# Quality Management of Software and Systems (WS19/20)

## Problem Set 2

**Problem 1: SPC**

**1.1)** The execution time of a time-critical routine is measured to see if it varies only statistically or if there are systematic influences. Develop the X-chart, including control and warning levels at +/- 3s and +/- 2s, respectively. Assume the cause for outliers is found and fixed. Repeat the analysis until no outliers occur:

| **no.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **time (ms)** | 7,6 | 8,0 | 8,1 | 8,2 | 7,2 | 17,1 | 8,2 | 7,7 | 6,7 | 8,1 | 7,3 | 8,4 | 14,9 | 6,9 |

Solution:

- Sample average value

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

- Estimation for the standard deviation

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$

- Standard deviation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \mu)^2}{n}}$$

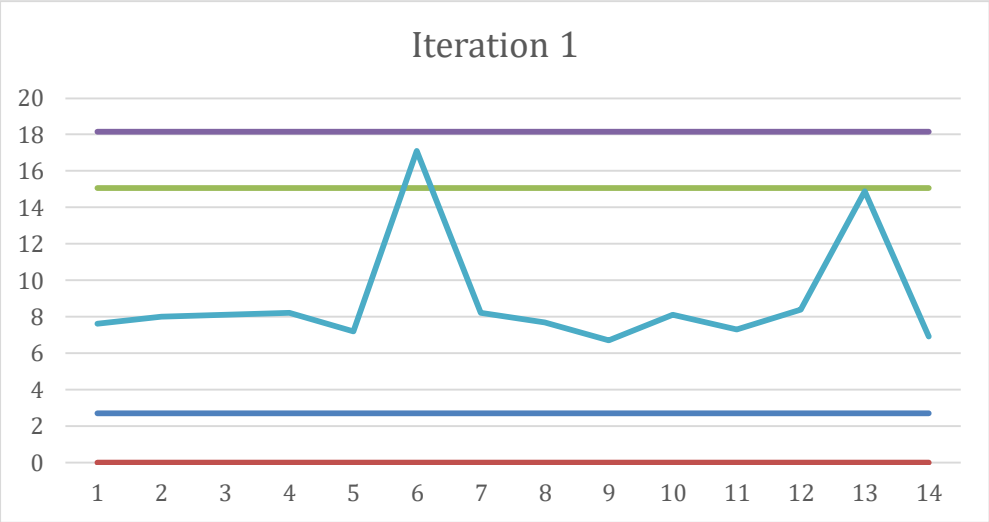
*Iteration 1*:

n = 14
$\bar{x}$ = 8.8857
S = 3.0882

$\bar{x} + 2s$ = 15.0620
$\bar{x} - 2s$ = 2.7094

$\bar{x} + 3s$ = 18.1502
$\bar{x} - 3s$ = - 0.3788 = 0

* UCL: Upper Control Limit
* LCL: Lower Control Limit

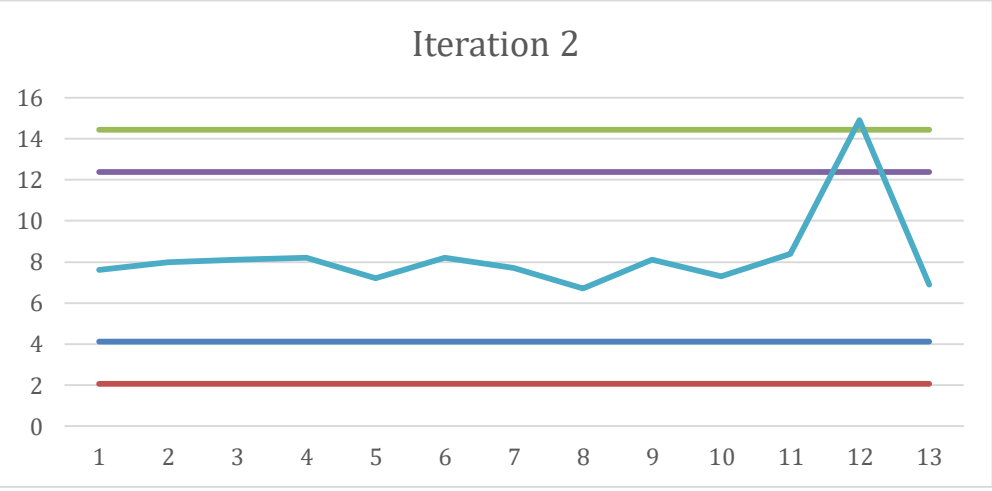



*Iteration 2*:

n = 13
$\bar{x}$ = 8.2536
S = 2.0679

$\bar{x} + 2s$ = 12.3896
$\bar{x} - 2s$ = 4.1181

UCL: $\bar{x} + 3s$ = 14.4574
LCL: $\bar{x} - 3s$ = 2.0503

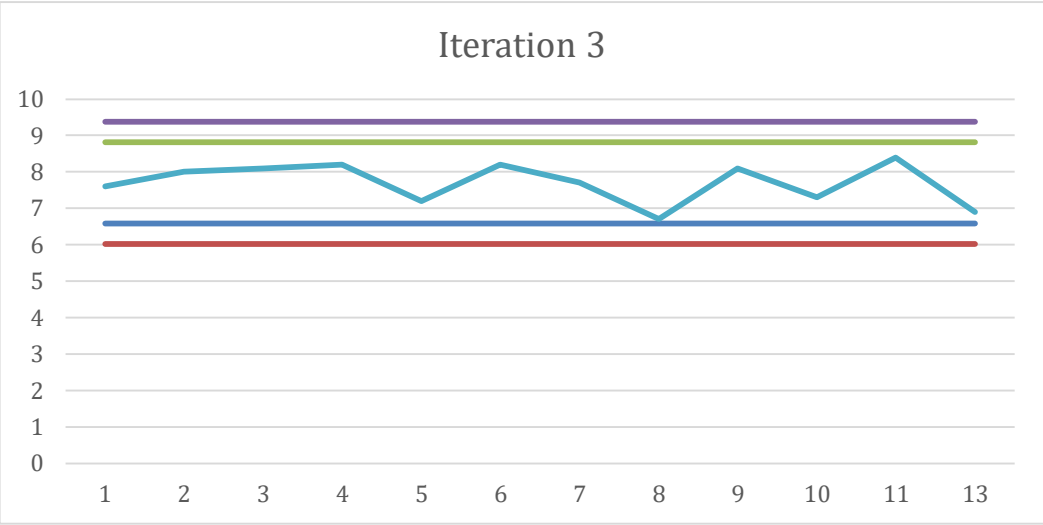


Iteration 3:

n = 12
$\bar{x}$ = 7.7
S = 0.5608

$\bar{x} + 2s$ = 8.8217
$\bar{x} - 2s$ = 6.5783

$\bar{x} + 3s$ = 9.3825
$\bar{x} - 3s$ = 6.0175




Remove the two outliers

**1.2)** During the production of steel rods, 25 samples of **size four** are extracted from the production. Calculate the mean values and the range of each sample, as well as the overall mean value and range. Use this data to calculate the warning and control levels and indicate which measures are between warning and control levels and which are outside control levels.

Hints: The standard deviation can be calculated using $\sigma = \frac{\bar{R}}{d_n\sqrt{n}}$ with; n the size of each sample and $d_n$ a constant found in the following table:

| **n** | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $d_n$ | 1,128 | 1,69 | 2,059 | 2,326 | 2,534 | 2,704 | 2,847 | 2,97 | 3,078 | 3,173 | 3,258 |

| **Sample** | **Rod Length (in mm)** | | | | **Sample** | **Rod Length (in mm)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 144 | 146 | 154 | 146 | **14** | 144 | 160 | 150 | 149 |
| **2** | 151 | 150 | 134 | 153 | **15** | 150 | 146 | 148 | 157 |
| **3** | 145 | 139 | 143 | 152 | **16** | 147 | 144 | 148 | 149 |
| **4** | 154 | 146 | 152 | 148 | **17** | 155 | 150 | 153 | 148 |
| **5** | 157 | 153 | 155 | 157 | **18** | 157 | 148 | 149 | 153 |
| **6** | 157 | 150 | 145 | 147 | **19** | 153 | 155 | 149 | 151 |
| **7** | 149 | 144 | 137 | 155 | **20** | 155 | 142 | 150 | 150 |
| **8** | 151 | 157 | 159 | 155 | **21** | 146 | 156 | 148 | 160 |
| **9** | 158 | 150 | 149 | 156 | **22** | 159 | 161 | 156 | 160 |
| **10** | 145 | 148 | 152 | 154 | **23** | 143 | 156 | 151 | 151 |
| **11** | 151 | 150 | 154 | 153 | **24** | 151 | 152 | 157 | 149 |
| **12** | 155 | 145 | 152 | 148 | **25** | 154 | 140 | 157 | 151 |
| **13** | 152 | 146 | 152 | 142 | | | | | |

Solution:

n = 4

$d_n$ of n = 4 = 2.059

i.e. Range, R for sample 1: 154-144=10

$\bar{X}$ = 150.65

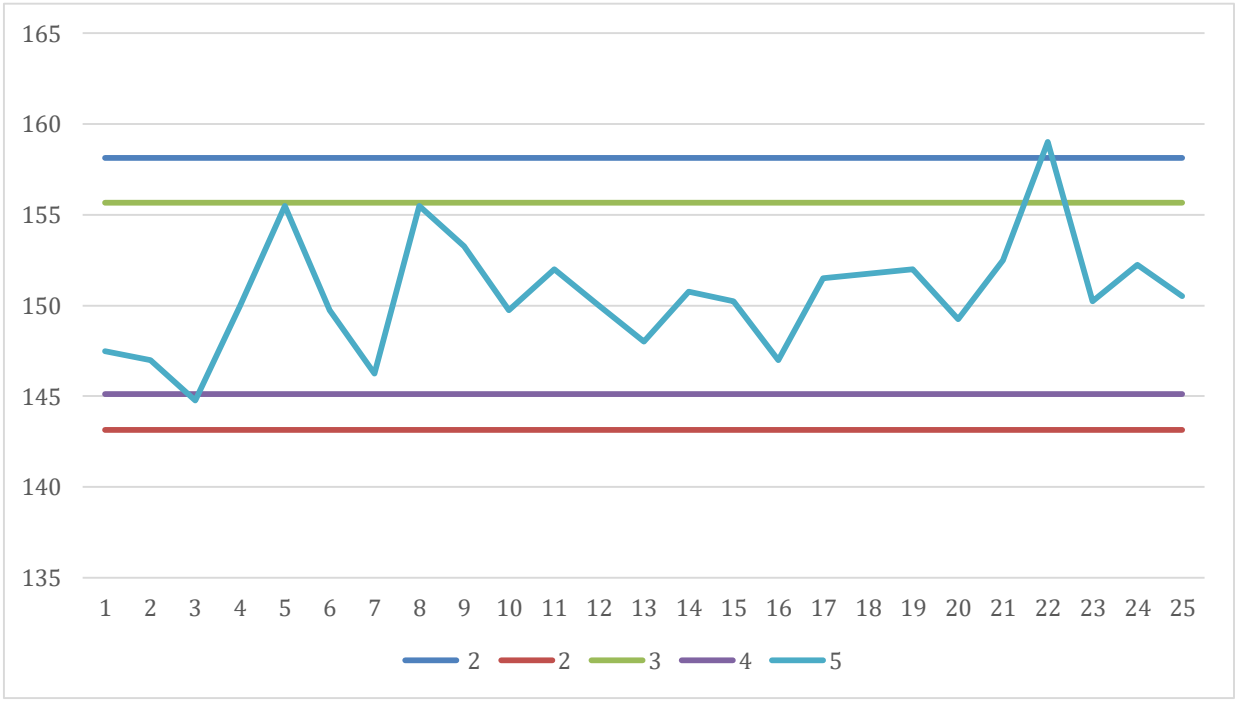
$\bar{R}$ = 10.32

$\sigma = \frac{10.32}{2.059\sqrt{4}} = 2.5061$

$\bar{x} + 2s$ = 155.6621
$\bar{x} - 2s$ = 145.1318

$\bar{x} + 3s$ = 158.1682
$\bar{x} - 3s$ = 143.1318

| **Simple** | Rod length | | | | mean/sample | R/sample |
|---|---|---|---|---|---|---|
| **1** | 144 | 146 | 154 | 146 | 147.5 | 10 |
| **2** | 151 | 150 | 134 | 153 | 147 | 19 |
| **3** | 145 | 139 | 143 | 152 | 144.75 | 13 |
| **4** | 154 | 146 | 152 | 148 | 150 | 8 |
| **5** | 157 | 153 | 155 | 157 | 155.5 | 4 |
| **6** | 157 | 150 | 145 | 147 | 149.75 | 12 |
| **7** | 149 | 144 | 137 | 155 | 146.25 | 18 |
| **8** | 151 | 157 | 159 | 155 | 155.5 | 8 |
| **9** | 158 | 150 | 149 | 156 | 153.25 | 9 |
| **10** | 145 | 148 | 152 | 154 | 149.75 | 9 |
| **11** | 151 | 150 | 154 | 153 | 152 | 4 |
| **12** | 155 | 145 | 152 | 148 | 150 | 10 |
| **13** | 152 | 146 | 152 | 142 | 148 | 10 |
| **14** | 144 | 160 | 150 | 149 | 150.75 | 16 |
| **15** | 150 | 146 | 148 | 157 | 150.25 | 11 |
| **16** | 147 | 144 | 148 | 149 | 147 | 5 |
| **17** | 155 | 150 | 153 | 148 | 151.5 | 7 |
| **18** | 157 | 148 | 149 | 153 | 151.75 | 9 |
| **19** | 153 | 155 | 149 | 151 | 152 | 6 |
| **20** | 155 | 142 | 150 | 150 | 149.25 | 13 |
| **21** | 146 | 156 | 148 | 160 | 152.5 | 14 |
| **22** | 159 | 161 | 156 | 160 | 159 | 5 |
| **23** | 143 | 156 | 151 | 151 | 150.25 | 13 |
| **24** | 151 | 152 | 157 | 149 | 152.25 | 8 |
| **25** | 154 | 140 | 157 | 151 | 150.5 | 17 |



**1.3)** Calculate the warning and control levels analogue to exercise a) for the following data. You can use the same formula and table to calculate the standard deviation as in exercise b). Additionally, try to give a statement to the measured values and the underlying process.

| Sample | Measures (in dB) | | | | | Sample | Measures (in dB) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 11.1 | 9.4 | 11.2 | 10.4 | 10.1 | **11** | 10.6 | 9.9 | 10.7 | 10.2 | 11.4 |
| **2** | 9.6 | 10.8 | 10.1 | 10.8 | 11.0 | **12** | 10.8 | 10.2 | 10.5 | 8.4 | 9.9 |
| **3** | 9.7 | 10.0 | 10.0 | 9.8 | 10.4 | **13** | 10.7 | 10.7 | 10.8 | 8.6 | 11.4 |
| **4** | 10.7 | 8.4 | 10.2 | 9.4 | 11.0 | **14** | 11.3 | 11.4 | 10.4 | 10.6 | 11.1 |
| **5** | 12.4 | 10.0 | 10.7 | 10.1 | 11.3 | **15** | 11.4 | 11.2 | 11.4 | 10.1 | 11.6 |
| **6** | 10.1 | 10.2 | 10.2 | 11.2 | 10.1 | **16** | 10.1 | 10.1 | 9.7 | 9.8 | 10.5 |
| **7** | 11 | 11.5 | 11.8 | 11.0 | 11.3 | **17** | 10.7 | 12.8 | 11.2 | 11.2 | 11.3 |
| **8** | 11.2 | 10.0 | 10.9 | 10.5 | 10.9 | **18** | 11.9 | 11.9 | 11.6 | 12.4 | 11.4 |
| **9** | 10.6 | 10.4 | 10.5 | 10.5 | 10.9 | **19** | 10.8 | 12.1 | 11.8 | 9.4 | 11.6 |
| **10** | 8.3 | 10.2 | 9.8 | 9.5 | 9.8 | **20** | 12.4 | 11.1 | 10.8 | 11.0 | 11.9 |

Solution:

$\bar{X}$ = 10.658
$\bar{R}$ = 1.59
$\sigma$ = 0.3057

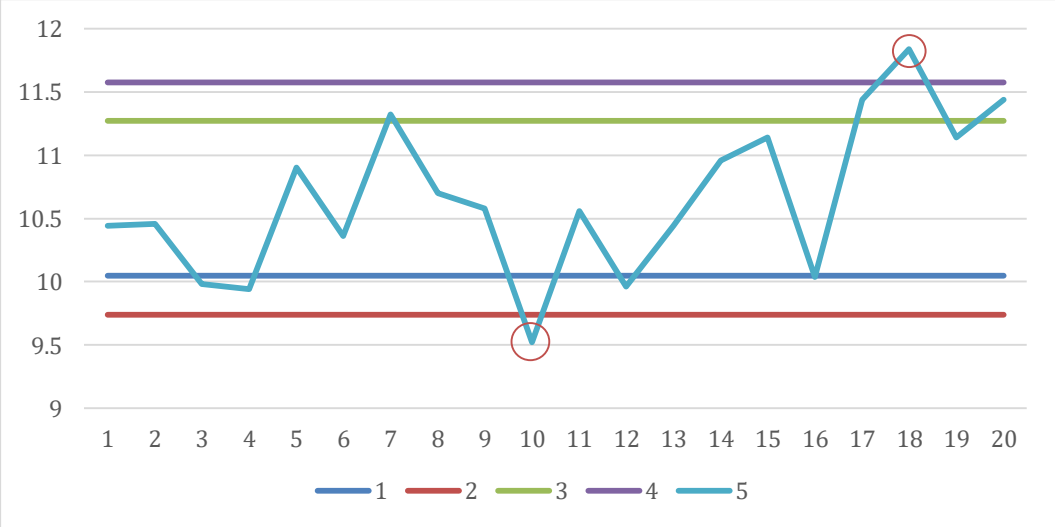
$\bar{x} + 2s$ = 11.2694
$\bar{x} - 2s$ = 10.0466

$\bar{x} + 3s$ = 11.5751
$\bar{x} - 3s$ = 9.7409

| Sample | Measures (in dB) | | | | | mean / sample | R / sample |
|---|---|---|---|---|---|---|---|
| **1** | 11.1 | 9.4 | 11.2 | 10.4 | 10.1 | 10.44 | 1.8 |
| **2** | 9.6 | 10.8 | 10.1 | 10.8 | 11.0 | 10.46 | 1.4 |
| **3** | 9.7 | 10.0 | 10.0 | 9.8 | 10.4 | 9.98 | 0.7 |
| **4** | 10.7 | 8.4 | 10.2 | 9.4 | 11.0 | 9.94 | 2.6 |
| **5** | 12.4 | 10.0 | 10.7 | 10.1 | 11.3 | 10.9 | 2.4 |
| **6** | 10.1 | 10.2 | 10.2 | 11.2 | 10.1 | 10.36 | 1.1 |
| **7** | 11 | 11.5 | 11.8 | 11.0 | 11.3 | 11.32 | 0.8 |
| **8** | 11.2 | 10.0 | 10.9 | 10.5 | 10.9 | 10.7 | 1.2 |
| **9** | 10.6 | 10.4 | 10.5 | 10.5 | 10.9 | 10.58 | 0.5 |
| **10** | 8.3 | 10.2 | 9.8 | 9.5 | 9.8 | 9.52 | 1.9 |
| **11** | 10.6 | 9.9 | 10.7 | 10.2 | 11.4 | 10.56 | 1.5 |
| **12** | 10.8 | 10.2 | 10.5 | 8.4 | 9.9 | 9.96 | 2.4 |
| **13** | 10.7 | 10.7 | 10.8 | 8.6 | 11.4 | 10.44 | 2.8 |
| **14** | 11.3 | 11.4 | 10.4 | 10.6 | 11.1 | 10.96 | 1 |
| **15** | 11.4 | 11.2 | 11.4 | 10.1 | 11.6 | 11.14 | 1.5 |
| **16** | 10.1 | 10.1 | 9.7 | 9.8 | 10.5 | 10.04 | 0.8 |
| **17** | 10.7 | 12.8 | 11.2 | 11.2 | 11.3 | 11.44 | 2.1 |
| **18** | 11.9 | 11.9 | 11.6 | 12.4 | 11.4 | 11.84 | 1 |
| **19** | 10.8 | 12.1 | 11.8 | 9.4 | 11.6 | 11.14 | 2.7 |
| **20** | 12.4 | 11.1 | 10.8 | 11.0 | 11.9 | 11.44 | 1.6 |

* Nearly every second point as an outliner. Here the assumption could be made, that the measured points are not statistical distributed like a normal distribution

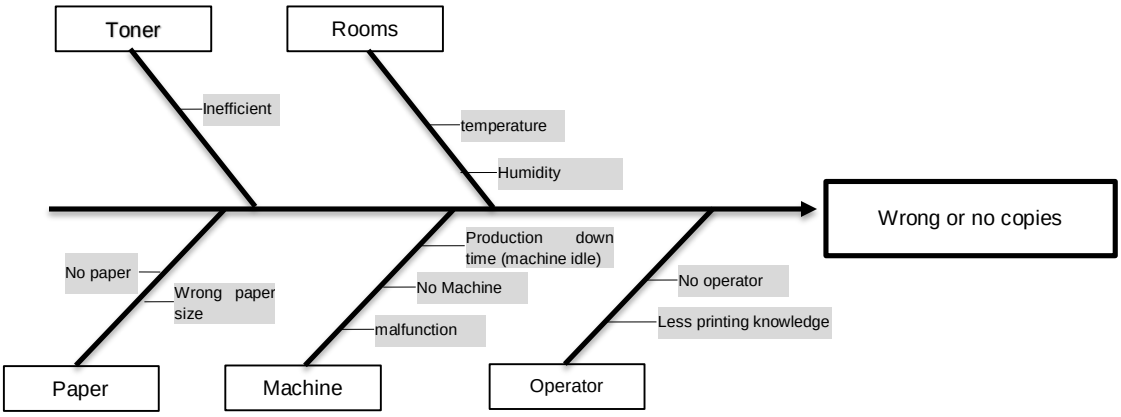
* It seems like the process is out of control



**Problem 2: Cause and Effect Diagram**

**2.1** *Copyking*, a copier manufacturer, is currently writing the manual for their latest product. The last chapter should deal with malfunctions. Develop a Cause-and-Effect Diagram for the problem: no or wrong copies!

Solution:



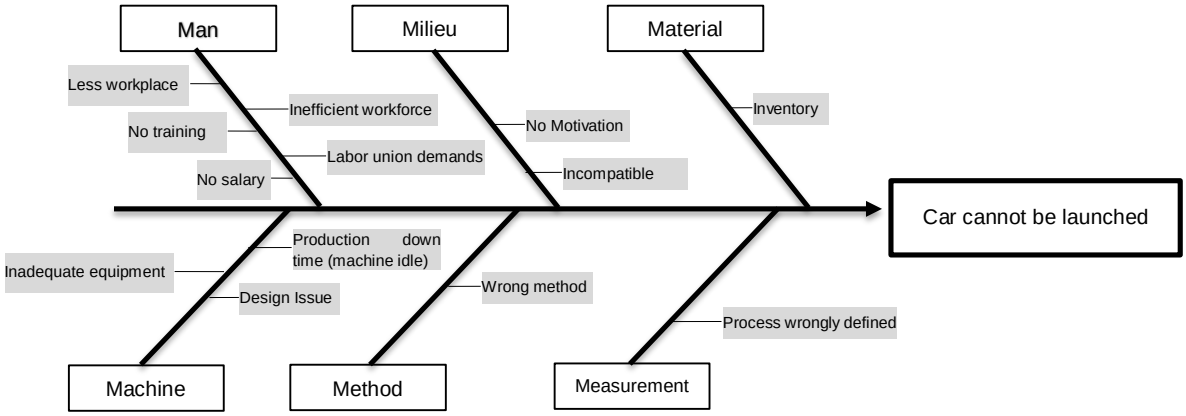

Develop a Cause-and-Effect diagram for the following problems:

**2.2** Car cannot belaunched.

Theory: Cause-and-Effect-Diagram
(Fishbone Chart, Ishikawa-Diagram) Example

- Procedure
  - Define problem (effect) and attach it to the head of the "fishbone"
  - Attach the major causes to the "sidewise fishbones" (often used: the 6 m: man, machine, method, material, milieu, measuring)
  - Attach minor causes to the branches of the "sidewise fishbones" (brainstorming: identification with the aid of the questions: what, why, how, who, when, where)

Solution:




*** Note: Man, milieu, material, machine, method and measurement are not all, can be more. These are industrial practice and can be categorize in general.

**Problem 3: Pareto Analysis**

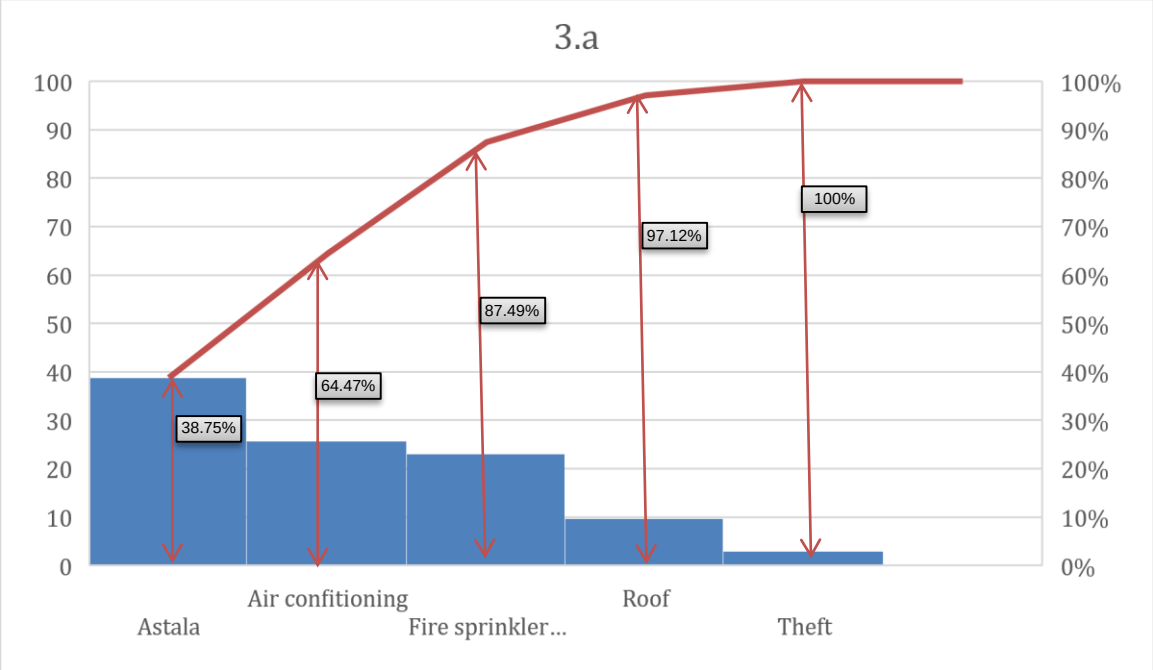
**3.1)**

Let's assume a library with some problems: The library has a rusting fire sprinkling system, causing 70688 € per failure. Additionally, the air conditioning is defect, causing a 78959 € per failure. The roof, where the rain comes through, causes only 7390 €, as only part of the books is destroyed. At the reception, the new operating system "Astala" crashes regularly, causing 838 € per crash, as an external technician is needed. Last but not least, thieves frequently visit the library, because it is known that the alarm system is not operating. A book has an average value of 79 €. The following frequencies have been reported for the individual failures:

| | |
|---|---|
| Fire sprinkling system | 1 |
| Air conditioning | 1 |
| Roof | 4 |
| Astala | 142 |
| Theft | 112 |
| Sum | 260 |

Solution:

| Problems | Cost/Failure | Failures | Costs overall | Distribution | Priority |
|---|---|---|---|---|---|
| Fire sprinkling system | 70688 | 1 | 70688 | 23.02% | 3 |
| Air conditioning | 78959 | 1 | 78959 | 25.72% | 2 |
| Roof | 7390 | 4 | 29560 | 9.63% | 4 |
| Astala | 838 | 142 | 118996 | 38.75% | 1 |
| Theft | 79 | 112 | 8848 | 2.88% | 5 |
| | | | | | |
| Sum | | 260 | 307051 | | |



**3.2)**

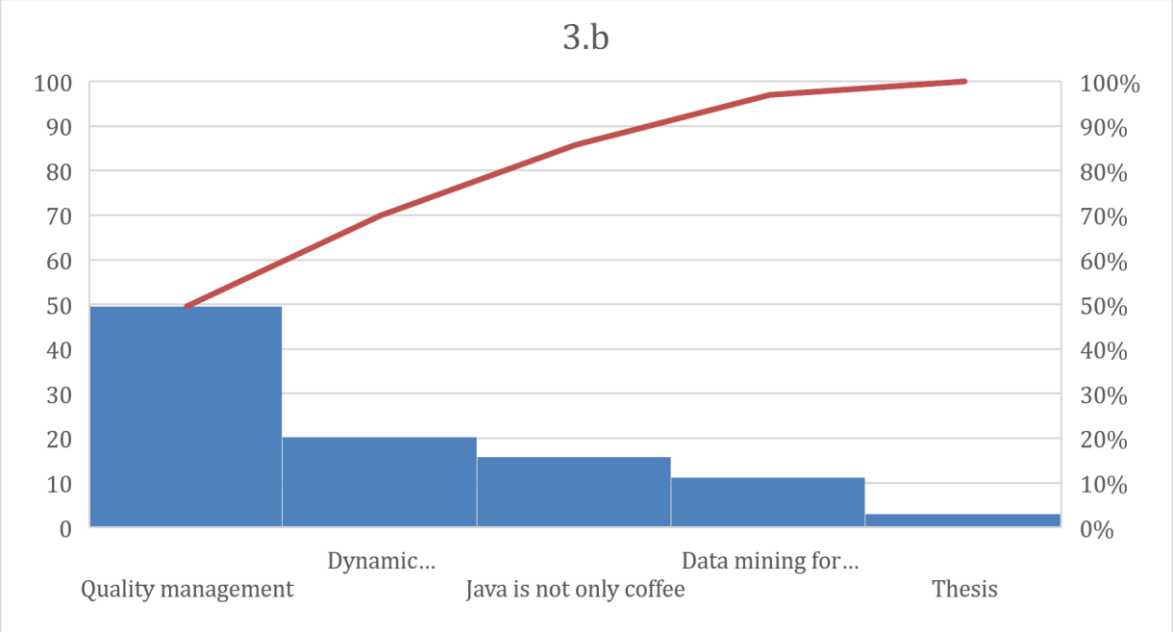
Peter has a little time management problem. He has only 18 days left until he leaves for holidays. Until then, he has to finish his master's degree. Therefore, he needs 7h for the lecture "Quality Management", 44h for the lecture "Java is not only coffee", "Dynamic programming" needs 41h, and "Data Mining for Beginners" needs 31h. Unfortunately, his master thesis also needs completion. He analyzes his day and discovers that he sleeps 7h per day and stays 5h at university. The remaining time can be spent to the aforementioned tasks. Additionally, the examination office told him the allotment for the final mark:

| | |
|---|---|
| Thesis | 4% |
| Quality Management | 5% |
| Java is not only coffee | 10% |
| Dynamic Programming | 12% |
| Data Mining for beginners | 5% |

Which topics should Peter handle first?

Solution:

| Days Left | 18 | | | | | |
|---|---|---|---|---|---|---|
| Hours per day to be allocated | 12 | | | | | |
| Hours left total | 216 | | | | | |
| | | | | | | |
| **Lecture** | **Hours needed** | **Marks allotment** | **Marks allotment normalized** | **Marks/Hour** | **Marks/Hour normalized** | **Priority** |
| Thesis | 93 | 4% | 11.11% (4%/36%) | 0.12% | 2.99% | 5 |
| Quality management | 7 | 5% | 13.89% | 1.98% | 49.65% | 1 |
| Java is not only coffee | 44 | 10% | 27.78% | 0.63% | 15.80% | 3 |
| Dynamic programming | 41 | 12% | 33.33% | 0.81% | 20.35% | 2 |
| Data mining for beginner | 31 | 5% | 13.89% | 0.45% | 11.21% | 4 |
| | | | | | | |
| Sum | | 36% | 100% | 4.00% | 100.00% | |



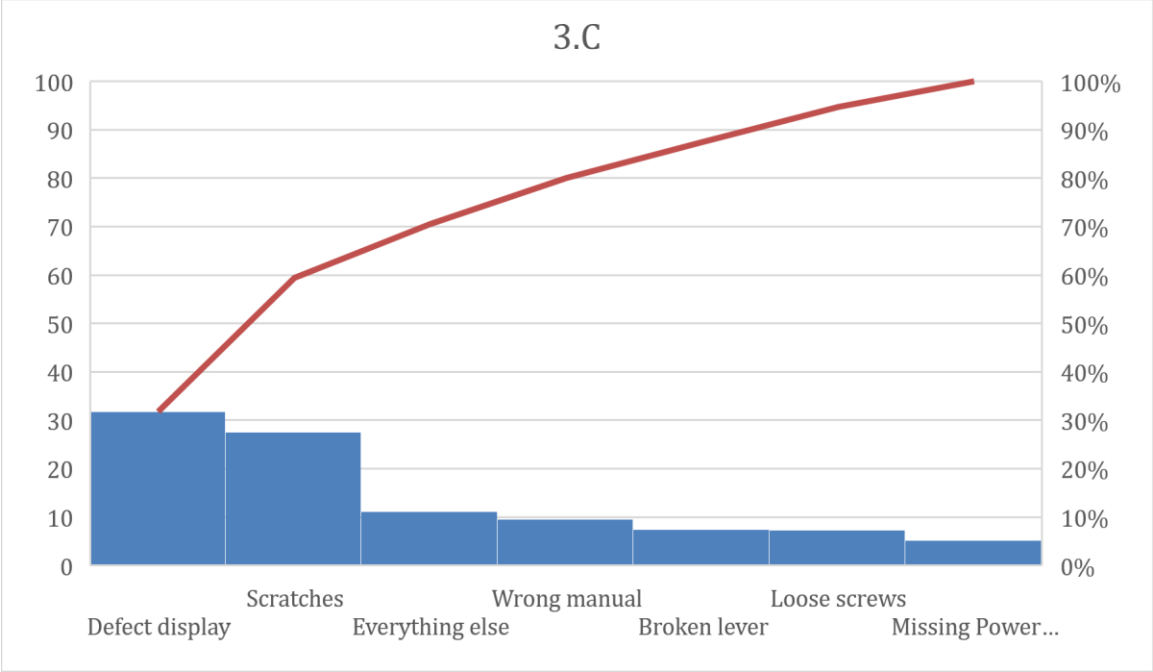
**3.3)**

manufacturer sells alarm clocks. During the final control failures occur, requiring a costly network. Analyze the causes using a Pareto-Analysis.

| Failure | Costs | Quantity |
|---|---|---|
| Missing Power Cable | 7 € | 7 |
| Broken lever | 35 € | 2 |
| Defect display | 60 € | 5 |
| Loose screws | 3 € | 23 |
| Wrong manual | 5 € | 18 |
| Scratches | 20 € | 13 |
| Everything else | 15 | 7 |

Solution:

| Problem | Costs | Quality | Total costs | Costs normalized | Priority |
|---|---|---|---|---|---|
| Missing Power Cable | 7 | 7 | 49 | 5.20% | 7 |
| Broken lever | 35 | 2 | 70 | 7.42% | 5 |
| Defect display | 60 | 5 | 300 | 31.81% | 1 |
| Loose screws | 3 | 23 | 69 | 7.32% | 6 |
| Wrong manual | 5 | 18 | 90 | 9.54% | 4 |
| Scratches | 20 | 13 | 260 | 27.57% | 2 |
| Everything else | 15 | 7 | 105 | 11.13% | 3 |
| | | | | | |
| | | | 943 | | |



**3.4)**

A bicycle vendor receives pre-assembled bikes from his distributor. Unfortunately, most bikes require additional work, before they could be sold. Which problem should the distributor address first?

| Problem | Time needed | Quantity |
|---|---|---|
| Light defect | 0,5 h | 35 |
| Loose spokes | 0,3 h | 9 |
| Spikes not correctly mounted | 0,3 h | 7 |
| No canvas (flat tube after pumping) | 0,5 h | 5 |
| Fork stem to short | 3,0 h | 3 |
| Screws askew | 0,3 h | 3 |
| Brake cable too short (can't turn handle bar completely) | 0,6 h | 10 |
| Creaks in the bottom bracket | 1,0 h | 49 |
| Suspension loses oil | 0,6 h | 20 |
| Paintwork damage | 0,5 h | 2 |

Solution:

| Problem | Time | Quantity | Total time | Total time normalized | Priority |
|---|---|---|---|---|---|
| Lights | 0.5 | 35 | 17.5 | 17.04% | 2 |
| Spokes | 0.3 | 9 | 2.7 | 2.63% | 6 |
| Spikes | 0.3 | 7 | 2.1 | 2.04% | 8 |
| Flat tires | 0.5 | 5 | 2.5 | 2.43% | 7 |
| Forks | 3 | 3 | 9 | 8.76% | 4 |
| Screws | 0.3 | 3 | 0.9 | 0.88% | 10 |
| Brakes | 0.6 | 10 | 6 | 5.84% | 5 |
| Creaking | 1 | 49 | 49 | 47.71% | 1 |
| Suspensions | 0.6 | 20 | 12 | 11.68% | 3 |
| Paint | 0.5 | 2 | 1 | 0.97% | 9 |
| | | | | | |
| | | | 102.7 | 100.00% | |