of all residential blocks are under 1.5 hectares while 92 percent of all commercial blocks are under 3.0 hectares. (Source: HDR | Calthorpe)

## METRIC 6.2:
### Setbacks

Decrease setbacks to a maximum of 1 meter for retail, 3 meters for commercial, and 5 meters for residential

In order to maintain a consistent and active street edge, buildings must be placed close to the sidewalk, with setbacks based on ground floor use. Setting maximum setbacks instead of minimum setbacks makes small blocks work optimally. Decreased setbacks promote the connection between the building and the public sphere as represented by the sidewalk. They also increase the building floor space that developers can sell.

The stipulated setbacks that buildings must be placed based on their ground-floor use are:

- Maximum: one meter for retail
- Maximum: three meters for commercial
- Maximum: five meters for residential

It is assumed that a five-meter setback will provide privacy to ground-floor residential uses; anything less than three meters is appropriate for non-residential ground-floor uses. The setback shall be measured from the property line.

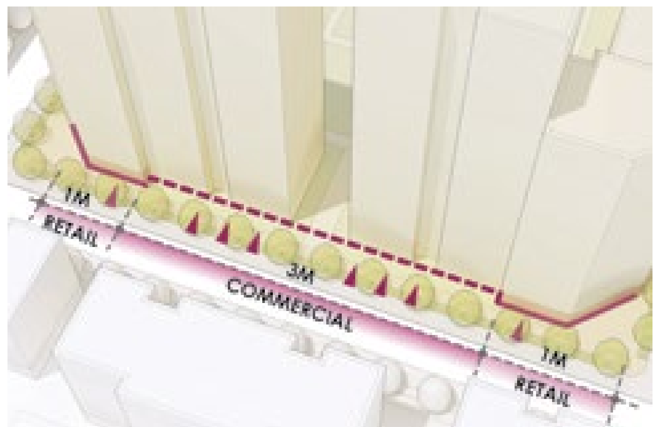



**Figure P6-35:** Illustration showing one meter maximum setback for retail buildings and three meter for commercial buildings from property line. (Source: HDR | Calthorpe)

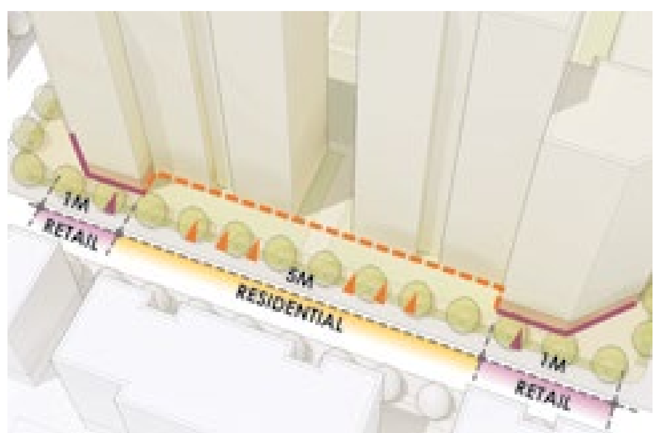



**Figure P6-36:** Illustration showing five meter maximum setback for residential buildings from property line. (Source: HDR | Calthorpe)

## METRIC 6.3:
### Street Size

No street should be more than 40 meters wide in non-industrial districts

It has been demonstrated that small blocks achieve urban design and circulation goals. Equally important is designing streets that are pedestrian-friendly and human-scaled. Wide streets create longer pedestrian crossings which result in lengthy delays compared to those that would be required for a narrower street. Narrow streets enhance pedestrian safety and comfort and achieve the desired goals. No street in non-industrial areas should be more than 40 meters with the exception of highways or major throughways at the edge of an urban district.

**Figure P6-37:** The City of Des Moines, Iowa is reenvisioning its downtown Market District through master plan concepts that mix residential, commercial, retail and civic land uses, while prioritizing better mobility for pedestrians and bikes through human-scaled urban design. (Source: HDR)

## METRIC 6.4:
### Auto-Free Streets

Create auto-free streets for any combination of pedestrian, bike, or transit at an average spacing of 1km

Auto-free streets should form a network connecting to transit stations, community amenities, parks, and local destinations so people can use them not only for recreation but also for other daily commuting needs. To achieve an efficient network, any combination of auto-free streets (pedestrian, bike, or transit) should be provided at an average interval of one kilometer across the city grid.

**Figure P6-38:** The auto-free street network within the North TOD plan for Zhuhai, China incorporates public transit, bike lanes, pedestrian streets, open green space and water, and ecological systems. Streets are spaced less than one kilometer apart. (Source: HDR | Calthorpe)

**Figure P6-39:** Zhuhau's North TOD plan features a network of auto-free streets that form a fundamental element of the open space and transit structure of the development. (Source: HDR | Calthorpe)

**CASE STUDY**

# Singapore

**Population:** 5,453,600 [20]
**2030 Forecast:** 6,900,000 [21]
**Size:** 728.6 km² [22]

## "CAR-LITE" SINGAPORE: ROBUST PEDESTRIAN NETWORKS AND CAR-FREE TOWN CENTERS

Considered one of the most sustainable and livable cities in Asia, Singapore is creating urban design guidelines for pedestrian-friendly neighborhoods and car-lite city centers within high-density contexts. As part of the Sustainable Singapore Blueprint and the Singapore Green Plan 2030, the city-state is investing in a robust pedestrian network and car-free city centers to reduce the nation's reliance on cars.

Singapore's Urban Redevelopment Authority (URA) guidelines encourage the provision of through-block pedestrian links within developments to improve ground-floor permeability (the ease with which pedestrians can move throughout an urban form) and pedestrian-level connectivity throughout Singapore. Through-block links enable pedestrians to move through buildings and blocks via publicly available paths, connecting one public space to another. In utilizing through-block links rather than requiring pedestrians to navigate the perimeter of large blocks, Singapore creates safer and more direct, continuous foot paths, scaling large blocks down to accommodate pedestrians.

These links are implemented through a set of planning parameters and urban design guidelines used to assess new development proposals. They are incentivized by exempting linkages from Singapore's gross floor area calculations if the links comply with the Urban Redevelopment Authority's requirements. These requirements include good practices such as a minimum path width of four meters, use of ramps to cover floor level changes, remaining open to public use, clear signage, and the linkage of two parcels of public areas such as roads, promenades, and open space.[23]

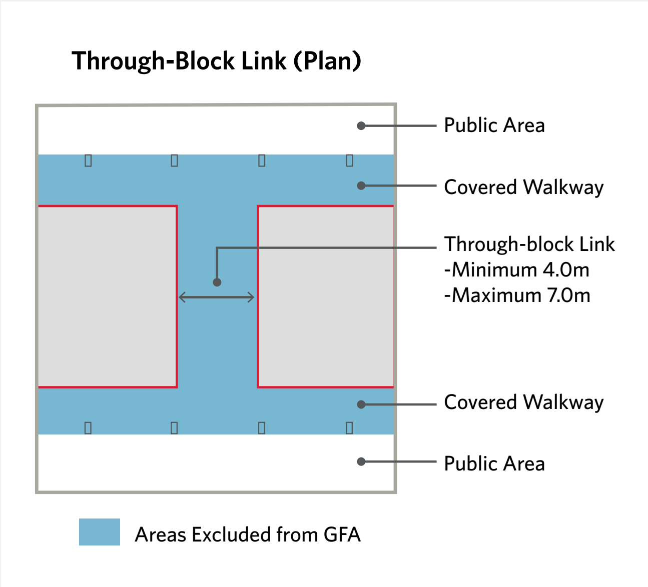



**Figure P6-40:** Singapore's through-block link plan (Data source: Urban Redevelopment Authority)

Through-block links are a part of Singapore's greater vision for a pedestrian-friendly city center with reduced car usage. As a small and extremely dense island city state, efficient use of space downtown in important. Links are complemented by covered walkways, second-story pedestrian linkages, and laneways between buildings that are all aimed at supporting connectivity throughout Singapore's comprehensive pedestrian network. To support sustainability, Singapore is hoping to make walking, cycling, and riding public transport a way of life while limiting car usage in urban centers through congestion pricing, a strict permitting system, and the gradual implementation of car-free downtowns.

As part of their greater vision for a car-lite Singapore, the URA has converted numerous roads into car-free pedestrian areas and walkways in the civic district, the birthplace of modern Singapore. Home to historically significant buildings including the former Supreme Court and Old Parliament House, the civic district has been transformed into a pedestrian-friendly center featuring car-free roads, open space, lush landscaping, power plug-ins, and a new children's playground. This extension of pedestrian space now connects the district's arts institutions in a park-like setting. To further motivate transitioning to car-free roads, URA piloted "car-free Sundays" in the area around the civic district and central business


**Figure P6-41:** Through-block link in Singapore connecting to MRT (Source: Khalzuri Yazid, CC BY-SA 2.0, www.flickr.com/photos/khalzuri/4058184065) district, closing streets to vehicular traffic on the last Sunday morning of every month. This allowed cyclists, walkers, and joggers to enjoy the roads and connect with the adjacent open spaces that are programmed with fitness events and family friendly activities.

Singapore's Housing and Development Board went beyond simply converting roads to pedestrian paths for its new Tengah Park District, the nation's first "car-free" town. Expected to house 42,000 new homes upon its completion, the district will feature roads that run beneath the town center, freeing the ground level for a pedestrian-scaled community.[24] Tengah Park District is planned to be oriented around a network of parks and greenways with direct links to retail, recreation, and the MRT. The vision behind this unique district is creating a community that is highly connected to nature, encouraging residents to pursue a healthier lifestyle.

**Figure P6-42:** Singapore's Civic district has been transformed into a pedestrian-friendly center with beautifully landscaped open space. (Source: Williamcho, Dreamstime.com)

**CASE STUDY**

## Hammarby Sjöstad District, Stockholm, Sweden

**Population:** 975,345 [12]
**2030 forecast:** 1,757,000 [13]
**Size:** 381.63 $km^2$ [14]

### HAMMARBY SJÖSTAD ECOLOGICAL DISTRICT

Built as a demonstration of sustainable development on a former industrial waterfront brownfield, Hammarby Sjöstad is a 200-hectare district that houses approximately 20,000 people in 9,000 housing units and offers 200,000 square meters of commercial space that provide jobs for 10,000 people.[15] Educational, cultural, and recreational spaces are also part of the programming. Hammarby Sjostad is the first Eco-City District in Stockholm.

The district is highly connected, with a dedicated tram line and free ferry service connecting to downtown accommodating 52 percent public transit mode share.[16] Low parking standards, and dedicated spaces for car-sharing services help diminish car usage. These mechanisms include approximately 0.15 on-street parking spaces per household, and 0.55 spaces per household in public or private garages. Non-vehicular mode share accounts for 27 percent of journeys, enabled by a beautiful network of walkways, green paths and plazas and bike lanes that cross through the entire district.[17] The city made sure the Hammarby public transit line was operational before residents moved in to ensure that they began with green commuting habits.

The transit-oriented approach informed a pedestrian-oriented street design, featuring blocks that average 100 by 80 meters. A typical block covers an area of 7,500$m^2$, with a building footprint of 3,500$m^2$. Density is 76 dwelling units per acre with a FAR of 2.82 over an average of six floors. The blocks are dual sided—one frontage contains retail and public uses on the transit corridor, while the other frontage turns to a walkable, green corridor that also functions as green infrastructure, filtering stormwater and forming a gradual slope protecting against storm surge and flooding in extreme weather. A pedestrian-only mid-block passage leads through the semi-private courtyards, offering the option of secluded, quiet shortcuts. Some of the blocks are angled to create variability, places for interaction, and space for tree canopy to increase privacy on higher floors. The irregularity also breaks wind flow that sometimes discourages people from walking in the harsh Swedish winter. Many of the blocks do not surround a full perimeter, but leave the backside more perforated, increasing views to waterfront from front-facing apartments, while creating open access to inner courtyards from the green walking route.

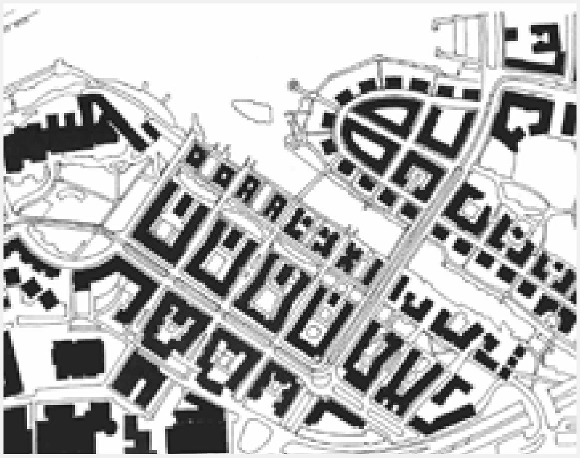


**Figure P6-43:** Hammarby Sjöstad figure ground (Source: John Ellis)

**Figure P6-44:** Water canal and floodable plazas (Source: Design for Health/Flickr, CC BY 2.0, https://www.flickr.com/photos/designforhealth/6359946395

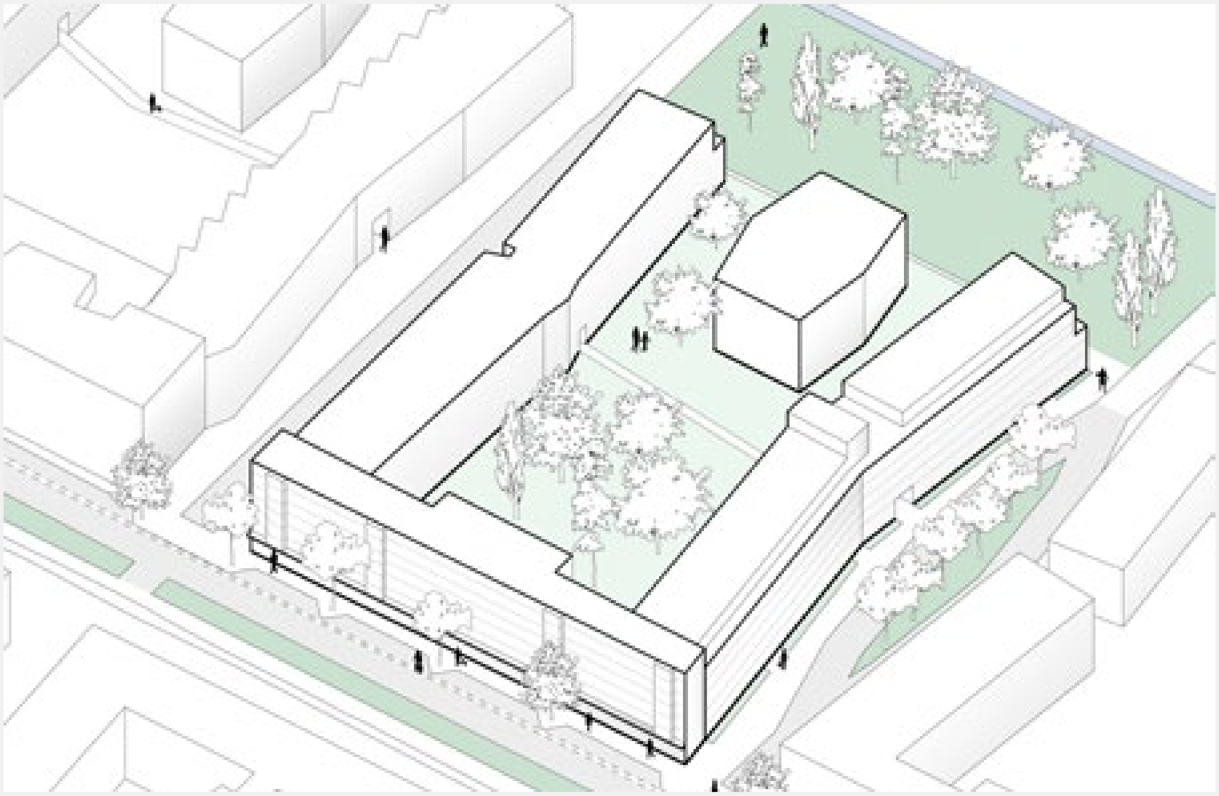


**Figure P6-45:** Parallel routes: transit and shops on main road, blue-green walkway in the back and a narrow mid-block pedestrian path through courtyards (Source: Robert Ungar)

**CASE STUDY**

# Lima, Peru

**Population:** 9,751,717[18]
**2030 forecast:** 12,221,000[19]
**Size:** 2,672 km²

## INFORMAL INCREMENTAL DEVELOPMENT IN PAMPA DE COMAS

Peru's sprawling capital city is home to nearly one-third of the country's population, a result of mass migration from rural areas over the past decades. Many of the newcomers settled in what is commonly called asentamientos humanos (human settlements), informally occupied and self-built by their inhabitants. In most cases, over time, people turn shacks into homes, services and infrastructure are gradually introduced, and eventually the local government titles the land to its inhabitants.

A noteworthy example of this is El Carmen, a neighborhood in the Comas District on the Andean slopes northeast of central Lima. In the 1960s, the district was planned by groups of newcomers, usually organized around religious representatives. They came together to prepare for an organized occupation of the land around a clear, agreed set of spatial rules. With the help of local civil engineering students, the site was surveyed and a block pattern grid was laid out with 20 lots measuring 10 by 20 meters each (200 $m^2$ per family) and 10-meter roads between them. Space for future community facilities—education, market, or park—was reserved in the form of empty blocks.

Unlike many informal settlements that are usually characterized by extreme density, narrow streets, and lack of public space for infrastructure or community services, the small block pattern in Comas leaves 27 percent of the land to streets, and an additional three percent to open space. Sufficient space for streets and high connectivity are two major factors identified in a UN-Habitat report on the state of global streets. These factors contribute to the prosperity of cities by supporting productivity, infrastructure development, environmental sustainability, quality of life, and social inclusion.

Similar to other informal settlements in the city, occupiers started with a shack, accumulated material for a perimeter three-meter wall, and gradually built their home from the outside in. The wide streets enable an incremental integration of infrastructure such as electricity, sewage, roads, sidewalks and streetlights. The organized grid and uniform lot size helped form a social and economic equality among residents. Today, Comas is a walkable middle-class neighborhood that has become well incorporated into the formal city faster than other settlements.

**Figure P6-46:** Informally developed, El Carmen in the Comas District is well integrated in the city fabric today. (Source: Google Earth)

## ENDNOTES


1 Institute for Transportation and Development Policy. "Unpublished Analysis with Details Available upon Request.," 2014.

2 Energy Foundation. Design Manual for Low-Carbon Development, 2011. http://www.chinastc.org/sites/default/files/CSCP_LowCarbonDevelopmentDesignManual_EN.pdf.

3 Interview with Chinese developer from Energy Foundation, September 2014.

4 Florida, Richard. Startup City: The Urban Shift in Venture Capital and High Technology. Martin Prosperity Institute, University of Toronto, 2014.

5 Interview with Chinese developer from Energy Foundation, September 2014.

6 Energy Foundation. Design Manual for Low-Carbon Development, 2011. http://www.chinastc.org/ sites/default/files/CSCP_LowCarbonDevelopmentDesignManual_EN.pdf.

7 Creutzig, F, and D He. Climate Change Mitigation and Co-Benefits of Feasible Transport Demand Policies in Beijing. Vol. 14, 2009.

8 Marshall, Wesley, and Norman Garrick. "Street Network Types and Road Safety: A Study of 24 California Cities." Urban Design International, August 2009. http://www.sacog.org/complete-streets/ toolkit/files/docs/Garrick percent20& percent20Marshall_Street percent20Network percent20Types percent20and percent20Road percent20 Safety.pdf.

9 Center for Urban Transportation Research. "Pedestrian Safety at Midblock Locations," September 2006. http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_PL/FDOT_ BD544_16_rpt.pdf.

10 Levenda, A., and C. Huang. "The Pearl District an urban development case study of the Pearl District and Brewery Blocks in Portland." Oregon, CDCB, Portland Oregon (2015).

11 Portland Development Commission. Portland: River District housing implementation strategy annual report (2005). Portland Development Commission, 2005.

12 "Population by Region, Population Changes, Sex and Month". Statistics Sweden, September 2021. Accessed October 28, 2021. https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BE__BE0101__BE0101G/ManadBefStatRegion/table/tableViewLayout1/.

13 United Nations. Department of Economic & Social Affairs. "The World's Cities in 2016 Data Booklet". 2016. p.10-26.

14 Statistics Sweden. "Localities 2010, area, population and density in localities 2005 and 2010 and change in area and population". 29 May 2012. Accessed December 5, 2018.

15 "Hammarby SJÖSTAD, Stockholm, Sweden." Urban Green-Blue Grids for Sustainable and Resilient Cities. Atelier GroenBlauw. Accessed October 21, 2021. https://www.urbangreenbluegrids.com/projects/hammarby-sjostad-stockholm-sweden.

16 Grontmij, A. B., and Karolina Brick. "Report Summary—Follow Up of Environmental Impact in Hammarby Sjöstad: Sickla Udde, Sickla Kaj, Lugnet and Proppen." Retrieved February 18 (2008): 2012.

17 Ibid.

18 "Lima Population 2021 (Demographics, Maps, Graphs)". World Population Review, 2021. Accessed October 10, 2021. https://worldpopulationreview.com/world-cities/lima-population.

19 Ibid.

20 Singstat. "Population and Population Structure". Department of Statistics Singapore. Accessed 5 August 2021. https://www.singstat.gov.sg/find-data/search-by-theme/population/population-and-population-structure/latest-data.

21 "Does the Government have a population target, e.g. 10 million?" gov.sg, July 1, 2020. https://www.gov.sg/article/does-the-government-have-a-population-target#:~:text=At percent20that percent20update percent2C percent20the percent20Government,below percent206.9 percent20million percent20by percent202030.

22 SIngstat. "Environment" Department of Statistics Singapore. Accessed 5 August 2021. https://www.singstat.gov.sg/find-data/search-by-theme/society/environment/latest-data.

23 "Gross Floor Area: Covered Walkway and Linkages".Urban Redevelopment Authority. Updated October 5, 2020. https://www.ura.gov.sg/Corporate/Guidelines/Development-Control/gross-floor-area/GFA/CoveredWalkwayandLinkages.

24 "About Us: Tengah". Housing & Development Board. Accessed October 20, 2021. https://www.hdb.gov.sg/cs/infoweb/about-us/history/hdb-towns-your-home/tengah.