The evolution of a mountain road network from the original war-use to the forest one and its current management
Raffaele Cavalli, Stefano Grigolato, Marco Pellegrini
Introduction

- During the First World War period most of the front between Italian and Austro-Hungarian Armies lay on the Alpine areas
- The lack of transportation infrastructures forced to design and build a wide road network necessary for troops displacement and material supply
- The most of the roads are still present and used as forest road network
Introduction

- During the First World War period most of the front between Italian and Austro-Hungarian Armies lay on the Alpine areas

- The lack of transportation infrastructures forced to design and build a wide road network necessary for troops displacement and material supply

- The most of the roads are still present and used as forest road network

Aims

- Road Network (RN) extension from the 1st WW to nowadays

- The evaluation of the original transport network according to its re-engineered condition and its current use
Material and methods

Studied sites

- Two sites were selected in the Altopiano dei Sette Comuni (NE of Italy)
- The two sites differed mainly for the terrain slope gradient

A first analysis focused on the status of the current Road Network (2010-11 RN) by GPS surveys during the 2010 and 2011
Material and methods

Historical RN (1915-17 RN and 1953-54 RN)

Road Network during the 1st WW (1915-17 RN)
- 9 maps of the Carta d’Italia revised on the 1917 with the same scale, revising time and origin (1:25 000)

Road Network at half of the XX century (1953-54 RN)
- Historical aerial-photos of the Italian Aereonautic Group (GAI) of the 1953-54 and corresponding cartographic maps (1:25000)
Characteristics of the 1915-17 RN

The *Carta d’Italia (1917)* divided the road network in 4 main operative classes plus one indicating permanent trails adapted to haulage by mules (*mulattiera)*.

<table>
<thead>
<tr>
<th>Class</th>
<th>Width m</th>
<th>Slope %</th>
<th>Other features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt; 8</td>
<td>&lt; 7; 7 - 12; &gt; 12</td>
<td>Wall; bottlenecks and extra width</td>
</tr>
<tr>
<td>2</td>
<td>6 - 8</td>
<td>&lt; 7; 7 - 12; &gt; 12</td>
<td>Wall; bottlenecks and extra width</td>
</tr>
<tr>
<td>3</td>
<td>&lt; 6</td>
<td>&lt; 7; 7 - 12; &gt; 12</td>
<td>Wall; bottlenecks and extra width</td>
</tr>
<tr>
<td>4</td>
<td>Not indicated</td>
<td>Not specified</td>
<td>Wall; bottlenecks and extra width</td>
</tr>
<tr>
<td>Mulattiera</td>
<td>Not indicated</td>
<td>Not specified</td>
<td>Not specified</td>
</tr>
</tbody>
</table>

The Class 4 is defined by width < 4 m and gradient also higher than 12%.

The *mulattiera* is defined as a trail with a width variable between 1.5 to 2.5 m and a gradient higher than 10% up to 25%.
Material and methods

The RN extension database

The definition of the RN database for analyzing the upgrading of the RN considered:

1. The integration of the 1915-17 RN to the 2010-11 RN (overlapped segments)
Material and methods

The RN extension database

The definition of the RN database for analyzing the upgrading of the RN considered:

1. The integration of the 1915-17 RN to the 2010-11 RN (overlapped segments)
2. The integration of the 1953-54 RN to the 2010-11 RN (overlapped segments)
Material and methods

The RN extension database

The definition of the RN database for analyzing the upgrading of the RN considered:

1. The integration of the 1915-17 RN to the 2010-11 RN (overlapped segments)
2. The integration of the 1953-54 RN to the 2010-11 RN (overlapped segments)
3. The creation of the final RN database reporting the existence of the road segment during the 1915-1917, 1953-1954 and 2010-2011
Material and methods

Evaluation of the 1915-17 RN condition

- The analysis attempted to survey the 2010-11 RN currently overlapping 1915-17 RN
- The surveyed sections (25 m length) were randomly extracted

In each section the survey focus on:

1. The 2010-11 RN compared to the 1915-17 RN: completely re-engineered, partially re-engineered, partially preserved, completely preserved
2. The deterioration of the historical artifacts: high, medium, low, not valuable
Results

Increment of the RN from 1915 to 2011

The analysis on the improvement of the RN indicated a considerable increment (+126%) of its extension from the 1st WW (1915-17 RN) to nowadays (2010-11 RN)
The only class present in the 1915-17 RN were Class 3, Class 4 and *mulattiera*.

The roads were characterized generally by a width smaller than 6 m (including shoulders and carriageway) and the *mulattiera* was a considerable element of the 1915-17 RN.
## Results

### Original 1915-17 RN

The Analysis of Variance lets to compare the means of the road gradient between the operative classes for 214 segments extracted from 1915-17 RN.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Road Gradient (VG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-B</td>
<td></td>
</tr>
<tr>
<td>Class 3</td>
<td>Class 4</td>
<td>-1.0</td>
</tr>
<tr>
<td></td>
<td>mulattiera</td>
<td>-4.3*</td>
</tr>
<tr>
<td>Class 4</td>
<td>Class 3</td>
<td>+1.0</td>
</tr>
<tr>
<td></td>
<td>mulattiera</td>
<td>-3.3*</td>
</tr>
<tr>
<td></td>
<td>Class 3</td>
<td>+4.3*</td>
</tr>
<tr>
<td></td>
<td>Class 4</td>
<td>+3.3*</td>
</tr>
</tbody>
</table>

(*the difference of the mean is significant at the 0.05 level)

- The RN segments of Class 3 and Class 4 showed an average gradient of 5.75% and 6.72% with a maximum value of 18.8%.
- The *mulattiera* was the element of the 1915-17 RN with the higher gradient (mean 10.0%, max 23.8%).

---

The evolution of a mountain road network from the original war-use to the forest one and its current management
Raffaele Cavalli, Stefano Grigolato, Marco Pellegrini
Results

Current status of the 1915-17 RN

- The 1915-17 RN still in use covers the 31.3% of the current 2010-11 RN
- The current carriageway widths (m) and road gradient (VG, %) were verified for 87 segments

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>Carriageway (W, m)</th>
<th>Road Gradient (VG, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A-B</td>
<td>A-B</td>
</tr>
<tr>
<td>Class 3</td>
<td>Class 4</td>
<td>+0.8 *</td>
<td>-0.9</td>
</tr>
<tr>
<td></td>
<td>mulattiera</td>
<td>+0.6 *</td>
<td>-2.3</td>
</tr>
<tr>
<td>Class 4</td>
<td>Class 3</td>
<td>-0.8 *</td>
<td>+0.9</td>
</tr>
<tr>
<td></td>
<td>mulattiera</td>
<td>-0.3</td>
<td>-1.4</td>
</tr>
<tr>
<td>mulattiera</td>
<td>Class 3</td>
<td>-0.6 *</td>
<td>+2.3</td>
</tr>
<tr>
<td></td>
<td>Class 4</td>
<td>+0.3</td>
<td>+1.4</td>
</tr>
</tbody>
</table>

(*the difference of the mean is significant at the 0.05 level)
The evolution of a mountain road network from the original war-use to the forest one and its current management
Raffaele Cavalli, Stefano Grigolato, Marco Pellegrini

Results

Current status of the 1915-17 RN

According to the *Carta d’Italia* classification

Upgrading of the 1915-17 RN

Deterioration of the alignment and artifacts of the 1915-17 RN
Results

Current status of the 1915-17 RN

According to the current use

Upgrading of the 1915-17 RN

Deterioration of the alignment and artifacts of the 1915-17 RN

The evolution of a mountain road network from the original war-use to the forest one and its current management
Raffaele Cavalli, Stefano Grigolato, Marco Pellegrini
Conclusions

• The results confirms that an appreciable part of the 1915-17 RN is still in use

• A part of the 1915-17 RN has been substantially re-engineered in order to support the ordinary traffic related to agriculture and forest activities and nowadays also summer and winter recreational activities

• Part of the 1915-17 RN remained partially preserved because only used for low intensive forest activities

Further works

• Original detailed planning projects will be collected during the 2012 in order to get more details on the original road construction technique and materials

• The area will be covered by Lidar data which could support a more detailed analysis on the historical RN
Thank you for your attention

Raffaele Cavalli, Stefano Grigolato, Marco Pellegrini

University of Padua
Land, Environment, Agriculture and Forestry Department
Forest Operations Management Unit