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by

Clemens Pfurtscheller, Elisabetta Genovese

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Clemens Pfurtscheller* Elisabetta Genovese†

Abstract

The Felbertauern landslide of May 2013 caused the total destruction of approximately 100 meters of road including an avalanche gallery, generating traffic disruption and several direct and indirect impacts on the regional economy. The Felbertauern Road, an important traffic artery for the whole NUTS-3 region East-Tyrol (Austria), was totally blocked for several weeks. Shortly after the event, regional decision makers sought to estimate the regional-economic impacts of the road blockage, in order to determine whether reopening the road or building an alternative route would be more economically feasible. This economic analysis was carried out using scattered information two weeks after the incident. The analysis is based on a three-month interruption scenario, though the road blockage was finally two months. Due to the fact that, shortly after the event, no up-to-date data on regional-economics at helpful scales was available, we calculated impacts on tourism by analysing overnight stays, additional transportation costs and time losses for the local companies. Using these numbers, a cost-benefit-analysis was then carried out for a projected bypass, a mid-term 1.5 kilometre long route as an alternative to the destroyed road. Finally, the impacts on the local companies were severe, due to additional transportation costs of approx. € 760,000 to 1.4 million. The impacts on regional tourism were calculated at € 7.7 to 8.6 million. This study demonstrates the strong impact of traffic disruption on a regional economy and describes the importance of cost-benefit analysis for policy making in order to get rapid decisions and to prevent large economic losses.

* clemens.pfurtscheller@lfv-vorarlberg.at, Regional Firebrigade Association of Vorarlberg, Natural hazards prevention and disaster management, Florianistrasse 1, 6800, Feldkirch, Austria

† Corresponding author: elisabetta.genovese@ircres.cnr.it; Research Institute on Sustainable Economic Growth (IRCrES), National Research Council (CNR), via Bassini 15, 20133 Milano, Italy

1. Introduction

Landslides result in billions of dollars of economic losses and thousands of fatalities yearly on a global scale. The Centre for Research on the Epidemiology of Disasters (CRED) calculates that landslides account for about 17% of the victims of natural hazards (Kjekstad and Highland 2008). Landslide economics deals with important topics such as risk assessment, which involves the study of risk components, namely: exposure, hazard, vulnerability (Genovese and Przyluski 2013), as well as sensitivity and resilience to landslide, and impact assessment, which includes both damage assessment and costs evaluation (Crovelli and Coe 2009; Wills et al. 2014).

Interest in studying these topics has grown significantly in recent years, considering both natural environment impacts and socio-economic impacts (Jaiswal 2011; Kjekstad and Highland 2008). Estimating the costs and economic effects of natural hazards is vital in order to provide a sound basis for risk reduction (Meyer et al. 2013; Pfurtscheller 2014). However, quantification of socio-economic losses, effects of landslides on infrastructure development, disruption of economic activities and the implementation of effective mitigation strategies and land use policies are critical aspects related to landslides (Ciurean et al. 2014). In fact, it is hard to get reliable data for the socio-economic impact of landslides, mostly because a landslide often happens in conjunction with other natural disasters such as earthquakes, flooding, hurricanes or typhoons, and more generally because of lack of standards in data collection and analysis (Kjekstad and Highland 2008). Landslides can generate both direct and indirect consequences and related costs. Direct effects are those effects which were directly caused by the direct physical contact of properties with the hazard, e.g. buildings, inventories, and infrastructure (Smith and Ward 1998; Meyer et al. 2013). Direct consequences affect the area in the aftermath of the disaster, while indirect impacts may emerge and last over the long term (Alimohammadlou et al. 2013). Indirect damages concern e.g. loss of real estate values and tax revenues on devalued properties, commercial traffic and tourist flows reduction, negative effects on water quality, and physical injuries and psychological trauma to people causing productivity losses (Kjekstad and Highland 2008; Vranken et al. 2013). Moreover, the cost associated with landslides is usually calculated in monetary terms and only includes direct damage. This makes it difficult to take indirect environmental, social and indirect damages into account. Indirect economic losses resulting from traffic disruption are mostly not analysed for landslide risks and events, which probably leads to an underestimation of the total loss (Jaiswal 2011).

Assessing the risk and eventually evaluating the damage costs resulting from landslide impacts is a challenging process requiring readily availability data from past events. The combination of these territorial datasets, listing assets and other exposed economic values, can provide a cost assessment for inhabited areas. To assess landslide impacts, different approaches and related methods of landslide cost assessment can be used: ex-post or ex-ante approaches, surveys on costs and finally risk analyses (Meyer et al. 2013). From an economic point of view, post-disaster costs comprise all adverse monetary consequences triggered by a natural hazard, whereas pre-disaster costs comprise all costs of mitigation or prevention measures for achieving a certain level of safety (Pfurtscheller and Thieken 2013). Ex-post approaches better address issues arising from spatial and temporal landslide distribution and the lack of relationships between intensity, adverse impacts, and the total costs. On the other hand, ex-post approaches are strictly focused on cost surveys, which extend their applicability basically to the local and regional level and short time periods (Klose at al. 2014)

The main aspect of landslides damages we are interested in investigating in this article are impacts on infrastructures and transports. Blockages of roads and railways by natural disasters for periods of hours to days can result both in direct and indirect impacts. For instance, the devastating earthquake in Sichuan Province in China of May 2008 caused landslides that blocked the main roads to several provinces and impeded the search and rescue teams from entering the epicentral area (Yin et al. 2010). Additionally, disasters affecting public services and transportation networks can cause interruption of economic processes and business continuity, loss of public income in tourism regions, and related loss of industrial, agricultural and forest productivity. These losses can be included in the ‘business interruption costs’ cost category in a cost assessment (Meyer et al. 2013). Pfurtscheller (2014) assessed the indirect economic impacts of the 2005 floods in western Austria and demonstrated that disturbed traffic networks were the main cause of depressed revenues.

The assessment of landslide indirect costs and business interruption costs is complex and may include the larger area beyond the landslide zone (Alimohammadlou et al. 2013). When considering the very high number of annual landslide losses on a global scale, published studies show that the transportation sector is the most affected economic sector (Schuster 1996; Kjekstad and Highland 2008; Trezzini et al. 2013). Even so, only a few studies analysed past landslide events and their impacts traffic routes (Klose et al. 2014). In particular, methodological approaches of systematic cost assessments for transportation infrastructures have only been developed in a few studies (Guzzetti et al. 2003).

Most studies considered transport networks from an engineering point of view, focussing on network connectivity/accessibility (Sullivan et al. 2010). Recent studies focused on the direct impacts of landslides on the major road network using fragility curves related to infrastructures (Pitilakis and Fotopoulou 2011; Papathoma-Khöle et al. 2012). Zêzere et al. (2007) evaluated direct and indirect costs resulting from a road disruption using scenarios of future landslides. Klose et al. (2014) present a methodology for an ex-post assessment of landslide costs for transportation infrastructures by using tools to compile, model, and extrapolate landslide losses on different spatial scales. However, economic effects of hazards in the Alps have not been measured and widely analysed until now, except for high-impact flood events at the macro-economic level, developed for instance for the 2002 floods in Austria (for an overview of such studies see Pfurtscheller 2014).

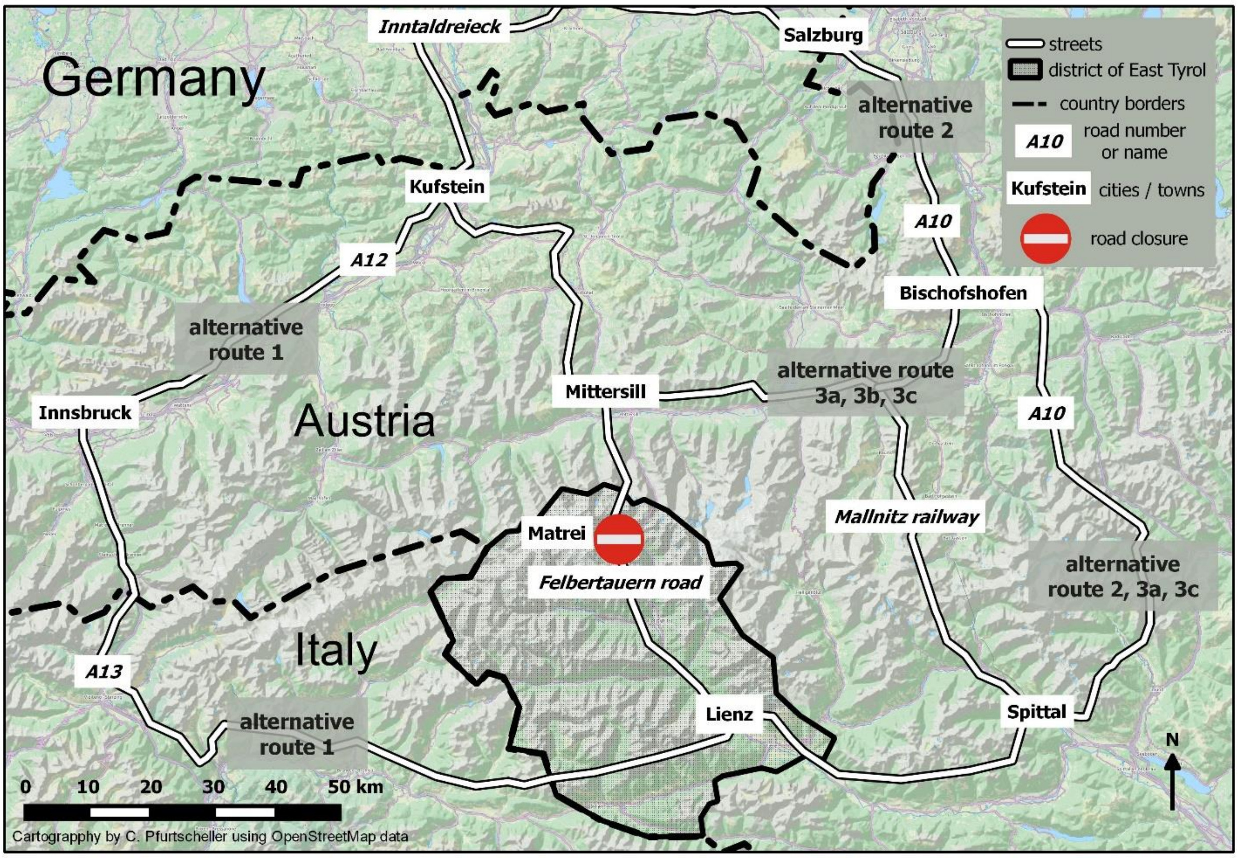
To fill existing research gaps, this paper aims to estimate the regional-economic effects of the Felbertauern Road interruption due to a landslide in May 2013 across consecutive months. It is important to mention that this assessment was initiated two weeks after the event in order to generate policy-relevant results, but to do so relies on fragmentary data. At that time, regional policy makers keenly sought to quantify the possible economic impacts in order to inform alternatives to reopening the road. Therefore, the main objective of the study was to set limits for the regional-economic and entrepreneurial impacts using a three-month-interruption scenario. The road has high rates of commuters and tourist flows and its interruption makes local businesses vulnerable to indirect effects (e.g. commuters can’t reach their workplace, additional transportation costs, sales decline). However, the Felbertauern landslide offered a perfect case study to analyse possible regional-economic impacts, due to the relatively isolated study area. Since we only had two weeks to analyse the impacts, we concentrated on decline of tourism income and additional time and transportation costs for companies that used the road, since they had to transport goods or conduct services using large bypasses instead of the more direct Felbertauern Road. The paper is structured into three sections: the first section describes the event and effects on the Felbertauern Road and on the affected Region of East-Tyrol; the second section outlines necessary assumptions, methods and data; and the final section describes and validates results, where significant and possible. Lastly, a discussion of the results and concluding remarks are presented.

2. Felbertauern landslide impact

2.1. Event and study area description

The transport organization and logistic services have a main place in the economic system of a region. It includes competitive advantages in relation to territorial development, tourism, production, business, and the role of these factors in raising the regional economic efficiency (Tadini, 2011). The Felbertauern Road is the most important traffic node used by the local / regional economy and tourists from the north and north western destinations (mainly Germany, Netherlands, and Belgium) to East-Tyrol. There is also a network of public authorities that are involved in mobility issues in a regional area, as a result of the administrative decentralization (Tadini, 2009). The Felbertauern Road Limited (Felbertauernstrassen AG in German) is a public toll road owned and managed by the Federal State of Tyrol (37%) and the Federal Republic of Austria (62%). It links the remote East Tyrol area (geographical enclave of the Federal State of Tyrol) with the Federal States of Salzburg and Tyrol and regions to the north, overcoming the need for long detours through Italy or the Federal State of Carinthia (see Figure 1). The 36 kilometre road, with a tunnel through the main ridge of the Alps, was opened in 1967. The road is largely protected against avalanches and rock fall by hundreds of meters galleries to minimise risks. Periodically, the road is interrupted a few days in the year because of avalanche warnings. Additionally, small-scale hazard events (e.g. rock fall, avalanches) were recorded in the last decades.

Fig. 1: Overview of the study area, blocked Felbertauern Road and alternative long-ranging bypasses after the rockslide



During the night of 13th May, 2013, the avalanche gallery (*Schildalm*) located at the south ramp of the Felbertauern Road, near the entrance of the through-alp tunnel (municipality of Matrei, Federal State of Tyrol, Austria), was completely destroyed by a rockslide for a length of 92 meters (Figure 2). 10,000m^3 of blocks and debris were mobilized in about 1,770 m.a.s.l and fell on the gallery at 1,580 m.a.s.l (Riepler and Scholl 2013). Forest cover was totally destroyed by the event. The landslide track was approximately 75 to 100 meters wide with an average slope of 45°. The main trigger of the landslide was assumed to be the advanced stage of weathering of surface rocks in combination with snow melt. After the event large gaps in the bedrock were found around the activation area of the rockslide (Riepler and Scholl 2013).

Fig. 2: The Felbertauern rockslide with destroyed road and gallery, photo from September 2013

Initially plans were to close the road for one and a half weeks. Although the removal of loose rocks did not last long, geologists decided that the road should remain closed much longer than initially anticipated- for general safety reasons.

2.2. Chronology of the landslide aftermath

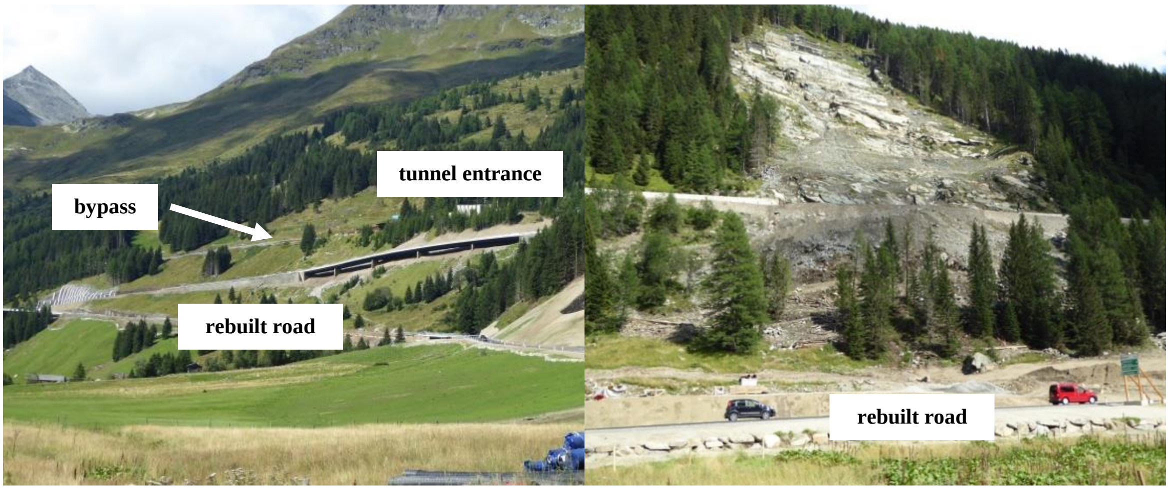
Table 1 depicts chronological information starting with the opening of the Felbertauern Road in 1967 to the re-opening of the destroyed section of the *Schildalm* gallery in September 2015. At the time of the analysis in May 2015, further developments were very uncertain. Despite the scattered information and uncertain results, the study was used as a basis for decisions concerning investments and a relief programme delivered by the Federal State.

On an annual basis the Felbertauern Road has been closed for short periods for safety reasons during high avalanche risk time, despite technical and non-technical mitigation efforts. In 2012, nearly 1.3 million vehicles used the road, including 1 million passenger cars, 123,000 lorries, 63,000 motorcycles and 10,000 buses. This means about 185 commercial transports a day. The toll for a single journey of passenger car is € 10, and € 80 for a lorry with trailer. Annual revenue was about € 8.1 million in 2012 and € 5.2 million in 2013, and 56 employees were employed on the road. In 2013 the economic result from ordinary activities ended with a loss of € 4.2 million, due to the landslide and the road interruption as well as the costs for rebuilding. This means a decline in vehicles of 30% to 880,000. Additionally, a long-term decline of commercial traffic has been recorded, with a loss of 20% between 2012 and 2015. Figure 2 depicts an overview of the whole region, the Felbertauern Road and the alternative long-ranging bypasses after the landslide. Due to the long-ranging bypasses and use of alternative routes, approximately 60 local businesses suffered from additional transportation costs (personnel, fuel, maintenance, road tolls).

Table 1: Chronology of the Felbertauern landslide from the opening in 1967 to the reopening in 2015, sources: press releases, media reports, and official homepage of the Felbertauern Road Limited (http://www.felbertauernstrasse.at/en)

Year	Remarks
1967	Opening of the Felbertauern after five years building, road length 36 kilometres, tunnel length 5,313 meters, several avalanche and rockslide galleries
2002	The *Schildalm* gallery was built for slope reinforcement, protection against rock slides and avalanches in a special endangered zone
14th May 2013	Rockslide event at 1:40 with 35,000 m^3 material triggered by snow melting, search for possible victims
16th May 2013	Begin of blasting loose rocks and clean-up
20th May 2013	Bus-shuttle for commuters including a 20 minutes' walk
1st June 2013	Assessment of the regional-economic impacts of the rockslide using a three-month interruption-scenario, later decision to build a mid-term bypass, costs € 1.5 to 2.5 millions
25th June 2013	Official estimate of the total direct losses and decline of tolls 34.5€ million, estimated costs for the new gallery € 22 million
25th June 2013	Financial relief of the Federal State and Federal Republic of Austria including raising the capital stock of the Felbertauern Road (€ 13.5 million), tourism programs (advertising, € 800,000), bus service (€ 340,000), relief for companies for additional transportation costs (€ 800,000), total € 25 millions
July 2013	Option of tunnelling the whole section: total costs € 44-55 millions
27th July 2013	Opening of the 1.5 kilometres bypass after 6 weeks building for vehicles < 27 tons and <12 meters of length, total costs € 2.5 million
September 2013	Decision on construction of a new roadway with upgraded mitigation, 2 years building time
End of August 2015	Re-opening of the 3.5 kilometres rebuild road segment *Schildalm* (see Fig. 3), total building costs of € 18.5 million, total losses approx. € 27 million including costs for rebuilding and loss of tolls

Fig. 3: Rebuilt road before (left picture) and at the section *Schildalm* (right picture), photos from August 2015



2.3. The affected NUTS 3 - Region East-Tyrol

East Tyrol (equivalent to the administrational district of Lienz, see Fig. 2) has a population of 49,600 inhabitants, a working population of 24,500 in 2012 (Federal State of Tyrol 2013), and a gross regional product at current prices of € 1.366 billion in 2012 (Statistic Austria 2015). The gross regional product is € 27,800 per year and per capita, falling below the Austrian average. Thus East Tirol contributes approximately 5% to the economic performance of the whole Federal State of Tyrol. About 2,300 people commute to East Tyrol every day, but the commuter balance is negative because 5,000 people commute from East Tyrol to outside regions, especially to the north. Thus, 500 to 800 commuters use the Felbertauern Road every day.

The district of East Tyrol's main economic disadvantage is its geographical separation from the rest of the federal State (see Figure 2). This remote area is economically weaker than the rest of the State and, hence, the Felbertauern Road, as the main traffic node to the north, has a huge economic importance for the region. Nevertheless, the district capital of Lienz with 11,800 inhabitants is a regional centre with supra-regional importance due to its strong focus on trade and industry (e.g. the production of refrigerators of the international company Liebherr with 1,320 employees). Moreover, large parts of the district economy, particularly small sized companies, rely on tourism and agriculture. East Tyrol had a total of 1.9 million overnight stays in 2012, with the general trend slightly increasing during the winter season and a decline in summer tourism.

3. Assessing the regional-economic impacts shortly after the event

3.1. Temporal and spatial delimitation of the effects

The economic effects of (alpine) natural hazards at local or regional scales are usually not considered in literature, since it is hard to predict and delineate them. However, it is possible to assess these effects considering the empirical evidence, as demonstrated in Pfurtscheller (2014), who assessed the 2005 floods in the Federal State of Tyrol (Austria). This means that basic principles have to be used and some assumptions need to be made, as shown by Merz et al. (2010) and Messner et al. (2010) in the case of flood events. These basics can also be used for the case of landslides and similar mountain hazards. We set the temporal and spatial delimitation of the possible effects. Due to the multiplicity of possible regional-economic effects, we decided to analyse only the impact on the most affected stakeholders groups: local governments, tourist industry and production company. Therefore we considered tourism impacts using overnight stays, additional transportation costs (personnel, fuel, and road charges), and additional time costs due to the large bypasses for commercial traffic.

Due to the very short timeframe after the event when the assessment was conducted, and the resulting scarcity of data on the exact impacts, a scenario based on the length of time of the road blockage was defined in order to conduct the regional-economic impact analysis using a three-month interruption. For tourism impacts, measured in overnight stays, some empirical data was obtained from press reports in local newspapers and from the regional tourism association. In the first weeks after the event, a 30% decrease in overnight stays was reported in the main affected municipality of Matrei compared with 2012 information. As part of the scenario, it was then assumed that overnight stays in the whole region declined an average of 25% in May and June, 10% in July and finally of 5% in August. It was also assumed that tourists used alternatives routes to visit East Tyrol from May 2013. For the analysis of additional transport and time costs, a three-month interruption was the basis for the analysis. This corresponds to approximately 66 working days. Medium or long-term effects, such as possible declining taxes, loss of reputation for the region and the affected companies, were neglected in the study. Also benefits were calculated for three-months interruption period, even if benefits probably last more period that that.

In assessing regional-economic impacts a spatial border for the analysis was drawn. Therefore, effects in the district of East Tyrol were analysed, and those that were felt outside of this region were not considered. From a national perspective, the total economic effects from the Felbertauern landslide can neither be measured, nor analysed, due to the very little share of economic activities of East Tyrol to the national economy.

3.2. Data description

The analysis required a subdivision of regional-economic (e.g. gross regional product, as a sum of the economic activities of the region) and entrepreneurial variables (revenues, costs). A company is the smallest unit of an economy and both scales of an economy influence each other. While cost increases for companies mainly have direct and measurable influence on the entrepreneurial revenue and profit (and therefore these are the essential issues for the company), the effects of the road interruption on Gross Regional Product (GRP) is not directly perceptible and measurable in the same period of investigation. Quantitative impacts of the road interruption can be positive or negative for the regional-economy, e.g. when costs for a company increases (in theory undesirable), this leads also into a rise of GRP (desirable in theory). On the other side, when revenues of local companies are declining (e.g. due to higher transportation costs), the GRP will decrease. Therefore, we need to analyse the possible impacts separately and to focus on the effects that occur inside the region, which were necessary for decision makers.

The analysis of regional-economic effects of natural hazards usually requires a large amount of data, which generally are often not available at the necessary scale and spatial resolution. Therefore, surveys are necessary in order to fill this gap. In this study, however, a survey on changing revenues of affected companies could not be carried out (for instance, like that used by Pfurtscheller 2014), due to the speed at which results were required to inform policy makers. Consequently, analysis draws only on the scattered data and information were available at the time of the landslide. One important data source was local press releases and press reports. They provided interviews and statements of representatives of affected companies concerning the estimated economic impacts. Although the reliability of such data is often hard to validate, its use was extremely important since no other data was available. However, validated data sourced from the Chamber of commerce of East Tyrol and the Regional tourism association regarding the number of affected companies, average daily traffic and road charges by the Felbertauern Road management organisation, and data on overnight stays in East Tyrol in 2012 and 2013, added considerably to the data used for analyses.

3.3. Methodological approach and calculations

In order to assess the loss categories that we previously selected (decrease of tourist flows and additional costs of commercial transports), to get more reliable results and to outline possible uncertainties, we applied the following methodology. To calculate the decrease of tourist flows, we first used a simple approach relying on estimates of the decline of overnight stays (see section 3.1). Press reports highlighted that there were up to “25% of overnight stays were cancelled in May” resulting in “heavy economic losses of 35%” in the affected region”. This was closely connected to the temporal delimitation of the effects. Therefore, we assumed that overnight stays in the whole region would also have declined an average of 25% in May and June, 10% in July, and finally 5% in August. The main reason for the assumed drop in rates of use considers that tourists may get adapted to the road closure and choose alternative routes to get to their destination. To convert the drop of overnight stays to monetary units, the average daily expenditures in the Federal State of Tyrol in the summer season was used (€ 104/night in 2013). To validate the results of tourism impacts the approach developed by Nöthiger (2003) was used. He provides a calculation tool for the forecast of tourism impacts expressed in declining daily spending. Although this approach is empirically grounded on the avalanche winter of 1999 in Switzerland, where large parts of the country were affected, it is assumed that it can also be used for smaller events. Nöthiger´s tool used the following sources of input data: days of the month, average overnight stays in the month prior to the event, average overnight stays in the month of the event, duration of the effects of the hazard event (estimate 15 days), death toll, rate of daily tourists of total tourists visiting the region (10%), and average daily spending (€ 104).

Moreover, we also adapted an approach to analyse the regional-economic impacts originally developed by the Swiss Federal Roads Office (FEDRO 2009). When using this approach, the additional costs of commercial transports were calculated based on: i) additional driving time (original approach), and ii) additional kilometres driven. The adaptation of ii) was undertaken to outline possible uncertainties associated with the results, and to present data including road charges and maintenance costs, which were not incorporated in FEDRO (2009) approach. The original traffic jam cost calculation has been developed by the Swiss Federal Roads Office (formula 1). Here $C_{total\ A}$ represents the total cost of the additional driving time [€], d is the duration of the road interruption [days], ADT is the average daily traffic [number of vehicles], C_h represents the cost of a traffic jam per vehicle per hour [€], $d_{h1,2,3}$ is the additional driving time per vehicle on road alternatives 1, 2, and 3 [hours], and finally $p_{1,2,3}$ is the probability that alternative routes 1 to 3 are available.

$$C_{total\ A} = d * ADT * C_h * \sum_1^3 (d_{h1,2,3} * p_{1,2,3}) \tag{1}$$

This formula is generally used for losses of a road interruption after an event. Essentially, the FEDRO concept relies on willingness-to-pay surveys for avoided traffic jams presented by the Federal Office for Spatial Development ARE (2007) and this is reflected in the values of C_h. It does not include fuel, road charges and costs for maintenance. For that reason, formula 1 has been adapted to reflect the total costs of the additional driven kilometres in € ($C_{total\ B}$, formula 2), where km are the additionally driven kilometres [km], ADT is the average daily traffic [number of vehicles], C_{km} are the costs per kilometre per vehicle (€), $d_{km1,2,3}$ are the additional driven kilometres per vehicle on road alternatives 1 to 3, and finally $p_{a1..3}$ is the probability that alternative routes 1 to 3 are available (formula 2).

$$C_{total\ B} = km * ADT * C_{km} * \sum_1^3 (d_{km1,2,3} * p_{1,2,3}) \tag{2}$$

Additional cost for commercial traffic of companies lying in the affected NUTS-3 region has been calculated, and external effects were neglected. However, d is defined by the three month interruption scenario (this means 66 workings days); km, $d_{km1,2,3}$ and $d_{h1,2,3}$ is quantified using the Google Maps routing function; ADT is known from average daily traffic statistics provided by the Felbertauern Road Limited; C_h is provided by the Federal Office for Spatial Development ARE (2007), converted to € values, deflated and relativized using purchasing power parities (since the values for the same product was higher in Switzerland than in Austria in 2013). The additional travel expenses were also split into commercial traffic <3.5 tons, and commercial traffic >3.5 tons for higher specificity. The additional costs incurred for commercial transport traffic >3.5 tons is then € 69.28, for commercial traffic <3.5 tons € 64.72. C_{km} is based on inflation-adjusted values provided by Kummer & Lenzbauer (2008) and average toll costs of different vehicles provided by ASFINAG in 2013.

Table 2: Basis data for the calculation of additional driven kilometres

<table>
<tr><th>Data and data source</th><th>Traffic >3.5 tons</th><th>Traffic <3.5 tons</th></tr>
<tr><td>Average costs per km including personnel and fuel (Kummer & Lenzbauer 2008)</td><td>1.4€</td><td>0.8€</td></tr>
<tr><td>Number of rides (Felbertauern Road Limited)</td><td>100</td><td>85</td></tr>
<tr><td>Average toll costs (ASFINAG 2013)</td><td colspan="2">0.25</td></tr>
</table>

We assumed that daily commercial traffic used the three alternative routes equally ($p_{1,2,3}$) (see Fig. 2). For longer-distance drives alternative route 1 was used: this route uses a direction to the west to Italy and Brenner pass to the border of Germany using the A13 and A12 motorways to the “Inntaldreieck”. Alternative route 2 (long-distance) followed the Inntaldreieck via Spittal (Carinthia) and the A10 Tauern motorway. The alternative route 3 (local traffic) is separated by the tonnage. Traffic >3.5 tons uses the A10 Tauern motorway to Bischofshofen and then to Mittersill (route 3a). Traffic weighing less than 3.5 tons was assumed to be equally distributed between the Mallnitz railway and the A10 motorway from Spittal to Mittersill (alternative route 3b, c; see Figure 2). The additional road toll costs for the railroad possibility via Mallnitz were considered high, costing 17€ per drive. Diversion via the Tauern motorway is therefore the most realistic alternative to the north from a cost and time perspective. Therefore, additional tolls for the Brenner motorway A13 were neglected.

In addition to the above calculations, the decline of revenues of small companies and trades based on lower sales has been a significant issue. Due to expert judgements from representatives of the Chamber of Commerce, these possible declines was evaluated as marginal, except for some small businesses, which were directly affected by decreasing traffic (e.g. fuel stations). Hence, they were not assessed.

4. Results

4.1. Decline of tourism

In total, the decline in overnight stays triggered by the closure of the Felbertauern Road was calculated at 74,118 over the period of May to August 2013. This translates to an approximate decline of regional income of € 7.7 million (table 3).

Table 3: Decline of overnight stays and daily expenses using average overnight stays of 2010-2012 for the months April to August 2013

	April	May	June	July	August	Total
2013	32,105	-**	-**	-**	-**	n.a.
2012	64,058	44,131	129,259	284,582	372,376	894,406
2011	57,100	36,093	130,040	284,827	368,558	703,053
2010	58,243	46,351	116,449	282,279	356,055	859,377
Average overnight stays	52,877	42,192*	125,249*	283,896*	365,663*	869,877
Assumed decline overnight stays	0%	25%	25%	10%	5%	
Decline of overnight stays	0	5,274	31,312	28,390	9,142	74,118
Decline of daily expenses (€)	**0**	**548,492**	**3,256,483**	**2,952,518**	**950,724**	**7,708,217**

* Estimates using values of 2012; ** Numbers not available at time of the analysis

Using the approach developed by Nöthiger (2003), the decline of daily income was calculated to be € 10.6 million (table 4). This value included expenses for overnight stays, food and beverages, small trade, cable cars and transport and long-term effects. To compare the results, the 2013 impacts should only be used. Hence, the total decline of tourism expenses (decline of revenues) can be estimated with € 7.7 to 8.6 million. This means a drop of 4% of overnight stays for the whole East Tyrol region and a decline of approx. 0.6 to 0.8 per cent of the GRP of 2013.

Table 4: Decline of daily expenses applying the methodology of Nöthiger (2003) with 2013 values

Category of expense	Overnight stays	Food and beverages	Small trades	Cable cars	Other expenses	Total
In the month of the event	1,141,900	666,600	433,900	118,500	258,000	2,618,900
in %	29%	28%	25%	28%	27%	28%
In the subsequent month	3,118,000	1,318,200	811,300	236,600	530,100	6,014,200
in %	27%	19%	16%	19%	18%	21%
Long-term	1,040,100	439,900	270,800	79,000	176,900	2,006,700
In the year of the event	4,259,900	1,984,800	1,245,200	355,100	788,100	8,633,100
Total	**5,300,000**	**2,424,700**	**1,516,000**	**434,100**	**965,000**	**10,639,800**

4.2. Estimating costs using additional driving time

Table 5 presents the calculation (based on the avoided traffic-jam approach) of the additional costs for commercial traffic to and over 3.5 tons triggered by the Felbertauern Road interruption for companies domiciled in the region. In total, the landslide caused additional time costs of € 763,360 excluding fuel, road charges, and costs for maintenance.

Table 5: Calculation of the additional costs using a prevented traffic-jam approach based on FEDRO (2009)

	Alternative route 1	**Alternative route 2**	**Alternative route 3**
Weighted alternative routing	1/3	1/3	1/3
Additional driving time [min]	7	38	123
Number drives <3.5 tons	28.3	28.3	28.3
Average costs per transport per day <3.5 tons	8	41	264
Total costs per day <3.5 tons	214	1,161	3,744
Number drives >3.5 tons	33.3	33.3	33.3
Average costs per transport per day >3.5 tons	8	44	283
Total costs per day >3.5 tons	269	1,463	4,715
Total costs per month (22 working days)	10,634	57,727	186,092
Total costs for a three-month-interruption scenario		**€ 763,360**	

4.3. Estimated costs using additional kilometres

Table 6 shows in details the costs based on the necessary additional kilometres rather than additional driving time. This estimate includes average costs for personnel, maintenance, fuel, and road tolls.

Table 6: Calculation of the additional costs using additional kilometres to drive based on FEDRO (2009)

	Alternative route 1	**Alternative route 2**	**Alternative route 3**
Weighted alternative routing	1/3	1/3	1/3
Additional kilometres	-4*	121	174
Number drives <3.5 tons	28.3	28.3	28.3
Average costs per transport per day <3.5 tons	-3	97	560
Total costs per day <3.5 tons	-91	2,743	3,080
Number drives >3.5 tons	33.3	33.3	33.3
Average costs per transport per day >3.5 tons	-11	212	536
Total costs per day >3.5 tons	-366	7,076	8,930
Total costs per month (22 working days)	-10,054	216,018	264,220
Total costs for a three-month-interruption scenario		**€ 1,410,552**	

* The negative value is due to the shortening of the original vs. alternative route. The original route is faster.

4.4. Cost-benefit-analysis of the project "bypass"

At time of the analysis, regional decision makers especially from the chamber of commerce required an estimation of the regional-economic impacts of the road blockage to inform a decision concerning alternatives to reopen the road in order to minimize the adverse effects on the local economy. Cost-benefit-analysis is a useful tool to identify the economically most reasonable option and is widely used for infrastructure projects (see e.g. Hanusch 1994, Hanley & Spash 1994). This analysis explores the benefit-cost ratio (BCR). If this ratio is higher than 1, the project has a positive economic case, while options or alternatives with a ratio lower than 1 should be avoided. The specific question at the time of analysis was: if the project "bypass", a 1.5 kilometre long medium-time alternative route for the destroyed road section, should be built or not (see Figure 3). The main reason for building the bypass was to minimise the decline of revenues incurred as a result of the use of alternative routes where road tolls were high. On the other hand, some of the revenue decline, in tolls, for the road company could be seen as a benefit to local companies and trades, in terms of saved tolls, but this can be considered negligible. This can partially compensate companies decline in revenues, that we decided to not assess, as explained in section 3.3. Table 7 shows the main pillars for a simple cost-benefit-analysis, including costs for planning and construction of the bypass, and the reconstruction of the *Schildalm* section. The benefit section (as adverse effects) accounts for road tolls, additional transportation costs for local companies, and decline of revenues. We found that the project bypass has a positive economic case, due to positive cost-benefit-ratios using the results of the calculations (Table 7).

Table 7: Cost-benefit-analysis of the projected "bypass" using a three-month-interruption scenario

Costs		Benefits	
Planning and construction of the „bypass“	approx. € 1.5 to 2.5 million*	Cost savings for the Felbertauern Road Limited due to drop of road tolls	€ 3.375 Million**
Planning and reconstruction of the destroyed *Schildalm* section	approx. € 3.5 million*	Cost savings for production small companies and trades	marginal
		Cost savings for local companies	€ 763 360 / 1 410 552
		Cost savings for touristic revenues	€ 7 708 217 / 8 633 100
Total costs € 5 to 6 million		**Total benefits € 11.8 to 13.4 million**	
Cost-benefit-ratio: 2.24 to 2.4			

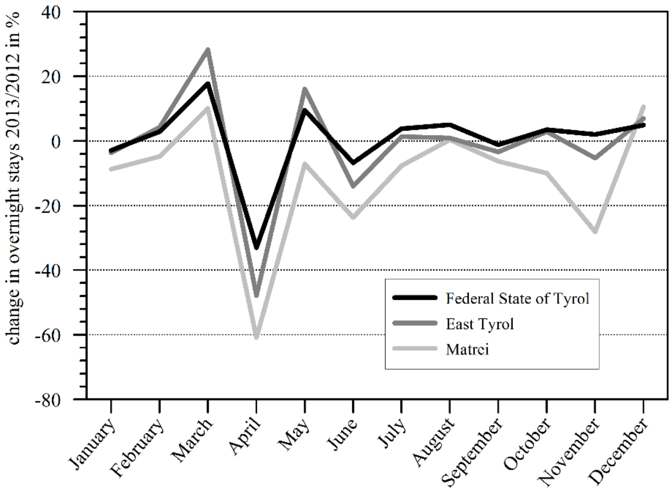
* Data provided by the Felbertauern Road, ** calculated using the annual revenue of the Felbertauern Road Limited of 2012, 50% of revenues are generated in June, July, August and September.

5. Discussion

When we performed the analysis, only fragmentary and empirically data was available. Hence, uncertainty in these results is high. A validation of results is therefore necessary after a certain time lag and could be take into account for a future study. Moreover, the weather in May 2013 was unfavourable from a tourism point of view. The small decline in June in overnight stays can also be attributed to flood events in the neighbouring Federal States of Tyrol and Salzburg, which affected large areas a few weeks after the landslide. Matrei shows generally a weaker tourism development compared with 2013. In the whole year tourism rose 1.8% in Tyrol, a plus of 0.7% in East Tyrol and a decline of 5.8 % in the municipality of Matrei was been observed (see Figure 4). The sharp decline in April 2013 can be attributed to the early finish of the winter season due to very high temperatures combined with little precipitation. Hence, the calculations of decline of revenues caused by the landslide have been probably overestimated at the regional level. A certain effect is anyway measureable at a more local level for some directly affected municipalities such as Matrei, since the impacts from the road closure lasted until the opening of the bypass at the end of July 2013.

For all these reasons, the approaches used in this study can only partially be used to calculate the decline of tourism revenue, which is strongly connected with the scale of assessment. It was assumed that the whole region would suffer badly from the landslide and the blocked road (this is also stated in all press reports, and from representatives from the Chamber of Commerce). Retrospectively, the tourism impacts due to the landslide were marginal at the regional level.

Fig. 4: Overnight stays per month in 2013 compared to 2012 in the Federal State of Tyrol (without the affected NUTS-3-region East-Tyrol), in the affected NUTS-3-region East-Tyrol (without Matrei), and in the most affected municipality Matrei, source: Federal State of Tyrol 2015



The results of the additional costs for companies, calculated using additional driving time and additional kilometres, were considered realistic by regional policy and the Chamber of Commerce, even if they cannot be validated. This was reiterated by the relief programme of the Federal State for companies which was in total € 800’000 (see Table 1). Nevertheless, a validation of these approaches in the aftermath of the 2013 event would be necessary. This could be done in a future study by surveying all companies that are domiciled in East Tyrol. Even so, the results of the cost-benefit-analysis must be treated with caution.

6. Conclusions

This study aimed to determine the medium-term regional-economic effects triggered by the Felbertauern road interruption in May 2013, to help inform decision makers and regional policy. The landslide caused several million Euros direct and indirect losses. The analysis was conducted after the event and was based on a three-month-interruption-scenario. At time of the analysis, policy makers required fast advice on quantifying the possible regional economic impacts to inform alternatives for reopening this important traffic node. Despite of the scattered information and uncertain results, the study was used as a basis for deciding on investments and a relief programme delivered by the Federal State.

The additional transportation costs for a scenario with a three month interruption of the Felbertauern Road were estimated to be about € 760’000 to € 1.4 million. These losses of the companies (as additional costs) resulted in a profit decline and weakened the economy of East Tyrol as a whole. Since the road has always been intensively used by commercial traffic, goods were instead delivered using long bypasses instead of the interrupted Felbertauern Road. These additional costs were assessed by a traffic jam cost approach (FEDRO 2009) and were calculated by additional driven kilometres and additional driving time. For the calculation of tourism decline, overnight stays were assessed. These lost revenues could be quantified at € 7.7 to 8.6 million again using the three-month-interruption scenario for East Tyrol. This represents a decline of approximately 4% of annual overnight stays in East Tyrol and a decrease of approximately 0.6 to 0.8% of the total economic output of the region. The results imply that mainly the tourism and production industries in the region suffered economically from the road closure.

Using these results, and estimated costs for a mid-term 1.5 kilometre long bypass and the rebuilding of the road, a cost-benefit-analysis was been carried out. The calculated benefits (for preventing losses) of the bypass exceed the total cost of a factor of about 2.2 to 2.4. Based on the analysis, regional decision makers gave absolute priority to the bypass building, resulting in a total traffic interruption of only six weeks. Later, a new roadway was built and the road was re-opened in August 2015. The total costs (including losses) were € 27 million as stated by Felbertauern Road Limited.

While the study faced several challenges (especially in the context of obtaining accurate and verifiable data), it nevertheless represents a first and provisional analysis documenting the local and regional economic impacts of an interruption by natural hazard on a vital traffic node. The analysis demonstrates that the road closure is a main trigger for economically adverse impacts for production and tourism industries. A functioning transport infrastructure plays a vital role also for the population, especially of East Tyrol, which is geographically isolated and it is a major concern to have an axis to the Federal State of Tyrol and to other northern destinations. This means that the cost/benefit argument does not always plays a role for policy decisions and therefore, the necessity to keep the connection open could be more important than economic effectiveness. Notwithstanding, the most obvious measure to alleviate the regional economic effects is the fastest possible reopening of crucial transport nodes. The study also demonstrates the value of redundant traffic infrastructures (in this case the mid-term bypass) can be used to uphold the exchange of goods and business traffic.

Taken together, the study identified that the scale of assessment and the temporal and spatial delimitations are crucial premises when assessing regional-economic effects triggered by natural hazards, even though an exact distinction of the effects outside and inside the study region was not possible in this case. More efforts are needed to improve and validate the approaches to evaluate economic losses, using the knowledge and lessons that may be applicable in other regions. Also important is a strong need for standardisation in cost modelling or cost calculations a point also highlighted by Meyer et al. (2013). Consistent costs-benefit-analyses of disaster impact on transports are vital to inform local planners and decision makers to inform strategies capable of preventing and reducing losses. However, this requires the development of minimum standards for the collection of economic data at local and regional level, and the development of methods and approaches that combine ex-ante and ex-post analyses for effective validation. This approach also includes a validation of results through several subsequent economic periods. Further research should also be carried out to identify the most important triggers of indirect effects and regional-economic impacts.

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