Human populations and urban systems

Topic8 · SL and AHL

A country that started to shrink

> Birth totals can rise in a year when the population still falls.

- China's population fell in 2022, 2023 and 2024.
- NBS 2024: 9.54 million births, 10.93 million deaths; births rose from 2023 while population fell.
- This unit: populations $\rightarrow$ cities $\rightarrow$ urban air.

Measuring population change

Measure	How to calculate
Crude birth rate	births $\div$ population $\times$ 1000
Crude death rate	deaths $\div$ population $\times$ 1000
Natural increase (%)	(CBR $-$ CDR) $\div$ 10
Doubling time	70 $\div$ growth rate (%)

Rates from a town

1. **Given.** Invented one-year records: mid-year population 10000; 150 births, 100 deaths, 300 immigrants, 200 emigrants.
2. **Rates.** CBR $= 150/10000 \times 1000 = 15$; CDR $= 100/10000 \times 1000 = 10$ per 1000 per year. NIR $= (15-10)/10 = 0.5\%$ per year.
3. **Total change.** $150 - 100 + 300 - 200 = +150$, so 1.5 %
4. **Doubling time.** $70 \div 1.5 \approx 47$ years

Decision

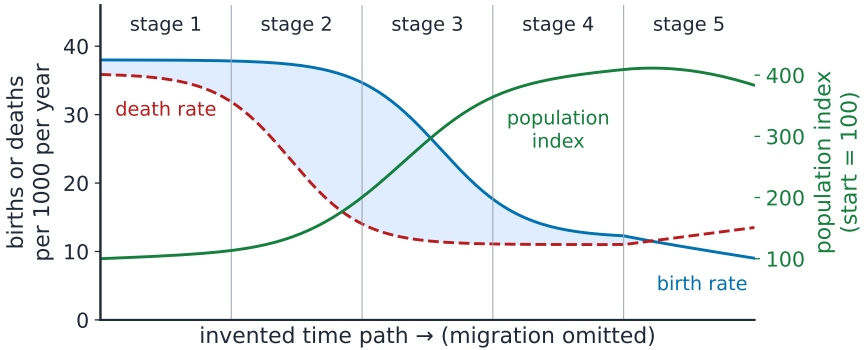
Migration makes this town grow three times faster than natural increase

Replacement level

Period fertility, age structure, mortality and migration jointly shape change; replacement is not one universal immediate threshold.

- Period TFR applies current age-specific fertility rates to a hypothetical lifetime.
- A period TFR differs from completed family size; compare dated age-specific fertility estimates.

The demographic transition model



Invented rate curves give a population index; migration is omitted.

Why the rates fall

Death rate falls

Better food and clean water.

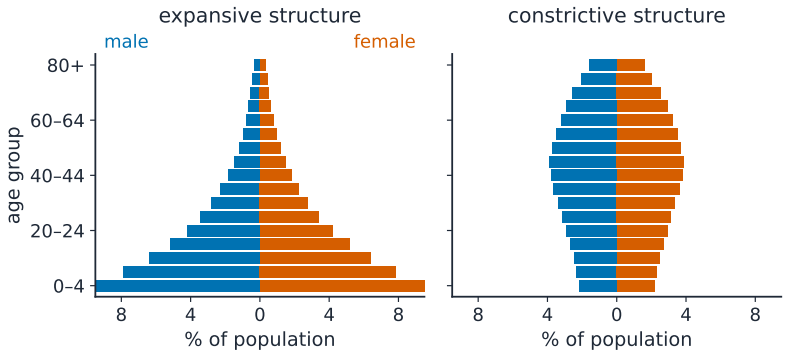
Sanitation, vaccines, medicine.

Birth rate falls

Contraception; girls' education.

Urban life; fewer infant deaths.

Population pyramids



Age structure shows cohorts; shape alone does not establish their causes.

Dependency ratio

- Many children need schools; many old people need pensions and healthcare.
- Age-based dependency is not an employment ratio; participation and productivity also matter.

$$\text{dependency ratio} = \frac{(0\text{–}14) + (65 \text{ and over})}{15\text{–}64} \times 100$$

Example, $(18 + 22) \div 60 \times 100 \approx 67$.

Malthus or Boserup?

Malthus (1798)

Population outgrows food.

Famine, disease and war limit it.

Boserup (1965)

Pressure drives invention.

Food supply rises to meet demand.

Fertility policies and wider development

Direct interventions

China later relaxed birth restrictions; assess rights as well as births.

Singapore's dated Baby Bonus supported eligible families; policy versions change.

Indirect pathways

Bangladesh: education and employment alongside family planning.

Kerala: education, public health and child survival; multiple causes interact.

Pyramids describe cohorts

What is shown

Label five-year bands and numbers or percentages.

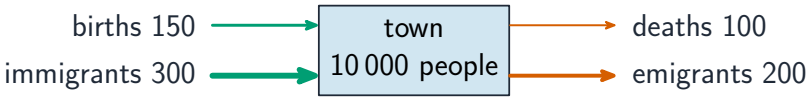
Large young cohorts can support growth momentum.

What needs more evidence

Shape alone does not measure life expectancy or current employment.

Birth history, survival and selective migration can alter a pyramid.

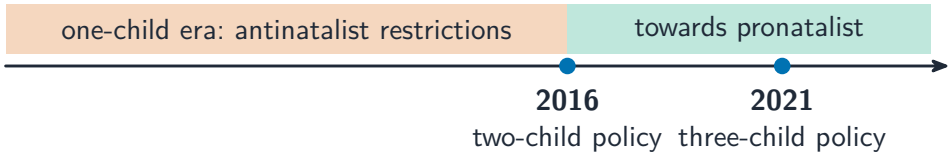
A town's population change



natural increase $150 - 100 = +50$ (0.5%); migration $300 - 200 = +100$
total $+150$ people $= 1.5\%$ a year; doubling time $\approx 70/1.5 \approx 47$ years (invented)

Total $+150$, or 1.5% of 10,000

China's population policy



evaluate fertility with education, living costs, prior trends and reproductive rights

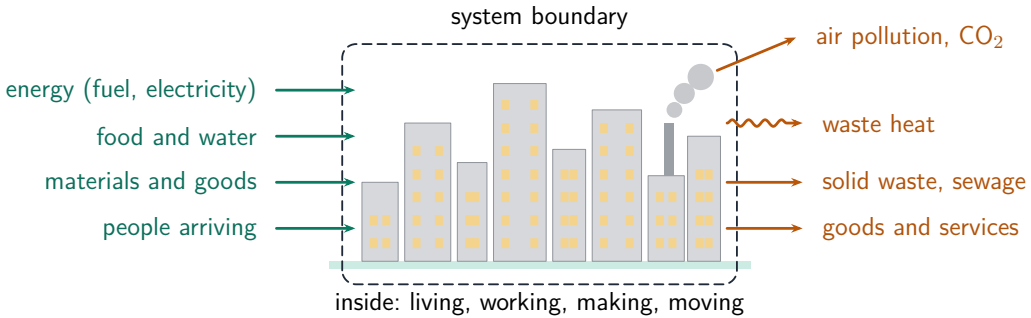
The policy moved towards **pronatalist**

The rise of cities

> Push factors drive people from the countryside; pull factors draw them to cities.

- Urban shares depend on reference year, definition and geographic boundary.
- **Urbanisation** is an increasing share; urban growth concerns numbers or area.

A city as a system



Track matter, energy and people across the stated city boundary.

Cities change their environment

> Housing security, reliable services and affordability vary among residents.

- **Urban heat island**, several degrees warmer, especially at night.
- Impermeable surfaces can increase rapid runoff; sprawl fragments habitats.

Sustainable urban planning

Strategy	**Example**
Compact, mixed-use design	Homes, shops, offices together
Public transport	Curitiba bus rapid transit
Green belts, green space	London green belt
Water-sensitive design	Sponge cities such as Wuhan

Urban numbers can rise while urban share falls

1. **Initial share** $60\,000 / 100\,000 \times 100 = 60\%$
2. **Later share** $66\,000 / 120\,000 \times 100 = 55\%$
3. **Urban-number growth** $6000 / 60\,000 \times 100 = 10\%$

Decision

Urban growth occurred; **urbanisation** did not under the increasing-share definition.

Land cover and an invented storm

1. **Rain volume** 0.010 m $\times$1 000 000 m^2 =10 000 m^3
2. **Sealed surface** Runoff fraction 0.8 gives 8000 m^3
3. **Vegetated surface** Runoff fraction 0.3 gives 3000 m^3

Decision

The 5000 m^3 difference illustrates a mechanism; real runoff needs site data.

Ecological planning connects functions

Land and living systems

Green roofs and wetlands can link habitat, cooling and water storage.

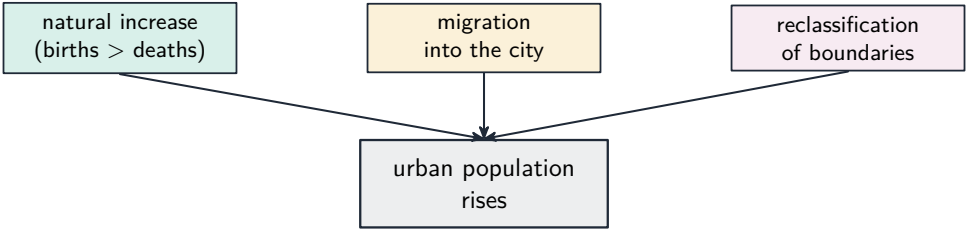
Map connectivity and permeable ground, not just green colour.

People and services

Include affordable housing, work, finance, health and safe transport.

Maintain systems and measure access and actual outcomes.

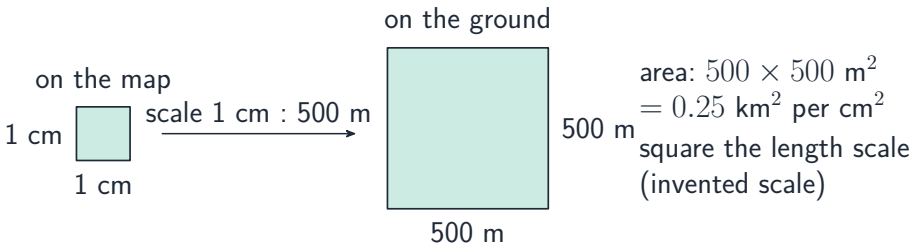
Why the urban population grows



compare maps at the same scale and boundary before blaming migration alone

> Three routes raise the urban count

Map scale and area



Square the length scale for area

Primary and secondary pollutants

Primary (emitted)

CO, NO_x, SO_2.

Particulates, VOCs.

Secondary (formed in air)

Tropospheric ozone.

Sulfuric and nitric acids.

Acid deposition

Acid deposition is regional; it falls hundreds of kilometres downwind.

- SO_2 and NO_x form sulfuric and nitric acids.
- Lakes lose fish; forests and limestone buildings are damaged.

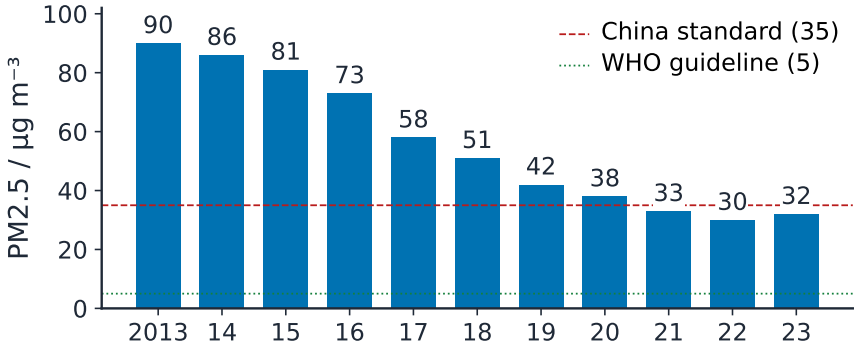
Check: which level?

Your turn

Fitting catalytic converters to cars works at which level of pollution management?

A. Changing the human activity
B. Controlling the release of the pollutant
C. Cleaning up and restoring
D. None of these

Beijing's cleaner air



The 2023 annual mean is 6.4 times the WHO annual guideline.

Primary, secondary and particle size

Formation

Primary emissions include dust, soot, CO and sulfur dioxide.

Ozone and some sulfate/nitrate particles form through atmospheric reactions.

Particle fractions

PM 2.5 is contained within PM 10; do not add as disjoint categories.

Natural dust or fire emissions can still harm health.

Acid deposition: chemistry and effects

Net formation

$2\ SO_2 + O_2 + 2\ H_2O \rightarrow 2\ H_2SO_4$

$4\ NO_2 + O_2 + 2\ H_2O \rightarrow 4\ HNO_3$; these are net summaries.

Damage and restoration

Acidity mobilises aluminium and removes nutrient ions; geology affects buffering.

Liming treats acidity, not upwind emissions; restoration may need repeating.

Plan a safe lichen investigation

Sampling

Equal quadrats, repeated trees, defined road distances and background sites.

Match tree species, height and aspect; protect organisms and people.

Inference

Record bark, shade and moisture; compare calibrated monitoring.

A lichen pattern does not identify one gas concentration or prove traffic causation.

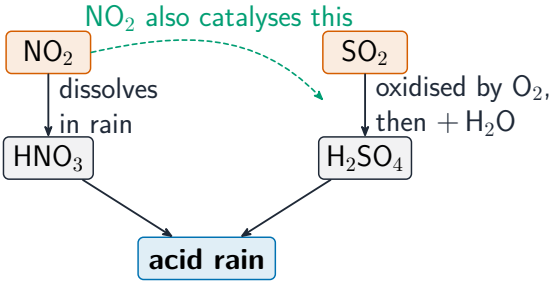
Beijing: distinguish rounding and benchmarks

1. **Rounded reduction** $(90-32)/90 \times 100 = 64.4\%$; official 64.2% uses unrounded data.
2. **WHO annual comparison** $32 / 5 = 6.4$ times the 2021 annual guideline.
3. **Interpretation** Annual means differ from daily peaks; one legal limit does not mean zero risk.

Decision

Evaluate weather, activity, costs, reliable heating, jobs and regional emissions.

How acid rain forms



Both fall as acid rain

AHL: Population momentum and comparison

Age cohorts

Birth totals depend on number of potential parents as well as fertility.

Age dependency is not a count of employed and unemployed people.

Country trajectories

Compare China and Niger around 1990,2024 and conditional 2060 data.

Do not mix projection revisions or treat DTM stages as permanent ranks.

AHL: Multiply IPAT changes

1. **Population** +20% gives multiplier 1.20
2. **Other factors** Consumption 1.10 and impact per consumed unit 0.75
3. **Combine** 1.20 $\times$1.10 $\times$0.75 =0.99

Decision

The defined impact falls 1%; adding percentage changes is incorrect.

AHL: Read projection horizons

Evidence

UN 2024 central projection: peak near 10.3 billion in mid-2080 s.

WPP 2024 ends at 2100; do not invent an official value beyond it.

Sensitivity

Invented index 100 at 0.5% gives 128.3 after 50 years and 164.7 after 100.

At 1% the indices are 164.5 and 270.5; constant rates are assumptions.

AHL: Migration after Cyclone Idai

Documented event

IOM monitored displacement in Mozambique after the 2019 cyclone.

Damaged homes and livelihoods affected people for months.

Limits and responses

Internal displacement differs from international migration or legal refugee status.

Hazards interact with assets and policy; include housing, livelihoods and participation.

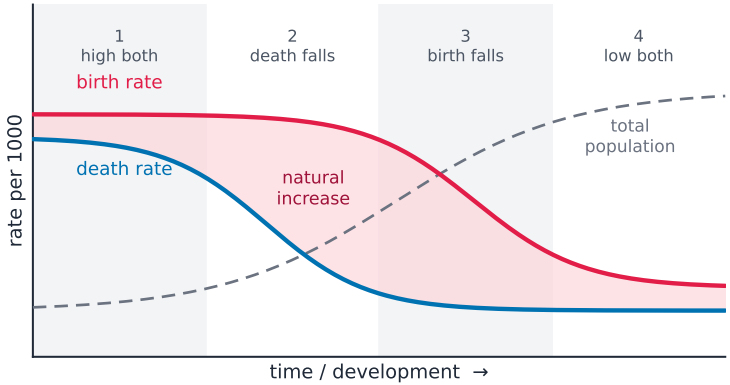
AHL: Test a rank association

1. **Invented ranks** Education 1,2,3,4,5; fertility 5,4,3,2,1
2. **Squared rank differences** $16+4+0+4+16 = 40$
3. **Spearman coefficient** $1-6\times 40/(5\times 24) = -1$

Decision

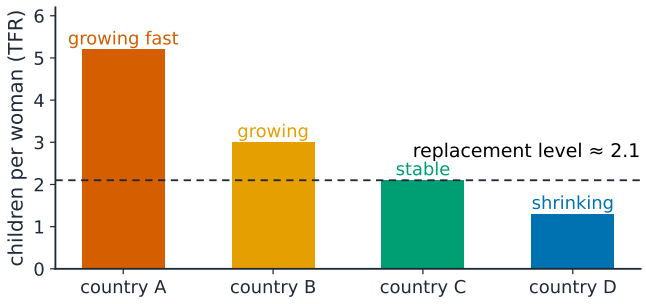
Perfect inverse rank order is not a causal effect or a physical slope; check ties and confounding.

The demographic transition



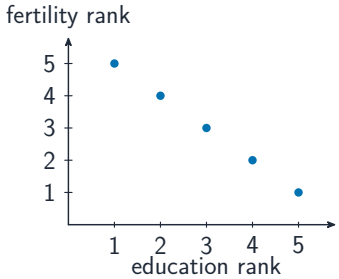
Population grows fastest in stages 2 and 3

Fertility and replacement level



Ignoring migration

A perfect negative rank correlation



ranks perfectly reversed:
every $d = 4, 2, 0, 2, 4$
$\sum d^2 = 40$, so $r_s = -1$
association across regions;
not individual causation
(invented regions)

Rank correlation -1: correlation is not cause

AHL: Compactness, mixed use and social mix

Potential benefits

Compactness can limit sprawl and support frequent public transport.

Mixed use shortens trips; social mix supports inclusive access.

Conditions

Prevent overcrowding and unaffordable housing.

Include safe walking, accessible services and green space.

AHL: Green access and environmental justice

Invented comparison

Equal populations: districts have 10 and 30 m^2 green space per person.

A mean 20 m^2 hides unequal provision.

Evaluate distribution

Measure safe access, quality, shade and participation.

Rising rents can displace intended beneficiaries; protect housing access.

AHL: Amsterdam's circular strategy

Dated 2020–2025 example

A doughnut framework links social needs and ecological limits.

Connect food, consumer goods and construction through repair/reuse/procurement.

Measure outcomes

Collection does not prove useful reuse or avoided virgin production.

Include material losses, imported impacts and actual progress towards targets.

AHL: Buildings over their lives

Climate-responsive design

Combine shading, insulation, ventilation, materials and comfort.

Windcatchers and evaporative cooling depend on wind, humidity and water.

Whole-life assessment

Compare embodied and operating impacts, maintenance and access.

Vauban includes different standards; one green feature does not establish sustainability.

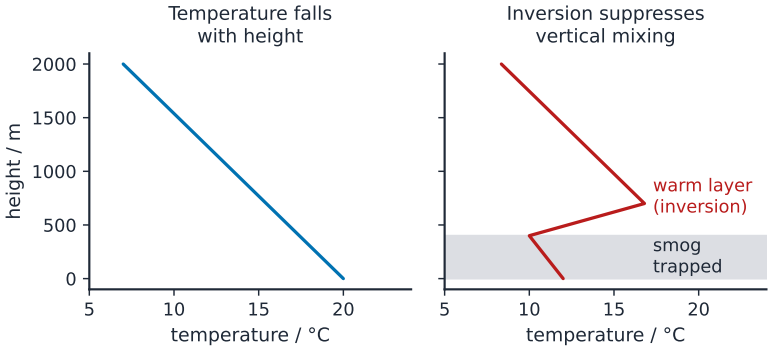
AHL: Photochemical smog

- Traffic releases NO_x and VOCs in the morning.
- Afternoon ozone peaks are common, not universal; chemistry, transport and weather matter.

$$NO_2 \xrightarrow{\text{sunlight}} NO + O \qquad O + O_2 \rightarrow O_3$$

Ozone near the ground irritates lungs and damages crops.

AHL: Temperature inversions



A stable warm layer suppresses vertical mixing and dilution.

AHL: Net ozone accumulation

NO_2 photolysis and cycling

Light splits NO_2; O joins O_2 with a third body to form O_3.

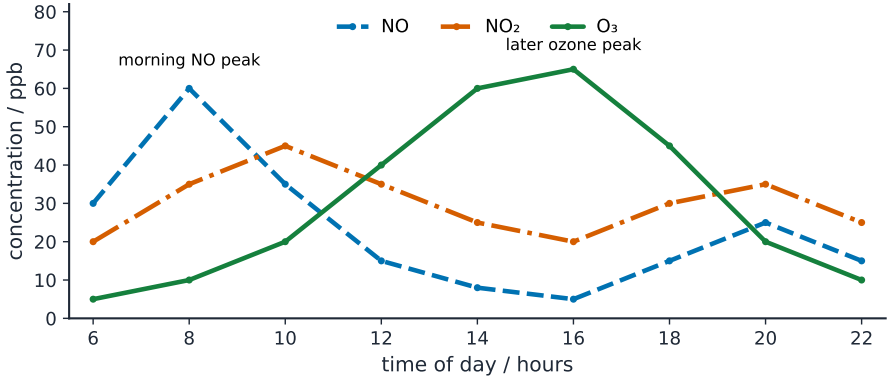
Fresh NO can remove ozone and reform NO_2.

Why VOC chemistry matters

VOC-derived radicals can convert NO to NO_2 without consuming ozone.

Net accumulation and PAN formation depend on precursor chemistry; responses can be non-linear.

AHL: Read an invented daily pollutant curve



Invented ozone change: +55 ppb (+550%); timing depends on conditions.

AHL: Stability and consequences

Mixing

An inversion suppresses vertical mixing; weak winds and topography can retain pollution.

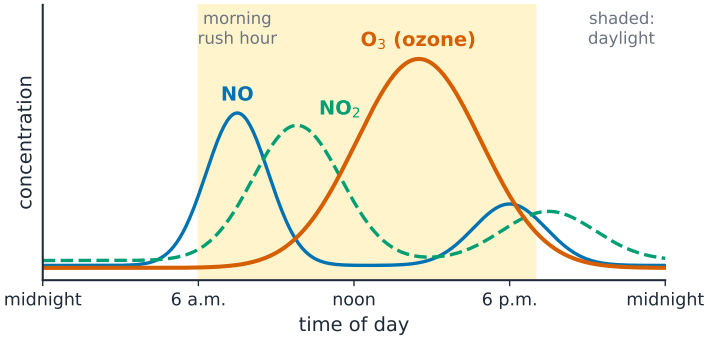
A falling environmental temperature alone does not establish parcel buoyancy.

Effects and management

Eye/airway irritation, plant injury and rubber damage are direct effects.

Healthcare costs, lost work and unequal exposure require source controls and protection.

A day of photochemical smog



Ozone needs sunlight to form

Exam tips

> **Tropospheric ozone** is a pollutant; stratospheric ozone protects us.

- Show working in rate calculations; give per 1000 or %.
- For the DTM, give each change and a reason.
- Use activity, release and clean-up for pollution management.

Check yourself

Try these

A country of 50 million has 900 000 births and 400 000 deaths in a year. Find CBR, CDR and NIR.

Evaluate China's one-child policy.

Plan a safe lichen investigation and explain its causal limits.