

NUMERACY IN GLOBAL CITIES: LONDON, BARCELONA, PARIS, KYOTO, TAIPEI

城市裡的數感素養課：環遊世界，發掘大都市的數學方程式！

Have you ever wondered how major international cities became the glamorous tourist destinations that they are today? This book combines mathematics and history to take readers on a journey through the fascinating stories and context behind city planning.

Today, the ancient Japanese city of Kyoto is a favorite destination for tourists from all over the world, but did it really used to be a jumbled mass of tall buildings and shop signs? Is it possible that London, which is known for its abundance of green parks and trees, was once a hotbed of pollution and disease? And was transit-oriented Taipei previously a pedestrian nightmare? Perhaps what's most surprising is that the secret behind the transformation of these amazing global cities is something that many people find boring: mathematics!

This book introduces five cities, each with their own chapter: London, Barcelona, Paris, Kyoto, and Taipei. Each chapter starts by presenting the city as it is today and highlighting its famous landmarks, then describing the city's history and culture. This is followed by an explanation of the reasons the government has embarked on its process of urban planning and regeneration, as well as how the designers of these cities have used interesting math to create friendly, convenient, people-oriented living environments. Analogies are also used throughout the book to explain complex numbers with simple concepts. The chapters conclude with



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mathematical stories and discussion questions to review and supplement the knowledge of both the city and the math covered in that section.

The authors take a thematic approach to the writing and goes into depth on the historical and cultural context behind each city, using fun, simple math to combine interdisciplinary topics and knowledge to demonstrate the creative thought that goes into city planning and design. They hope to encourage readers to explore how mathematics solves life's problems and shapes the world around us.

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Lai I-Wei is an assistant professor of Electrical Engineering at National Taiwan Normal University, and is the co-founder of the popular mathematics literacy platform Numeracy Lab. He is also the author of several works of fiction including the romance novel *Ring of the Day* which was adapted for television and aired on HBO in 2020.

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Benson Lee graduated from the Department of Japanese Language and Literature at National Taiwan University. With some help from Numeracy Lab's mascot NumNum, he's out there spreading the word on just how much fun math can be. He also runs a YouTube channel called "Purpnight" where he reviews Japanese books, music, and television.

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A Green and Open Mathematical Capital

London

London used to have suffocating air and disgusting water, but now it is one of the greenest cities in the world. See how London set the standard for greening with mathematical ratios and created a financial centre that coexists with forest parks.



A Green and Open Mathematical Capital

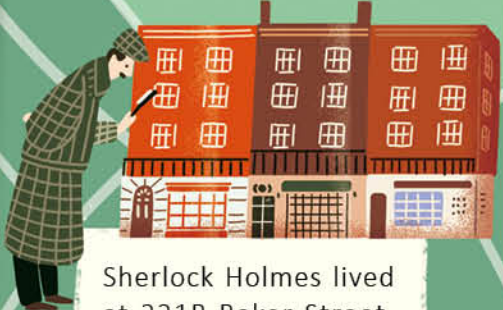
LONDON

UK


When it comes to world-famous metropolises, London, the capital of the United Kingdom, will definitely be near the top of your list. Imagine going for a walk in central London: there's the liveliness of Soho, the shop-till-you-drop of Oxford Street, and literary attractions like the platform at King's Cross Station where Harry Potter caught the train to Hogwarts, and Baker Street, where Sherlock Holmes lived. Then there's Big Ben, Westminster Abbey, the British Museum, the London Eye, and other famous sights.

When you're tired and want a break, London has a number of royal parks that are several times bigger than Taipei's Daan Forest Park. It would take a few hours to walk around some of the parks, some of which have free-roaming deer or boating lakes. This is what Londoners love about London: they can be in the middle of the city one minute, and stepping into nature to relax and clear their minds the next.


The reason why London is ranked as one of the world's metropolises is not only because of its historical, economic or political status, but also because of its greening. It's expected that London will become a "National Park City", where the urban centre is like a national park supporting a rich variety of plants and animals. In order to provide an environment that can sustain these plants and animals, the amount of green space must be increased.




Sherlock Holmes lived at 221B Baker Street. There are so many images of him in the neighbourhood that you feel sure you'll meet him as you pass through.




Big Ben rings every 15 minutes, and the Changing of the Guards takes place every day at 11 o'clock.



Harry Potter boarded the train to Hogwarts on Platform 9 $\frac{3}{4}$ at King's Cross.



The London Eye is 135 metres high, and one rotation takes 30 minutes.



But, did you know that London wasn't such a green city in the past? In fact, the opposite was true. It used to be a filthy city, lost in a fog of smoke, and black with dirt.

Once Upon a Time
London Was the City of Fog



The beautiful haze that pervades London earned it the name City of Fog. But, the fog was, in fact, smog, and the name dates back to the serious pollution of the Industrial Revolution. People mostly used coal to generate electricity, but as soon as it came into contact with the bitterly cold air, the pollutants merged and produced a poisonous smoke so thick that you couldn't see the fingers on your own hand.



Back then, London's sewage system was not ideal, and most of the waste water accumulated in underground cesspools. When there was too much, it would overflow into the Thames, turning the Thames into a foul-smelling waterway. To make matters worse, the Thames was the source of drinking water at the time. Many people got diarrhoea and died.



Starting with the steam engine in the 18th century, the Industrial Revolution caused many jobs that required a lot of manpower and manual work to be replaced by machines. People no longer had to toil endlessly, but many lost their jobs completely. They were forced to leave the countryside to come and look for new work in the cities. By the end of the 19th century, the time of Sherlock Holmes's books, the population was growing faster and faster thanks to improved healthcare and a more developed economy, but the urban infrastructure could not keep up with the population growth, and the whole environment became worse and worse.

People who migrated from the fresh air of the countryside to the dirty cities naturally couldn't stand such a terrible environment. Londoners wanted to see beautiful country scenes in the city, and to improve their quality of life. So, starting with residents' squares, London began to green. These green spaces were originally designed for public use, but as the economy transformed, the green spaces in the city became less and less accessible. Gradually they became the privilege of the aristocracy and the bourgeoisie, and the green spaces filled with trees and bushes became private gardens, in stark contrast to the squalor on the streets.

But that wasn't fair! And under great social pressure, the royal gardens became the first public park in London. Gradually, many green spaces ceased to be privately owned, and the masses began to enjoy the right to relax in parks and green spaces. It was not until the 20th century that the concept of public ownership of green spaces was finally established.



The Value of Green, and the Greening of London

Compared with a dense concrete jungle, the “greening” of a city brings many benefits to the economy, the environment, and the quality of life. For example, if there is greening near a store, consumers will be willing to stay longer, and employees will be more productive. It has been calculated that every \$1 invested in trees and woodland can generate \$9 for the local area.

Greening also solves the problem of hotter cities and more polluted air. You only have to think how comfortable it would be to stand at an intersection in the summer waiting for the lights to change if there was tree shade overhead. Research shows that tree shade can reduce the surrounding temperature by 2 to 8 degrees – it’s a natural air conditioner.

How Green Is London?

As greening has so many benefits, let’s take a look at the results of greening in London. If we start by asking how much of London is green, we can see that the largest green spaces are the mega-parks. There are several of these in London: even the smallest is 19 hectares, and the largest, Richmond Park, is almost 1000 hectares.

In all these mega-parks, when the weather is fine, you can often see citizens having picnics, doing exercise, or sitting on deck chairs reading a book, enjoying a leisurely afternoon.

LONDON

How Big Is One Hectare?

We don’t often talk about hectares in everyday life, so it’s hard to imagine how big a hectare is. Let’s do some calculations: one hectare is 10,000m², and one classroom including the corridor is about 100m², so one hectare is the size of 100 classrooms with corridors.



Taipei’s Mega-Park

Taipei’s mega-park, the Daan Forest Park, is about 25 hectares. Compared to Richmond Park in London, it’s very small, but even in this “mini” park, you can often see citizens coming to exercise, having picnics or attending events.

With comparisons like this, it’s easy to imagine that London is very green indeed. However, if you think about it carefully, you’ll find there some things need clarification. For example, although London has a lot of mega-parks, it is a super metropolis, and Taipei is a much smaller city. Is it fair to compare them like this? Also, if you’ve been to London, you’ll probably know that Richmond Park is on the outskirts of the city, and if we were to include the green spaces in the outskirts of Taipei, there is Yangmingshan National Park at the northern end of the city!

To illustrate clearly how green a city is, we can’t just rely on mega-parks; we have to look for real figures and do the maths.



$$1 \text{ Richmond Park} = 40 \times \text{Daan Forest Park} \\ = 100,000 \text{ classrooms} + \text{corridors}$$



The Three Goals of Greening:

Bigger, Closer, Greener

In order to become even greener, London continues to work towards three goals: bigger, closer and greener. These are the usual indicators for measuring how green a city is. As the words suggest, bigger refers to the size of the parks and grassy areas, closer to how easily citizens can get to a green space, and greener to the level of green (grassy areas and forests being completely different). In other words, a forest park in the city centre has a higher greening value than a grassy area of the same size in the suburbs because the city centre is more accessible to the public and trees are more greening than grass.

So, let's see which figures or calculations we should use to calculate the indicators of bigger, closer, greener more accurately, and see how London scores this time!



Whose Park Is the Biggest,

Closest, and Greenest?

Let's imagine that the mayor of London comes to visit Taipei. He sees Daan Forest Park and immediately assumes that Taipei isn't very green. So the two mayors make an on-the-spot comparison to see whose park scores highest on the three criteria. From the following conversation, can you see a way to judge the three criteria? If not, don't you find that strange?



Whose Park Is Bigger?

Mayor of Taipei:
My park is so big that there is a lake inside!

Mayor of London:
My park is big enough to keep deer in it!

Whose Park Is Closer?

Mayor of Taipei:
My citizens can take the MRT to the park.

Mayor of London:
My citizens can walk to the park!

Whose Park Is Greener?

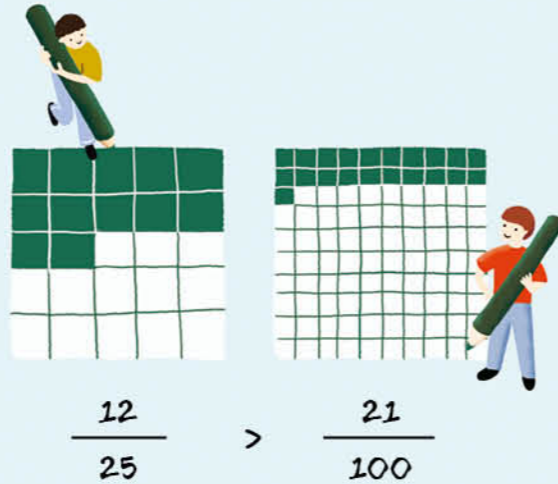
Mayor of Taipei:
My park is as green as a green coloured pencil.

Mayor of London:
My park is as green as the leaves on a tree.



The Bigger the Green Space, the Better

“See who’s greenest.” The most intuitive way to assess greening is like colouring in the squares on squared paper – the more squares you fill in, the greener you are. But even with an intuitive comparison like that, there are still some factors to consider. For example, if there are 12 green squares in a 25-square grid and 21 green squares in a 100-square grid, we should not just look at the number of green squares, but also consider the number of squares in the whole grid and then calculate the “relative” result. That’s the only fair comparison.



Green Space Coverage and Green Space per Capita

Comparing the number of green squares against the total number of squares in the grid gives us the first indicator of urban greening. “Green space coverage” is the ratio of green space to urban area.

For example, the entire Greater London area is about 1,600 km², of which nearly 700 km² is green space, including parks, natural environments, outdoor sports venues, and so on. This translates to more than 40% of the green space coverage of the Greater London area.

But this indicator is not good enough. Imagine if a park was crowded, and you had to get a numbered ticket and queue up to get in, then it would no longer be “providing a place for citizens to relax”. So, in addition to green space coverage, we should look at another indicator that is often used: “green space per capita”. Green space per capita is a calculation of the amount of green space that each citizen can enjoy. For London’s population of about 9 million, each person can enjoy about 78 m² of green space, which is slightly less than one classroom and corridor (about 100 m²). No wonder Londoners are happy!



$$\frac{\text{Green Space Coverage}}{\text{Urban Space}} = \frac{\text{Green Space}}{\text{Urban Space}}$$



$$\frac{\text{Green Space per Capita}}{\text{Urban Population}} = \frac{\text{Green Space}}{\text{Urban Population}}$$

The Triangle of Population, Urban Area, and Green Space

Urban Area, and Green Space

Green space coverage and green space per capita are both significant. From the figure, we can also see the relationship between three important numerical values: population, urban area, and green space.



Q1

Did you notice the relationship between urban area and urban population?

ANSWER

Urban population density = urban population / urban area

Q2

Now, think about why the following equation is correct.

Green space per capita x urban population density = green space coverage

ANSWER

Green space per capita means “how much green space one person can have”. Urban population density means “how many people there are per square metre”. If we multiply these together, the answer will give us “how much green space there is per m²”. It’s easier to understand with real numbers. For example, if 1 person has 3 green spaces, and there are 3 people per m², then there will be 9 green spaces per m².

CHALLENGE

According to a news report in 2018, the green space coverage in Taipei is about 4.8%. Taipei covers an area of about 270 km² and has a population of about 2.6 million. Please give the equation for the green space per capita in Taipei, and use a calculator to work out your answer.

ANSWER

4.8% x 270 ÷ 2600000 ≈ 0.000005 (km² per capita)