# INSTITUTE OF ACTUARIES OF INDIA

# EXAMINATIONS

## November 2026

## CP2 - Actuarial Modelling (Paper B)

## Time allowed: 3 Hours 15 Minutes

## Total Marks: 100

## Exam requirements

Read the Overview of the project, which describes the background on which the base model has been built and the work that remains outstanding.

Read the Audit Trail, which has been written by your colleague, another member of the actuarial team, for the calculations that they performed. This will assist you in following and understanding the calculations performed in the Excel model provided.

**You are not required to add to or amend the Audit Trail.**

**You should assume that your colleague's calculations have been checked and are correct.**

**Expand the spreadsheet model to produce the additional calculations set out in Q1 below. You should ensure that the additional work you undertake contains appropriate self-checks, and you should not overwrite the existing calculations.**

### Q.1) Additional information and modelling steps

Recalculate the AQI for each month, the highest and lowest AQI month, under each of the three scenarios below. The impact of each scenario must be calculated separately and independently of the others.

#### i) Scenario 1: Odd-Even rule for vehicles along with EV/CNG incentive

- 45% of petrol/diesel vehicles are off the road under the rule.
- Government incentives (e.g., additional registration/parking benefits) accelerate EV/CNG vehicles adoption among the remaining on-road fleet as the restriction continues. The assumed adoption rates are provided in the table below:

| Month | EV/CNG vehicles Adoption % (of Petrol/Diesel remaining vehicles) |
|---|---|
| Jan | 5% |
| Feb | 7% |
| Mar | 9% |
| Apr | 11% |
| May | 13% |
| Jun | 15% |
| Jul | 17% |
| Aug | 19% |
| Sep | 21% |
| Oct | 23% |
| Nov | 25% |
| Dec | 27% |

Adoption is capped at a 22% ceiling, reflecting the assumption that the vehicle fleet cannot transition to EV/CNG faster than this rate. Therefore, the applied EV/CNG vehicles adoption rate for each month is the lower of the stated monthly adoption rate and 22%.

The applied EV/CNG vehicles adoption represents the proportion of the remaining on-road fleet that transitions from petrol/diesel to EV/CNG. It is assumed that EV/CNG vehicles are used for the same distance as petrol/diesel vehicles, however there are no emissions from these vehicles, leading to a reduction in the fuel-mix emission factor.

- The remaining vehicles after EV/CNG adoption are driven 15% further each (car-pooling / one vehicle covering multiple trips) as a result of the overall reduction in vehicles under this rule.

Calculate the impact of Odd even scenario along with EV/CNG incentive on monthly AQI as compare to base (absolute and relative), along with the impact on statistics. **[5.5]**

**ii) Scenario 2: Construction restrictions**

- Traditional construction technique usage is reduced progressively, with sites moving to modern technique. The reduction is 5% of the traditional share in January, increasing by a further 8 percentage points each month (13% in February, 21% in March, and so on), and is applied to that month's traditional share proportionally.

- November to February only, construction activity is suspended on a number of sites: 15 commercial sites and 25 residential sites stop operating in each of those four months. These sites cease activity altogether and are removed from the active site counts - they are not reclassified from one category to the other. Note that because the commercial and residential shares are derived from the site counts themselves, both shares will move as a result.

- Anti-smog misting systems are installed on site scaffolding to suppress construction dust. The effectiveness of the systems increases with installed height, as a higher-mounted misting system covers a wider radius. Assume 1% suppression per metre of installed height.

| Month | Installed Misting-System Height (metres) |
|---|---|
| Jan | 10 |
| Feb | 14 |
| Mar | 18 |
| Apr | 22 |
| May | 26 |
| Jun | 30 |
| Jul | 34 |
| Aug | 38 |
| Sep | 42 |
| Oct | 46 |

| | |
|---|---|
| Nov | 48 |
| Dec | 50 |

The systems are rolled out progressively as more systems become available.

Suppression effectiveness for each month is capped at 40%. Therefore, monthly suppression effectiveness is based on the installed height and the 1% per metre assumption, subject to the 40% ceiling. Beyond 40%, additional misting does not provide further dust suppression because wind disperses the water mist before it can effectively settle the dust.

The resulting suppression effectiveness reduces the existing construction AQI factor proportionately, in addition to the technique shift and site suspensions described above.

Calculate the impact of Construction restrictions on monthly AQI as compare to base (absolute and relative), along with the impact on statistics. **[5]**

**iii) Scenario 3: Cloud Seeding (Oct-Feb, area coverage)**

- The city has a total area of 800 km2. The Committee's ambition is that, if the whole city could be seeded, the Weather Multiplier would fall by 30% - this is the full-coverage target, not a guaranteed result.
- A prototype cloud-seeding fleet is flown October to February only, each unit covering 120 km2 a month. The fleet is sized to prioritise the worst months: 2 units in October, 4 in November, 6 in December, 8 in January and 6 in February.
- The area a prototype unit can cover in a month is limited, so the fleet deployed in a given month may or may not be enough to cover the whole city. Where the fleet's combined coverage exceeds the city's area, the excess delivers no further benefit; the city cannot be covered more than once.
- The Committee's 30% ambition assumes the whole city is seeded. Where only part of the city is covered in a month, only a proportionate share of that ambition is achieved, and the Weather Multiplier for that month is reduced accordingly.

Calculate the impact of cloud seeding on monthly AQI as compare to base (absolute and relative), along with the impact on statistics. **[4.5]**

**iv) For all three scenarios**

- Prepare a monthly AQI comparison summary for base and three scenarios along with % change.
- Show a summary of how average AQI, highest AQI and lowest AQI change compared to the base model, for each scenario.
- Create the relevant graph(s).
- Add appropriate checks in all scenarios to make sure that relevant fields are changed only and vice-versa.

**[8]**

**[23 Marks]**

**Q.2) Summary document**

Prepare a summary document of around five to seven pages, capturing the main features and results of the work completed by you and your colleague.

You can assume the summary is being prepared for the Committee Head, who will present the work to the Environment Committee and use it to decide what to recommend to government on an AQI action plan.

**Your summary should include the following:**

- purpose of the project, data, assumptions and method used by you and your colleague
- results, including charts
- commentary on the results
- key conclusions
- suggested next steps.

**Commentary on the results should cover, but not be limited to:**

- analytical comments on each stage of the results, including explaining patterns in the results and any unusual features
- an explanation of the differences between the results under the base model and each of the scenarios modelled, and why those differences arise
- why the highest and lowest AQI months occur when they do under each scenario, and which driver is responsible in each case.

**You are not required to add to or amend the Audit Trail, but all results from the three scenarios should be included in the summary.**

**Marks available for the summary:**

| | | |
|---|---|---|
| **i)** | Methodology (including purpose, data, assumptions and method) | **[25]** |
| **ii)** | Results, including charts | **[5]** |
| **iii)** | Commentary on results and conclusions | **[17]** |
| **iv)** | Next steps | **[20]** |
| **v)** | Drafting | **[10]** |
| | | **[77 Marks]** |

**Overview of the project**

ABC is a mid-sized city whose Air Quality Index (AQI) has worsened steadily over recent years, particularly through the winter months. AQI is a composite measure of ground-level air pollution: higher values mean more pollution, and sustained readings above 200 are associated with measurable increases in respiratory and cardiac admissions, school closures and lost working days. ABC's readings now exceed that level for several months of the year, and the winter peak has become severe enough to attract national attention.

The city government has come under pressure to act, but has so far lacked an evidence base for deciding *what* to act on. Public debate has focused almost entirely on vehicle traffic, while construction activity and seasonal weather conditions have received little attention despite both being plausible contributors. Previous interventions have been announced reactively during bad-air episodes, without any assessment of their likely effect, and without a way of telling afterwards whether they worked.

An independent Environment Committee has been formed, bringing together public health, transport and urban planning representatives, to establish what is actually driving the deterioration and to recommend a concrete, costed action plan to government. The Committee has engaged an actuarial team to build and test a quantitative model of AQI, so that competing interventions can be compared on a consistent basis rather than on assertion.

The Committee has set out three requirements for the work:

- it must separate AQI into its underlying drivers, so that the contribution of each can be seen month by month rather than as a single unexplained number
- it must be built from measurable, real-world quantities the city already collects or can reasonably obtain, so that the model can be maintained and re-run in future years
- it must be capable of testing proposed interventions against a consistent baseline, so that options can be ranked.

A colleague on the team has already built the base model, which estimates AQI for each of 12 months from three underlying drivers: Traffic, Construction and Weather each itself derived from measurable sub-factors. Traffic and Construction are emission sources; Weather is not, and acts only on how much of what is emitted remains near ground level. The Senior Actuary has provided you with this model and the Audit Trail written by your colleague, describing how it was built.

The Committee is weighing three possible interventions and has asked the actuarial team to model the impact of each on the base model before it reports back. Each is deliberately a different kind of lever, so that the Committee can see not just whether an intervention helps, but through which mechanism, and in which months, it does so:

- **An odd-even style restriction on private vehicles**, combined with incentives to accelerate the switch to EV/CNG vehicles. This is the traffic-side lever and the most direct one available, since it targets Traffic without requiring new infrastructure. Similar restrictions have precedent in other Indian cities during severe pollution episodes, giving the Committee a reasonably well-understood starting point for likely public reaction and compliance. It is also the most politically exposed of the three, affecting the daily routine of every vehicle-owning household.
- **Restrictions on construction**, combining a progressive shift away from traditional technique (i.e. gradually moving to modern technique), a suspension of activity on a number of sites through the winter months, and the installation of anti-smog misting systems. This is the construction-side lever. Technique is a natural target because dust-suppression methods already exist in the sector, so a mandate requires nothing new to be developed; the winter suspension is more disruptive, carrying a direct cost in construction output and employment, which the Committee will need to weigh against the AQI benefit.
- **A cloud-seeding programme flown only in the winter months (Oct-Feb)**, sized by the physical area a prototype fleet can actually cover against a stated full-coverage ambition. This is the only lever that acts on dispersion rather than emissions. It does not reduce what the city produces, only how much of it remains near ground level. It is unproven at city scale and its benefit is constrained by fleet capacity, so the Committee wants to understand what a limited, technology-based intervention can realistically deliver alongside the two behavioural and regulatory levers above.

The Committee is conscious that the levers are not directly comparable in cost, disruption or deliverability, and that the first two are modelled with a second, physically-grounded layer on top of the restriction itself, since a restriction alone rarely tells the whole story. It has asked for the AQI impact of each to be established first, so that the trade-offs can be discussed on the basis of evidence.

You are required to use the model provided and test the impact of the three scenarios above. You are also required to prepare a summary report which the Committee Head can use to brief the wider Committee and government on what action, if any, to recommend.

**You are not expected to include the additional scenario modelling you undertake in the Audit Trail, but the approach and results of all three scenarios should be included in the summary.**

## Audit Trail

### Background

ABC's Air Quality Index (AQI) has worsened over recent years, particularly through the winter months. The Environment Committee has engaged an actuarial team to establish what is driving this - separately for Traffic, Construction and Weather and to model the AQI impact of possible interventions.

Rather than treating AQI as a single unexplained number, the model builds it up for each of the 12 months from three underlying drivers, each derived from measurable, real-world sub-factors. Traffic and Construction are emission sources; Weather is not, and acts only on how much of what they emit remains near ground level.

### Objective

The objective of this work is to:

- Calculate monthly AQI from its three underlying drivers - Traffic, Construction and Weather - and identify which driver contributes most in the highest and lowest AQI months.
- Provide a base model against which the Committee's proposed interventions can be tested.
- Establish which intervention, if any, delivers a material improvement in AQI.
- Prepare a summary of the findings for the Committee Head, to use in briefing government on next steps.

### Data used - the 'Base Data' tab

The data was supplied by the Committee, drawn from the following sources:

- **Traffic:** vehicle registration records and the periodic household travel survey, both held by the city Transport Department.
- **Construction:** building permit and site inspection records held by the Municipal Corporation.
- **Weather:** monthly observations from the national meteorological service.
- **Emission factors and baseline AQI:** published national air-quality research.

All data was provided for a single representative year, at monthly granularity.

All inputs are held in the 'Base Data' tab and referenced from there into the 'Base Model - AQI' tab, so that no figure is typed into the model twice. The tab has four blocks:

**Constants (rows 3 to 12):** the fixed weights that convert a raw activity count into a pollution contribution. Petrol emission factor 0.13 and diesel 0.23, so diesel is assumed materially dirtier per km. Old-vehicle factor 1.3 and new 0.8, so an older fleet emits more for the same distance. Commercial building factor 1.4 and residential 0.8, so commercial sites disturb more ground per site. Traditional technique factor 1.5 and modern 0.5, so dust-suppressing technique is assumed to cut site emissions by roughly two thirds. Base AQI of 25 is the irreducible background level present in every month.

**Traffic data (rows 16 to 28):** for each month, the number of days in the month, the average distance driven per vehicle per day, the vehicle count in '000s, the % diesel share and the % old-vehicle share. Distance is deliberately given as days multiplied by a daily distance rather than as a single monthly figure, so that a 28-day February is not treated like a 31-day January, and so that seasonal variation in daily driving can be reflected.

**Construction data (rows 31 to 43):** for each month, the number of active commercial sites and the number of active residential sites given separately as counts rather than as a single total with a percentage split, and the % of sites using traditional technique.

**Weather data (rows 46 to 68):** the Weather Multiplier is not given directly. Instead, the tab holds three measured monthly climate inputs - mixing (boundary layer) height in metres, rainfall in mm and relative humidity % - together with, for each of them, an annual average reference value and a sensitivity weight, plus a floor on the maximum washout benefit that rainfall can deliver.

**Assumptions**

- Commercial and residential site counts vary month by month, and the commercial/residential mix is therefore an output of those counts rather than a fixed assumption.
- Distance driven per vehicle varies by month, calculated as days in the month multiplied by an assumed average daily distance which itself varies seasonally.
- Weather is exogenous: it is independent of Traffic and Construction, and unaffected by any of them. The climate inputs are treated as a representative year rather than a forecast.
- The sensitivities applied to mixing height, rainfall and humidity are judgemental weightings chosen to give a plausible spread of monthly multipliers; they are not fitted to observed AQI data.
- The Base AQI of 25 is fixed in every month and represents background pollution unrelated to the three modelled drivers.

**The calculation - the 'Base Model - AQI' tab**

The tab is laid out as four blocks: Traffic, Construction and Weather are each calculated separately, and then combined.

**Traffic Analysis (columns A to J, rows 4 to 16).** Vehicle count (column B) and distance driven per vehicle (column C, calculated as days in the month multiplied by daily distance and scaled to '000 km) are brought in from Base Data. The % diesel share is brought in as column D and % petrol derived as 1 minus that in column E; % old is brought in as column F and % new derived in column G. The Fuel-Mix Emission Factor in column H is %Petrol multiplied by the petrol factor plus %Diesel multiplied by the diesel factor. The Age Adjustment in column I is built the same way from the old and new shares. Column J multiplies all four together:

Traffic AQI Factor = Vehicles x Distance Driven (‘000) x Fuel-Mix Emission Factor X Age Adjustment

**Construction Analysis (columns A to J, rows 21 to 33).** Commercial and residential site counts are brought in as columns B and C. Their shares are then derived from the counts themselves - column D is commercial divided by the two added together, and column E is residential on the same basis - so the mix always reconciles to the underlying counts rather than being stated separately. The % traditional technique is brought in as column F and % modern derived in column G. The Type-Mix Emission Factor in column H weights the commercial and residential shares by their factors, and the Technique Adjustment in column I does the same for the traditional and modern shares. Column J multiplies the total site count by both:

Construction AQI Factor = (Commercial Sites + Residential Sites) x Type-Mix Emission Factor X Technique Adjustment

**Weather (columns A to H, rows 38 to 50).** The three climate inputs are brought in as columns B, C and D, and each is converted into its own factor by comparing the month against its annual average:

- Mixing-Height Factor (column E) = 1 + sensitivity x (reference height - actual height) / reference height. A shallow winter mixing layer traps pollutants in a smaller volume of air and gives a factor above 1; a deep monsoon layer gives a factor below 1.
- Rainfall Washout Factor (column F) = 1 - sensitivity x (actual rainfall - reference rainfall) / reference rainfall, subject to a floor. Heavier rain washes particulates out of the air, but the floor prevents the benefit growing without limit in the wettest months.
- Humidity Factor (column G) = 1 + sensitivity x (actual humidity - reference humidity) / reference humidity, reflecting that moist air encourages particulate growth and fog formation.

Weather AQI Multiplier (column H) = Mixing-Height Factor x Rainfall Washout Factor X Humidity Factor

**Base Model combination (columns L to X, rows 4 to 16).** The Traffic AQI Factor, Construction AQI Factor and Weather Multiplier are brought across from their blocks into columns M, N and O. Column P adds the irreducible Base AQI to the two emission factors to give the month's Load, and column Q applies the Weather Multiplier to it:

AQI = (Base AQI + Traffic AQI Factor + Construction AQI Factor) x Weather Multiplier

Each driver's own share of that month's AQI is then isolated in columns R, S and T by applying the Weather Multiplier to that driver alone, and columns U, V and W express the same three contributions as a percentage of the month's AQI. This makes it possible to say not just how high AQI was in a given month, but which driver put it there.

**Statistical Analysis (columns L to M, rows 21 to 29).** Calculated directly from the 12 monthly AQI figures: the average, median and standard deviation across the year, the highest and lowest AQI with the month in which each occurs identified alongside, and the range between them.

**Which factor drives the peak and lowest months.** Two further tables look up the Traffic, Construction and Weather contributions for the single month identified as highest, and again for the month identified as lowest, and express each as a percentage of that month's AQI. These identify the driver responsible at each extreme, which is not necessarily the same driver in both cases.

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