Statistical Process Control

2025-04-08

Executive Summary

This report presents a Statistical Process Control (SPC) analysis of brewery operations based on data from 100 brewing batches across 8 beer styles and 10 production locations. The analysis focuses on identifying process variations, control patterns, and quality correlations to optimize brewing operations.

Key findings:

All key process variables are in statistical control but show suspicious run patterns pH levels and gravity values demonstrate strong consistency across beer styles Losses during production vary significantly across different beer styles and production stages Production location plays a significant role in brewhouse efficiency variation Temperature and pH level show weak but measurable correlations with quality scores

Introduction

Statistical Process Control (SPC) is a method for monitoring, controlling, and improving a process through statistical analysis. In brewing operations, SPC helps maintain product consistency, identify sources of variation, and prevent quality issues before they reach customers. This analysis examines brewery data using SPC principles to understand:

1. Process stability and capability
2. Factors affecting quality
3. Variations across beer styles and production locations
4. Opportunities for process improvement

Process Stability Analysis

Control Limits for Key Process Variables

We calculated 3-sigma control limits for key process variables:

Process Control Findings

1. Point Conformance: All process variables showed no points outside the 3-sigma control limits, which indicates good statistical control of the process.
2. Run Patterns: Despite point conformance, run tests revealed suspicious patterns in all variables:

- pH Level: Longest run of 14 consecutive points above/below mean
- Gravity: Longest run of 10 consecutive points
- Temperature: Longest run of 10 consecutive points

- Other variables: Similar patterns with runs of 8-16 consecutive points

3. Coefficient of Variation (CV):

Process variables show varying degrees of consistency: Gravity is the most consistent (CV = 1.38%) pH Level shows good consistency (CV = 5.55%) Temperature and Alcohol Content show moderate variation Loss measurements show high variability (CV > 37%)

```
## Package 'qcc' version 2.7

## Type 'citation("qcc")' for citing this R package in publications.

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union

## New names:
## Rows: 100 Columns: 16
## -- Column specification
## -------------------------------------------------------- Delimiter: "," chr
## (2): Beer_Style, Location dbl (14): ...1, Fermentation_Time, Temperature,
## pH_Level, Gravity, Alcohol_C...
## i Use 'spec()' to retrieve the full column specification for this data. i
## Specify the column types or set 'show_col_types = FALSE' to quiet this message.
## * '' -> '...1'
```
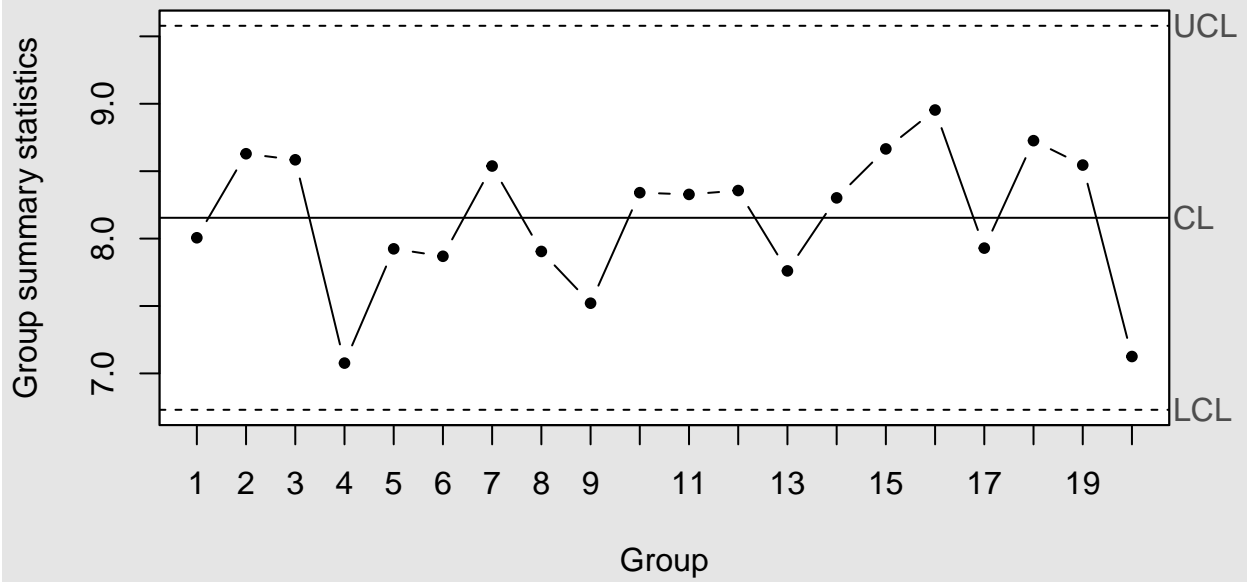
X–bar Chart for Quality_Score

Group summary statistics

Group

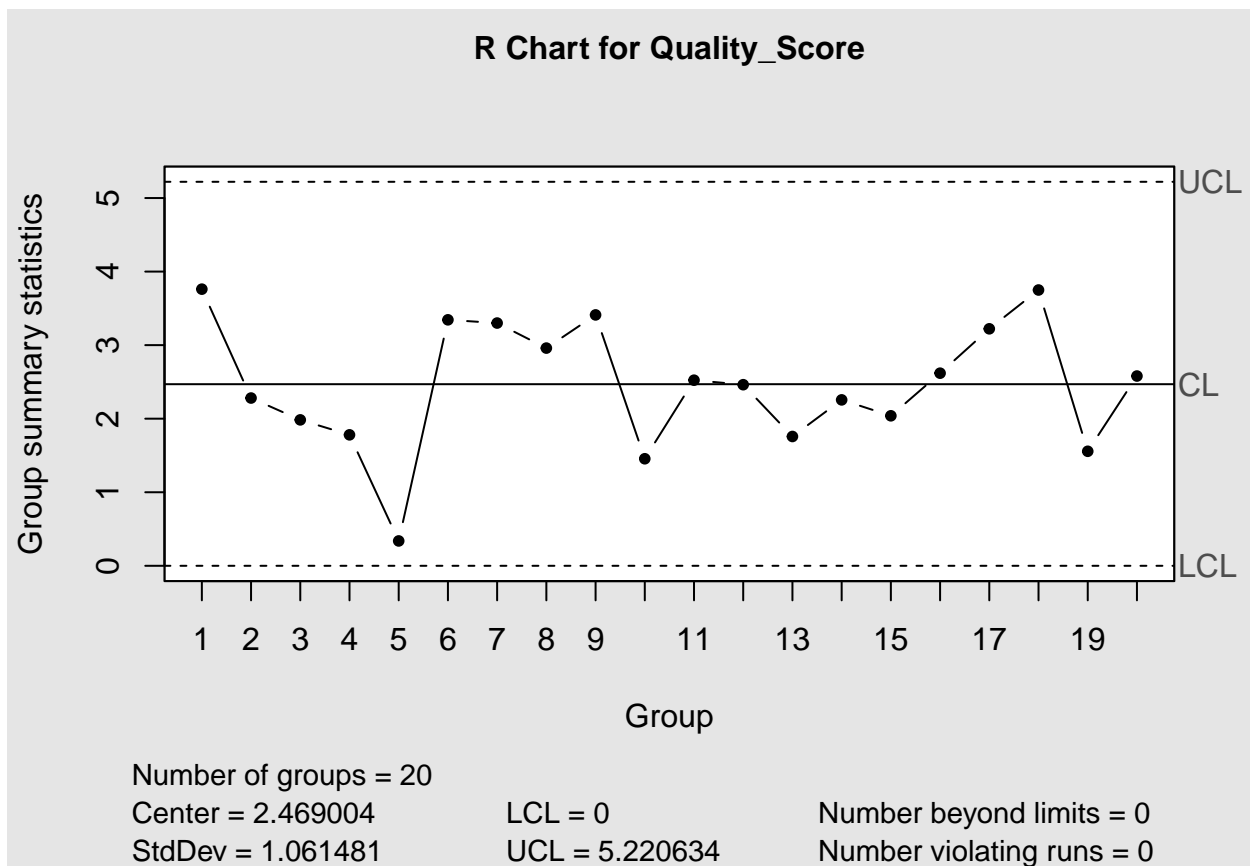Number of groups = 20
Center = 8.154298   LCL = 6.730172   Number beyond limits = 0
StdDev = 1.061481   UCL = 9.578424   Number violating runs = 0

R Chart for Quality_Score

Number of groups = 20
Center = 2.469004   LCL = 0   Number beyond limits = 0
StdDev = 1.061481   UCL = 5.220634   Number violating runs = 0

```
## List of 11
##  $ call      : language qcc(data = var_subgroups, type = "xbar", title = paste("X-bar Chart for",
##  $ type      : chr "xbar"
##  $ data.name : chr "var_subgroups"
##  $ data      : num [1:20, 1:5] 9.96 9.89 9.71 7.75 7.84 ...
##   ..- attr(*, "dimnames")=List of 2
##  $ statistics: Named num [1:20] 8.01 8.63 8.58 7.08 7.92 ...
##   ..- attr(*, "names")= chr [1:20] "1" "2" "3" "4" ...
##  $ sizes     : int [1:20] 5 5 5 5 5 5 5 5 5 5 ...
##  $ center    : num 8.15
##  $ std.dev   : num 1.06
##  $ nsigmas   : num 3
##  $ limits    : num [1, 1:2] 6.73 9.58
##   ..- attr(*, "dimnames")=List of 2
##  $ violations:List of 2
##  - attr(*, "class")= chr "qcc"
## List of 11
##  $ call      : language qcc(data = var_subgroups, type = "R", title = paste("R Chart for", var))
##  $ type      : chr "R"
##  $ data.name : chr "var_subgroups"
##  $ data      : num [1:20, 1:5] 9.96 9.89 9.71 7.75 7.84 ...
##   ..- attr(*, "dimnames")=List of 2
##  $ statistics: Named num [1:20] 3.761 2.281 1.984 1.781 0.338 ...
##   ..- attr(*, "names")= chr [1:20] "1" "2" "3" "4" ...
##  $ sizes     : int [1:20] 5 5 5 5 5 5 5 5 5 5 ...
##  $ center    : num 2.47
```

```
## $ std.dev  : num 1.06
## $ nsigmas  : num 3
## $ limits   : num [1, 1:2] 0 5.22
##  ..- attr(*, "dimnames")=List of 2
## $ violations:List of 2
## - attr(*, "class")= chr "qcc"
```

np Chart for Defective Bottles

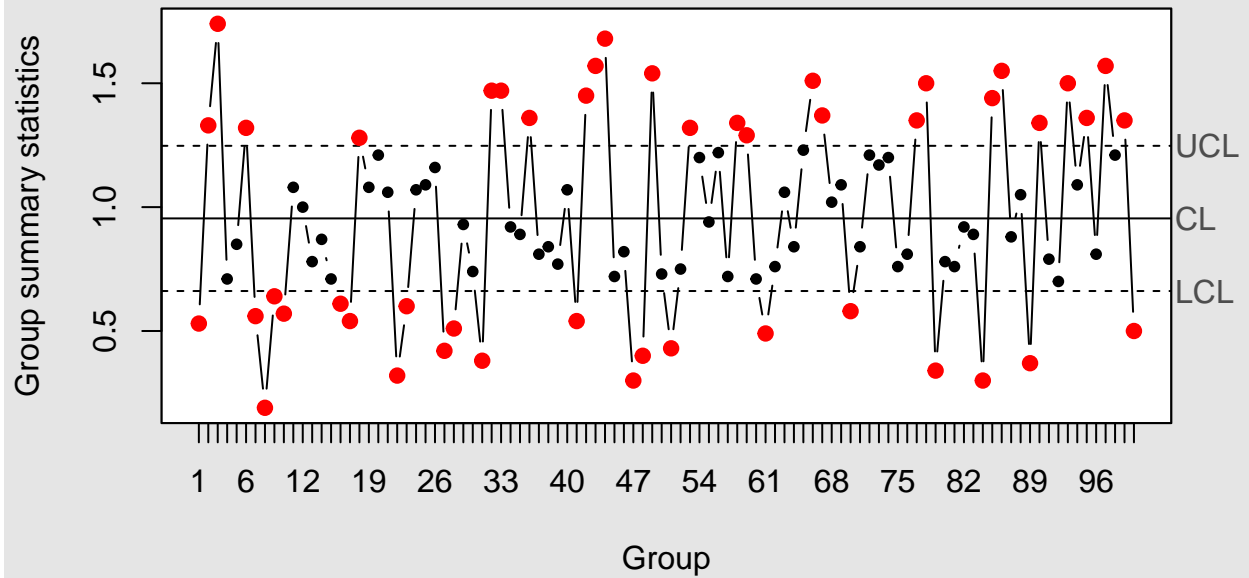Number of groups = 100

Center = 2.01   LCL = 0   Number beyond limits = 3
StdDev = 1.403424   UCL = 6.220272   Number violating runs = 10
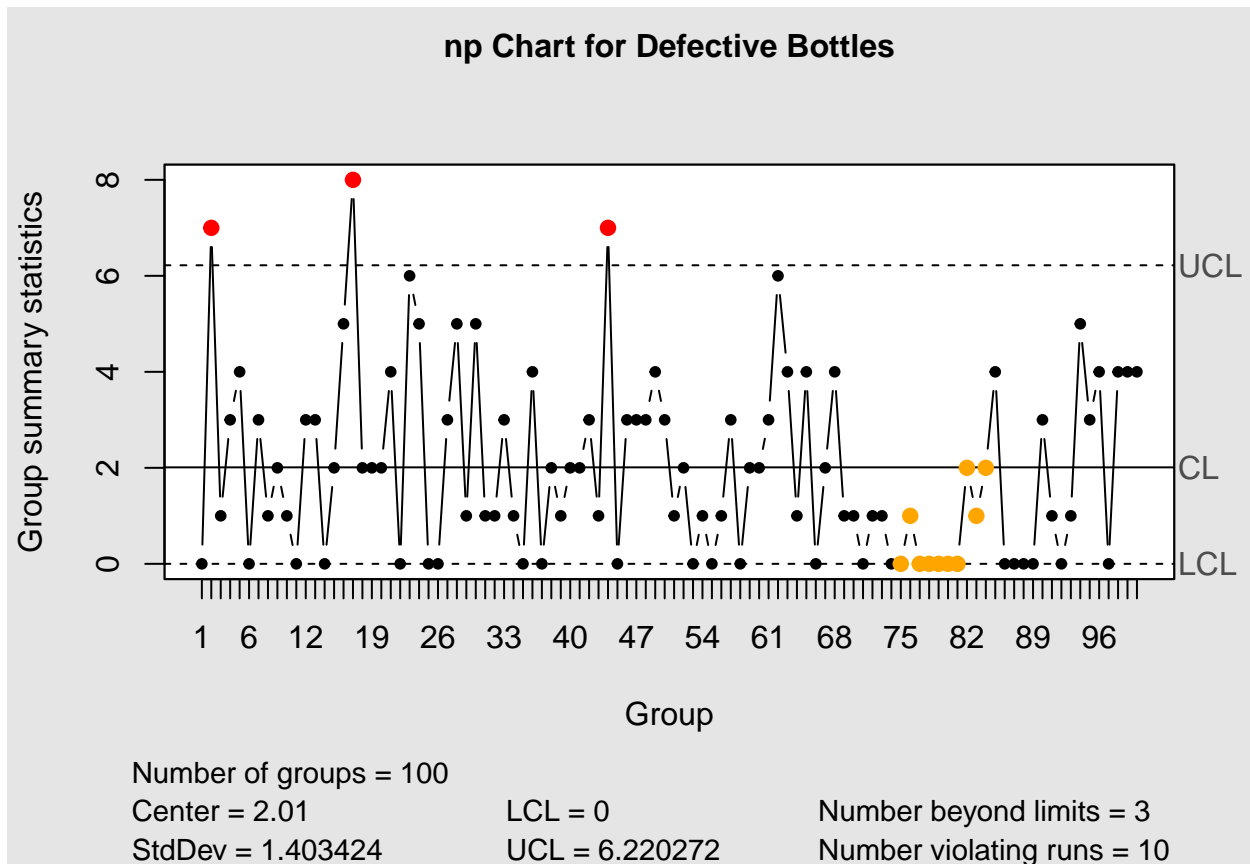
p Chart for Proportion of Defective Bottles
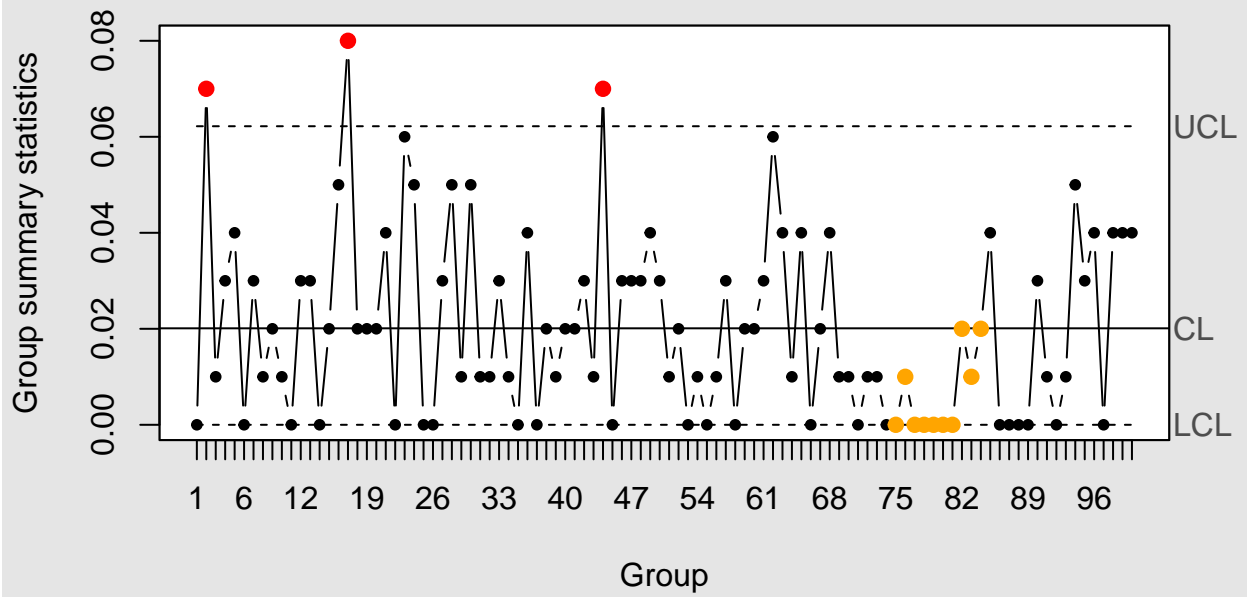
Number of groups = 100
Center = 0.0201   LCL = 0   Number beyond limits = 3
StdDev = 0.1403424   UCL = 0.06220272   Number violating runs = 10

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u Chart for Defects per Bottle

Number of groups = 100

Center = 0.9544   LCL = 0.6613198   Number beyond limits = 47

StdDev = 0.976934   UCL = 1.24748   Number violating runs = 0

p Chart for Defective Rate – Ale
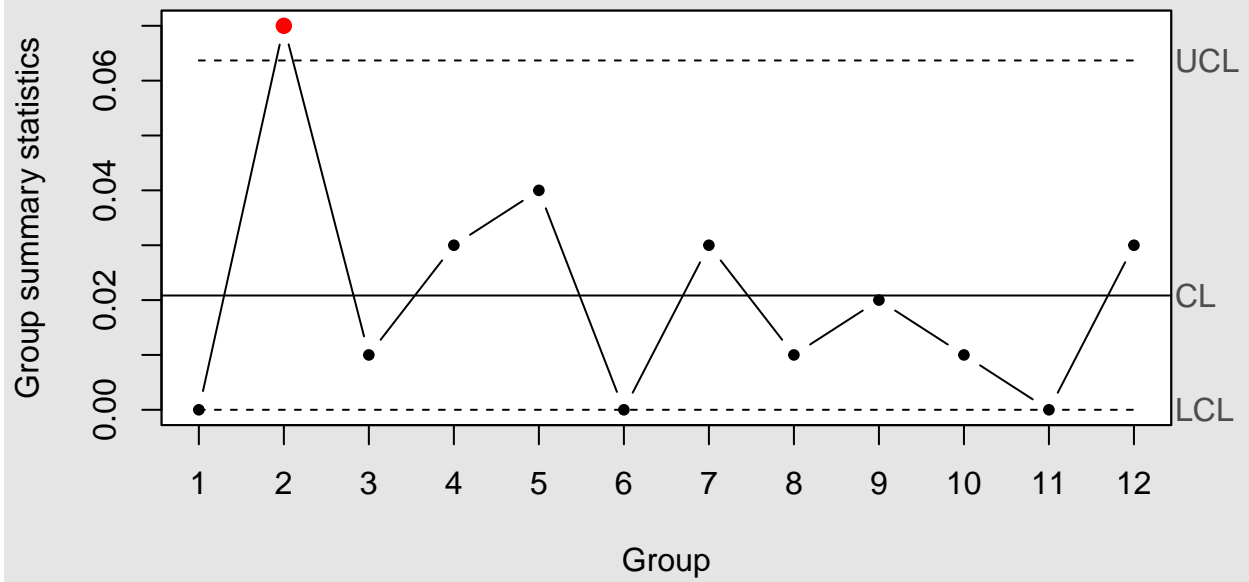
Number of groups = 12
Center = 0.02083333   LCL = 0   Number beyond limits = 1
StdDev = 0.1428261   UCL = 0.06368117   Number violating runs = 0

p Chart for Defective Rate – IPA
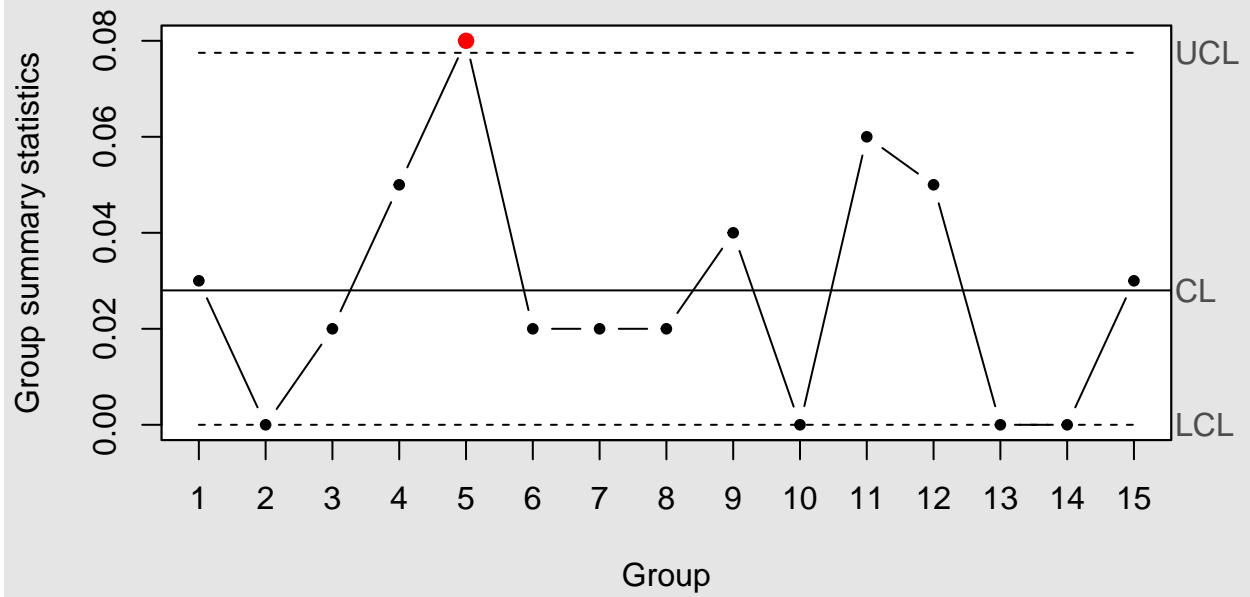
Number of groups = 15
Center = 0.028   LCL = 0   Number beyond limits = 1
StdDev = 0.1649727   UCL = 0.07749182   Number violating runs = 0

p Chart for Defective Rate – Lager
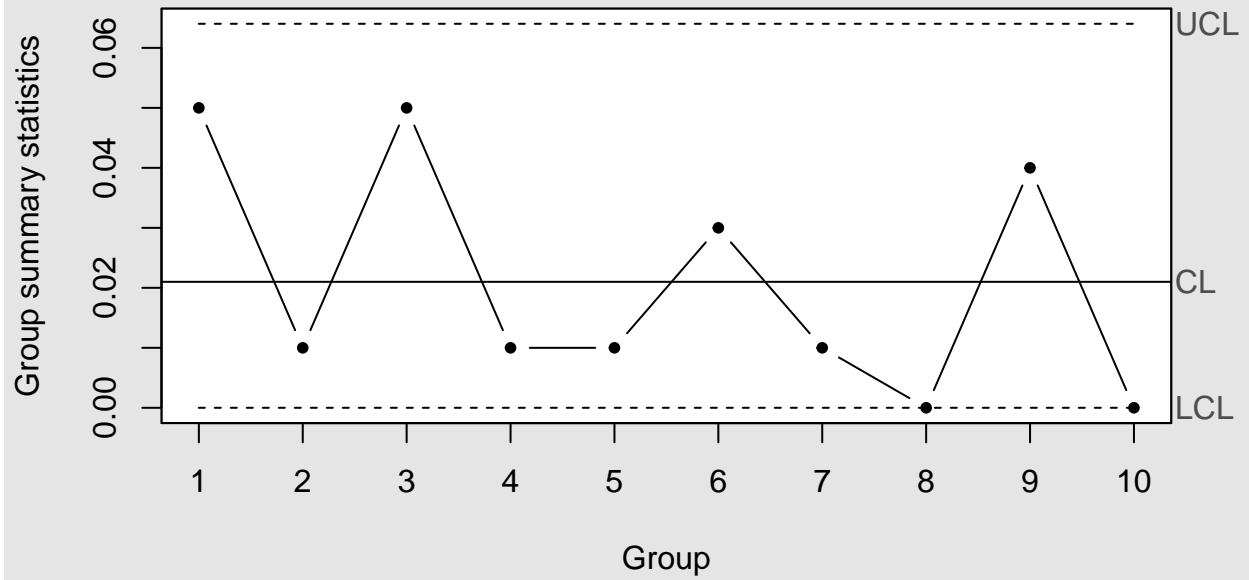
Number of groups = 10
Center = 0.021   LCL = 0   Number beyond limits = 0
StdDev = 0.1433841   UCL = 0.06401523   Number violating runs = 0

p Chart for Defective Rate – Pilsner
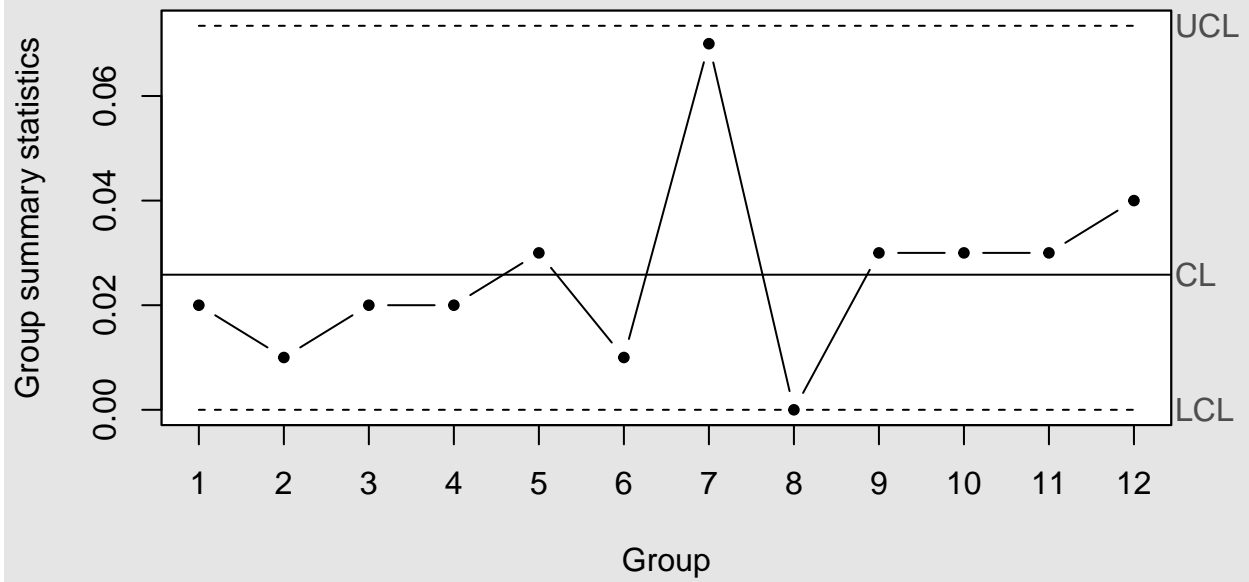
Number of groups = 12
Center = 0.02583333   LCL = 0   Number beyond limits = 0
StdDev = 0.1586379   UCL = 0.07342469   Number violating runs = 0

p Chart for Defective Rate – Porter
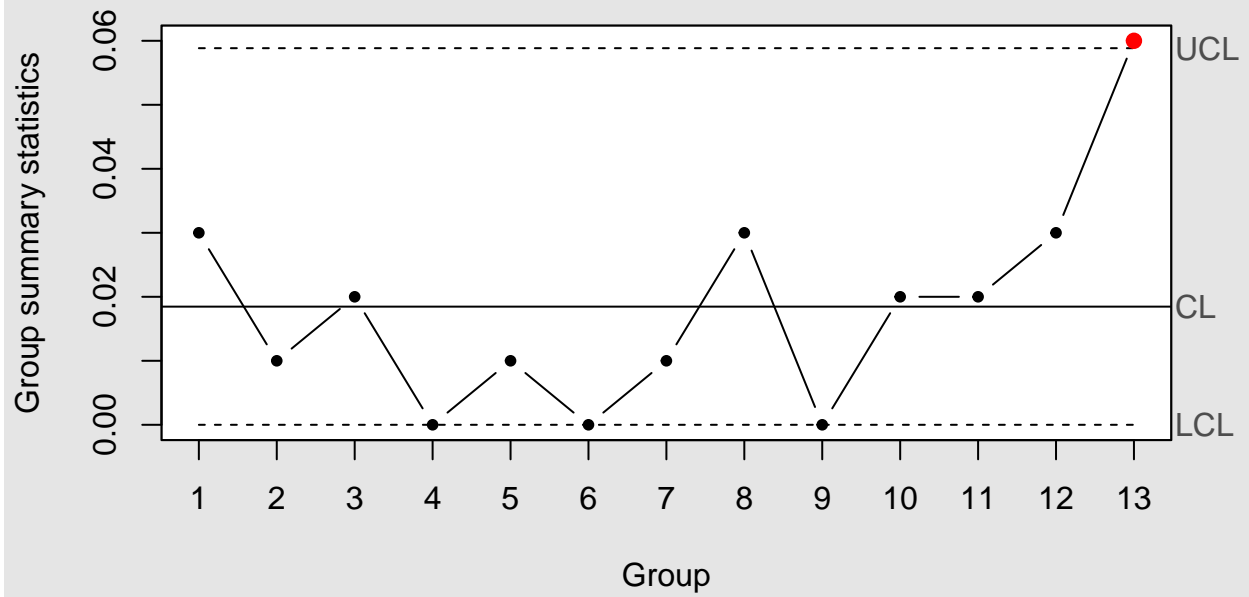
Number of groups = 13
Center = 0.01846154   LCL = 0   Number beyond limits = 1
StdDev = 0.1346132   UCL = 0.05884549   Number violating runs = 0

p Chart for Defective Rate – Sour
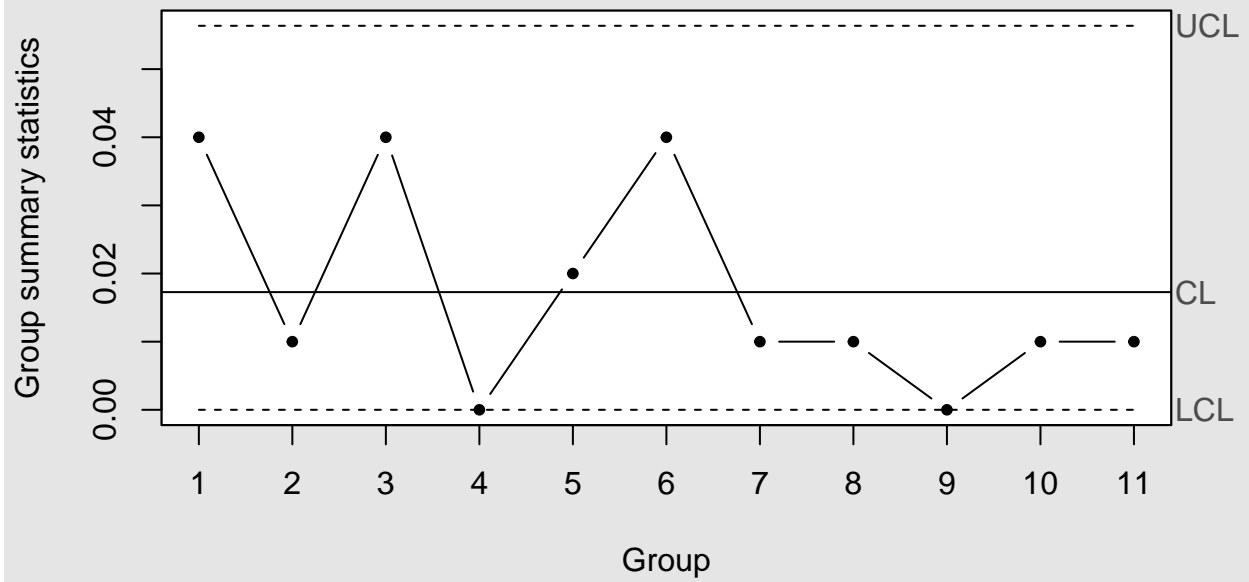
Number of groups = 11
Center = 0.01727273   LCL = 0   Number beyond limits = 0
StdDev = 0.1302858   UCL = 0.05635846   Number violating runs = 0

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p Chart for Defective Rate – Stout
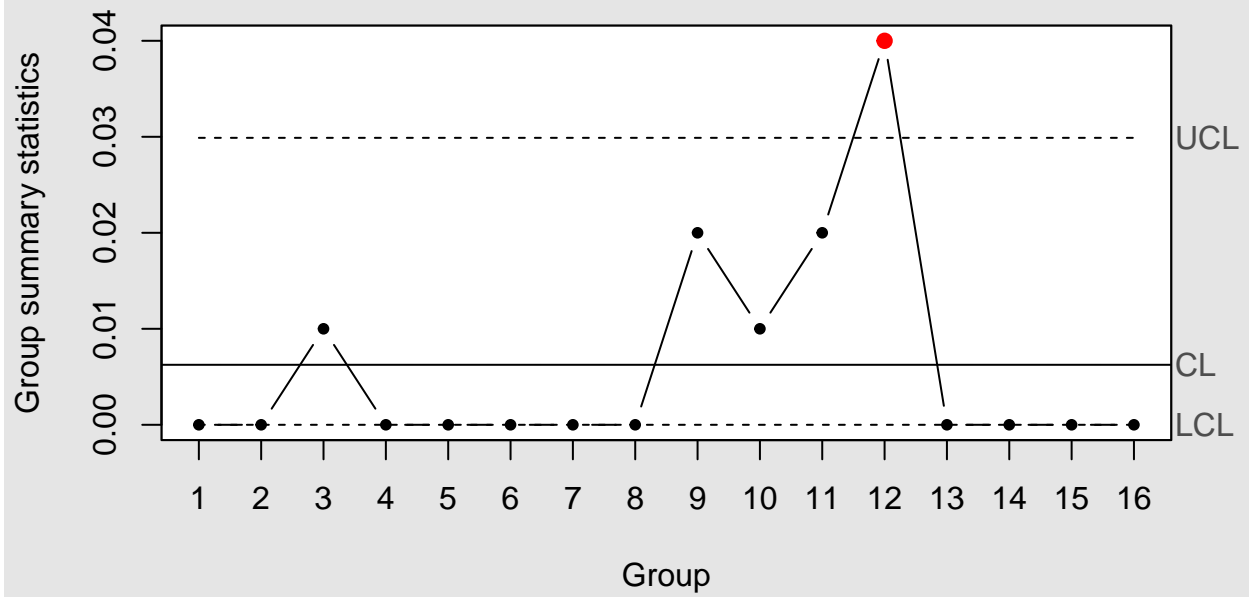
Number of groups = 16
Center = 0.00625   LCL = 0   Number beyond limits = 1
StdDev = 0.0788095   UCL = 0.02989285   Number violating runs = 0

p Chart for Defective Rate – Wheat Beer
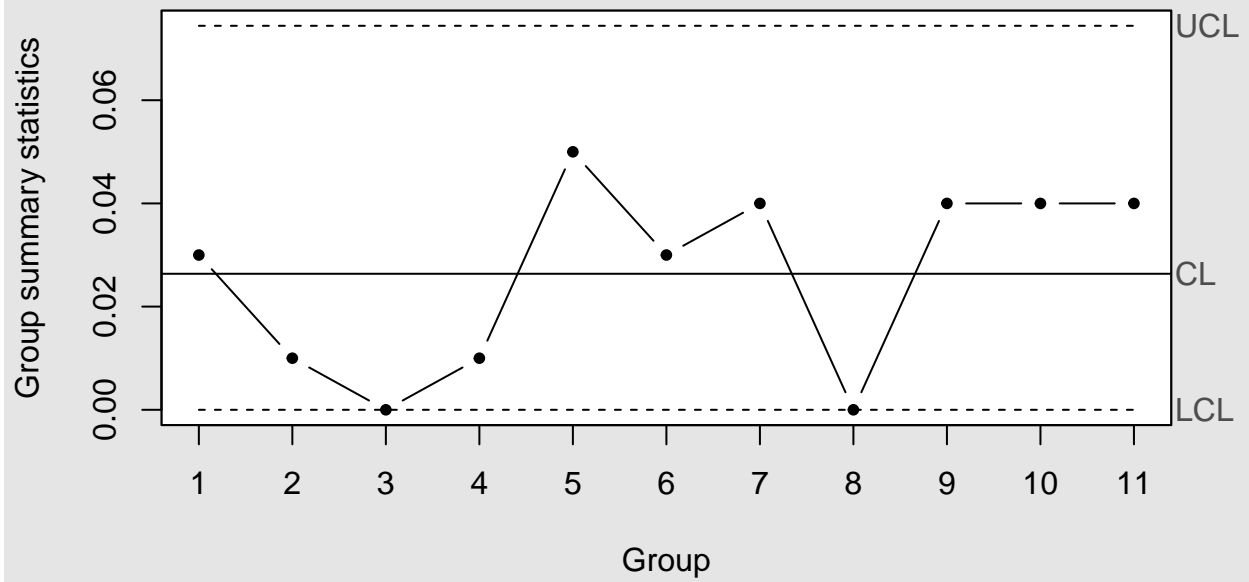
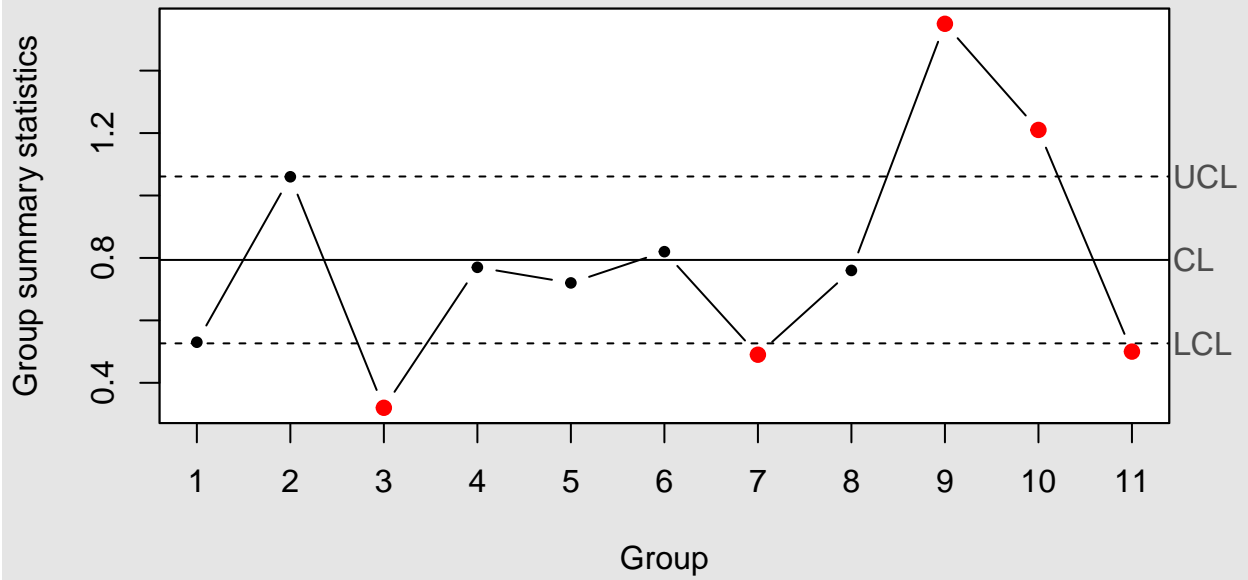Number of groups = 11
Center = 0.02636364   LCL = 0   Number beyond limits = 0
StdDev = 0.1602142   UCL = 0.0744279   Number violating runs = 0

u Chart for Defect Rate – Marathahalli

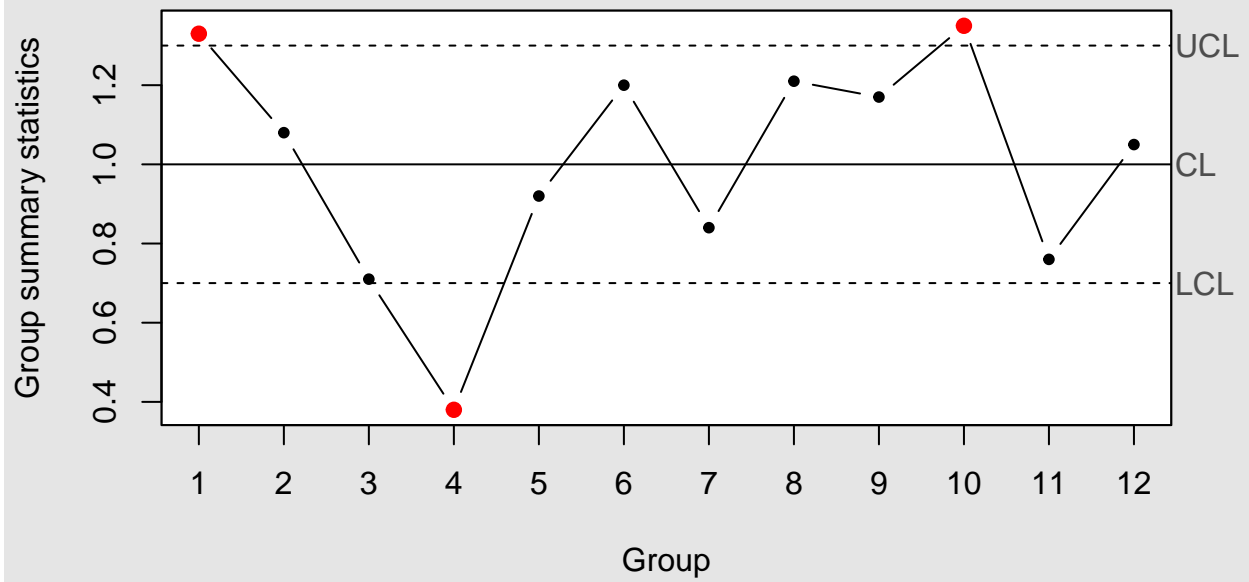Number of groups = 11
Center = 0.7936364   LCL = 0.5263776   Number beyond limits = 5
StdDev = 0.8908627   UCL = 1.060895   Number violating runs = 0

u Chart for Defect Rate – Yelahanka

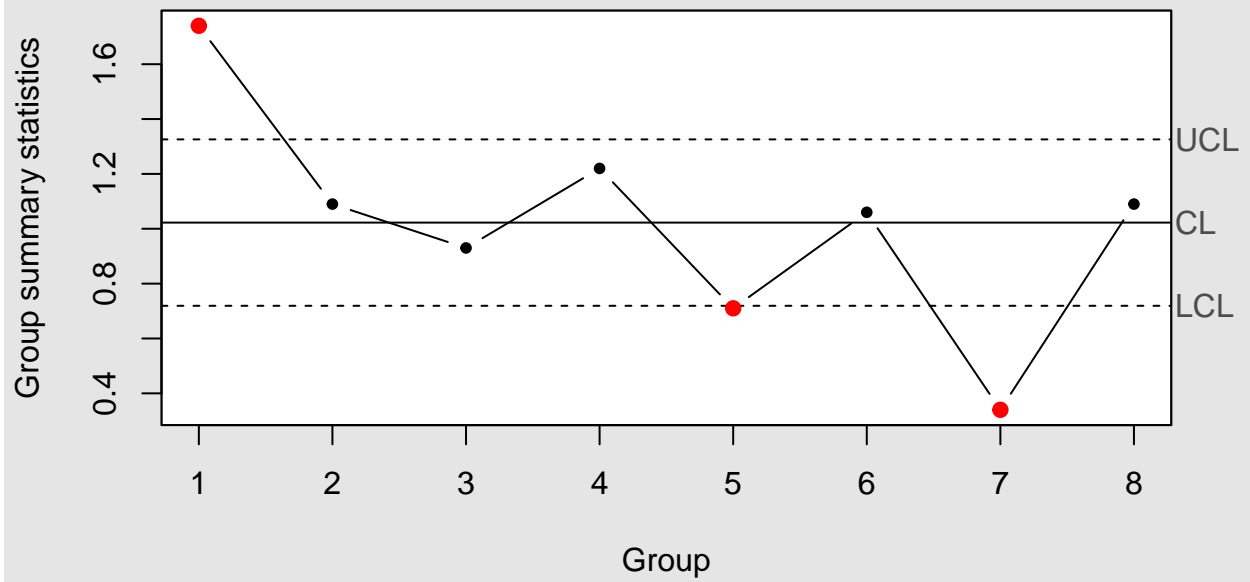Number of groups = 12
Center = 1   LCL = 0.7   Number beyond limits = 3
StdDev = 1   UCL = 1.3   Number violating runs = 0

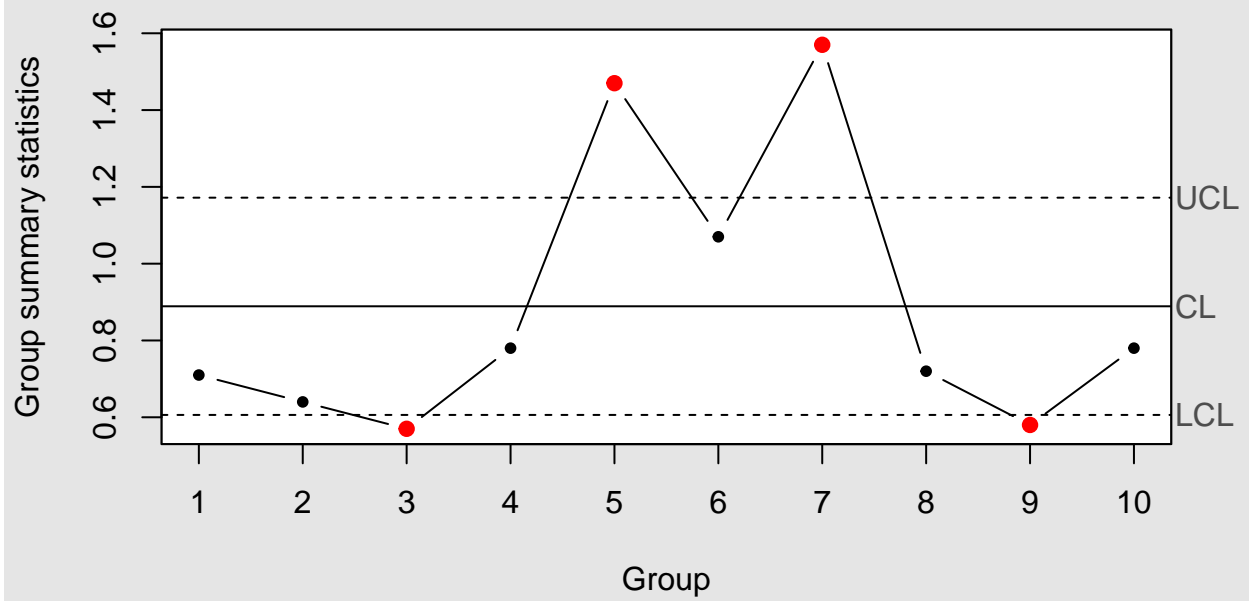## u Chart for Defect Rate – Jayanagar

Number of groups = 8
Center = 1.0225   LCL = 0.7191438   Number beyond limits = 3
StdDev = 1.011187   UCL = 1.325856   Number violating runs = 0

u Chart for Defect Rate – Indiranagar

Number of groups = 10
Center = 0.889   LCL = 0.6061396   Number beyond limits = 4
StdDev = 0.942868   UCL = 1.17186   Number violating runs = 0

u Chart for Defect Rate – HSR Layout
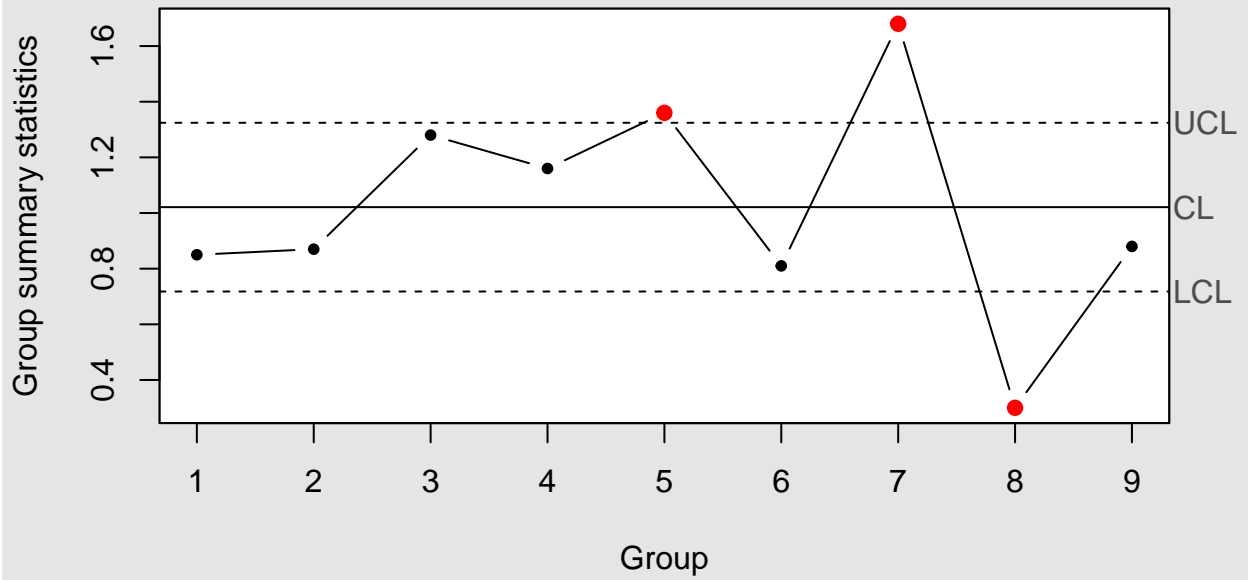
Number of groups = 9
Center = 1.021111   LCL = 0.717961   Number beyond limits = 3
StdDev = 1.0105   UCL = 1.324261   Number violating runs = 0

u Chart for Defect Rate – Rajajinagar
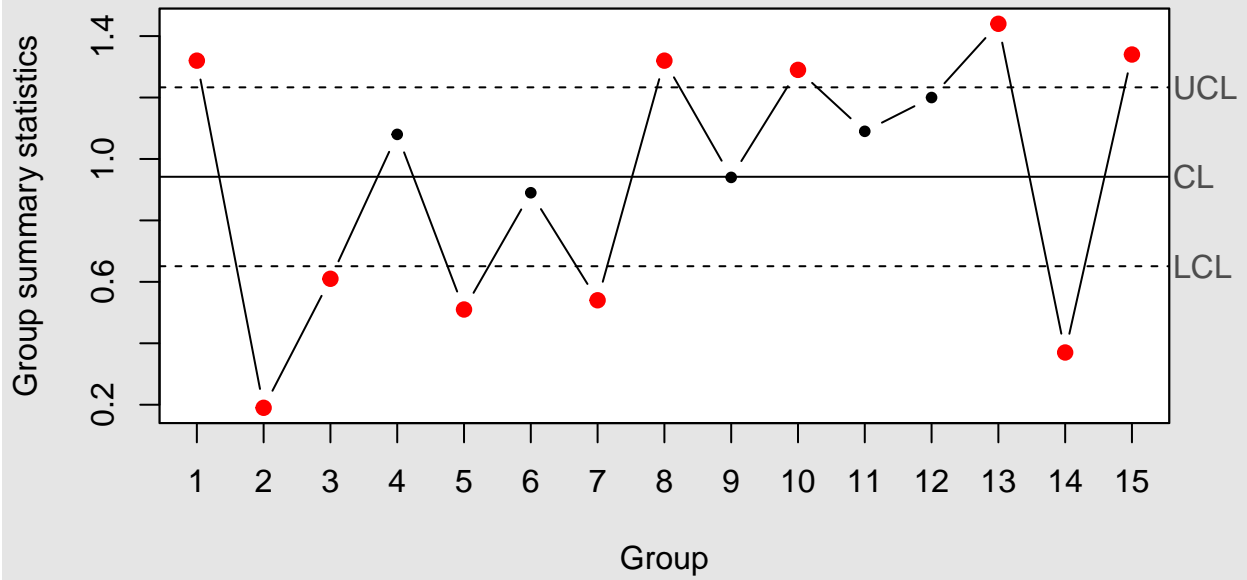
Number of groups = 15
Center = 0.942   LCL = 0.6508299   Number beyond limits = 10
StdDev = 0.9705668   UCL = 1.23317   Number violating runs = 0

u Chart for Defect Rate – Electronic City
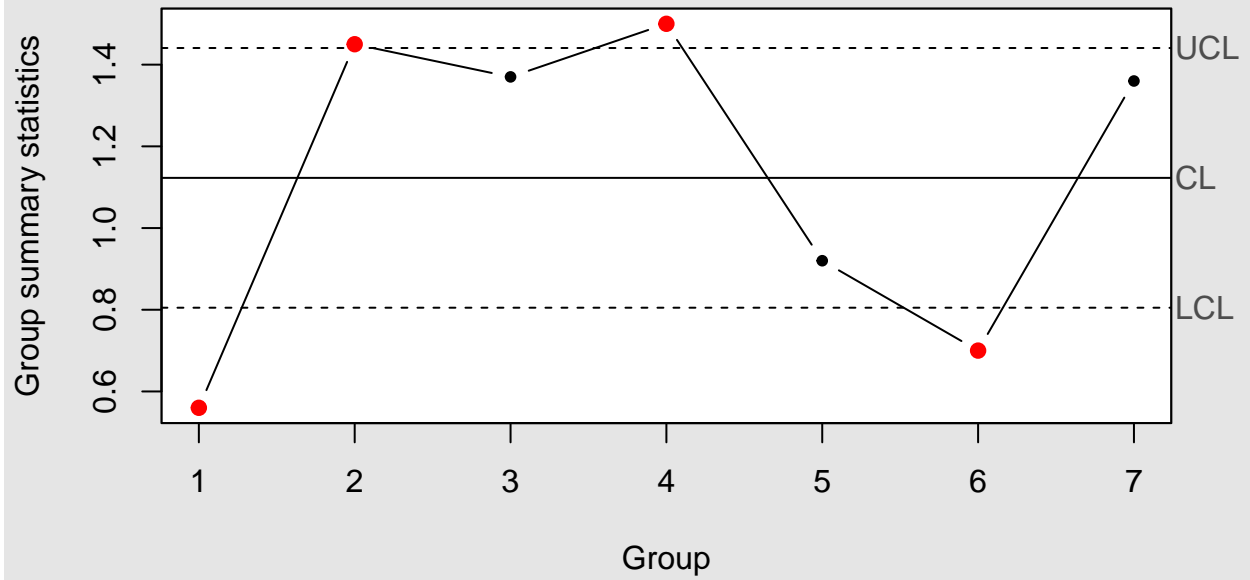
Number of groups = 7
Center = 1.122857   LCL = 0.8049623   Number beyond limits = 4
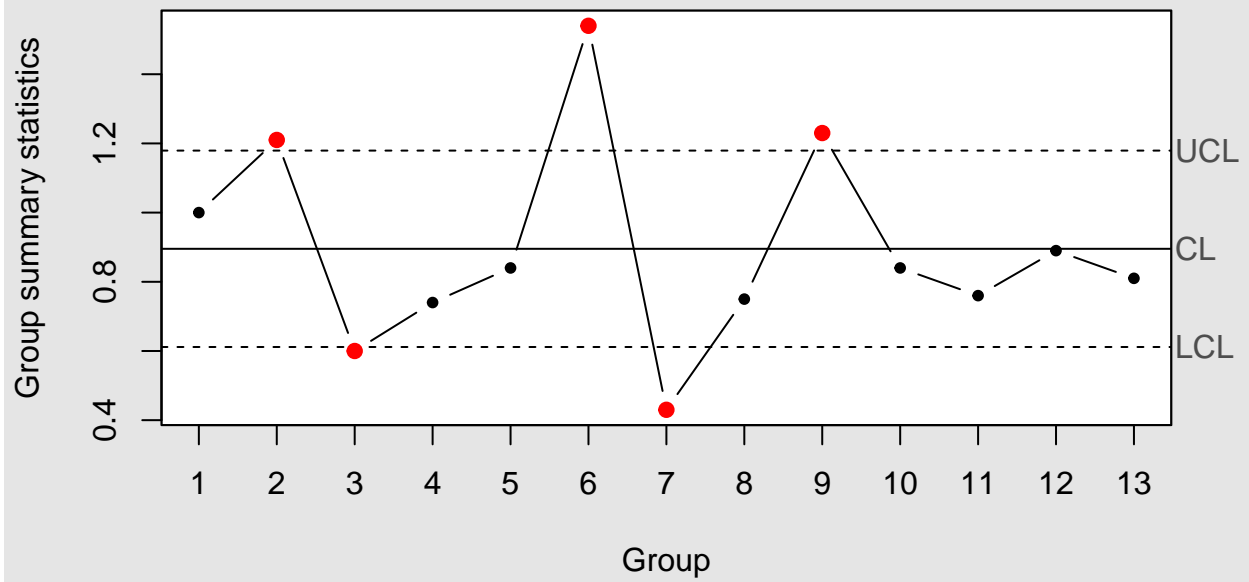StdDev = 1.05965   UCL = 1.440752   Number violating runs = 0

u Chart for Defect Rate – Whitefield

Number of groups = 13
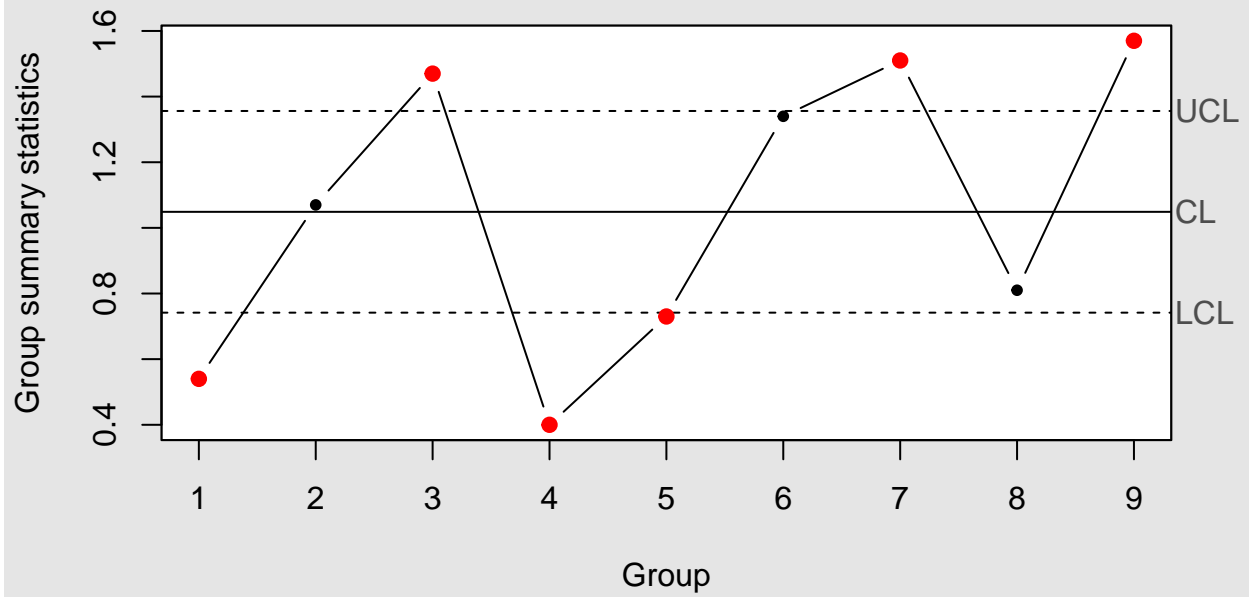Center = 0.8953846   LCL = 0.6115103   Number beyond limits = 5
StdDev = 0.9462477   UCL = 1.179259   Number violating runs = 0

u Chart for Defect Rate – Koramangala

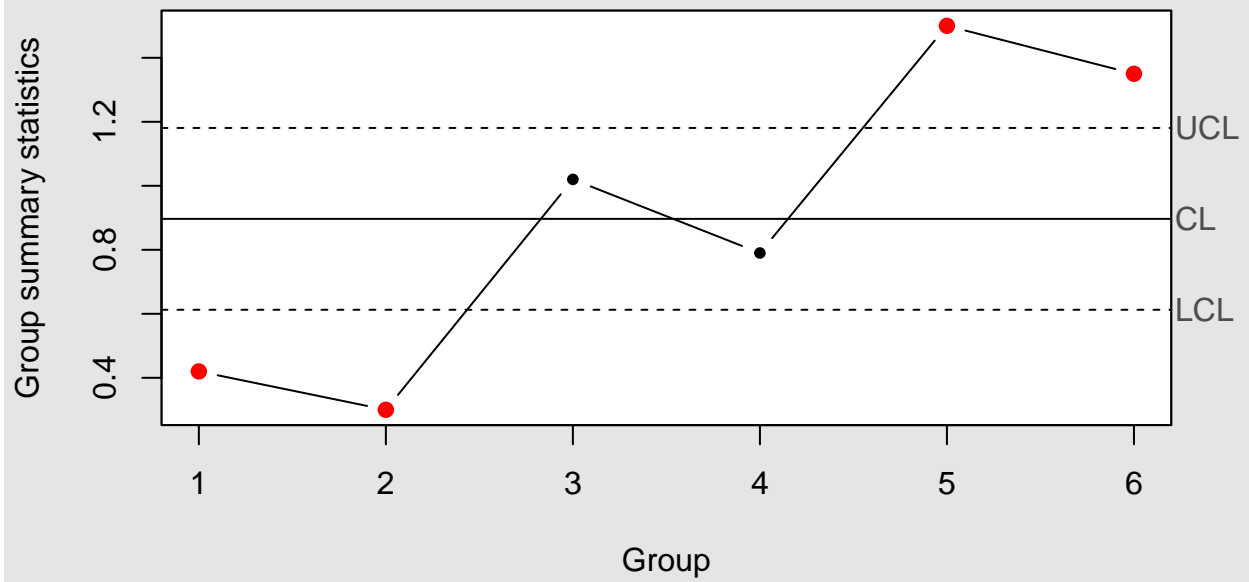Number of groups = 9
Center = 1.048889   LCL = 0.7416431   Number beyond limits = 6
StdDev = 1.024153   UCL = 1.356135   Number violating runs = 0

u Chart for Defect Rate – Malleswaram

Number of groups = 6
Center = 0.8966667   LCL = 0.6125892   Number beyond limits = 4
StdDev = 0.9469248   UCL = 1.180744   Number violating runs = 0