Chapter 2
Location, Variability and Process

Section 2.3
Analysis of Processes over Time:
The Run Chart

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Application and Definition

Business Process Management

The process is the core unit for organizing business activities

- To evaluate process performance, consider variables that generate values over time such as
  - time to complete the procedure
  - inventory for physical parts
  - satisfaction and ratings from customers of the process
- **Business Process**: Structured set of procedures that generate output over time to accomplish a specific business goal
- A functioning business is essentially a set of interrelated business processes that ultimately lead to delivery and servicing of the product
- **Key Concept**: Managing a business is managing its processes, so evaluating the on-going performance of the constituent business processes is a central task for managers

Examples of Outcome Variables for Business Processes

Processes span the business environment

- Supply Chain: Ship Time of raw materials following the submission of each purchase order
- Manufacturing: Length of a critical dimension of each machined part
- Production: Amount of cereal by weight in each cereal box
- Order Fulfillment: Pick time, elapsed time from order placement until the order is boxed and ready for shipment
- Accounting: Time required to forward a completed invoice from the time the order is placed
- Sales: Satisfaction rating of customers after purchasing a new product
- Health Care: Elapsed time from an abnormal mammogram until the biopsy

The Run Chart

Consider the time dimension of an ongoing process

- Effective management decisions about when to change the process, to understand its performance, to know when to leave it alone, to evaluate the effectiveness of a deliberate change, require knowledge of how the system behaves over time
- Evaluation of a process first requires accurate measurements of one or more relevant outcome variables over time
- **Run Chart**: A plot of the values of a variable in their order of occurrence, with line segments connecting individual points
- **Index**: The ordinal position of each value in the overall sequence, usually numbered from 1 to the last data value
- Plot the values on the vertical axis, and on the horizontal axis display the Index
- A run chart may also be called a sequence chart, and is an example of what is more generally called a line chart

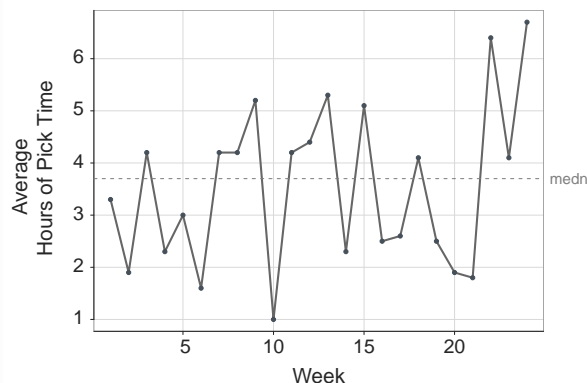## Business Process Ex: Pick Time

Obtain the run chart

- ▶ Consider pick time, the elapsed time from order placement until the order is packaged and ready for shipment
- ▶ Pick time is central to the more general order fulfillment process, and requires management oversight to minimize times and to detect any bottlenecks should they occur
- ▶ The variable is Hours, the average number of business hours required for pick time, assessed weekly, in file pick.csv

    http://lessRstats.com/data/pick.csv

- ▶ Obtain the run chart with the lessR function Plot, specify to display the values in sequence with the run parameter

    > Plot(Hours, run=TRUE)

- ▶ The center line, the median, is automatically added if the values of the variable tend to oscillate about the center

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Run Chart: Example

```
> Plot(Hours, run=TRUE, xlab="Week",
      ylab="Average Hours of Pick Time")
```

Variation: A Fundamental Property of Process Output

The outcome of any process varies over time

- ▶ What does the manager seek to understand from a run chart?
- ▶ **Key Concept**: Random influences contribute to every process outcome, obscuring the underlying process characteristics
- ▶ A primary task of process management is to assess process performance in the context of this random variation, to know
  - ○ The average level of performance of the process
  - ○ The amount of random variation about the average level inherent in the process
- ▶ The next task is to actively manage process performance
  - ○ Adjust the average level of performance up or down to the target level, if needed
  - ○ Continue to minimize the random variation about the desired average level of performance

2.3b
Process Stability and Non-Stability

The Stable Process

A single process for generating data

- ▶ Ensure that the values to be analyzed are actually from the same process, with the same underlying mean and variability
- ▶ **Stable process** or system in control: All values result from the same level of random variation about the same mean
- ▶ In a stable process all data values are sampled from the same process, as in the previous example of pick time
- ▶ The run chart of a stable process displays random variation about the center line, traditionally the median, but also possibly the mean
- ▶ **Common cause variation**: Variation inherent in the process, influences common to *all* process output
- ▶ Common cause variation is the aggregate of innumerable, typically small influences that result in random variation about the center

The Stable Process or "Constant-Cause" System

Recognize stability in the presence of random variation

- ▶ W. Edwards Deming popularized the stable process as perquisite to establishing quality control of process output

There is no such thing as constancy in real life. There is, however, such a thing as a constant-cause system. The results produced by a constant-cause system vary, and in fact may vary over a wide band or a narrow band. They vary, but they exhibit an important feature called stability. ... [T]he same percentage of varying results continues to fall between any given pair of limits hour and hour, day after day, so long as the constant-cause system continues to operate. It is the distribution of results that is constant or stable. When a ... process behaves like a constant-cause system ... it is said to be in statistical control.[1]

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[1]W. Edwards Deming, "Some Principles of the Shewhart Methods of Quality Control, " Mechanical Engineering, 66, 1944, 173-177.

Non-random Sources of Process Variation

Sources of process instability

- ► Some sources of variation are not random
- ► Non-random sources of variation represent a change in the process, classified as temporary or permanent
- ► **Special cause** or assignable cause: A different process that generates outcome values mixed with the outcome values of the reference or baseline process of interest
- ► For an assignable cause, the reason for the change, when known, can be assigned to a specific source, such as
  - ○ the output of a temporarily malfunctioning machine
  - ○ a new computer system not yet fully implemented
- ► Variation of the data values in this situation is due not only to random variation about each respective population mean, but also because there are at least *two* different population means

Is the Process Stable?

Is there a single process that generated the data?

- ► The emergence of a non-random source of variation indicates that the process has changed, either permanently or temporarily
- ► The change is due perhaps to a deliberate re-engineering or perhaps to unforeseen influences
- ► Two primary indicators of a process change
  - ○ **Outlier**: A value considerably different from most remaining values of the distribution, typically generated by a different process than that of the remaining values
  - ○ **Run**: A sequence of consecutive data values on one side of the center line, which can indicate a longer term change
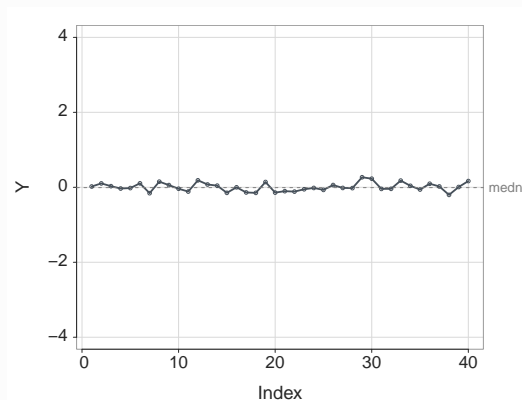- ► Look for unusually long runs, usually longer than 7 values, and also the total number of runs

2.3c

Stable Process Observed with Differing Amounts of Error
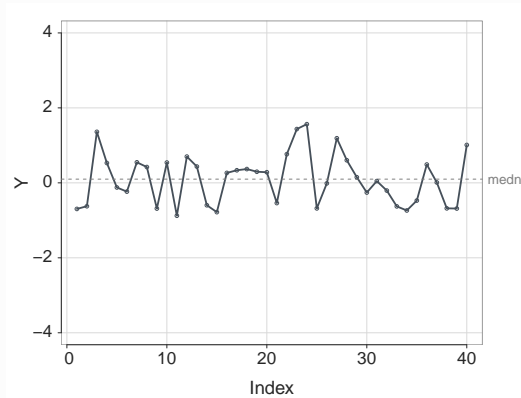

Underlying Structure of a Stable Process

- ▶ No error in the observations, pure structure that is never observed

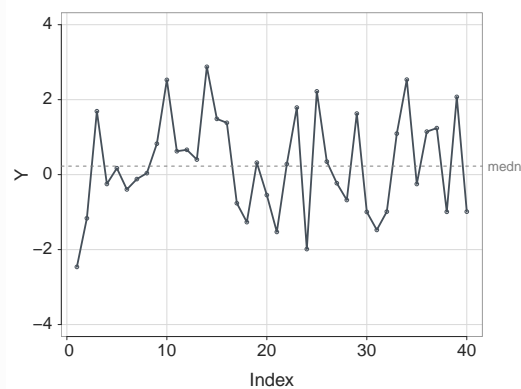---

Small Amount of Error for a Stable Process

- ▶ Underling structure apparent

More Error Imposed Upon a Stable Process
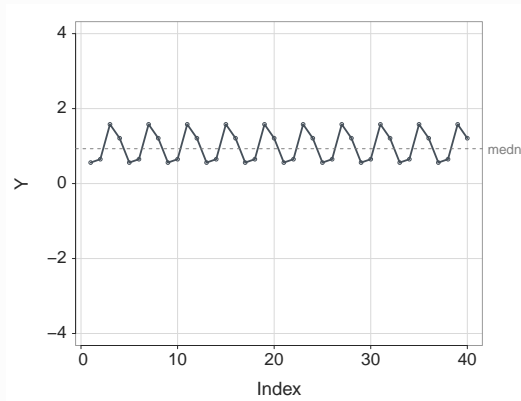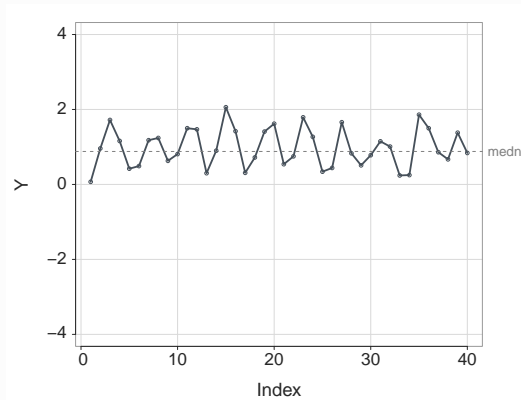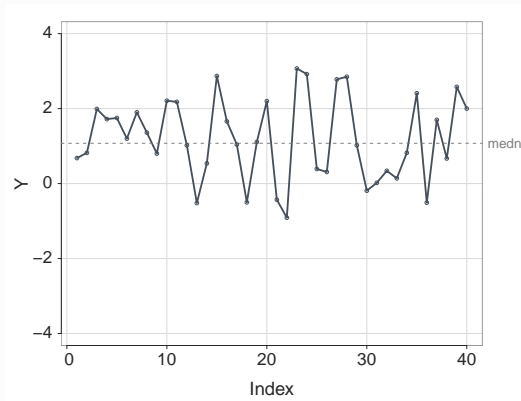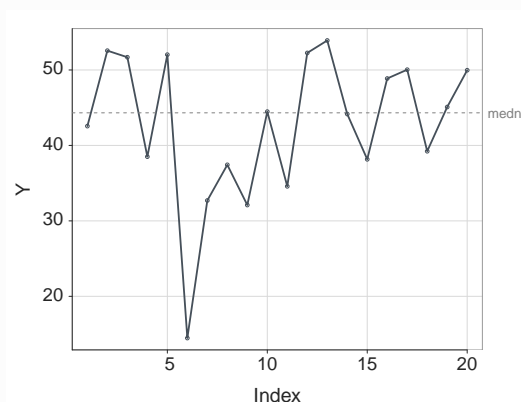

► Underlying structure more obscured

Large Amount of Error Imposed Upon a Stable Process

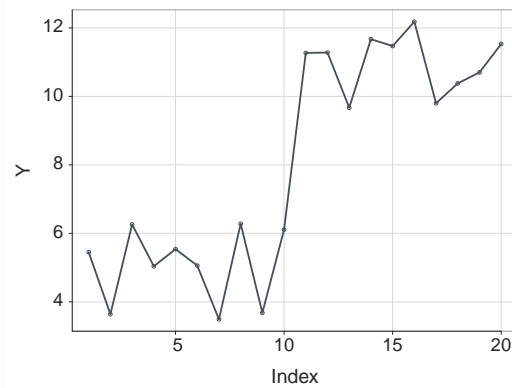

► Process is stable even though amount of error is large, no patterns or structure other than stability

Seasonality Observed with Differing Amounts of Error

Underlying Structure of a Seasonal Process

▶ No error in the observations, pure structure

Small Amount of Error Imposed Upon a Seasonal Process

▶ Underling structure apparent

More Error Imposed Upon a Seasonal Process

▶ Underlying structure more obscured

Large Amount of Error Imposed Upon a Seasonal Process

► Process is seasonal, but amount of error is large

2.3d
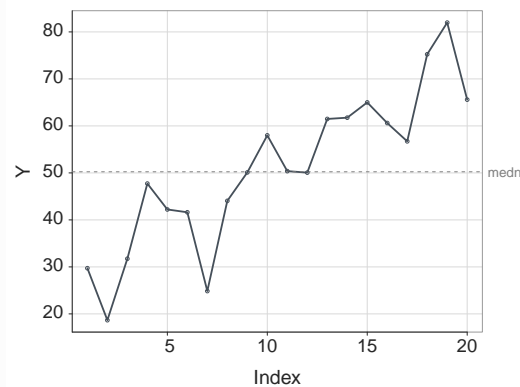## Non-stable Processes (with Error)

Violation of Stability: The Outlier

► The presence of an outlier indicates that a special cause, a temporary event, likely resulted in a deviant data value
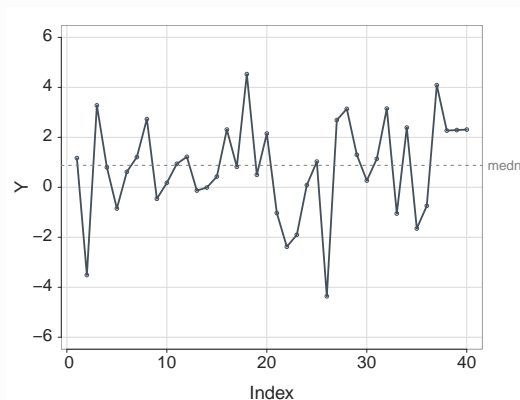
Violation of Stability: Level Shift

▶ **Level shift**: Sudden but relatively permanent shift in the overall level of performance
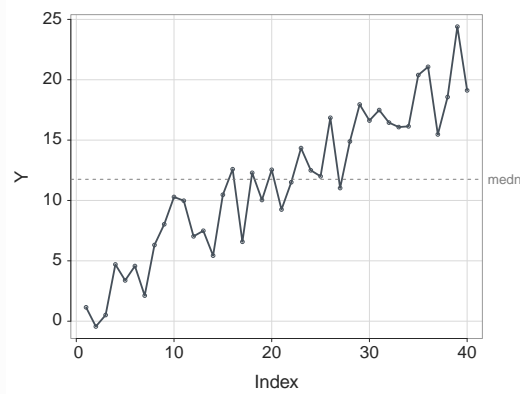
Violation of Stability: Trend

▶ **Trend**: Long term direction of movement of the data values over time, a general tendency to either increase or decrease

Violation of Stability: Seasonality

▶ **Seasonality**: Periodic fluctuations that follow a regular pattern
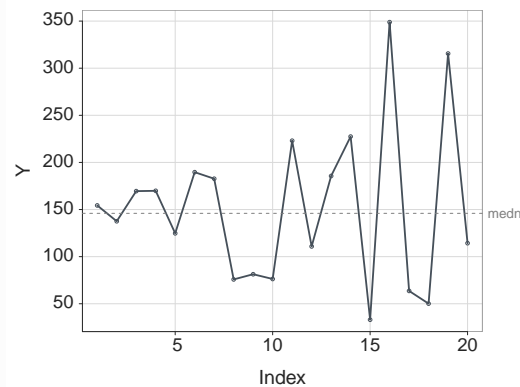
Violation of Stability: Trend and Seasonality

- ▶ Seasonality and trend combine

Violation of Stability: Increasing Dispersion

- ▶ The center remains constant, but the variability of the system increases over time

Index　Subtract 2 from each listed value to get the Slide

- The End