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Data in Mobility as a Service: A Real-World Trial in Queensland, Australia

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1. Introduction

Mobility as a Service (MaaS) is a data-driven, user-centric, and integrated mobility service which conducts journey planning, booking, ticketing and payment processes for an entire multimodal journey through a single digital interface (Giesecke et al., 2016). Based on the foundation of service integration in MaaS, the integration of information, data, platform, etc., are preconditions of MaaS (Sochor et al., 2018). Multiple data sources will be integrated into a MaaS system, including but not limited to:

- Movement data: such as user's mobility data from mobile phone network data and GPS, vehicle data from connected vehicles, including passenger cars and goods vehicles.
- Public transit data: public transport (PT) timetables, real-time vehicle locations, location of the PT station.
- Mobility provider data: real-time vehicle locations of shared micro-mobility devices, taxi, car sharing, and ridesharing.
- Transaction data: from credit cards and ticketing, including PT, taxi, and shared micro-mobility.
- User's profile data: user's preferences in mode choice, purchased packages, reward points, email.

Efficient MaaS services can be provided by data integration and analysis of these data sets. On the other hand, the data produced from the MaaS platforms can improve transportation infrastructure and assist in developing an efficient and sustainable transportation ecosystem (Li et al., 2022).

UbiGo was the first-ever development of MaaS in 2013 in Gothenburg, Sweden. UbiGo was based on a monthly subscription and offered different transportation modes such as car sharing, bike sharing, PT, car rental, and taxi. To improve user experience and optimise its services, UbiGo conducted different surveys with 151 adults before, during, and after the operation (Karlsson et al., 2016). To the best of our knowledge, we could not find any documentation about users' mobility big data processing techniques in UbiGo platform. Whim, a service of MaaS Global Ltd., was launched in 2016 in Helsinki, Finland. Whim offers daily, monthly, and seasonal subscriptions with different transportation modes such as car rental, bike-sharing, PT, e-scooters, and taxis. Hartikainen et al. (2019), using the first year's travel data of Whim, analysed geographical characteristics, trip distribution, and multimodal trip preferences of

Whim users. Similarly, to the best of our knowledge, we could not find any documentation about users' mobility data processing techniques in the Whim platform. Moovit was founded in Israel in 2012. Moovit offers real-time journey planning services and digital payments across transportation modes such as car sharing, bike sharing, PT, scooters, and taxis. Moovit has been serving over 950 million riders across 112 countries. Moovit collects more than 6 billion data points from users' daily mobility. Using this big data set, Moovit analyses the efficiency of transportation infrastructure through an Urban Mobility Analytics tool and simulates operation scenarios in potential areas. Moovit also developed On-Demand Operation Modules to provide a demand response for smart shuttles.

The role of data and the data processing techniques in MaaS platforms is an emerging topic both in academia and industry, but not many studies or technical reports can summarise the systemic knowledge in this field. Using The University of Queensland (UQ)'s real-world MaaS trial – ODIN PASS, this study aims to address this knowledge gap. Contributions are demonstrated through – types of integrated/produced data, data processing techniques/platforms, data potential for insights, and data storage practices.

2. The UQ MaaS Trial

UQ, Queensland Department of Transport and Main Roads[1] (TMR), and iMOVE CRC[2] have deployed a 12-month MaaS trial for UQ staff and students with up to 10,000 participants since late July 2021. Participants of this trial can purchase a variety of monthly MaaS bundles, which vary in price depending on the specific inclusions. The bundles include options such as unlimited PT (Translink) and unlimited electric bike/scooter share (Bean and Neuron), as well as discounts on taxi trips (13Cabs) and car rental (GoGet). The results of this trial will be used to evaluate the potential impacts of MaaS on travel behaviour at UQ and, more broadly, across Queensland. This project also aims to provide detailed insights into consumer willingness to pay for MaaS bundles/services and consumer preferences towards different transport modes. This analysis will, in turn, be used to determine whether a sustainable business model exists for MaaS in Australia and whether MaaS is introduced permanently at UQ.

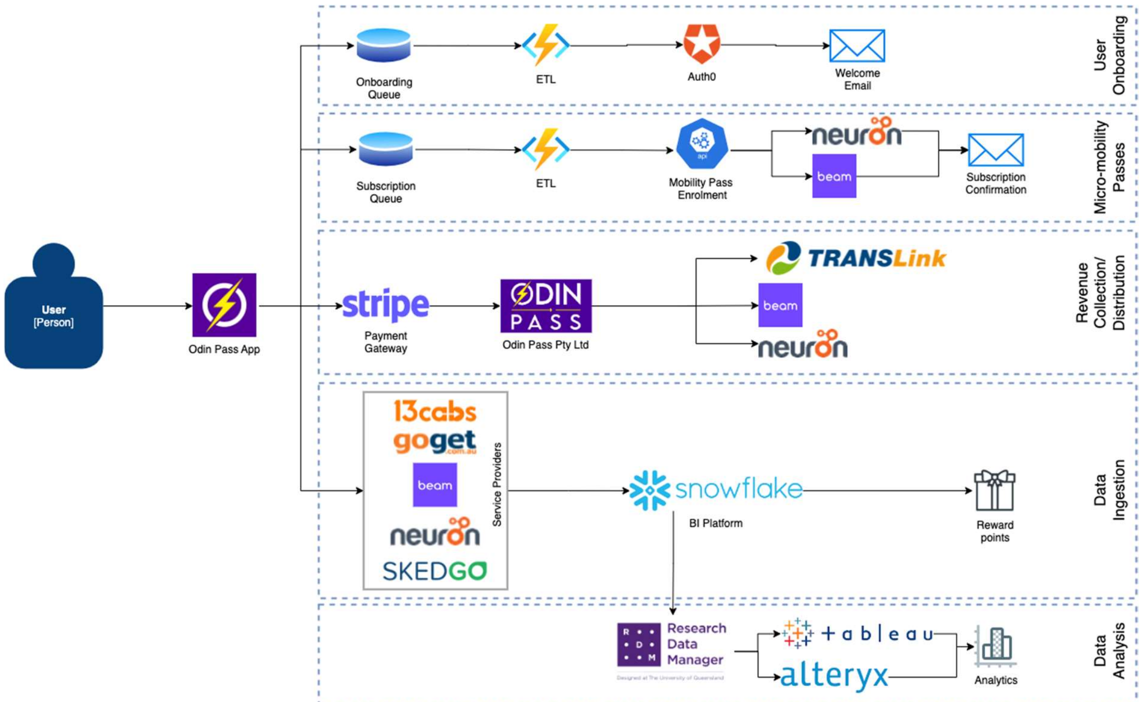
A MaaS mobile app was developed for this trial to facilitate user interactions, such as accessing real-time information, subscribing to mobility bundles, checking mobility history, enjoying mobility discounts and offers, as well as to facilitate data collection and storage, bundle design, payments and the integration of transport service providers. The ODIN PASS[3] mobile app was developed based on SkedGo[4]'s multimodal travel planner TripGo, with the addition of bespoke functionality. The ODIN PASS app is available to download for free in the Apple Store and Google Play Store, but only UQ staff and students are onboarded and able to access bundles for purchase and the included benefits. A new bundle with a specific name, price, inclusions, and a short description, can be added to the ODIN PASS platform via the administration dashboard.

3. Data Processing

The ingestion of the multi-source data is performed across various methods determined through a combination of transport service provider (TSP) preferences and ease of implementation/maintenance. The overall architecture is presented in Figure 1, showing the data functions of the platform as classified.

Figure 1: ODIN PASS user data process

[1] https://www.tmr.qld.gov.au/
[2] https://imoveaustralia.com/
[3] https://odinpass.com.au/
[4] https://skedgo.com/



3.1. User Profile Data

All potential participants (UQ students and staff) register on the ODIN PASS website through an online application form, delivering all responses to a user database. A Python data processing script was developed to address the differences in user types for data verification and onboarding. Verification is performed for the following parameters:

- User types: student, staff, or promotional concession.
- Email domains: valid UQ student or staff email domains only.
- Promotional codes: valid codes for promotional concessions.

User onboarding is handled in series through a separate function in the script. The onboarding function includes features for email reporting that can inform users or system administrators about status and errors in real-time. This script interfaces through the Auth0 user authentication platform for robust credential storage and access authorisation. As such, this interface uses Management APIs to perform the following actions:

- Retrieve users by email: checks if a user has an existing account with ODIN PASS through Auth0.
- Create a user account: appends a new user account onto Auth0, enabling ODIN PASS platform access.

With the creation of each user, a pre-programmed action on Auth0 delivers a welcome email to the user (see *User Onboarding* in Figure 1). This action, when performed, successfully onboards the user to the ODIN PASS platform. The number of registered UQ users to date on the platform is more than 2,500 unique individuals.

3.2. Bundle Subscriptions Data

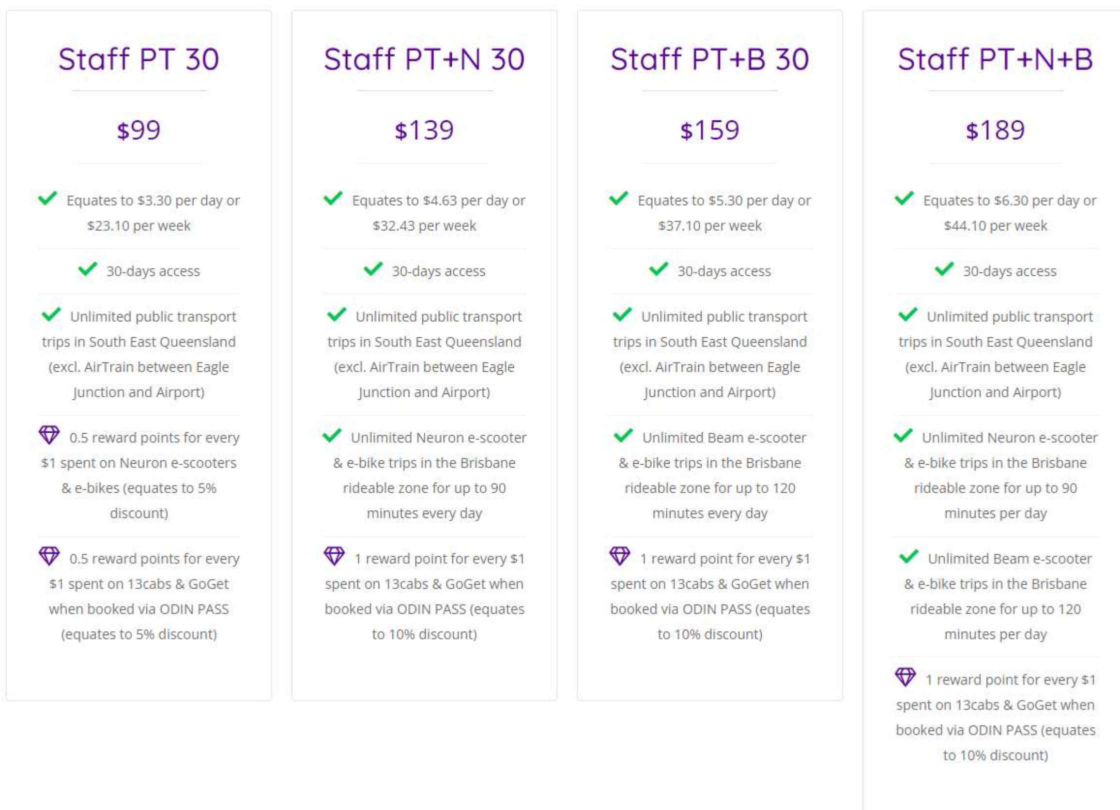
ODIN PASS offers a list of available monthly transport bundles with different inclusions and prices (please visit https://odinpass.com.au/). For instance, Figure 2 illustrates the designed bundles for the UQ staff in July 2022. Users can review each bundle's description on the ODIN PASS app and choose the one that best suits them. Once a bundle has been purchased, a 30-day subscription is immediately activated. The payment transaction is processed via Stripe[5], and the subscription data is collected and attached to the user's profile (see *Revenue Collection/Distribution* in Figure 1). The subscription data include the user ID, email address, the purchased bundle, and payment description (full payment, reward points redemption) and is combined with mobility data for users' subscription analysis (see Section 3.3).

Suppose the subscribed bundle includes micro-mobility services (i.e., Neuron/Beam). In this case, it triggers a back-end script responsible for redeeming the subscription bundle through the service providers' API (see *Micro-mobility Passes* in Figure 1). This script performs the following actions and verifications, leading to a pass redemption from the service providers; this process is similarly repeated for subscription renewals.

- Verifying and enrolling users into the micro-mobility services (importing user credentials).
- Verifying and redeeming micro-mobility passes.

This process ensures that users are enrolled on the service providers' database and that they do not possess a current pass prior to redemption.

Figure 2. Designed bundles for the UQ staff



3.3. Mobility Data

ODIN PASS receives PT usage data from SkedGo, along with all other user data from other mobility providers (micro-mobility, taxi, car-rental usage data) on a weekly basis. This data is ingested through a custom business intelligence (BI) platform, which combines the multiple usage datasets into a format that can be more easily analysed (see *Data Ingestion* in Figure 1).

[5] https://stripe.com/en-au

This platform has been developed on the Snowflake[6] Data Cloud and includes a complex fare calculator for estimating Translink fares using the General Transit Feed Specification (GTFS). The fare calculator analyses trips taken across the entire Translink network in South East Queensland and can account for multiple journey transfers, distribution of fares across different operators, and identify potential user errors. The final component of the BI Platform is a reward points generator, which assigns reward points to ODIN PASS users based on their spending on non-PT modes, matching their usage data with the respective reward points ratio they are entitled to under their current, active bundle.

PT is the only mode fully integrated into the app as part of a secure flash pass developed in consultation with Translink. This flash pass, or ticket, is shown in the app when users book a PT trip. After the user inserts the origin and destination of a trip in the app, a list of possible modes by different providers and their estimated fee, time, CO_2 emissions, and calories is shown in the journey planner results. Then, using deep links from the app, users can seamlessly book a service, referred from the ODIN PASS app to the external TSP app, with origin and destination details transferred over to the TSP app.

Once the data is ingested into the BI Platform, ODIN PASS extracts PT data and reformats this to meet Translink's requirements for billing ODIN PASS. The data is also made available to UQ for research purposes and stored in the UQ Research Data Manager (RDM), which provides a collaborative, safe and secure large-scale storage facility to practice good stewardship of research data (see *Data Analysis* in Figure 1).

On average, the UQ research team receive 4GB of PT data to analyse each month. The PT data includes: user ID, user type (student or staff), email address, purchased bundle and its start/end dates, displayed PT trips on the user's mobile phone, studied PT trips on the user's mobile phone, booked PT trips by the user, trip ID, PT service provider, PT stop ID of trip origin/destination, coordinates of trip origin/destination, trip legs, trip mode, and trip departure/arrival date and time. Also, the UQ research team receive over 2,500 records per month from non-PT service providers. This data includes trip ID, email address, trip coordinates, trip mode, and trip departure/arrival date and time.

The UQ research team has developed multiple Mobility Analytics Assets, using Alteryx (2021) to analyse users' spatial travel behaviour, cost and revenue analysis, usage of private and public transport modes, first/last mile mode, the impact of bundle's price and inclusions on users' travel behaviour, and the number of active users over time/bundle. For example, using the Alteryx Distribution Analysis Tool, Figure 3a shows that the average number of PT trips per person in October 2021 was 35 (mean value), with 531 active PT users.

Also, to gain insight from the massive amounts of data provided by different mobility providers and to report project progress to stakeholders, i.e., TMR and iMOVE CRC, Visual Mobility Dashboards, using Tableau (2021), have been developed. These interactive dashboards enable the project team to visualise ODIN PASS data, filter on-demand and interrogate the underlying data. For example, visualisation is important for analysing trips for micro-mobility data, which includes trip ids and waypoints (geographic coordinates). An example of this is shown in Figure 3b, with an ODIN PASS user who went to the St Lucia campus by e-scooter in the morning and returned in the afternoon by bus.

The mobility data analysis also has been used to improve MaaS offers. As an instance, this analysis has identified that 22% of micro-mobility trips are first/last mile trips to/from PT stations. To show the transfer rate between micro-mobility and PT services, a visualised

[6] https://www.snowflake.com/

dashboard has been developed (Figure 4) and shared with Neuron and Beam for revising their micro-mobility devices' distribution models to improve users' experience.

The discussed data architecture and availability of the data are prerequisites for operating ODIN PASS in the market 1) for user account management and validation of personal information, 2) for payments and bookings, 3) to retrieve availability of services/vehicles/rides, 4) for mobility partners' payments (such as development of PT fare calculator explained in Section 3.3), and 5) for data collection for research purposes.

Figure 3. Data analysis and visualisation examples showing (a) frequency of PT Trips in October 2021, and (b) a visual dashboard

(a) Frequency of PT trips **(b) Visual dashboard**

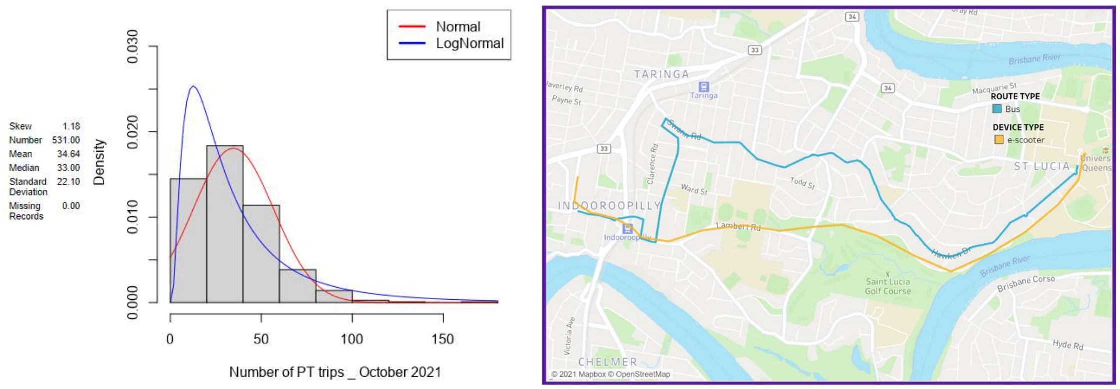
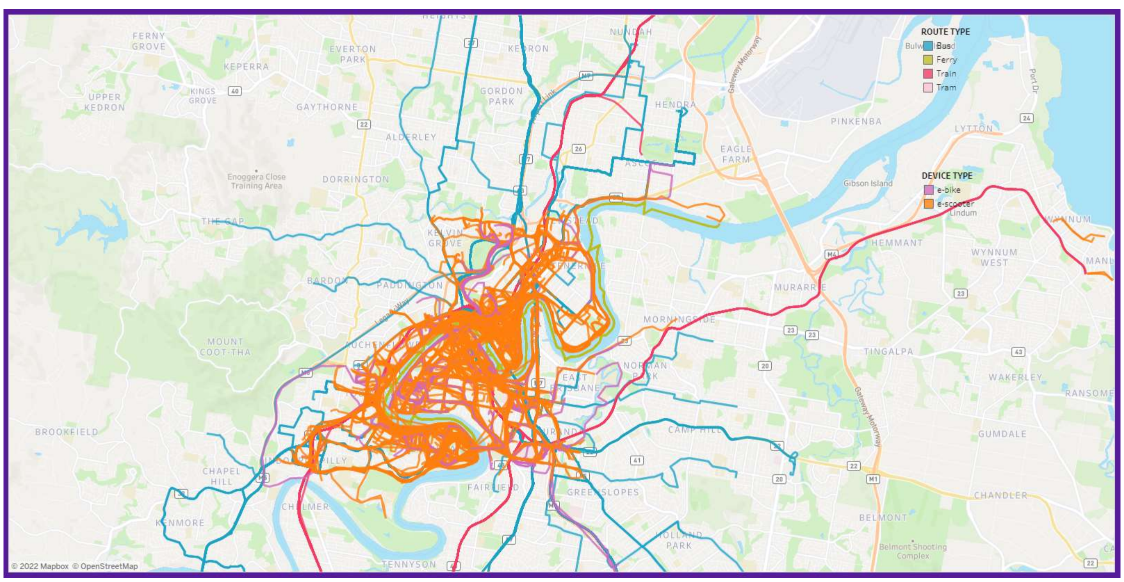


Figure 4. PT and micro-mobility trips in a visual dashboard



3.4. Open and Closed Data

Overall, the integrated data in the ODIN PASS platform is sourced from open and closed data: 1) PT static timetables – GTFS, 2) PT real-time locations and arrivals – GTFS-R, 3) Disruption data – GTFS-R, 4) Road and footpath network – OSM, 5) Cycle/Wheelchair/Accessibility friendliness – OSM, 6) GoGet locations – Closed proprietary APIs, 7) Beam/Neuron – GBFS, proprietary APIs, 8) Mapping layers – Google/Apple maps - A free proprietary service, 9) Auth0 – Partially open-source APIs, and 10) Back ends – Open-source Python libraries (e.g., email, requests).

4. Conclusion

MaaS requires the support of many technologies and analyses, such as information and communication technologies, and demand analyses and management, to provide a new business model for transportation. Therefore, data processing technologies will play an important role in offering such support. Also, the vast amounts of mobility data collected through a MaaS system contain a considerable amount of information and insights, which requires visualisation technology to present the underlying knowledge. This paper has presented data processing steps, platforms, and technologies utilised as a part of the UQ MaaS trial. Cloud computing and analysis, and visualisation tools are effectively used to support the framework of the ODIN PASS system. However, the remaining challenge in the development of MaaS is analysing and visualising large-scale data in real-time, considering that MaaS operators mainly rely on the transport service providers to share the usage data. There is currently a lack of regulation to encourage and/or enforce the sharing of data among private mobility operators. Even though this MaaS trial is principally a research project, a number of notable parties were unwilling to share data or unable to provide data in a format appropriate for the research project. Thus, government support will likely be required to facilitate data-sharing to enable wider deployment of MaaS in Australia, and internationally.

Acknowledgements

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