The evolution of a mountain road network from its original use during the First World War to meeting today's forestry needs: current management

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Abstract

In some mountain areas of northeastern Italy, the present forest road network has been partially developed using the previous military road network built during the First World War (WW I). The current management of the areas of forest considers the road network essential to provide access for forestry activities, but also to increase the value of recreational activities and tourism related to the historical importance of this area. The aim of the study was to investigate the technical evolution of a mountain road network from the beginning of the last century to today. The research consisted in a preliminary reconnaissance of the original road network using the WW I military maps, a further reconnaissance using the technical maps dated to the 1960s, and the survey of the current road network through the differential global positioning system (D-GPS). The study also aimed to evaluate the current condition of the original road network according to the use made of it today in order to highlight how building standards influenced its evolution in terms of transportation systems and traffic management.

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Key words: road network, mountainous areas, historical roads, First World War.

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Introduction

Forest management today has to meet numerous objectives. The planning of multi-functional forest road networks is essential to meeting the aims of sustainable forest management (Gumus *et al.*, 2008).

When wood harvesting is considered the principal economic benefit, the planning of forest road networks has to ensure the efficiency both of the operation itself and of the wood transportation (Klč, 2005). Forest road network parameters change according to construction location requirement and management activities. Furthermore, forest roads also bring together in a wider sense all those activities directly or indirectly related to the movement of goods, people and materials (Sudenberg and Silversides, 1988).

The ways in which forest access roads in mountain areas have been used and managed have been substantially modified over time. In the Italian Alps, the forest road networks are frequently the consequence of a historical combination of different requirements for mountain access. In this area, one of the most significant moments in the expansion of access to mountainous areas was just before and during the First World War (WW I). In fact, due to the lack of transportation infrastructures, the armies of those countries bordering the Alpine regions were forced to design and build a vast mountain road network for troop displacement and supplies; cable-car systems were only used in very steep areas.

Such was the great care taken to ensure that the technical features incorporated in these road networks and the materials used were suitable for the terrain, that most of the roads are still open today and are mainly used for forestry purposes (Boglione, 1998).

The purpose of this study is to use historical maps, geographical information system (GIS) analysis and field surveys to investigate how a transport network in a mountainous forest area has improved from the beginning of WW I to today, and to evaluate the condition of the original transport network according to its re-engineered condition and its current use.

Materials and methods

Study area

Study areas are located in the Altopiano dei Sette Comuni in the northeastern part of Italy (N45°45'00-46°01'00, E11°21'00-11°41'00). It represents a significant case study to analyze the expansion of the transport network from WW I to the present day (Cavalli *et al.*, 2011). Two forest areas were identified: Boscon and Verena. The main difference between them was the average slope of the terrain while they had the same extent of forest area and almost the same area managed through the Forest Management Plans (Table 1).

At the beginning of WW I, both areas were controlled by the Royal Italian Army. Two important Italian fortresses were located in the Verena area and the transport network was designed mainly to provide logistical access to them. The roads that were built were steep in order to provide the shortest route possible to reach the fortresses. The Boscon area remained in Italian possession for the whole of WW I while the Verena area was occupied by the Austro-Hungarian Army from May 1916 until the end of the war, and during this period the transport network was improved.

Current extension of the road network

The road network in these two areas developed differently over time and their layout over the terrain is also different. The geographical patterns of roads in forest landscapes can differ substantially from place to place, with commensurate differences in operational level (Cavalli and Grigolato, 2010). Nevertheless, few technical details are known about how far the forest read network extends, even excluding those roads mainly used by the public that are fully described in the regional public road database. For these reasons, the current forest road network of the two areas was surveyed between 2010 and 2011 (155 km in the Boscon area and 102 km in the Verena area) using a professional differential global positioning system (D-GPS) (Trimble Pathfinder ProXH) (WGS 84 UTM 32 N) and by post-processing the acquired data in order to obtain precise positions. Therefore, each road segment was classified according to its current main use (Table 2) and operative level (Table 3).

Historical maps

The evolution of the road network from its original military use to its forestry use and its current management was based on: i) initial period as shown by historical WW I maps (*Carta d'Italia*, up-graded during the

Table 1. Main characteristics of the two study areas.

Study area	A ha	FA %	MF %	PA % MF	AT m a.s.l.	MT -	Terrain slope % (mean)	% (SD)
Verena	5776	86.7	80.8	75	1430	Spruce and fir	40.3	14.26
Boscon	3372	86.8	86.8	90	1250	Spruce and beech	28.8	31.37

A, area; FA, covered by forest; MF, managed forest; PA, productive area; AT, altitude; m a.s.l., meters above sea level; MT, main tree species; SD, standard deviation.

Table 2. Current road classification according to use.

Class	Functional classification	Main road use
O	Ordinary roads	National and regional major roads generally not used for forestry purposes
C	Access roads	Principal roads and roads rarely used for forestry purposes
MF	Multi-function roads	Secondary roads with free access commonly used for rural, forestry or recreational purposes
FOR	Forest roads	Forest roads with free or restricted access for forestry purposes
NC	Not classified	Network of temporary skid roads or trails not suitable for vehicles, including recreational trails

Table 3. Current road classification according to upper limit transportation system and standard layout.

	Class	Slope gradient %	Width m	Curve radius m	Upper limit transportation system
1	Low mobility and high-load capacity	3.0-8.0 (max 14)	5.0-6.0 (min 3.5)	10	Truck with trailer
2	Low mobility and medium (+) load capacity	3.0-8.0 (max 18)	4.0-5.0 (min 3.0)	7	Truck
3	High mobility and medium (-) load capacity	3.0-8.0 (max 25)	3.0-4.0 (min 3.0)	7	Forwarder or tractor with forest trailer
4	High mobility and low or null load capacity	5.0-10.0 (max 25)	3.0-4.0 (min 2.5)	5	Small tractor with single axle carriage
0	Temporary skid roads or trail not suitable for vehicles				

Table 4. List of the collected and georeferenced historical maps for military use.

Code	Map	Scale	First survey	General reconnaissance	Upgrade (date)
Conco	Sheet 37 *Carta d'Italia* Sez. III N.E.	1:25,000	1887	1910	15.8.1917
Valstagna	Sheet 37 *Carta d'Italia* Sez. IV S.E.	1:25,000	1886	1910	15.8.1917
Asiago	Sheet 37 *Carta d'Italia* Sez. IV S.O.	1:25,000	1886	-	-
Monte Lisser	Sheet 37 *Carta d'Italia* Sez. IV N.E.	1:25,000	1886	-	15.8.1917
Cima Dodici	Sheet 37 *Carta d'Italia* Sez. IV N.O.	1:25,000	-	1910	15.8.1917
Monte Verena	Sheet 36 *Carta d'Italia* Sez. I N.E .	1:25,000	-	-	15.8.1917
Rotzo	Sheet 36 *Carta d'Italia* Sez. I S.E.	1:25,000	1886	1912	15.8.1917
Caltrano	Sheet 36 *Carta d'Italia* Sez. III N.O.	1:25,000	1887	-	15.8.1917
Arsiero	Sheet 36 *Carta d'Italia* Sez. II N.E.	1:25,000	1886	1912	31.5.1917

Sez., section.

WW I for military use); ii) intermediate period as confirmed by historical aerial-photographs (Italian Aeronautic Group material dated 1954-55); iii) current period as reported by GPS survey (2010-11).

In order to analyze the evolution of the road network in the two study areas, we explored the availability of historical maps and aerial-photographs. To guarantee the standardization of the data, we considered using historical maps with the same scale, the same revision time and of the same origin. Initial research identified 9 historical maps of the map of Italy (*Carta d'Italia)* up-graded during WW I for military use (IGM, 1886, 1917) and these were collected from the Biblioteca Civica Bertoliana, Vicenza, north-eastern Italy (Table 4).

The collected maps reported a considerable number of geographical features and, in particular, gave a precise and detailed description of features of the transport network. Roads are categorized in 4 main operative classes; permanent trails adapted for haulage by mules (*mulattiera*) are also reported.

A simple explanatory categorization of the road transportation network during WW I in mountainous conditions similar to those of the *Altopiano dei Sette Comuni* is reported by Sigurtà (2002) that indicates *camionabili* as truck roads (generally over 4.0 m wide and a less than 10% gradient) and the *carrozzabili* as roads adapted for tractors with trailer (2.50-4.0 m wide and a less than 10% gradient). Sigurtà also describes the *mulattiera* which varies between 1.5-2.5 m in width with an over 10% gradient (max. 28-30%). Boglione (2008) reports that, in mountainous areas, the *camionabili* and *carrozzabili* roads also have short sections with gradients of over 10% (max. 12-14%). The maps were scanned to obtain digital images. The scanned maps were then aligned and georeferenced in WGS 84 UTM 32 N and then grouped in a single dataset.

In order to verify the condition of the forest road network at an intermediate state, historical aerial-photographs of the Italian Aeronautic Group (GAI) dating from 1954-55 (AA.VV., 2011) were collected and grouped in a single dataset. The GAI aerial-photographs were scanned at 600 dpi resolution to be adapted to an application scale of 1:10,000 (Savio, 2011).

The two datasets concerning the maps of the *Carta d'Italia* for military use and the GAI aerial-photographs were then up-loaded into a single geodatabase (Figure 1).

Extraction of the historical transport network

The transport network on the 1917 historical maps was digitalized in vector format. For each transport network segment (identified as the road segment between two nodes of the road network), the class, the width, the gradient and the presence of walls, bottlenecks and extra widths (such as landings, switchback area and square) were reported according to the legend and the technical notes reported in the maps (Table 5).

As a first step, the digitalization considered the same layout shown by the maps. Since the horizontal layout of the transport segments of the maps was not always reliable (because of the accuracy of the historical maps), a second step took into account the alignment of the digitalized segment to the current road network previously surveyed by the D-GPS.

The alignment considered integration of the information of the historical road network to the current road network. The integration was evaluated only where the segments in the maps clearly overlapped (within a buffer of 30 m, corresponding to 12 mm on the map at a scale of 1:25,000) the segment surveyed by the D-GPS. Where the historical road network differed (approximately 33%) in terms of horizontal layout, and outside the buffer area of 30 m, the road network was considered different from the current network alignment and for this reason was not integrated to the dataset of the current road network.

In order to verify the maps of the *Carta d'Italia* for military use, and to obtain more information about the standard construction and the road design for mapped roads, the original road construction projects and the road maintenance plans of the Alpine Troop Command (*Comando Truppe Altipiano*) and the Italian 6th Army (*6th Armata*) were examined. The data were retrieved from the collection of historical documents at the Museum of the Institute of the History and Culture of the Engineer Corps (ISCAG, 1916, 1917a, 1917b) in Rome. The data collected were up-loaded into the geodatabase.

As a consequence, the forest road network shown in the GAI aerial-photographs was digitalized and then integrated into the current road network according to methods applied described above. The final geodatabase covered each segment of the current road network in three periods: 1915-1918, 1953-1954, 2010-2011.

All GIS operations, dataset management and analyses were supported by ArcGIS 10 software (ESRI, 2010) while Statistic software SPSS Release 18 (SPSS Inc., IBM Company, Chicago, IL, USA) was used for statistical analysis.

Field survey plan

We analyzed current road segments overlapping the historical transportation network in the first period (WW I). The main features analyzed were the deterioration of the artifacts and the re-engineered condition of the historical transportation network. The surveys were carried out to cover all the road classes included in the legend of the historical *Carta d'Italia*. The survey plan had been previously randomly extracted with the support of the GIS analysis by considering one survey point every 0.5 km of the historical road network.

The field procedure considered the collection of different parameters and information within 25 m segments. Length and slope gradients were measured by a laser rangefinder with an integrated compass, and an inclinometer allowed us to measure straight stretches of road (5-400 m). A standard measuring tape was used for distances under 5 m.

Table 5. Transport network classification of the *Carta d'Italia* for military use during World War I.

Class	Width m	Road gradient %	Other features
1	>8	<7; 7-12; >12	Wall; bottlenecks and extra width
2	6-8	<7; 7-12; >12	Wall; bottlenecks and extra width
3	<6	<7; 7-12; >12	Wall; bottlenecks and extra width
4	Not indicated	Not specified	Wall; bottlenecks and extra width
mulattiera	Not indicated	Not specified	Not specified

Figure 1. Map composed from enlargement of the *Carta d'Italia* and Italian Aeronautic Group aerial-photographs integrated in a single geodatabase.

Table 6. The extension of the road network between World War I to 2010-2011.

Area	World War I A		1953-1954 B	Δ AB		2010-2011 C	Δ AC	
	km	m ha^{-1}	km	km	m ha^{-1}	km	km	m ha^{-1}
Verena	69.8	12.1	105.9	36.1	18.3	155.4	85.6	26.9
Boscon	44.1	13.1	90.6	46.5	26.9	102.2	58.1	30.3
Total	113.9	12.5	196.5	82.6	21.5	257.6	143.7	28.2

The survey included qualitative and quantitative features for each road segment:

- width: the current average running surface, including shoulders and carriageway (m);
- gradient: the current road gradient (%);
- current condition compared to the standard WW I layout: completely re-engineered, partially re-engineered, partially preserved, completely preserved;
- historical artifacts: retaining walls, drainage systems (such as cambers, culverts, ditches or cross drain), and bridges;
- historical artifact deterioration: high, medium, low, not evaluable;
- road surface: current road surface (asphalt, gravel or natural);
- current access: reporting road traffic limitations and use.

Results and discussion

The road network from the First World War to today

The data obtained from the digitalization of the historical maps of the WW I and from the digitalization of the GAI aerial-photographs indicated a considerable increase (+126%) of the extension of the road network extracted from the WW I *Carta d'Italia* maps (113.9 km) to today (257.6 km) (Table 6).

We included the Class 3 and Class 4 road networks of WW I since the legend of the *Carta d'Italia* detailed them as suitable for vehicles, in contrast to the *mulattiera* that were not suitable and were, therefore, not taken into consideration.

By comparing the extension of the road network (including forest, pasture and grassland areas) from WW I to today, the road network density in the Verena area increased from 12.1 m ha^{-1} to 26.9 m ha^{-1}, while in the Boscon area, road network density increased from 13.1 m ha^{-1} to 30.3 m ha^{-1}.

Table 7 reports the extension of the current road network as classified according to operative level. Table 8 shows the WW I road network extension according to the operative classification indicated in the legend of the *Carta d'Italia*.

The original alignment of the First World War transport network

As detailed in Table 8, the WW I road network within the study areas was composed of only Class 3 and Class 4 roads and *mulattiera*. According to the legend of the *Carta d'Italia*, it is evident that the roads were generally no more than 6 m wide (including shoulders and carriageway) and the *mulattiera* represented a considerable part of the WW I transportation network. This is similar to the condition of the military road network in mountain areas described by Boglione (2008) in northwestern Italy and by Sigurtà (2002) in northern-central Italy.

The analysis verified the location of the transportation network according to the characteristics of the terrain surrounding each transport segment (a buffer of 50 m was considered for both the sides of the road segment). The analysis considered the steepness of the terrain

Table 7. Operative level of the current road network according to road classification as described in Table 3.

Operative level Class	Verena km	%	m ha^{-1}	Boscon km	%	m ha^{-1}
1	12.8	8.2	2.2	7.3	7.1	2.2
2	26.2	16.9	4.5	42.1	41.2	12.5
3	67.2	43.3	11.6	31.0	30.4	9.2
4	49.2	31.7	8.5	21.8	21.4	6.5
Total	155.4	100	26.9	102.2	100	30.3

Table 8. Operative level of World War I transport network as described in Table 5.

Operative level Class	Verena km	%	m ha^{-1}	Boscon km	%	m ha^{-1}
3	39.5	32.6	6.8	35.1	51.0	10.4
4	30.3	25.0	5.2	9.0	13.1	2.7
mulattiera	51.3	42.4	8.9	24.7	35.9	7.3
Total	121.1	100	21.0	68.8	100	20.4

(or terrain slope) as a percentage. The terrain slope was calculated by a Digital Terrain Model with a resolution of 5×5 m. At this resolution, the morphology of the terrain was considered constant for the entire period from WW I to the situation today. According to this approach, the results highlighted that in the Verena area the WW I transportation network (135 segments with an average steepness of the surrounding terrain of 30.95%) was located in terrain steeper than in the Boscon area (102 segments with an average steepness of the surrounding terrain of 22.17%). The two means were, therefore, compared by Mann-Whitney non-parametric test with the null hypothesis that the two means were equal. The result reported P=0.000, justifying the rejection of the null hypothesis. Therefore, a total of 237 segments were extracted and analyzed in terms of road gradient. The road gradient was determined by considering the difference between the start and the end vertex of each segment and the length of the same segment. The procedure was based on a semiautomatic method developed in ArcGIS 10. Data obtained on the gradient of each transportation network segment showed an average gradient of 5.93% for the Boscon area and of 8.62% for the Verena area. The Independent-Samples t-test was applied to test the significance of the difference between the two means with a 95% confidence interval (CI) The t-test reported P=0.000, justifying the rejection of the null hypothesis that the two means were equal.

The one-way analysis of variance (ANOVA) procedure was then used to compare the means of the road gradient for the three groups: Class 3, Class 4 and *mulattiera*. As the Levene statistical test confirmed the null hypothesis that the group variances were equal, the pairwise multiple

Table 9. Least significant difference test on the means of the road gradient for the three historical transportation classes.

WW I transportation class A	B	Mean difference (A-B)	SE	P	Confidence interval 95% Lower bound	Upper bound
3	4	-0.965	0.987	0.329	-2.91	0.98
	*mulattiera**	-4.259	0.812	0.000	-5.86	-2.66
4	3	0.965	0.987	0.329	-0.98	2.91
	*mulattiera**	-3.294	1.013	0.001	-5.29	-1.30
mulattiera	3*	4.259	0.812	0.000	2.66	5.86
	4*	3.294	1.013	0.001	1.30	5.29

*Mean difference is significant at P=0.05. SE, standard error; WW I, First World War.

comparisons were based on the least significant difference (LSD) test. The main results of this statistical analysis are reported in Table 9. We can see that the *mulattiera* was the part of the WW I transportation network with the highest road gradient: an average 10.0%, maximum 23.8%. The Class 3 and Class 4 road segments included showed an average road gradient of 5.75% and 6.72% with a maximum value of 18.8% and 18.9%, respectively.

The current alignment of the First World War transport network still in use

A total of 80.5 km of the current road network overlapped the WW I transportation network, *i.e.* approximately 31.3% of the existing road networks. Therefore, the current alignment of the WW I transport network still in use as a forest road network was analyzed in terms of carriageways and gradient (Table 10) by considering the data collected by GPS during 2010 and 2011.

The road network analyzed was composed of 87 segments grouped according to their original classification as reported in the *Carta d'Italia*. The resulting means for the carriageways and the road gradient are reported in Table 11.

One-way ANOVA was used to compare the means of the carriageway and the road gradient between the three road classification groups (Class 3, Class 4 and *mulattiera*) of the *Carta d'Italia*. The pairwise multiple comparisons were based on the LSD test for the evaluation of the means of carriageway, as the Levene statistical test confirmed the null hypothesis that the variances of the three groups were equal (Table 12). For the road gradient, the Levene statistical test did not confirm the null hypothesis that the group variances were equal and for this reason the Tamhane T2 test was applied (Table 13).

As can be seen from Table 12, the Class 3 reported significantly larger carriageways than Class 4 and *mulattiera*; alternatively, the statistical analysis indicated that the means of the carriageways of Class 4 and *mulattiera* are equal.

As indicated in Table 13, the means of the road gradient of all the groups are equal. As far as the *mulattiera* are concerned, it could be suggested that only the *mulattiera* that have been re-designed with a gradient suitable for vehicles are part (10.8%) of today's road networks.

The remaining artifacts of the historical transportation network

The current state of the WW I transportation network was evaluated through a survey of 145 control points along the current road network. Thirty-six percent of the control points were collected on roads originally WW I Class 3, 48% on roads originally Class 4, and the remaining 16% on roads originally WW I *mulattiera*.

The results show that a great number of road segments originally

Table 10. Extension of the World War I transport network still in use as forest road network.

Operative level / WW I transportation class	Verena km	%	m ha^{-1}	Boscon km	%	m ha^{-1}
3	25.4	62.1	7.5	19.5	49.0	3.4
4	6.3	15.5	1.9	16.3	41.2	2.8
mulattiera	9.1	22.4	2.7	3.9	9.8	0.7
Total	40.8	100	12.1	39.7	100	6.9

WW I, First World War.

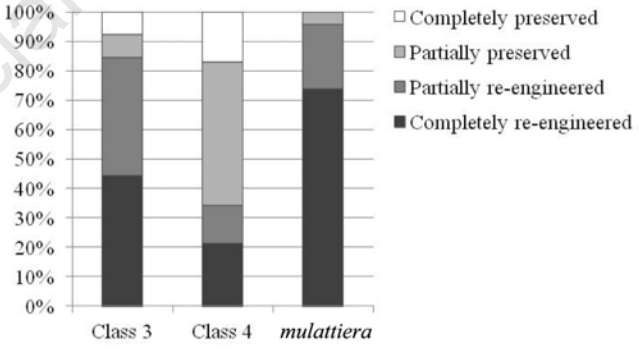

Figure 2. Upgrading of the historical transportation network according to the transportation classes reported in the *Carta d'Italia*.

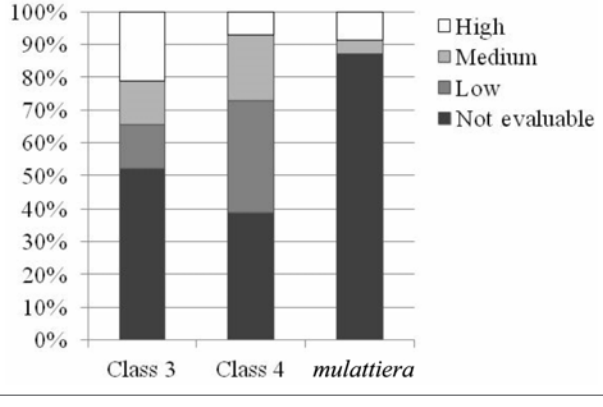

Figure 3. Deterioration of the alignment and artifacts of the World War I transportation network.

classified as Class 3 (*Carta d'Italia* classification) are currently adapted to vehicles with low mobility and high-load capacity (corresponding to Class 1 and Class 2 of the current operational classification reported on Table 3) (Table 14). The results also show that the *mulattiera* has often been re-engineered to the current operational Class 2 and Class 3, while the road segments originally classified as Class 4 have been adapted to a high mobility and medium-low load capacity or to a high mobility and a low or null load capacity (corresponding to the current Class 3 and Class 4 in the operational classification reported in Table 3). As shown in Figure 2, *mulattiera* have mostly been completely re-engineered in their horizontal and gradient alignment. Where they could still be evaluated, the *mulattiera* and the Class 3 roads (according to the *Carta d'Italia* classification) showed appreciably high deterioration of the historical artifacts (Figure 3).

Table 11. Descriptive statistic for the carriageway and the road gradient of the World War I transport network still in use as forest road network.

Variable	Group (Class)	No.	Mean	SD	SE	Confidence interval 95%		Min	Max
						Lower bound	Upper bound		
CW (m)	3	46	3.6	0.660	0.097	3.4	3.8	2.5	5.0
	4	22	2.8	0.527	0.112	2.6	3.0	2.0	4.0
	mulattiera	19	3.1	0.762	0.175	2.7	3.4	2.0	4.0
	All	87	3.3	0.746	0.080	3.1	3.5	2.0	5.0
VG (%)	3	46	4.3	3.300	0.487	3.3	5.3	0.0	10.3
	4	22	5.2	3.540	0.755	3.6	6.8	0.0	10.3
	mulattiera	19	6.6	5.450	1.250	4.0	9.2	0.0	16.2
	All	87	5.0	3.974	0.426	4.2	5.9	0.0	16.2

SD, standard deviation; SE, standard error; CW, carriageway; VG, road gradient.

Table 12. Least significant difference test on the means of the carriageway.

Group (Class)		Mean difference	SE	P	Confidence interval 95%	
A	B	(A-B)			Lower bound	Upper bound
3	4*	0.842	0.170	0.000	0.504	1.179
	*mulattiera**	0.584	0.178	0.002	0.230	0.939
4	3*	-0.842	0.170	0.000	-1.179	-0.504
	mulattiera	-0.257	0.205	0.213	-0.664	0.150
mulattiera	3*	-0.584	0.178	0.002	-0.939	-0.230
	4	0.257	0.205	0.213	-0.150	0.664

*Mean difference is significant at P=0.05. SE, standard error.

Table 13. Tamhane T2 test on the means of the carriageway.

Group (Class)		Mean difference	SE	P	Confidence interval 95%	
A	B	(A-B)			Lower bound	Upper bound
3	4	-0.875	0.898	0.707	-3.115	1.366
	mulattiera	-2.270	1.342	0.280	-5.717	1.177
4	3	0.875	0.898	0.707	-1.366	3.115
	mulattiera	-1.395	1.461	0.722	-5.088	2.297
mulattiera	3	2.270	1.342	0.280	-1.177	5.717
	4	1.395	1.461	0.722	-2.297	5.088

SE, standard error.

Table 14. Current operational classification of the World War I transportation network.

WW I operational classification (see Table 5)	Current operational classification (see Table 3)			
	Class 1	Class 2	Class 3	Class 4
Class 3	7.7%	55.8%	32.7%	3.8%
Class 4	-	10.0%	67.1%	22.9%
mulattiera	-	56.5%	43.5%	-

WW I, First World War.

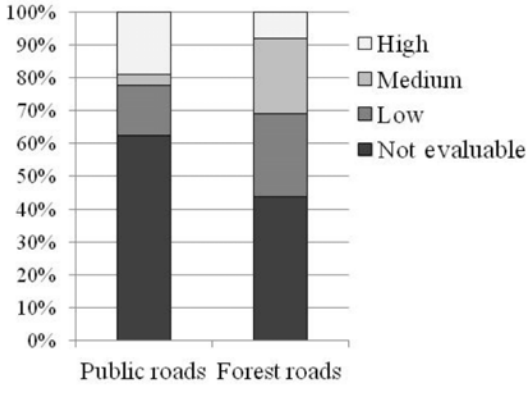

Figure 4. Upgrading of the World War I transportation network according to current traffic limitations.

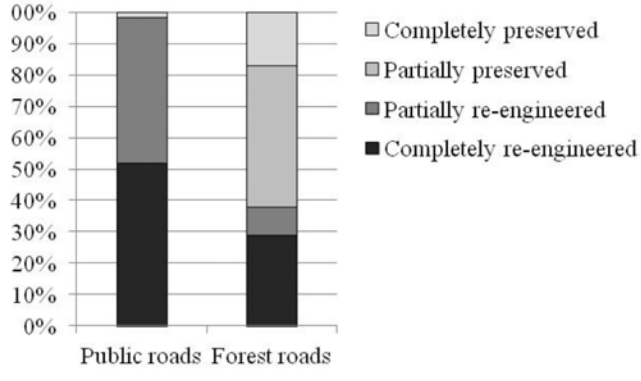

Figure 5. Deterioration of the alignment and artifacts in relation to current traffic limitations.

Furthermore, the current roads closed to ordinary traffic (forest roads) are the best-preserved in term of the original alignment and artifacts, while the current forest roads open to ordinary traffic (public roads) are the most up-graded and re-engineered with respect to their origin (Figure 4). For both groups, 50% of the artifacts clearly show a high or medium deterioration (Figure 5).

Conclusions

The purpose of this study was to investigate the improvement of the transport network from the beginning of the First World War to today's road network in mountainous forest areas.

The first results for the two areas selected in the Altopiano dei Sette Comuni confirmed that an appreciable part (68%) of the original WW I transportation network is still in use. Part of the network has been totally re-engineered (generally with a wider carriageway and a lower road gradient) in order to safely support ordinary traffic related to agriculture and forestry activities, and nowadays also for both summer and winter recreational activities. In fact, most of the re-engineered road segments have been asphalted, and now have larger shoulders and protective barriers as safety features to ensure drivers do not go off the roads. Part of the network has only been partially preserved because it is only used for servicing forestry or quarrying activities.

Future projects include the use of LiDAR-Light Detection And Ranging, a remote sensing technique combined with statistical analysis and mathematical modeling. The LiDAR technique is able to unmask many hidden features such as unused roads, trails and other historical features in a woodland landscape (Crow, 2009; Pirotti *et al.*, 2012) and its use will promote greater accuracy of the survey and a more detailed analysis of the road network.

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