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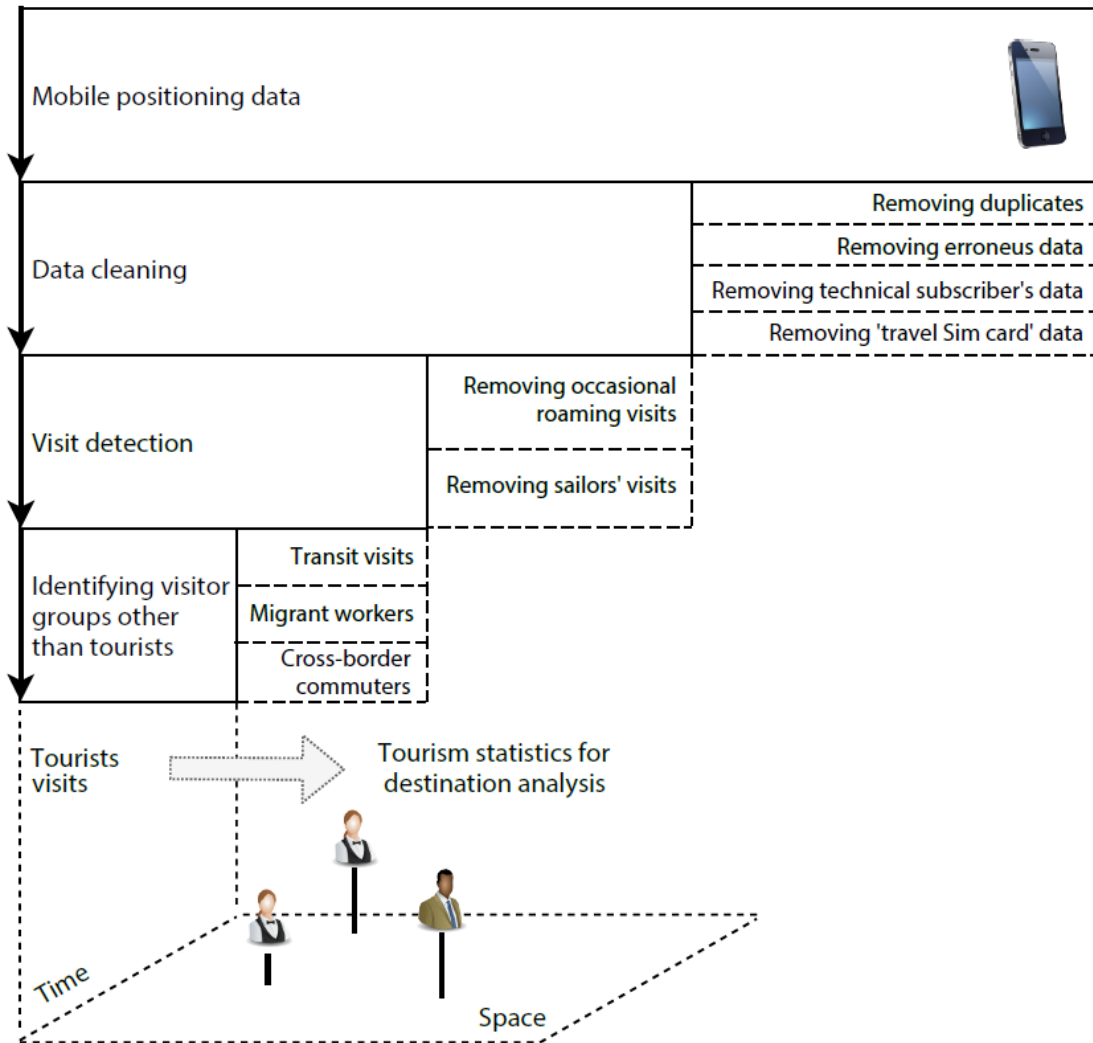
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Mobile Positioning Data (MPD) can be collected via active or passive means. Active mobile positioning means asking permission from the phone user, and the data are obtained from mobile network operators via special queries or via an installed application, using, for example, GPS (Silm, Järv and Masso, 2020). Passive MPD are obtained using cellular network data, which are stored automatically by the mobile network operator for customer billing and network maintenance purposes. Active MPD is seldom used in producing tourism statistics, but the importance of passive MPD is increasing.

The most widespread type of passive MPD is call detail record (CDR). CDRs consist of call activities made by the user, e.g., outgoing and incoming calls and sent messages. Less frequently are used internet protocol data records, data detail records, and probed data from signalling information (e.g., cell handover or location update) (Saluveer *et al.*, 2020). Call activities are recorded in the host mobile network or via roaming service, which allows the use of mobile phones in countries other than those in which they are registered. Mobile network operators collect three forms of data: 1) foreign roaming service users' data inside the operator's home country (inbound), 2) outbound roaming data of their clients travelling abroad (outbound), 3) domestic operator customer data at the home country (domestic).

Mobile network operators do the initial data processing. After processing, each record in the person-based CDR database usually includes 1) the randomly generated id number of the phone used, 2) the time of the call activity, 3) the location coordinates of the network antenna, and 4) the mobile country code for roaming data. The spatial accuracy of the data depends on the geographical distribution of the mobile network antennas. It is more accurate in urban areas (100-500 metres) and less precise (0.5-5 kilometres) in sparsely populated areas.

Different mobility types, from everyday commuters to long-term stayers and transnationals (Silm *et al.*, 2020), can be distinguished from mobile phone data. In order to identify tourists' visits from passive MPD, several steps must be taken: 1) data cleaning, 2) visit detection, 3) identifying tourists' visits, and 4) generating aggregated statistics (Saluveer *et al.*, 2020). International tourists' visits are determined by the duration and frequency of visits. The process of tourist visit detection from MPD by removing non-tourism related data and extracting tourism statistics in Estonia is shown in the figure.



The process of inbound and outbound tourist visit detection from passive MPD by removing non-tourism related data and extracting statistics for tourism destination analysis. (Raun, 2020)

Passive MPD can be used for producing tourism statistics about all three forms of tourism: inbound, outbound, and domestic tourism. The statistics derived from mobile phone data can be used for tourism destination management and marketing. More importantly, MPD can be used as part of the smart tourism infrastructure (Buhalis, 2020) that will support the provision of real-time services in tourism (Buhalis and Sinarta, 2019).

There have been several small-scale pilot studies in different countries to use MPD for producing tourism statistics, for example, Finland, France, Italy. However, in 2020 there were only two countries in the world that used MPD to produce national tourism statistics: Estonia and Indonesia (Saluveer *et al.*, 2020). The potential of using MPD in tourism statistics has also been noted at the European Union and United Nations, where special working groups have been initiated and studies have been carried out (Eurostat, 2014; United Nations, 2020). Passive MPD have been mostly used for analysing inbound tourism trips. Outbound tourism trips have received less attention because the spatial accuracy of MPD for outbound trips is often not disaggregated further than the country visited. For domestic tourism analysis, MPD are seldom used due to the difficulties in detecting domestic visitors.

The use of MPD based tourism statistics enables to analyse various aspects: movement patterns of tourists, destination functions, seasonality of tourists, segmentation of repeat visitors, destination loyalty, destination identification based on visitor flows, etc. The most valuable indicator derived from MPD is the number of tourists at destinations. It enables to monitor changes in tourism volumes (arrivals and departures) with good temporal and spatial detail. This makes it possible to analyse the carrying capacity of destination areas. In places where the number of tourists is already causing negative impacts, the focus should be on alleviating pressure on the core areas and market those places that are visited less often (Kalvet *et al.*, 2020). There is also great potential for providing personalised and contextualised tourism services (Buhalis, 2020; Buhalis and Sinarta, 2019).

The good spatial resolution of MPD enables to analyse the geographical extent of the visits. For example, in Estonia, geographically smaller destination areas can be identified within the whole country (Raun, Ahas and Tiru, 2016). However, most of the visits remain in close proximity to the main gateway – the capital Tallinn. There is a significant decrease in visitation to areas further away from the capital (Raun, Shoval and Tiru, 2020). This detailed information can be used for creating additional tourism routes for tourists who are more willing to drift off the main track. The good temporal detail of the data enables to analyse the daily, weekly and seasonal rhythm of the visits. Monitoring the daily rhythm of visitors is important, for example, in cities that have a large share of same-day visitors, such as coastal cities welcoming cruise ships. Weekly rhythm is important for planning tourism activities – opening hours, tour times and so on. As MPD can be collected longitudinally, it is possible to follow the changes in tourism arrivals seasonally.

This spatiotemporal information of tourists' visits helps to identify high and low seasons and to plan tourism events accordingly – for example, organise big tourism events such as fairs, concerts, exhibitions during the shoulder season. The visitors of those events can be again detected from MPD. This is useful for evaluating the hinterlands of the events. Where do people come from, what other places do they visit and for how long do they stay. The longitudinal character of MPD enables to detect repeat visitation. Each phone in the CDR data set has its own unique ID. The analysis of reoccurring IDs in the database throughout the years enables to identify all the visits a person has made during the data period. Repeat visitors are a valuable segment as they usually make longer visits and travel to less touristic areas.

The use of MPD enables to distinguish between tourists from different countries of origin. The country of origin is derived from the phone's SIM card registration. Thus, the temporal and spatial indicators can be analysed among different visitor segments. Long-haul travellers tend to visit more tourism hot-spot areas, whereas visitors from neighbouring countries tend to visit smaller and not so popular attractions. Visitors from neighbouring countries are also less influenced by season and visit destinations all year round, while visitors from more distant countries tend to be more high season oriented. The information gained from MPD about tourists' visits can be used in destination analysis to improve destination management and planning. The use of MPD enables to identify the whole visitation pattern within a country based on the call activities done during one trip. This makes it possible to identify connected places at different times and to amend marketing and management strategies accordingly. Understanding how visitor flows emerge and evolve at destinations is the core for deciding which specific planning interventions are needed (Beritelli, Reinhold and Laesser, 2020).

Passive MPD have several advantages. Because data are collected automatically and cost-effectively, it is possible to have large samples and cover vast areas over long periods (Shoval and Ahas, 2016). MPD enable to capture same-day visitors who do not spend the night at the destination and tourists who are not staying at official accommodation establishments. Such as people staying with their

family or friends or people using Airbnb rentals that are quite often not included in the official accommodation statistics. Good consistency and resolution over time mean that MPD can be collected almost in real-time and for longer periods.

The main limitations of MPD are the lack of qualitative information, differences in phone use, and difficulties in access to data (Reif and Schmücker, 2020; Saluveer *et al.*, 2020). The latter has so far been the biggest obstacle in the use of MPD when it comes to producing official statistics or carrying out scientific research. Problems in access arise from international or national legislation and regulatory limitations. In addition, methodological consistency and clarity are missing. It means the reproducibility and overall transparency of the methodology are somewhat limited. Hence, passive MPD do not substitute traditional data sets but rather complement them.

For more widespread use of MPD in tourism statistics, three key aspects need to be improved. First, develop better legislation and regulation to access the data. Second, find additional baseline data to compare the results derived from MPD. Third, create a transparent and unified methodology for extracting indicators generated from MPD (Saluveer *et al.*, 2020).

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