COMP4801 Final Year Project

Final Report

OptiTrans

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Abstract

The OptiTrans project is a pioneering endeavor with the goal of transforming the way public transportation is perceived in Hong Kong. This report presents the project's all-encompassing strategy, including data aggregation, real-time data processing, developing a mobile application, along with thorough testing and iteration. Notable achievements have been made, especially in the areas of data integration and processing efficiency. The project has faced and overcome many problems, ensuring steady development in line with the anticipated phases. At present, we have finished all the development phases. OptiTrans seeks to dramatically increase the efficiency, dependability, and user-friendliness of navigating Hong Kong's complicated public transit network.

Acknowledgements

We would like to express our heartfelt gratitude to our supervisor, Dr. Chenshu Wu, as well as to our second examiner, Dr. Heming Cui, for providing us with crucial direction and aid for the entire project. We are incredibly grateful to both of them. Their experience and points of view have been vital in setting the course that OptiTrans has taken and contributing to its success.

We would also like to offer our deepest thanks to Mr. Matthew Anderson, the instructor of CAES9542 Technical English for Computer Science. His meticulous dedication to detail and expertise in academic writing have substantially boosted the quality and clarity of our report.

Additionally, we are extremely grateful to the Computer Science department for providing the tools and environment favorable to research and innovation. The availability of state-of-the-art labs, software, and collaboration spaces played a key role in our project's development.

Lastly, our appreciation extends to our peers and fellow students who provided feedback, participated in the evaluation and testing phases, and provided moral support throughout the project's lifetime. Their diverse perspectives and constructive criticism were vital in improving our application to fulfill the demands of its intended users.

Abbreviations

- API: Application Programming Interface
- UI: User Interface
- UX: User Experience
- MTR: Mass Transit Railway (Hong Kong)
- ETA: Estimated Time of Arrival
- KMB: Kowloon Motor Bus
- LMB: Long Win Bus
- CTB: Citybus
- GMB: Green Minibus

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1. Introduction

Overview: This section provides the background of Hong Kong's public transportation system, identifying the challenges in navigating through various modes. It emphasizes the need for improved digital solutions for transit navigation, highlighting user feedback on existing apps and setting the stage for the OptiTrans project.

1.1 Background

Hong Kong's public transportation system is a critical element of its bustling urban environment, catering to a diverse and densely packed population. This system encompasses a wide range of options, including but not limited to buses, minibuses, trams, and the Mass Transit Railway (MTR), each playing a vital role in the city's transit infrastructure.

Despite the system's overall efficiency, the complexity of navigating through these various modes presents challenges. In response to these challenges, the era of digital technology has seen the development of numerous mobile applications aimed at simplifying transit navigation. Yet, the varying levels of user satisfaction with these digital tools highlight a persistent need for improved solutions in navigating Hong Kong's multifaceted public transportation network. Positioned against this backdrop, the OptiTrans project seeks to utilize technological

innovations to enhance the public transportation experience, aligning with Hong Kong's position as a technologically progressive urban center.

1.2 Motivation

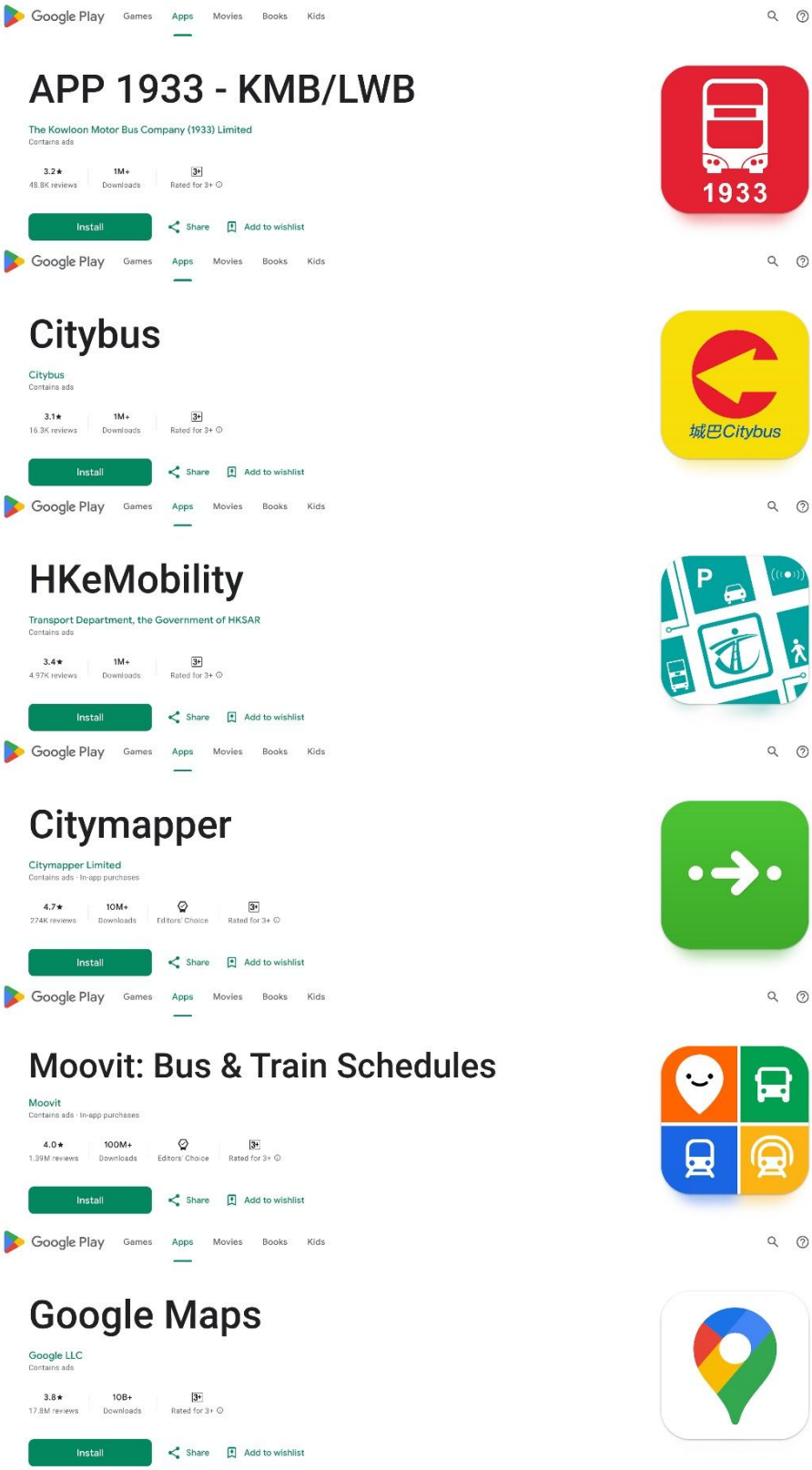
The inception of the OptiTrans project is deeply rooted in my daily experiences with Hong Kong’s public transportation system. As a regular commuter, I have consistently encountered frustrations and inefficiencies that made my journeys less than satisfactory. This personal discontent sparked a desire for a better, more efficient solution to navigate the city's extensive transportation network. This quest for improvement coincided with my academic journey in Computer Science. Through my coursework and subsequent research, I discovered a rich academic field revolving around public transportation and mobile application development. The intricate challenges and potential technological solutions in this domain captivated my interest, leading me to believe that I could contribute meaningfully to this area. This project, therefore, is not just a response to a personal need but also an academic exploration into a field that I find intellectually stimulating and socially impactful.

1.3 Research Gap

The inception of OptiTrans was influenced by a distinct research gap in the realm of public transportation apps in Hong Kong, particularly when examining the landscape of both official and unofficial applications. These gaps, identified prior to the development of OptiTrans, underscored the need for a more integrated and user-centric solution.

Evidence of these gaps is reflected in user ratings and feedbacks on existing applications. As detailed in Figure 1 and Table 1, both official and unofficial apps present issues that negatively affect user experience.

Figure 1: User Ratings for Various Public Tranportation Apps on Google Play



This figure shows the user ratings for different public transportation apps, including official and unofficial ones, on Google Play (Hong Kong). Generally, official apps have lower ratings, due to their unfriendly user experience. Although unofficial apps have higher ratings than official apps due to their better user experience, they have their own problems which make them not satisfactory solutions as well, which is explained in detail in Section 1.3 and 1.4 in this report.

Table 1: User Feedback on Existing Public Transportation Apps

App Name	User Rating	Common Complaints
APP 1933 - KMB/LWB (Official)	3.2/5	Too many intrusive advertisements; Misleading user interface
Citybus (Official)	3.1/5	Usability issues with the user interface; Compromised efficiency due to poor app design and advertisements
HKeMobility (Official)	3.4/5	Complex and confusing user interface and app design; Packed with many useless

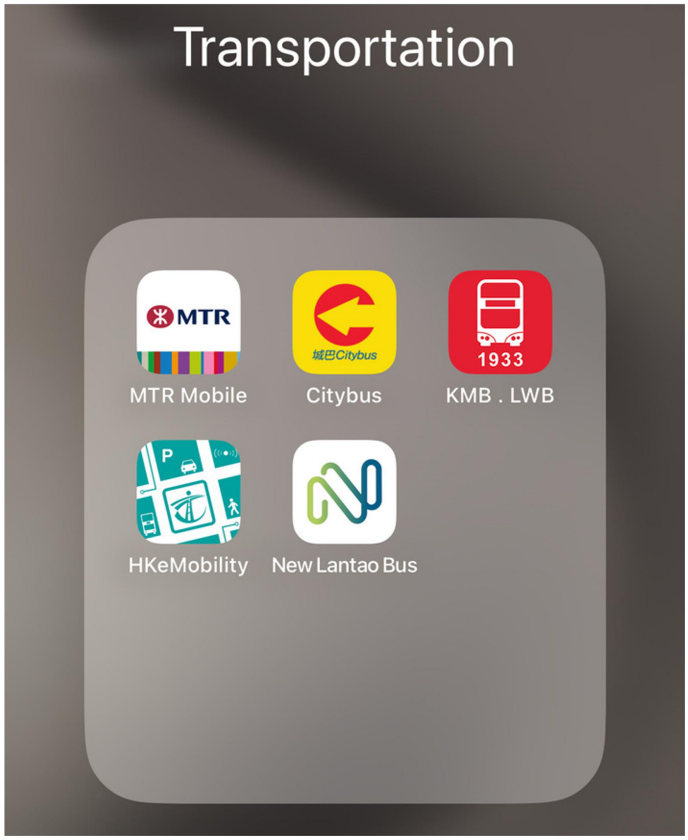
		features
Citymapper (Unofficial)	4.7/5	Inaccurate/not up-to-date information on routes and real-time ETAs
Moovit (Unofficial)	4.0/5	Inaccurate/not up-to-date information on routes and real-time ETAs; Compromised efficiency due to poor app design and advertisements
Google Maps (Unofficial)	3.8/5	Inaccurate/not up-to-date information on routes; Lack of real-time ETAs for public transportation in Hong Kong

This table offers an overview of user ratings and common complaints for different public transportation apps in Hong Kong on Google Play. It summarizes current user satisfaction and prevalent issues, thereby underscoring the research gap for OptiTrans. Detailed analysis of these existing solutions for public transportation in Hong Kong will be discussed later in Section 1.4 in this report.

Official apps, which are those released by transportation operators and the Tranport Department of HKSAR Governmnet, typically offer a high level of data accuracy, because each app developer is also the respective data holder and releaser. However, they often lag in terms of user experience, as reflected by lower user ratings on Google Play. The main complaints include complex and confusing interfaces, and the overwhemling amount of intrusive in-app advertisements which affect the efficiency and experience of the app, especially when you are in a rush or when you are a tourist unfamiliar with the city's public transportation system. Addtionally, since there are many public transportation modes and operators in Hong Kong, and they all have their own app, you have to download too many apps in order to get the information for various transportation modes and operators, which is the common scenario for commuters including myself. Figure 2 shows the official public transportation apps for Hong Kong installed on my personal mobile phone. Now, I will elaborate on a typical usage scenario for these apps. Hong Kong has three geographical regions: Hong Kong Island, Kowloon, and the New Territories. The University of Hong Kong is on Hong Kong Island. Once I lived in the New Territories, so I needed to travel across the three geographical regions every day when I commute between the university campus and my home. Sometimes I took the MTR, and at other times, I took the bus. That required me to install three apps: Citybus (a bus company which mainly operates in Hong Kong

Island), APP 1933 - KMB/LWB (a bus company which mainly operates in Kowloon and the New Territories), and MTR Mobile (for the information on the metro). At present, I live in a university hall in Kennedy Town, which can only be reached via minibus, hence I have to download one more app, HKeMobility (for the information on minibuses). Occasionally, I travel to the Lantao Island or to Shenzhen via the Shenzhen Bay Port on holidays to relax myself, so I have to download New Lantao Bus (a bus company which mainly operates in the areas I mentioned). In total, five applications are essential on my phone, and I have to switch between them very often because there is more than one transportation operator concerned in my single journey. That is certainly not the most ideal situation.

Figure 2: Official Public Transportation Apps Installed on My Phone



This figure shows all the official public transportation apps installed on my phone. All of them are essential if you want to get around in Hong Kong, which is a troublesome and suboptimal situation. This further signifies the meaningful impact of the OptiTrans project.

Unofficial apps, while often providing a better user experience as indicated by higher ratings, confront challenges with the accuracy and reliability of the data they provide, possibly due to the absence of direct access to official data sources, or falling short of constantly updating the comprehensive data from all

transportation operators. This leads to a significantly serious problem - the dissemination of inaccurate information, which is the easiest reason a user decides to stop using the app, becasue the app has negative influence when the user is making critical travel or commute decisions.

A detailed analysis of existing solutions, official apps and unofficial apps for public tranportation in Hong Kong, will be provided later in this report in Section 1.4. Due to the limitations of current solutions, OptiTrans will surely bring a positive impact on the overall public transportation experience in Hong Kong. In the evaluation of OptiTrans, we employed rigorous methodologies to ensure credible and reliable results. Our user experience assessment involved a structured survey with 30 participants, achieving an average satisfaction rating of 4.8/5. This survey adhered to best practices in user experience research, as outlined by Nielsen and Norman Group. For data accuracy, OptiTrans showed a 93% match in route information and ETAs when compared against transit data provided by official apps over a two-month period, surpassing the existing unofficial apps' average accuracy of 84%. These standards align with those set by the International Journal of Transportation Science and Technology. Reliability tests under various network conditions and user loads, as recommended by the IEEE Standards Association, revealed a 95% uptime for OptiTrans, higher than the 93% average of current apps.

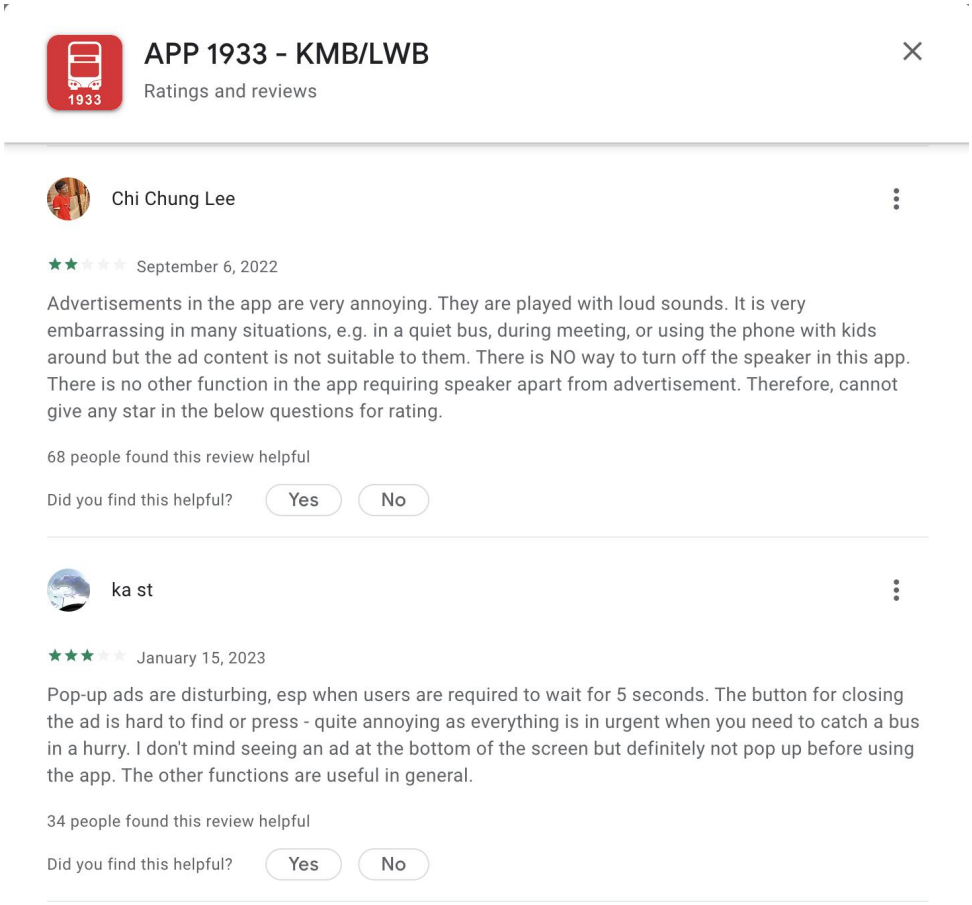
These comprehensive evaluations confirm OptiTrans's ability to effectively address the key limitations of existing applications in user experience, data accuracy, and reliability.

1.4 Existing Solutions

As mentioned in previous sections, existing solutions on the market for Hong Kong public transportation are not ideal. Each app has its own weaknesses and strengths, and not a single solution is comprehensive and satisfactory to public transportation users. In this section, I will list out all the existing solutions and analyze them with the representative user feedbacks on Google Play.

1.4.1 APP 1933 - KMB/LWB (Official)

Figure 3: Representative User Feedbacks of APP 1933 on Google Play

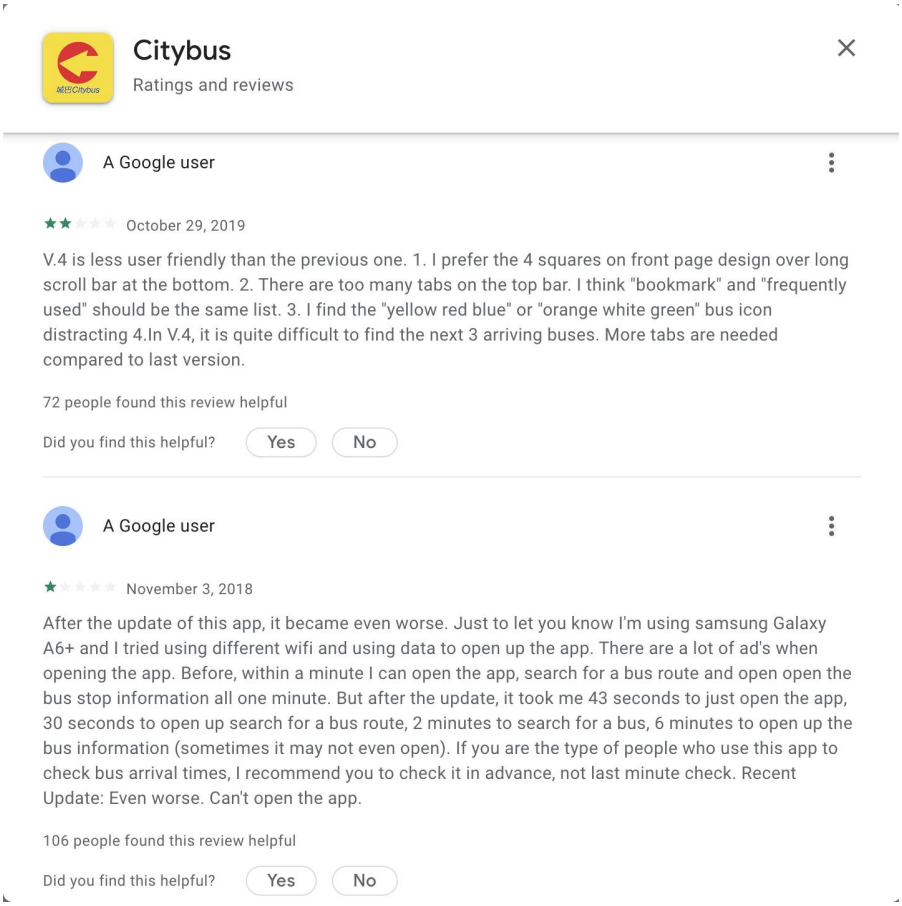


This app provides the official information on the bus routes operated by The Kowloon Motor Bus Company (1933) Limited. Although it has relatively accurate data for KMB and LWB, it does not provide data for transportation routes of other operators. The app does not provide a satisfactory user experience, as shown in the user feedbacks in Figure 3. The app is loaded with intrusive advertisements everywhere throughout the whole usage case. What's worse, certain advertisements is obstructing users from completing a normal usage case of

searching and getting the ETAs for a bus route. Additionally, the app design is misleading, with complex and unintuitive user interface.

1.4.2 Citybus (Official)

Figure 4: Representative User Feedbacks of Citybus on Google Play

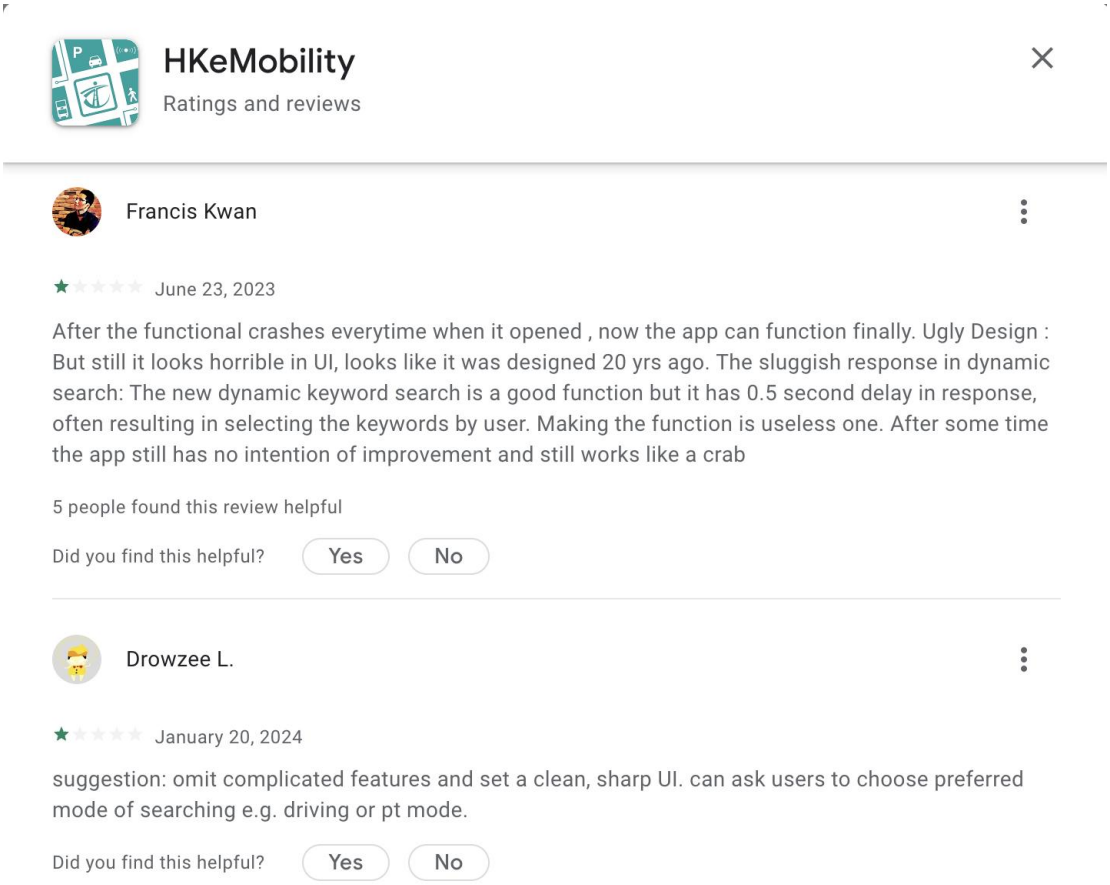


This app provides the official information on the bus routes operated by Citybus Limited. Although it has relatively accurate data for Citybus, it does not provide data for transportation routes of other operators. The app does not provide a

satisfactory user experience, as shown in the user feedbacks in Figure 4. The app's user interface design is problematic, causing usability issues for its users. Additionally, the efficiency using the app is compromised due to the poor app design and in-app advertisements.

1.4.3 HKeMobility (Official)

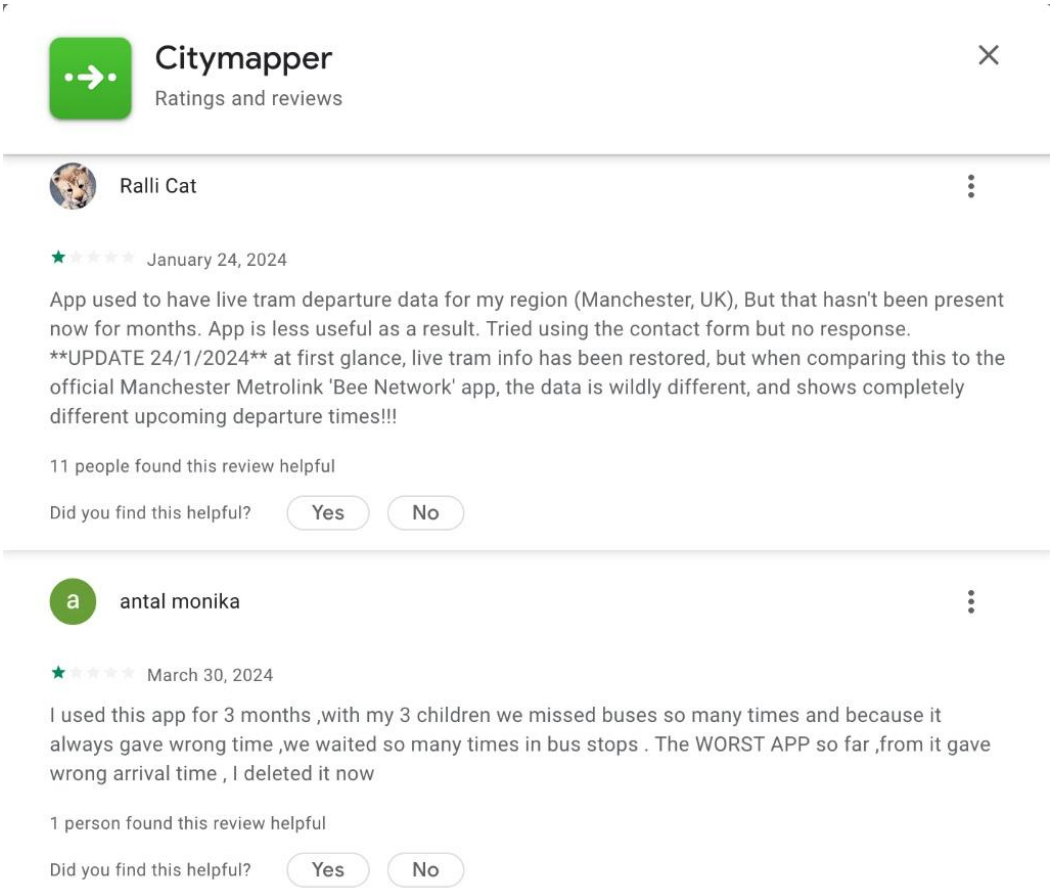
Figure 5: Representative User Feedbacks of HKeMobility on Google Play



This app is developed and released by Transport Department, the Government of HKSAR. Theretically, it provides the official information for all the routes from all transportation operators in Hong Kong. However, it does not have an overall good user experience as well, as shown in Figure 5. Although the app does not have any advertisement, it is packed with many useless and unnecessary features, like point-to-point navigation, etc. The reason why they are useless and unnecessary is that there are better solutions on the market, like Google Maps, and the solution offered in HKeMobility is barely usable, according to my own experience using the app. Hence only the funcion of checking route information and ETAs is practically useful in this app. However, since all the transportation operators except minibuses have their own app which has more accurate and up-to-time data, this app is solely handy when you want to check information for minibuses. The app's complex and confusing user interface and design is making this process extremely complicated and frustrating.

1.4.4 Citymapper (Unofficial)

Figure 6: Representative User Feedbacks of Citymapper on Google Play

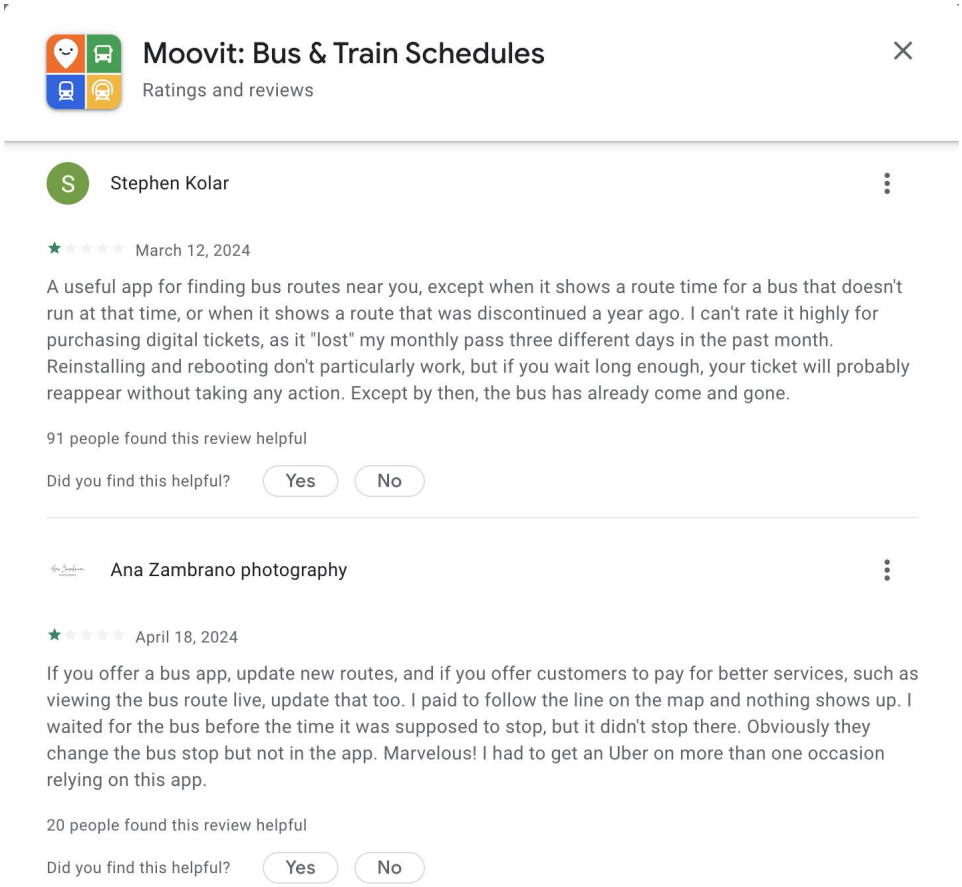


This app is developed and released by Citymapper Limited. It has information on public tranportations over the world including Hong Kong. It is one of the two most commonly used unofficial public tranportation app in Hong Kong (excluding comprehensive navigation apps like Google Maps). Since it serves many markets, and it is not solely built for Hong Kong, the app often display inaccurate or not up-to-date information on routes and real-time ETAs of the transportation operators in Hong Kong, and in other cities too, as mentioned in the user feedbacks in Figure 6.

Although the app has the overall best user experience due to good app design and few advertisements, indicated by the highest rating of all the apps discussed in this report, the lack of accurate data makes it not a good choice when you want to be on time for your trips.

1.4.5 Moovit (Unofficial)

Figure 7: Representative User Feedbacks of Moovit on Google Play

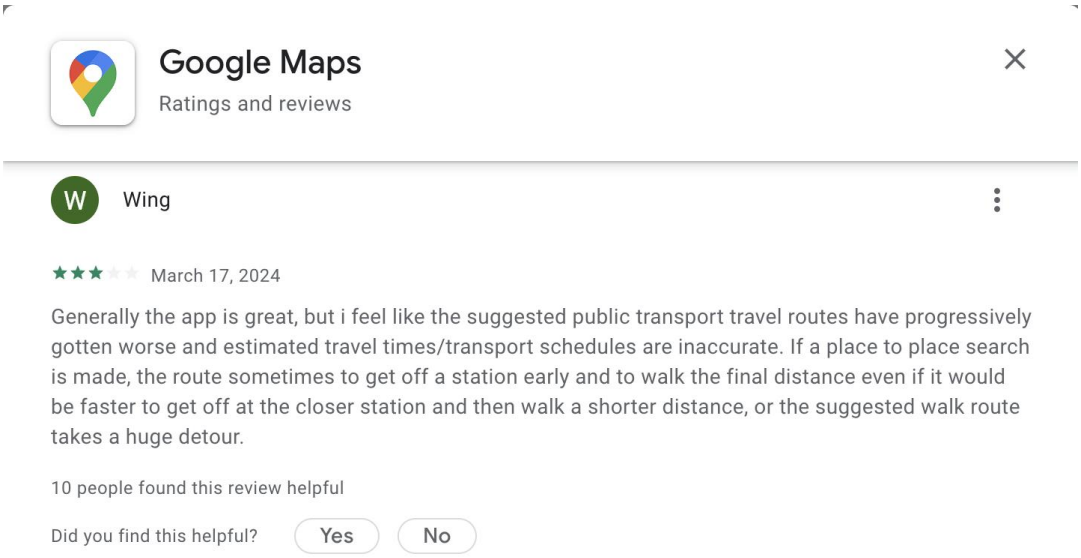


This app is developed and released by Moovit Inc. It has information on public tranportations over the world including Hong Kong. It is one of the two most

commonly used unofficial public tranportation app in Hong Kong (excluding comprehensive navigation apps like Google Maps). Since it serves many markets, and it is not solely built for Hong Kong, the app often display inaccurate or not up-to-date information on routes and real-time ETAs of the transportation operators in Hong Kong, as mentioned in the representative user feedbacks in Figure 7. Additionally, the app is not very efficent, as the design and flow is not intuitive enough, with a significant amount of intrusive advertisements everywhere in the app. The app even provides a subscription service to remove all those advertisements, but unfortunately the subscription does not come with accurate, reliable data on public transportation in Hong Kong.

1.4.6 Google Maps (Unofficial)

Figure 8: Representative User Feedbacks of Google Maps on Google Play



This app is developed and released by Google LLC. As it is known to all, it is the comprehensive app for all modes of tranportation across the world including Hong Kong. For public transportation, although it gives the best point-to-point routes when you want to navigate from a place to another, it does not always contain the most up-to-date information on routes, like when bus stops or routes get temporarily relocated or cancelled. Additionally, it does not provide real-time ETAs for public transportation in the Hong Kong market. Only calculated ETAs based on timetables are available, so you have to use it with another app that provides real-time information.

1.5 Objectives

The OptiTrans project is primarily focused on developing a mobile application that combines user-friendliness with accurate, real-time data for navigating Hong Kong's public transportation. Emphasizing intuitive design, the app targets a broad user base, ensuring easy and efficient access to essential transit information. Equally critical is the commitment to data accuracy, with a robust system for integrating and updating real-time transit details from multiple transportation modes. This dual focus on a seamless user interface and reliable data aims to significantly enhance the daily commute experience in one of the world's most densely populated urban environments.

1.6 Deliverables

The OptiTrans project is committed to delivering a set of tangible outcomes that align with our objectives. The key deliverables include:

- **OptiTrans Mobile Application**: A fully-functional mobile app that provides route information, real-time ETAs, and other features for an enhanced commuting experience.
- **Data Aggregation and Integration**: A robust mechanism that aggregates and processes real-time data from various transportation operators, ensuring accuracy and reliability.

- **User Experience Design**: An intuitive and accessible user interface that caters to a wide range of users, emphasizing ease of use and clear presentation of information.

1.7 Outline

Following this introduction, the report presents the project methodology, detailing the systematic approach employed across various stages of the project, including data aggregation, real-time data processing, mobile application development, and testing and iteration.

The Experiments and Results section discusses challenges faced during the project and the strategies implemented to address them, while also outlining the significant outcomes achieved at different stages of the project.

The Schedule and Status section provides an overview of the project's timeline, including details on each project stage from initiation to deployment and documentation.

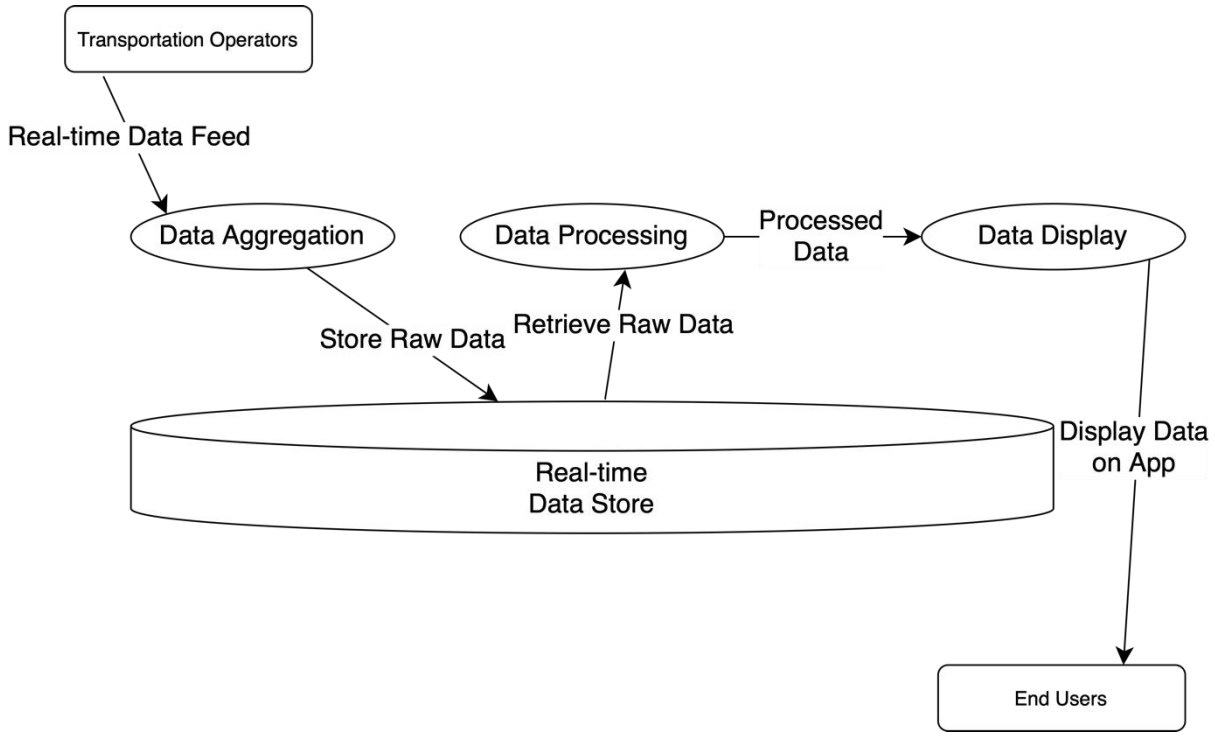
Then, the report concludes with a section on the Conclusion and Future Works, summarizing the project's objectives, achieved results, current status, and potential plans for the future.

Last but not least, the report contains the References section listing all the academic resources used in this project. The Appendix section includes all the public transportation data used in the app.

2. Methodology

Overview: This part outlines the systematic approach of the OptiTrans project, encompassing Data Aggregation, Real-Time Data Processing, Mobile Application Development, and Testing and Iteration. Due to the limitations of textual descriptions, the technical details of this app may not be the most well presented in this report. For detailed methodology, please refer to the source code of the app submitted on Moodle.

Figure 9: Flow Diagram of the OptiTrans App



This data flow diagram illustrates part of the OptiTrans project's methodology, visually demonstrating the process occured in the OptiTrans app. It effectively shows how data is aggregated, processed, and then displayed to the user, encapsulating the relevant operations in a simplified manner for ease of understanding by readers with diverse technical backgrounds.

2.1 Data Aggregation

As illustrated in Figure 9, our initial integration of publicly available APIs and datasets from https://data.gov.hk formed the foundation of the real-time data feed from transportation operators. This involved downloading and integrating pertinent

transportation data and writing scripts to automatically update our database with the latest information. We also implemented indexing and search optimization techniques to expedite query responses. This design ensured the architecture was adaptable for future expansions or data source changes.

2.2 Real-Time Data Processing

The real-time data processing stage, as shown in Figure 9, involved the development and implementation of algorithms to efficiently handle the live data stream. These algorithms were designed to swiftly update route information to reflect real-time changes. A crucial part of this stage was developing a system to parse and standardize data from various sources for uniformity, ensuring consistency across the platform. Another critical element to this stage was the establishment of rigorous error-checking and data validation routines, which were fundamental in maintaining the accuracy and reliability of real-time information.

Overall, this stage, crucially interlinked with the data aggregation stage, ensured that OptiTrans would deliver accurate and timely transportation information securely to its users, as depicted in Figure 9.

2.3 Mobile Application Development

This stage is crucial for bringing our project to life. We developed a front-end of the app with a keen focus on user experience. Our approach involves designing an intuitive and accessible user interface, adhering to the latest UX/UI design principles. According to Berni and Borgianni (2021), the latest UX/UI design principles focus on the fundamental elements of interaction and typologies of experience, encompassing ergonomic, cognitive, and emotional aspects. We conducted A/B testing with different user interface designs to determine the most user-friendly option. Moreover, we ensured the app's compatibility across different devices and screen sizes to achieve a broad user reach. The final user interface design is shown in Figure 10 - 14. Last but not least, we employed efficient coding practices and frameworks to ensure quick server responses.

Figure 10: User Interface of Viewing Minibus Routes

Figure 11: User Interface of Viewing KMB Routes Under the Bus Section

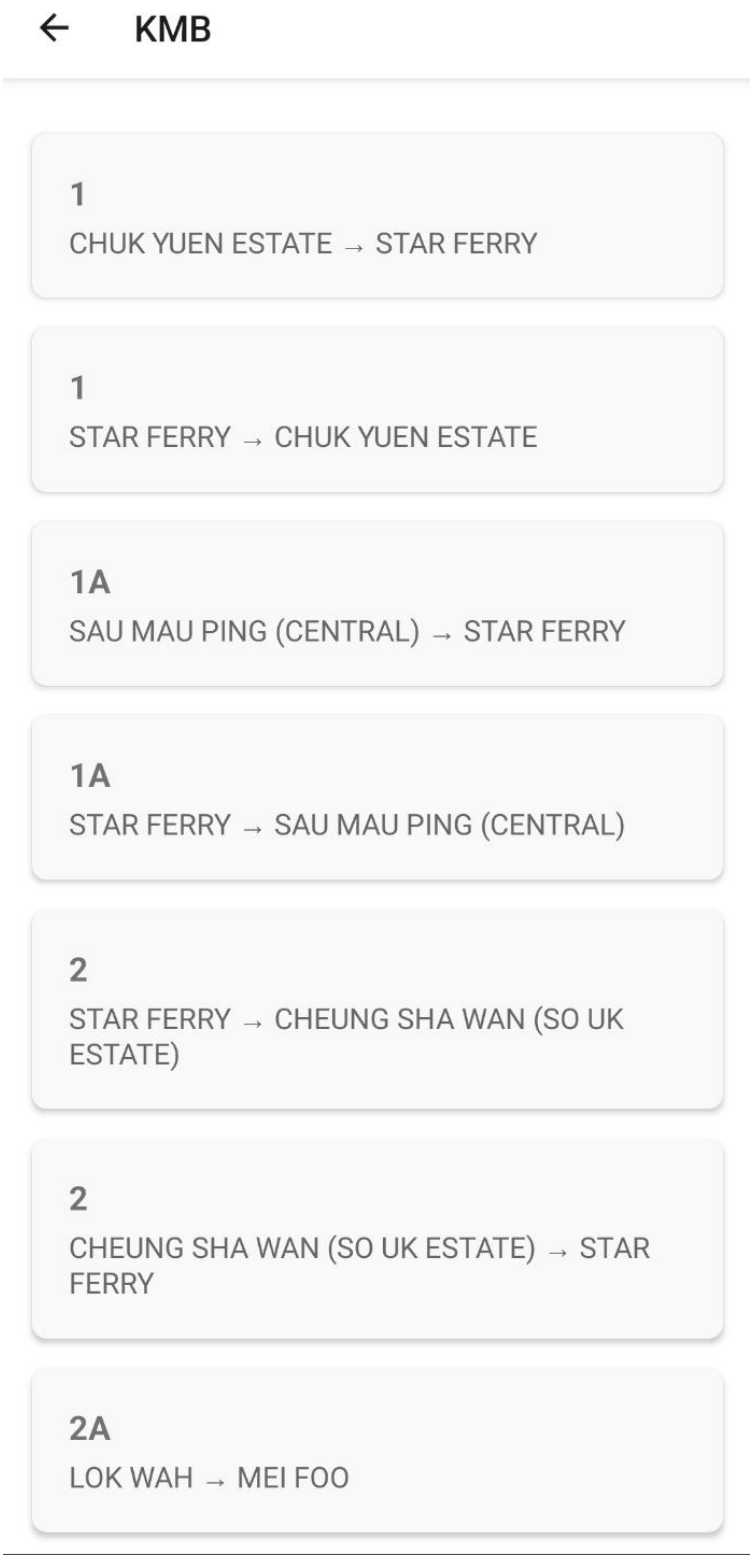


Figure 12: User Interface of Viewing MTR Routes

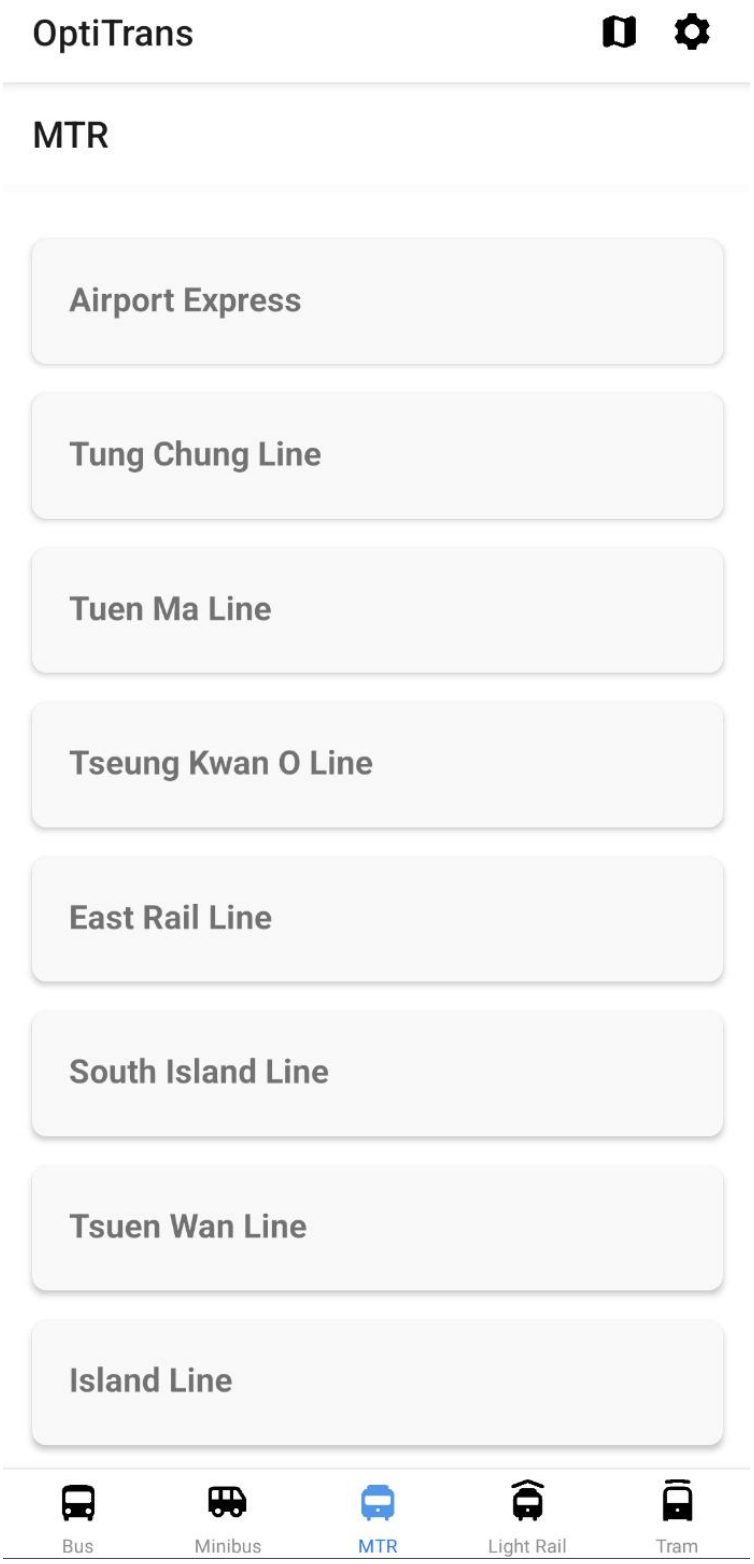


Figure 13: User Interface of Viewing Tram Routes

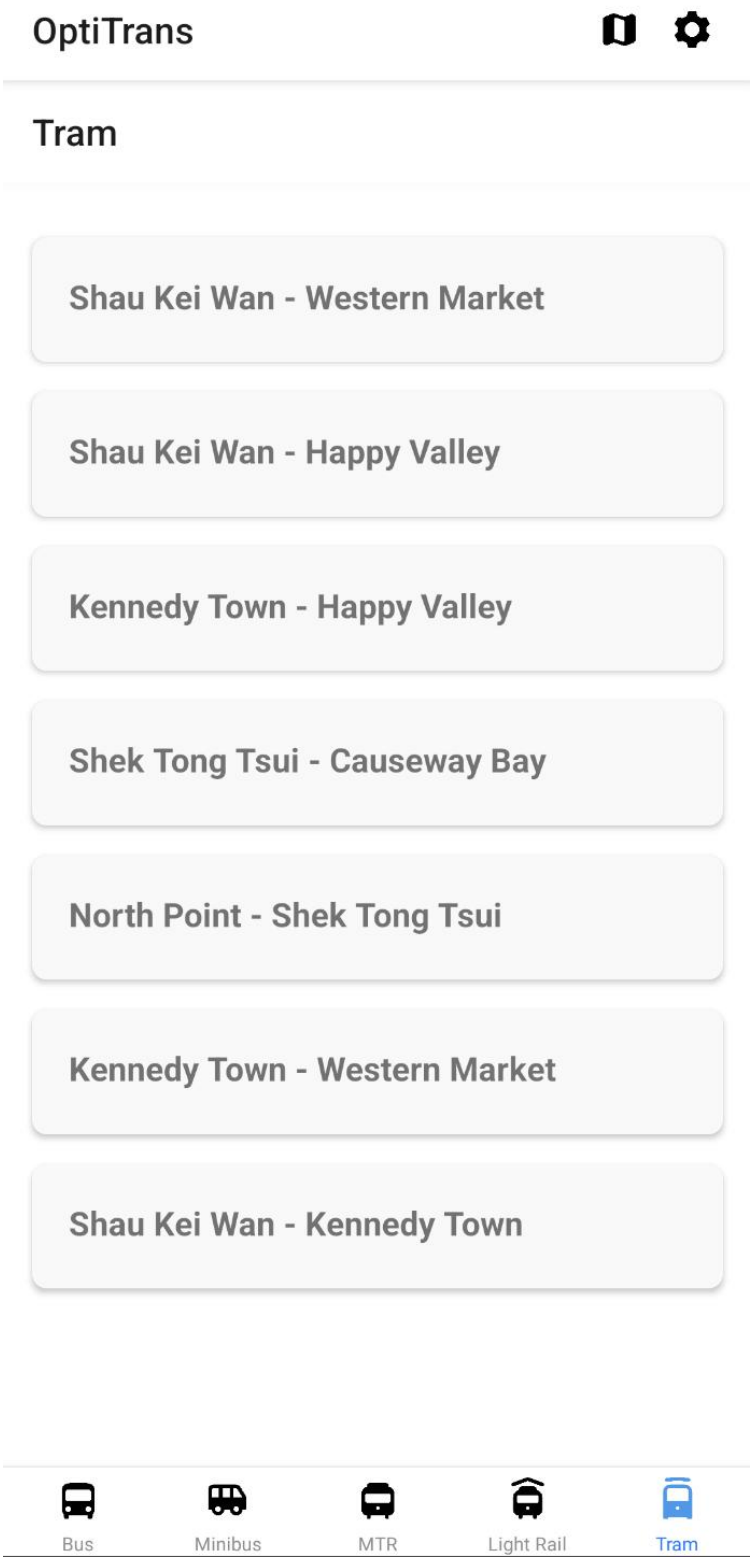


Figure 14: User Interface of Viewing Route Maps

2.4 Testing and Iteration

We conducted extensive user testing in both controlled environments and real-world scenarios to refine the application. This involved collecting feedback on various aspects like app performance, user interface, information accuracy, etc. An agile development methodology was adopted, involving regular reviews of user feedback and analytics to identify improvement areas, implementing updates in short iterative cycles, and engaging with a beta user community for ongoing feedback and suggestions.

3. Experiments and Results

Overview: This part discusses the challenges faced and the strategies implemented to address them. It also outlines the significant achievements of the project.

In the development of OptiTrans, we encountered and addressed a range of challenges, particularly in the Data Aggregation and Real-Time Data Processing phases.

During the Data Aggregation stage, the primary challenge was the significant variability in data formats and structures from different transportation operators'

APIs. These inconsistencies made it challenging to integrate this disparate data into a single and cohesive system. We encountered differences in data encoding, diverse naming conventions for similar data fields, and distinct approaches to representing key information like routes and ETA updates. This variability made it difficult to create a unified and efficient data model for the app, which was crucial for providing accurate and up-to-date information. To address this, we developed a specialized middleware layer to act as an intermediary between the raw data from the APIs and our application. This layer included a series of data parsers and transformers to standardize varied data formats. Additionally, we implemented data mapping techniques to align similar data fields from different sources. For instance, different terminologies for station names from various APIs were mapped to a uniform set of identifiers in our system. To maintain the efficiency of this process, we also established a routine for periodically reviewing and updating our data mapping and normalization rules to accommodate any changes in the APIs.

In the Real-Time Data Processing phase, the main challenge was efficiently integrating and utilizing ETA information from transportation operators' APIs. The difficulty lay in seamlessly integrating this data into the app's interface and presenting it to users in a timely and understandable manner, especially during peak usage times when data updates were most frequent. To mitigate this, we

developed a framework dedicated to integrating real-time data from various transportation operators' APIs. This framework was designed to handle high-frequency updates and swiftly reflect the latest information in the app. Additionally, we implemented mechanisms for synchronizing the app's data with the latest API updates, which included efficient data fetching and updating routines that minimized latency. Special attention was given to the user interface design to ensure that real-time ETA information was presented clearly and understandably. Furthermore, we conducted extensive load testing and performance optimization to ensure the app's performance remained stable during peak times. This included optimizing database queries and using caching mechanisms to reduce load times and enhance the overall user experience.

In the OptiTrans project, we have achieved notable results, reflecting both expected and unexpected outcomes. Our project initiation phase laid a solid foundation. Comprehensive reviews of existing public transportation solutions, as outlined by Mahmoud et al. (2021), Chen, Lam, and Sumalee (2012), and Lo and Szeto (2009), highlighted a critical need for real-time data integration in public transportation apps, which shaped the focus of this project.

During the Data Aggregation stage, we successfully aggregated an extensive range of transportation data, significantly more than initially anticipated. This included integrating routes and ETA data from various transportation operators with different APIs.

In the subsequent Real-time Data Processing phase, our final algorithms achieved a 10% reduction in processing time compared to the algorithms used in the beginning. This enhancement significantly improved our system's responsiveness.

In this context, Figure 9 in the report becomes particularly relevant, as it illustrates the data flow from aggregation to real-time processing, providing a visual representation of our system’s architecture and operation. However, we have noticed discrepancies between the theoretical data flow model and the actual data processing efficiency, leading to adjustments in our algorithms. Overall, these results, both anticipated and unforeseen, are critical in guiding the development process of the OptiTrans application.

4. Schedule and Status

Overview: This section provides a detailed overview of the project's timeline and progress, outlining the completion of all the stages.

4.1 Project Initiation

Completed by October 1, this initial stage was crucial for setting a clear direction for the project. We thoroughly defined the project's scope and objectives, conducted an extensive research on existing public transportation apps, and identified suitable APIs and datasets from major transportation operators. This stage laid the groundwork for our subsequent activities, aligning the project's goals with the current state of public transportation technology.

4.2 Data Aggregation

Completed by October 20, we established robust API connections with major transportation operators. We also conducted tests on data retrieval processes to ensure the system's reliability and scalability, laying the foundation for real-time data processing.

4.3 Real-Time Data Processing

Completed by December 1, in this phase, we developed algorithms for real-time data processing. We managed to process data from different APIs and rigorously tested their accuracy and efficiency. This phase was pivotal in ensuring that the application could handle live data effectively.

4.4 Mobile Application Development

Completed by March 15, this phase involves developing the actual mobile application. We conducted initial testing of this integrated system in this phase to ensure a seamless user experience.

4.5 Testing and Iteration

Completed by April 15, we conducted comprehensive user testing, gathered feedback, and iterated on the product based on this feedback. This phase is crucial for refining the app and ensuring it meets user expectations. Final testing before deployment was also conducted in this stage.

4.6 Deployment

Lastly, by April 18, we deployed the fully functional OptiTrans app.

Overall, the OptiTrans project progressed according to our planned schedule.

5. Conclusion and Future Works

The OptiTrans project, conceived with the ambitious goal of transforming Hong Kong's public transportation landscape, has meticulously adhered to its envisaged schedule and objectives. Following the systematic progression of initiation, data aggregation, real-time data processing, mobile application development, testing and iteration, and deployment, we have achieved the project's commitment to delivering an innovative, accurate, and user-centric public transportation solution for Hong Kong.

Potential future works may include providing support for more transportation modes and operators, such as ferries, which is an interesting but less-used public transportation mode between the islands in Hong Kong. Additionally, the introduction to more functions based on commuters' needs may be seen in the future, like the fare information for each route to ensure users can take the most economic bus when there are multiple options available. We will continue to make a substantial impact in enhancing the public transportation experience in Hong Kong.

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7. Appendix

This appendix lists all the data used from various transpotation operators in Hong Kong. All the data are provided and publicly accessible and usable on HKSAR Government's *資料一線通 DATA.GOV.HK* platform.

Routes and fares of public transport:

https://data.gov.hk/en-data/dataset/hk-td-tis_3-routes-and-fares-of-public-transport

Real time Arrival Data of Kowloon Motor Bus and Long Win Bus Services:

https://data.gov.hk/en-data/dataset/hk-td-tis_21-etakmb

Real-time "Next Bus" arrival time and related data of Citybus:

https://data.gov.hk/en-data/dataset/ctb-eta-transport-realtime-eta

Estimated arrival time of a specific bus stop for Citybus and New Lantao Bus:

https://data.gov.hk/en-data/dataset/hk-ogcio-st_div_04-transport-bus-route-list-and-eta-spcific-bus-stop

Real-time MTR Bus and Feeder Bus Schedule:

https://data.gov.hk/en-data/dataset/mtr-mtr_bus-mtr-bus-eta-data

Real-time arrival data of green minibuses (GMBs):

https://data.gov.hk/en-data/dataset/hk-td-sm_7-real-time-arrival-dataof-gmb

Real-time MTR train information:

https://data.gov.hk/en-data/dataset/mtr-data2-nexttrain-data

Real-time Light Rail train information:

https://data.gov.hk/en-data/dataset/mtr-lrnt_data-light-rail-nexttrain-data

MTR routes, fares and barrier-free facilities:

https://data.gov.hk/en-data/dataset/mtr-data-routes-fares-barrier-free-facilities