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Tracking tourists' travel with smartphone-based GPS technology: a methodological discussion

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Abstract This methodological paper discusses the implications of differing approaches for tracking tourists' movement through destinations and then describes an innovative new method that utilises smartphone-based Global Positioning Systems (GPS) technology and a mobile app to track tourists through regional destinations and attractions over an extended period. The method was developed by the *Tasmanian Sensing Tourist Travel* project team and is among the largest tracking studies ever conducted in tourism, both spatially and temporally and in terms of sample size. It tracked the movement of 472 tourists in real time via an app with three integrated surveys and GPS tracking. The research team was faced with multiple challenges given the ambitious nature of the project, including: app design, securing tracking hardware, forging partnerships with providers, participant recruitment, and the ethical and legal dimensions of both the tracking and the provision of mobile data as an incentive to participate. This paper discusses the lessons from the project and a holistic study design model to support continuous methodological progress in this growing research area.

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1 Introduction

New technologies are enabling advances in tourist tracking. Wearable GPS (Global Positioning Systems) technology, social media geotagging and hashtag analytics, smartphone applications, and most recently Bluetooth technology, have allowed researchers to more accurately and less invasively follow visitor movements (Shoval and Ahas 2016). These technologies have been applied to buildings and at specific sites (e.g. Moussouri and Roussos 2015; Schautz et al. 2016; Yalowitz and Bronnenkant 2009; Yoshimura et al. 2014), in large cities and rural areas (Kellner and Egger 2016; Thimm and Seepold 2016), and for entire days (e.g. Birenboim et al. 2013; Edwards and Griffin 2013a, b; Spangenberg 2014; Shoval et al. 2011). Despite the potential of these technological advances, their application to rigorous tourism research has often been problematic given the technical complexities associated with employing digital tracking technologies, the challenges related to recruiting and gaining consent from participants, and on-going limitations in terms of data quality i.e. accuracy. Given these challenges, tracking research has, by and large, continued to rely on paper-based surveys to collect contextual information such as socio-demographic data (Blečić et al. 2016). However, techniques incorporating such methods are of limited effectiveness and efficiency in comparison to purely digital approaches (Toha and Ismail 2015; McKercher and Lau 2009). In short, there is a clear need to develop viable methods to make tourist tracking effective and scalable.

This methodological paper responds to the technological and logistical challenges of electronic tourist tracking reported in the literature, by initially reviewing the range of electronic tourist tracking techniques and methods that have been trialled by researchers, before describing the approach developed through our own *Tasmanian Sensing Tourist Travel* (TSTT) research project in early 2016. The TSTT used smart phones that had GPS capabilities and equipped them with a mobile app that transmitted both real-time GPS location and survey data to a central server. The embedded surveys within the app 'popped up', to capture real-time demographic data and insights into tourists' travel styles, preferences and experiences in specific locations. Conducted from February to May 2016, TSTT was perhaps the most ambitious tourist tracking study to date. It successfully tracked the movement of 472 independent tourists who visited Australia's island state of Tasmania for between 4 and 14 days, which represented the most common time for tourists to visit the state. The success of the project was dependent on developing an approach that participants would be willing to engage with for an extended period of use. The app was developed in English and Chinese, to cater to the rapidly growing market of mainland Chinese visitors (Tourism Australia 2016), and participants were offered free mobile data as an incentive. Yet while the TSTT study was successful overall, the experiences and learnings from this study

demonstrate a need to further develop methodological advances in tourist tracking research.

2 Options for tracking research: a stocktake from the tourism literature

Within tourism research, a variety of methods have been used to track the movement of visitors. There are essentially three options for tracking: direct observation; survey and interview-based methods such as the use of travel diaries or drawing on maps; and digital tracking that can be conducted through GPS tracking using specialist devices or mobile apps tracking via Wi-Fi or Bluetooth, or via geo-tags. Before describing the methods used in the TSTT study it is important to assess the merits of each of these methods and how these assessments informed the design of the TSTT method.

2.1 Direct observation

The benefits of direct ethnographic observation include the precise information that can be collected including insights into decision-making and group dynamics (McKercher and Lau 2009). However, McKercher and Lau (2009, p 44) have argued that the approach is the 'least practical and most ethically questionable method available' to track tourist movement and behaviour due to it depending on deception so that the tourists do not know that they are being followed (cf. Thimm and Seepold 2016). When informed consent is gained, it has been criticised for its intrusive nature (Valance 1995). It has also been critiqued as being resource-intensive (McKercher and Lau 2009; Edwards et al. 2010), requiring an observer to be assigned to each tourist being tracked. For these reasons, this method has rarely been used (McKercher and Lau 2009).

2.2 Self-completed paper-based approaches

For many years, maps and trip diaries have commonly been used to collect information on tourists' movements (see McKercher and Lau 2009; Thornton et al. 1997). Participants have been required to annotate maps to indicate their route and stops or to record activities and locations in a daily travel diary. On the positive side, these approaches leave tourists feeling free to move around unobserved. However, they do not allow for fine grain detail of movement (Lau and McKercher 2006; Shoval et al. 2011) and can also be inaccurate, as they depend on tourists' recall of details such as routes taken, places at which they stopped, and time taken at particular sites (Thimm and Seepold 2016; Shoval and Isaacson 2007; Modsching et al. 2008; Beeco et al. 2013). Trip diaries in particular, necessarily require assumptions to be made by researchers on the routes travelled between two points, which may be incorrect (Lau and McKercher 2006). A further difficulty comes when analysing data obtained from maps and trip diaries, as it has proven very complicated to classify such data and to determine patterns from it (McKercher and Lau 2009; McKercher and Lew 2004; Shoval et al. 2014).

2.3 GPS tracking

Global Positioning Systems loggers and GPS-enabled smart phones enable tourists' movements to be traced precisely. GPS units allow researchers to continuously collect high resolution data that can show movement in time and space, over an extended duration. In tourism research, GPS-based tracking has been used on numerous occasions with varying degrees of success and in a variety of ways. In one study cross country ski racers' locations were automatically recorded (O'Connor et al. 2005); while other studies have combined GPS tracking with other methods, such as paper-based surveys, in order to analyse differences in movement amongst cohorts. These have included studies of recreational walkers on trails in South Carolina (Beeco and Hallo 2014; Hallo et al. 2012); visitors in Virginia (Beeco et al. 2013); tourists in Hong Kong (McKercher et al. 2012; Grinberger et al. 2014a, b); tourists in theme parks (Birenboim et al. 2013); tourists in Melbourne and Sydney (Edwards and Griffin 2013a, b); those attending sports events (Pettersson and Zillinger 2011); tourists in German cities (Modsching et al. 2008); and cruise ship tourists (de Cantis et al. 2016).

Yet GPS and spatial science as a data collection method and analysis are not without their critics: critical geographers have argued that it emphasises movement but neglects participants' subjectivities and that it is too reductionist (Gren 2001). There have been concerns that the knowledge that one is being tracked may result in participants changing their behaviour (Winters et al. 2008). There have also been ethical concerns raised regarding the violations of privacy that can result from the close tracking of movement (Curry 1997; Versichele et al. 2014), although in the context of academic research, these are typically negated by institutions' ethical requirements for informed consent. GPS tracking has also been regarded as too expensive (Shoval et al. 2014), although the cost varies considerably depending on the equipment used and increasingly the technology is becoming lower in cost.

Despite the significant potential of GPS technologies there are also significant challenges when it comes to tracking tourists over an extended period and in certain environments. Previous studies that have used personal GPS devices have only been conducted for one day at most (Edwards and Griffin 2013a, b; McKercher et al. 2012; Grinberger et al. 2014a, b). This could be due to limited battery life of technology used or because of difficulties collecting devices from participants after more than 1 day. Furthermore, signals can be compromised in a range of situations such as when travellers are indoors, in densely forested areas or in highly urbanised environments with high rise buildings (Pettersson and Zillinger 2011). Accuracy can also be compromised if the tracking unit is placed in a handbag or a car boot. Therefore, while GPS tracking is able to capture highly accurate data on where tourists go, the necessity for tourists to hold or wear a device may be viewed as a limitation.

Yet, despite these limitations, GPS tracking has many strengths: it is unobtrusive and highly accurate (Yun and Park 2015); it is precise and has the potential to provide continuous tracking of individuals, including their velocity and directionality; and, if combined with surveys, it has the ability to provide rich information on the travel patterns that different types of tourists take (Asakura and Iryo 2007;

O'Connor et al. 2005). Indeed, few researchers dispute the fact that GPS data is significantly more accurate than that which can be collected through travel diaries or post-travel surveys (Edwards et al. 2010).

2.4 App-based GPS tracking

Whereas early GPS tracking studies used GPS-enabled watches, chips and other hardware, the development and rapid proliferation of GPS-enabled smartphones has the potential to revolutionise tourist tracking research by lowering the cost of data collection and minimising the inconvenience to study participants (Yun and Park 2015). Many smartphone apps used by tourists automatically track movements across space and time to provide desired location-based services. Smartphone apps are therefore a natural fit for tracking studies. Consumers often happily trade off privacy in order to seize the benefits of location-aware apps (Dou et al. 2016) or are not even aware of potential privacy losses (Anuar and Gretzel 2011). While businesses can easily exploit such data within the boundaries of user agreements because they offer valued services in return, the use of app-based tracking for research purposes only is ethically problematic and requires informed consent. That tourists are willing to make privacy trade-offs to support research is not guaranteed. Tracking app studies seek to overcome this problem by mimicking the service offerings of commercial apps.

A recent academic study of particular relevance to our study attempted to track tourists around the tourism destination of Lake Constance (Bodensee) in Germany, using a purpose-built app (Thimm and Seepold 2016). The app contained what were thought to be incentives: information relevant for tourists such as calories burned, CO_2-tracking and a travel diary feature. 65 tourists initially expressed interest in the app. However, only two tourists downloaded the app—and only one of these activated the tracking mode and then de-activated it 380 m later. In this case, the findings of McKercher and Lau (2009) were confirmed—smartphone tracking was probably seen to be too invasive in relation to the incentives offered, and tourists were unwilling to cooperate.

In Korea, Yun and Park (2015) tracked tourists for five days while in the confined space of a festival. The festival-goers were asked to download a specialised GPS fitness and tracking app called Tranggle GPS. 95 people agreed to participate with 65 reporting back their data at the end of 5 days—they had to upload their tracking records to the researchers for analysis. No socio-demographic data was collected via the app, but rather via personally administered questionnaires. Yun and Park (2015) raised the concern that getting people to download an app meant that only a limited demographic would be prepared to participate: those who were technologically savvy. The authors also raised concerns about: battery life of mobile phones, explaining that they only selected participants who had good battery life on their phones; and the need for incentives to encourage participation. They further expressed ethical concerns despite securing participants' agreement to participate in the study. However, Yun and Park's (2015) study demonstrated that despite significant unresolved challenges, researchers are able to successfully use

participants' own phones without having to use additional GPS devices to track tourist movement.

There are also several additional technical and methodological challenges with app-based tracking. These include that many people's phones often have only limited memory left (Prweb.com 2014) and therefore not enough space to download an app; that when travelling, they may not have a data provider, thereby limiting their phone's internet connectivity; that phones need to be charged for apps to function and the increased mobility of tourists and their ventures into rural and remote areas could make this a challenge; that apps with GPS functionality drain battery life; and that tourists need to feel that the app is worth their while to download onto their phones, even for the relatively short period they will be using it, given the travel context (Anuar and Gretzel 2011).

But again, like traditional forms of GPS tracking, app-based tracking has many advantages. The now almost ubiquitous ownership of smartphones and pervasive use of them in tourism contexts (Wang et al. 2012, 2014) surely provides a reliable platform from which GPS tracking and survey data can be collected. Moreover, an increasing understanding by the public that apps do track movement and mine personal information has arguably relaxed perceptions of privacy, compared to attitudes in 2006 when McKercher and Lau conducted their research.

2.5 Bluetooth and Wi-Fi tracking via IPNs

Recently, the tracking of movement using Internet Protocol (IP) addresses, which are unique identifiers attached to mobile phones, has been conducted using devices that 'farm' IPs that pass by a receiver when either their Bluetooth or Wi-Fi is enabled. Multiple receivers can be installed at different locations, allowing research to covertly determine traffic flows between different locations. The technique is very cost effective, but limited because while it can track individual phones as they move between locations with receivers, analysts will not necessarily know the demographics of the owner of the phone and the technique provides no insight into how tourists move between receivers. This technology was used by Versichele et al. (2014) to track attendees at the Ghent Festivities event by installing 22 Bluetooth sensors across the festival site. Participants were not aware they were being tracked and no survey data was collected. The researcher argued that Bluetooth technology produces more accurate results than mobile phone tracking data and worked well when tracing movement over a relatively small site such as a festival. However, this technology was limited to those whose devices had Bluetooth-enabled phones. Such limitations can be overcome when mobile phone data is directly obtained from telecommunications companies (see for instance the research by Raun et al. 2016), but obtaining such data is usually cost-prohibitive.

2.6 Tracking via social media disclosures with geo-location tags

For social media users, tagging disclosures (images, videos, text posts, etc.) with geo-location data has become widely practiced. Applications like Foursquare popularised the act of 'checking in' at locations to produce longitudinal digital

traces of where users had been. Facebook, Twitter, and Instagram have also integrated geotagging into their core functionality. These digital traces allow social media users to 'perform location', sharing their whereabouts with friends while also constructing a record of their own movement and places they have visited for themselves. As Wilken (2014) has argued, the global significance of sites like Facebook is amplified when its locative properties are considered. There is significant market value in knowing where certain disclosures are made, and where users go, along with equally troubling implications for user privacy. From a research perspective, this normalisation of geolocation data has opened new opportunities for tracking.

Kadar (2014) accessed approximately 500,000 geotagged photos on Flickr to explain tourist visitation of sites in Vienna, Budapest and Prague, downloading geographical coordinates, user ID, and the dates photographs were taken. Kadar suggests that this method provides the accuracy of GPS tracking with the advantage of large data-sets on Flickr. Kadar found a significant correlation between the time tourists spent in a city and the number of photographs taken, and was able to identify key clusters of locations where photos were taken and uploaded to Flickr, thus producing detailed tourist hotspot maps of these cities.

Vu et al. (2015) also analysed geotagged photos on Flickr, drawing on a sample of 29,443 photos from 2100 tourists in Hong Kong. From this dataset they were able to identify locations of interest, travel patterns, and daily activities. For example, they were able to infer that Western tourists seemed to be more interested than Asian tourists in the Tian Tan Buddha Statue in Hong Kong, thus having implications for marketing plans, transportation arrangements, and promotional opportunities (Vu et al. 2015: 230).

Both Kadar (2014) and Vu et al. (2015) lament the challenges researchers face in properly tracking and understanding the movement of tourists, and suggest that studying geo-coded images shared on social media like Flickr is one step forward in better understanding tourist movement. However, the limitations of this method are also clear. For both of these studies, only photos uploaded to Flickr are included, therefore capturing only the movements of the minority of active social media content producers (Yoo and Gretzel 2011) and producing impressions of places centred on key attractions. The more 'banal' sites of travel (hotels, shops, toilet stops) and routes taken are rendered invisible in such analyses. This was the point of differentiation for this study—the high level of detail illustrated for the first time the exact movements and use of infrastructure by tourists. The TSTT research team sought to overcome several of the challenges described in the literature.

3 The Tasmania Sensing Tourist Travel Study

3.1 The study region: Tasmania

Tasmania is Australia's only island State, located 240 km from the country's south east tip. Stretching 517 km from north to south and 400 km east to west, Tasmania has a population of just over half a million. In recent years, the Tasmanian tourism

sector has grown significantly, contributing about \$2.3 billion per annum to the Tasmanian economy—9% of Gross State Product (State of Tasmania 2015a). In 2014–2015 Tasmania experienced an 8% increase in visitor numbers from the previous year—up to 1.15 million visitors whose combined expenditure was almost \$1.89 billion. Approximately 86% were from mainland Australia (State of Tasmania 2015a), with most visitors attracted by the State's wilderness and natural areas (Tourism Tasmania 2016).

Tasmania's island status has long been both friend and foe of the tourism industry: 'The upside for a tourism destination such as Tasmania is that it has all the mystery, magic scenery and exotic lifestyle of a remote location. The downside is getting there' (AICD, 2001 cited in Harwood 2011: 138). Visitation to Tasmania is reliant, in part, on the availability of flights from mainland population centres (State of Tasmania 2015b). While most visitors arrive by air, 10% come by sea on the *Spirit of Tasmania*, oftentimes choosing this option so that they can bring their own vehicles.

3.2 Existing tourism data

The Tasmanian Visitor Survey (TVS) has collected data on visitor demographics, experiences, motivations and sites of interest since 1978. This survey is administered by a market research company on behalf of Tourism Tasmania, the Tasmanian Government's tourism marketing agency. Data is collected via an exit survey of approximately 9000 visitors each year with the primary aim of creating an annual and a longitudinal profile of visitor characteristics, travel behaviour and expenditure. The data includes the total number of visitors, nights spent in Tasmania, expenditure, accommodation patterns, sites visited, demographics and data on specific niche markets.

Data from the long-running TVS provides some insight into the travel patterns of both domestic and international tourists and general information about different touring routes. However, apart from anecdotal accounts from tourism operators, little was known about the travel routes taken by independent visitors prior to our project. Specifically, there was no robust data to indicate which roads were used, in what direction visitors travelled, and how long visitors spent in different regions. There was also no information regarding patterns in travel routes, and how these patterns may vary between different types of visitors. Advances in tracking technologies including the success of some small scale studies overseas suggested that tracking visitor movements in Tasmania was possible, not the least because there were only three entry/exit ports through which to recruit participants. However, as described above/below previous research indicated that tracking would not be without its challenges. The research team made the decision to track visitors for between four and 14 days because this length of travel contained the majority of free independent visitors who came to Tasmania to tour around the state.

3.3 Method design

There were a variety of consequences of our choice of study site. The limited number of arrival ports and relatively small amount of visitor arrivals meant that recruitment was contained to the three arrival locations and recruiters were physically able to approach a large percentage of people who arrived. However, the remoteness of much of Tasmania's landscape meant much of the terrain throughout the state can be regarded as wilderness, and these areas often did not have strong, if any, internet coverage. Consequently, a critical challenge for the research team was to design a technique that could work on a large temporal and spatial scale, in a non-urban environment.

The team decided that, wherever possible, demographic questions used in the tracking method should be designed to align with the TVS. In addition to the use of questions from the TVS, the team also designed a suite of additional questions that would draw out more information on travel styles. These questions were determined to be lacking in the TVS and addressed issues such as participants' expectations and use of social media, their psychographic characteristics, their propensity to plan and factors that influenced any spontaneous decisions that they made.

The research team was aware that the uptake of apps is generally low in the context of tracking studies (McKercher and Lau 2009) and the team was concerned that an app alone, even if it was promoted, would not be attractive for participants to download. Moreover, the scarce availability of Wi-Fi for participants to be able to download an app was of great concern. Much of the published tracking research has been conducted in highly urbanised regions (see McKercher and Lau 2009). At the time of our study, one of the arrival ports did not have free Wi-Fi available and much of Tasmania has limited mobile phone coverage. Therefore, for those travelling from overseas who may not have any data in Australia, it would have been impossible for them to download an app at the start of their trip. Moreover, even for Australians who had data, there was very limited mobile phone coverage in Tasmania for two of Australia's three major networks. Consequently, our app needed to be paired with a solution that would provide participants with connectivity to: (a) download the app; and (b) provide a strong signal for up to 14 days.

3.4 Choice of technology

Over a series of months the project team considered and tested various types of technology that could deliver a survey and collate GPS tracking data. Solutions such as a 'Dongle' were considered, which would provide internet data to tourists as an incentive to participate and would be conveniently small for participants to carry around. However, this solution was dismissed, given that it would have required a paper-based survey to be administered concurrently and the team was keen to avoid such 'hybrid' solutions.

The project team considered developing an app that could be downloaded onto participants' own personal phones and which would both track them and deliver surveys to them. However, this was dismissed due to concerns that many

participants may have little memory left on their phone. In addition, given the failure of other studies to get participants to download apps (McKercher and Lau 2009), and the team's suspicion that people regard tracking apps on their own phones as intrusive, the team considered that relying on a method that depended on study participants' personal phones would be too risky. Furthermore, this approach required both Android and iOS versions of the app to be developed which, at the time, was considered too costly and time consuming.

Given these challenges the research team also considered using the latest generation of wearable GPS technology. Smartphone Watches together with an app were considered as it was felt that they would be an incentive for tourists to participate due to being such a new and 'trendy' form of technology. However, they were soon dismissed as being too expensive and having too small a screen to display surveys. Fit Bit style devices were also considered, but dismissed for similar reasons and because free data as an incentive to participate could not be offered.

In the end the team decided to use smartphones with 3 G of data as the project device. The smartphones were able to be tethered via Bluetooth to participants' personal devices, thus providing participants with a significant incentive of free internet data. 240 Samsung Galaxy ACE3 GT-S7275Y smartphones were purchased, with the assumption that they would be used more than once. The phones accessed GPS and GLONASS networks. Previous testing of our chosen model indicated their quality was reasonably good despite having encountered some problems in forests (such as multi-path problems) compared to other GPS units with good antennas (i.e. Garmin Edge 500). There was some concern over the quality of the antenna and the potential slowness of the phones in locking onto GPS signals. However, when the chosen phones and their technical ability were weighed up in conjunction with their cost, they were considered to have enough operational capacity to be appropriate for the study.

An app was designed by a local company. The app allowed delivery of entry and exit surveys, as well as a pop-up survey triggered by entering a specific geographic area. As with other studies, the benefits of using the smartphones were seen as: the ability to provide internet data via the smartphone and not having to rely on Wi-Fi infrastructure; having only one platform for app development; being reasonably cost efficient; and offering all features needed in one device (see Smith et al. 2015). They were also seen as being separate from participants' phones and the team hypothesised that this physical separation may be regarded as less intrusive than downloading an app. The negatives were seen as; the additional burden to the participant to have to carry around and charge another device; and the possibility that many phones may not be returned. The first negative was partially addressed by providing all participants with an in-car charger, explaining to all participants at the point of recruitment that the phone should be charged each night and by including a reminder in their paperwork about the importance of keeping the phone charged up. The second challenge was addressed by including a reply-paid padded envelope in the bag all participants received and explaining to participants that this could be posted back from anywhere in Australia. At the time of writing 185 of the 240 handsets have been received back and the phones were used up to three times each.

As with all successful GPS tracking research, the smartphones required a minimum amount of satellites (four satellites) to be visible in order to avoid suffering from a multi path problem which could affect the positional accuracy of the GPS data. To overcome this issue, we carefully checked our data accuracy by overlaying the data with different location-based spatial layers (e.g. road, river, national park boundary, landmark locations) that were publically available from a Tasmanian government-administered online database called Land Information System Tasmania. This allowed the research team to ensure that the research data aligned with real world topographical locations.

3.5 Incentives

Smith (2010) has observed that the effectiveness of incentives offered to tourists to participate in research varies substantially depending on the population being studied and the value of the incentive being offered. Previous use of incentives in tourist tracking research has been met with mixed results. For example, McKercher and Lau (2008) offered SIM cards which provided participants with free local phone calls. However, no tourists consented to be tracked and so it would seem that the incentive offered was not sufficient to counteract what was seen as an invasion of privacy. As noted above, Thimm and Seepold's (2016) attempt failed despite offering an app with a CO_2 tracker, a calorie counter and a travel diary.

Most research using GPS loggers was conducted over the period of a day or part-day. It would seem that getting people to participate for short periods using simple loggers is easier, as incentives do not seem to have been offered in any of the studies (Shoval et al. 2011; Beeco and Hallo 2014; McKercher et al. 2012; Hallo et al. 2012; Birenboim et al. 2013; de Cantis et al. 2016; Beeco et al. 2013). Conversely, Edwards and Griffin (2013a, b) tracked 40 tourists in Sydney and 108 in Melbourne for one-day periods using either wrist-based or round-the-neck GPS loggers. They offered shopping vouchers as incentives for participation. Spangenberg (2014) tracked 55 people for one-day periods in the Harz area of Germany using GPS loggers. The researcher provided an individualised printed holiday map to each participant in the study as an incentive.

In light of the apparent reticence to partake in long term tracking research, the project team agreed that an innovative incentive should be offered to encourage visitors to participate in the project. This was deemed to be particularly important given that the level of engagement that was required from our participants was relatively high as they were being requested to (a) ensure the phone was always charged; (b) carry the phone at all times; (c) complete up to three surveys; and d) consent to being tracked at all stages of their travel in Tasmania. After careful consideration, the team opted to provide the smartphones with 3 gigabytes of data that could easily be tethered to participants' personal mobile phone, using the personal hotspot function. A secondary incentive was also designed to allow participants access to two maps. One was a daily map that recorded where they had travelled each day. The second was a map that was posted to participants upon completion of their final survey. The map illustrated where they had been in Tasmania and could be shared via social media, thus acting as a digital trace that

participants could use and share, in order to reflect upon their journey. The team felt that these incentives worked in a complementary fashion, with the free internet data enticing tourists to participate initially and the promise of the individualised tour map encouraging them to continue participation until the end of their time in Tasmania.

Anecdotally at least, recruiters found that the incentives proved to be a key to the success of their recruitment. Unexpectedly, the opportunity to participate in university research that aimed to help to improve infrastructure, planning and the visitor experience in general in Tasmania, also appeared to play a key role in the minds of the participants, particularly those who identified as being culturally Chinese. Significantly, the success of the recruitment suggests that tourists' attitudes have changed regarding the privacy of their personal information (see McKercher and Lau 2009). Indeed, recruiters noted that the issue of being tracked was barely brought up by would-be participants.

3.6 Functionality of the chosen technology

One of the major technical issues for tracking research is the strain that GPS data places on battery life (Shoval et al. 2011; McKercher et al. 2012). Given this project ran for up to 14 days, this was a significant challenge. The design of the app used several technological solutions to enhance battery life, including slowing down the transmission of signals when the app sensed the smartphone was not moving.

In addition, the app had to be designed to be as user-friendly as possible. Four iterations of pilot testing took place to ensure that it was user-friendly, could update automatically and was able to store and transmit data when in remote locations. This was a difficult and laborious process, which often encountered unexpected challenges. Examples included a national mobile network outage that caused our entire network to collapse and the failure of the app when a website that it was connected to changed its credentials.

In order to enhance the success of the app, recruiters took time to show participants the functions of the app, and emphasised the importance of keeping the mobile phone charged at all times. Upon review of the data during the pilot phase, it became apparent that further training of recruiters and participants is needed in future iterations of research, as the performance of the GPS was reduced when the mobile phones were stored in handbags and car boots. Knowledge of this would have increased the strength of GPS signal and significantly enhanced the accuracy of the data.

3.7 Ethical and legal implications

Following formal ethics approval that covered issues of informed consent and participant anonymity and confidentiality, we became aware that our tracking technology required that our research also conform to federal information technology legislation. This included the need for all mobile phones and SIM cards to be registered in the name of the lead Chief Investigator (as an agent of the University). To ensure that this person was not implicated if a phone was misused,

and that participants understood and accepted their responsibilities regarding responsible phone usage, we were required to collect and retain the names, addresses and phone numbers of all participants. In addition, participants were required to view and sign a substantial legal indemnity form at the point of recruitment.

This not only had implications for the complexity and length of time of recruitment—participants now had to read and sign a legal document as well as an information sheet and informed consent form. It also had implications for participant confidentiality. If a participant undertook an illegal activity such as copyright infringement, accessing exploitative material or an act of terrorism, then confidentiality could not be guaranteed as we were legally obliged to pass their identifying information on to authorities upon request. This aspect of the research was unexpected at the outset and it became clear to the research team that different jurisdictions have different laws regarding the use of SIM cards and mobile phones.

3.8 Outcomes of the technological choice

The methodological choices made it possible to recruit a sample size of 472, and to collect a combination of locational and survey data. There were four data sets; entry survey data (n = 427, response rate 90.5%), exit survey data (n = 133, response rate 28.2%); Freycinet visitor survey data (n = 199, response rate 42.2%); and tracking data (n = 472) (see Table 1). All participants who completed the exit survey also completed the entry survey and were successfully tracked.

The entry survey data set was drawn from 13 survey questions that covered socio-demographic factors, reason for visit, mode of transport and frequency of visitation to Tasmania. The design of these questions was informed by the Tasmanian Visitor Survey question design to allow for comparison, analysis and interpretation across these different surveys. The exit survey data came from seven questions that covered key sources of visitor information while in Tasmania, social media usage (type and frequency), levels of expenditure and overall trip satisfaction. The latter two were designed to dovetail with the Freycinet data set which included 12 questions focused on personal experiences and perceptions when in Freycinet National Park.

Table 1 Survey respondents based on demographic factors

	Entry survey % (N = 427)	Exit survey % (N = 133)	Freycinet survey % (N = 199)
Female	51.3	51.7	49.8
Over 60 years old	23.5	22.8	1.5
Income less than $78,000/annum	42.4	12.9	14.2
Tertiary education	59.6	57.8	58.3
Working full-time	50.5	52.0	48.0
Australian residents	64.3	61.7	73.0
China (inc. Hong Kong) residents	10.3	13.2	7.2

The tracking data set showed, with 10 m accuracy, the movement of participants for the duration of their trip and included time and date data, distance and speed data, and longitudinal and latitudinal data. This could be used to ascertain arrival and departure points, travel route and direction, key destinations including overnight accommodation locations, and the pace and duration of travel.

The 472 tracks were associated with entry survey data and were usable in analysis i.e. there was enough data in each of these tracks so that when combined with other tracks, forms of analysis could be legitimately applied. Interestingly, most individual tracks did not provide full track logs for entire trips with small or moderate sections of travel data missing. This missing data may be accounted for due to technological error (e.g. problems with the phone network or GIS signal sent from the handset), user error (e.g. forgetting to recharge the phone for a period or leaving the phone in accommodation while travelling elsewhere), or user choice (e.g. some participants may have chosen to not participate in the study after recruitment and let the phone run out of charge or may have chosen turn the phone off for periods of their trip).

Overall, these combined data sets can be used, amongst other things, to determine the following:

- The influence that factors such as entry point within the state, reasons for stay, group size, repeat visitation and demographic characteristics have upon itinerary choice;
- How niche tourists, such as those who travel to experience wilderness, consume natural destinations but significantly it will also illustrate what other, non-natural activities they undertake while travelling;
- Which tourist cohorts are driving at high speeds, late at night and on poorly maintained roads. In rural and regional areas, where wildlife presents a risk on the roads at night and in a state where, in 2014, motorcyclists accounted for 46% of tourists involved in serious casualty crashes (Tourism Tasmania 2015a), this is of course a highly significant issue.

4 Implications for tourist tracking research

Despite the challenges noted above the TSTT study was a resounding success. We argue that this was due to the holistic approach taken. Figure 1 describes the model that drove the design and implementation of the technological tracking solutions. The six elements of this model and their interrelationships will now be briefly discussed.

1. Research questions: including spatial location and temporal aspects of the study area

Big data analysis often stresses the value of after-the-fact, data-driven discovery. In contrast, the TSTT study experience suggests that, ideally, a set of well-articulated research aims and questions should underpin and guide the design of research into the movement of tourists. Aspects such as requirements for accuracy
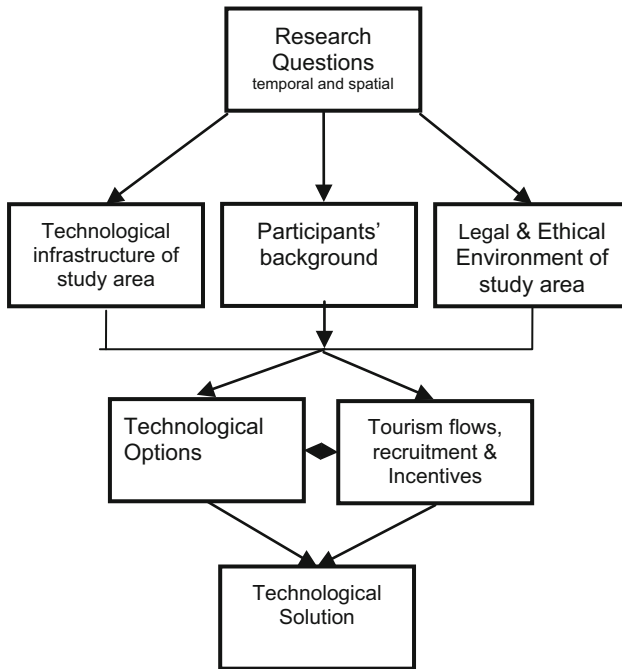
Fig. 1 A methodological model to guide the design and selection of tourist tracking technology

in movement, the correlation of movement with demographic data, and the option to align findings with existing data sets, all need to be considered.

2a. Technological infrastructure within the study region

Following the design of the research question, the technological infrastructure within the study region must be considered. If the research is being conducted in regions with highly developed infrastructure such as free, high speed Wi-Fi, the design of the technology will be very different to that which would occur in remote areas with limited coverage. For example, an app designed to collect GPS data in an urbanised region with strong Wi-Fi signals may not need to place as great an emphasis on aspects such as the frequency of the signal being transmitted back to the central server. Conversely, design for use in wilderness areas should ensure that GPS data may be stored when the mobile phone signal is low, thus creating less of a drain on battery life.

2b. Ethical/legal environment of the study region

Depending on the style of research and the requirements of the research institute in which the study is being undertaken, researchers are likely to encounter differences in what is required in relation to informed consent. In some cases, such as this study, ethical and legal requirements may contradict each other. This means that while participants must be de-identified during the data collection and analysis phase in order to meet ethical requirements, their details must be stored and secured in a separate area, in case illegal acts occur. This differs from traditional research

where de-identified data usually means that personal identification information is permanently destroyed during the analysis phase.

2c. Participants' cultural background

For this study, participants from a variety of cultures were engaged. Particular emphasis was given to those from Hong Kong and Mainland China as well as from Australia. This was a result of our funding bodies' desire to test whether cultural background was a determinant of travel behaviour, in order to create culturally relevant experiences. In the study area at the time of the research being conducted, the China market was growing rapidly (Tourism Tasmania 2015b). Specific cultural differences were noted to impact upon recruitment and willingness to participate. For example, our bilingual Mandarin-speaking recruiters noted far more initial scepticism when recruiting mainland Chinese tourists, so were required to emphasised that the research was being conducted for a university, in order to build rapport and trust. This demonstrated that the design of methods to collect tracking data must take into consideration the cultural factors that may affect the perceived credibility and importance of the project as well as cultural acceptance of tracking research.

3a. Technological options

Only after the participants' cultural background, the ethical and legal context of the region under study, and the infrastructure of the study region have been assessed may technological options be considered. This study demonstrated that this stage may result in several options appearing relevant. In situ comparison and field testing of efficiency may be required to assess different technological capabilities and abilities to answer the research questions.

3b. Tourism flows, recruitment and incentives

Given that tracking ultimately involves participants and their willingness to be involved, the final selection of the technology, should it require informed consent, should be influenced by the ability to recruit participants to take part in the study. When participants are required to fill out paperwork, wear, carry or engage with devices and/or apps, consideration of tourism flows and ultimately their recruitment into the study is paramount for the success of tourist tracking studies. It is at this stage that the attractiveness of the technology to the participants who are travelling, and therefore highly mobile, becomes significant.

In addition to recruitment, the incentives that are offered to participants need to be considered.

4. Technological solutions

The final solution to collating data on the spatial patterns of tourists will arise only after the aforementioned aspects of the study have been taken into consideration. Ultimately the solution that is chosen needs to be case, context and culturally appropriate. Technological solutions also need to be highly user-friendly and supported by highly effective participant training.

5 Conclusion

This research was ground-breaking for a number of reasons. Until now, research requiring apps to be used for tourist tracking where informed consent was required have proven to be difficult to run successfully (McKercher and Lau 2009; Thimm and Seepold 2016). This was not the case for this research. For the first time, informed consent research approach to track the movement of a large cohort of tourists over a significant temporal period and spatial area was used with success. The success of this project was not without challenges, all of which were largely related to methods and technological design. The lessons gained from these challenges have resulted in a model that can be used to guide future tourist tracking approaches. The model illustrates that responsive approaches which consider study regions' technological infrastructure, cultural contexts, and legislative environment, plus aspects related to recruitment and tourism flows, are likely to develop appropriate and attractive technological options for tracking tourists.

In the case of this study, a uniquely rich data set emerged as a result of combining a survey that was embedded within the app, with precision of the GPS capabilities of the smartphone. This elicited data that illustrated where different types of tourists travelled to within 10 m of accuracy and the speed at which they moved between and within specific destinations and attractions. Ultimately, this data is extremely valuable in a number of contexts. For the broader field of tourism research, this data will elicit uniquely rich insights into the factors that affect itinerary choice, including demographics, repeat visitation, entry and exit ports, length of stay, weather, group size and group composition. Previously much research into tourists' movement through destinations has relied on traditional methods such as diaries and recollection and has been limited spatially or temporally (see McKercher and Lau 2009; McKercher et al. 2011). The details that were gained through this study will deliver far more nuanced models of tourist movement through destinations, given the unique spatial and temporal nature of this study.

In addition, this data will make significant contributions to understanding of niche/special interest tourism. The research team will be able to examine tourists' stated motivations for visiting Tasmania, i.e. for wilderness and nature or for art and culture, and compare that to actual travel behaviour. In this way unprecedented insights into the behaviour of special interest tourists will be gained.

From an industry perspective, this data will assist destination management organisations in understanding risk-taking segments, such as those who drive late at night or at high speeds. The fine-grained nature of the GPS data will give destinations and attractions insights into how long visitors stay at their destination, which infrastructure is used and where new infrastructure is required. If conducted on a longitudinal basis, data such as this will ultimately allow destinations to assess the success or otherwise, of marketing campaigns.

The challenge for future research is to respond to the ever-changing technological environment, whilst also considering the highly mobile and rapidly changing tourism environment including the fast-changing consumer attitudes and behaviours

with respect to smartphone and app use. How these factors are taken into account will ultimately ensure the success of future tourist tracking research.

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