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Tourism Peaks on the Three Peaks.
Using big data to monitor where,
when and how many visitors impact
the Dolomites UNESCO World Heritage Site

Keywords: overtourism, big data, Dolomites UNESCO, tourism flows.

Overtourism studies are increasingly focused on the relationship between tourists and residents. This includes the livability of the destination and the well-being of its residents; the growth of the tourism sector (particularly unchecked or unlimited growth), as well as the threat to natural heritage, such as beaches and mountains. A number of researchers have also highlighted the popularity of the term, as well as the lack of a theoretical understanding of the implications of it, and practical solutions to the problems posed by overtourism. This research aims to monitor the impact of, and understand the problems posed by, overtourism through approaching the phenomenon through the lens of big data analytics. The location of this research is a UNESCO World Heritage site in Italy, namely the Dolomites. By using telco data, we were able to apply a big data analysis of a destination in order to monitor the movement of tourists and day visitors. By analyzing their behaviour at the destination, it has been possible to quantify daily visitors and analyse how they impact this natural site. In addition, it has been possible to compare statistical data with big data, which offers new insights into tourism at the destination. This research, by exploiting the value of big data in tourism, creates a heritage usage rate as well as new indicators for the measurement of overtourism. Ultimately, this can help to control tourism flows and mitigate negative externalities.

Overtourism *alle Tre Cime. Un'analisi big data applicata al sito Patrimonio UNESCO delle Dolomiti per il monitoraggio dei turisti*

Parole chiave: *overtourism*, big data, Dolomiti UNESCO, flussi turistici.

Gli studi legati all'eccesso di turisti e alle relative esternalità negative che ne conseguono si possono concentrare sul rapporto oramai conflittuale tra turista e residente della

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destinazione, sulla crescita (senza limiti) delle infrastrutture turistiche, minacciando la tutela e la vivibilità non solo di destinazioni urbane ma anche del patrimonio naturale come spiagge e aree montane. Alcuni ricercatori hanno sottolineato l'eccessiva popolarità del termine overtourism e la mancanza di soluzioni teoriche e pratiche. Questa ricerca mira a monitorare gli impatti e i problemi dell'overtourism adottando un approccio analitico attraverso l'utilizzo di big data per una attrazione naturale all'interno di patrimonio dell'UNESCO in Italia, il sito delle Dolomiti. Applicando un metodo quantitativo che utilizza i big data da compagnie telefoniche per monitorare la mobilità dei turisti e il loro comportamento nella destinazione, è stato possibile analizzare gli impatti sul sito naturale, sulla destinazione e sulla comunità locale concentrandosi sui flussi di visitatori. Questa ricerca produce come risultato il quadro del tasso di utilizzo di un'attrazione naturale e delle ricadute su tutto il sistema turistico allargato, ottenendo nuovi indicatori per studiare i turisti e nuove modalità di misurazione della congestione turistica.

1. Overtourism in cities and in heritage sites. – In recent years, the term overtourism has become more frequently used when speaking about negative externalities connected to the tourism sector, namely: overcrowding; the exceeding of the tourist carrying capacity; anti-tourism movements; touristification; environmental sustainability and the loss of cultural identity and local traditions. In this context, the economic benefits of high tourism flows, the popularity of destinations, as well as the large number of employees in tourism facilities, are separated in order to focus attention on the impacts of tourism on destinations (Milano, Cheer and Novelli 2018, 2019), the resident community, quality of life (Alexis, 2017, Martín Martín, Guaita Martínez, and Salinas Fernández, 2018), tourism experience (Alonso-Almeida, Borrajo-Millán and Yi, 2019) and finally, on the preservation of cultural heritage and city centres. The phenomenon of overtourism has predominantly been associated with popular urban destinations such as Barcelona, Venice and Amsterdam (Alonso-Almeida, Borrajo-Millán and Yi, 2019, Hospers, 2019, Stanchev, 2018, Bertocchi and Visentin 2019), as well as cities noted for their attractiveness or history. However, it is now affecting other kinds of destinations including non-urban destinations such as the Baleari islands (González-Pérez, 2019) as well as areas celebrated for their natural beauty, including the Galapagos, Iceland and the Norwegian Fjords (Pecot and Ricaurte-Quijano, 2019, Jóhannesson and Lund 2019, Oklevik *et al.* 2019). This broadens the scope fo the research by not only focusing on the negative impacts on cultural sites (Adie, Falk and Savioli, 2019; Vecco and Caust, 2019).

A number of researchers have questioned whether the term overtourism is becoming a buzzword, and the interest and research surrounding the subject merely a popular trend (Koens, Postma, and Papp, 2018, Benner, 2019), rather than identifying new solutions to an old problem – namely the global increase of tourists.

However, international organizations such as the World Tourism Organization (UNWTO 2018, 2019a, 2019b) and European bodies like the European Parliament, and European Tourism Futures Institute (ETFI) (Peeters *et al*., 2018), have focused their attention on the phenomenon. They highlight the causes, impacts and risks, by examining real cases of best and worst practices of destinations, territories and areas facing overtourism. Despite a growing awareness of this phenomenon "overtourism is still at the early stages of being defined and currently lacks a standardized, recognized characterization" (Capocchi *et al*., 2019, p. 6). Nevertheless, it is possible to start analysing overtourism by using the description given by Goodwin in 2017 who defines overtourism as a situation in which either local people or tourists feel that a place is simply over-visited, and as a consequence the destination's character changes, losing its authenticity (mainly for tourists) and causing irritation and annoyance (primarily for residents). These situations need data, measures and indicators to weigh and scale the over-capacities of the destinations to better understand tourism growth dynamics and impacts on the destinations.

By reevaluating overtourism today, it is possible to describing a number of different aspects of it:

- it is a global phenomenon, not only concentrated in urban destinations and historical centres but also in other tourism areas including islands, beaches and cultural sites;
- it is multi-dimensional and shaped by a diverse range of disciplines from sociology to economics, and impacted by issues ranging from the environment to gentrification and imitation;
- it requires data, controlling systems and measures in order to monitor where tourism reaches its social and physical capacity;
- it is most often studied and understood through case studies and best practices, in order to identify actions, discover problems as well as finding and testing solutions;
- in this current global situation, defined by an intern-continental stop of tourism flows and activities due to the Covid-19 Pandemic, there is a certain irony in writing about overtourism. Domestic tourism in Italy in the summer of 2020 was characterised by people opting to spend their time and holidays in open-air locations such as mountains or other natural attractions, rather than in large and congested urban spaces. This was revealed by the Tourism Economics statistics that described tourism during the Italian 2020 lockdown period after spring (Enit, 2020, n. 9).

2. Measuring and monitoring overtourism. – According to the research of Visentin and Bertocchi (2019), that attempts to list the warning signs of overtourism, a range of indicators and measures are needed to assess when overtourism

occurs in order to understand when the positive impacts of tourism are under-mined and the physical, social, ecological, economic and physiological carrying capacity of a destination is exceeded (Peeters *et al.*, 2018; Butler, 2020). As many regions witness the continuous growth of tourist arrivals, it is crucial to measure this growth and create indicators to estimate sustainable tourist caps or growth limits. This is not only to measure overcrowding and congestion, but a calcula-tion of the tourism carrying capacity also allows for economic sustainability to be taken into consideration (Canestrelli and Costa, 1991; Bertocchi *et al.*, 2020) as well as environmental preservation (Coccossis and Parpairis, 1992) and the conser-vation of societal aspects (Graefe, Vaske, Kuss, 1984). It also provides a common structure of indicators to benchmark destinations and monitor – using time and location – the growth and impacts of tourism as well as massive visitor flows. Tourism carrying capacity is able to describe what number of visitors will over-burden locations and the tourism facilities available, as well as describing when tourism becomes a significant inconvenience for permanent residents. It is also strongly connected with management and policy actions (Wall, 2020). Papatha-nassis in 2017 observes how the externalities of tourism have become increasingly visible over the last decade, especially regarding popular destinations. These reac-tions, in conjunction with the corresponding press attention, have led to a variety of proposed measures by tourism stakeholders and decision-makers aimed at controlling tourism development and restricting incoming tourism. The document from the European Parliament named "Overtourism: impact and possible policy responses" (Peeters, 2018) listed various methods to create measures and indicators in order to address the lack of monitoring systems at the destination level, as well as focusing on a larger scale, namely European territories at Nuts 2 level. In order to create a sort of barometer of the state of European overtourism, open data from statistical offices and Eurostat have been used. In this research it has been shown that eight main groups of indicators are useful to describe overtourism: tourism intensity; tourism density; air transport density; the percentage of available accom-modation dedicated to Airbnb; what percentage of the economy tourism accounts for, as well as the proximity to cruise ports, airports and World Heritage Sites. Some analysis and results of these measures are a good toolkit for weighting the impacts of tourism, even if the authors argue that setting an "early-warning limit" for these indicators is not feasible.

Other researchers suggest creating indicators and measures through developing a qualitative method of questionnaires and surveys (Anuar *et al.*, 2019; Oklevik *et al.*, 2019; Cheer, Milano and Novelli, 2019; Milano, Novelli and Cheer, 2019) directed at residents, tourists and tourism stakeholders. This analysis diverges from the quantitative method as it is more subjective and dependent on the context and people interviewed but has the potential to enrich the results with qualitative

evaluation by also using focus groups and living labs with stakeholders and policy-makers. In the last years other possibilities of analysis have emerged thanks to the development of new technologies and the generation of different kinds of data. As Yang, Pan, Evans, and Lv (2015) outline, the use of big data could overcome limitations caused by sample size issues that survey data users face. This could provide a new way to understand tourist behaviour. The use of big data in tourism is not a recent phenomenon and indeed plays a key role in the technological infrastructure of a Smart Tourism Destination (Gretzel, Sigala, Xiang and Koo, 2015; Gretzel, Werthner, Koo, Lamsfus and Koo, 2016). It can also provide destination managers with meaningful insights into tourist mobility behavior, visitors' experiences and statistics about the most-visited attractions. The role of big data in the travel and tourism sector is still rather fragmented and "relegated to isolated research questions" as suggested by Mariani *et al.* (2018, p. 3516). According to Mariani (2019) the majority of scientific research on big data analysis applied in tourism has focused on User-Generated Content data (e.g. eWom – electronic word-of-mouth, text and photos from social networks, reviews website, blogs), followed by location data (especially using GPS) and information about research displayed on browsers and websites' analytics. In the last few years new kinds of device data sources, including time and location information, has emerged to support the analysis of tourist mobility and behaviors through the application of telco data analysis. These analyses have focused on various case studies including urban contexts and urban destinations (Ahas, Aasa, Silm and Tiru, 2007; Baggio and Scaglione, 2018; Delaplace, Gautherat and Kebir, 2018; Park *et al.*, 2020; Psimopoulos, Maresa, Vasileiadis & Tsarapatsanis, 2016; Steenbruggen, Tranos & Nijkamp, 2015); the transportation sector, namely airports and aviation (García, Herranz and Javier, 2016) as well as territories and countries (Ahas *et al.*, 2007; Raun, Ahas and Tiru, 2016; Saluveer *et al.*, 2020; Kubo *et al.*, 2020; Zaragozí, Trilles and Gutiérrez, 2021). To the best of our knowledge, few studies have been developed regarding mobile phone data analysis and overtourism problems, and instead the emphasis has been on congestion and overcrowding in urban contexts (Bekhor, Hirsh, Nimre and Feldman, 2008) without significant attention focused on the monitoring and management of tourist flows. Therefore, with this research we intend to contribute to the discussion of two topics, overtourism and big data. This will be done by using a smaller scale of analysis and focusing on a single natural attraction in a mountain context.

This can then provide a basis for the analysis of tourist presence and behavior in natural areas of the Dolomites UNESCO site. This will then be helpful in developing overtourism actions and solutions. In addition, they will also be relevant in building a new strategic management plan of overcrowded areas that takes into account the necessity of social-distancing and other new health care

guidelines that the travel and tourism sector currently face as a result of the COVID-19 pandemic. Regarding this last point, Butler, 2020, emphasises that the traditional dimensions of carrying capacity are strictly connected to the concept of overtourism, implying that the idea of too many tourists in a location is linked to resident attitudes and physical capacity. These factors are still crucial in the destination and in tourist flows management, even in open-air situations, during post COVID pandemic times, especially in prominent cultural and natural sights. The carrying capacity approach is therefore still needed, but what has changed due to COVID-19 is our perspective (Gössling, Scott and Hall, 2020): from a position of "over-" to that of "safe-" tourism. Today, it is of even greater importance to consider tourism carrying capacity solutions such as density calculation, limitation of visitors, booking systems and new mobility plans, as well as the restriction of particular activities and new visitors regulations (Wall, 2020). This will not only help to preserve environmental, social and economic sustainability, but also assist in solving health and safety issues related to tourism activities (Qui *et al.*, 2020).

3. A new way of measuring the problem: big data from telco. – In this research we propose using a purely quantitative method in order to understand overtourism dynamics and develop indicators using big data. According to the research carried out by Salas-Olmedo and his colleagues in 2018, it is possible to provide insights into the spatial pattern of the tourist and their behaviour in a destination without surveys or questionnaires but rather by using big data. In the research by Xiang, Schwartz, Gerdes and Uysal (2015) it is emphasised that big data analytics could develop new knowledge that could reshape our understanding of the tourism industry and support decision-making processes. In addition, according to Li *et al.* (2018, p. 302) "big data have substantially changed the traditional tourism research based on traditional data".

Big data data-sources are disparate, and encompass the internet and webpages (internet searches, social network activities, reviews), mobile phone data, credit/bank card transactions, city-sensors (cameras, weather and air condition) as well as User-Generated Content from reviewers and bloggers (Li *et al.*, 2018). Collecting and analysing these kinds of big data offers new opportunities in tourism research for not only does it provide contextual information (about the traffic, the weather and so on) but also by providing spatial and temporal data that is able to describe the behaviour and mobility of tourists and visitors. This kind of data supplies a large quantity of information while still respecting the 3 *Vs* of big data: *volume*, *velocity* and *variety* (Laney, 2001; McAfee *et al.*, 2012). In 2011 Gantz and Reinsel added another *v* to represent the *value* of the data, and by Kitchin in 2013 emphasizing their exhaustive in scope and fine-grained in resolution. According to Kitchin (2014, p. 2) big data is characterized by being generated continuously and

he points to some examples such as "digital devices that record and communicate the history of their own use (e.g. mobile phones)". Li, Tang and Li outlined three main and primary sources, whereby "tourist behaviour and [the] tourism market can be better explored and understood by both academia and industries" (Li, Tang and Li, 2018, p. 302). These three sources are:

• data from users – all the data and information created by users such as user-generated content from social media and blogs (text, photo, video etc.);

• data from devices – all the data produced and collected from the internet of things (IoT) and their connected sensors that provide spatial-temporal information (GPS, telco data, Bluetooth, etc.);

• data from operations – all the data created based on operation such as payment transactions, web searching, webpage visiting and online booking.

Using these data allowed policy makers, destinations and private stakeholders to better understand the tourism demand, tourist behaviour and satisfaction and other tourism issues such as spatial patterns, the most visited places as well as the impact and pressure on cities, attractions and areas. This is not only based on big data characteristics and sources, but also on various analytic techniques. This information might prove to be useful to different tourism issues and research scopes.

In this research telco data from one of the major Italian operators, Vodafone Italia, has been used. This source, as described by Baggio and Scaglione in 2018, is created passively, by automatically storing information which is kept by mobile operators. This log track is composed of the unique ID of a user (without personal and sensitive information in accordance with the directives of the European General Data Protection Regulation (GDPR), a timestamp such as the date and time, and the location of the position of the antenna (tower station) of the cell network. The localisation of the antenna is referring to a coverage area (from a minimum of hundreds of meters to a maximum of several kilometres) and not to specific coordinates. This dataset is composed by 2g, 3g and 4g passive signals created by the mobile device while connecting to the phone network and not only when making calls, receiving and sending messages or internet use. In addition, this dataset is characterized by the nationality of the user's sim card, so it is possible to estimate the origin of the users. This data, for privacy reasons, are provided by Vodafone in an anonymized and aggregated format that only shows clusters of 30 users. Lastly, with a Vodafone proprietary calibration algorithm, the number of people in the clusters are re-proportionated to the entire network of users and not only Vodafone or foreigner sim card users who are connecting to the Italian national network.

Big data generated by telco companies provides new insights into the tourism sector which allows not only accurate monitoring at a smaller scale when compared to official statistics (usually present at municipal or regional level), but

also offers a quantification of the total number of travellers, rather than those staying in official accommodation. In fact, all the people that elude registration on official statistics, such as tourists in second homes, guests visiting friends or people staying in short-term rentals (represented lately by the sharing economy such as Airbnb) are monitored and quantified through big data from cell phones. This information makes it possible to develop estimations on the hidden part of tourism, such as tourism that does not pass through the compulsory registrations at police headquarters and communication to municipal and/or regional statistics. The present study develops such a comparison with statistical data collected by the Italian National Institute of Statistics (ISTAT) in order to quantify the impact on a natural attraction which, relative to neighboring tourist destinations (again using the statistics produced by ISTAT), is over-burdened by huge tourist flows.
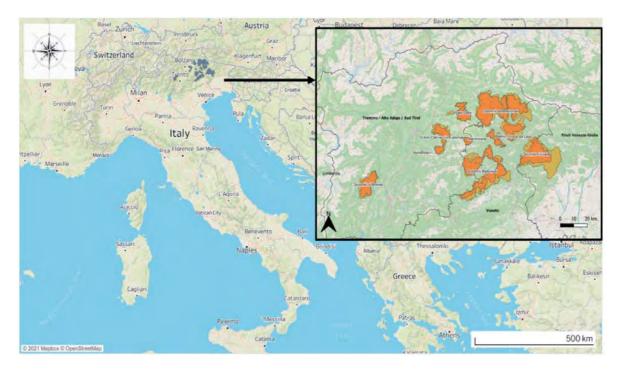
Using big data and telco data provides an opportunity to better monitor tourist activity in cities and attractions, by revealing the total number of users, the total time spent in a destination, as well as understanding tourists' behaviour and mobility patterns. In addition, by using this detailed information, it is possible to cluster users into categories such as day-trippers or holiday-makers, as well as other categories, such as nationality. Furthermore, telco data provides the opportunity to count people in a particular area at specific time and thus it is possible to weight and verify if overtourism occurs, by providing evidence for three conditions of overtourism: too many people, that are in the same place, at the same time of the day or season.

The data recorded by the activity of a smartphone is produced automatically, continuously providing records of each sim card every minute. To make sense to this huge source of data, and to extract value from them, data are aggregated for each user into tables and divided according to minutes and hours. The table structured according to minutes indicates which cell antenna a phone is most frequently connected to within a minute, while in a similar way the hourly table represents the geographical area (usually census area or municipality) and corre-sponding cell antenna in which the user's phone connects most frequently to. Through these first aggregations it is possible to provide almost all the analysis necessary to illustrate the behavior of people in the territories under discussion, and to provide valuable insights for the study of tourism. Through these tables it is possible to construct the number of tourists resident (in this case defined as 'telephone residence') by observing the most densely populated geographical area at night. It is possible to identify the length of stay in an area and understand if the user has visited, and how much time has been spent, at a destination or an attraction during the daytime hours. Additionally, the data is able to verify where the user stayed at night, thus providing a study of the tourist's behavior. In this

research we use data from telco to build three different profiles of visitors: residents of the area, daily visitors, and tourists on holiday (longer than a day). We quantify their presence every day of the summer season, the length of time they stayed in the area and the locations where holiday-makers stayed overnight. In addition, using the same variables that structure official statistics, we calculated the number of individual tourists (comparable to "tourist arrivals" offered by official statists) in the territory's primary destinations, and then multiplied this by the average stay of Italian and foreign tourists. This allowed us to obtain and compare the number of tourist overnights stays with those provided by official statistics.

4. The case of The Dolomites UNESCO area. – The area of focus for this analysis of monitoring the pressure and dynamics of overtourism with big data is the World Heritage Site, The Dolomites. This Italian mountain range has been listed as a World Heritage Site by UNESCO in 2009 owing to the aesthetic value of its landscape, and for the scientific importance of its geology and geomorphology. It is composed of 9 mountain systems in a territory of 142.000 hectares and stretches across five north-Italian provinces: Belluno, Bolzano, Pordenone, Trento and Udine. In 2010 the provincial authorities charged with managing the Dolomites World Heritage Site made a commitment to UNESCO by setting up the Fondazione Dolomites UNESCO in order to encourage communication and collaboration between the various local authorities that manage the site. The main targets of the foundation are the conservation, communication, and enhancement of the 9 natural attractions. Recently, attention has been focused on the promotion of sustainable tourism. When The Dolomites were declared a UNESCO World Heritage Site the committee stated that "the sublime, monumental and colourful landscapes of the Dolomites have also long attracted hosts of travellers". Tourism is a key point of the management plan of the foundation that develops a "Dolomite-friendly ways of dealing with tourism that take account of the values of the property and the need to conserve them for future generations. This requires some of the existing approaches to be re-scaled and modified, with the introduction of new, more balanced forms of tourism that consider the delicate nature of the locations and the needs of the local population. Sustainable, Dolomite-friendly tourism must be promoted to those involved, targeting visitors, tour operators and the local population as well. Sustainable tourism means establishing a deep harmony with the places people visit, helping local people and operators to express this in good practice" (from the foundation website www.dolomitiunesco.info).

This research focuses on mountain system number 5 (see Fig. 1), the Natural Park of Tre Cime, one of the most iconic and extensive of the UNESCO Dolomite systems, covering an area of 53,586 hectares in the provinces of Belluno and

Source: author's elaboration.

Fig. 1 - The nine mountain systems of The Dolomites Unesco World Heritage Site. Tre Cime di Lavaredo sight is located inside "Dolomiti Settentrionali" System

Bolzano. This area is also significant in that it is home to the most famous part serve as the Dolomiti Foundation's logo. This area has become very popular for tourists and visitors in the last decades (Tempesta and Thiene, 2000; Franch, Martini, Buffa and Parisi, 2008; Della Lucia and Franch, 2017; Scuttari, Orsi and Bassani, 2019) in part because of a famous – and overcrowded – walk called 'Around the Tre Cime di Lavaredo' (visiting three Peaks). With the explosion of social media, web 2.0 and content generated by users, Tre Cime di Lavaredo has become even more popular and is now one of the primary tourist attractions in the territory. Massive numbers of pictures and videos on Facebook, Instagram, Google, tourism blogs and other websites of The Dolomites are evidence of the popularity of the site, and further promote the destination, attracting Italian and foreign tourists alike.

5. Results and discussion. – In this section we show how big data from telco can provide answers to crucial questions posed by the problems of over-tourism, including congestion and tourism pressure. The site in question is remote, sitting more than 2000 meters above sea level and accessible only by using public or private transport from Lake Misurina, or by walking along several mountain paths. Therefore, this case study does not have permanent citi-
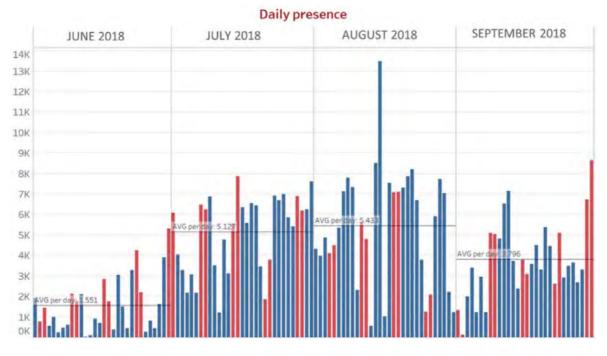
zens and residents and it is not possible to monitor the direct social impact on the area in the same way that an urban area could be analyzed. The focus of the analysis was to observe and count the total number of visitors in this particular area of The Dolomites, as well as studying the behaviour and movement of these visitors in order to investigate what the physical overcapacities of the area may be. By applying a big data analysis we could identify overtourism contributory causes, namely congestion in a particular place at a particular time of the year. The data refers to a period of 122 days in the summer season of 2018, from June to September. We analysed the presence of visitors in the area, creating clusters of users from their mobility pattern.

5.1 *Presence and density in Tre Cime di Lavaredo area.* – In order to create a clear picture, the total number of users visiting Tre Cime each day we defined a user as someone who stayed in the area for a minimum of 30 minutes, thus eliminating users classified as in transit as well as the noise produced by the network itself (e.g. signal jitter). As we can see in figure 2, Tre Cime di Lavaredo is very popular in July and August, with an average of 5127 visitors in July and 5433 in August 2018. This graph draw attention to the high numbers of tourists seen throughout the week, without strong differences between the weekend (in red) and the weekdays (in blue).

Source: author's picture.

Fig. 2 - Tre Cime di Lavaredo Site most iconic image taken by the Author's in 2015 from Rifugio Locatelli/Drei Zinnen Hutte

Source: author's elaboration.

Fig. 3 - Daily presence in the Tre Cime di Lavaredo Site studied by telco data with monthly average levels. Weekdays in blue and Weekend days in red

There is a substantial increase of visitors in the two central months of the analysis as there are less tourists in June, when visitors are more likely to travel to the Tre Cime di Lavaredo Site on weekends. The analysis revealed that over 51 days there was an average of 3998 visitors. This average lever produces a spatial density rate of 22 people per single hectare (the calculated total area for hiking and walking activities is 180 hectares). This density of visitors on the natural site is more than tripled during the peak days, as illustrated on 15th of August 2018 when there were 13.467 visitors, creating a density level of 75 people per hectare. The total number of people in the analysed period is 430.740. Overtourism is characterized by an exceeding of the physical and natural capacity of an area or tourism facilities. On this site, attention is focused on tourism facilities where overcapacity is most noticeable, through a calculation of a facility per person. This analysis focused on food facilities, where we see a ratio (if the average level during summer is taken) of 1,7 people per every single sitting place to have lunch, both inside and outside the mountain refuge. The analysis also examined public toilets where the average summer level ratio is 105 people per single toilet. Another interesting value is the level of usage of the public transportation to reach the Tre Cime site. There currently are three different ways to reach Tre Cime Site: one is using public transportation (8

euro single route, 16 euro round-trip); a second route is through a tollgate by car (30 euro), motorbike (20 euro), Caravan (25 euro); the third one in by foot-paths from the Veneto and the South-Tirol territories. A comparison of the total number of people per day with the number of tickets purchased for the public shuttle per day (data from the two public companies – DolomitiBus (Veneto) and SAF (South-Tirol) – that have the permission to carry people up to the Rifugio Auronzo) has been calculated. This comparison reveals that only 13.5% of visitors decided to reach the site in a more sustainable and less impactful way by using public transportation instead of private vehicles. This discrepancy is, in part, explained by the difference in price, for a car carrying only two people costs less than it would for two people to use the public buses. Yet, from a sustainability perspective it has a negative impact on the natural ecosystem.

5.2 *Profile and type of users.* – Telco data that is created passively, as described earlier, has an extreme rate of granularity and it is therefore possible to study the movement of users in the area and classify them according to different behavior. The first classification of users in our analysis is Italian users connected to the mobile network with an Italian sim card, while the second classification is foreign users with a sim card from other countries and connected to the phone network via roaming. In the period under analysis Italian users were 164.910, while foreign visitors were 265.830. In the case of Italian users it is possible to track their movement throughout the country. Their home municipality could be determined without needing personal information, and instead be based on the most frequent night antenna that their phone registers with within an entire month. This night location can help us to define the Italian users' provenance and identify whether or not they are residents in the two provinces, namely Belluno and Bolzano, that the UNESCO Site took into consideration. The total number of Italian visitors classified as residents is 28.236 people, with an average of 231 visitors per day. In addition, by taking into account an analysis of the busiest cell antennas and where visitors stay at night, it is possible to cluster the users into two typologies:
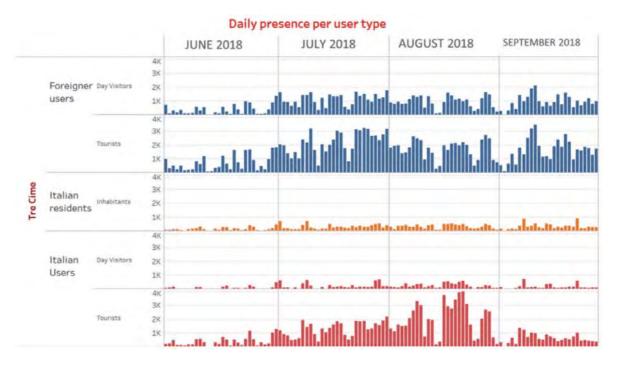1. tourists: users who visited the UNESCO Site and spent the night in a destination inside either of the two provinces of Belluno and Bolzano:
2. day-visitors: the users who visited the UNESCO Site and spent the night outside Belluno and Bolzano (Table 1 and Figure 4).

Table 1 - Total presence per type of visitors. Author's elaboration using Telco data from Vodafone

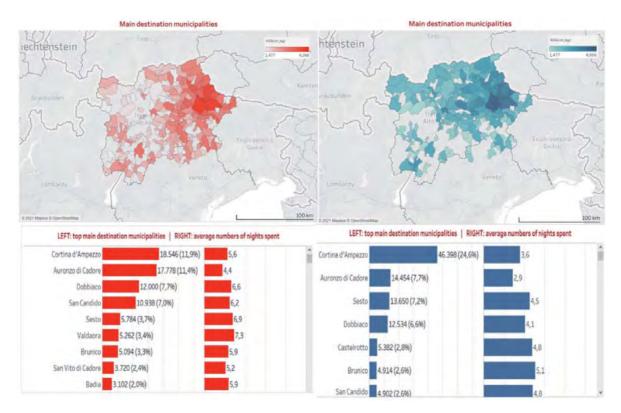| Visitor nationality	Visitor Type	Total number of visitors
Foreigner users	Day Visitors	92.322
Foreigner users	Tourists	173.508
Italian residents	Inhabitants	28.236
Italian Users	Day Visitors	16.746
Italian Users	Tourists	119.928

Source: author's elaboration.

These statistics reveal the imbalance in the flows of users to this natural site, with residents being pushed out of an area that is dominated by tourists and visitors. The international visitors are predominantly from countries close to Italy: Germany (39%), Austria (15%), France (10%), Switzerland (7%) and Spain (4%). Many Italian tourists come from bordering regions, yet there are notable numbers from of visitors from the south and centre of Italy with Lazio (29%), Veneto (27%), Lombardy (12%), Emilia-Romagna (6%) and Liguria (5%) showing an higher pattern of mobility.

Source: author's elaboration.

Fig. 4 - Daily trend per type of visitors: in blue foreigners users, in orange residents users and in red Italian users

5.3 *Impact on the destinations.* – Rather than following a unique person but instead creating clusters of people with similar behaviour, it is possible to investigate which tourists are likely to repeat their visit. It turns out both Italian visitors and foreign visitors have a low rate of repetition, with 96.5% of the Italians, and 97.5% of the foreigners, who visited the Tre Cime Site did so only once in the summer season. Thus, it can be stated that the Tre Cime Site is considered an attraction worthy of visiting, but usually only for one day in a holiday, or as a day trip. With telco data it is possible to understand the behaviour and movement of tourists and detect what their primary destination is, and which province this falls into. All of this also helps us understand what kind of gravitational pull this UNESCO site exerts in terms of attracting tourists. The geographical patterns of tourists staying in the nearby municipalities differs slightly according to tourist nationalities. Italians, in red (Figure 5), are more concentrated in the municipalities close to the Site, Cortina d'Ampezzo (12%) which is one of the major tourist destinations in the area. After this the highest concentration of Italian visitors are in the municipality where the Tre Cime Site is located, Auronzo di Cadore (11%) while the main destinations of South Tirol area Dobbiaco (8%), San Candido

Source: author's elaboration.

Fig. 5 - Italians in red and Foreigners in blue main destinations in the three provinces. On the maps logarithmic value on total number of tourists in the municipality, lower, percentage of tourists per destination and average number of nights spent

(7%) and Sesto (4%). The average stay in these locations for Italian tourists is between 4,4 and 7 days, except in south Tirolian destinations where the average is higher. Foreigners, in blue, prefer to stay in Cortina d'Ampezzo (25%) or the 'Pearl of The Dolomites – *Perla delle Dolomiti*' as it is famously known. Additionally, the trend of tourists from abroad reveals shorter average stays in the Veneto Region (Cortina 3,6 days and Auronzo 2,9 days) with longer stays in the Trentino-Alto Adige Region (Sesto 4,5 days, Dobbiaco 4,1 days, Castelrotto 4,8 days). The picture of tourism preference that is painted by the results from this analysis can help us to better understand tourist behavior and preferences according to nationality. One such piece of information is that foreigners generally decided to spend shorter amounts of time in the municipalities of these three provinces, and preferred south Tirol areas This is perhaps due to the fact that German-speaking tourists are attracted to the region because of a shared language.

Combining this information with official statistics from the Italian National Institute of Statistics (ISTAT) that measure overnight stays, it is possible to weight the attractiveness of the Tre Cime di Lavaredo Site in terms of the number of people who stayed in major tourist destinations in this area. The calculation aims to understand how many tourists, from the total of overnight tourists in the main destination municipalities, visited the Tre Cime di Lavaredo site in a month. With this information we can estimate how key a role the Tre Cime Site plays in the tourism offer of the territory. To develop this it is important to explain the differences between the two database: the official dataset from ISTAT is built using data from the accommodation facilities (e.g. hotels, B&Bs, hostels, camping) that are obliged to register Italian and foreigners tourists and communicate this information to the police headquarters and to the regional tourism offices. One the other hand, telco data encompasses all the Italian and international users who spent the night in one of the municipalities in the provinces of Belluno, Bolzano and Trento which would include not only official accommodation users, but also people who slept the not-conventional facilities like short-tourism rentals, second homes or with friends or family members. The main destinations that benefit from the popularity of this natural attraction are the major mountain tourist destinations in the region of Veneto, including Cortina d'Ampezzo with a total of 269.000 overnight stays made by visitors who also visited Tre Cime di Lavaredo. Other municipalities that benefited were Auronzo di Cadore, with a total of 114.259 overnight stays, and the South Tirolian territory of Dobbiaco, with 120.000 overnight stays. In the top 10 destinations' list that benefit from Tre Cime, only two destinations belong to the Veneto region, while the other eight are are situated within the Autonomous Province South Tirol. This highlights how the Site appeals differently to tourists in the two regions. This imbalance in terms of tourism appeal is echoed in the official statistics of overnight stays in different municipalities, drawing attention to the higher numbers of tourists in the South Tirolian area.

What does display a more balanced relationship in both the Belluno and Bolzano provinces is Tre Cime di Lavaredo's – and The Dolomites more broadly – power to attract a high number of visitors from all over the world. Tre Cime di Lavaredo showed a significant % rate of Tre Cime di Lavaredo tourists stayed overnight in the same area. The results show peaks of 91% for the municipality of Badia (South Tyrol) in July 2018, 72% in Cortina D'Ampezzo and 66% in Castelrotto during September 2018. The Badia municipality seems to benefit most from the attractiveness of Tre Cime, during the summer season for 2 overnight tourists, 1 of them visits Tre Cime (56%). September is the period when tourists are most willing to visit the site with 4 tourists per every 10 overnight stays. By using a big data analysis it can be stated that in the summer season for every 10 tourists who stayed overnight in these municipalities, an average of three of them visited the Tre Cime di Lavaredo. It is worth noting that this statistic might be explained by arguing that tourists spend their holidays in Badia, but take the opportunity to visit Tre Cime.

6. Practical implications. – In this research we illustrate how big data, and telco data in particular, can help destination managers, policy makers and UNESCO Site administrators to monitor tourism flows and congestion. Furthermore, it has been shown that telco data, thanks to its deep granularity regarding users' mobility, can help managers to better understand and evaluate how the three overtourism factors, *where, when* and *how many (*as explained in Visentin and Bertocchi, 2019; Kuščer and Mihalič, 2019; Nilsson, 2020) are manifested, and how many times during the tourism high season this pressure become unsustainable for the environment, the local community and the for the tourism experience itself. Monitoring tourist flows and tourist peaks is still crucial during the post-spring 2020 total lockdown due to the Covid-19 Pandemic, not only in order to study how tourism impacts the natural environment, but also by focusing attention on social security as well as safeguarding the health of residents, workers and tourists. Telco data for The Dolomites depicts peak days, the total number of visitors per day, the typology of the users (holiday-makers or day visitors), the main destination where they decided to stay in and the number of days they decided to stay. With this information, public administration as well as The Dolomites Foundation itself, can put a daily limit on visitors in order to preserve this natural site. Additionally, they could also control access to the site in an eco-friendlier manner (e.g. bicycle or walking) or with the public transportation that links the site to the primary tourist destinations where tourists stay. In this specific case, after a consultation process with municipalities, the provinces and the UNESCO Dolomites Foundation, it emerged that the priorities are to re-design a new mobility system in the area. This would include the addition of traffic circles, as well as an

underground parking lot with a system that monitors how many spaces within the parking lot are available and communicates this to visitors in order to avoid traffic jams. It is also hoped that this would encourage visitors to use public transportation or access the site by foot along mountain paths.

In this study we used big data from telco to quantify the number of daily visitors to a large natural attraction, studying the behaviour of tourists and illustrating the influence and attractiveness of a UNESCO site on summer tourism in two Italian provinces. However, the possibilities offered by big data are much broader, and it has been decided to leave in-depth analyses of the different nationalities of visitors for subsequent studies. In this way the marketing and tourism promotion of the destination can be customized. Another aspect to be explored in the future that is of particular interest for tourism monitoring is the profiles of so-called 'day visitors', users who are almost absent from official statistics and able to be studied only through qualitative methods and to a lesser extent through quantitative tools. Finally, the intersection of these big data with other data sources such as user-generated content from social networks, weather conditions and information on public transport can provide pertinent information for the management of flows in tourist attractions as well as for the governance and promotion of destinations.

In addition, this new information could be combined with other models in order to control and regulate tourism flows. One such example is a new mobility plan, while another is the calculation of the tourism carrying capacity (Butler, 2020) which would not only set a limit on the number of people who ought to access the site and monitor how many times this limit is exceeded, but also as a destination governance tool for the implementation of appropriate action. Future studies can focus on the use of this data to implement sustainable indicators based on real time data as well as big data, instead of relying solely on statistical data. This would allow the creation of a day-by-date monitoring system to control the evolution of tourism pressure, the density of tourists and the overcrowding of some facilities prone to being overwhelmed such as restaurants, bathrooms, parking areas and trails.

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