# Analytical estimation of map legibility

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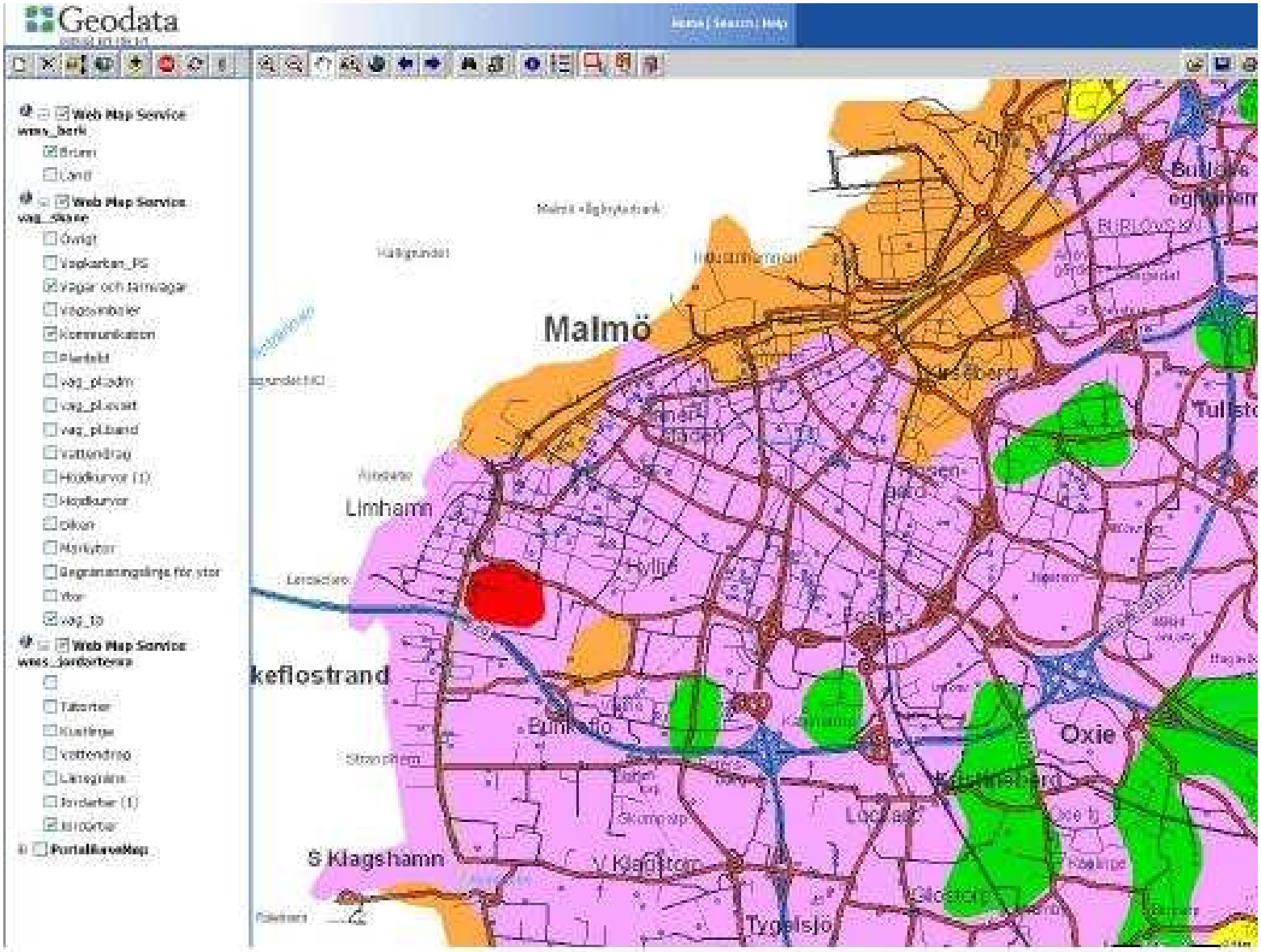
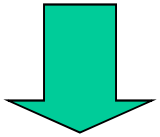
# Why estimating map legibility?



**Knowledge of map legibility**

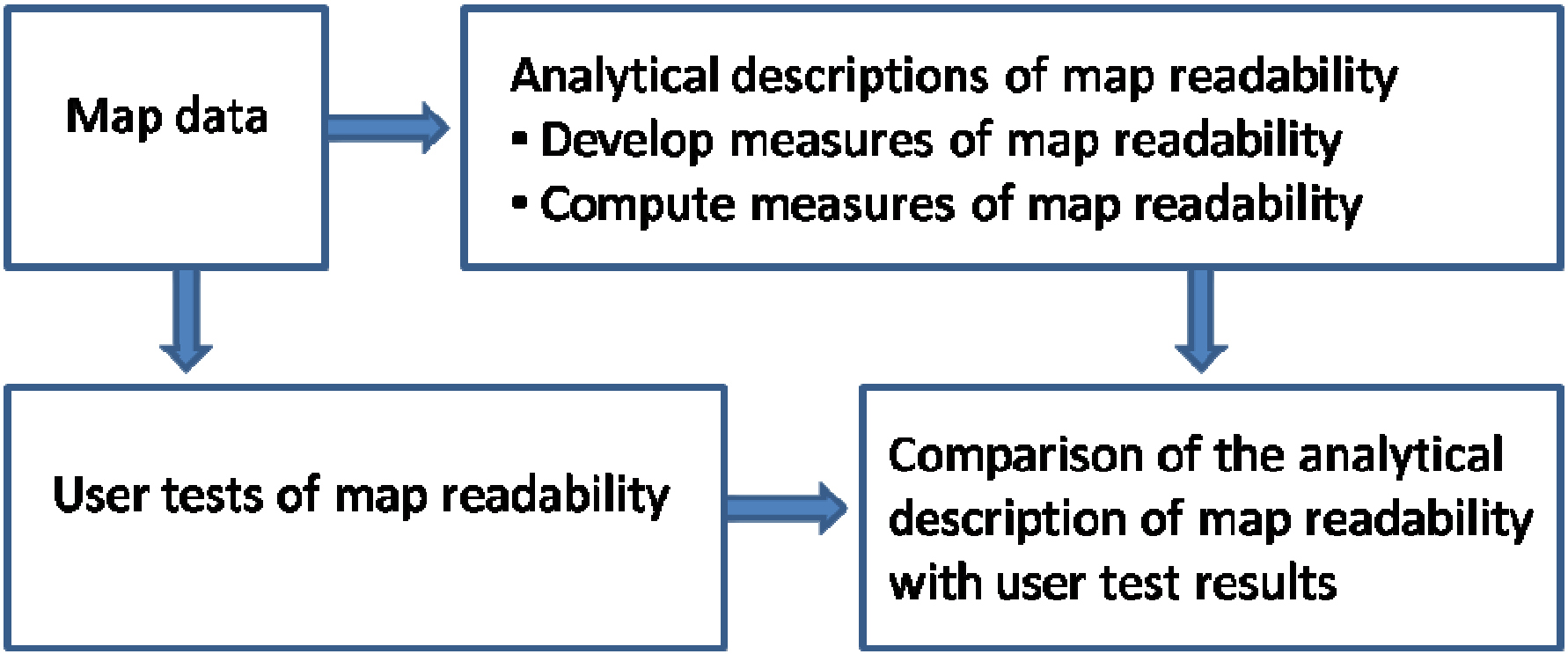


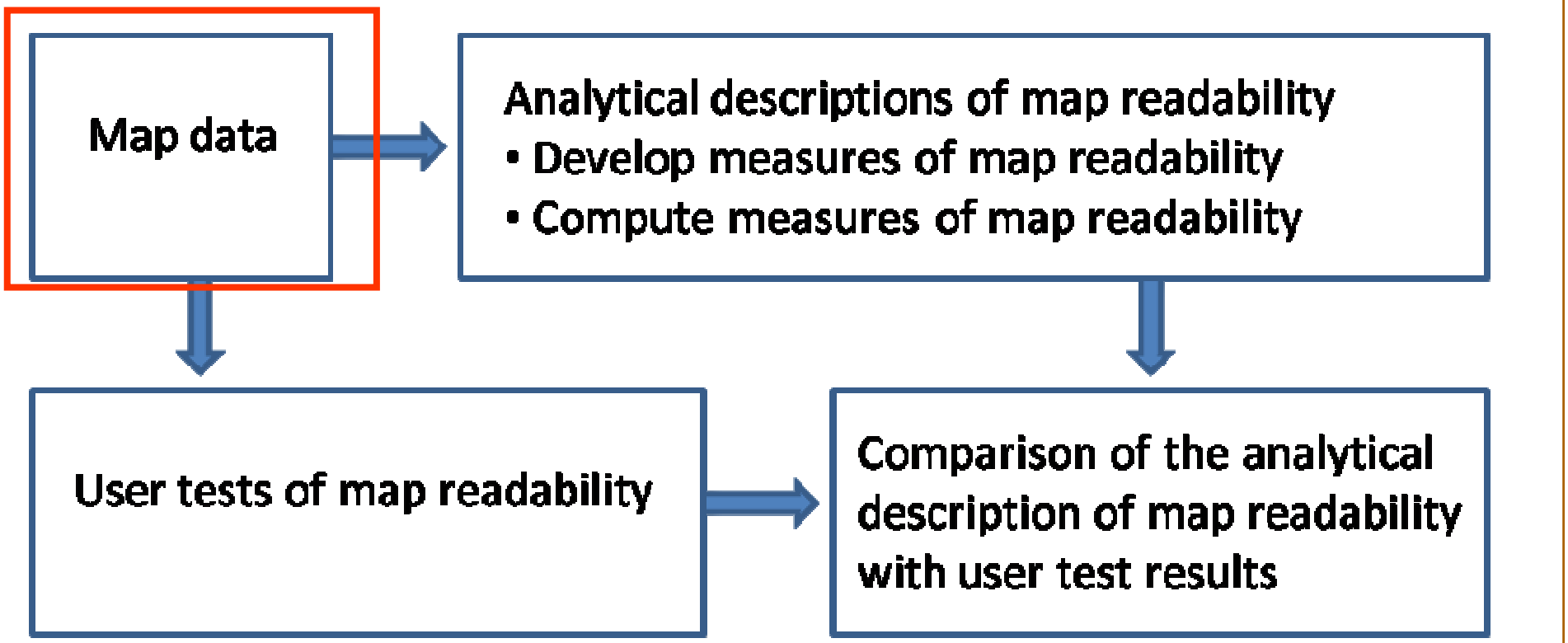
**Knowledge of when to generalise a map**

**In other words:**

**We aim at defining legibility constraints for the cartographic generalisation**

# Case study of estimating map legibility

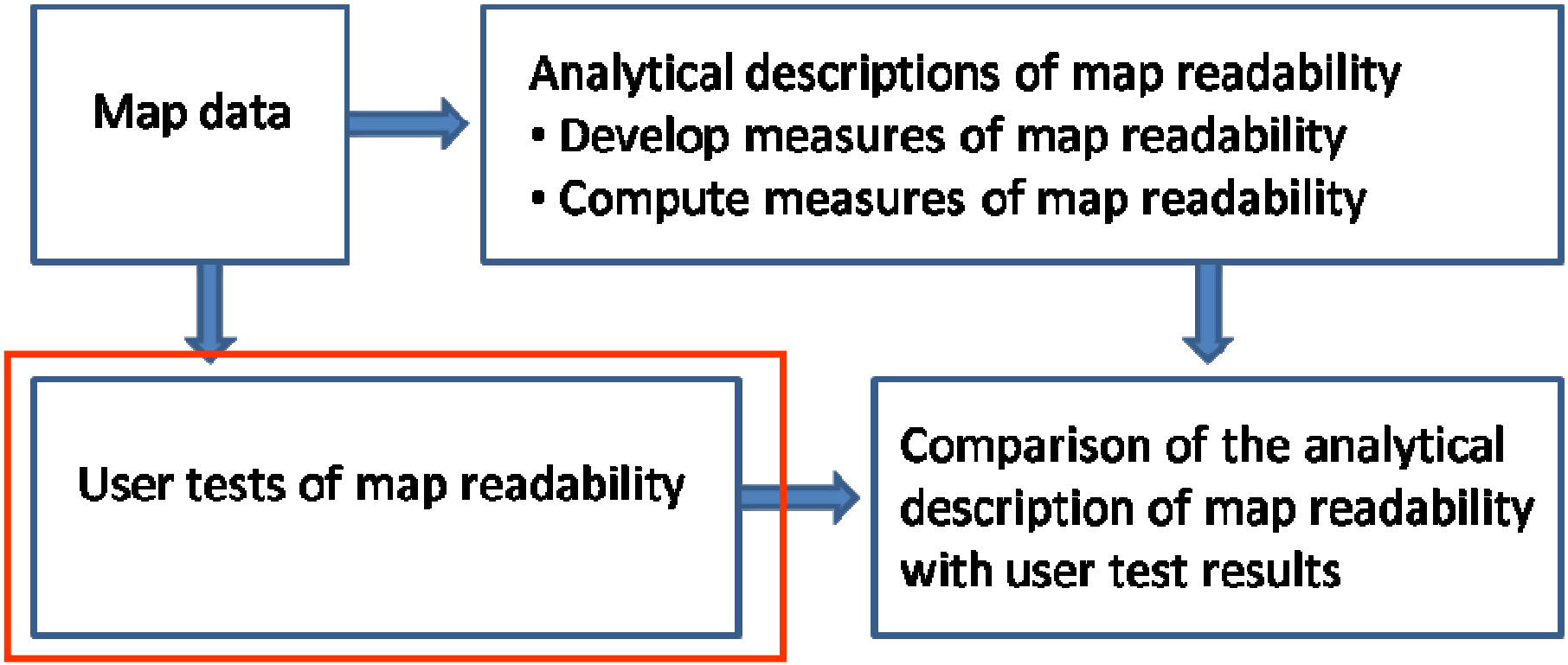



Map data
Analytical descriptions of map readability
• Develop measures of map readability
• Compute measures of map readability
User tests of map readability
Comparison of the analytical description of map readability with user test results

# Map data

- 175 map samples
- Size: 3x2 cm
- Scale 1:10 000 and 1:50 000
- Varying LoD

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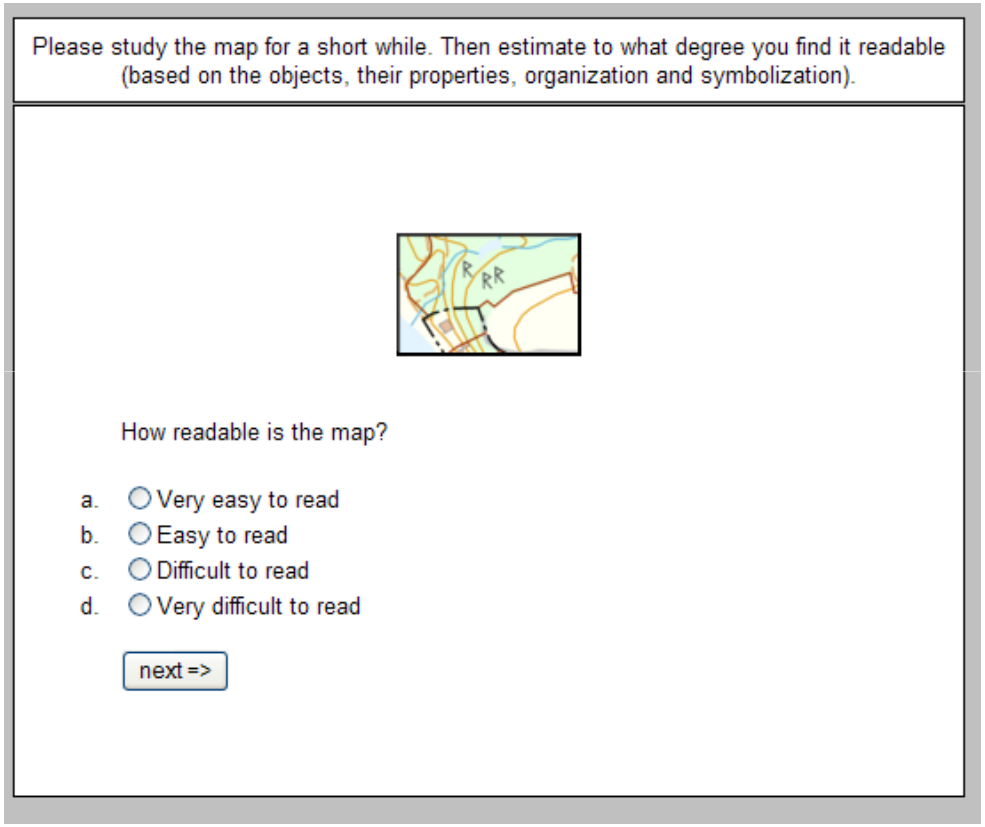
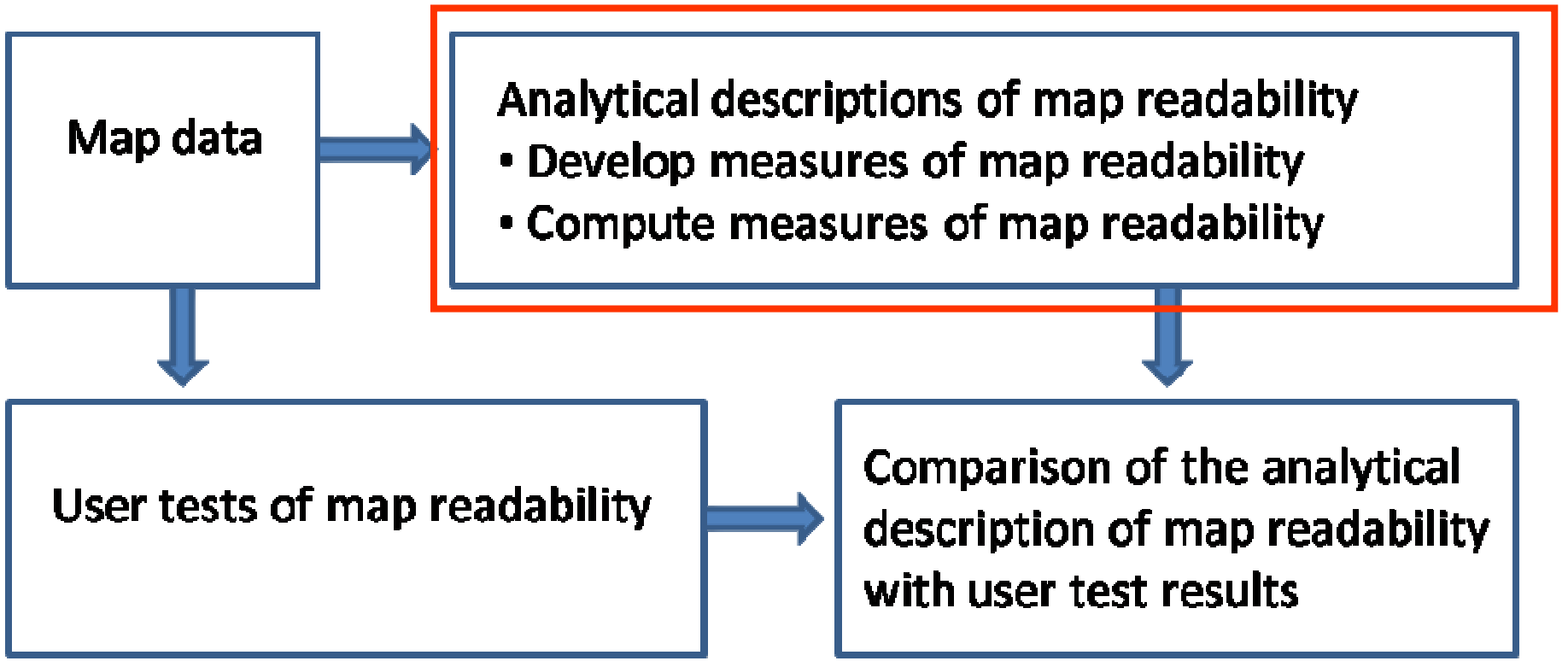
# User test of map legibility




- Web based
- 214 participants
- Preference study
- Usability study
- Took around 20 minutes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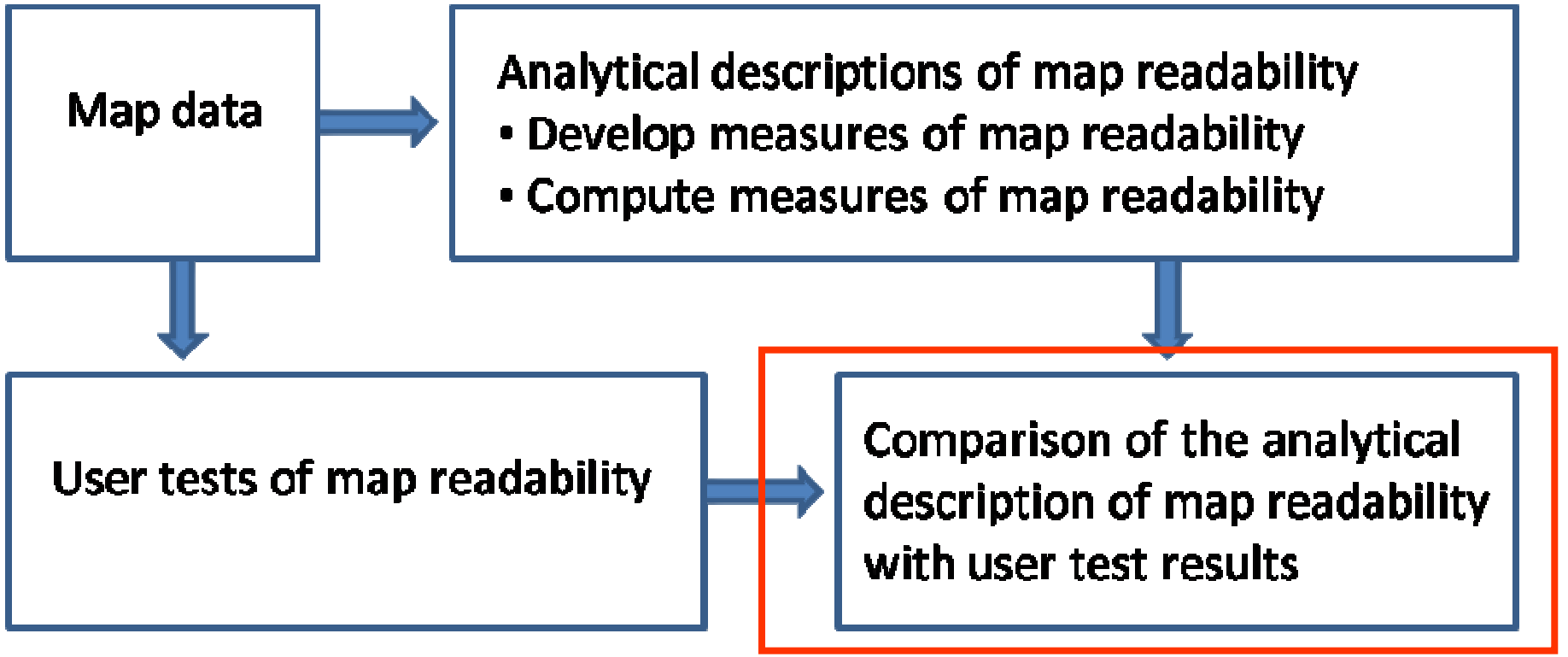
| | Amount of information | Spatial distribution | Object complexity | Graphical resolution |
|---|---|---|---|---|
| **Minor objects** | •Number of objects<br>•Number of vertices<br>•Object line length<br>•Object area | •Spatial distribution of objects<br>•Spatial distribution of vertices<br>•Number of neighbours<br>•Local density<br>•Semantic homogeneity | •Object size<br>•Line segment length<br>•Angularity<br>•Polygon shape | •Brightness difference<br>•Hue difference |
| **Line networks** | •Number of objects<br>•Number of vertices<br>•Object line length<br>•Object area | | •Line segment length<br>•Line connectivity<br>•Angularity | •Brightness difference<br>•Hue difference |
| **Tessellation objects** | •Number of objects<br>•Number of vertices<br>•Object line length | •Number of neighbours | •Object size<br>•Line segment length<br>•Angularity<br>•Polygon shape | •Brightness difference<br>•Hue difference |
| **Field-based data** | •Number of objects<br>•Number of points in the objects<br>•Object line length | | •Line segment length<br>•Angularity | |
| **All objects** | •Number of object types<br>•Number of objects<br>•Number of vertices<br>•Object line length<br>•Object area | •Proximity indicator<br>•Degree of overlap | | |

Java program

| | A | D | W | X | Y | Z | AA | AB | AC |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Region | ranking order | Layer: lin | Layer: lin | Layer: lin | Layer: lin | Layer: are | Layer: are | Layer: are |
| 2 | NyLM50_GL1_25 | 4 | 21.3589 | 62.8677 | 6.46529 | 16.4107 | 5.44047 | 102.966 | 11.6845 |
| 3 | NyLM50_GL2_08 | 3 | 50.5212 | 122.982 | 8.52255 | 45.0078 | 8.65502 | 140.091 | 12.4955 |
| 4 | NyLM50_GL2_25 | 2 | 21.3589 | 62.8677 | 6.46529 | 16.4107 | 5.44047 | 102.966 | 11.6845 |
| 5 | NyLM50_GL1_16 | 1 | 48.1583 | 116.265 | 9.12854 | 42.4154 | 4.23148 | 54.0017 | 7.21655 |
| 6 | | | | | | | | | |
| 7 | NyLM50_GL1_02 | 4 | 14.6934 | 100.036 | 5.24515 | 11.6305 | 5.83711 | 179.34 | 11.0225 |
| 8 | NyLM50_GL3_22 | 3 | 11.6869 | 43.1208 | 4.63397 | 13.8464 | 5.64197 | 130.37 | 10.7543 |
| 9 | NyLM50_GL3_04 | 2 | 20.1279 | 61.189 | 5.10836 | 21.2135 | 6.64222 | 123.586 | 10.5113 |
| 10 | NyLM50_GL3_12 | 1 | 16.9075 | 47.502 | 4.27942 | 5.60066 | 5.23327 | 120.969 | 12.1242 |
| 11 | | | | | | | | | |
| 12 | NyLM50_GL1_19 | 4 | 30.7958 | 99.4321 | 6.70276 | 25.5028 | 6.8435 | 137.675 | 13.9887 |
| 13 | NyLM50_GL3_26 | 3 | 17.31 | 50.3199 | 4.29289 | 8.83949 | 4.62943 | 119.157 | 11.185 |
| 14 | NyLM50_GL2_06 | 2 | 24.3814 | 89.4656 | 6.64317 | 23.7586 | 7.45546 | 210.969 | 13.245 |
| 15 | NyLM50_GL2_30 | 1 | 1.41308 | 10.0934 | 1.15898 | 0.3373 | 3.63363 | 57.5324 | 4.05038 |
| 16 | | | | | | | | | |
| 17 | NyLM50_GL1_29 | 4 | 11.8755 | 62.3966 | 5.30151 | 16.6118 | 12.4793 | 334.124 | 20.0102 |
| 18 | NyLM50_GL2_15 | 3 | 55.8565 | 147.001 | 10.289 | 62.6463 | 5.64614 | 125.223 | 12.1099 |
| 19 | NyLM50_GL3_15 | 2 | 47.5889 | 107.68 | 8.62736 | 42.084 | 4.83955 | 95.7828 | 11.3781 |
| 20 | NyLM50_GL1_07 | 1 | 2.61949 | 11.2839 | 1.3714 | 0.98829 | 3.42548 | 55.8152 | 5.33153 |
| 21 | | | | | | | | | |
| 22 | Trad50_GL1_25 | 4 | 21.3589 | 62.8677 | 6.46529 | 21.24 | 5.44047 | 102.966 | 11.6845 |
| 23 | Trad50_GL3_21 | 3 | 22.7446 | 74.6747 | 5.93524 | 19.9613 | 7.64862 | 184.171 | 13.8098 |
| 24 | Trad50_GL1_17 | 2 | 21.9395 | 70.2465 | 6.1345 | 20.1668 | 3.62303 | 92.7898 | 9.58541 |
| 25 | Trad50_GL3_04 | 1 | 20.1279 | 61.189 | 5.10836 | 17.3434 | 6.64222 | 123.586 | 10.5113 |
| 26 | | | | | | | | | |
| 27 | Trad50_GL3_29 | 4 | 8.8563 | 46.4956 | 4.3138 | 5.92247 | 11.2717 | 320.034 | 19.3403 |
| 28 | Trad50_GL2_08 | 3 | 50.5212 | 122.982 | 8.52255 | 57.2008 | 8.65502 | 140.091 | 12.4955 |
| 29 | Trad50_GL1_06 | 2 | 24.3814 | 89.4656 | 6.64317 | 25.8786 | 7.45546 | 210.969 | 13.245 |
| 30 | Trad50_GL3_10 | 1 | 4.02559 | 18.1152 | 2.34204 | 1.0133 | 4.42815 | 107.886 | 8.88568 |
| 31 | | | | | | | | | |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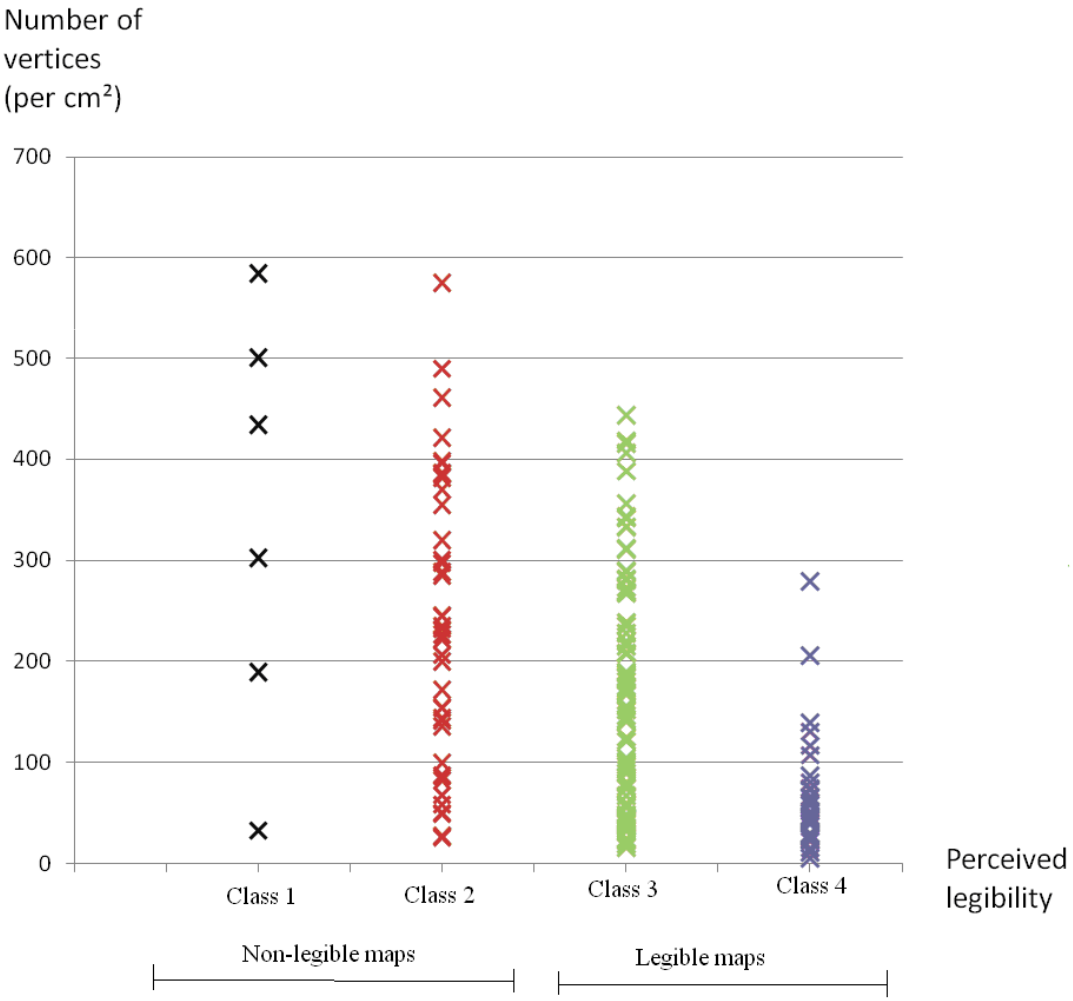
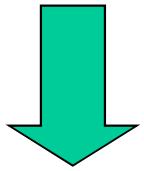
# Method 1: Manual interpretation of threshold values



* number of object types > 17
* number of objects (for area tessellations) > 11 cm-2
* object line length (for area tessellations) > 17 cm-1
* object line length (for continuous fields) > 4 cm-1
* object line length (for all objects) > 27 cm-1
* number of vertices (for continuous fields) > 70 cm-2
* number of vertices (for all objects) > 450 cm-2
* proximity indicators > 80 pairs
* degree of overlap (for disjoint objects) > 3
* angularity (maximal) > 40 cm-1



**85% percent agreement for legible and non-legible maps**

# Method 2: Multiple linear regression

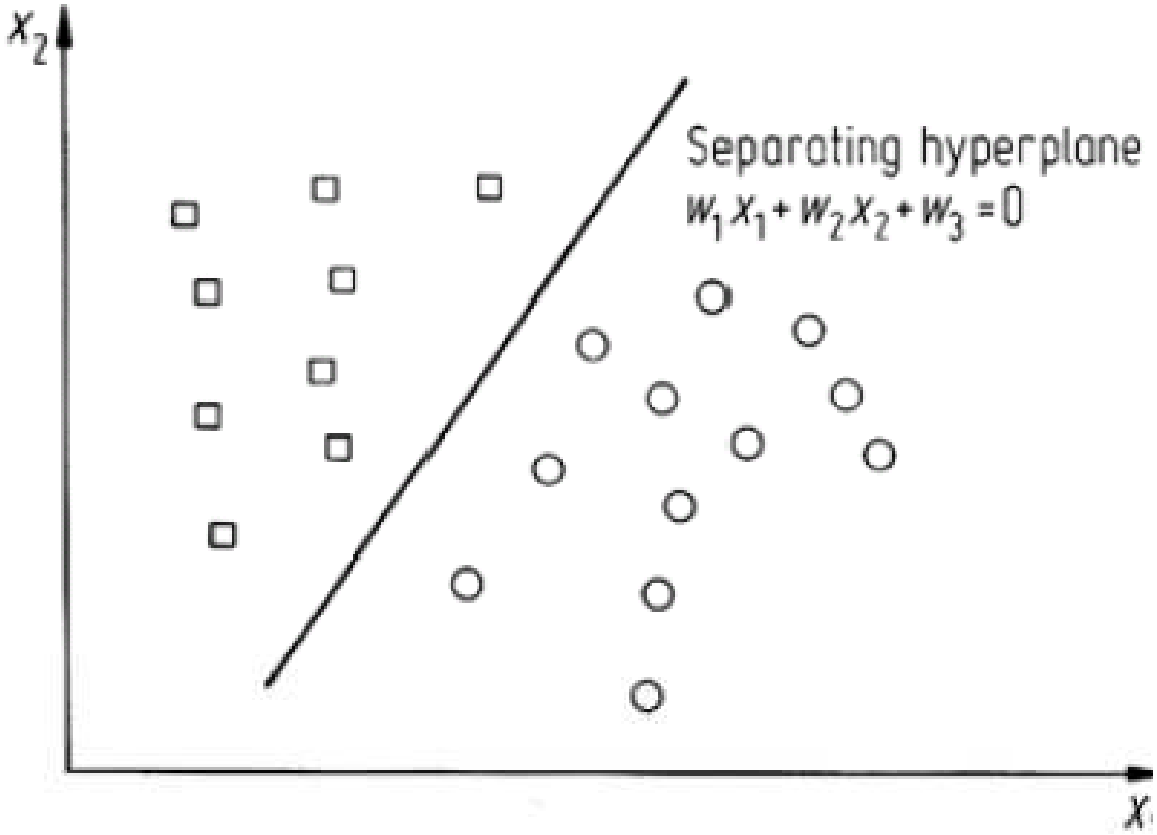
The following measures where used in the regression:

*m1* = Number of vertices (all objects)
*m2* = Number of object types (all objects)
*m3* = Degree of overlap of disjoint objects (all objects)
*m4* = Brightness difference (tessellation objects)
*m5* = Object size - 30% limit (minor objects)

# Result
# Multiple linear regression

| Attributes in the index | Percentage correct, 2 classes (%) | Cohen's weighted kappa, 2 classes |
|---|---|---|
| $m_1$ | 75 | 0.26 |
| $m_1$, $m_2$ | 77 | 0.34 |
| $m_1$, $m_2$, $m_3$ | 79 | 0.44 |
| $m_1$, $m_2$, $m_3$, $m_4$ | 78 | 0.45 |
| $m_1$, $m_2$, $m_3$, $m_4$, $m_5$ | 81 | 0.49 |

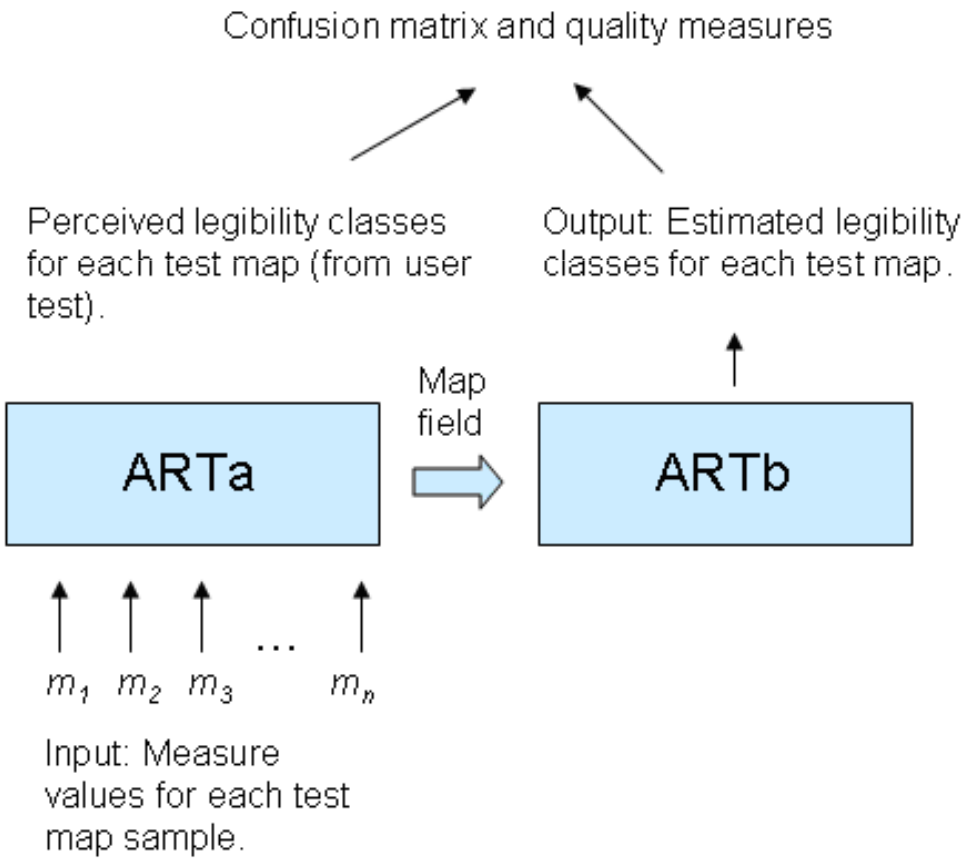
# Method 3: Support vector machine




# Result
# Support vector machine

| Attributes in the index | Percentage correct, 2 classes (%) | Cohen's weighted kappa, 2 classes |
|---|---|---|
| $m_1$ | 74 | 0.23 |
| $m_1$, $m_2$ | 76 | 0.31 |
| $m_1$, $m_2$, $m_3$ | 82 | 0.51 |
| $m_1$, $m_2$, $m_3$, $m_4$ | 79 | 0.43 |
| $m_1$, $m_2$, $m_3$, $m_4$, $m_5$ | 83 | 0.47 |

# Method 4: Neural network ARTMAP




# Result
# ARTMAP

| Attributes in the index | Percentage correct, 2 classes (%) | Cohen's weighted kappa, 2 classes |
|---|---|---|
| $m_1$ | 69 | 0.0049 |
| $m_1, m_2$ | 65 | 0.0037 |
| $m_1, m_2, m_3$ | 66 | 0.0015 |
| $m_1, m_2, m_3, m_4$ | 71 | 0.002 |
| $m_1, m_2, m_3, m_4, m_5$ | 67 | 0.0018 |

# Conclusions

- **We have got some knowledge about measures (including thresholds) that governs map legibility**
- **A few fundamental analytical measures are still missing**
- **Support vector machine is probably the best method to synthesize the measures**

# Thank you for your attention!

# Questions?

**Are user studies relevant / necessary for establishing legibility constraints?**

**To which extent can we express map legibility analytically?**