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iTrip, a Framework to Enhance Urban Mobility by Leveraging Various Data Sources

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Abstract

Available big data have proliferated rapidly in the last decade and continue to grow in popularity. The existing new data sources such as Online Social Networks (OSNs) and Internet of Things (IoT) influence many digital aspects in-order to shape/reshape normal life of people and other related parties such as businesses, stockholders etc. Urban mobility is one of the considerable impacted domains, where many applications and services have been provided by implicating user activities and other city information. This paper aims to provide a comprehensive view on the influence of various sources of data in the users' trips. To this end, at first we review relevant studies and available services that are designed to facilitate travelers' life as well as we identify the existing gaps in this domain. Next we propose a framework *iTrip*, which aims to utilize data from different data sources as input and then, recommend/provide advance services to various type of customers. The outcome of this framework will provide a set of summarized recommendations, predictions, decisions, and plans to be used in decision-making for long/short distance transportation mechanisms. In addition, as a future direction of this study a set of ideas and topics is provided.

Keywords: Big Data; OSNs; IoT; Urban mobility; Location based services; customer satisfaction, road planning

1. Introduction

We are living in the era of data where different large set of data is publicly available to the researcher and the challenging step now is how we can get valuable insight from this data to provide better services. This study aims to

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consider available data sources in advancing mobility services by providing various recommendations, predictions, preparations, and planning. One of these valuable sources of data are Online Social Networks (OSNs), featuring several applications with millions of active user interactions. Many OSNs systems incorporate user interactions such as content sharing and blogging based on their ideas, activities, pictures, events, and etc. In addition to social network data, in smart cities scenarios, plenty of huge set of data can be access from the deployed smart objects in an Internet of Things (IoT) infrastructure. On the other hand, nowadays organizations and governments (depending to the countries internal rules) provide multiple ranges of public open data such as weather information, inhabitants data, summarized reports of income and expenses of citizens, etc. Knowledge gaining all of these data sources is useful to tackle urban area challenges in different aspects such as cultural, weather, statistics, environmental, and transport. ICT paradigms such as Cloud Computing, big data, open data, and IoT are the essential elements for moving from urban area challenges to the vision of smart cities. Analysis performed on the data collected from all these elements help to improve public services, identify what milestones are available to improve those services, and also help drive the creation of innovative business/service that deliver social and commercial values based on different predictions and recommendations.

In this study, we aim to provide a framework to enhance urban mobility by leveraging all these various source of data and provide different range of services to different group of customers. To this end, this study introduces an integrated framework iTrip (intelligent trip) for urban sustainability issues by using data that have been generated in cities, e.g., traffic flow, mobility of people, goods distribution, and environmental data obtained from different sensors. The proposed framework combines several previous efforts to enhance users' experiences in the conventional city related areas like transportation, urban planning, environment, ecology, and sociology. The main contributions of this study are as follows:

- a comprehensive literature review identifying existing gaps in the previous studies related to this work
- identification of how available data sources can be used in recommendation/prediction systems in different problems related to urban city planning and operations
- proposal of a comprehensive framework that includes difference modules (Figure 1) based on various available data categories
- analysis of these modules in terms of types of services that the end users (travelers, citizens, businesses owners and consumers) and other entities, such as city planners can benefit
- a set of future work as next steps for the framework adaptability and transferability

The rest of the paper is organized as follows. In Section 2, we present a summary of the previous studies in-order to identify how various source of data are used in different route planning systems, location based services, and other aspects of urban mobility. Section 3 introduces the proposed framework and section 4 describes future research directions of this study. The paper conclusions are presented in Section 5.

2. Related Work

The related work to this study can be categorized in two groups. The first group includes studies that aim to use social network data to enhance citizens, tourism, and transport related aspects by providing new services. The second group of previous studies is using other data sensors such as IoT and open data for city planning and route planners.

In the literature there are only a few recommendation systems use social media content and many of them were target only one or few social networking platforms. Quercia et al. (2015) were able to reliably map smell related data collected from geo-referenced picture tags of Flickr, Instagram, and geo-referenced tweets from Twitter into a smell related words dictionary. Yet urban city planning concerned with people health and also attractiveness of different areas and therefore smelly and pleasant routes suggested by the previous work help to analyze urban air quality indicators. Vaca et al. (2015) did another study to map the functional use of the city areas such as cluster of hotels and electronic shops upon geo-referenced foursquare data. Another study is conducted by Quercia et al. (2014) about automatic suggestions for the emotionally pleasant routes like happy and beautiful routes using 7M geo-referenced Flickr pictures. Another study done by Quercia et al. (2012) in-order to analyze the characteristics of a community and its residents' use of words considering Twitter users. Apart from that many literatures can be identified on the location based services utilizing the social network information to track user mobility; Cheng et al. (2011), Gao et al. (2012), Scellato et al. (2011). Bao et al. (2012), and Gao et al. (2013) analyzed human behavior using location based social networks (LBSNs). Many of these studies investigate various aspects of human behaviors using temporal, spatial, and social information in LBSNs and provide services like location recommendations. Apart from that, many studies target to improve urban city development utilizing social media data. The authors of the paper Cranshaw et al. (2012) analyzed the dynamics of a city using check-ins gathered from Foursquare and make clusters showing distinctly characterized areas of the city. Another interesting concept identified by Karamshuk et al. (2013) is to get information about the optimal place for a new retail shops as it is one of the problems in land economy and they collected data from Foursquare and used various machine learning algorithms to retrieve popularity of retail stores. Daggitt et al. (2015) analyzed urban growth of 100 major cities worldwide based on the location based information collected from Foursquare.

Jing et al. (2012) propose a framework DRoF that discover different functional areas in a city based on points of interests located in a region and also using human mobility. Their framework can be adapted in urban planning, location choosing for a business, and recommendation systems.

Challenges faced in the bi-directional effects between human and opportunistic connections generated by smart devices such as smart vehicles and mobile devices in IOT are discussed by the authors Guo et al. (2013). They used a conceptual framework for dynamic network management, human behavior analysis, and information sharing among mobile devices. Enabling IoT in urban cities enhance the services offered to citizens in different aspects. Few examples are; intelligent waste containers Nuortio et al. (2006), GPRS sensors to measure air pollution Al-Ali et al. (2010), intelligent parking system using magnetic and ultrasonic sensors Lee et al. (2008), vehicle-based mobile traffic monitoring system Li et al. (2009). Another study done by Jin (2014) proposed a new framework for smart city IoT capabilities according to the impact areas of citizens (health and well-being), transport (mobility, productivity, and pollution), and critical community services using three sensing paradigms: RFID, WSN, and crowd sourcing. Apart from that, green concepts in the road systems (coaching drivers and efficient use of energy) are analyzed by the authors of the paper Ge et al. (2010) using mobile recommendations of location traces. Additionally, some studies can be found on travel recommendation systems based on offline data mining concepts using GPS trajectories of the residents and travel experts in-order to implement social itinerary recommendation system (Yoon et al. (2012)). Most of these studies are based on the data extracted from human mobility and smart devices. Few other studies are using cities open data. Pereira et al. (2015) introduced a new concept and model to design, deploy, and utilize open data from several cities in Europe in-order to help developers to use as an API which helps to implement cross-city applications targeting tourists and others. This was designed to be used by public or private entities and regional or national governments interested in publishing tourist information.

In summary, based on authors' knowledge, this study is different to previous efforts on this topic and advancing the literature by providing an integrated data sources from different type of information obtained from diversified data sensors and suggest services that can be provided to players covering all aspects of urban mobility facilitating strategic (planning) and operational levels.

3. *iTrip*, the proposed framework

The proposed framework in this study, namely iTrip, has three main components (Figure 1): (i) data management module, (ii) data analyzing module, and (iii) customer services as the output of the framework. Next we explore each of these components in detail and introduce their attributes separately.

3.1. Data Management Modules

This module includes three components which collect data from data sources as well as the historical output of the iTrip, and does some initial processing on the raw data. The detail of each module is explained below.

3.1.1. Data Sources

The first step is to have a good understanding of available source of data and how they can be collected and utilized in the proposed framework. The idea is to collect various set of data both related to users and other entities and objects related to a trip in urban mobility scenarios. The first box of the framework shown in figure 1 (i-a) includes different identified set of data sources. One of the main sources is human interactions in daily life and OSNs can be considered as a perfect source that can provide geo-referenced posts, locations, interests and most importantly users' social network profile information. Analysis performed on OSNs data help to understand most of the characteristics of users and later on we can classify users in many clusters based on their profiles and historical patterns in-order to deliver different services to dissimilar user clusters. Transportation data such as vehicle movements (especially from the successful taxi drivers) in the city area (accessible by GPS emitters) are quite useful to improve road traffic, city management, and parking spaces. Also we can collect location traces from WiFi and RFIDs of individual or object similar to the study of Ge et al. (2011). Besides that, many studies were trying to improve driving experiences based on real-time traffic patterns, GPS traces, and historical information of the vehicles. For example, Yuan et al. (2013) proposed a mechanism to process smart driving directions from the historical driving experiences and the intelligence of the taxi drivers. We can retrieve bus and train schedules using existing APIs such as Metro developer (e.g. http://developer.metro.net) in-order to improve the accuracy of the available prediction systems by obtaining the intelligence from all these data sensors. There are several studies done on public transportation system analysis such as to provide real time transport arrivals/departures to user's mobile device; Watkins et al. (2011), Schoner et al. (2013).

On the other hand, IoT data obtained from deployed sensors and devices in a smart city are useful in different scenarios such as enabling easy access with surveillance cameras, monitoring sensors and respective actuators, vehicles, and many appliances. The concept IoT capable of uniquely locate, identify, and connect different resources such as people, devices etc. in the livelihood which integrates several technologies and communications together. Another rich source of data is public open data are free to integrate and create novel applications tourists want. We can use RDF dumps or REST APIs based on the available city public data. An additional data source we can consider is the crowd data (e.g. aggregated data from a community of objects or human in a city, etc.) that help to collect and analyze many factors related to a city. One of the similar study on smart crowd is Franke et al. (2015) based on mobile phone based delivery of event specific information and location/situation specific information delivery. User feedbacks are very important for our prediction systems where we can evaluate real sense of their thoughts about the existing services. Weather forecasting data can be obtained by using several APIs like AccuWeather (http://www.accuweather.com), and OpenWeatherMap API (http://openweathermap.org/api) and also we can categorize weather related updates from the user posts of the OSNs sites like Facebook and Twitter.

3.1.2. iTrip Historical Database

An important module shown in Figure 1 (i-b) is the Historical data which is the previously produced output of iTrip framework particularly for that session. This historical data is useful when no updates are available for the target user session and in overall will help to enhance and accurate the results of prediction/recommendation systems.

3.1.3. Data Preprocessing, Filtering, Annonimization module

This module provides functionalities to convert collected data from heterogeneous sources in a unified format as the information collected from different sources are not in a format to perform direct analysis. This module includes different sub modules that conduct some preprocessing on the raw data and also apply required filtering mechanisms to ensure that necessary privacy consideration is applied in the data to respect users and regulations' concern in this regard (Figure 1, i-c). Most of the data sources are unreliable in a sense that for example, people provide biased information/opinions, data sensors may give faulty signals or may be broken etc. Therefore cleaning these data and understanding the required content is very important for the output of the iTrip framework. In addition, we need to filter the best subset for visualization using different sampling methods such as simple random sampling, stratified sampling or any other technique. Another important issue with large set of data is anonymization, where we cannot identify the exact source of the data but data remain practically useful. As a solution we can use k-anonymity model proposed in Sweeney et al. (2002) and that can be used to ensure privacy vulnerabilities also. Another important consideration with big data is trust, hence we can use trust enabled mechanisms to collect, transfer and mine data intelligence as proposed by Cao et al. (2016). Apart from that, since we are dealing with IoT data, some of the data producers need attention on data consumers and sometimes need to control the usage. One of the approaches is introduced by Cao et al. (2015) called DUPO, which capture the obligations and constraints resulting from the usage control in smart cities.

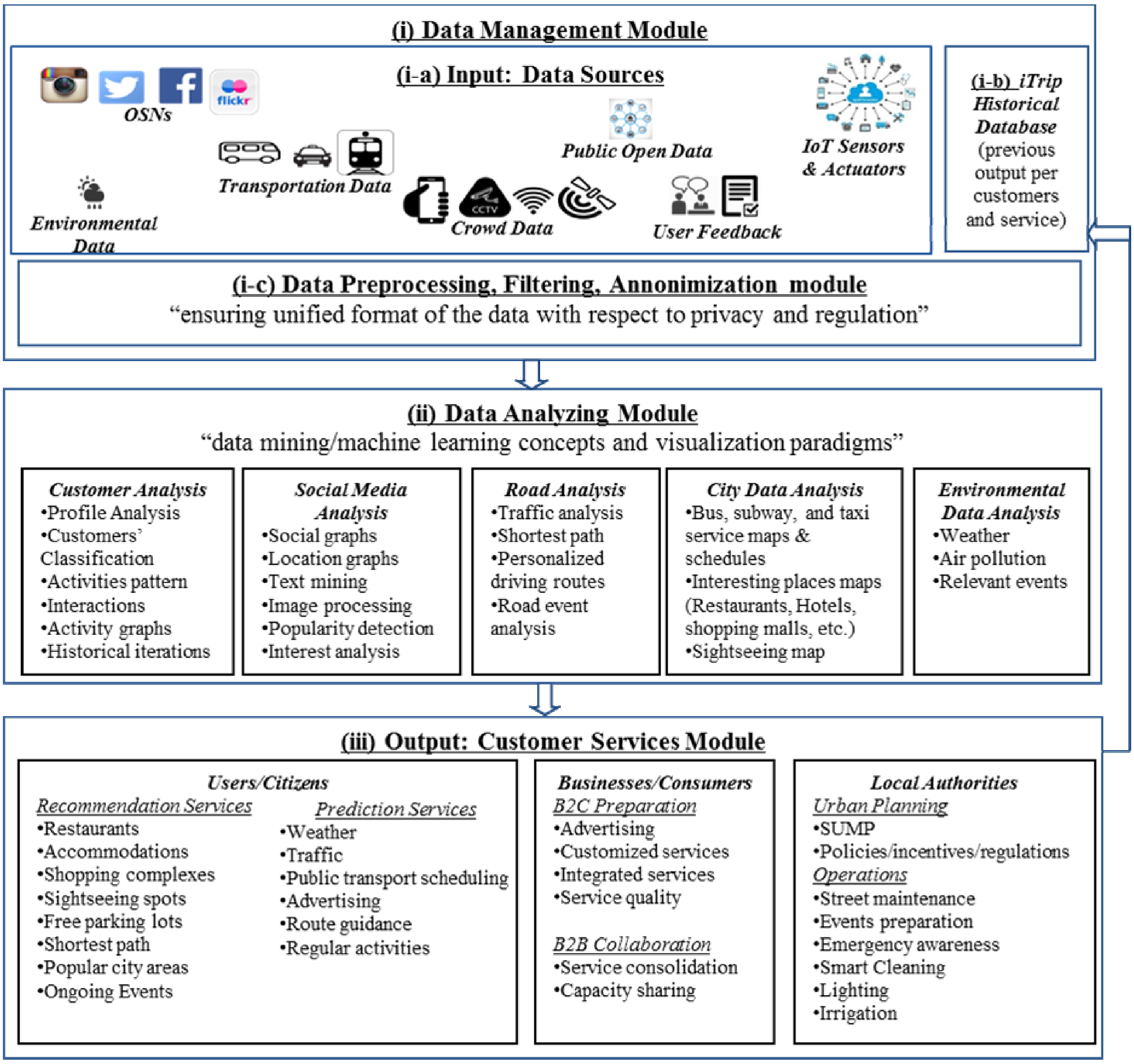

Figure 1: Interactions and components of the *iTrip* modules

3.2. Data Analyzing Module

After collecting data from the mentioned sources, we categorize them according to the functional requirements of the services and different mechanisms to analyze those data. Main challenge of the data analyzing in this study is, data from multiple sources are distributed in different systems and therefore it is impractical to analyze in a centralized environment. After pre-processing data from the data management module (i-c), we need to address several challenges to store, process, analyze, visualize, and manage large volumes of data. For this reason parallel system architectures and cloud platforms can be used with NoSQL databases to manage data effectively.

Furthermore, data analysis methods such as cluster analysis, correlation analysis, regression analysis or factor analysis can be used based on the service that we provide to the customer. Apart from that, we can use several data mining algorithms such as k-means, Apriori, C4.5 to extract hidden patterns and useful knowledge. According to the functional requirements of the services module, offline data analysis (using architectures like Hadoop) or real-time data analysis (parallel processing or architectures like HANA) can be performed.

The methodology of this work is explained below focused on five main components; user analysis, road analysis, social media analysis, city data analysis, and environmental data analysis. Analysis may be done in many different ways and there is a sufficient number of relevant applications in literature. Here, we present some indicative approaches, however, the framework is open to any approach the analyst decides on using.

3.2.1. Customer Analysis

This component analyzes all the collected data from different users (end users and business users) in-order to utilize *iTrip* framework for different objectives and interests. Each user has a distinct profile in the system that integrates with different platforms such as OSNs which contains information about user's own interests, specific activities performed daily or routinely, and also historical behaviors. Different classification algorithms and clustering algorithms can be adapted to generate these user analysis graphs. We can generate and cluster users based on various graphs by representing users as nodes and location, friendship relationship, similar interests, similar activities, similar behaviors, or similar historical patterns as edges. For example, location graphs can be generated based on both users and locations by mapping location-location and location-users similar to the study of Zheng et al. (2011) and Zheng et al. (2010) to recommend friends and locations by measuring the similarity among users in terms of their location histories obtained from location acquisition technologies such as GPS or GSM networks and also from user generated GPS trajectories in order to recommend people in the same geographical area. An HGSM framework (Zheng et al. (2011)) can be adapted to measure the similarity among users and individual's location history by incorporating content-based method into a user based collaborative filtering algorithm. Since limited data is available with a single user related to her iterations, proper user trace data can be collected using user-centered collaborative location and activity filtering (UCLAF) approach presented by Zheng et al. (2010) to gather many users' data together and to apply collaborative filtering mechanism to find like-minded users and like-patterned activities at different locations (example: culturally important places). This approach is developed for a recommendation system for city visitors on places where they might be interested to go and perform activities that they are likely to conduct in the surroundings.

3.2.2. Social Media Analysis

Social media analysis improves many issues in the existing prediction and recommendation systems. Social network data can be analyzed based on the content and association. Content based analysis mainly dealing with user posts, their profile information, and historical data. Associations are social links such as friendship, no-friendship, user-location, location-location, and location-user. We can use specified crawling methods to collect data from different OSN Web sites similar to the user profile analysis solution proposed by Reza et al. (2013) where this study use data from the Facebook. Friendship graphs, location graphs, and best routes graphs can be implemented with extracted and analyzed OSNs data. Friendship graph is similar to the user graph introduced in user analysis module that represents user-user relationship obtained from OSNs (Valafar et al. (2009)). We can make clusters based on user behaviors identified from the OSNs as the studies done by Benevenuto et al. (2009), Wilson et al. (2012), and Han et al. (2016). Location graphs can be implemented based on the user-location relationship obtained from geo-tagged images/video/text and check-ins. Users' historical data incorporates rich information about their pre-visits that we can use to cluster based on their similar historical interests similar to the study of Eagle et al. (2009). We can integrate smelly maps and emotionally pleasant routes introduced by Quercia et al. (2015) in order to implement best route graph in the social media analysis module.

3.2.3. Road Analysis

Main functionality of the road analysis component is traffic-related analysis, including recurrent situations and incidents, such as accidents (vehicle, human, etc), sport events, disasters, protests, pickets, celebrations, events, and etc. Chawla et al. (2012) experimented with large GPS dataset to model the road traffic as a time dependent flow network to measure the traffic between two regions apart from measuring only in the road. Pan et al. (2013) introduces social networks and mobility (GPS trajectories) based traffic patterns of the driver's routing behavior in the road. These two approaches can be combined to obtain very effective road prediction system by considering regions as well as road itself. Traffic management and predictions using AI technologies is proposed by Tigani et al. (2016) for smart cities to extract hidden knowledge in the collected dataset for the best decision making. Unusual local events in a monitored geo-region are analyzed by Lee et al. (2010) via Twitter posts by comparing with the knowledge on usual social events. The same technique can be adapted in our system to detect unusual events that happens in the city combining several OSNs together to obtain accurate information. There are a number of studies on shortest path and fastest driving route algorithms and maps. For example adaptive fastest path algorithm by Gonzalez et al. (2007), VANET routing Nzouonta by et al. (2009), Adaptive Beaconing Rate (ABR) approach based on fuzzy logic by Ghafoor et al. (2013) are few algorithms. We can evaluate best existing algorithms to find shortest and fastest path in order to improve user experiences based on the collected very large dataset. By considering user preferences and current conditions of the road network, a personalized driving routes algorithm FAVOUR is developed by Campigotto et al. (2016). Lastly it in our team we have implemented a visualized map namely *I-MOBI (http://imobivolos.uth.gr/website/index_en.html)* for road planning which we are going to integrate it in the *iTrip* framework as one of the future work.

3.2.4. City Data Analysis

There are two types of maps that can be considered in the city data analysis module; transportation map and touristic map of a city including interesting places and sightseeing spots. iTrip can collect available information (such as shopping malls, hotels, restaurants, sightseeing location, etc.) from the open data using its RDF format. These data provides information about the city and therefore can represent as a 3D city model using CityGML introduced by Kolbe et al. (2009). Moreover, we are witnessing a huge growth in IoT objects deployment in (smart) cities. Heterogeneous data collected from IoT devices can be mapped into Cloud of Things (CoT) for ease of abstracting and visualizing things. There are several topics in this direction which attract attention of researchers such tracking infected foods in the markets using IoT concepts (Zhang et al. (2013)). Transportation maps need to be evaluated as trajectories based on different transportation modes (bus, subways, driving, and bike). We can use GPS data and make trajectories using change point-based segmentation method as proposed by Zheng et al. (2010).

3.2.5. Environmental Data Analysis

Most of the environmental data (e.g. weather, humidity, temperature, and wind information) can be crawled from public Web applications and other available APIs. Many cities are measuring air quality using different station points and we can use those dataset in the air pollution analysis module. Real time air quality measurement approach using a vehicular based mobile approach is introduced by Devarakonda et al. (2013).

3.3. Customer Services Module

The output or services provided by the *iTrip* framework can be categorized based on different customers who are utilizing this framework as shown in the third module of the figure 1. We identifies three main customers; users/citizens, businesses/consumers, and local authorities. In overall these services include recommendation or prediction services for end users and citizen, advanced services for businesses and consumers (for both B2C - business to customers' type of services such as preparation and B2B - business to business collaboration) as well as urban mobility planning and operational actions to the local authorities. A short list of different detail services in each of the mentioned categories of customers is provided in the Figure 1.

4. Future Research Directions

There are several future research topics out of this paper which a short list of them is as follow:

- An immediate important step to follow is to set a prototype of the *iTrip* framework and implement some of the mentioned modules as well as collecting some set of data from the identified sources to evaluate the performance of the framework.
- Some of the mentioned modules in the analysis part can be studied in depth as the prior work didn't pay a lot of attention to them. An important task here is the integration between different modules and adapts it to the heterogeneity of the data which is available from different sources.
- As social media is an important source of data and previous studies are mainly based on the geo-referenced images, locations, and user chick-ins for the prediction systems, there is the possibility to use more information from them such as users' social graph which helps to enhance the framework and specifically customer service.
- Similarly, content analysis both those content generated by users and those which are available online from different parties is another hot topic. It will be interesting to collect smartly that information and analyze them to find historical behaviors and patterns using machine learning concepts to improve the framework services.
- Another future work out of this study is to provide customizable user interface including a map to enable/disable options provided by the recommendation systems unlike other static recommendation systems. To this end, we have an implemented application namely *I-MOBI* which can be used in this regard (http://imobivolos.uth.gr/website/index_en.html).

5. Conclusion

The framework introduced in this paper, namely *iTrip*, provides various types of innovations that can be implemented for providing different services for different customers in urban mobility. Firstly we overview comprehensively the liturature and identified some existing gaps. Next we propose a framework including different modules and component. The iTrip framework is an integration of all these studies with a rich information set that can be used to implement very accurate decision making systems with new technologies such as cloud based IoT analysis systems. Lastly a list of future ideas is proposed based on the iTrip framework.

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