TECHNICAL REPORT

CONFERENCE EDITION

CHONGQING 2035

URBAN GROWTH SCENARIOS

WORLD BANK GROUP

Global Platform for Sustainable Cities

ENERGY FOUNDATION

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CHONGQING 2035: Urban Growth Scenarios

Technical Report

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Executive Summary

Dependent on planning and policy, urban growth in Chongqing may take vastly different forms, with varying implications for economic development, livability, social inclusiveness, and environmental sustainability. What will be the effects of continuing past land development trends of urban sprawl and fragmentation? Or by contrast, what if Chongqing prioritizes a more focused, coordinated development strategy? Which patterns can better support the clustering of economic activities necessary to attract and spur more diversified growth?

The Chongqing 2035 scenario study compares the modeled outcomes of two different development paths, as represented by land use scenarios for projected growth of 5.8 million new urban residents and 4 million new jobs. A "**Trend" scenario** continues past patterns of land development, characterized by continued centralization of high-level employment around the existing downtown core, and expansive superblock, office park, and industrial development throughout the central city area. For comparison, a **"Compact Growth**" scenario posits a polycentric regional structure created through focused, walkable, mixed use development around existing and planned transit nodes. While other possibilities exist on the spectrum between and around these two alternative futures, they embody the principal development choices facing Chongqing as it looks ahead, serving to highlight the range of benefits and consequences that can be expected.

Urban development patterns have substantial effects on laying the foundation for progress in climate mitigation and environmental sustainability. While policies that address the technological aspects of vehicle efficiency, building performance, and energy supply also play roles in conserving resources and reducing emissions, the impacts of land use on either increasing or reducing demand highlight the role of strategic development as a fundamental step.

The technical report describes the scenarios and their implications for Chongqing and its residents, and the methodology behind the RapidFire model as adapted for use in the city. Examining the comprehensive effects of growth on **a range of performance indicators** – including **land consumption, transportation mode share and auto travel, infrastructure costs, energy use, and emissions** – has shown how greatly Chongqing's potential urban development patterns vary in their ability to support its growth as a global, sustainable city.

Study Context

With a population of nearly 34 million and an area of 824,000 km^2, Chongqing municipality is one of the biggest cities in the world. Located in the southwest of inland China, it is strategically positioned as a gateway to China's west, a key connection in the Yangtze River Economic Belt, and a strategic base for China's Belt and Road Initiative. Administratively, it is equivalent to Beijing, Shanghai, and Tianjin in its status as a provisional city that reports directly to the central government.

In two decades, Chongqing has made an extraordinary transformation – growing its GDP per capita by 16 times between 1996 and 2016, and seeing its urban population rise from 29.5 percent to 62.6 percent. The city's formerly agricultural and heavy industry-based economy is now more economically balanced, with the secondary and tertiary sectors contributing to 44.2 percent and 48.4 percent of GDP, respectively. Today's Chongqing is the largest automobile and motorcycle manufacturing base in China and produces one-third of the world's laptops and 90% of the world's IT network terminals.

Chongqing's growth in the past 20 years reflects China's own development trajectory. As China enters a new growth era, however, it has moved away from pursuing GDP growth targets and is instead focusing on a model of development that emphasizes sustainability and a high quality of growth. Cities like Chongqing are a critical part of China's new engine for growth, offering an opportunity for a new modality of urban development that aims for quality, equality, and sustainability.

In line with the central government's strategic two-stage development plan for China, the city's leadership has set an ambitious goal of making Chongqing a global city within the next 15 to 20 years. It is within this context that the World Bank has directed this effort to explore the impacts of land use and development decisions on advancing or impeding the city's progress.

Figure 1. Chongqing municipality is located in the southwest of inland China

Central City Study Area

The scenario study examines urban growth options for the "**central city**" area of Chongqing municipality, which encompasses the nine districts including and surrounding the Yuzhong District, the historic city center of Chongqing. It is depicted by the orange and red areas in Figure 2. The areas beyond the central city include a wider ring of 12 districts intended for primarily industrial growth (depicted in yellow) and two "wings" intended for conservation (depicted in blue and green).

With an area of approximately 5,500 km^2 and an urban population of 7.4 million, the central city itself functions as an interconnected metropolitan area, the geographic extent and transportation infrastructure of which are comparable to other metropolitan "regions." The outlying areas of Chongqing municipality will also see growth and are subject to the challenges posed by dispersed development patterns. Although the scenario study does not explicitly address growth in these other areas, it is understood that the broader regional economic context will have a bearing on development in the central city area, and vice versa. While it is beyond the scope of this study to forecast Chongqing's economic progression, the land use scenarios are compatible with a range of potential futures.

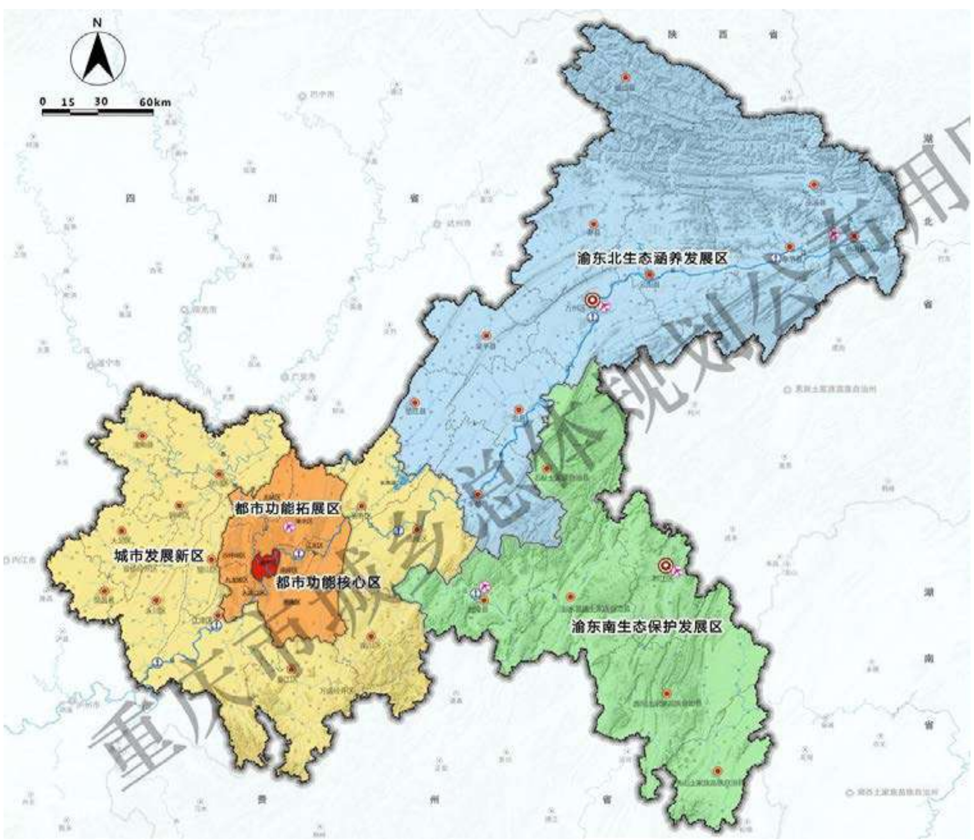


Figure 2. Functional zones within Chongqing municipality. The study for this report covers the areas in red and orange.

Development Location

For the purposes of scenario definition and analysis, the central city was divided into three subareas (as illustrated in Figure 3). The subareas – the Core, Core-Adjacent, and Extension areas – were identified based on the extent of Chongqing's existing development and its mountainous topography. The Core corresponds to the highly built-up urban center of Chongqing; the Core-Adjacent areas adjoin the Core and are bounded by the ridgelines to the east and west; and the Extension areas lie beyond. These locational designations are meaningful for conceptualizing the spatial structure of the central city and the relative balance or imbalance of jobs and housing in different areas. The subareas are also associated with variations in the urban form and resulting performance characteristics of the place types that comprise the scenarios.

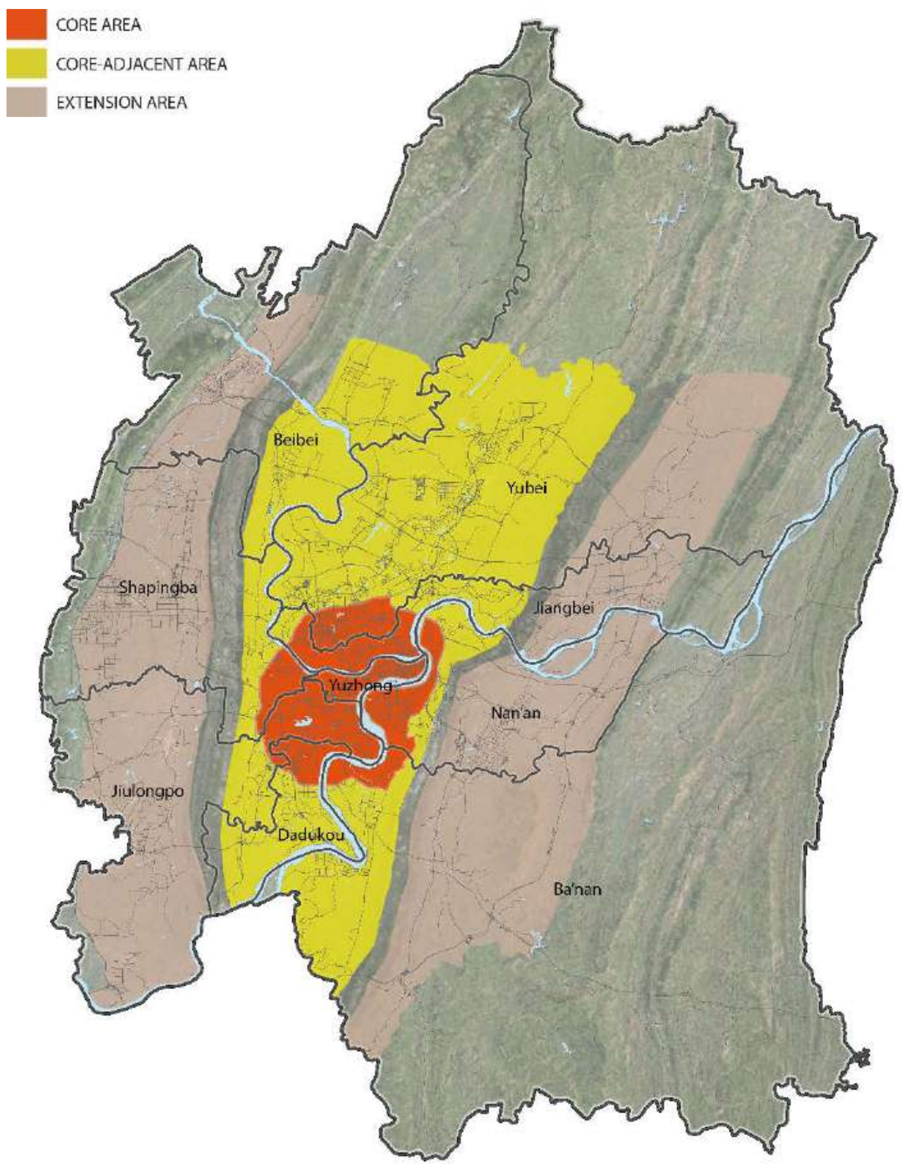


Figure 3. The Chongqing central city study area, with location designations and district boundaries

Superblocks vs. Walkable Development

The differences between superblock development and compact, walkable, mixed-use development are at the heart of the differences between the scenarios and their impacts. Superblock development has been dominant throughout China, and in Chongqing, over the past two decades. Characterized by single-use zoning that separates residential and commercial areas, and large blocks served by wide arterial streets, superblocks are oriented foremost to autos rather than pedestrians. This development configuration has led to Chongqing's growing fragmentation, vast expansion, and decreasing densities.

By contrast, walkable development features small blocks served by dense street networks that enhance walking, biking, and traffic flow. Scaled to the pedestrian and with a mix of jobs, housing, and services, this form of development supports active communities. These characteristics make for what can be termed people-oriented development, or POD – a concept that aligns with China's 2016 urban development guidelines. Near transit, walkable development can be considered transit-oriented development, or TOD.

Both patterns – superblock and walkable development – are represented throughout Chongqing today. Walkable development is not a new concept, but rather represents a return to more traditional neighborhood design principles. Superblock development, however, has been the de facto norm for new development, with evident consequences. The scenario study analyzes the impacts of these growth patterns on land consumption, transportation behavior and emissions, energy use, infrastructure provision and costs, and livability for residents and workers.

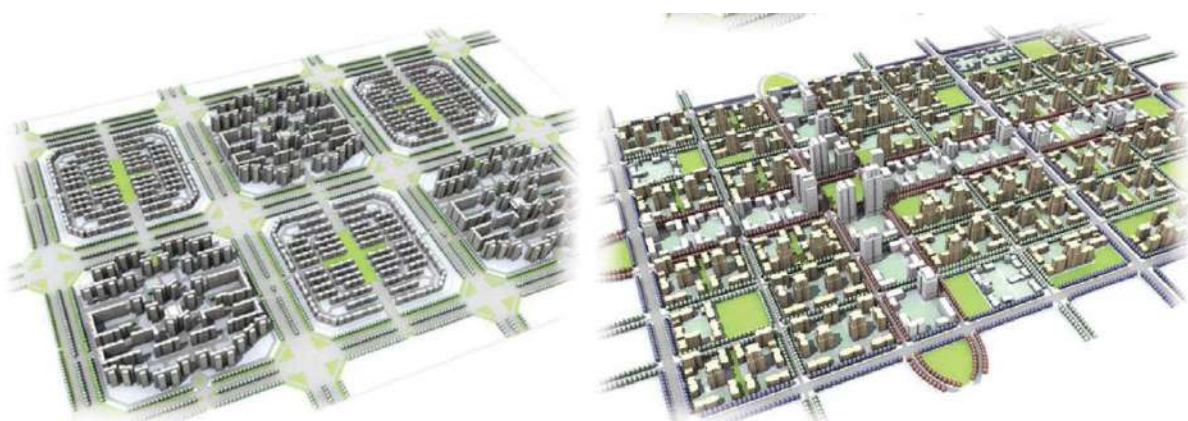


Figure 4. Illustrative diagrams depicting the urban form of superblocks (left) and walkable development (right). The diagrams are at the same scale.

Figure 5. Superblock development (left) and transit service in a walkable development pattern (right)

RapidFire Scenario Modeling

The RapidFire model depicts existing development and new growth in terms of "place types." **The framework of place types represents development according to the dimensions of location; proximity to high-capacity, fixed-alignment transit; and urban form**. Scenario analysis is based on the **built form characteristics of the place types (such as building floor area ratios and resulting densities), and their related assumptions for travel behavior, building performance, and infrastructure requirements.**

The locational designations for Chongqing include the previously described Core, Core-Adjacent, and Extension subareas. There are two transit proximity conditions: within 800 m walking distance of a metro station, and not. And lastly, there are the two primary urban form types: walkable mixed-use and superblock single use, which are each further differentiated into three subtypes based on predominant use. Combining these three variables of location, transit, and urban form yields a legible schema of 36 types, as shown in Figure 6 and listed in Table 1. Figure 7 shows a sample place type summary description from the full report. With minor variations, the schema of place types developed for the Chongqing scenarios can be applicable for use throughout China.

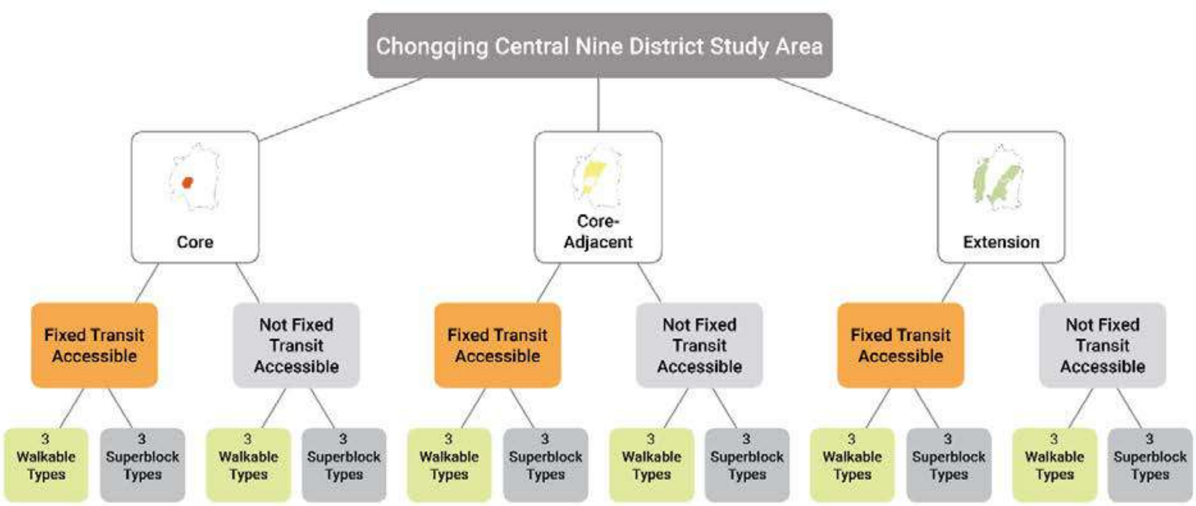


Figure 6. Chongqing place types schema diagram

Table 1. List of Chongqing place types

Subarea	**Transit Proximity**	**Place Type Code**	**Urban Form**
Core *Infill/ Redevelopment*	Transit Oriented (walkable development within 800 meters of structured transit)	1A	Walkable Commercial Mix
		1B	Walkable High Density Residential Mix
		1C	Walkable Medium Density Residential Mix
	Transit Adjacent (non-walkable development within 800 meters of structured transit)	1D	Superblock Commercial Mix
		1E	Superblock Residential Mix
		1F	Superblock Industrial
	No transit	2A	Walkable Commercial Mix
		2B	Walkable High Density Residential Mix
		2C	Walkable Medium Density Residential Mix
	No transit	2D	Superblock Commercial Mix
		2E	Superblock Residential Mix
		2F	Superblock Industrial
Core-Adjacent Greenfield	Transit Oriented	3A	Walkable Commercial Mix
		3B	Walkable High Density Residential Mix
		3C	Walkable Medium Density Residential Mix
	Transit Adjacent	3D	Superblock Commercial Mix
		3E	Superblock Residential Mix
		3F	Superblock Industrial
	No transit	4A	Walkable Commercial Mix
		4B	Walkable High Density Residential Mix
		4C	Walkable Medium Density Residential Mix
	No transit	4D	Superblock Commercial Mix
		4E	Superblock Residential Mix
		4F	Superblock Industrial
Extension Greenfield	Transit Oriented	5A	Walkable Commercial Mix
		5B	Walkable High Density Residential Mix
		5C	Walkable Medium Density Residential Mix
	Transit Adjacent	5D	Superblock Commercial Mix
		5E	Superblock Residential Mix
		5F	Superblock Industrial
	No transit	6A	Walkable Commercial Mix
		6B	Walkable Residential Mix
		6C	Walkable Medium Density Residential Mix
	No transit	6D	Superblock Commercial Mix
		6E	Superblock Residential Mix
		6F	Superblock Industrial

Walkable Commercial Mix *with Transit* (Place Types 1A, 3A, 5A)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	2.0	1.5	1.5
Employment	5.0	4.0	2.5
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	200	140	140
Employees	1,200	550	360
Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily commercial areas of urban mixed-use centers, with the highest densities in the Core, slightly lower densities in the Core-Adjacent, and lower densities in the Extension areas. High concentrations of office, retail, and civic employment. Mid- to high-rise buildings oriented to street, easily accessible and with minimal setbacks, create walkable environments. Grid or otherwise small-block street pattern. Parking limited to on-street supply, with some structured and underground parking. Accessible by regional metro transit, attracting commute and other trips from throughout the region.

Local example: Guanyinqiao. Total FAR: 3.9 / Population density: 280 / Employment density: 1,710

Figure 7. Key place type characteristics include floor area ratio, densities, and employment mix, as shown in this sample place type summary description. (Descriptions for all types are included in the full report.)

Two Scenarios for Urban Growth

The Chongqing 2035 land use scenarios were created using a top-down approach that asserts the location, form, and magnitude of new growth via allocations of new urban population, housing, and jobs to place types. Both scenarios account for the same amount of growth – 5.8 million people and 4 million jobs – roughly constituting a 78% increase over current population and jobs in the central city. Whether this long-range growth projection is realized by 2035 or at some point before or after, assessing the potential forms of growth and its ensuing impacts is an imperative for planning and policy development in the near term.

The scenarios represent sharply divergent land use patterns. **The Trend scenario represents the future as an extension of the past, with more isolated land uses in superblock configurations spreading outward from the Core.** It stands as a "status quo" representation of the kind of development that will take place by default if regional policy development, coordination, or implementation efforts fall short.

The Compact Growth scenario is driven by a need to contain urban expansion and grow as a much more compact city. Compared to the rate of development in Chongqing municipality from 2005 to 2015, during which the average rate of additional land consumption per new inhabitant was 139 m^2, the Compact Growth scenario consumes less than half as much land.[1] Focusing growth in

[1] Note that the measurement of land per new resident varies depending on the definition of developed land and whether it refers to built-up area or urbanized extent, and whether the measurement is inclusive of parks, reserved open spaces, and other special use areas. In the context of the scenario study, new land consumption is assumed to be inclusive of "net" developed parcel area, plus "gross" areas that include park areas, civic areas, and rights-of-way in typical proportions.

walkable, mixed-use centers largely accessible by transit makes best use of available land capacity and maximizes the investments made in transit infrastructure.

The scenarios also vary significantly in where new housing and job growth occurs. The Trend scenario continues to locate new jobs in the Core, reflecting a monocentric employment focus for higher-level services employment. Meanwhile, housing is allowed to grow in the Core-Adjacent and distant Extension areas, creating a jobs/housing imbalance that will lead to long in-commutes and inefficiencies of infrastructure provision.

By contrast, the Compact Growth scenario represents a polycentric urban structure that adds fewer jobs to the Core and instead steers them to the Core-Adjacent area to anchor new mixed-use TOD centers. Fostering the growth of employment clusters outside the existing Core area – largely in the Core-Adjacent area – will help Chongqing achieve better local jobs/housing balance, alleviating the negative impacts and inefficiencies of a monocentric pattern. Accordingly, the Compact Growth scenario also locates the majority of new housing in the Core-Adjacent area and limits the amount of housing in the Extension areas.

Table 3 summarizes the key variations between the scenarios, contrasting their growth allocations to the three subareas and their development characteristics. As different as they are, both scenarios are illustrative of what can conceivably occur depending on political direction and varying degrees of coordination in planning, strategic policy making, and implementation.

Table 2. Summary of scenario characteristics

Scenario Characteristic	Trend	Compact Growth
Population growth and distribution by subarea	5.8 million urban population, located by area as follows: Core: 10% Core-Adjacent: 45% Extension: 45%	5.8 million urban population, located by area as follows: Core: 10% Core-Adjacent: 80% Extension: 10%
Job growth and distribution by subarea	4 million jobs, located by area as follows: Core: 25% Core-Adjacent: 45% Extension: 30%	4 million jobs, located by area as follows: Core: 5% Core-Adjacent: 80% Extension: 15%
Population density	Lower: 11,100 residents/km2 on average	Higher: 13,300 residents/km2 on average
Job density	Higher in Core, lower in Core-Adjacent and Extension Areas	Lower in Core, higher in Core-Adjacent and Extension Areas
Jobs/population ratio	Regional average 0.7 jobs per capita, though less balanced locally than in the Compact Growth scenario. Perpetuates pattern of greater concentration of jobs in the Core.	Regional average 0.7 jobs per capita, more balanced locally than in the Compact Growth scenario. Locates employment in mixed-use areas outside the Core.
Job growth by sector	50% Industrial 50% Tertiary and above	34% Industrial 66% Tertiary and above
Development pattern	Primarily superblock development throughout the region, including near transit.	Primarily small-block, walkable POD development throughout the region, with higher intensities near transit.
Land development	Infill and redevelopment in the Core continue, while superblock development in the Core-Adjacent and Extension areas perpetuate expansive, fragmented development and high land consumption.	Infill and redevelopment in the Core and compact, focused development in the Core-Adjacent and Extension areas contain greenfield expansion.

Key Scenario Results

The scenarios were analyzed for their performance on a range of indicators tied to the city's goals to become more environmentally sustainable, economically competitive, socially inclusive, and culturally rich. Scenario metrics include measurements of urban form as asserted through the composition of the scenarios, and the resulting outputs for land consumption, auto vehicle kilometers traveled, travel mode share, travel time, auto pollutant emissions, building energy use and emissions, infrastructure costs, and household driving and utilities costs. The results show how distinctly the Trend and Compact Growth development patterns vary in their ability to help or hinder Chongqing as it grows.

To isolate the impacts of land use, the scenarios were analyzed assuming baseline factors for vehicle performance, energy efficiency, and fuel and energy emissions. The uptake of improved technologies into the future would reduce fuel use, energy use, and emissions even further.

Urban Form

The plans and patterns represented by the scenarios contribute to substantially different spatial structures for the central city that will determine how people move around, how efficiently economic activity is supported, and how livable the region will be. **Differences in urban form and the relative location of housing and jobs are the basis for all performance variations between the scenarios.** The Trend scenario locates most new homes and jobs in superblocks, while the Compact Growth scenario locates most in walkable place types of varying densities.

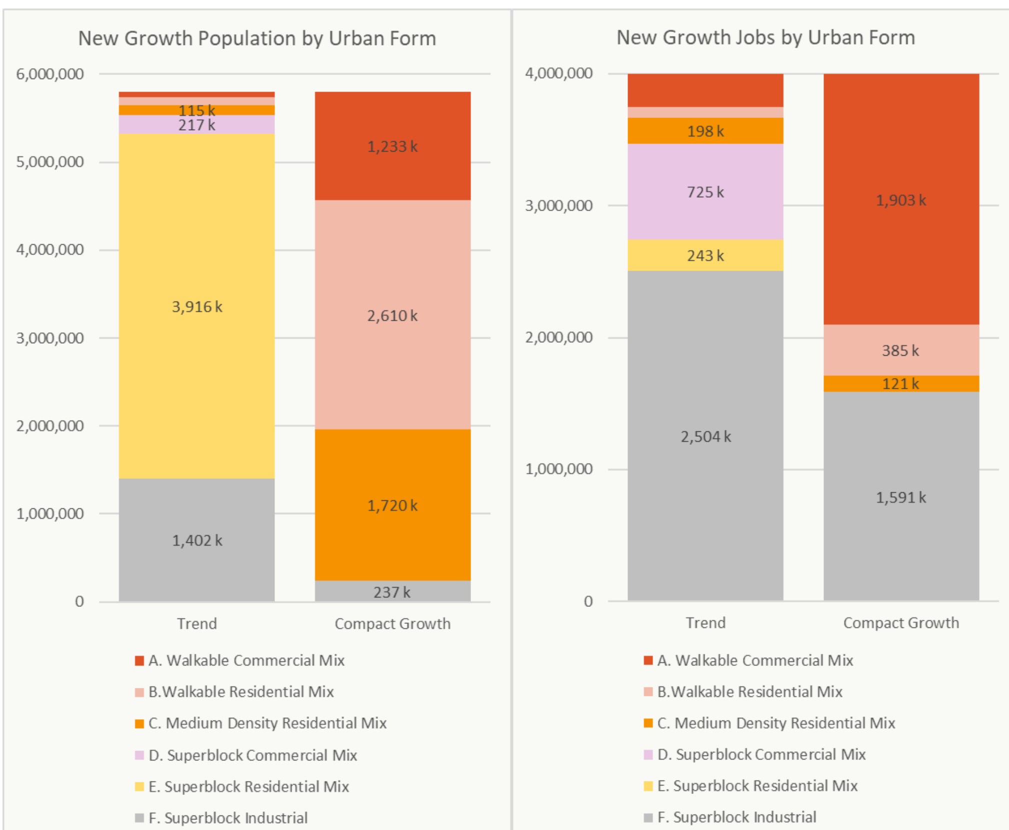


Figure 8. New population growth (left) and job growth (right) by urban form type

Job Accessibility

The ratio of jobs to population over a given area reflects the level of opportunity people have to live within a reasonable distance from where they work. While the Trend and Compact Growth scenarios have the same overall jobs to population ratio region-wide, they differ significantly in the Core and Extension areas. ("Endstate" refers to existing development plus new growth.)

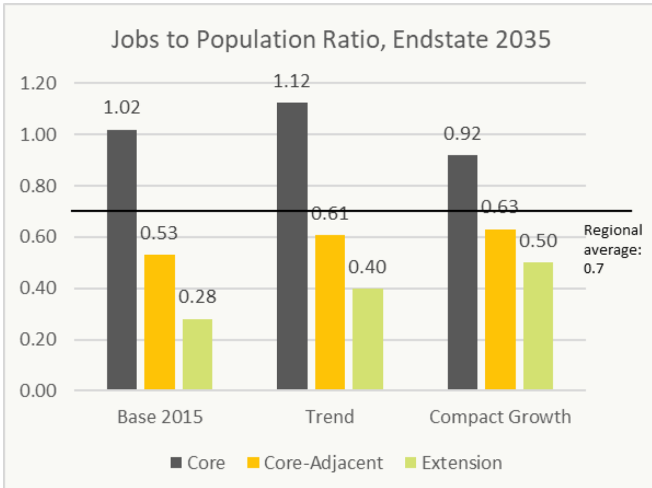


Figure 9. Jobs to population ratio in 2035, by subarea

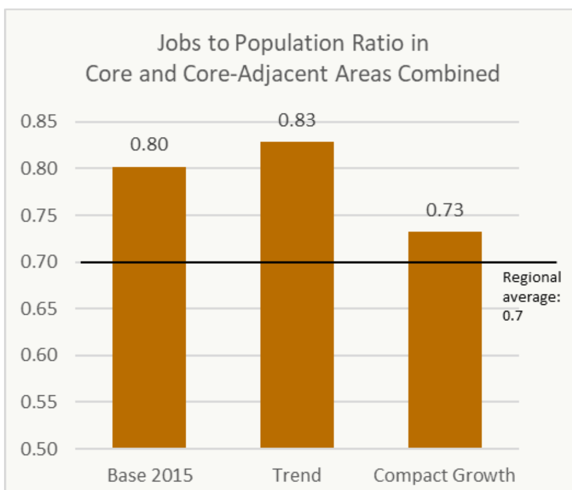


Figure 10. Jobs to population ratio for the Core and Core-Adjacent areas combined

Accessibility to Services and Amenities

The proportion of population in walkable, people-oriented development (POD) areas is a measure of livability. The ability to access destinations via non-auto transportation options is particularly important for seniors, the proportion of whom is projected to grow into the future as Chongqing's population ages. **The Compact Growth scenario locates over 40% more population and 15% more jobs in POD areas.**

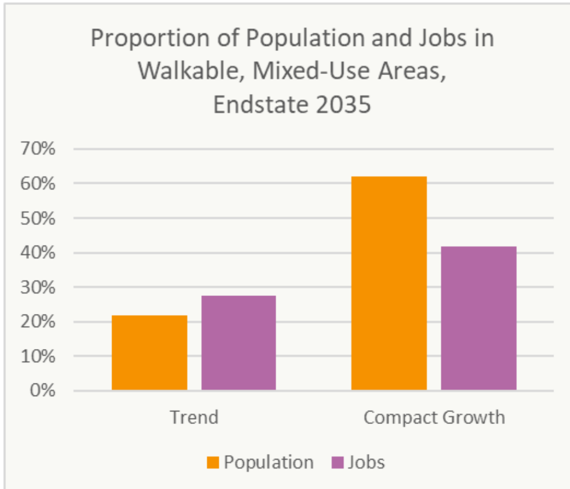


Figure 11. Proportions of population and jobs in walkable, mixed-use areas by 2035

New Land Consumption

New land consumption is a pivotal measure of future development. The amount of land consumed for growth has implications for ecological systems and agriculture, as well as the relative compactness and efficiency of urban areas. A compact urban footprint enables shorter travel distances, more efficient infrastructure networks, and building forms that are more energy- and water-efficient. Relative to existing built-up area in the central city study area, the Trend scenario increases the urban footprint by 87%, as compared to a 57% increase with the more compact, focused development in the Compact Growth scenario. **As compared to the Trend scenario, the Compact Growth scenario saves 195 km^2 of land from development.**

Figure 12. New greenfield land consumption by subarea

Transportation Mode Share

How people travel to commute to work and meet their daily needs is a measure with environmental as well as social implications. While transportation choices determine transportation energy use and GHG emissions, they also have a bearing on household costs, health, and quality of life. **The Compact Growth scenario results in a 9% higher mode share for walk and transit trips combined. This corresponds with a 9% lower auto mode share, meaning that residents in the Compact Growth scenario are significantly less auto-dependent than in the Trend scenario.**

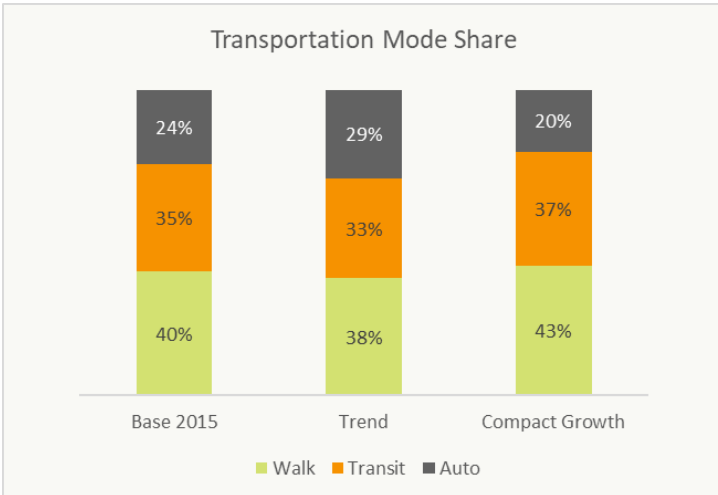
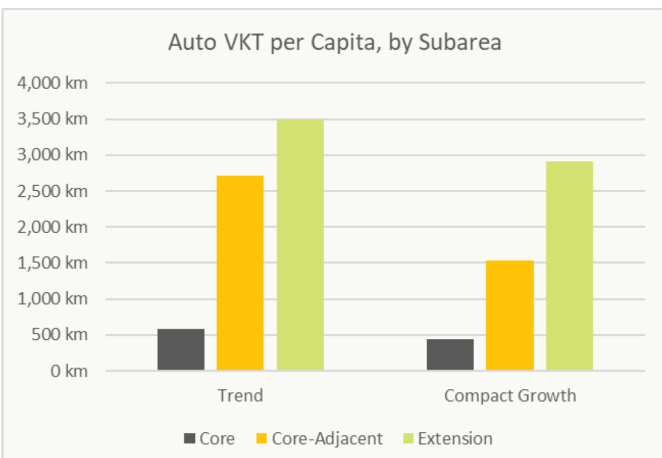


Figure 13. Transportation mode share

Auto Vehicle Kilometers Traveled

Through lower auto use and shorter travel distances, **the Compact Growth scenario results in 39% lower vehicle kilometers traveled (VKT) than the Trend scenario**.



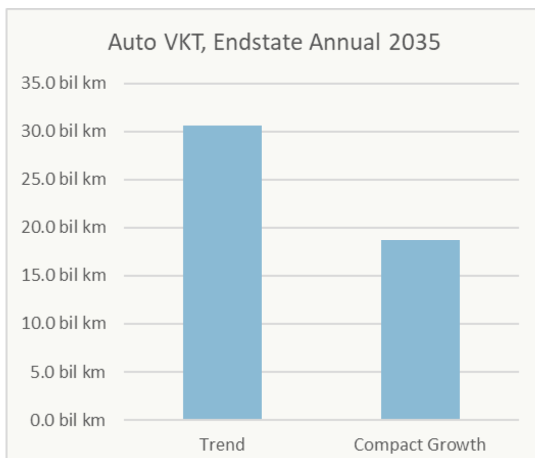


Figure 14. Auto VKT per capita, annual 2035 (left)
Figure 15. Auto VKT total, annual 2035 (right)

Travel Time

Travel time is a function of accessibility, mobility, distance, and congestion. How much time people spend commuting or otherwise getting around to meet daily needs plays a big role in their quality of life. Including all modes, **residents in the Compact Growth scenario save, on average, five minutes of travelling time per day**.

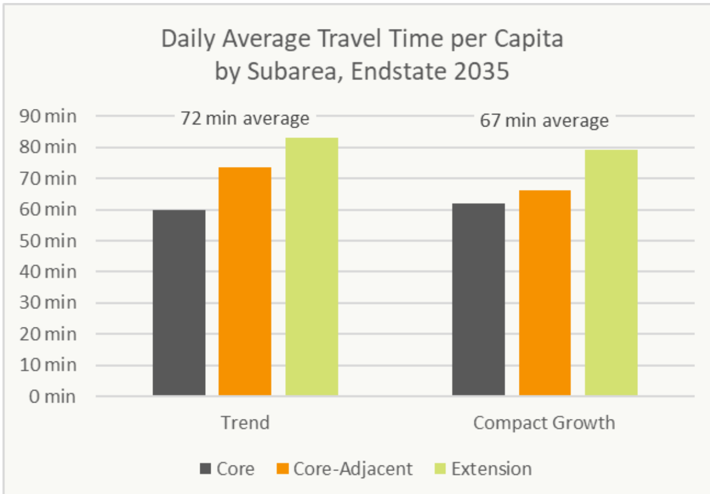


Figure 16. Average daily travel time per capita by subarea, endstate 2035

Greenhouse Gas Emissions from Auto Travel

The Compact Growth scenario reduces annual CO2 emissions from auto travel by 2.6 MMT as compared to the Trend scenario. Cumulatively to 2035, the emissions savings would total 22 MMT. GHG emissions from passenger vehicles in 2035 are estimated assuming current vehicle performance. The uptake of newer, more energy-efficient vehicle technologies into the future would lower emissions even further.

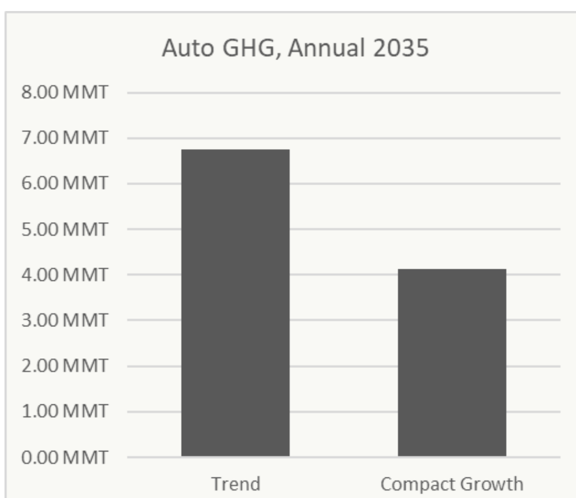


Figure 17. Greenhouse Gas Emissions from Autos, Annual 2035

Air Pollutant Emissions

Air pollutant emissions from transportation also decrease along with VKT. **The Compact Growth scenario emits 293,000 MT, or 39% less in total NO_x, CO, THC, PM, black carbon, and SO_2 emissions annually in 2035 as compared to the Trend.**

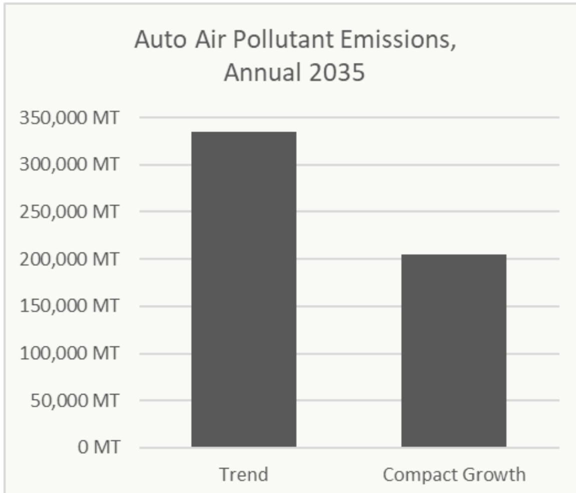


Figure 18. Total air pollutant emissions from passenger vehicles, annual in 2035

Household Costs

Development patterns affect how much households spend on transportation and home energy use. **The Compact Growth scenario saves the average household over 5,100 RMB annually** (in 2018 RMB). Cumulatively to 2035, this savings would total 229 billion RMB – money that could otherwise be applied to housing or other living expenses.

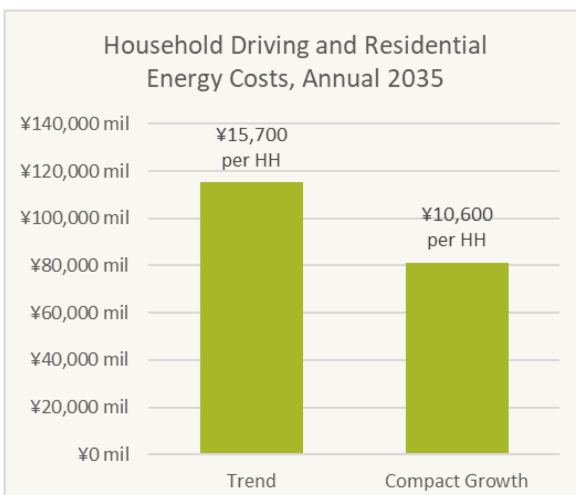


Figure 19. Average household costs, annual 2035

Infrastructure Costs

The lower road, water, and sewer infrastructure required for the Compact Growth scenario saves ¥34 billion cumulatively to 2035 as compared to the Trend scenario. Ongoing operations and maintenance costs would compound this difference.

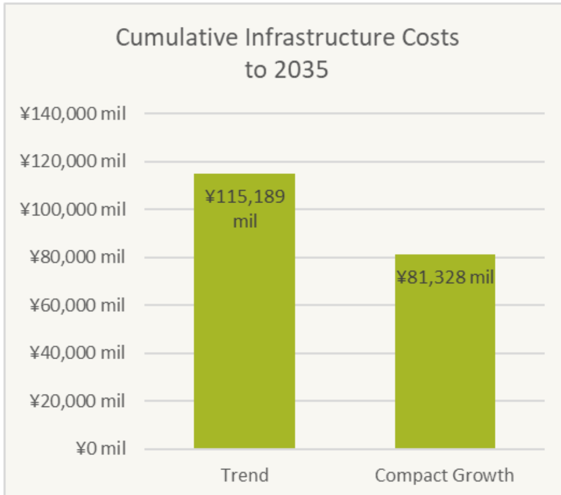


Figure 20. Cumulative infrastructure costs to 2035

Technical Report

1. Introduction

This technical report describes the development and analysis of land use scenarios for Chongqing, China using the RapidFire model. The objective of the Chongqing 2035 scenarios – a component of the World Bank's efforts to advance sustainable development in the region – is to bring actionable information on the impacts of various land use patterns to decision makers as they structure plans and policies for future growth. Chongqing's ability to become a sustainable, high-performing global city will depend on its success at proactively planning for growth. With 5.8 million new population and 4.0 million new jobs projected over the next 15-20 years, it is critical to explore the forms that growth can take and its consequent effects on livability, environmental sustainability, and economic efficiency.

1.1 Study Context

With a population of nearly 34 million and an area of 82,400 km^2, Chongqing municipality is one of the biggest cities in the world. Located in the southwest of inland China, it is strategically positioned as a gateway to China's west, a key connection in the Yangtze River Economic Belt, and a strategic base for China's Belt and Road Initiative. Administratively, it is equivalent to Beijing, Shanghai, and Tianjin in its status as a provisional city that reports directly to the central government.

In two decades, Chongqing has made an extraordinary transformation – growing its GDP per capita by 16 times between 1996 and 2016, and seeing its urban population rise from 29.5 percent to 62.6 percent. The city's formerly agricultural and heavy industry-based economy is now more economically balanced, with the secondary and tertiary sectors contributing to 44.2 percent and 48.4 percent of GDP, respectively. Today's Chongqing is the largest automobile and motorcycle manufacturing base in China and produces one-third of the world's laptops and 90% of the world's IT network terminals.

Chongqing's growth in the past 20 years reflects China's own development trajectory. As China enters a new growth era, however, it has moved away from pursuing GDP growth targets and is instead focusing on a model of development that emphasizes sustainability and a high quality of growth. Cities like Chongqing are a critical part of China's new engine for growth, offering an opportunity for a new modality of urban development that aims for quality, equality, and sustainability.

In line with the central government's strategic two-stage development plan for China, the city's leadership has set an ambitious goal of making Chongqing a global city within the next 15 to 20 years. It is within this context that the World Bank has directed this effort to explore the impacts of land use and development decisions on advancing or impeding the city's progress.

Figure 21. Chongqing municipality is located in the southwest of inland China

1.1.1 Central City Study Area

The scenario study examines urban growth options for the "central city" area of Chongqing municipality, which encompasses the nine districts including and surrounding the Yuzhong District, the historic city center of Chongqing. Comprising an area of approximately 5,500 km^2 with an urban population of 7.4 million, the geographic extent, population, and transportation infrastructure of the central city make it comparable to areas typically defined and studied as metropolitan "regions."[2]

The central city area is depicted by the orange and red areas in Figure 2, which shows all of Chongqing municipality. The areas beyond the central city include a wider ring of 12 districts intended for primarily industrial growth (depicted in yellow) and two "wings" intended for conservation (depicted in blue and green).

The outlying areas of Chongqing municipality will also see growth and are subject to the challenges posed by dispersed development patterns. Although the scenario study does not explicitly address growth in these other areas, it is understood that the broader regional economic context will have a bearing on development in the central city area, and vice versa. While it is beyond the scope of this study to forecast Chongqing's economic progression, the scenarios presented here are compatible with a range of potential futures.

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[2] Note that throughout this report, the term "region" is used to describe the study area, in accordance with its urban structure and functioning. Elsewhere the term may refer to the Chongqing municipality, or the broader mega-city region of which Chongqing and the study area is a part.

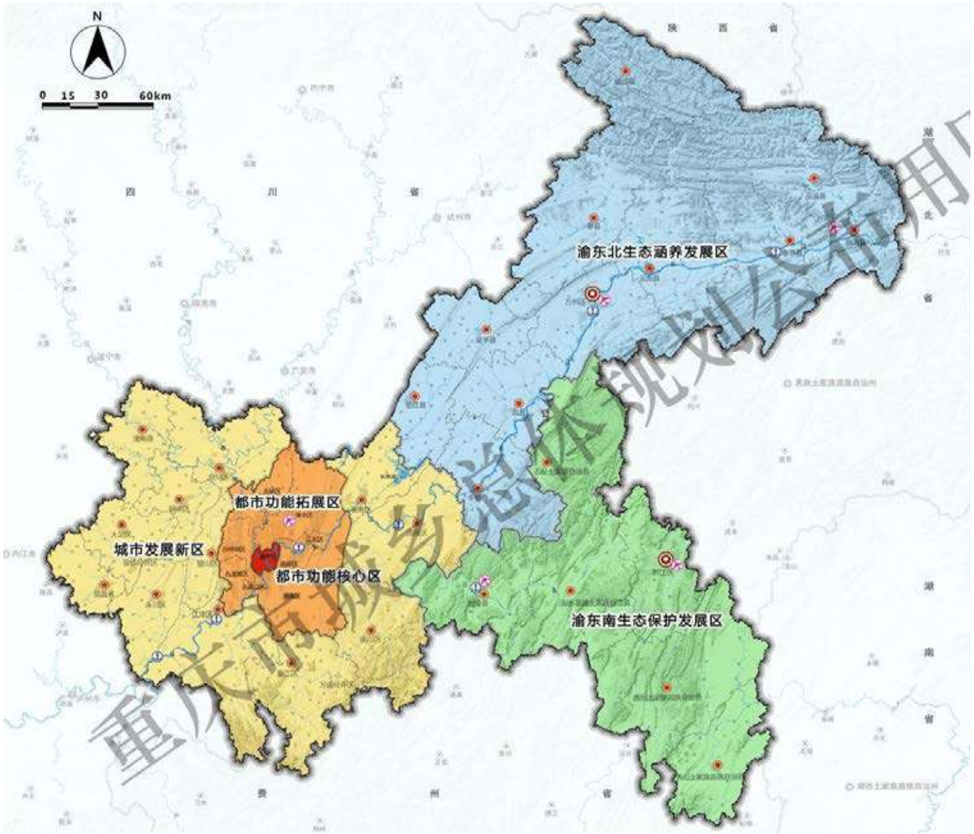

Figure 22. Functional zones within Chongqing municipality

1.2 Planning for Urban Growth in Chongqing

New growth provides an opportunity to restructure the central city area through close coordination of strategic development decisions with transportation and other infrastructure investments. Pedestrian-scale, walkable, connected neighborhoods organized around transit have been shown to provide better mobility and contribute to “place-making.” By contrast, largely separate-use superblock development located in dispersed locations exacerbate existing inefficiencies and challenges to livability. Prioritizing focused development patterns in the context of a regionally balanced plan can enable Chongqing to attract and support the economic growth it envisions.

Planning for the location and form of new urban development presents a range of challenges and opportunities. Chongqing’s ability to position itself as a global city may be dependent on its success at defining and proactively addressing goals for environmental sustainability, economic competitiveness, social inclusiveness, and cultural richness. Fortunately, goals across these dimensions are not at odds with one another – they are best realized in an integrated manner. **Smart, coordinated development choices guided by a vision can help Chongqing thrive in all areas. On the other hand, it is also possible for development patterns to generate or exacerbate existing problems.**

To what extent can different forms of urban development in Chongqing impact measures of transportation use, land consumption, infrastructure needs, household costs, and greenhouse gas emissions? Performance on these and other measures have been gauged by modeling a range of alternative land use scenarios. Each scenario accommodates the same amount of projected population and jobs growth to 2035. However, the scenarios vary substantially in the location and form of new development and related to these factors assume different proportions of new industrial vs. tertiary sector jobs.

The scenarios have been informed by Chongqing's unique demographic and development context and are structured to explore very different directions in development. Key factors include:

- A monocentric Core focus (Yuzhong district and the adjacent developed area) vs. a polycentric structure
- Variations in the amount of infill and redevelopment in existing urbanized areas
- Variations in urban form
- Variations in the form and amount of new development built in proximity to fixed guideway, high-capacity transit infrastructure
- Potential economic shifts that result in different proportions of industrial and tertiary employment
- Variations in jobs-housing balance by subarea
- Projected demographic shifts in age distribution over time, which will consist of an aging population with fewer workers on average per household
- Variations in the amount of new land consumption/rural land conversion

1.3 RapidFire Modeling Approach

The RapidFire model, which was newly adapted for use in Chongqing and the Chinese context, was originally developed by Calthorpe Analytics to provide timely analysis of regional transportation and land use plans throughout California. Prompted by the passage of state climate legislation (California Senate Bill 375) to mandate greenhouse gas emissions reductions into the future by reducing passenger vehicle travel at the regional level, RapidFire was developed and used to represent and model the regional transportation plans/sustainable communities strategies of each major metropolitan planning organization region in California. While SB 375 focused on reducing vehicle miles traveled (VMT) and carbon emissions, RapidFire served to quantify a range of related "co-benefits" also realized by compact development patterns, including reductions in land consumption, building energy use, water use, infrastructure costs, household utility and driving costs, and air pollution and related health impacts.

Since then, RapidFire has been deployed for analysis at the state, regional, and city scales throughout California and the United States, as well as for the Mexico City region and now Chongqing. As a programmatic, spreadsheet-based model, its data requirements are relatively less intensive and more flexible than geospatial models, which require a minimum set of geographic data to run.[3]

RapidFire, which is built as a Microsoft Excel spreadsheet tool, was designed to be receptive to varying data inputs such that it can be adapted for use in different locations, with varying amounts of data. Its analysis modules can incorporate evolving research on the role of land use and transportation systems on automobile travel; emissions; and land, energy, and water consumption. Variable technical assumptions allow policy options, such as vehicle fuel efficiency or energy

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[3] UrbanFootprint, Calthorpe Analytics' web-based geospatial model, currently comes supplied with a breadth of datasets for use in the United States. Given sufficient data inputs, it could be applied in other countries and contexts.

efficiency targets, to be tested in combination with land use alternatives to understand or "bracket" the range of possible impacts.

For example, a trend-based land use pattern could be tested with baseline levels of vehicle efficiency, carbon content of fuels, and building energy use to understand a worst-case future. At the other end of the spectrum, an infill-focused, compact land use pattern can be tested with aggressive policies for low-emission vehicle technologies and building energy efficiency to determine the maximum potential of planning, policy, and technological improvement to mitigate the negative impacts of growth.

The Chongqing 2035 scenarios focus on land use variations and not technological advancements; however, the model setup and scenarios do provide a basis for gauging the potential impacts of land use in concert with policies to effect technological improvements into the future. In the context of meeting aggressive climate targets, modeling has shown that concerted, cross-sector approaches inclusive of compact development as a foundational strategy are necessary.

In its capacity as a high-level, programmatic model, RapidFire is not intended to replace more complex travel models. Rather, it provides a transparent and flexible platform for reviewing and analyzing plans and policies at multiple scales to highlight the role of land use on a comprehensive range of metrics -- specifically informing land use and transportation planning and providing the land use context for policy development in other sectors, such as energy efficiency.

The RapidFire modeling methodology and assumptions have been subject to peer review and technical development assistance by academic researchers and experts from academic institutions, government agencies, and organizations in California, Mexico, and China. The adaptation of the model for the Chongqing context incorporates academic research and travel model development by Yang Jiang and Peiqin Gu of the China Sustainable Transportation Center (CSTC), while the built form characteristics of the modeled place types are grounded in the urban planning and design work of Peter Calthorpe and Calthorpe Associates in Chongqing, Beijing, Kunming, and other cities in China.

RapidFire Scenario Modeling

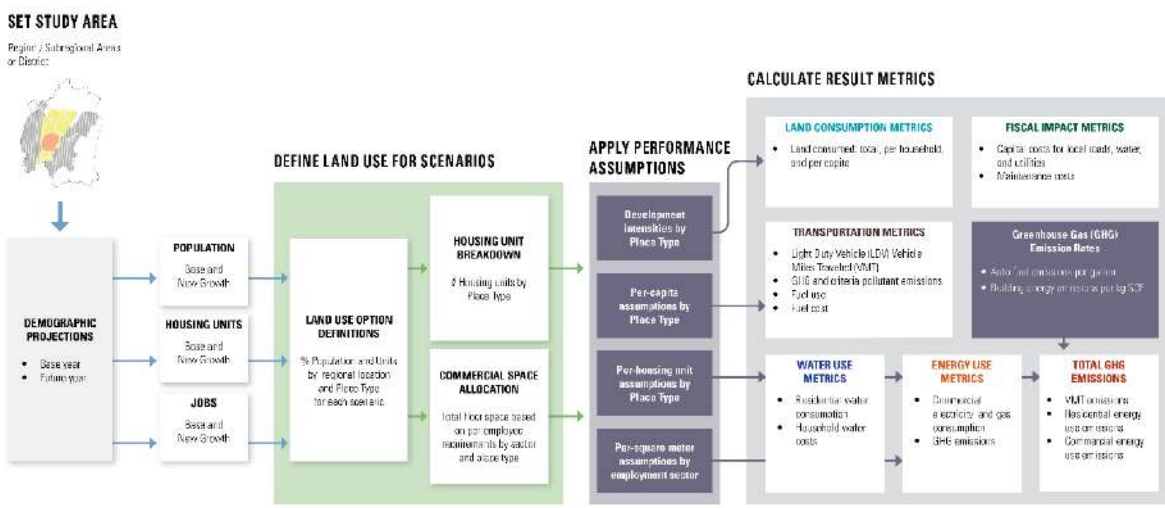
RapidFire is an Excel-based model that represents land use in terms of "place types." Place types are an effective proxy for development pattern and location. Defined to represent typical patterns for a study area, place types are inclusive of the buildings, streets, and other civic infrastructure that together comprise the built environment. Built form and related performance characteristics – for example, residential and employment density, or daily auto travel per capita – are associated with each place type based on empirical data and research.

Land use scenarios are defined within the model as allocations of population, housing units, and jobs to the various place types. The model calculates scenario metrics by applying place type characteristics to the allocations. For example, land consumption is a product of population and employment growth within a place type and the densities of that place type. The model is structured so that results can be isolated for existing development and new growth, stratified by place type, or determined for specific time ranges.

RapidFire also incorporates assumptions to calculate the impacts of technological improvements in concert with land use. Assumptions for vehicle performance, building energy and water use, fuel and energy emissions, pollutant emissions, costs, and other rates can be varied to gauge the impacts of specific policy pathways – a valuable assessment for guiding strategic, comprehensive planning and policy development.

The Chongqing 2035 scenario study involved the development of a new framework of place types to represent the Chinese development context, tuned to the study area's specific locale. The embedded transportation "sketch" model was customized based on regional travel model outputs and the application of research-based elasticities representing the impacts of the built environment on travel behavior. Technical assumptions for the full range of metrics, as described in the Methodology chapter of this report, were also customized for Chongqing municipality.

The chart below summarizes the RapidFire model flow from inputs and outputs.



2. Chongqing 2035 Scenarios

The two scenarios that were analyzed – "Trend" and "Compact Growth" – represent divergent development patterns, the results of which "bookend" the range of potential impacts stemming from land use. While the Trend scenario continues a pattern of dispersed, separate-use superblock development throughout the entire central city area, the Compact Growth scenario focuses growth in walkable, mixed-use centers largely accessible by transit, and contained to the Core and Core-Adjacent areas. The scenarios stand in sharp contrast to each other, yet are both illustrative of what can conceivably occur depending on political direction and varying degrees of coordination in planning, strategic policy making, and implementation.

Initially, four scenario concepts were explored, driven by different assumed planning conditions and objectives. The concepts included the Trend and Compact Growth scenarios, along with two other scenarios: one representing the general trajectory of the Chongqing 2030 Master Plan, and a "Balanced" scenario that located housing and job growth among the Core, Core-Adjacent, and Extension areas to result in a similar jobs/housing ratio within each area. Analysis of the Master Plan and Balanced scenarios yielded outcomes falling in the range between the Trend and Compact Growth scenarios. To maintain clarity in communicating the predominant development options facing Chongqing, only the Trend and Compact Growth scenarios are presented.

Each scenario accommodates the same amount of population and job growth to 2035: 5.8 million new urban population, a projection provided by the Chongqing Planning Bureau; and 4.0 million new jobs, a projection that would result in an average 0.7 jobs to population ratio for the study area by 2035. While it has been noted that these high projections may be optimistic as year-2035 projections, they are consistent with Chongqing's vision for growth on the path to becoming a global city. Independent of a precise time frame, the purpose of the scenarios is to conceptualize growth according to long-range plans. Development decisions made today can either expand or limit possibilities into the future. Working with nearer-term projections would discount the magnitude of the impacts that less coordinated land use decisions can have, and not illuminate the potentially divergent paths that lie ahead.

The scenario concepts can be broadly conceptualized in terms of regional job location, proximity to transit, and predominant urban form:

- Job Location: New high-level sector employment growth would either be constrained to the Core and Core-Adjacent locations or occur throughout the rest of the nine-district area. Within these two options there is more nuance as to growth in the secondary vs. tertiary employment sectors, and how those can support a monocentric or polycentric urban structure. All scenarios assume that industrial job growth will continue to occur, though they accommodate different proportions to reflect alternate possibilities for how much may be located in the central city study area vs. in outlying districts in Chongqing municipality.

- Proximity to Transit: Fundamental to regional circulation and compact development are the quantity and types of transit opportunities. Travel behavior, congestion, air quality, and costs are all related to the proportion of trips taken by transit in the region. Chongqing has a very robust planned metro system and an extensive set of bus routes. The scenarios vary by how much and what type of development is proximate to these facilities.

- Urban Form: Urban development would either occur as primarily walkable, people-oriented development (POD), or as status-quo auto-oriented superblocks in generally separate-use districts. Capacity to support POD is tied to the spatial distribution of higher-level services jobs that would form the foundations for mixed-use POD centers near transit. Given Chongqing's rapidly growing transit network, the Compact Growth scenario would have a strong investment and infrastructure foundation.

2.1 Trend Scenario

The Trend scenario is an important baseline against which to compare the Compact Growth scenario. Although recent plans in Chongqing have conceptualized a polycentric structure built around the existing and planned metro transit network, the Trend stands as a "status quo" representation of the kind of development that will take place by default if regional policy development, coordination, or implementation efforts fall short.

The Trend scenario represents the future as an extension of the past, with more isolated land uses in superblock configurations spreading outward from the Core. Its primary assumption is the ratio of new jobs and housing applied to the three subareas. Job growth is evenly distributed across the three areas, but housing growth is projected to occur mostly in the Core-Adjacent and Extension areas – 45% in each. In fact, the Core area sees a reduced rate of housing growth as compared to recent years.

Carrying forward past development trends leads to further urban expansion, increasing fragmentation, decreasing densities, and greater subarea jobs/housing imbalance. This scenario results in the largest footprint of new development at 553 sq. km, with only 5% of new residents and 9% of new jobs in small block, walkable POD configurations. The resulting population density is the lowest at 11,130 per sq. km, and the percent of lands in walkable TOD is just 14% overall. The resulting ratio of jobs to population is extremely out of balance in the core area at 1.1 jobs per person, while a balanced ratio would be 0.7. This will inevitably result in large in-commuting patterns. The combination of the Core and Core-Adjacent areas is still out of balance at 0.83 jobs/pop, meaning that workers would even need to commute a great distance from the Extension areas.

2.2 Compact Growth Scenario

Driven by a need to contain urban expansion and grow as a much more compact city, housing and job growth in this scenario is focused primarily in walkable POD patterns within the Core and Core-Adjacent areas. Prioritizing balanced growth at strategic locations in proximity to existing and planned metro stations will establish a polycentric spatial structure. These POD nodes near transit can support new economic clusters outside the existing Yuzhong-centered Core. Fostering the growth of employment nodes outside the existing Core area – largely in the Core-Adjacent area – will help Chongqing achieve better local jobs/housing balance, alleviating the negative impacts and inefficiencies of a monocentric pattern.

Most new development in this scenario is focused in areas around existing and planned metro stations in the Core-Adjacent area. Except for some industrial development in the Core-Adjacent and Extension areas, nearly all new development near transit occurs in walkable, small block configurations to make best use of the land capacity and maximize the investments made in transit infrastructure.

Analysis of existing conditions demonstrate more than sufficient capacity for POD development near transit. The Liangjiang New Area in the northern section of the Core-Adjacent area can accommodate a major portion of the region’s projected growth. Development could also be prioritized around the metro transit lines south of the Core. There is also potential around stations in the Extension areas, though the priority would be for growth to occur at the highest intensities in the Core-Adjacent area. The location and form of growth in the Compact Growth scenario accords with the underlying rationale of plans for the Liangjiang New Area, which asserts the need for regional strategy and coordination to guide the development of a hierarchy of new centers. Fundamentally, the development characteristics and intensity of new centers must be tuned to location, level of transit service, and proximity to key sites such as educational centers, new central business district (CBD) areas, and the new convention facility.

Growth in the Core occurs entirely as infill and redevelopment, while growth in the Core-Adjacent and Extension areas occurs largely as greenfield development – though to much different extents in the Trend and Compact Growth scenarios. In this case the Core area sees 10% of the new population and 5% increase in jobs, largely on old industrial lands that redevelop. The Core-Adjacent area grows in a more balanced way, capturing 80% of new population and 75% of new jobs. The Extension area grows slowly with 10% of the population and 20% of new jobs, primarily in industrial and lower density office parks. As there is infrastructure and existing industrial areas in the Extension areas, the Compact Growth scenario would continue with this type of employment. This would result in a better jobs/population balance than Trend.

With these allocations, overall growth is compact: land development is down 195 sq km to just 358 sq km compared to Trend, and density up an average of 2,190 people per sq km (p/sq km). The Core area gets denser but more balanced with 22,160 p/sq km and a jobs/population ratio of 0.9. But the ratio for the Core plus Core-Adjacent area is 0.73, almost in balance across what is easily considered a compact metropolitan area. The focused growth occurs as TOD, with the percent of new residents and jobs in TOD in the Core plus Core-Adjacent area at 87% and 59%, respectively.

2.3 Overview of Scenario Characteristics

Table 3 summarizes the key variations between the scenarios, contrasting their relative allocations of growth to the three subareas and their development characteristics.

Table 3. Summary of scenario characteristics

Scenario Characteristic	Trend	Compact Growth
Population growth and distribution by subarea	5.8 million urban population, located by area as follows: Core: 10% Core-Adjacent: 45% Extension: 45%	5.8 million urban population, located by area as follows: Core: 10% Core-Adjacent: 80% Extension: 10%
Job growth and distribution by subarea	4 million jobs, located by area as follows: Core: 25% Core-Adjacent: 45% Extension: 30%	4 million jobs, located by area as follows: Core: 5% Core-Adjacent: 80% Extension: 15%
Population density	Lower: 11,100 residents/km2 on average	Higher: 13,300 residents/km2 on average
Job density	Higher in Core, lower in Core-Adjacent and Extension Areas	Lower in Core, higher in Core-Adjacent and Extension Areas
Jobs/population ratio	Regional average 0.7 jobs per capita, though less balanced locally than in the Compact Growth scenario. Perpetuates pattern of greater concentration of jobs in the Core.	Regional average 0.7 jobs per capita, more balanced locally than in the Compact Growth scenario. Locates employment in mixed-use areas outside the Core.
Job growth by sector	50% Industrial 50% Tertiary and above	34% Industrial 66% Tertiary and above
Development pattern	Primarily superblock development throughout the region, including near transit.	Primarily small-block, walkable POD development throughout the region, with higher intensities near transit.
Land development	Infill and redevelopment in the Core continue, while superblock development in the Core-Adjacent and Extension areas perpetuate expansive, fragmented development and high land consumption.	Infill and redevelopment in the Core and compact, focused development in the Core-Adjacent and Extension areas contain greenfield expansion.

2.4 Scenario Assumptions and Drivers

The Chongqing 2035 scenarios were developed using the best available local information and data, supported by spatial analysis of existing and planned conditions as possible. This section outlines the data sources, reference points, and assumptions used in developing the scenarios.

2.4.1 Scenario Study Area and Subareas

The study area is comprised of the nine districts of Yuzhong, Jiangbei, Nan'an, Jiulongpo, Yubei, Dadukou, Shapingba, Banan, and Beibei. This area is also known as the "central city" area. Since the scenarios are not depicted on an explicitly spatial basis, the study area is divided into the three subareas – the Core, Core-Adjacent, and Extension areas – that are used as a framework for classifying and modeling growth. As described earlier, the subareas are defined by the existing core of the city, and the topography of the region. The Core corresponds to what has been known officially as the "Core Metropolitan Function Area," while the Core-Adjacent and Extension areas comprise what has been known as the "Extended Metropolitan Function Area." Figure 23 shows the study area, the three subareas, and the boundaries of the nine districts.

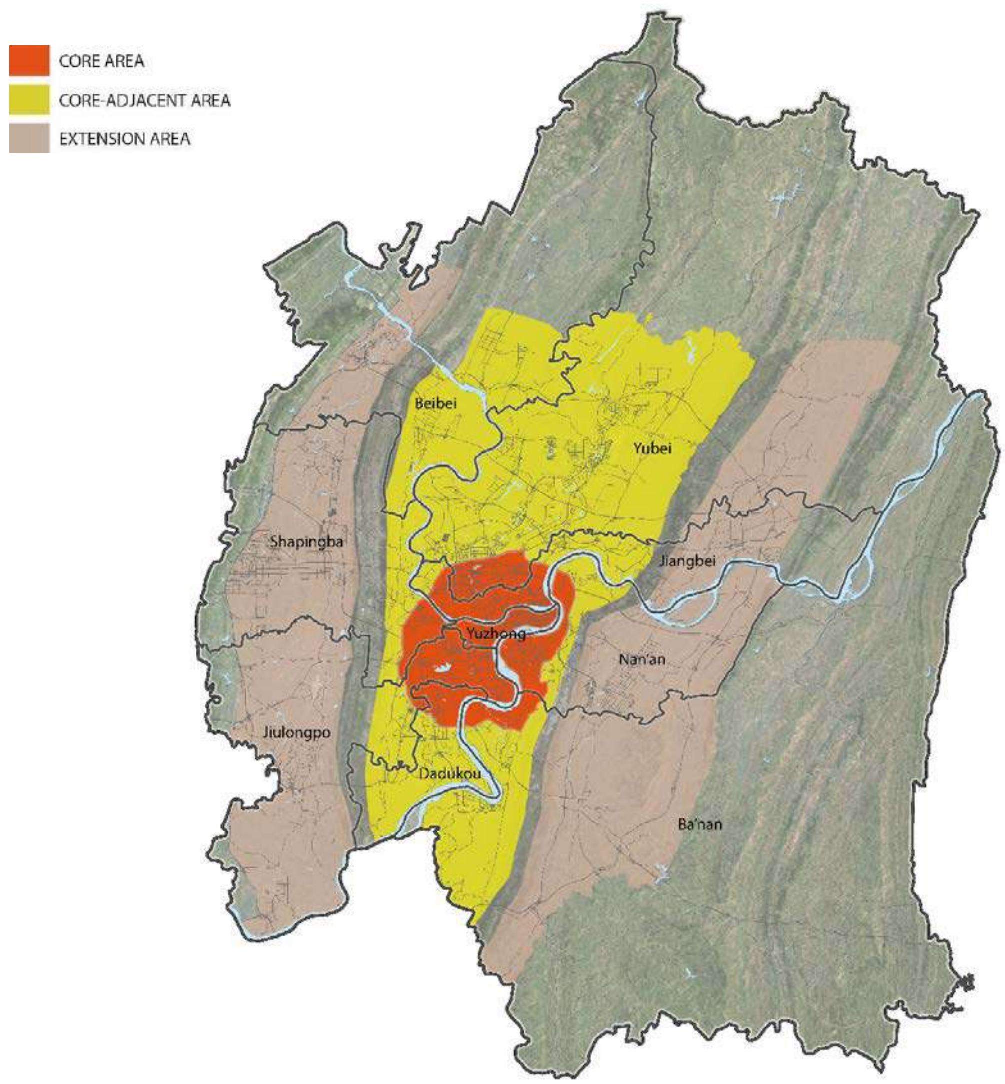


Figure 23. Study area, subareas, and district boundaries

2.4.2 Population, Households, and Jobs

Information for baseline and projected population, households, and jobs were sourced as shown in Table 4.

Baseline population and employment
Baseline 2015 population and jobs were assumed to be 7.5 million and 5.2 million, respectively. The locations of population and jobs in the Core, Core-Adjacent, and Extension zones were based on official figures, and an assessment of population and employment imputed at the transportation analysis zone (TAZ) level.

Population growth projections
Urban growth projections were provided for growth in the “Core Metropolitan Function Area” and “Extended Metropolitan Function Area” as shown in Table 4. Projections for the year 2040 were applied for the 2035 end year of the scenario.

Table 4. Population estimates and projections

		2013[a]		2015[b]		2020 (2030)[c]		2040[d]	
		Population (million)		**Population (million)**		**Population (million)**		**Population (million)**	
Function Zone	**Zone Definition**	**Total**	**Urban**	**Total**	**Urban**	**Total**	**Urban**	**Total**	**Urban**
Core Metropolitan Function Area	Area within the Inner ring highway	3.08	3.08	3.74	3.74	2.80	2.80	2.70	2.70
Extended Metropolitan Function Area	Area within nine districts of the study area that is outside the Core Metropolitan Function area	5.01	4.02	4.61	3.65	8.70	8.20	10.80	10.50
a. Chongqing 2014 Master Plan									
b. Chongqing Statistics Bureau (http://www.cqtj.gov.cn/tjsj/sjzl/tjgb/201601/t20160128_423836.htm)									
c. Chongqing 2014 Master Plan. Considering the current trend, however, experts from Chongqing urban planning institute suggested the year 2020 figures be used for year 2030 forecast.									
d. Data provided by the Chongqing urban planning institute.									

To note on the population projections: The net growth projection for urban population indicated from 2015 to 2040 is 5.8 million, comprising a net reduction of 943,000 in the Core and a gain of 4.55 million in the rest of the study area. This projection of population decline in the Core was incorporated into a scenario representing the direction of the Master Plan.

By contrast, the Trend scenario assumes a pattern of continued population growth in the Core as indicated by the 2013 and 2015 figures. Of the 5.8 million new population projected to 2040, the Core receives 10 percent, or 580,000 new population.

Employment growth projections

Employment growth for the study area was projected based on maintaining the baseline regional average jobs/population ratio of 0.69 jobs per capita into the future. Pegging employment growth to population growth of 5.8 million yields an additional 4.0 million new jobs. While the ratio of jobs to housing into the future is subject to numerous demographic, economic, and policy factors – and thus likely to change – for the purposes of this study the existing ratio was assumed. All scenarios plan for the same number of new jobs, yet vary in their relative distribution to the Core, Core-Adjacent, and Extension areas to articulate differences in addressing local jobs/housing balance. The Trend scenario continues with centralization of jobs in the Core, leading to an endstate (2035) ratio of 1.12 jobs per capita in the Core, 0.61 jobs per capita in the Core-Adjacent, and 0.40 jobs per capita in the Extension areas. The Compact Growth scenario reflects a more balanced development pattern, with endstate ratios of 0.92, 0.63, and 0.50 jobs per capita in the Core, Core-Adjacent, and Extension areas, respectively. Looking at the Core and Core-Adjacent areas combined, the Trend scenario results in 0.83 jobs per capita, whereas the Compact Growth scenario results in 0.73 jobs per capita.

Employment growth by sector

The scenarios also vary in terms of growth by sector. The Trend scenario continues with a distribution of 50% industrial sector (secondary) and 50% services (tertiary and higher-level) jobs, a current distribution that has been projected forward. The Compact Growth scenario varies this slightly, with 34% industrial and 66% services jobs. The scenarios accommodate industrial and services jobs in different locations, and with different place types. The scenarios do not correspond to any specific macroeconomic projections for either the study area or the greater Chongqing municipality; rather, they have been defined to explore the land use implications of growth in industrial vs. higher-level sectors.

2.4.3 Urbanized Land Area

Existing urbanized land is estimated at 633 km^2, an assessment based on TAZ data used to type existing development, spatial data representing the full urban extent, and spatial data representing developable areas. This estimate of urbanized land area is used only in the context of comparative results among scenarios.[4] As growth context, the land available for urban use within the study area is estimated to be 563 km^2.

2.4.4 Metro Transit Network

The existing and planned metro transit network were used to quantify transit-proximate land area as a reference point for the scenarios. Land area around new transit was calculated as developable area in tranportation analysis zones (TAZs) within 800m of planned stations. This area, inclusive of some existing built-up area, amounts to approximately 74 km^2 in the Core, 179 km^2 in the Core-Adjacent area, and 194 km^2 in the Extension areas.

2.4.5 Current Local Plans

Liangjiang New Area Plan

The Liangjiang New Area plan is Chongqing's major zone for focused development. The 1,200 km^2 total area and 550 km^2 of developable area of Liangjiang cover parts of the Core and Core-Adjacent areas as defined for the scenarios. Calthorpe Associates' urban design and master planning work for the Liangjiang New Area, as well as areas in other Chinese cities, provided prototypical urban form parameters to substantiate the walkable transit- and person-oriented development Place Types.

Master Plan Land Use

Information from the 2014 Master Plan, including maps of planned land use, developable lands, and reserved areas, was used to inform the scenario allocations.

Figure 24 and Figure 25 show existing and planned large low-density employment zones, respectively, according to the 2020 Master Plan. The location of these areas and proximity to existing and planned transit have provided context for scenario development.

[4] The given official figure for existing urbanized land is 545 km^2, while the full urban extent, including sparsely developed areas, can be estimated at 812 km^2. There can be significant variation in the assessment of "developed" or "urbanized" area depending on criteria and the extent to which special uses, right of way and infrastructure areas, and sparsely developed peripheral or interstitial areas are accounted for.

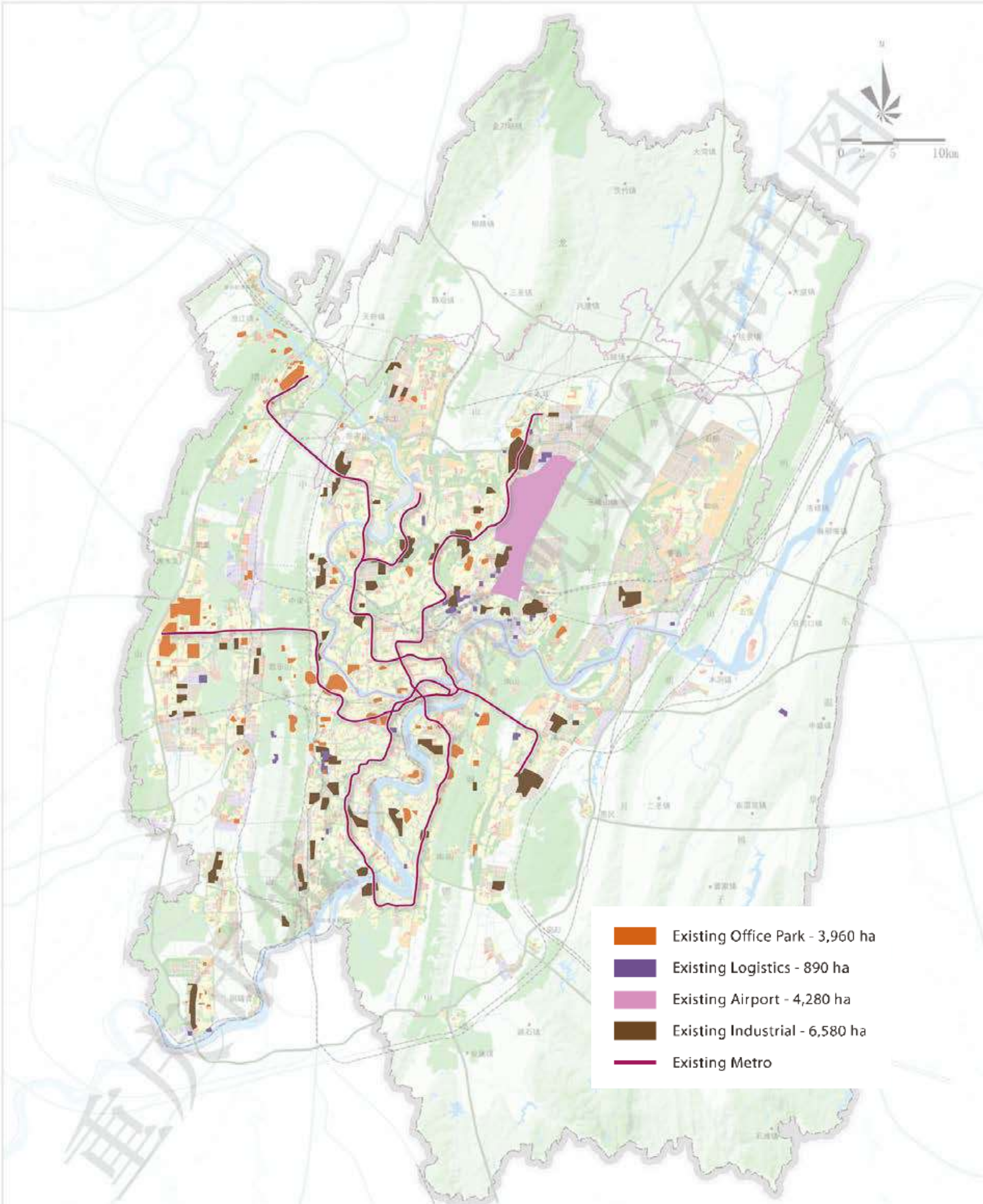


Figure 24. Existing industrial, logistics, and office park areas and metro transit

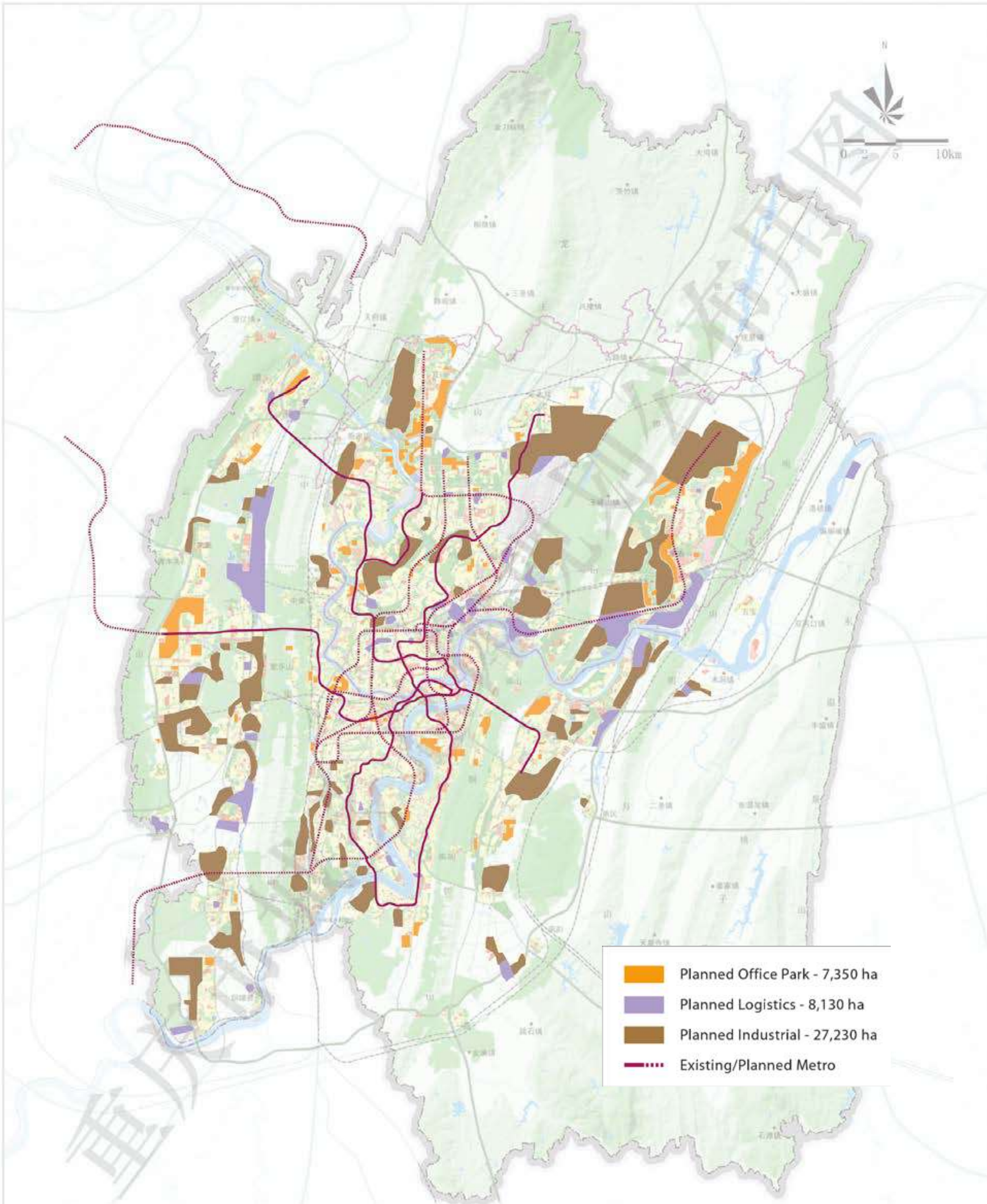


Figure 25. Planned industrial, logistics, and office park areas and metro transit

3. Scenario Results

The scenarios were analyzed for their performance on a range of indicators tied to the city's goals to become more environmentally sustainable, economically competitive, socially inclusive, and culturally rich. Scenario metrics include measurements of urban form as asserted through the composition of the scenarios, and the resulting outputs for land consumption, auto vehicle kilometers traveled, travel mode share, travel time, auto pollutant emissions, building energy use and emissions, infrastructure costs, and household driving and utilities costs. The results show how distinctly the Trend and Compact Growth development patterns vary in their ability to help or hinder Chongqing as it grows.

Table 5 offers a summary view of key scenario metrics associated with new growth ("Growth"), and in total including existing development ("Endstate") by 2035 in each scenario. Modeled or estimated baselines for the "base" year of 2015 are also shown. The sections that follow describe each metric in greater depth. The modeled performance of the scenarios across these dimensions – indicators of the substantial bearing of land use and development patterns on economic, environmental, and social factors into the future – supports the policy recommendations presented in the main project report.

Table 5. Summary of key scenario metrics

Scenario Metric	**Base 2015**	**Trend 2035**		**Compact Growth 2035**	
	2015	Growth	Endstate	Growth	Endstate
Proportion of population in walkable areas	35%	5%	22%	96%	62%
Proportion of jobs in walkable areas	42%	9%	27%	42%	42%
Proportion of population in TOD areas	20%	5%	13%	96%	56%
Proportion of jobs in TOD areas	37%	13%	27%	60%	53%
Jobs to population ratio					
Regional average	0.7	0.7	0.7	0.7	0.7
Core	1.02	1.72	1.12	0.34	0.92
Core-Adjacent	0.53	0.69	0.61	0.69	0.63
Extension	0.28	0.46	0.40	1.03	0.50
Greenfield land consumption	633 km2	553 km2	1,186 km2	358 km2	991 km2
Net infill land use	n/a	18 km2	n/a	10 km2	n/a
Transportation mode share					
Auto	24%	33%	29%	14%	20%
Walk	40%	36%	38%	45%	43%
Transit	35%	31%	33%	41%	37%
Auto vehicle kilometers traveled (VKT) (Annual)	11.3 bil km	15.9 bil km	30.6 bil km	4.4 bil km	18.7 bil km
Daily travel time per capita	59 min	76 min	72 min	61 min	67 min
Auto CO_2 emissions (Annual, million metric tons)	2.49 MMT	3.51 MMT	6.74 MMT	0.96 MMT	4.12 MMT
Auto pollutant emissions (Annual, metric tons)	123,162 MT	173,928 MT	334,254 MT	47,544 MT	204,325 MT
Combined building energy and auto energy use (Annual, petajoules)	126 PJ	137 PJ	257 PJ	128 PJ	232 PJ
Combined building energy and auto CO_2 emissions (Annual, million metric tons)	13.7 MMT	12.3 MMT	26.7 MMT	9.7 MMT	24.0 MMT
Household auto and residential building energy costs per household (Annual)			15,700 RMB		10,600 RMB
Infrastructure costs for new growth to 2035 (Cumulative to 2035)	n/a	115,189 mil RMB	n/a	81,328 mil RMB	n/a

3.1 Urban Form

The Chongqing 2035 scenarios represent dynamically different land use futures. New growth in the Trend scenario reflects continued superblock development, while the majority of growth in the Compact Future scenario is in focused people- and transit-oriented centers and neighborhoods. Overall, these plans and patterns contribute to substantially different spatial structures for the central city that will determine how people move around, how efficiently economic activity is supported, and how livable the region will be. Differences in urban form, and the relative location of housing and jobs locally and throughout the region, are the basis for all performance variations between the scenarios.

3.1.1 Walkable, Mixed-Use Development

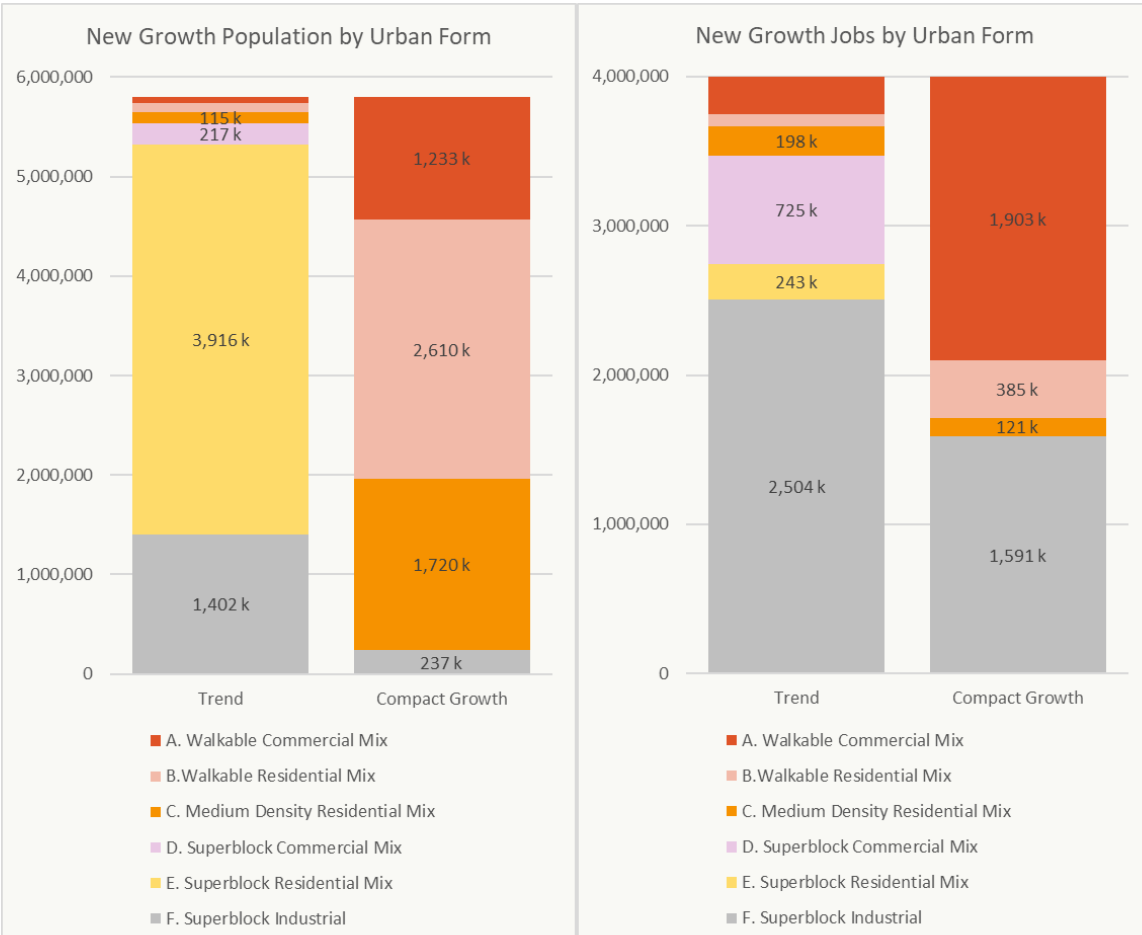


Figure 26. New population growth (left) and job growth (right) by urban form type

Compact, walkable places are vital not only to quantifiable results, but to the qualitative aspects of neighborhood character and livability. The imposing scale of superblock development stands in marked contrast to the vibrant atmosphere of Chongqing's historic neighborhoods. In a way, superblock development is generic and reinforces a placeless quality that can become monotonous and appear to be anywhere. This quality of placelessness negates the unique qualities of Chongqing's history, culture, and topography. TOD design principles are fundamentally people-oriented design principles. Walkable, small-block development with a mix of uses invites walking and contributes to active street life and lively public spaces – the characteristics of which can come to define the identity of a neighborhood and its residents.

Walkable, mixed use development promotes more sustainable transportation choices, and fosters unique, varied, and livable communities. The Trend scenario sees most new homes and jobs located in superblock developments, which despite having some mix of uses generally keep housing and employment areas separated by distance, or adjacent but divided by wide roads that are not friendly to pedestrians. By contrast, the Compact Growth scenario locates most new homes and jobs in walkable place types of varying densities.

Figure 26 compares the amounts of population and job growth by place type in the scenarios. The Compact Growth scenario allocates nearly all new housing, and over half of new jobs, to walkable areas. Occurring largely in the Core-Adjacent area, this projected new growth represents an opportunity to reinforce and expand upon Chongqing's unique character through the definition of a cohesive structure of new communities. The Trend scenario, by contrast, allocates the majority of new housing to superblocks.

The allocation of TOD – walkable, mixed-use growth with transit access – in the Compact Growth scenario was informed by the amount of available land around existing and planned metro transit. Achieving this high proportion of new residential and employment growth in TOD areas – effectively making TOD the standard for new development – requires strategic, coordinated policy making, planning, and implementation. TOD prioritization for infill, redevelopment, and greenfield development is fundamental, and best supported by the designation of an urban growth boundary and investment in high-quality transit service. Measurement and benchmarking of progress, for example targets for the proportion or amount of new growth occurring within TOD areas, are a component of the policy recommendations made in the main report.

Accessibility to Services and Amenities

"Livability" can be considered a qualitative measure of effective planning from the regional to the neighborhood scale. At the regional scale, the close coordination of land use decisions – where new housing and jobs are located, and in what form – with transportation investments will determine how readily residents can make their way from home to work and other destinations, and by what transportation mode. The ability to access destinations via non-auto transportation options is particularly important for seniors, the proportion of whom is projected to grow into the future as the population in Chongqing ages. Figure 29 shows the differences in regional population and jobs that fall within walkable, mixed-use areas – otherwise known as people-oriented development (POD) – by 2035.

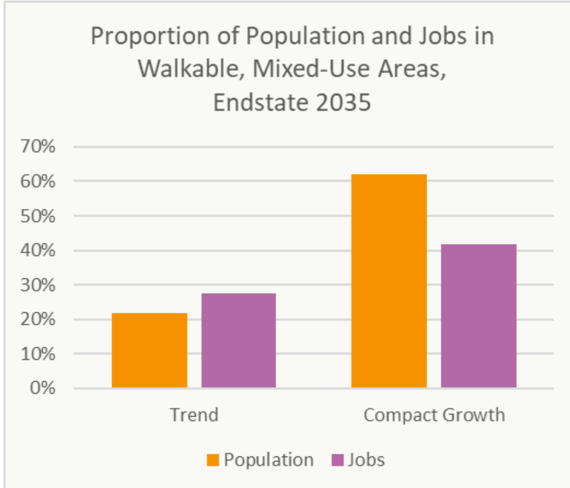
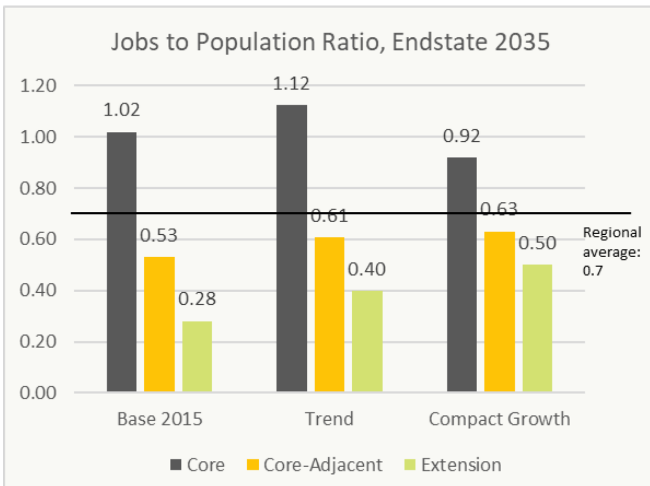


Figure 27. Proportions of regional population and jobs in walkable, mixed-use areas by 2035

3.1.2 Job Accessibility



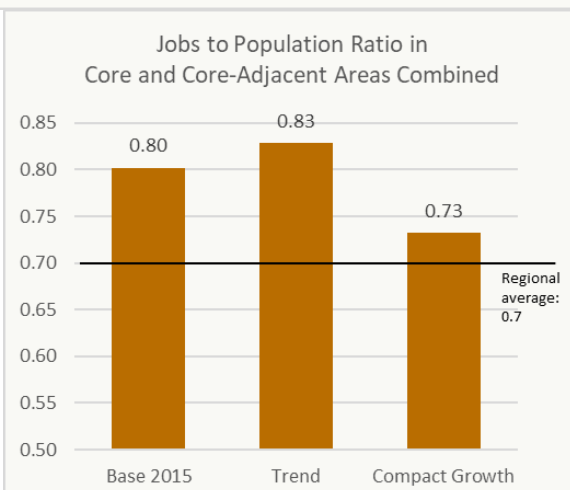


Figure 28. Jobs to population ratio in 2035, by subarea (left)
Figure 29. Jobs to population ratio for the Core and Core-Adjacent areas combined. (right)

The ratio of jobs to population over a given area reflects the level of opportunity people have to live within a reasonable distance from where they work. While job fit – the correspondence between workers and jobs of their corresponding skill types – is an important component of job accessibility, our analysis does not have the data foundation necessary to analyze existing conditions for this or project into the future. Thus, the jobs-to-population ratios for the three subareas are used as a broad proxy indicator of job accessibility. Figure 27 compares the jobs to population ratio by subarea. While the Trend and Compact Growth scenarios have the same overall jobs to population ratio region-wide, they differ significantly in the Core and Extension areas. The Trend scenario becomes more jobs-heavy while the Extension area receives more population growth than can be supported by local jobs.

3.2 Transportation Impacts

Mode share and auto vehicle kilometers traveled (VKT) are directly linked to the environmental impacts of fuel use and greenhouse gas emissions, the health impacts of pollutant emissions, and the social and economic impacts of household spending. Congestion also impacts the movement of goods and services and therefore the overall economic efficiency and competitiveness of the region. Auto VKT is a function of transportation mode choice and travel distance, which are together determined by local and regional land use patterns. As new development, whether it be for housing or jobs and services, spreads farther afield, average trip distances increase.

The walkable neighborhood design, compact spatial pattern, and better local balance of jobs and housing of the Compact Growth scenario not only support higher shares of transit and walking but reduce average travel distances as compared to the Trend scenario. Clustered employment at metro transit nodes throughout the Core and Core-Adjacent area supports a polycentric regional pattern that would provide greater accessibility for more workers than would a polarized approach that centralizes higher-level jobs in the Core and locates the majority of other office and industrial jobs in single-use areas beyond the easy reach of transit.

Additionally, with services and other destinations in mixed-use areas accessible by transit, and in closer proximity to housing, all residents – from the young to the elderly – can more readily take transit or make short walk trips to meet their daily needs. By contrast, separate-use districts and superblock patterns that increase walking distances – both predominant features of Trend development – favor or even necessitate driving.

With the scenarios structured around the same planned metro network, the amount of available land in proximity to transit is the same in each scenario. However, the scenarios vary in the utilization of this valuable capacity. Small-block development within walking distance of metro transit, or with nearby access through feeder bus networks, provides the best mobility options for all. At the regional scale, the resulting impacts on mode share, household auto VKT (that is, non-commercial auto VKT), and in turn the emissions associated with auto travel, are substantial.

3.2.1 Mode Share

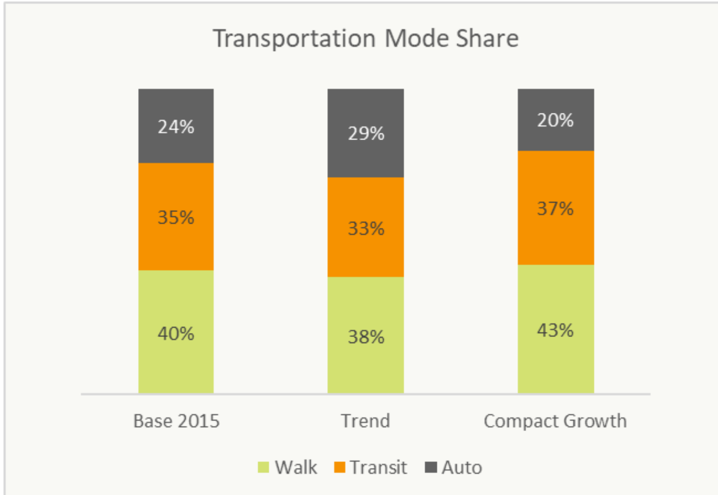


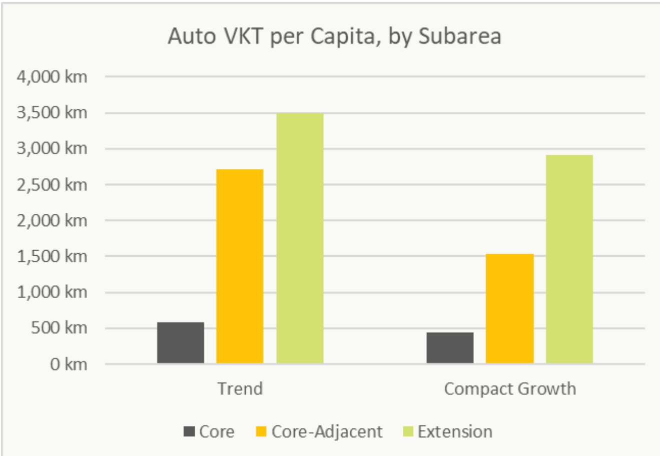
Figure 30. Transportation mode share

How people travel to commute to work and meet their daily needs is a measure with environmental as well as social implications. While transportation choices determine transportation energy use and GHG emissions, they also have a bearing on household costs, health, and quality of life. The time and distances involved for people to reach their destinations have impacts on daily life. Land use patterns that prioritize auto use and traffic movement are generally not conducive to walking and transit use and exacerbate inequities between those who drive and those who do not.

Transit-oriented patterns, by contrast, can go hand in hand with the development of healthy and sustainable communities. Walking (and biking, though not as common in Chongqing as elsewhere in China) is supported by small blocks, narrow streets, and a sufficient density of development and mix of uses to put more destinations within a short distance. Putting these principles into practice would allow people, including higher-income workers who might otherwise choose to drive, to forego car ownership and instead take other modes.

Mode share is an indicator of the extent to which the local urban environment and regional land use patterns support non-auto alternatives. The walk and transit shares of trips are 5% and 4% higher, respectively, in the Compact Growth scenario than in the Trend scenario, while the auto share is 9% lower. The mode shares for the scenarios are summarized in Figure 30.

3.2.2 Vehicle Kilometers Traveled



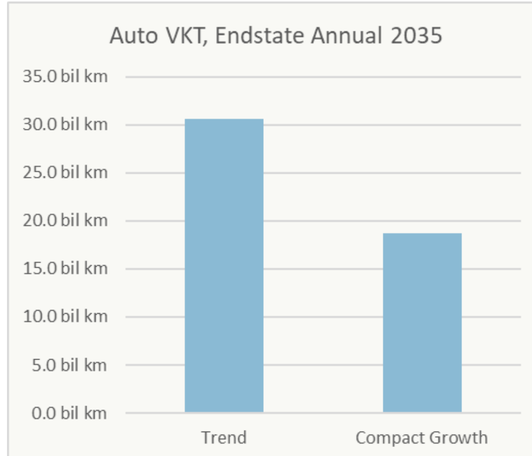


Figure 31. Auto VKT per capita, annual 2035 (left)
Figure 32. Auto VKT total, annual 2035 (right)

Relative to existing travel patterns, auto use increases in the Trend scenario and decreases in the Compact Growth scenario. Auto trips currently account for 24% of daily travel. The Trend scenario causes auto share to increase to 29%, while the Compact Growth scenario decreases it to 20%. Auto travel distances are also longer in the Trend scenario, with an average modeled trip distance of 9.6 km in the Trend scenario as compared to 8.4 km in the Compact Growth scenario.

Through lower auto use and shorter travel distances, the Compact Growth scenario results in 18.7 billion VKT annually in 2035, or 39% less as compared to the 30.6 billion VKT of the Trend scenario. Average VKT per capita is 2,320 km annually in the Trend scenario, as compared to 1,420 km in the Compact Growth scenario. Figure 31 illustrates the annual VKT results per capita, and Figure 32 shows total annual VKT.

Cumulatively to 2035, the VKT difference between the Trend and Compact Growth scenarios is immense. While VKT in the Trend scenario totals 410 billion km, VKT in the Compact Growth scenario totals 311 billion km. The difference of 99 billion km is equivalent to over seven years of driving at current levels.

3.2.3 Air Pollutant Emissions

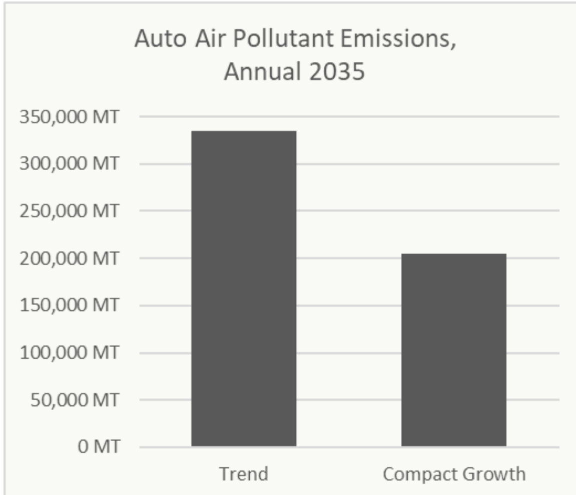


Figure 33. Total air pollutant emissions from passenger vehicles, annual in 2035

Air pollutant emissions from transportation also decrease along with VKT. The Compact Growth scenario emits 293,000 MT less in total NO_x, CO, THC, PM, black carbon, and SO_2 emissions annually in 2035 as compared to the Trend, a difference of 39%. These emissions savings exceed current annual emissions from auto travel within the regional study area. Figure 33 shows the annual emissions from passenger vehicles in 2035, assuming current vehicle performance. As with GHG, uptake of newer, cleaner vehicle technologies into the future would lower emissions even further.

3.2.4 Travel Time

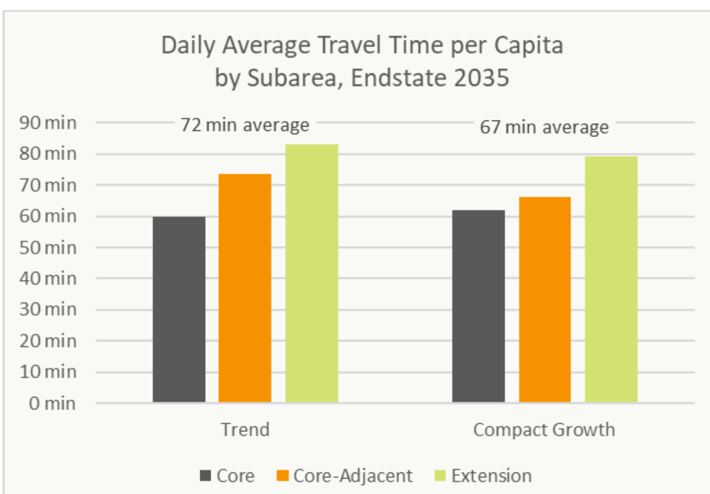


Figure 34. Average daily travel time per capita by subarea, endstate 2035

Travel time is a function of accessibility, mobility, distance, and congestion. How much time people spend commuting or otherwise getting around to meet daily needs plays a big role in quality of life. Beyond the social dimensions, travel time also has an impact on economic productivity. Figure 34 shows the average daily travel times per capita by mode and subarea for the scenarios. The differences by subarea reflect the impacts of location efficiency and are somewhat offset by the slower speeds of walking and transit as compared to driving. Including all modes, residents in the Trend scenario spend, on average, an extra five minutes per day travelling.

3.3 Environmental Sustainability

Environmental sustainability can be measured in terms of greenfield land consumption, infill and redevelopment, and greenhouse gas emissions from building energy and transportation use. Urban development patterns can have substantial effects on laying the foundation for progress in each of these dimensions by reducing energy demand. Approaches to improving vehicle efficiency, building energy efficiency, and energy generation are also vital, but not sufficient in themselves for conserving resources and meeting emissions targets.

3.3.1 New Land Consumption

Figure 35. New greenfield land consumption by subarea

New land consumption is a pivotal measure of future development. The amount of land consumed for growth has implications for ecological systems and agriculture, as well as the relative compactness and efficiency of urban areas. A compact urban footprint enables shorter travel distances, more efficient infrastructure networks, and building forms that are more energy- and water-efficient.

The location and form of new growth in the two scenarios result in vastly different amounts of land developed. Development trends in Chongqing over the past two decades have involved accelerating urban expansion, leading to increased fragmentation and decreasing densities. The Trend scenario continues in this direction, assuming some infill of housing and jobs in the Core but steering most new growth to superblock development in the Core-Adjacent and Extension areas. The Compact Growth scenario instead accommodates new growth through infill, redevelopment, and focused walkable development in proximity to transit nodes.

The amount of new land consumed is tied to where growth is allocated; the scenarios vary distinctly in the amount of population and employment growth projected in the Core, Core-Adjacent, and Extension areas. While the Core can absorb new growth only through infill and redevelopment, growth in the Core-Adjacent and Extension areas is assumed to occur primarily as greenfield (rural or otherwise not previously developed for urban uses) development. Another key variation between the scenarios is the utilization of land in proximity to existing and planned transit stations. The Compact Growth scenario maximizes the opportunity presented by planned transit investments with appropriate levels of density, precluding development in less connected locations in the Core-Adjacent and Extension areas.

While the Trend Scenario assumes a significantly higher proportion of job growth in the Core, representing a monocentric orientation for higher-level jobs growth, the predominantly superblock form of development elsewhere throughout the central city study area leads it to require 553 km^2 of new land for development. By comparison, the Compact growth scenario saves 195 km^2. Relative to existing built-up area in the central city study area, the Trend scenario expands the urban footprint by 87%, as compared to a 57% increase with the more compact, focused development in the Compact Growth scenario. Moreover, land development in the Trend scenario occurs in a dispersed, fragmented manner that would induce further expansion. Figure 35 shows the amount of greenfield land needed for each scenario in the Core-Adjacent and Extension areas.

Accordingly, additional land consumption per new inhabitant varies significantly. The Trend scenario requires 95 m^2 per new inhabitant (offset by the amount of population and employment growth in the Core, which does not incur new land consumption), while the Compact Growth scenario requires 62 m^2. Compared to the rate of development from 2005 to 2015, during which the average rate of additional land consumption per new inhabitant across all of Chongqing (not only the central nine districts) was 139 m^2 (*reference from main report*), the Compact Growth scenario consumes less than half as much land.[5]

[5] Note that the measurement of land per new resident varies depending on the definition of developed land and whether it refers to built-up area or urbanized extent, and whether the measurement is inclusive of parks, reserved open spaces, and other special use areas. In the context of the scenario study, new land consumption is assumed to be inclusive of "net" developed parcel area, plus "gross" areas that include park areas, civic areas, and rights-of-way in typical proportions.

3.3.2 Infill and Redevelopment

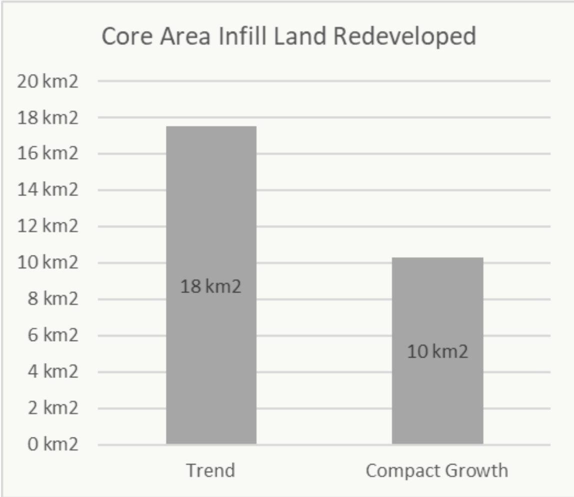


Figure 36. Infill land redeveloped to accommodate new growth

The scenarios also vary in the amount of land in the Core that would need to be intensified through infill and redevelopment to accommodate projected growth. Because the Trend scenario allocates more growth to the Core than the Compact Growth scenario, it entails greater amounts of infill and redevelopment. Figure 36 shows the difference in infill land needed to absorb new growth in the Core. (Note that infill land development is measured in terms of net developable area, not inclusive of the streets, parks, and civic areas that are measured as a component of greenfield land consumption.) If less Trend growth occurred within the Core, the differences in new greenfield land consumption would be even higher. Achieving strategic growth to bring the Core into better jobs/housing balance will involve identifying infill and redevelopment potential, particularly in proximity to metro transit. Policy actions, including establishment of an urban growth boundary, will also be necessary to prioritize infill and redevelopment throughout the central city.

3.3.3 Greenhouse Gas Emissions from Auto Travel

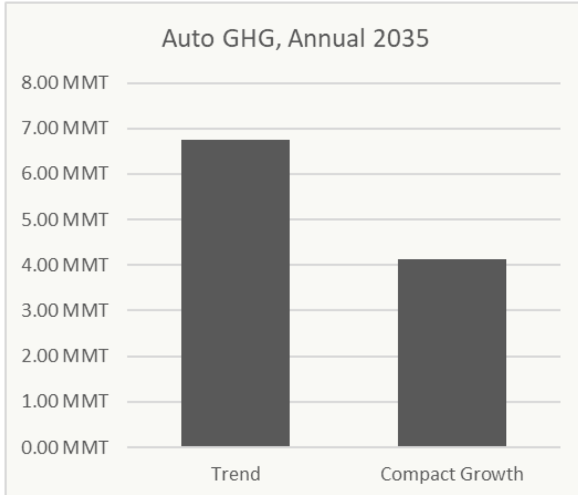


Figure 37. Greenhouse Gas Emissions from Autos, Annual 2035

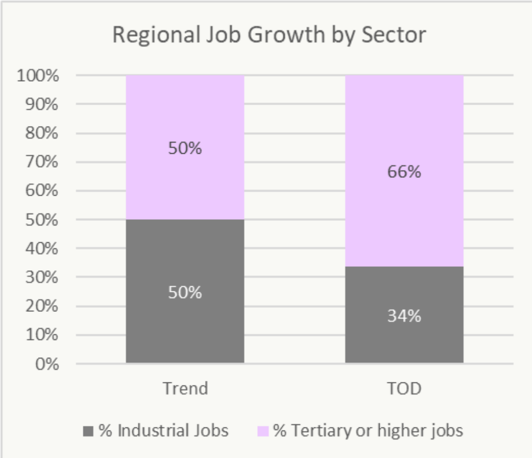
The difference in auto VKT between the scenarios corresponds to an equivalent difference in greenhouse gas emissions, with the Compact Growth scenario emitting 2.6 MMT less CO_2 emissions annually in 2035 as compared to the Trend. These emissions savings exceed current annual CO_2 emissions from auto travel within the regional study area. Figure 37 shows the annual GHG emissions from passenger vehicles in 2035, assuming current vehicle performance. The uptake of newer, more energy-efficient vehicle technologies into the future would lower emissions even further.

3.4 Economic Competitiveness

With its many strengths, Chongqing is on the path to becoming a global city. To sustain the economic growth the city has seen over the past 20 years, the city must continue to plan strategically to ensure that it can attract, support, and nurture business development and human capital. Although it is beyond the scope of this study to project the direction and shape of future economic growth and industry development, the scenarios represent how land use patterns can vary in accommodating growth in the industrial and tertiary sectors.

It is key that Chongqing create the conditions to foster the formation of economic clusters that connect to national and global flows. Creating accessible, desirable locations for new employment centers is a vital part of a strategy for Chongqing to diversify its economic base. Building on the assets of its existing industrial base, but readying for transition and focusing on livability, can assist Chongqing in attracting higher-level jobs as it envisions.

3.4.1 Job Growth by Sector



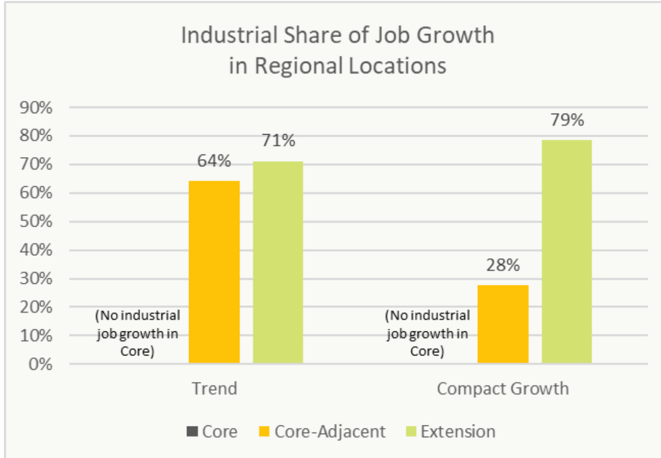


Figure 38. Industrial share of new jobs growth, regional average (left)
Figure 39. Industrial share of new jobs growth by subarea (right)

Compact, transit-oriented development patterns better support, and are in turn supported by, jobs in the office and retail sectors. The Trend and Compact Growth scenario vary in their relative proportion of tertiary as compared to industrial jobs. The Trend future, which continues the prevailing development paradigm of superblock development at the urban edge and beyond, posits a relatively more conservative 50/50 proportion of tertiary and industrial jobs.

While employment growth is certainly affected by macroeconomic factors, urban form plays a role in the relative attractiveness of a region to employers and continued economic growth. Thus, the Compact Growth scenario projects a slightly different 66/34 proportion of tertiary to industrial jobs, assuming that the future sees more growth in professional and other service sector employment as better supported by more livable neighborhoods and efficient transportation options.

Figure 38 compares the share of job growth by sector in the region as a whole, while Figure 39 compares the share of growth by sector in the Core-Adjacent and Extension areas (neither scenario locates new industrial jobs in the Core).

3.4.2 Household Costs

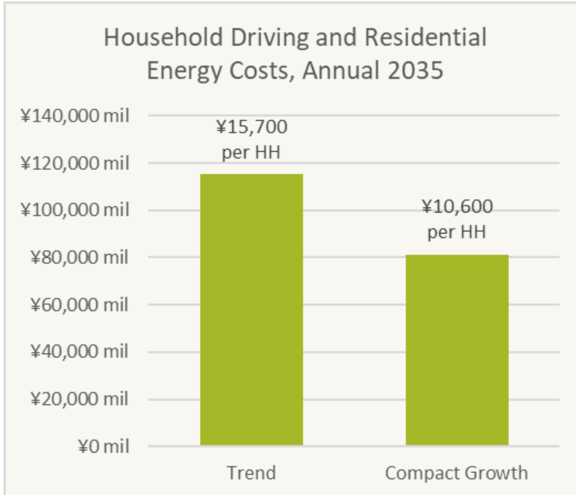


Figure 40. Average household costs, annual 2035

Development patterns affect how much households spend on transportation and home energy use. The greatest savings are to be had on the transportation side. Auto use entails high costs for car ownership, maintenance, and fuel. Avoiding the need for a car altogether can allow households to apply more of their income towards housing or other expenses. The Compact Growth scenario, on average, saves households over 5,100 RMB annually in 2035. Figure 40 shows a comparison of average annual costs per household (in 2018 RMB).

3.4.3 Infrastructure Costs

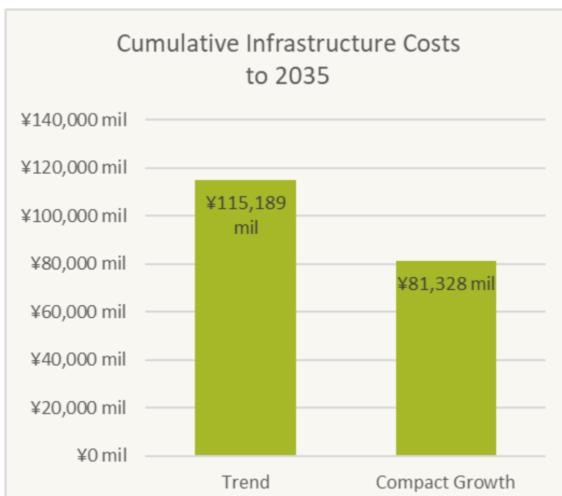


Figure 41. Cumulative infrastructure costs to 2035

The costs of new infrastructure built to serve growth varies in proportion to the extent of coverage required. More dispersed growth in superblock configurations requires greater lengths of roads, water, drainage, and natural gas infrastructure – all of which require significant capital investment as well as long-term, ongoing costs for operations, maintenance, repair, and replacement.

The results show that the Trend scenario, with its greater amount of newly developed land and more road-intensive form, requires 36% greater road, water, and sewer infrastructure coverage than the Compact Growth scenario. This result is based on local development pattern alone and not accounting for the extensions necessary to reach growth in dispersed locations throughout the region. Depending on road and water and sewer line costs, this could mean a difference in the range of ¥34 billion in public spending to 2035. Ongoing operations and maintenance costs would compound this difference.

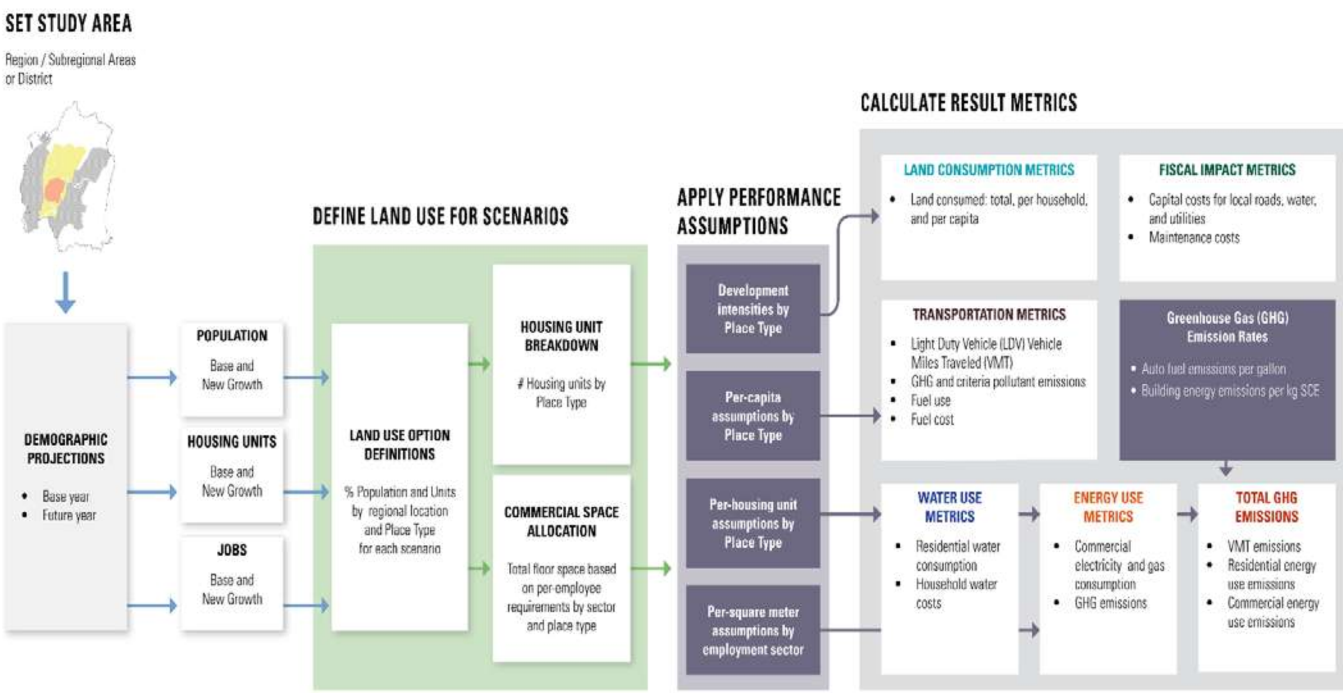
The infrastructure cost savings associated with more compact building forms and less dispersed development patterns can be a strong driver for policy interventions to reduce urban sprawl, including implementation of an urban growth boundary, prioritization of POD and TOD, and investment in structured transit networks rather than road infrastructure that induces urban expansion.

4. Methodology

This section describes how the Chongqing growth scenarios were composed and analyzed. Put simply, scenarios are defined by allocations of population and job growth to place types, which vary in terms of their built form components and related characteristics and performance factors. Results are calculated, in turn, by applying performance factors (such as vehicle kilometers traveled per capita), in combination with technical assumptions (such as average vehicle fuel economy), to the scenario allocations. Figure 42 provides an overview of the scenario modeling and flow from inputs to outputs.

4.1 Representing Land Use Using Place Types

Scenarios represent future development alternatives through the concept of place types. Each place type varies by subarea, walkability, and proximity to transit. For the Chongqing study, three distinct subareas were defined: the Core, Core-Adjacent, and Extension areas. There are two primary development types: walkable mixed-use and superblock single use, which are further



differentiated by predominant use. And finally, there are two transit accessibility conditions; within 800 km walking distance of a station, and not. Combining these three variables and adding logical density variations based on location renders 36 distinct types (see Figure 44). With minor variations, the schema of place types developed for the Chongqing scenarios can be applicable for use throughout China.

The three subareas, illustrated in Figure 43, have been identified based on Chongqing's topography and historic development patterns. The Core area is the 210 km^2 area centered around the Yuzhong District, corresponding to what has been referred to officially as the "Core Function Area," The Core-Adjacent area, which covers approximately 1,528 km^2 to the north and south of the

Core, is currently planned for major development, and is defined by ridgelines to the east and west. The Extension areas, which cover approximately 3,710 km^2, are located over the ridgelines and have been envisioned for major industrial development. Together, the Core-Adjacent and Extension areas comprise what has been referred to officially as the "Extended Function Area."

The subareas are meaningful for differentiating urban form and performance characteristics among the place types. For example, walkable, mixed-use commercial areas in the Core will be developed at higher intensities than their counterparts in the Extension areas.

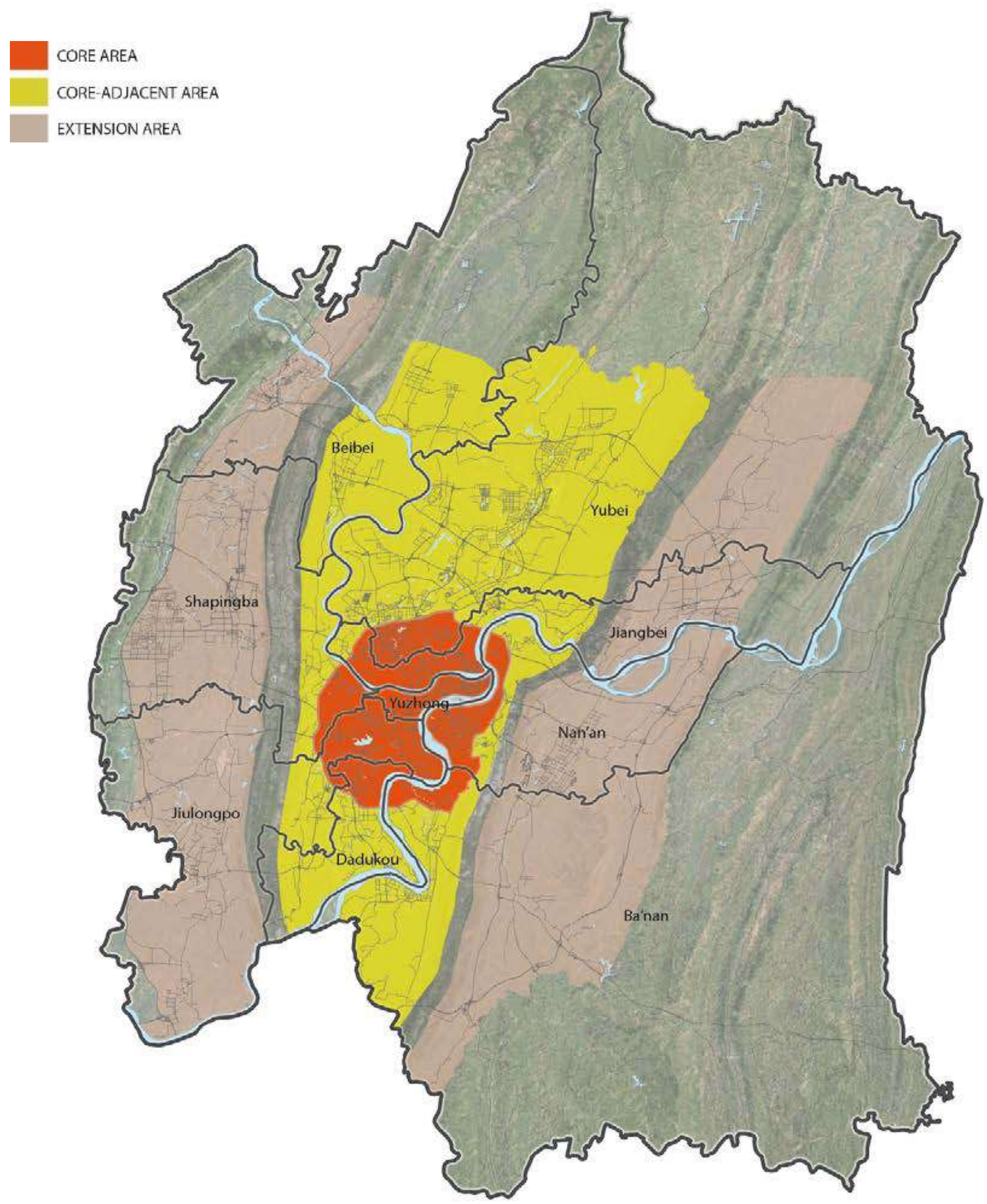


Figure 43. Chongqing study area, with subareas and district boundaries

The place types include three walkable variants defined by density and use along with three superblock configurations also varied by density and use. Each can exist in areas with and without access to transit. The resulting matrix of 36 place types is shown in Figure 44. Finally, the variation in mix and density is determined by national and local norms. Densities vary according to the specified floor area ratios (FAR) of residential and commercial uses. Figure 44 provides an overview of the place type framework.

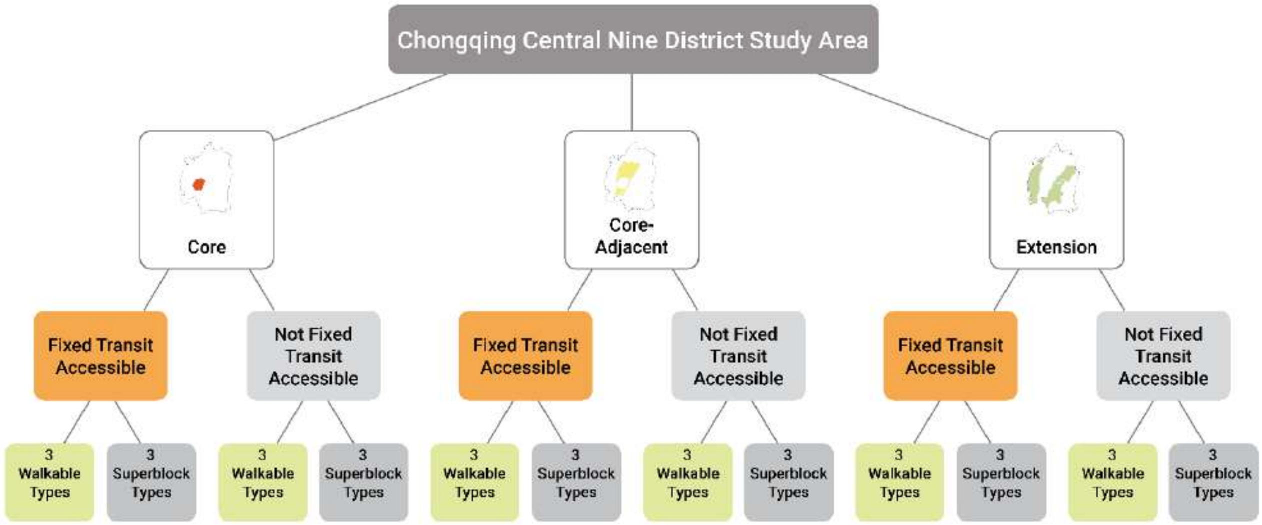


Figure 44. RapidFire place type framework for Chongqing

4.1.1 Primary Development Patterns: Superblocks vs. Walkable Development

Two dominant forms of urban growth are contrasted in the scenarios: superblocks within expansive land use patterns, and walkable, people-oriented development within compact development patterns.

Superblock Development

Superblocks have been the dominant form of urban development throughout China, and in Chongqing, over the past two decades. Characterized by single-use zoning that separates residential and commercial areas, and large blocks served by wide arterial streets, superblocks are oriented foremost to autos rather than pedestrians. It is this development configuration that has led to Chongqing's growing fragmentation, vast expansion, and decreasing densities.

The three superblock urban form variants include Superblock Commercial, Superblock Residential, and Superblock Industrial. These types represent development that is mostly separate-use, though incorporate some mix of housing and jobs to account for the local shops and services located within residential areas and workforce housing in commercial and industrial areas.

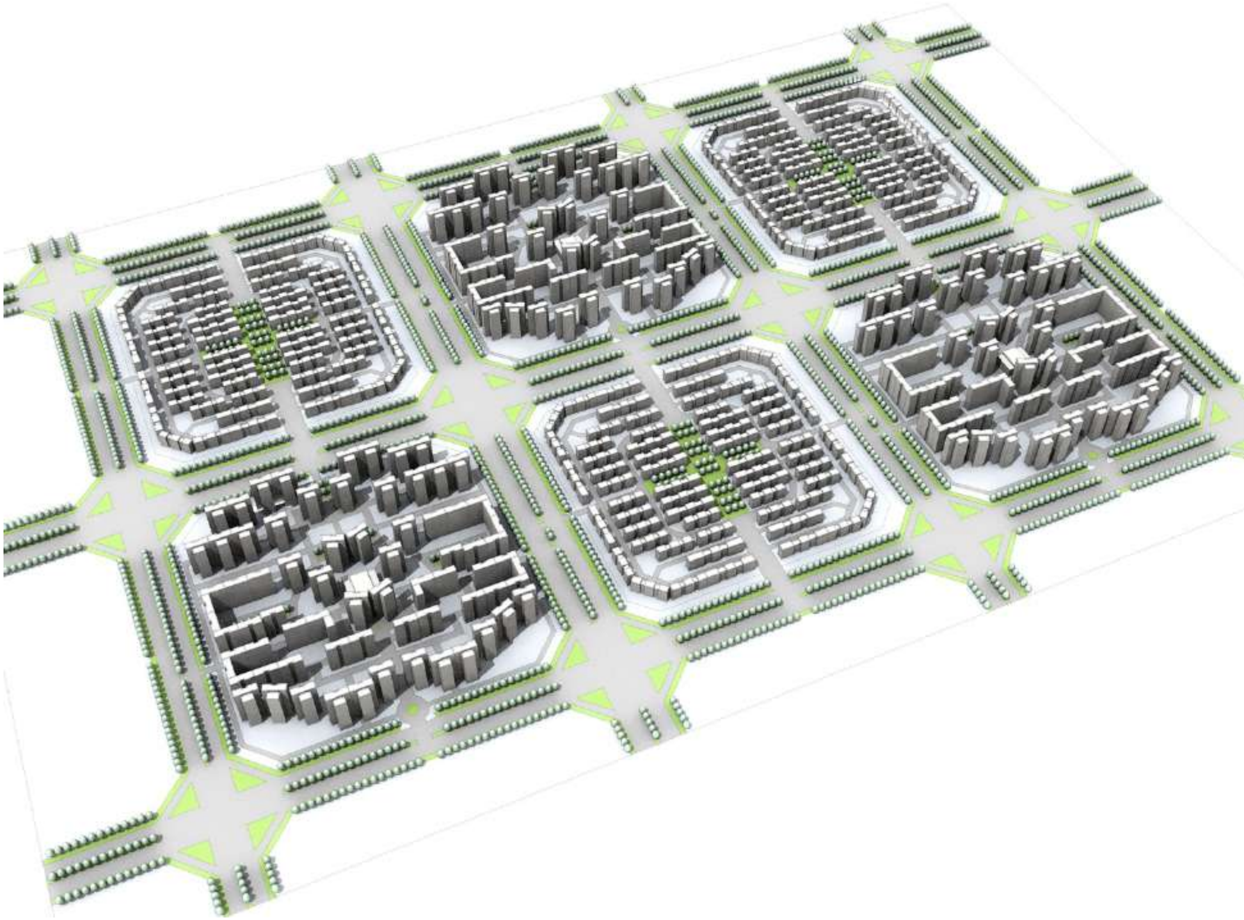


Figure 45. Illustrative diagram depicting the urban form of superblocks

Walkable, People Oriented Development

People oriented development, or POD, is used here as a general term that refers to development designed to be compact, walkable, and above all, livable. If built in proximity to high-capacity transit, POD is considered transit-oriented development, or TOD – a more specific classification. The "people-oriented development" concept aligns with China's 2016 urban development guidelines. Essentially, POD is designed at a scale, and with a mix of jobs, housing, and services, to support active communities. Small blocks are served by dense street networks that enhance walking, biking, and traffic flow. Density and the mix of uses are coordinated to transit capacity, making mobility more complementary to transit and active transportation modes rather than auto use.

Walkable POD areas can encompass a range of development intensities, from urban centers with floor-area ratios (FARs) as high as 8 to 10, to nearby moderate-density residential-focused neighborhoods with FARs of 1.5 to 3. They can also vary in use from primarily commercial development appropriate at major transit nodes to create job centers, to residential developments that support secondary and feeder transit locations. In all cases POD would be mixed use with worker- and resident-serving ground-floor shops, restaurants, and services enhancing street life and walkability.

The three walkable urban form variants include Walkable Commercial Mix, Walkable Residential Mix, and Walkable Medium-Density Residential Mix. All types include a mix of housing and employment uses, though with different relative concentrations. The Walkable Commercial Mix and Walkable Residential Mix types are the highest-intensity place types, consisting of high- and mid-rise buildings, that anchor mixed-use, transit-oriented centers. Their densities reach as high as 250 people and over 1,000 employees per hectare (in terms of gross area) in the Core area, with densities that taper down in the Core-Adjacent and Extension areas. The Walkable Medium-Density Residential Mix type, by contrast, represents largely mid-rise compact residential neighborhoods, inclusive of local shops, public facilities, and services, which may be located adjacent to the higher-intensity portions of mixed-use centers.

It is important to note that not all development around transit stations can be considered TOD. While proximity is one criterion for TOD, development must also be designed for walkability, and with mixed uses. Superblock development near transit can only be considered transit-adjacent. Of the 36 place types used in the scenario analysis, only nine meet the location and urban form criteria to be classified as TOD.

Chongqing contains many precedents for TOD. The metro system, because it is large and expanding, provides significant land capacity for TOD within walking distance from existing stations, as noted earlier. Proximity to a station is not the only defining criteria for TOD; to make the best use of transit and ensure high ridership, development must occur at sufficient densities to provide good accessibility to a multitude of destinations. And buildings, blocks, and streets must be configured to support the movement of people rather than cars.

Figure 45. Illustrative diagram depicting the urban form of walkable development

Comparing TOD and Superblock Performance

The substantial impacts of urban form on household travel behavior have been demonstrated throughout the world, and specifically in China by a detailed empirical study carried out in Jinan[6]. It compared nine neighborhoods which represent four different urban form typologies commonly found in Chinese cities: "traditional", "grid", "enclave", and "superblock". Respectively, they represent characteristics of the local city development during different historic periods in a rough time sequence. A summary of the nine neighborhood cases and their form features associated with each typology is shown in Table 6. Summary of urban form features of neighborhood typologies explored in Jinan.

Table 6. Summary of urban form features of neighborhood typologies explored in Jinan[7]

Neighborhood 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	Small 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	5. Zhang-Village	5. Old Commercial District	3. Wuying-Tan 4. Yanzi-Shan 5. Dong-Cang 6. Foshan-Yuan	7. Shanghai-Garden 8. Sunshine 100 9. Lv-Jing

6 Jiang, Y., Gu, P., Chen, Y., He, D. and Mao, Q., 2017. Influence of land use and street characteristics on car ownership and use: Evidence from Jinan, China. *Transportation Research Part D: Transport and Environment*, *52*, pp.518-534. https://doi.org/10.1016/j.trd.2016.08.030

7 Ibid

Based on travel diaries filled out by occupants, weekly travel distances show large differences. Households in the “superblock” travel 250 km total per week on average, whereas households in the other three types travel much shorter distances (150 – 170 km). As seen in Figure 45, the difference comes mostly from car travel distances, not distances by other modes. In addition, the composition of travel distance by mode is somewhat unique for the “traditional” typology, where households use less transit and travel very little by car compared to others; instead, they travel more with E-bikes and less distance overall.

In comparing the mode share, there is also a large difference in car use between the “superblock” and the others. In the “superblock,” among all weekly trips, about 33% of trips are made by car, whereas the shares in other neighborhood types are lower than 8%.

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 distance and more likely by car. To help chart a more energy-efficient Chinese urban future, the analysis suggests neighborhood forms in China should move towards Low Carbon Design Principles including walkable small blocks, mixed-use, pedestrian and bike friendly design, transit convenience and restriction of parking supply. At the city scale, it is recommended to provide ubiquitously good regional accessibility by developing a polycentric city structure matched with a robust transit network.

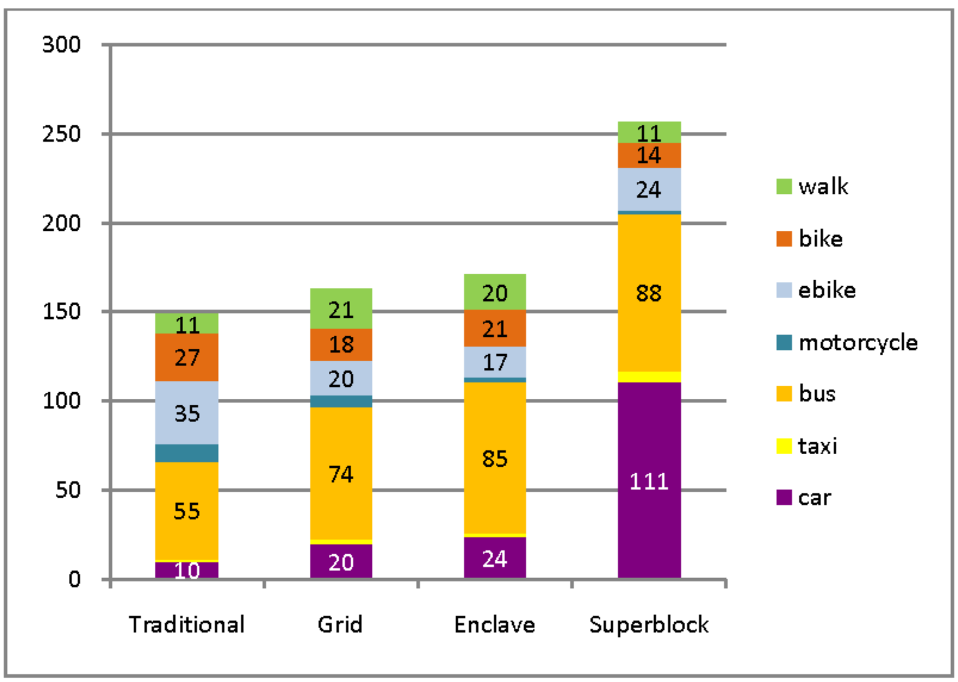


Figure 45. Average household weekly travel distance (km) across the four neighborhood typologies

4.1.2 Place Type Composition

The characteristics of the place types result from the following set of inputs:

Average residential and commercial building floor-area ratio (FAR)
FAR is defined as the ratio of building floor area to parcel area. Residential FAR is used to calculate net residential density along with inputs for residential unit size and building use efficiency. Commercial FAR is used to calculate net employment density along with inputs for the distribution of jobs by employment space type, commercial floor area per employee, and building use efficiency. Gross density is calculated, in turn, by multiplying net density by a net-to-gross factor.

Distribution of jobs by employment space type
The modeled employment space types include office, retail, civic, industrial, and warehouse. The place types vary in their relative proportions of each, with the walkable, mixed-use types primarily accommodating buildings for office, retail, and civic employment. Industrial and warehouse buildings, defined separately because they have different space requirements per employee, are considered to house employment in the industrial sector, and are located mostly within the superblock types.

Distribution of housing by type
The model allows users to specify the proportions of single-family and multifamily housing in each place type. Due to the minimal proportion of single-family home development in the Chongqing it was assumed that all housing growth would occur within multifamily building types.

Average residential unit sizes
Due to standards for the provision of residential space per capita, residential unit sizes were not varied among the place types. A uniform home size of 120 square meters was assumed. This assumption is used as a component in net density calculations.

Average floor area per employee, by employment space type
The inputs for floor area per employee, by employment space type, were varied among the place types based on subarea and transit proximity. These assumptions are used as a component in net density calculations.

Building use efficiency
Building use efficiency is defined as the percent net or leasable building floor area of total building floor area. These assumptions are used as a component in net density calculations.

Net-to-gross factor
A net-to-gross factor is defined as the percent of total land area within a place type covered by "net" parcel area. The net-to-gross factor plus the percentages of land for streets, parks, and civic areas total 100%. Multiplying a net density by a net-to-gross factor yields a gross density. (For example, an area with an average net residential density of 150 units per hectare and a net-to-gross factor of 65% would have an average gross residential density of 98 units per hectare when measured over "gross" area inclusive of streets, park, and civic areas.)

Streets, parks, and civic areas
Streets, parks, and civic areas are required to serve all new development. The amounts of each by place type are specified separately as percentages of total "gross" land area. To support the infrastructure provision and cost estimates, street area is further delineated in terms of the proportions of road length for primary and secondary roads.

Table 7 summarizes the core characteristics of the place types.

Table 7. Summary of place type characteristics (part 1 of 2)

SUBAREA	TRANSIT PROXIMITY	PLACE TYPE CODE	URBAN FORM	URBAN FORM CHARACTERISTICS: Block size	Residential FAR	Commercial FAR	Building Heights
Core *Infill/ Redevelopment*	Transit Oriented	1A	Walkable Commercial Mix	Small	2.0	5.0	High-rise
		1B	Walkable Residential Mix	Small	3.2	0.9	High-rise
		1C	Walkable Medium Density Residential Mix	Small	2.2	0.5	Mid-rise
	Transit Adjacent	1D	Superblock Commercial Mix	Large	1.6	4.4	Mid- to High-rise
		1E	Superblock Residential Mix	Large	2.7	0.8	Mid- to High-rise
		1F	Superblock Industrial	Large	0.5	1.8	Low-rise
	No transit	2A	Walkable Commercial Mix	Small	0.8	3.2	High-rise
		2B	Walkable Residential Mix	Small	2.2	0.5	High-rise
		2C	Walkable Medium Density Residential Mix	Small	2.0	0.5	Mid- to High-rise
	No transit	2D	Superblock Commercial Mix	Large	0.8	3.2	Mid- to High-rise
		2E	Superblock Residential Mix	Large	2.0	0.5	Mid- to High-rise
		2F	Superblock Industrial	Large	0.4	1.6	Low-rise
Core-Adjacent Greenfield	Transit Oriented	3A	Walkable Commercial Mix	Small	1.5	4.0	Mid- to High-rise
		3B	Walkable Residential Mix	Small	2.7	0.5	Mid- to High-rise
		3C	Walkable Medium Density Residential Mix	Small	2.0	0.5	Mid-rise
	Transit Adjacent	3D	Superblock Commercial Mix	Large	0.4	3.6	Mid- to High-rise
		3E	Superblock Residential Mix	Large	2.2	0.5	Mid- to High-rise
		3F	Superblock Industrial	Large	0.3	1.5	Low-rise
	No transit	4A	Walkable Commercial Mix	Small	0.7	2.9	Mid- to High-rise
		4B	Walkable Residential Mix	Small	2.0	0.5	Mid- to High-rise
		4C	Walkable Medium Density Residential Mix	Small	1.5	0.5	Mid-rise
	No transit	4D	Superblock Commercial Mix	Large	0.4	2.2	Low- to Mid-rise
		4E	Superblock Residential Mix	Large	1.5	0.5	Low- to Mid-rise
		4F	Superblock Industrial	Large	0.3	1.5	Low-rise
Extension Greenfield	Transit Oriented	5A	Walkable Commercial Mix	Small	1.5	2.5	Mid-rise
		5B	Walkable Residential Mix	Small	2.2	0.5	Mid-rise
		5C	Walkable Medium Density Residential Mix	Small	1.6	0.5	Mid-rise
	Transit Adjacent	5D	Superblock Commercial Mix	Large	0.4	2.6	Low- to Mid-rise
		5E	Superblock Residential Mix	Large	1.7	0.5	Low- to Mid-rise
		5F	Superblock Industrial	Large	0.3	1.5	Low-rise
	No transit	6A	Walkable Commercial Mix	Small	0.5	2.5	Mid-rise
		6B	Walkable Residential Mix	Small	1.7	0.5	Mid-rise
		6C	Walkable Medium Density Residential Mix	Small	1.3	0.5	Low- to Mid-rise
	No transit	6D	Superblock Commercial Mix	Large	0.2	1.8	Low- to Mid-rise
		6E	Superblock Residential Mix	Large	1.2	0.5	Low- to Mid-rise
		6F	Superblock Industrial	Large	0.3	1.5	Low-rise

Summary of place type characteristics (part 2 of 2)

SUBAREA	TRANSIT PROXIMITY	PLACE TYPE CODE	GROSS DENSITY: *Gross population per hectare*	GROSS DENSITY: *Gross employees per hectare*	Mix of uses	Job mix
Core *Infill/ Redevelopment*	Transit Oriented	1A	200 pop/ha	1,200 emp/ha	High	Office, retail, public
		1B	300 pop/ha	170 emp/ha	Med	Regional and local office and retail
		1C	240 pop/ha	110 emp/ha	Med	Local services
	Transit Adjacent	1D	160 pop/ha	1,040 emp/ha	Low	Office, public
		1E	250 pop/ha	170 emp/ha	Med	Local services
		1F	60 pop/ha	130 emp/ha	Low	Industrial
	No transit	2A	80 pop/ha	790 emp/ha	High	Office, retail, public
		2B	210 pop/ha	90 emp/ha	Med	Regional and local office and retail
		2C	200 pop/ha	90 emp/ha	Med	Local services
	No transit	2D	80 pop/ha	790 emp/ha	Low	Office, public
		2E	190 pop/ha	90 emp/ha	Med	Local services
		2F	60 pop/ha	140 emp/ha	Low	Industrial
Core-Adjacent Greenfield	Transit Oriented	3A	140 pop/ha	550 emp/ha	High	Office, retail, public
		3B	230 pop/ha	70 emp/ha	Med	Regional and local office and retail
		3C	160 pop/ha	80 emp/ha	Med	Local services
	Transit Adjacent	3D	40 pop/ha	500 emp/ha	Low	Office, public
		3E	190 pop/ha	70 emp/ha	Med	Local services
		3F	30 pop/ha	120 emp/ha	Low	Industrial
	No transit	4A	60 pop/ha	280 emp/ha	Med	Office, retail, public
		4B	170 pop/ha	70 emp/ha	Med	Regional and local office and retail
		4C	170 pop/ha	70 emp/ha	Med	Local services
	No transit	4D	30 pop/ha	220 emp/ha	Low	Office, public
		4E	130 pop/ha	70 emp/ha	Med	Local services
		4F	40 pop/ha	110 emp/ha	Low	Industrial
Extension Greenfield	Transit Oriented	5A	140 pop/ha	360 emp/ha	High	Office, retail, public
		5B	190 pop/ha	70 emp/ha	Med	Local office and retail
		5C	150 pop/ha	80 emp/ha	Med	Local services
	Transit Adjacent	5D	40 pop/ha	370 emp/ha	Low	Office, public
		5E	150 pop/ha	70 emp/ha	Med	Local services
		5F	30 pop/ha	120 emp/ha	Low	Industrial
	No transit	6A	50 pop/ha	360 emp/ha	Med	Office, retail, public
		6B	150 pop/ha	70 emp/ha	Med	Local office and retail
		6C	140 pop/ha	70 emp/ha	Med	Local services
	No transit	6D	20 pop/ha	130 emp/ha	Low	Office, public
		6E	110 pop/ha	60 emp/ha	Med	Local services
		6F	40 pop/ha	80 emp/ha	Low	Industrial

4.1.3 Place Type Profiles

The following profiles provide local examples of the schema of place types and summarize their key characteristics.

Walkable Commercial Mix *with Transit* (Place Types 1A, 3A, 5A)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	2.0	1.5	1.5
Employment	5.0	4.0	2.5
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	200	140	140
Employees	1,200	550	360
Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily commercial areas of urban mixed-use centers, with the highest densities in the Core, slightly lower densities in the Core-Adjacent, and lower densities in the Extension areas. High concentrations of office, retail, and civic employment. Mid- to high-rise buildings oriented to street, easily accessible and with minimal setbacks, create walkable environments. Grid or otherwise small-block street pattern. Parking limited to on-street supply, with some structured and underground parking. Accessible by regional metro transit, attracting commute and other trips from throughout the region.

Local example: Guanyinqiao. Total FAR: 3.9 / Population density: 280 / Employment density: 1,710

Walkable High-Density Residential Mix *with Transit* (Place Types 1B, 3B, 5B)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	3.2	2.7	2.2
Employment	0.9	0.5	0.5
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	300	230	190
Employees	170	70	70
Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily residential areas of urban mixed-use centers, with retail and services mainly as ground floor uses. Mid- to high-rise buildings oriented to street, easily accessible and with minimal setbacks, create a walkable environment. Grid or otherwise small-block street pattern. Parking limited to on-street supply, with some structured and underground parking. Adjacent to Walkable Commercial Mix areas, and accessible by regional metro transit.

Local example: Hanyu Road. Total FAR: 2.7 / Population density: 560 / Employment density: 410

Walkable Medium-Density Residential Mix *with Transit* (Place Types 1C, 3C, 5C)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	2.2	2.0	1.6
Employment	0.5	0.5	0.5

Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	240	160	150
Employees	110	80	80

Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily residential neighborhood areas, with local-serving retail and services as ground floor uses along main streets, or interspersed in neighborhoods. Mid-rise buildings oriented to street, easily accessible and with minimal setbacks, foster street life walkability. Grid or otherwise small-block street pattern. Parking limited to on-street supply, with some parking lots. Short walking distance to regional metro transit or nearby mixed-use centers.

Local example: Renmin Square Neighborhood. Total FAR: 2.1 / Population density: 220 / Employment density: 120

Walkable Medium-Density Residential Mix *without Transit* (Place Types 2C, 4C, 6C)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	2.0	1.5	1.3
Employment	0.5	0.5	0.5

Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	200	170	140
Employees	90	70	70

Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily residential neighborhood areas, with local-serving retail and services as ground floor uses along main streets, or interspersed in neighborhoods. Mid-rise buildings oriented to street, easily accessible and with minimal setbacks, foster street life walkability. Grid or otherwise small-block street pattern. Parking limited to on-street supply, with some parking lots. Access to regional metro transit or nearby mixed-use centers via local transit connections, or longer walking distances than in transit-proximate variants of this type.

Local example: Longmen Road. Total FAR: 0.9 / Population density: 120 / Employment density: 125

Superblock Commercial *with Transit* (Place Types 1D, 3D, 5D)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	1.6	0.4	0.4
Employment	4.4	3.6	2.6
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	160	40	40
Employees	1,040	500	370
Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily commercial areas in segregated-use superblock configurations. Highest employment densities are found in the Core, with lower densities in the Core-Adjacent and Extension areas. Can accommodate office and civic employment. Mid- to high-rise towers are oriented to the interiors of large-scale blocks. Typically gated, buildings within superblocks are not freely accessible. Wide, auto oriented streets do not foster pedestrian activity, while a large-grain urban fabric creates longer travel distances. Sufficient parking in the form of surface lots and underground garages. Adjacent to transit, though not designed for easy walk accessibility.

Local example: Xiejiawan. Total FAR: 2.9 / Population density: 150 / Employment density: 810

Superblock Commercial *without Transit* (Place Types 2D, 4D, 6D)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	0.8	0.4	0.2
Employment	3.2	2.2	1.8
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	80	30	20
Employees	790	220	130
Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	15%	40%
Office, retail, civic, and other	100%	85%	60%

Description

Primarily commercial areas in segregated-use superblock configurations. Densities are lower than in areas close to transit. Can accommodate office, civic, and light industrial employment, along with some housing. Mid- to high-rise towers are oriented to the interiors of large-scale blocks. Typically gated, buildings within superblocks are not freely accessible. Wide, auto oriented streets do not foster pedestrian activity, while a large-grain urban fabric creates longer travel distances. Sufficient parking in the form of surface lots and underground garages. Not readily accessible by transit.

Local example: Danlong Road. Total FAR: 2.1 / Population density: 165 / Employment density: 310

Superblock Residential *with Transit* (Place Types 1E, 3E, 5E)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	2.7	2.2	1.7
Employment	0.8	0.5	0.5
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	250	190	150
Employees	170	70	70
Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily residential areas in segregated-use superblock configurations. Residential densities vary slightly depending on regional location, though building patterns are homogenous. Some retail, services, and community facilities are located within residential blocks. Mid- to high-rise towers are oriented to the interiors of large-scale blocks. Typically gated, buildings within superblocks are not freely accessible. Wide, auto oriented streets do not foster pedestrian activity, while a large-grain urban fabric creates longer travel distances. Sufficient parking in the form of surface lots and underground garages. Adjacent to transit, though not designed for easy walk accessibility.

Local example: Beibinyi Road. Total FAR: 2.4 / Population density: 280 / Employment density: 140

Superblock Residential *without Transit* (Place Types 2E, 4E, 6E)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	2.0	1.5	1.2
Employment	0.5	0.5	0.5
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	190	130	110
Employees	90	70	60
Employment Mix	Core	Core-Adjacent	Extension
Industrial	0%	0%	0%
Office, retail, civic, and other	100%	100%	100%

Description

Primarily residential areas in segregated-use superblock configurations. Residential densities are lower than in areas close to transit, and vary slightly depending on regional location. Building patterns are homogenous. Some retail, services, and community facilities are located within residential blocks. Mid- to high-rise towers are oriented to the interiors of large-scale blocks. Typically gated, buildings within superblocks are not freely accessible. Wide, auto-oriented streets do not foster pedestrian activity, while a large-grain urban fabric creates longer travel distances. Sufficient parking in the form of surface lots and underground garages. Not accessible by transit.

Local example: Fenglin Road. Total FAR: 2.0 / Population density: 190 / Employment density: 90

Superblock Industrial *with Transit* (Place Types 1F, 3F, 5F)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	n/a	0.3	0.3
Employment	n/a	1.5	1.5
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	n/a	30	30
Employees	n/a	120	120
Employment Mix	Core	Core-Adjacent	Extension
Industrial	n/a	75%	75%
Office, retail, civic, and other	n/a	25%	25%

Description

Industrial employment zones in large-scale block configurations. New industrial growth occurs only in the Core-Adjacent and Extension areas, with locations near transit more likely to be developed for light or "smart" industrial. Areas may accommodate some office and retail employment, as well as housing. Building form, job density, and proximity to other uses vary according to employment activity. Parking provided in structures and surface lots. Industrial uses near transit facilitate employee accessibility, though the large block stucture hinders pedestrian activity.

Local example: Jinguo Avenue. Total FAR: 1.6 / Population density: 40 / Employment density: 360

Superblock Industrial *without Transit* (Place Types 2F, 4F, 6F)

Floor Area Ratio (FAR)	Core	Core-Adjacent	Extension
Residential	0.4	0.3	0.3
Employment	1.6	1.5	1.5
Gross Density (per hectare)	Core	Core-Adjacent	Extension
Population	60	40	40
Employees	140	110	80
Employment Mix	Core	Core-Adjacent	Extension
Industrial	79%	88%	90%
Office, retail, civic, and other	21%	12%	10%

Description

Industrial employment zones in large-scale block configurations. New industrial growth occurs only in the Core-Adjacent and Extension areas. Areas may accommodate some office and retail employment, as well as on-site housing. Building form, job density, and proximity to other uses may vary according to employment activity. Sufficient parking provided in surface lots. Industrial areas away from regional transit may be served by local connections to the metro network, or employee shuttles.

Local example: Jinyu Avenue. Total FAR: 1.0 / Population density: 60 / Employment density: 220

4.1.4 Representation of Existing (“Base”) Development

In RapidFire model terminology, existing development is known as the “base,” with respect to which new growth is applied. In the scenario end year (2035), the base and growth added together is known as the scenario “endstate.” Scenario metrics and results can be isolated for new growth alone or assessed in total for all development. The distinction between the base and new growth is significant to modeling the transitions projected to occur over time.

For the purposes of scenario modeling, existing development in the central city study area is represented in terms of the place types. The typing process was performed using transportation analysis zone (TAZ)-level data populated with a mixture of empirical and imputed data for population, employment, building area, and developed area. Given the scale and imprecise nature of the base data that could be shared, relatively broad criteria were used for typing, as summarized in Table 8. The resulting modeled base is a generalized depiction of existing conditions appropriate for modeling the relative differences among scenarios.

Table 8. Base place typing criteria

REGIONAL LOCATION	TRANSIT PROXIMITY	PLACE TYPE CODE	URBAN FORM	Road Density	FAR	Job Density
Core *Infill/Redevelopment*	Transit Oriented	1A	Walkable Commercial Mix	/	>3	>10,000/km^2
		1B	Walkable Residential Mix			≤10,000/km^2
		1C	Walkable Medium Density Residential Mix		≤3	
	Transit Adjacent	1D	Superblock Commercial Mix	≤5 km/km2	≤1.5	>10,000/km^2
		1E	Superblock Residential Mix			≤10,000/km^2
		1F	Superblock Industrial			>10,000/km^2 & job_ind > 500
	No transit	2A	Walkable Commercial Mix	/	>3	>10,000/km^2
		2B	Walkable Residential Mix			≤10,000/km^2
		2C	Walkable Medium Density Residential Mix		≤3	
	No transit	2D	Superblock Commercial Mix	≤5 km/km2	≤1.5	>10,000/km^2
		2E	Superblock Residential Mix			≤10,000/km^2
		2F	Superblock Industrial			>10,000/km^2 & job_ind > 500
Core-Adjacent *Greenfield*	Transit Oriented	3A	Walkable Commercial Mix	/	>3	>10,000/km^2
		3B	Walkable Residential Mix			≤10,000/km^2
		3C	Walkable Medium Density Residential Mix		≤3	
	Transit Adjacent	3D	Superblock Commercial Mix	≤5 km/km2	≤1.5	>10,000/km^2
		3E	Superblock Residential Mix			≤10,000/km^2
		3F	Superblock Industrial			>10,000/km^2 & job_ind > 500
	No transit	4A	Walkable Commercial Mix	/	>3	>10,000/km^2
		4B	Walkable Residential Mix			≤10,000/km^2
		4C	Walkable Medium Density Residential Mix		≤3	
	No transit	4D	Superblock Commercial Mix	≤5 km/km2	≤1.5	>10,000/km^2
		4E	Superblock Residential Mix			≤10,000/km^2
		4F	Superblock Industrial			>10,000/km^2 & job_ind > 500
Extension *Greenfield*	Transit Oriented	5A	Walkable Commercial Mix	/	>3	>10,000/km^2
		5B	Walkable Residential Mix			≤10,000/km^2
		5C	Walkable Medium Density Residential Mix		≤3	
	Transit Adjacent	5D	Superblock Commercial Mix	≤5 km/km2	≤1.5	>10,000/km^2
		5E	Superblock Residential Mix			≤10,000/km^2
		5F	Superblock Industrial			>10,000/km^2 & job_ind > 500
	No transit	6A	Walkable Commercial Mix	/	>3	>10,000/km^2
		6B	Walkable Residential Mix			≤10,000/km^2
		6C	Walkable Medium Density Residential Mix		≤3	
	No transit	6D	Superblock Commercial Mix	≤5 km/km2	≤1.5	>10,000/km^2
		6E	Superblock Residential Mix			≤10,000/km^2
		6F	Superblock Industrial			>10,000/km^2 & job_ind > 500

Figure 46 illustrates existing built-up area classified by urban form type, excluding industrial uses. Note that outside the Core there is very little existing walkable development (as defined by block size), even around existing metro stations. But the large quantity of walkable urban fabric shown in the Core explains Chongqing's high mode share for walking as compared to other Chinese cities.

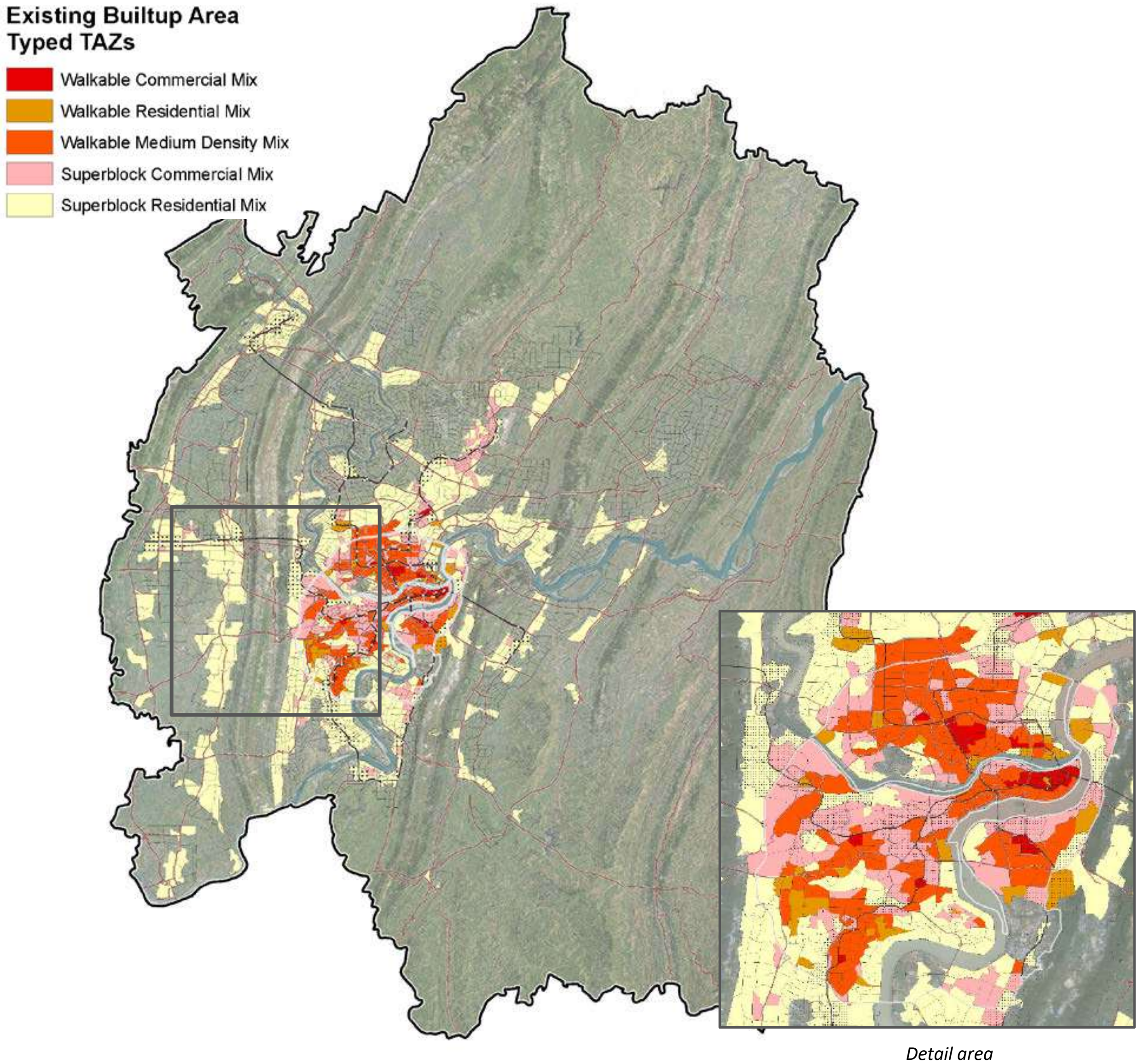


Figure 46. Existing built-up area classified by place type (industrial not shown)

4.2 Scenario Composition

Using the 36 place types, a range of scenarios was developed to understand the implications of growth trajectories that vary the spatial structure, intensity, design, transit proximity, and employment focus of new urban growth in Chongqing. The scenario concepts can be broadly conceptualized in terms of regional job location, proximity to transit, and predominant urban form. Two primary scenarios – "Trend" and "Compact Growth" – were developed to clarify options at either end of a spectrum. The scenarios are described in detail in Section 2.

Scenarios are defined in terms of population, dwelling unit, and job growth allocations to place types. As described earlier, the place types represent land use patterns in varying conditions of transit proximity and subarea. The distribution of population and job growth in the Chongqing scenarios are summarized in Table 9. The model uses these allocations as inputs for the calculations that comprise the analytical modules within RapidFire.

Table 9. Scenario population and job growth distribution by place type

	TREND						COMPACT GROWTH					
Population Growth Distribution	A. Walkable Commercial Mix	B. Walkable Residential Mix	C. Medium Density Residential Mix	D. Superblock Commercial Mix	E. Superblock Residential Mix	F. Superblock Industrial	A. Walkable Commercial Mix	B. Walkable Residential Mix	C. Medium Density Residential Mix	D. Superblock Commercial Mix	E. Superblock Residential Mix	F. Superblock Industrial
Core Transit	1%	2%	1%	0.5%	2%	0%	2%	6%	3%	0%	0%	0%
Core no Transit	0%	0%	0%	0.2%	3%	0%	0%	0%	0%	0%	0%	0%
Core-Adjacent Transit	0%	0%	1%	0%	19%	0%	19%	35%	22%	0%	0%	2%
Core-Adjacent no Transit	0%	0%	0%	1%	15%	8%	0%	0%	0%	0%	0%	2%
Extension Transit	0%	0%	0%	1%	4%	0%	1%	4%	5%	0%	0%	0.4%
Extension no Transit	0%	0%	0%	1%	24%	16%	0%	0%	0%	0%	0%	1%
Job Growth Distribution												
Core Transit	6%	2%	5%	5%	0%	0%	4%	1%	0%	0%	0%	0%
Core no Transit	0%	0%	0%	6%	1%	0%	0%	0%	0%	0%	0%	0%
Core-Adjacent Transit	0%	0%	0.5%	3%	2%	17%	43%	8%	3%	0%	0%	2%
Core-Adjacent no Transit	0%	0%	0%	1%	1%	20%	0%	0%	0%	0%	0%	24%
Extension Transit	0%	0%	0%	1%	0.4%	3%	0.5%	0.2%	0.2%	0%	0%	4%
Extension no Transit	0%	0%	0%	1%	2%	22%	0%	0%	0%	0%	0%	11%

4.3 Scenario Analysis

As described earlier, place types are defined in terms of their built form characteristics. These quantified characteristics are used as direct inputs for calculating land consumption, infrastructure requirements, building energy use, and water use. The built form characteristics are indirectly related to assumptions about travel behavior – for example, small-block areas within a regional job center, with close proximity to transit, leads to lower travel distances and auto mode share, as has been represented based on a combination of empirical data and research-based model assumptions.

The following sections describe how results are calculated for the full range of scenario metrics – land consumption, infrastructure requirements and costs, building energy and water use and related impacts, and passenger vehicle travel and related impacts – based on place type characteristics, scenario allocations, technical assumptions, and assumed cost factors.

4.3.1 Land Consumption

New land consumption is estimated based on the population and employment density of place types, and the assumption as to whether new development occurs on greenfield land or as infill or redevelopment in already urbanized areas. As a generalized assumption, all growth in the Core is assumed to occur as infill or redevelopment, while growth in the Core-Adjacent and Extension areas is assumed to occur on previously non-urbanized land.

The population and employment density of each place type are calculated from the "bottom up", according to assumptions about building form and occupancy, including residential and commercial floor area ratio (FAR); the size of housing units; and building floor area per employee. FARs are varied significantly among the types, while the average size of housing units is assumed as a constant of 120 square meters. Building floor area per employee varies by place type and sector, ranging from a minimum of 15 square meters per office employee in Walkable Commercial Mix place type near transit in the Core, to a maximum of 150 square meters per industrial employee in the Superblock Industrial place type in the Extension area.

Taken together, the built form assumptions yield net densities for each place type. Densities over "gross" land area, in turn, are estimated via assumptions about the proportion of net parcel area to land area inclusive of the streets, parks, and civic areas needed to serve new development. Note that the types do not account for the development of large open spaces, or interstitial undeveloped areas within an expanded urban footprint that can occur with very fragmented, dispersed development patterns.

Scenarios vary in their land consumption, then, depending primarily upon the FAR, housing, and employment densities of the place types, and the place types to which population and job growth is allocated.

The FARs, net to gross land area factors, and resulting densities of the place types are summarized in Table 10.

Table 10. Floor area ratios (FARs), net to gross land area factors, and densities by place type

				URBAN FORM CHARACTERISTICS					GROSS DENSITY	
REGIONAL LOCATION	TRANSIT PROXIMITY	PLACE TYPE CODE	URBAN FORM	Block size	Residential FAR	Commercial FAR	Net to gross land area factor	Building Heights	*Gross population per hectare*	*Gross employees per hectare*
Core *Infill/ Redevelopment*	Transit Oriented	1A	Walkable Commercial Mix	Small	2.0	5.0	62%	High-rise	200 pop/ha	1,200 emp/ha
		1B	Walkable Residential Mix	Small	3.2	0.9	58%	High-rise	300 pop/ha	170 emp/ha
		1C	Walkable Medium Density Residential Mix	Small	2.2	0.5	58%	Mid-rise	240 pop/ha	110 emp/ha
	Transit Adjacent	1D	Superblock Commercial Mix	Large	1.6	4.4	62%	Mid- to High-rise	160 pop/ha	1,040 emp/ha
		1E	Superblock Residential Mix	Large	2.7	0.8	58%	Mid- to High-rise	250 pop/ha	170 emp/ha
		1F	Superblock Industrial	Large	0.5	1.8	70%	Low-rise	60 pop/ha	130 emp/ha
	No transit	2A	Walkable Commercial Mix	Small	0.8	3.2	62%	High-rise	80 pop/ha	790 emp/ha
		2B	Walkable Residential Mix	Small	2.2	0.5	58%	High-rise	210 pop/ha	90 emp/ha
		2C	Walkable Medium Density Residential Mix	Small	2.0	0.5	58%	Mid- to High-rise	200 pop/ha	90 emp/ha
	No transit	2D	Superblock Commercial Mix	Large	0.8	3.2	62%	Mid- to High-rise	80 pop/ha	790 emp/ha
		2E	Superblock Residential Mix	Large	2.0	0.5	58%	Mid- to High-rise	190 pop/ha	90 emp/ha
		2F	Superblock Industrial	Large	0.4	1.6	80%	Low-rise	60 pop/ha	140 emp/ha
Core-Adjacent Greenfield	Transit Oriented	3A	Walkable Commercial Mix	Small	1.5	4.0	56%	Mid- to High-rise	140 pop/ha	550 emp/ha
		3B	Walkable Residential Mix	Small	2.7	0.5	54%	Mid- to High-rise	230 pop/ha	70 emp/ha
		3C	Walkable Medium Density Residential Mix	Small	2.0	0.5	54%	Mid-rise	160 pop/ha	80 emp/ha
	Transit Adjacent	3D	Superblock Commercial Mix	Large	0.4	3.6	56%	Mid- to High-rise	40 pop/ha	500 emp/ha
		3E	Superblock Residential Mix	Large	2.2	0.5	54%	Mid- to High-rise	190 pop/ha	70 emp/ha
		3F	Superblock Industrial	Large	0.3	1.5	70%	Low-rise	30 pop/ha	120 emp/ha
	No transit	4A	Walkable Commercial Mix	Small	0.7	2.9	54%	Mid- to High-rise	60 pop/ha	280 emp/ha
		4B	Walkable Residential Mix	Small	2.0	0.5	52%	Mid- to High-rise	170 pop/ha	70 emp/ha
		4C	Walkable Medium Density Residential Mix	Small	1.5	0.5	59%	Mid-rise	170 pop/ha	70 emp/ha
	No transit	4D	Superblock Commercial Mix	Large	0.4	2.2	56%	Low- to Mid-rise	30 pop/ha	220 emp/ha
		4E	Superblock Residential Mix	Large	1.5	0.5	54%	Low- to Mid-rise	130 pop/ha	70 emp/ha
		4F	Superblock Industrial	Large	0.3	1.5	80%	Low-rise	40 pop/ha	110 emp/ha
Extension Greenfield	Transit Oriented	5A	Walkable Commercial Mix	Small	1.5	2.5	58%	Mid-rise	140 pop/ha	360 emp/ha
		5B	Walkable Residential Mix	Small	2.2	0.5	54%	Mid-rise	190 pop/ha	70 emp/ha
		5C	Walkable Medium Density Residential Mix	Small	1.6	0.5	54%	Mid-rise	150 pop/ha	80 emp/ha
	Transit Adjacent	5D	Superblock Commercial Mix	Large	0.4	2.6	58%	Low- to Mid-rise	40 pop/ha	370 emp/ha
		5E	Superblock Residential Mix	Large	1.7	0.5	54%	Low- to Mid-rise	150 pop/ha	70 emp/ha
		5F	Superblock Industrial	Large	0.3	1.5	70%	Low-rise	30 pop/ha	120 emp/ha
	No transit	6A	Walkable Commercial Mix	Small	0.5	2.5	58%	Mid-rise	50 pop/ha	360 emp/ha
		6B	Walkable Residential Mix	Small	1.7	0.5	54%	Mid-rise	150 pop/ha	70 emp/ha
		6C	Walkable Medium Density Residential Mix	Small	1.3	0.5	61%	Low- to Mid-rise	140 pop/ha	70 emp/ha
	No transit	6D	Superblock Commercial Mix	Large	0.2	1.8	58%	Low- to Mid-rise	20 pop/ha	130 emp/ha
		6E	Superblock Residential Mix	Large	1.2	0.5	54%	Low- to Mid-rise	110 pop/ha	60 emp/ha
		6F	Superblock Industrial	Large	0.3	1.5	80%	Low-rise	40 pop/ha	80 emp/ha

4.3.2 Infrastructure Requirements and Costs

The RapidFire model can account for one-time construction costs, as well as ongoing maintenance costs, for infrastructure as scaled to the coverage of new greenfield development. The infrastructure costs for the Chongqing scenarios include construction costs for new primary and secondary roadways, water supply lines, wastewater drainage (sewer, stormwater, and combined wastewater) lines, and natural gas lines. Cost assumptions are applied on a per-kilometer basis to the lengths of new local infrastructure estimated to serve new greenfield development. Costs for new major highways are not included; however, further study could be undertaken to project the network coverage of new highways required to serve the land patterns of the alternative scenarios.

The lengths of new roadways needed to serve each hectare of new development are calculated based on the percentage street area coverage and relative proportion of primary and secondary roads assumed for each place type, and assumptions for the average dimensions of roadways by class based on roadways constructed in the year 2015 in Chongqing Municipality[8]. The place type assumptions are differentiated by broad land development pattern, as summarized in Table 11. Average road widths are summarized in Table 12.

The water supply, wastewater drainage, and natural gas supply pipeline lengths are estimated with respect to roadway length. The ratios of pipeline lengths to road lengths are derived from year-

[8] Chongqing Statistical Yearbook, 2016

2015 total infrastructure length figures for Chongqing Municipality[9], and are summarized in Table 13. Unit costs per kilometer of infrastructure are summarized in Table 14.

Table 11. Local roadway proportions by place type

Subarea	Transit Proximity	Place Type Code	Infrastructure: Primary road length share	Infrastructure: Secondary road length share
Core *Infill/ Redevelopment*	Transit Oriented	1A	15%	85%
		1B	15%	85%
		1C	10%	90%
	Transit Adjacent	1D	24%	76%
		1E	24%	76%
		1F	24%	76%
	No transit	2A	15%	85%
		2B	15%	85%
		2C	10%	90%
	No transit	2D	24%	76%
		2E	24%	76%
		2F	24%	76%
Core-Adjacent Greenfield	Transit Oriented	3A	15%	85%
		3B	15%	85%
		3C	10%	90%
	Transit Adjacent	3D	24%	76%
		3E	24%	76%
		3F	24%	76%
	No transit	4A	15%	85%
		4B	15%	85%
		4C	10%	90%
	No transit	4D	24%	76%
		4E	24%	76%
		4F	24%	76%
Extension Greenfield	Transit Oriented	5A	15%	85%
		5B	15%	85%
		5C	10%	90%

[9] Chongqing Statistical Yearbook, 2016

	Transit Adjacent	5D	24%	76%
		5E	24%	76%
		5F	24%	76%
	No transit	6A	15%	85%
		6B	15%	85%
		6C	10%	90%
	No transit	6D	24%	76%
		6E	24%	76%
		6F	24%	76%

Table 12. Infrastructure dimensions

Roadway type	Average width
Primary	37 m
Secondary	23 m

Table 13. Water, sewer, and natural gas line lengths in proportion to roadway length

Infrastructure type	Ratio of length to roadways
Water supply pipelines	2.0
Natural gas supply pipelines	2.6
Wastewater drainage pipelines	1.7

Table 14. Infrastructure cost assumptions

Infrastructure type	Cost per km
Primary road	40,719,492 RMB
Secondary/Collector road	24,761,853 RMB
Water supply pipeline	1,016,304 RMB
Natural gas supply pipeline	576,656 RMB
Water drainage pipelines	331,909 RMB
Primary road	40,719,492 RMB

4.3.3 Building Energy Use

Building energy use varies according to many factors, including building type and use, energy efficiency measures, behavior, and climate. Modeling residential and commercial energy use on the basis of land use patterns primarily shows the energy implications of varying the types of buildings, and the amounts of building area, constructed to accommodate new housing and jobs. Significant variation among building types – for example, large single-family detached homes as compared to multifamily homes – lead to substantial differences in energy use. The energy use of commercial buildings varies according to employment type, with office needs being different from retail, industrial, or other uses.

The RapidFire model estimates residential and commercial energy by applying energy use intensities (energy use per square meter of building floor area) to estimated floor area by building type. Evaluating scenario results using current-year baseline energy use factors highlights the effects of land use alone on energy demand. The further impacts of energy efficiency and supply policy can be gauged by applying assumptions for improved energy efficiency over time, or reductions in the carbon intensity of fuels.

Due to building regulations, there is little basis for varying residential unit sizes or building types assumptions for the place types in Chongqing. The scenarios assume a uniform average housing unit size, resulting in the same estimated residential energy use. Changes attributable to improvements in building efficiency as relates to policy can be tested by projecting lower energy use rates into the future.

Commercial energy use varies significantly among the scenarios because they assume different employment projections into the future. The Trend scenario accommodates a much higher proportion of industrial sector jobs than the Compact Future scenario. Thus, the differences in results are not representative of the impact of land use alone and are not presented for comparison. However, changes attributable to improvements in building efficiency as relates to policy can be tested by projecting lower energy use rates into the future.

Building Energy Carbon Emissions

Building energy CO_2 emissions are calculated by applying a per-kilogram emission rate to estimated energy use. A current emissions rate of 2.72 kg CO_2 per kilogram of standard coal equivalent is assumed. The results presented in the report assume the current rate into the future to highlight the impact of land use alone in reducing emissions. Lower future-year emissions rates that would result from improvements in energy efficiency, fuel mix, and the portfolio of electricity sources.

Building Energy Costs

Residential building energy costs are included, along with driving costs, as a component of household costs. They are estimated by applying unitary energy prices to calculated energy use. A price of 1.19 RMB per kilogram of standard coal equivalent in year-2018 dollars, calibrated to current average household use and cost, was applied as a composite energy price.

4.3.4 Water Use

Water use can be impacted by different land use patterns where there can be significant variations in landscaped areas, and irrigation needs due to climate. Chongqing is not subject to either of these conditions, so water use results are not presented for the scenarios. However, water use could be estimated to broadly gauge the impact of overall growth, and efficiency policies, on regional water demand. The RapidFire model estimates indoor water use on a per-capita basis for residential use, and a per-employee basis for commercial use. Outdoor water use is estimated based on assumptions for the percentage of developed area in each place type that is landscaped and irrigated, and reference evapotranspiration, which determines the rate at which grass needs to be irrigated.

4.3.5 Transportation – Vehicle Kilometers Traveled, Mode Choice, and Travel Time

Transportation impacts in the RapidFire model are calculated on a per-capita basis using rates derived from regional travel model outputs, coupled with adjustment factors to account for the impacts of walkable, mixed use development throughout the region on travel mode share and distances.

As an overview, the model works by applying per-capita factors to population based on place type. Endstate VKT in the model is calculated by multiplying the factors by the endstate total population in each place type.

*Travel distance factor = daily average trip number * mode share * trip distance*

The transportation model in RapidFire is sensitive to income, subareas, transit supply, and urban form configurations including development density and block size. The scenarios represent these factors via different combinations of place types. For the Trend scenario, urban form attributes of superblocks and other place types are based on analysis of existing development in Chongqing. For the Compact Growth scenario, urban form attributes of transit-oriented centers and neighborhoods are based on verified transit-oriented development (TOD) design standards.

Data and information sources

Sources for the data and information used in developing the transportation model are summarized below.

- **Chongqing Transport Planning and Research Institute data**
  The local transport institute has provided a sample of 500 TAZs (i.e., Traffic Analysis Zones) out of 3033 TAZs attached with household travel survey results in 2015. The sampled TAZs are selected to cover a full range of place types in Chongqing as well as different subarea locations. In each of these 500 sampled TAZs, household travel behavior information including mode share, trip distance and trip time are presented in a discrete format. These data are originally collected from a household travel survey by the local transport institute in 2015.

- **Baseline data for calibration**
  For base year calibration, overall daily trip numbers and VKTs extracted from the published Chongqing Transportation Development Report 2015 were referenced. Furthermore, the local transport institute also provides regional transportation model results from master plan simulation, including trip mode share, average trip number per day and total VKT per day. These numbers were mainly used as the base for endstate year (2035) travel volume calibration.

- **Additional data for adjustment**
  The regional transport model does have two main limitations. First, it only reflects the travel-urban form interaction observed in year 2015. Without further calibration, it will produce biased scenario results for year 2035. Second, households in the core area of Chongqing tend to be wealthier, with higher auto ownership and use. However, the regional transport model is yet to capture this pattern, lacking important confounding factors such as income. Therefore, the team collected additional data as listed below to address the abovementioned issues.

  - First, 39,976 house transaction records in Chongqing in 2015 were collected from fang.com, a real estate agency. These records are evenly distributed over the central area of Chongqing. In the model, they are used as proxy to income so as to further control for the effect of socioeconomics on travel.
  - Second, mode share assumptions were built for each place type based on the CSTC household travel survey data in Beijing in fall 2012. This survey covers 15 neighborhoods consisting a total of 1500 household. This travel survey is conducted in year 2012, when the city has already established an extended 442 km of subway network and its GDP in 2012 is 87,474 RMB per capita, 1.67 times of Chongqing's in 2015 as 52,321 RMB per capita. The mode share level in Beijing 2012 is considered to be comparable in terms of city size, economic status, and rail presence level for Chongqing in the future.
  - Third, a number of elasticity factors in the model were applied to standardized travel mode share and current trip distance to simulate the impacts of changing income distribution and density over time on travel patterns. These elasticity factors were borrowed from CSTC's recently published papers on Jinan urban form and travel study as listed below. These papers were among the first studies to examine land use impacts on travel behavior in China; they also provide reference for income elasticities.

- Transport model calibration and adjustment process
  - Mode share and trip distances

    a) Place type assumption adjustment

    As pointed out earlier, the 2015 regional transport model could not represent travel variances among different locations and urban forms in appropriate ways partially due to a lack of socioeconomic factors. It also failed to reflect the level of motorized transportation in 2035. Such problems have to do with the inherent feature of local data provided by the Chongqing transport planning and research institute. Thus motorized mode share assumptions from our Beijing travel survey data were used for car, bus, and rail by subarea. The Chongqing data for walk share was used as it is reflective of the city's unique natural context and mountainous terrain, which cause people to walk more. Trip distance was aggregated according to place type categories for high/medium density and superblock development. Base mode share and trip distance by subarea and urban form is shown below. Merging these two tables produced the initial mode share and trip distance for 36 place types.

Table 15. Travel mode share by subarea

	Mode share			
	Walk	Car	Bus	Rail
Core Transit	48%	5%	26%	21%
Core No Transit	42%	11%	31%	16%
Core-Adjacent Transit	44%	13%	18%	25%
Core-Adjacent No Transit	39%	35%	15%	11%
Extension Transit	36%	22%	5%	37%
Extension No Transit	31%	32%	13%	23%

Table 16. Trip distance by urban form

	Trip distance in meters			
	Walk	Car	Bus	Rail
High Density Commercial Mix	666	5,998	5,855	6,330
High Density Residential Mix	666	5,998	5,855	6,330
Medium Density Residential Mix	649	6,661	6,085	7,089
Superblock Commercial Mix	710	7,300	6,000	4,050
Superblock Residential Mix	710	7,300	6,000	4,050
Superblock Industrial	710	7,300	6,000	4,050

b) Income standardization

Income is a strong factor in influencing travel patterns. The income factors as shown in Table 17 and Table 18 were applied to standardize mode share and travel distance among different place types. It produced a new set of place type assumptions by holding income constant and equal.

Table 17. Elasticity of mode share change by income change

	Mode Share
walk	- 0.256
motorized travel (car + transit)	0.619

Table 18. Elasticity of trip distance change by income change

	Trip Distance
Car	0.818
Transit (bus + subway)	0.497

First, a matrix of income variance was generated from home price as shown in Table 19. Then, elasticities from the Jinan study as shown in Table 17 and Table 18 were multiplied with income variance to generate standardized factors for motorized mode share, walk mode share, car trip distance, and transit distance for each place type in Table 19. Applying these factors resulted in standardized place type assumptions for travel mode share and trip distance, as shown in Table 20.

Table 19. Place Type Income Variance and Adjustment Factors Applied in the Study

Place Type	standardized income variance	Standardized Factors			
		motorized mode share	walk mode share	car trip distance	transit trip distance
Core Transit A	1.51	0.76	1.13	0.71	0.80
Core Transit B	1.52	0.76	1.13	0.70	0.79
Core Transit C	1.35	0.82	1.09	0.78	0.85
Core Transit D	1.12	0.93	1.03	0.91	0.95
Core Transit E	1.18	0.90	1.05	0.87	0.92
Core Transit F	1.16	0.91	1.04	0.89	0.93
Core No Transit A	1.30	0.84	1.08	0.80	0.87
Core No Transit B	1.32	0.84	1.08	0.79	0.86
Core No Transit C	1.17	0.91	1.04	0.88	0.92
Core No Transit D	0.96	1.02	0.99	1.03	1.02
Core No Transit E	1.02	0.99	1.01	0.98	0.99
Core No Transit F	1.00	1.00	1.00	1.00	1.00
Core-Adjacent Transit A	1.18	0.90	1.05	0.87	0.92
Core-Adjacent Transit B	1.19	0.89	1.05	0.86	0.91
Core-Adjacent Transit C	1.06	0.97	1.01	0.96	0.97
Core-Adjacent Transit D	0.87	1.09	0.97	1.12	1.07
Core-Adjacent Transit E	0.92	1.05	0.98	1.07	1.04
Core-Adjacent Transit F	0.91	1.06	0.98	1.08	1.05
Core-Adjacent No Transit A	1.10	0.94	1.03	0.92	0.95
Core-Adjacent No Transit B	1.11	0.93	1.03	0.92	0.95
Core-Adjacent No Transit C	0.99	1.01	1.00	1.01	1.01
Core-Adjacent No Transit D	0.82	1.13	0.95	1.18	1.10
Core-Adjacent No Transit E	0.86	1.09	0.97	1.13	1.07
Core-Adjacent No Transit F	0.85	1.11	0.96	1.14	1.08
Extension Transit A	0.95	1.03	0.99	1.05	1.03
Extension Transit B	0.96	1.03	0.99	1.04	1.02
Extension Transit C	0.85	1.10	0.96	1.14	1.08
Extension Transit D	0.70	1.23	0.92	1.33	1.18
Extension Transit E	0.74	1.19	0.93	1.27	1.15
Extension Transit F	0.73	1.20	0.93	1.29	1.16
Extension No Transit A	0.89	1.08	0.97	1.10	1.06
Extension No Transit B	0.89	1.07	0.97	1.10	1.06
Extension No Transit C	0.79	1.15	0.95	1.20	1.11
Extension No Transit D	0.65	1.27	0.91	1.39	1.21
Extension No Transit E	0.69	1.23	0.92	1.33	1.18
Extension No Transit F	0.68	1.25	0.92	1.36	1.19

Table 20. Standardized Place Type Assumptions of Travel Mode Share and Trip Distance

	Mode Share				Trip Distance in meter			
	Wal k	Car	Bus	Rail	Walk	Car	Bus	Rail
Core Transit A	54%	3%	24%	19%	666	4,231	4,671	5,050
Core Transit B	54%	3%	24%	19%	666	4,197	4,645	5,022
Core Transit C	52%	3%	25%	20%	649	5,169	5,178	6,032
Core Transit D	49%	4%	26%	21%	710	6,664	5,671	3,828
Core Transit E	50%	4%	25%	20%	710	6,349	5,500	3,712
Core Transit F	50%	4%	25%	21%	710	6,462	5,562	3,754
Core No Transit A	45%	8%	31%	16%	666	4,801	5,085	5,498
Core No Transit B	45%	8%	31%	16%	666	4,762	5,058	5,469
Core No Transit C	44%	9%	31%	16%	649	5,853	5,614	6,541
Core No Transit D	42%	11%	31%	16%	710	7,517	6,107	4,122
Core No Transit E	42%	11%	31%	16%	710	7,170	5,935	4,006
Core No Transit F	42%	11%	31%	16%	710	7,295	5,998	4,048
Core-Adjacent Transit A	46%	11%	18%	25%	666	5,226	5,373	5,809
Core-Adjacent Transit B	46%	10%	18%	25%	666	5,185	5,346	5,780
Core-Adjacent Transit C	45%	12%	18%	25%	649	6,362	5,916	6,892
Core-Adjacent Transit D	43%	15%	18%	25%	710	8,148	6,405	4,323
Core-Adjacent Transit E	43%	14%	18%	25%	710	7,779	6,233	4,207
Core-Adjacent Transit F	43%	15%	18%	25%	710	7,912	6,296	4,250
Core-Adjacent No Transit A	40%	33%	16%	12%	666	5,534	5,571	6,024
Core-Adjacent No Transit B	40%	32%	16%	12%	666	5,491	5,544	5,994
Core-Adjacent No Transit C	39%	35%	15%	11%	649	6,730	6,123	7,133
Core-Adjacent No Transit D	37%	40%	13%	10%	710	8,601	6,607	4,460
Core-Adjacent No Transit E	38%	38%	14%	10%	710	8,216	6,436	4,344
Core-Adjacent No Transit F	37%	39%	14%	10%	710	8,355	6,498	4,386
Extension Transit A	36%	23%	4%	37%	666	6,271	6,014	6,502
Extension Transit B	36%	23%	5%	37%	666	6,223	5,986	6,472
Extension Transit C	35%	26%	4%	36%	649	7,607	6,582	7,668
Extension Transit D	33%	30%	4%	33%	710	9,675	7,051	4,759
Extension Transit E	34%	28%	4%	34%	710	9,256	6,883	4,646
Extension Transit F	33%	29%	4%	34%	710	9,407	6,944	4,687
Extension No Transit A	30%	35%	13%	22%	666	6,621	6,209	6,713
Extension No Transit B	30%	35%	13%	22%	666	6,571	6,182	6,684
Extension No Transit C	29%	38%	12%	21%	649	8,021	6,783	7,902
Extension No Transit D	28%	42%	11%	19%	710	10,178	7,244	4,889
Extension No Transit E	29%	41%	11%	19%	710	9,745	7,078	4,778
Extension No Transit F	28%	41%	11%	19%	710	9,901	7,139	4,819

c) Scenario assumption

On top of the place type effects, two additional macro-level drivers influencing the mode shares and travel distance for future scenarios were included. The first driver is regional income distribution. It was assumed that the income distribution between the Core, Core-Adjacent, and Extension areas was very uneven in the Trend scenario, and more mixed in the Compact Growth scenario. These different patterns change the mode shares among place types. However, the walk share in endstate year is assumed to be stable, so it does not vary among scenarios. The second driver is regional density distribution. By allocating higher overall density, the place types further shorten motorized travel distance. In calibrating such elasticities, empirical findings were borrowed from the Jinan study.

Table 21. Regional Assumptions of VKT elasticity with respect to density change

	Subarea	Gross Residential Density Change as compared to the base year			Elasticity from Jinan study	Resulting post-process VKT reduction for future-year car travel		
		Trend	Master Plan	TOD		Trend	Master Plan	TOD
1	Core Transit	37%	0%	36%	-0.087	-3.2%	0.0%	-3.2%
2	Core No Transit	16%	0%	0%	-0.087	-1.4%	0.0%	0.0%
3	Core-Adjacent Transit	-11%	22%	33%	-0.087	0.9%	-1.9%	-2.9%
4	Core-Adjacent No Transit	-25%	-8%	-20%	-0.087	2.2%	0.7%	1.8%
5	Extension Transit	-33%	-39%	-25%	-0.087	2.9%	3.4%	2.2%
6	Extension No Transit	-41%	-30%	-47%	-0.087	3.6%	2.6%	4.1%

Table 22. Place Type Income Variance and Adjustment Factors Applied for the "Trend" Scenario

Place Type	reapplied income variance	Factors			distance change by density
		motorized mode share	car trip distance	transit trip distance	
Core Transit A	1.40	0.80	0.75	0.83	-3.22%
Core Transit B	1.40	0.80	0.75	0.83	-3.22%
Core Transit C	1.40	0.80	0.75	0.83	-3.22%
Core Transit D	1.40	0.80	0.75	0.83	-3.22%
Core Transit E	1.40	0.80	0.75	0.83	-3.22%
Core Transit F	1.40	0.80	0.75	0.83	-3.22%
Core No Transit A	1.30	0.84	0.80	0.87	-1.39%
Core No Transit B	1.30	0.84	0.80	0.87	-1.39%
Core No Transit C	1.30	0.84	0.80	0.87	-1.39%
Core No Transit D	1.30	0.84	0.80	0.87	-1.39%
Core No Transit E	1.30	0.84	0.80	0.87	-1.39%
Core No Transit F	1.30	0.84	0.80	0.87	-1.39%
Core-Adjacent Transit A	1.20	0.89	0.86	0.91	0.94%
Core-Adjacent Transit B	1.20	0.89	0.86	0.91	0.94%
Core-Adjacent Transit C	1.20	0.89	0.86	0.91	0.94%
Core-Adjacent Transit D	1.20	0.89	0.86	0.91	0.94%
Core-Adjacent Transit E	1.20	0.89	0.86	0.91	0.94%
Core-Adjacent Transit F	1.20	0.89	0.86	0.91	0.94%
Core-Adjacent No Transit A	1.10	0.94	0.92	0.95	2.16%
Core-Adjacent No Transit B	1.10	0.94	0.92	0.95	2.16%
Core-Adjacent No Transit C	1.10	0.94	0.92	0.95	2.16%
Core-Adjacent No Transit D	1.10	0.94	0.92	0.95	2.16%
Core-Adjacent No Transit E	1.10	0.94	0.92	0.95	2.16%
Core-Adjacent No Transit F	1.10	0.94	0.92	0.95	2.16%
Extension Transit A	1.05	0.97	0.96	0.98	2.86%
Extension Transit B	1.05	0.97	0.96	0.98	2.86%
Extension Transit C	1.05	0.97	0.96	0.98	2.86%
Extension Transit D	1.05	0.97	0.96	0.98	2.86%
Extension Transit E	1.05	0.97	0.96	0.98	2.86%
Extension Transit F	1.05	0.97	0.96	0.98	2.86%
Extension No Transit A	1.00	1.00	1.00	1.00	3.58%
Extension No Transit B	1.00	1.00	1.00	1.00	3.58%
Extension No Transit C	1.00	1.00	1.00	1.00	3.58%
Extension No Transit D	1.00	1.00	1.00	1.00	3.58%
Extension No Transit E	1.00	1.00	1.00	1.00	3.58%
Extension No Transit F	1.00	1.00	1.00	1.00	3.58%

Table 23. Place Type Assumptions of Travel Mode Share and Trip Distance for the "Trend" Scenario

	Mode Share				Trip Distance in meter			
	Walk	Car	Bus	Rail	Walk	Car	Bus	Rail
Core Transit A	54%	4%	23%	19%	666	5,436	5,419	4,077
Core Transit B	54%	4%	23%	19%	666	5,391	5,388	4,054
Core Transit C	52%	5%	24%	19%	649	6,640	6,007	4,870
Core Transit D	49%	6%	24%	20%	710	8,561	6,580	3,091
Core Transit E	50%	6%	24%	20%	710	8,155	6,380	2,997
Core Transit F	50%	6%	24%	20%	710	8,301	6,453	3,031
Core No Transit A	45%	10%	29%	15%	666	5,896	5,761	4,718
Core No Transit B	45%	10%	29%	15%	666	5,849	5,731	4,693
Core No Transit C	44%	12%	29%	15%	649	7,188	6,361	5,613
Core No Transit D	42%	15%	29%	15%	710	9,232	6,920	3,538
Core No Transit E	42%	14%	29%	15%	710	8,806	6,724	3,438
Core No Transit F	42%	14%	29%	15%	710	8,959	6,795	3,474
Core-Adjacent Transit A	46%	13%	17%	24%	666	6,139	5,962	5,334
Core-Adjacent Transit B	46%	13%	17%	24%	666	6,090	5,932	5,307
Core-Adjacent Transit C	45%	15%	17%	24%	649	7,473	6,565	6,328
Core-Adjacent Transit D	43%	18%	17%	23%	710	9,570	7,107	3,969
Core-Adjacent Transit E	43%	17%	17%	23%	710	9,137	6,916	3,863
Core-Adjacent Transit F	43%	17%	17%	23%	710	9,293	6,986	3,902
Core-Adjacent No Transit A	40%	34%	15%	11%	666	6,116	5,974	5,862
Core-Adjacent No Transit B	40%	34%	15%	11%	666	6,068	5,945	5,833
Core-Adjacent No Transit C	39%	37%	14%	10%	649	7,437	6,566	6,942
Core-Adjacent No Transit D	37%	41%	12%	9%	710	9,506	7,085	4,340
Core-Adjacent No Transit E	38%	40%	13%	9%	710	9,080	6,901	4,228
Core-Adjacent No Transit F	37%	41%	13%	9%	710	9,234	6,968	4,269
Extension Transit A	36%	24%	4%	36%	666	6,714	6,339	6,526
Extension Transit B	36%	24%	4%	36%	666	6,663	6,310	6,496
Extension Transit C	35%	26%	4%	35%	649	8,144	6,938	7,696
Extension Transit D	33%	31%	4%	32%	710	10,358	7,432	4,777
Extension Transit E	34%	29%	4%	33%	710	9,910	7,256	4,663
Extension Transit F	33%	30%	4%	33%	710	10,072	7,320	4,705
Extension No Transit A	30%	35%	13%	22%	666	6,857	6,432	6,954
Extension No Transit B	30%	35%	13%	22%	666	6,806	6,403	6,923
Extension No Transit C	29%	38%	12%	21%	649	8,308	7,026	8,185
Extension No Transit D	28%	42%	11%	19%	710	10,542	7,503	5,064
Extension No Transit E	29%	41%	11%	19%	710	10,094	7,331	4,949
Extension No Transit F	28%	41%	11%	19%	710	10,256	7,394	4,991

Table 24. Place Type Income Variance and Adjustment Factors Applied for the "TOD" Scenario

Place Type	reapplied income variance	Factors			distance change by density
		motorized mode share	car trip distance	transit trip distance	
Core Transit A	1.20	0.89	0.86	0.91	-3.16%
Core Transit B	1.20	0.89	0.86	0.91	-3.16%
Core Transit C	1.20	0.89	0.86	0.91	-3.16%
Core Transit D	1.20	0.89	0.86	0.91	-3.16%
Core Transit E	1.20	0.89	0.86	0.91	-3.16%
Core Transit F	1.20	0.89	0.86	0.91	-3.16%
Core No Transit A	1.20	0.89	0.86	0.91	0.00%
Core No Transit B	1.20	0.89	0.86	0.91	0.00%
Core No Transit C	1.20	0.89	0.86	0.91	0.00%
Core No Transit D	1.20	0.89	0.86	0.91	0.00%
Core No Transit E	1.20	0.89	0.86	0.91	0.00%
Core No Transit F	1.20	0.89	0.86	0.91	0.00%
Core-Adjacent Transit A	1.15	0.92	0.89	0.93	-2.87%
Core-Adjacent Transit B	1.15	0.92	0.89	0.93	-2.87%
Core-Adjacent Transit C	1.15	0.92	0.89	0.93	-2.87%
Core-Adjacent Transit D	1.15	0.92	0.89	0.93	-2.87%
Core-Adjacent Transit E	1.15	0.92	0.89	0.93	-2.87%
Core-Adjacent Transit F	1.15	0.92	0.89	0.93	-2.87%
Core-Adjacent No Transit A	1.10	0.94	0.92	0.95	1.75%
Core-Adjacent No Transit B	1.10	0.94	0.92	0.95	1.75%
Core-Adjacent No Transit C	1.10	0.94	0.92	0.95	1.75%
Core-Adjacent No Transit D	1.10	0.94	0.92	0.95	1.75%
Core-Adjacent No Transit E	1.10	0.94	0.92	0.95	1.75%
Core-Adjacent No Transit F	1.10	0.94	0.92	0.95	1.75%
Extension Transit A	1.05	0.97	0.96	0.98	2.16%
Extension Transit B	1.05	0.97	0.96	0.98	2.16%
Extension Transit C	1.05	0.97	0.96	0.98	2.16%
Extension Transit D	1.05	0.97	0.96	0.98	2.16%
Extension Transit E	1.05	0.97	0.96	0.98	2.16%
Extension Transit F	1.05	0.97	0.96	0.98	2.16%
Extension No Transit A	1.00	1.00	1.00	1.00	4.11%
Extension No Transit B	1.00	1.00	1.00	1.00	4.11%
Extension No Transit C	1.00	1.00	1.00	1.00	4.11%
Extension No Transit D	1.00	1.00	1.00	1.00	4.11%
Extension No Transit E	1.00	1.00	1.00	1.00	4.11%
Extension No Transit F	1.00	1.00	1.00	1.00	4.11%

Table 25. Place Type Assumptions of Travel Mode Share and Trip Distance for the "TOD" Scenario

	Mode Share				Trip Distance in meter			
	Walk	Car	Bus	Rail	Walk	Car	Bus	Rail
Core Transit A	54%	3%	23%	19%	666	4,768	5,264	5,691
Core Transit B	54%	3%	23%	19%	666	4,729	5,234	5,659
Core Transit C	52%	4%	24%	20%	649	5,825	5,835	6,797
Core Transit D	49%	5%	25%	20%	710	7,510	6,391	4,314
Core Transit E	50%	5%	25%	20%	710	7,154	6,198	4,183
Core Transit F	50%	5%	25%	20%	710	7,282	6,268	4,231
Core No Transit A	45%	9%	30%	15%	666	5,586	5,917	6,398
Core No Transit B	45%	9%	30%	15%	666	5,541	5,886	6,363
Core No Transit C	44%	11%	30%	15%	649	6,811	6,533	7,611
Core No Transit D	42%	14%	29%	15%	710	8,747	7,107	4,797
Core No Transit E	42%	13%	30%	15%	710	8,343	6,906	4,661
Core No Transit F	42%	13%	30%	15%	710	8,489	6,979	4,711
Core-Adjacent Transit A	46%	12%	17%	24%	666	5,699	5,860	6,335
Core-Adjacent Transit B	46%	12%	17%	24%	666	5,654	5,830	6,303
Core-Adjacent Transit C	45%	14%	17%	24%	649	6,938	6,452	7,516
Core-Adjacent Transit D	43%	17%	17%	23%	710	8,886	6,984	4,714
Core-Adjacent Transit E	43%	16%	17%	24%	710	8,483	6,797	4,588
Core-Adjacent Transit F	43%	17%	17%	24%	710	8,628	6,865	4,634
Core-Adjacent No Transit A	40%	34%	15%	11%	666	6,092	6,133	6,630
Core-Adjacent No Transit B	40%	34%	15%	11%	666	6,044	6,102	6,598
Core-Adjacent No Transit C	39%	37%	14%	10%	649	7,408	6,740	7,852
Core-Adjacent No Transit D	37%	41%	12%	9%	710	9,468	7,272	4,909
Core-Adjacent No Transit E	38%	40%	13%	9%	710	9,044	7,084	4,782
Core-Adjacent No Transit F	37%	41%	13%	9%	710	9,197	7,153	4,828
Extension Transit A	36%	24%	4%	36%	666	6,669	6,395	6,914
Extension Transit B	36%	24%	4%	36%	666	6,618	6,366	6,883
Extension Transit C	35%	26%	4%	35%	649	8,089	6,999	8,154
Extension Transit D	33%	31%	4%	32%	710	10,288	7,498	5,061
Extension Transit E	34%	29%	4%	33%	710	9,843	7,320	4,941
Extension Transit F	33%	30%	4%	33%	710	10,004	7,385	4,985
Extension No Transit A	30%	35%	13%	22%	666	6,893	6,465	6,990
Extension No Transit B	30%	35%	13%	22%	666	6,841	6,436	6,959
Extension No Transit C	29%	38%	12%	21%	649	8,351	7,062	8,227
Extension No Transit D	28%	42%	11%	19%	710	10,597	7,542	5,091
Extension No Transit E	29%	41%	11%	19%	710	10,146	7,369	4,974
Extension No Transit F	28%	41%	11%	19%	710	10,309	7,433	5,017

- Trip frequency:
  In accordance with data from the Chongqing Transport Planning and Research Institute, an average of number of 2.14 trips per capita per day and a total of 15,130,000 trips per day are used for base year calibration. For the endstate year, the number of trips per capita per day is estimated to be 2.4 in year 2035, as travel demand tends to increase with economic development. So, 2.4 is used directly as the trip frequency for all scenarios in 2035.

- Travel time:
  Travel time is calculated as dividing travel distance by travel speed. The average of travel speed for four modes are summarized from the regional transport model of Chongqing and then rebalanced with road average travel speed published in Chongqing Transportation Development Report 2015.

Table 25. Travel speed assumptions (km/h)

	car	bus	rail	walk
Core	10.72	7.56	10.20	4
Core-Adjacent	11.20	7.90	10.20	4
Extension	11.68	8.24	10.20	4

4.3.6 Transportation Impacts – Fuel Use, Carbon Emissions, Air Pollutant Emissions, and Costs

Transportation fuel use, carbon and air pollutant emissions, and costs are derived by applying factors to modeled results for passenger vehicle auto vehicle kilometers traveled (VKT).

Transportation Fuel Use

Transportation fuel use is calculated using assumptions for vehicle efficiency and average carbon emissions per liter of gasoline in China. A baseline average vehicle efficiency of 10.66 kilometers per liter was given by the local transportation institute. This rate was applied to auto vehicle kilometers traveled (VKT) results for the future-year scenarios to highlight the impact of land use alone in reducing fuel use and related impacts.

Transportation Carbon Emissions

Transportation CO_2 emissions are calculated by applying a per-liter emission rate to estimated VKT by passenger autos. A current emissions rate of 2.35 kg CO_2 per liter is assumed for gasoline. The results presented in the report assume the current rate into the future to highlight the impact of land use alone in reducing emissions. Lower future-year emissions rates that would result from improvements in vehicle or fuel standards, or the uptake of alternative-fuel vehicles, can be applied to test the joint impact of land use planning and vehicle policy.

Transportation Pollutant Emissions

Transportation air pollutant emissions, including nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter less than 10 and 2.5 µm (PM_{10} and $PM_{2.5}$), black carbon, sulfur dioxide (SO_2), and total hydrocarbons (THC), are calculated by applying per-kilometer emission rates to estimated VKT by passenger autos. The results presented in the report assume current rates into the future to highlight the impact of land use alone in reducing emissions. Lower future-year emissions rates that would result from improvements in vehicle standards can be applied to test the joint impact of land use planning and vehicle policy.

The emissions rates assumed are year-2015 rates for light-duty vehicle emissions (including sport-utility vehicles) in China, as estimated by the International Council on Clean Transportation (ICCT) Global Transportation Roadmap Model[10]. The model includes projected emissions rates in five-year increments to 2050. The rates applied for the Chongqing scenarios are summarized in Table 26.

Table 26. Light-duty vehicle air pollutant emissions rates (ICCT 2012)

Air Pollutant	Emissions rate
Nitrogen Oxides (NO_x)	0.91 g/km
Carbon Monoxide (CO)	9.99 g/km
Particulate Matter < 10 µm (PM_{10})	0.00858 g/km
Particulate Matter < 2.5 µm ($PM_{2.5}$)	0.00789 g/km
Black Carbon	0.00138 g/km
Sulfur Dioxide (SO_2)	0.02055 g/km
Total hydrocarbons (THC)	0.10 g/km

Transportation Costs

The costs associated with auto VKT, which are accounted for as a component of household costs, include fuel and auto ownership and maintenance. Fuel costs are based on an average cost per liter of gasoline in Chongqing. A current cost of 7.24 RMB per liter in year-2018 dollars is assumed into the future. Auto ownership and maintenance costs are calculated on a per-kilometer basis. A cost of 1.64 RMB per kilometer in year-2018 dollars is assumed into the future. This is estimated to include the annualized cost of owning, maintaining, and repairing a vehicle.

[10] ICCT Global Transportation Roadmap Model, 2012. Available from www.theicct.org.

5. Conclusion

The Chongqing 2035 scenarios and results highlight the deeply embedded relationships between land use patterns and performance across metrics for environmental sustainability, economic efficiency, and livability for residents and workers. The scenario study has applied what is known and quantifiable about the disparate impacts of compact, walkable development vs. expansive superblock development across a range of metrics to highlight the magnitude of benefits – or consequences – that Chongqing can expect to face as it grows.

The impacts on land consumption, transportation choices, resource efficiency, household costs, and the communities in which people go about their daily lives have implications for Chongqing's ability to attract and sustain the growth and living standards it is aiming for. Thus, policies to achieve strategically located, compact development are vital not only to the "bottom line" on particular metrics, such as carbon reductions, but Chongqing's ability to position itself as a global city.

An integrated set of policies is needed to achieve the sustainable development patterns envisioned for Chongqing. The policy recommendations presented in the main report are given support by the benefits as modeled for the Chongqing 2035 scenarios, and by what has been demonstrated to be successful in creating livable, high-performing places in cities and regions worldwide. Taken together, the recommendations comprise an integrated set of goals and actions to shape the spatial structure of the region as it grows, guide the urban form of its constituent communities, and improve livability for all residents.

6. References

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