

Introduction to Time Series:

Trends, Seasonality, and Change



- Time series: data ordered in time; cross-sectional: single snapshot



- Sequential dependence: each observed value is linked to prior ones



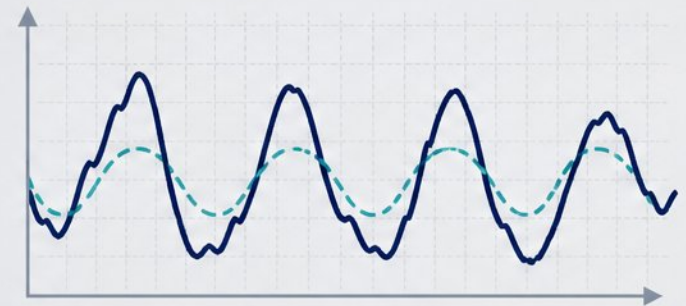
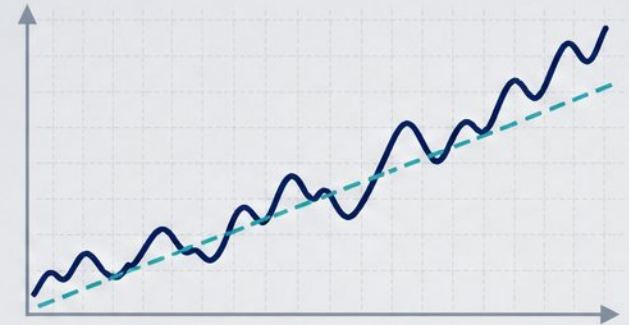
- Core patterns: trends (direction), seasonality (clock), change points (shifts)



- Boundary: visual description only; no forecasting or causal claims



- Goal: spot patterns, avoid post hoc traps, ask sharper questions



What Makes Time Series Special?

Sequential Dependence

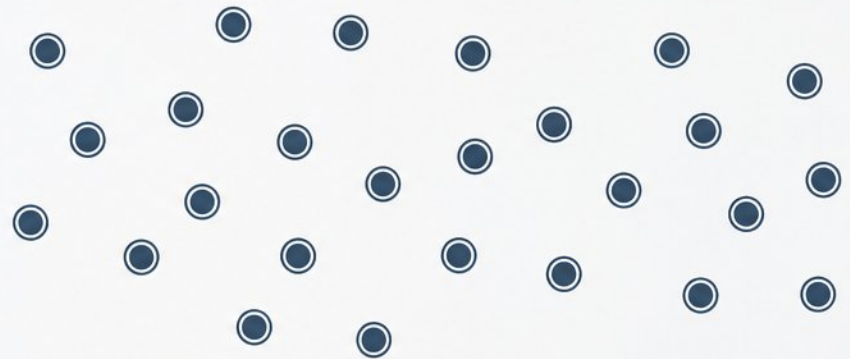
SEQUENTIALLY DEPENDENT (TIME SERIES)



Each point is linked to the past.
Information flows through time.

VS.

INDEPENDENT OBSERVATIONS

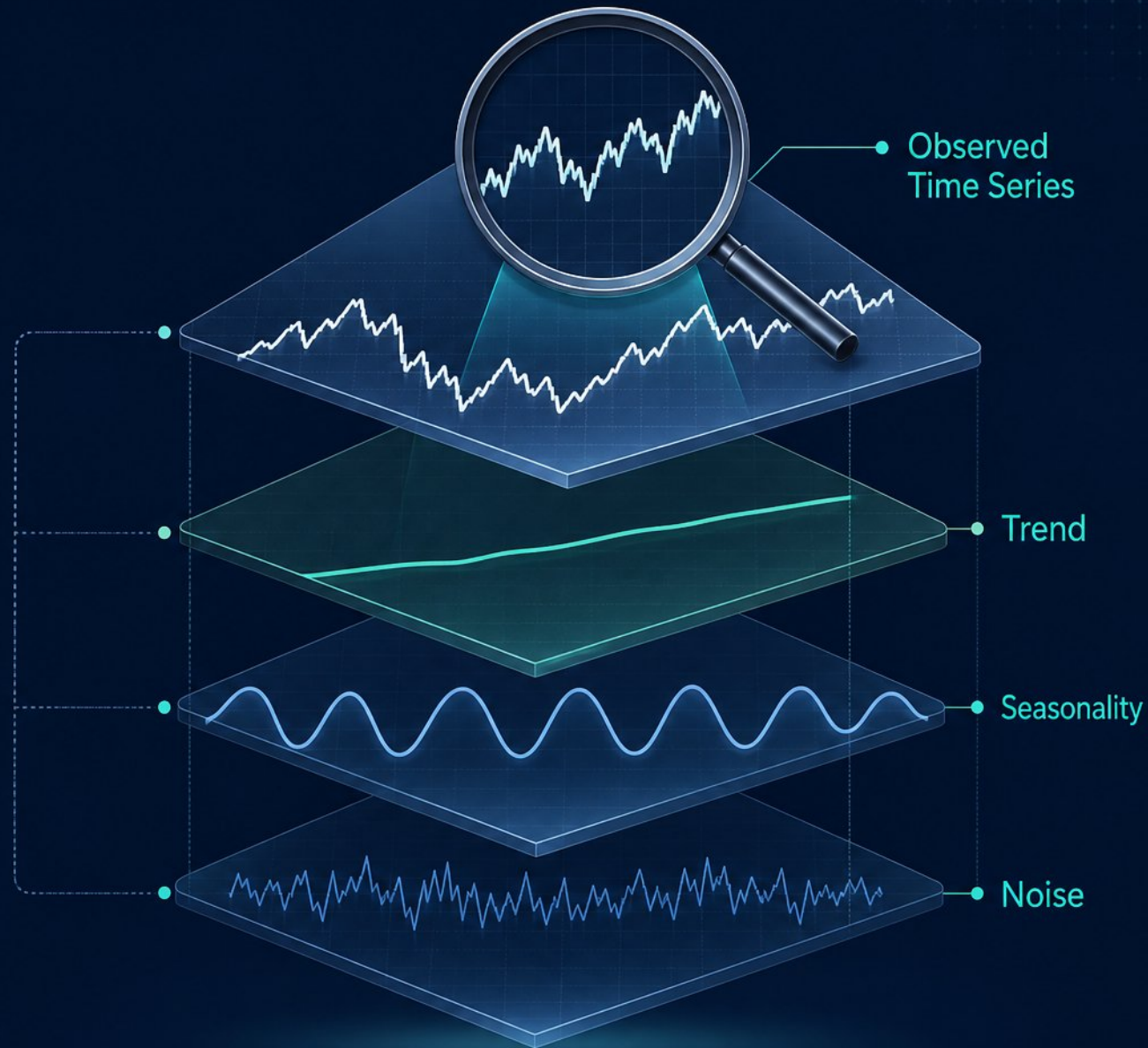


No links between points.
Observations stand alone.

- Each data point often depends on prior values, unlike independent survey responses.
- Examples: daily sales, monthly active users, hourly temperature, weekly web traffic.
- Treating time-ordered data as independent leads to spurious insights.
- High R^2 between two trending series is often meaningless (nonsense correlation).

Deconstructing the Additive Framework

- **Time Series** = Trend + Seasonality + Noise (additive model)
- **Level:** the average value around which the series fluctuates
- **Trend:** the long-term direction (up, down, or flat)
- **Seasonality:** repeating short-term cycles (e.g., daily, weekly, annual)
- **Noise:** the random, irregular jitter leftover after removing signal



Recognizing Trends: The Long-Term Direction

- ▶ - Trend: sustained directional movement over the entire observation period
- ▶ - Linear growth, exponential acceleration, plateauing, or flat/stationary
- ▶ - Identify trends by overlaying a simple moving-average line
- ▶ - Past upward trend does not logically imply future continuation



Understanding Seasonality: The Clock Inside Your Data



- **Seasonality:** a repeating pattern with a fixed, known period (hourly, daily, weekly, annual).



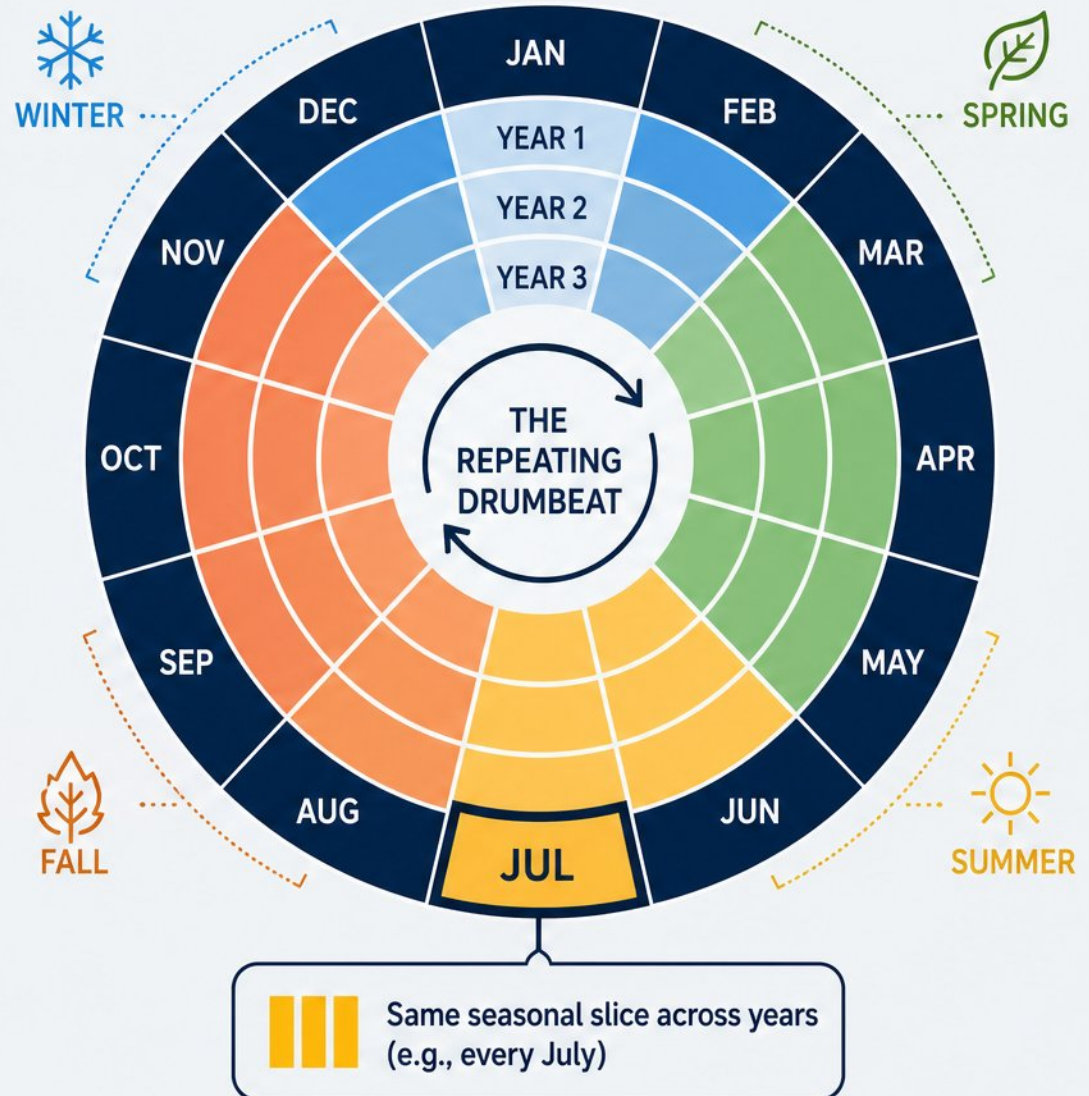
- Differs from irregular business cycles, which lack a fixed calendar period.



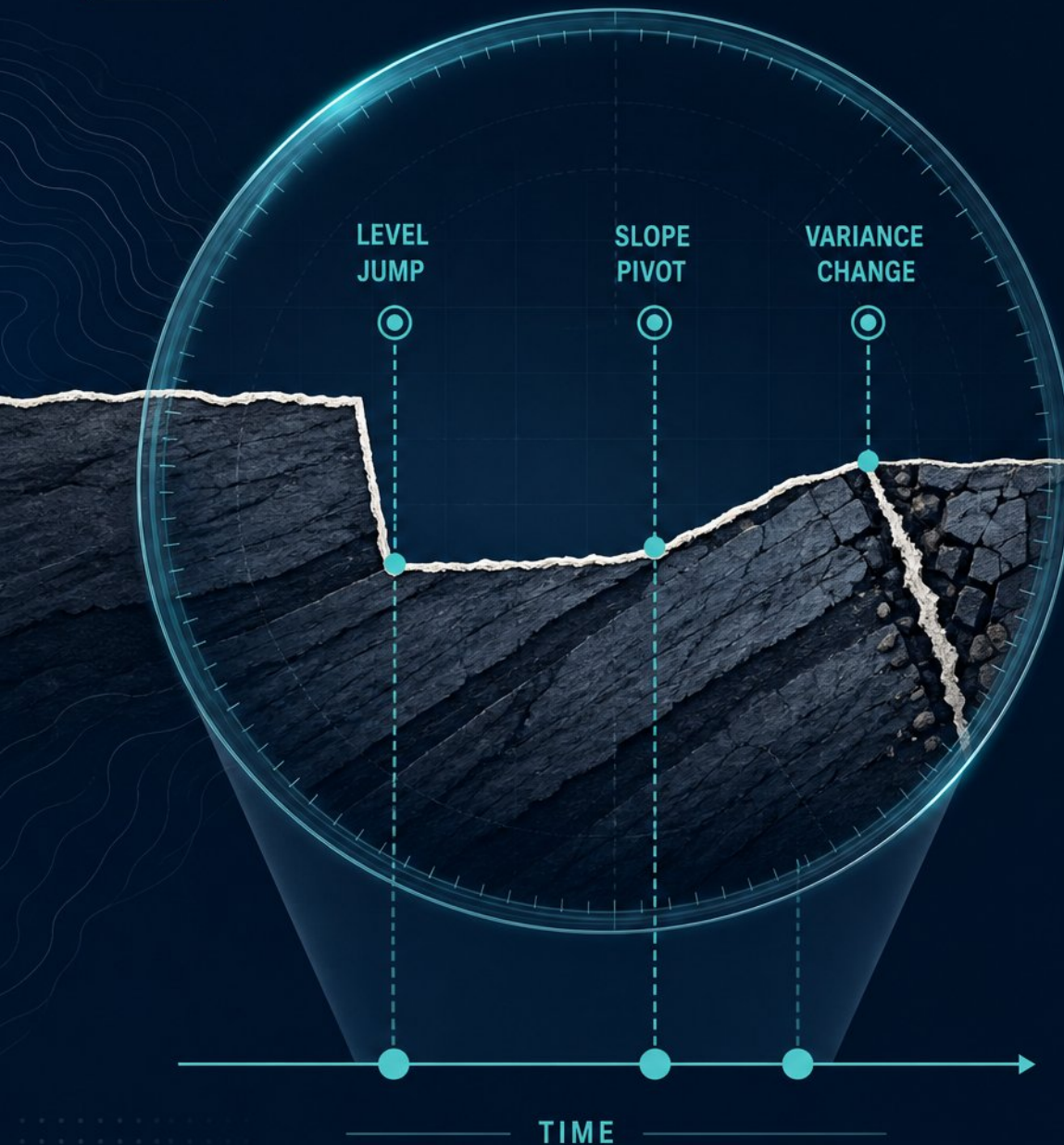
- **Examples:** Q4 retail spikes, summer tourism peaks, winter energy demand, Monday web traffic surges.



- Recognize by grouping the same seasonal slice across years (e.g., every July) to isolate the repeating drumbeat.



Detecting Change Points and Structural Breaks



- **Change point:** moment when the data process shifts abruptly, not gradually
- **Level jump:** sudden new baseline (e.g., system outage drop)
- **Slope pivot:** trend direction or steepness changes permanently
- **Variance change:** volatility clusters signal regime change
- Visually mark the date and magnitude; do not test for statistical significance

Separating Signal from Noise



- Signal = systematic (trend + seasonality); Noise = random jitter leftover



- Apply a moving-average line to suppress short-term fluctuations



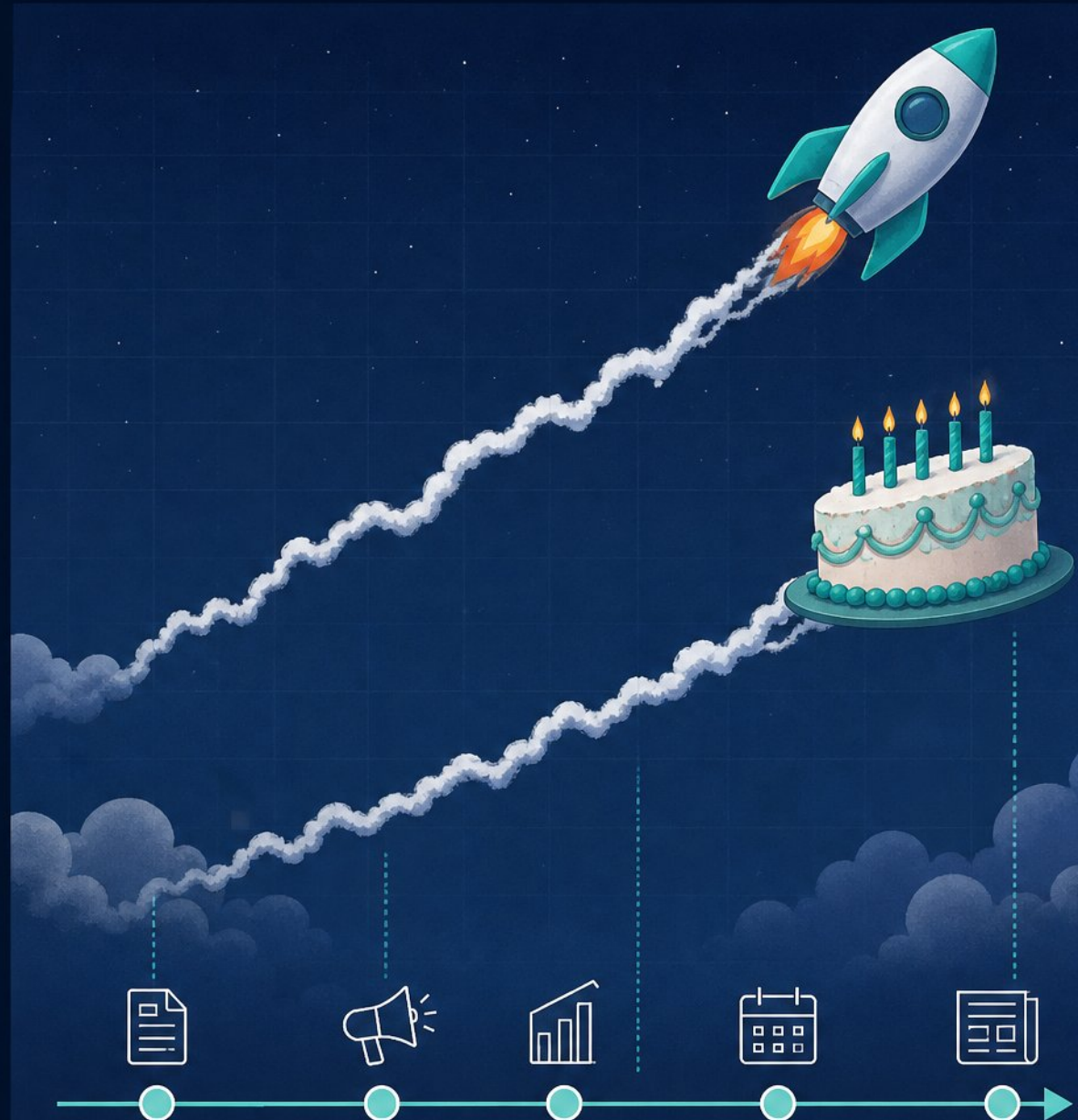
- Aggregate daily data to weekly totals to remove day-of-week noise



- Beware: excessive smoothing hides real events like brief sales drops

Spurious Traps: Correlation Is Not Causation

- Trending series can show high correlation by chance (e.g., $r=0.95$ for marriage vs. mortality rates)
- Two unrelated random walks with drift often produce R^2 near 1.0
- **Remedy:** analyze period-to-period differences, not cumulative levels
- **Post hoc trap:** "After campaign, sales rose" doesn't prove the campaign caused it
- **Warning signs:** $R^2 > 0.8$, no plausible mechanism, correlation strengthens with more data



Cherry-Picking and the Danger of the Time Window

- Choosing start/end dates can flip the story (“crash” vs. “normal dip”)
- Simpson's paradox: trends in subgroups can reverse when aggregated annually
- Truncating the y-axis makes a tiny 2% change look like an explosion
- Always view the longest available history and state the observed window



Walkthrough Part 1: The Classic Airline Passengers Dataset

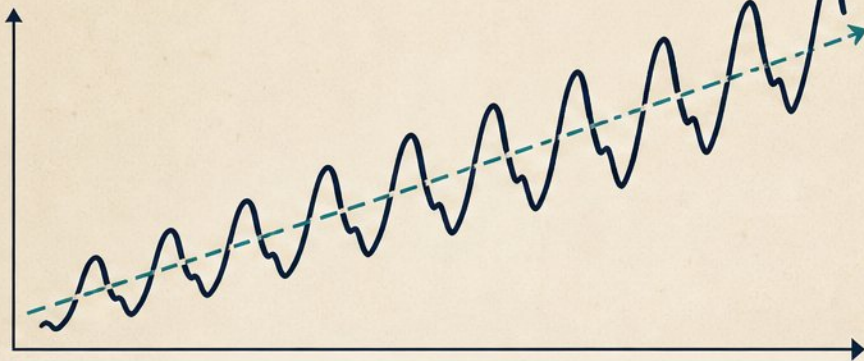
★ SPECIMEN PLATE I ★

AIRLINE TRAVEL

A STUDY IN SEASONAL MOVEMENT



PASSENGER CURVE (RAW TIME PLOT)



OBSERVE • ANALYZE • UNDERSTAND



- Monthly international airline passengers from 1949 to 1960



- Observe the raw time plot and describe its overall shape



- Identify the clear upward linear trend over 12 years



- Note the repeating annual wave with mid-year peaks





Walkthrough Part 2: Seasonality and Change Points in Airline Data



- Seasonal amplitude grows with the trend: higher peaks in later years



- Season plot confirms the July peak and November trough repeat annually



- 2020 pandemic caused a sharp structural break, severing the prior trend



- After the break, prior patterns no longer describe the new data reality

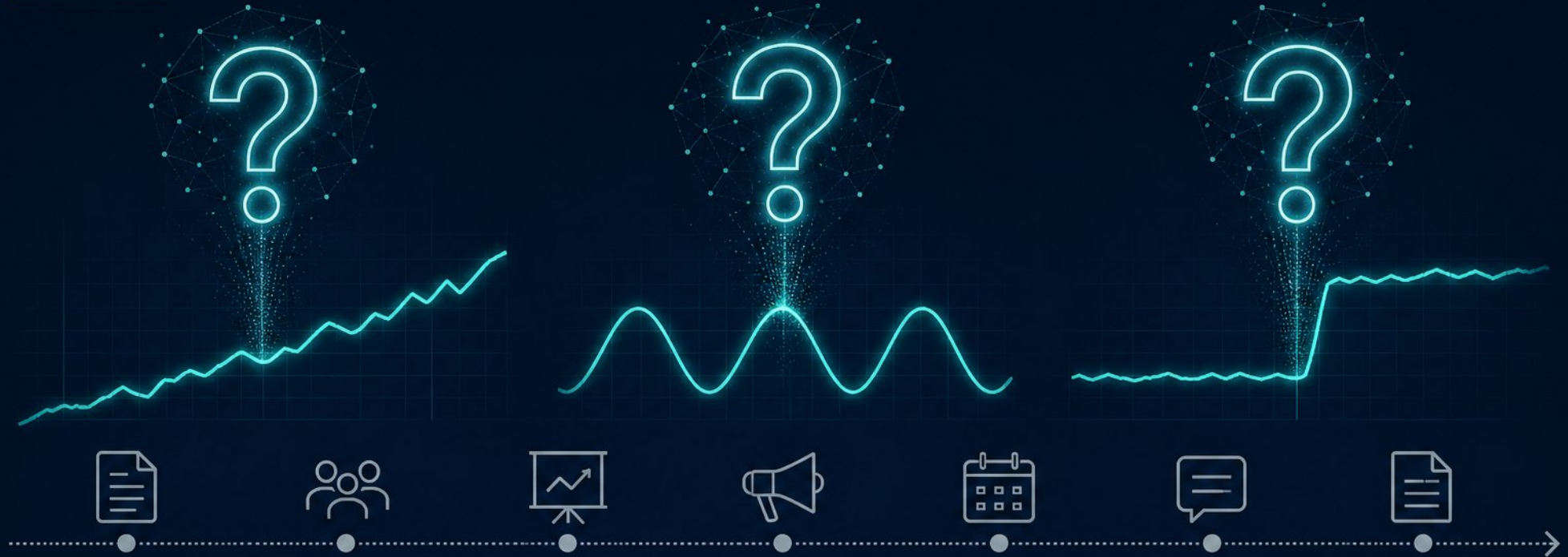


Practice Case: Retail, Operations, and Digital Metrics

- Use weekly online store sessions or quarterly software MRR data
- Identify overall trend, seasonal pattern, and one suspected change point
- Ask context questions: product launch, holiday, or market event?
- Follow protocol: raw data → add smooth → examine seasonal sub-series



From 'What Happened?' to 'What Should We Ask?'



- Translate visual patterns into actionable business questions, not conclusions



- Trend: Does this growth align with our hiring and capacity plan?



- Seasonality: Are we staffed for the Monday surge or July lull?



- Change Point: What market event around March 2024 explains this shift?



- Treat every pattern as a hypothesis to investigate with domain experts

Building the 'No-Statistics' Visual Inspection Checklist

1.



1. Context: What does the data measure and over what period?

2.



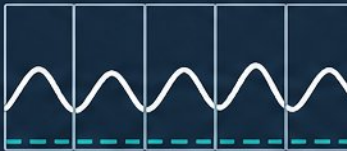
2. Gross Shape: Is the overall direction up, down, or flat?

3.



3. Smooth View: Apply a rough 7- or 12-period moving average.

4.



4. Seasonal Slices: Group by month or day-of-week to find repeating cycles.

5.



5. Breaks & Blips: Mark sharp level shifts or isolated outliers by date.



Summary and Core Rules of Thumb



- Three core patterns: trend, seasonality, and change points



- Boundaries: no forecasting, no causation, no advanced statistics



- Trend is not destiny; seasonality is a fixed clock



- Correlation is not causation; question your time window



- Escalate real forecasts and impact measurement to specialists



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