CSE 564 Project Report Phase 3

Team 7

Team Member Names:

1. Chi Ao, Chen
2. Aryan R. Suthar
3. Jean Anna Johnson
4. Dominic Baker
5. Hana Almuallem

Concept of Operations (Updated)

1. Received Requirements (Updated)....6
1.1. Shuttle scheduling 6
1.1.1. As an admin I want schedules to be created automatically to optimally fit the data. 6
1.1.2. As an admin I want to approve schedules manually to avoid potential issues. 6
1.1.3. As an environmental advocate I want the schedule to maximize shuttle utility. 6
1.1.4. As a student I want the shuttles' schedule to align with local transport. 6
1.2. Data Collection....6
1.2.1. As an admin I want student usage data to be collected from sensors. 6
1.2.2. As a student I want to give my schedule to the system for better shuttle scheduling. 6
1.3. Driver Schedule....6
1.3.1. As a driver I want to receive schedule change notifications. 6
1.3.2. As a driver I want to select my preferred work days & hours. 7
1.4. School Events....7
1.4.1. As an admin I want to schedule events on the system to allocate extra resources. 7
1.4.2. As an admin I would like to add information about scheduled events....7
1.5. Viewing Shuttle Schedule 7
1.5.1. As a student I want to view the shuttle schedule through the system to plan accordingly. 7
1.5.2. As a driver I want to view my schedule through the system to be on time....7
1.5.3. As a driver I want event days to be highlighted when there are added temporary stops. 7
1.6. Shuttle Routes....7
1.6.1. As a driver I want to view my route through the app to follow the schedule accurately. 7
1.6.2. As a student I want to see where the newly added stops are on the map. 7
1.7. App User Interface 7
1.7.1. As a student I want schedule info to be integrated on the map page for easy access. 7
1.7.2. As a student I want an abstract map for readability and faster load time. [2] 8
1.8. Delay Notifications....8
1.8.1. As a student I want to receive notifications when there are delays to plan accordingly. 8
1.8.2. As a driver I want to receive notifications relevant to my schedule through the app. 8
2. Derived Requirements 9
2.1. Shuttle Scheduling 9
2.1.1. Automated Schedule Creation 9
2.1.2. Manual Schedule Approval 9
2.1.4. Integration with Local Transport 10

2.2. Data Collection 11
2.2.1. Real-time Sensor Data 11
2.2.2. Student Schedule Integration 11
2.3. Driver Scheduling 11
2.3.1. Driver Notification System 11
2.3.2. Flexible Scheduling for Drivers 12
2.4. Event Scheduling 12
2.5. User Interface 13
2.5.1. Real-time Schedule Access 13
2.5.2. Map Interface 13
2.6. Notifications for Delays and Changes 14
2.6.1. Student Notifications for Delays 14
2.6.2. Driver-Specific Alerts 14
3. Draft Architecture 15
3.1. Functional Requirements [8], [9] 15
3.1.1. Real-time shuttle tracking 15
Description: The ASU Shuttle Dispatcher service allows real time tracking of the shuttle buses. 15
3.1.2. Dynamic scheduling 15
Description: The shuttles are scheduled to maximize student comfort & minimize waiting time. 15
3.1.3. Passenger Notification 15
Description: The shuttles are scheduled to maximize student comfort & minimize waiting time. 15
3.1.4. Driver communication 15
Description: The solution enables efficient & seamless communication with shuttle operatives. 15
3.1.5. Data collection and analysis 15
Description: The historical crowd data & user data is analyzed for efficient scheduling. 15
3.1.6. User feedback mechanism 16
Description: The historical crowd data & user data is analyzed for efficient scheduling. 16
3.2. Non-Functional Requirements [9][10] 16
3.2.1. Performance 16
3.2.2. Reliability 16
3.2.3. Usability 16
3.2.3. Security 16
3.2.4. Scalability 16

3.2.5. Maintainability 16
3.3. Reused Components 17
3.3.1. Real-Time shuttle tracking and Passenger Notification 17
3.3.2. Dynamic scheduling and Passenger Notification 17
3.3.3 Data Collection and analysis and User feedback mechanism 17
3.4. Logical View 17
3.4.1. Summary for the view 17
3.3.2. Graphical Representation 18
3.5. Process View 18
3.5.1. Summary for the view 18
3.5.2. Graphical Representation 19
3.6. Physical View 19
3.6.1. Summary for the view 19
3.6.2. Graphical Representation 17
3.7. Scenario View 20
3.7.1. Summary for the view 20
3.7.2. Graphical Representation 18
4. Requirements and Design Risk Management 22
4.1 Downside Risk 1 (Highest priority) [15][16] 22
4.1.1. Inaccurate shuttle scheduling due to data issues 22
4.1.2. Inconsistent student engagement 22
4.1.3. Manual data processing errors 22
4.1.4. Activities to Avoid this downside risk 22
4.2. Downside Risk 2 (Next highest priority) [16] 22
4.2.1. Schedule delay result from the manual approval 22
4.2.2. Inefficient alternate schedule proposals 22
4.2.3. Potential conflicts with optimal scheduling 23
4.2.4. Activities to Avoid this downside risk 23
4.3. Downside Risk 3 [17] 23
4.3.1. Data security and privacy concerns 23
4.3.2. Potential risk in system integration 23
4.3.3. Resistance to new shuttle system 23
4.3.4. Activities to Avoid this downside risk 23

4.4. Upside Risk 1 (highest priority) [18] 23
4.4.1 Optimized Shuttle Scheduling 23
4.4.2. Reduced Environmental Impact 24
4.4.3. Activities to benefit from this upside risk 24
4.5. Upside Risk 2 (Next highest priority) [19] 24
4.5.1. Real-Time Data Collection and Utilization 24
4.5.2. Enhanced Communication and Convenience 24
4.5.3. Activities to benefit from this upside risk 24
5. Conclusion 25
5.1. Overview 25
5.1.1. Integration of Data-Driven Scheduling (Conclusion 1) 25
5.1.2. Enhanced User Experience and Environmental Benefits (Conclusion 2) 25
5.1.3. Improved Driver Satisfaction and Operational Efficiency (Conclusion 3) 25
5.2. Open Issues 25
5.2.1. Data Security (Open Issue 1) 25
5.2.1.1. Data Protection Measures 25
5.2.1.2. Commitment to transparency and growth 26
5.2.2. System Scalability (Open Issue 2) 26
5.2.2.1. Performance during peak times 26
5.2.2.2. Proactive and User-focused Development 26
5.3. Parking Lot 26
5.3.1. Automated student feedback collection 26
5.3.2. Incorporating Predictive Maintenance 26
5.3.3. Expanded Multi-Modal Transport Integration 27
6. Appendix A: Credit Sheet 28

1. Received Requirements (Updated)

1.1. Shuttle scheduling

1.1.1. As an admin I want schedules to be created automatically to optimally fit the data.

- The schedules shall be created using machine learning.
- The system's accuracy shall improve with continued use.

1.1.2. As an admin I want to approve schedules manually to avoid potential issues.

- Admins get system proposed schedules and are prompted to accept or deny them.
- If denied, an alternate option is proposed by the system to the admin.

1.1.3. As an environmental advocate I want the schedule to maximize shuttle utility.

- The algorithm shall schedule shuttles to take as much students based on data.
- This will decrease the waste of empty seats and therefor carbon footprint.

1.1.4. As a student I want the shuttles' schedule to align with local transport.

- Shuttles shall be planned to leave after local transport arrives.
- Shuttles shall be planned to arrive before local transport leaves.
- This will enhance student transportation experience and quality for their success.

1.2. Data Collection

1.2.1. As an admin I want student usage data to be collected from sensors.

- The sensors need to collect data in real-time and send it to the system automatically.
- This will give us the most accurate crowd size and schedule data for optimal planning.

1.2.2. As a student I want to give my schedule to the system for better shuttle scheduling.

- This will help the system schedule around people's irregular schedules.
- Engagement will also help increase student trust in the system. [1]

1.3. Driver Schedule

1.3.1. As a driver I want to receive schedule change notifications.

- Shuttle drivers need to stay informed on their schedule to be on time
- This is important due to potential irregularities in dispatching.

---

[1] "Cognitive Psychology and Emotions in User Interface Design," TeaCode, accessed Oct. 20, 2024. [Online]. Available: https://teacode.io

1.3.2. As a driver I want to select my preferred work days & hours.

- The system shall schedule drivers based on their preferred times when possible.
- This will provide shuttle drivers with a more comfortable work experience.

1.4. School Events

1.4.1. As an admin I want to schedule events on the system to allocate extra resources.

- This must be possible through the calendar page.
- There can be multiple events on the same day.

1.4.2. As an admin I would like to add information about scheduled events

- Number of RSVP’s, event seats, and type of event.
- The system’s prediction shall use this information to enhance scheduling.

1.5. Viewing Shuttle Schedule

1.5.1. As a student I want to view the shuttle schedule through the system to plan accordingly.

- The schedule shall show the number of shuttles assigned for the time slot.
- The view shall

1.5.2. As a driver I want to view my schedule through the system to be on time.

- The view shall be at least two weeks in advance
- The view should show schedule on weekly and monthly blocks for readability

1.5.3. As a driver I want event days to be highlighted when there are added temporary stops.

- Drivers can click the event day to find the added stops and their ordering.
- This will help make sure drivers are aware of changes to their regular paths.

1.6. Shuttle Routes

1.6.1. As a driver I want to view my route through the app to follow the schedule accurately.

- Drivers have the option to see new routes and where the stops are on the app.
- They must also be able to see how long they stay at each stop.

1.6.2. As a student I want to see where the newly added stops are on the map.

- The stop shall be added visually on the map.
- This will help students and event attendees find and reach their destination on time.

1.7. App User Interface

1.7.1. As a student I want schedule info to be integrated on the map page for easy access.

- The stops shall display shuttle ETA and departure time.
- Shuttles shall be shown along their routes.

1.7.2. As a student I want an abstract map for readability and faster load time. [2]

- The map routes shall be drawn abstract (without detail) outside of campus.
- Only campus streets should be shown for navigation.

1.8. Delay Notifications

1.8.1. As a student I want to receive notifications when there are delays to plan accordingly.

- The notifications shall only go through within the students' inputted schedule.
- New ETA's and departure times would be included in the notification.

1.8.2. As a driver I want to receive notifications relevant to my schedule through the app.

- Only notify the driver of their personalized changes, not other drivers'.
- Color code notifications for dela, route changes,

---

[2] J. Stoter, L. Harrie, and S. Steiniger, "Map readability measures and automated generalization," *ISPRS International Journal of Geo-Information*, vol. 4, no. 2, pp. 420–435, 2015.

2. Derived Requirements

2.1. Shuttle Scheduling

2.1.1. Automated Schedule Creation

- **Requirement**: The system shall automatically generate shuttle schedules based on analyzed data patterns to optimize resource allocation and shuttle usage.
- **Derived points:**
  - The system should use predictive machine learning algorithms to assess historical data trends for accurate scheduling forecasts [3].
  - Integration with external data sources, like weather and traffic data, to further enhance the scheduling accuracy to anticipate delays and disruption.
  - The schedule will adjust shuttle frequency based on peak and off-peak hours to reduce idle times and improve efficiency.
  - Continuous feedback of the system refines scheduling over time, improving its accuracy and reliability while the system learns from usage data.
  - The scheduling engine should be able to simulate multiple scenarios to test potential schedules against different constraints [4].

2.1.2. Manual Schedule Approval

- **Requirement**: The system shall allow admins to approve or modify automatically generated schedules.
- **Derived Points**:
  - Administrators should have options to modify or override schedules for events or unexpected situations.
  - The system shall display the revision history of the admin changes to schedules.
  - Automated notifications should alert admins when the system proposes significant schedule adjustments.
  - Admin dashboard- Basic visualizations of shuttle use rates and possible scheduling issues.
  - It should record all scheduling changes approved by admins to refine future automated scheduling decisions.

---

[3] Noor, R. M., Rasyidi, N. B. G., & Nandy, T. (2020). "Campus Shuttle Bus Route Optimization Using Machine Learning Predictive Analysis." *Sustainability*, 13(1), 225. https://doi.org/10.3390/su13010225.

[4] Wang, J., Zhang, Y., Xing, X., Zhan, Y., Chan, W. K., & Tiwari, S. (2022). "A Data-Driven System for Cooperative-Bus Route Planning." *Annals of Operations Research*. https://doi.org/10.1007/s10479-022-04842-w

2.1.3. Environmental Optimization

- **Requirement**: The system should maximize shuttle utility and reduce environmental impact.
- **Derived Points**:
  - Shuttle utilization data should highlight occupancy levels, helping to reduce fuel consumption and emissions by maximizing route efficiency [5].
  - Scheduling algorithms should prioritize routes that minimize idle time and unnecessary mileage, further reducing carbon emissions [3].
  - Routes should be periodically reviewed for environmental impact and revised to optimize shuttle load.
  - The system shall report carbon emissions data to assess and communicate the program's environmental benefits, promoting sustainability initiatives on campus.
  - Environmental impact metrics should include greenhouse gas emissions, fuel usage, and seat occupancy rates, providing measurable insights into shuttle service optimization.

2.1.4. Integration with Local Transport

- **Requirement**: Shuttle schedules shall align with local transportation services.
- **Derived Points**:
  - An automated data feed to fetch updates of the schedules for local transport continuously is incorporated into the system.
  - The system automatically adjusts to changes in public transport schedules.
  - Shuttle timings adjust dynamically to accommodate students affected by delayed local transportation.
  - A notification feature alerts students and drivers of shuttle time changes due to local transport delays or cancellations.
  - The system prioritizes stops near major transport hubs, like train stations and bus terminals, during peak hours.
  - This would increase connectivity among modes and decrease transfer wait times.
  - Analytics data will identify high-demand transit connections and peak times to proactively prevent congestion through scheduling.

---

[5] Schuß, M., Rollwagen, A., & Riener, A. (2022). "Understanding Operator Influence in Automated Urban Shuttle Buses." *Multimodal Technologies and Interaction*, 6(12), 109. https://doi.org/10.3390/mti6120109

[3] Noor, R. M., Rasyidi, N. B. G., & Nandy, T. (2020). "Campus Shuttle Bus Route Optimization Using Machine Learning Predictive Analysis." *Sustainability*, 13(1), 225. https://doi.org/10.3390/su13010225.

2.2. Data Collection

2.2.1. Real-time Sensor Data

- **Requirement:** The system shall collect real-time data from sensors to inform scheduling.
- **Derived Points:**
    - Data from sensors should feed into a central repository, allowing real-time adjustments to shuttle routes and schedules, improving efficiency and user experience.
    - Anomalous data should trigger alerts for manual review to ensure data integrity, reducing errors in schedule adjustments [6].
    - Aggregated sensor data combined with external sources like event calendars should inform schedule modifications during high-demand events.
    - Data storage redundancy and encryption protocols are essential for protecting sensitive information and ensuring data reliability [6].

2.2.2. Student Schedule Integration

- **Requirement**: Students can input their schedules to improve shuttle scheduling accuracy.
- **Derived Points**:
    - The system automatically prompts students to refresh their schedules for up-to-date planning, aligning shuttle routes with current student needs.
    - A Privacy Policy and secure data protocol should ensure data confidentiality and compliance with legal requirements like GDPR and FERPA.
    - Schedule sharing for shuttle optimization will be opt-in.
    - Schedule data should be anonymized and summarized to protect personal information during analysis.
    - A user-friendly interface allows students to easily add, edit, and delete schedule entries, improving data accuracy.
    - The system should inform students how their schedule data helps shuttle efficiency and environmental benefits to encourage participation.

2.3. Driver Scheduling

2.3.1. Driver Notification System

- **Requirement:** Drivers should receive schedule notifications.
- **Derived Points:**
    - The system shall notify the drivers of actual changes in their routes and schedule.

---

[6] Schnarre, E., Appiah-Opoku, S., Weber, J., & Jones, S. (2022). "Improving Mobility on College Campuses for Commuting Students." *Urban, Planning and Transport Research*, 10(1), 466–482. https://doi.org/10.1080/21650020.2022.2104755.

- Notifications: This will include a clear interface with color-coded alerts in case of delays, route changes, and special event modifications.
- A notification history log shall be maintained, allowing drivers to review past alerts and track changes made to their schedules [7].
- The system should include an escalation feature that re-sends critical notifications if not acknowledged within a set timeframe, ensuring drivers remain informed of urgent updates [3].

2.3.2. Flexible Scheduling for Drivers

- **Requirement:** Drivers can set preferred work days and hours.
- **Derived Points:**
  - The system should include a driver availability database to align scheduling with their preferences and operational needs.
  - The system should allow shift swaps to accommodate last-minute driver schedule changes.
  - Drivers should have access to an interface where they can mark their availability for upcoming weeks, allowing for better advance planning [7].
  - The system should incorporate a driver notification feature for open shifts, allowing available drivers to fill in last-minute vacancies [5].

2.4. Event Scheduling

2.4.1. Resource Allocation for Events

- **Requirement:** The system should allocate additional resources during events.
- **Derived Points:**
  - Device event data should integrate into the scheduling model to dynamically update routes and add stops as needed, ensuring adequate shuttle resources.
  - Special event route mapping should display in driver and user interfaces, allowing event participants to view shuttle routes over the event area.
  - Shuttle routes and schedules should be updated dynamically in response to real-time attendance changes at events, ensuring sufficient capacity is available.
  - The system should enable admins to reserve specific shuttles or increase shuttle frequency during peak event times, enhancing service reliability [5].

---

[7] Alamatsaz, K., Quesnel, F., & Eicker, U. (2024). "Enhancing Electric Shuttle Bus Efficiency: A Case Study on Timetabling and Scheduling Optimization." *Energies*, 17(13), 3149–3149. https://doi.org/10.3390/en17133149.

[3] Noor, R. M., Rasyidi, N. B. G., & Nandy, T. (2020). "Campus Shuttle Bus Route Optimization Using Machine Learning Predictive Analysis." *Sustainability*, 13(1), 225. https://doi.org/10.3390/su13010225

2.4.2. Event Information Accessibility

- **Requirement:** Admins should add details about scheduled events for planning.
- **Derived Points:**
    - An events dashboard for displaying event details with RSVPs and additional shuttle resources required, thereby making for event management in real-time.
    - A reminder notification feature to let the students and drivers know an exact schedule of events in order to reduce disruption.
    - Admins should have the ability to update event information in real-time, ensuring the system remains responsive to any last-minute changes.
    - The event dashboard should include analytics on shuttle usage during events, allowing for future planning and adjustment based on actual data trends [4].

2.5. User Interface

2.5.1. Real-time Schedule Access

- **Requirement:** Students and drivers should have easy access to real-time shuttle schedules.
- **Derived Points:**
    - Real-time tracking of the location of the shuttle and estimated time of arrival at each stop should be provided in the app.
    - Filtering: The students can view the time of shuttles based on set filters-for instance, what time it is most busy or what time it will arrive next.
    - The system should provide “favorite routes” functionality, allowing frequent users to easily access information for their most-used shuttle stops [2].
    - A notification option could alert students when a shuttle is approaching, enhancing convenience and reducing wait times at shuttle stops.

2.5.2. Map Interface

- **Requirement:** The app should have an abstract map for readability.
- **Derived Points:**
    - Simplification techniques should ensure the map loads quickly without overwhelming viewers with irrelevant route and stop data.
    - By default, the map will automatically zoom into most relevant location based on the user's current or selected stop.

---

[4] Wang, J., Zhang, Y., Xing, X., Zhan, Y., Chan, W. K., & Tiwari, S. (2022). "A Data-Driven System for Cooperative-Bus Route Planning." *Annals of Operations Research*. https://doi.org/10.1007/s10479-022-04842-w

[2] Stoter, J., Harrie, L., & Steiniger, S. (2015). "Map Readability Measures and Automated Generalization." *ISPRS International Journal of Geo-Information*, 4(2), 420–435.

  - A “dark mode” option should be available for nighttime visibility, improving readability for users navigating in low-light conditions.
  - An option for users to toggle between “shuttle route view” and “campus view” could enhance usability by displaying more relevant information depending on the user’s needs.

2.6. Notifications for Delays and Changes

2.6.1. Student Notifications for Delays

- **Requirement:** Students should be notified of shuttle delays.
- **Derived Points:**
  - Notifications should include updated ETAs and routes to help students manage their schedules efficiently.
  - Notification timing should be customizable, alerting students only when delays significantly affect their planned schedules.
  - A priority-setting option could allow students to select high-priority routes for which they wish to receive immediate delay notifications.
  - Notifications should include a feature to suggest alternative routes when delays occur, helping students find the quickest available option [3].

2.6.2. Driver-Specific Alerts

- **Requirement:** Drivers should receive personalized alerts.
- **Derived Points:**
  - Specific route changes, new stop orders, and time adjustments should be notified to avoid confusion.
  - The system shall be able to provide acknowledgment features in which the driver can acknowledge the changes.
  - Alerts should be prioritized so that drivers receive updates on the most urgent changes (e.g., route alterations, delays) first.
  - A log feature could allow drivers to review past alerts, ensuring they stay updated on changes that may have occurred during off-hours [4].
  - Notification timing should be customizable, alerting students only when delays significantly affect their planned schedules.

---

[3] Noor, R. M., Rasyidi, N. B. G., & Nandy, T. (2020). "Campus Shuttle Bus Route Optimization Using Machine Learning Predictive Analysis." *Sustainability*, 13(1), 225. https://doi.org/10.3390/su13010225.

[4] Wang, J., Zhang, Y., Xing, X., Zhan, Y., Chan, W. K., & Tiwari, S. (2022). "A Data-Driven System for Cooperative-Bus Route Planning." *Annals of Operations Research*. https://doi.org/10.1007/s10479-022-04842-w

3. Draft Architecture

3.1. Functional Requirements [8], [9]

3.1.1. Real-time shuttle tracking

Description: The ASU Shuttle Dispatcher service allows real time tracking of the shuttle buses.

- Displays the current location of shuttles on a map.
- Provides estimated arrival times for each stop.
- Allows users to track the shuttle's progress along its route.

3.1.2. Dynamic scheduling

Description: The shuttles are scheduled to maximize student comfort & minimize waiting time.

- Adjusts shuttle schedules based on real-time events and passenger demand.
- Optimizes shuttle routes to minimize travel time and maximize efficiency.
- Notifies users of any changes to the schedule.

3.1.3. Passenger Notification

Description: The shuttles are scheduled to maximize student comfort & minimize waiting time.

- Sends alerts for delays, disruptions, or schedule changes.
- Provides notifications for upcoming stops or important announcements.
- Allows users to customize notification preferences.

3.1.4. Driver communication

Description: The solution enables efficient & seamless communication with shuttle operatives.

- Facilitates communication between drivers and dispatchers.
- Provides drivers with updated schedules and route information.
- Allows drivers to report incidents or request assistance.

3.1.5. Data collection and analysis

Description: The historical crowd data & user data is analyzed for efficient scheduling.

- Gathers data on ridership, wait times, and other metrics.
- Uses data to improve scheduling, dispatching, and resource allocation.
- Generates reports and visualizations to track performance.

---

[8] Maiti, Richard Rabin, et al. "Using OCR to read handwritten texts in search for NFRs in Agile Software Engineering." Journal of Software Engineering Practice 3.2 (2019): 1-10.

[9] Rocha, Álvaro, and João Álvaro Carvalho. "Influence of the Information System Function Maturity in the Approach to the Requirements Engineering." New Perspectives on Information Systems Development: Theory, Methods, and Practice. Boston, MA: Springer US, 2002. 205-215.

3.1.6. User feedback mechanism

Description: The historical crowd data & user data is analyzed for efficient scheduling.

- Collects feedback from passengers and drivers.
- Uses feedback to identify areas for improvement.
- Provides a channel for users to report issues or make suggestions.

3.2. Non-Functional Requirements [9][8]

3.2.1. Performance

- Ensures fast loading times for real-time tracking and schedule updates.
- Handles a large number of concurrent users and data requests.
- Maintains responsiveness during peak usage periods.

3.2.2. Reliability

- Provides accurate and up-to-date information.
- Minimizes downtime and ensures continuous service availability.
- Implements error handling and recovery mechanisms.

3.2.3. Usability

- Offers an intuitive and user-friendly interface.
- Provides clear instructions and helpful information.
- Is accessible to users with disabilities.

3.2.3. Security

- Protects user data and privacy.
- Secures the system against unauthorized access and cyber threats.
- Complies with relevant data protection regulations.

3.2.4. Scalability

- Adapts to increasing numbers of users and data volumes.
- Supports future expansion and integration with other systems.
- Can be easily deployed and maintained.

3.2.5. Maintainability

- Uses a modular design for easy updates and modifications.
- Provides clear documentation for developers and administrators.
- Implements logging and monitoring for troubleshooting.

---

[9] Rocha, Álvaro, and João Álvaro Carvalho. "Influence of the Information System Function Maturity in the Approach to the Requirements Engineering." New Perspectives on Information Systems Development: Theory, Methods, and Practice. Boston, MA: Springer US, 2002. 205-215.

[8] Maiti, Richard Rabin, Aleksandr Krasnov, and Deanna Marie Wilborne. "Agile software engineering & the future of non-functional requirements." Journal of Software Engineering Practice 2.1 (2018): 1-8

3.3. Reused Components

3.3.1. Real-Time shuttle tracking and Passenger Notification

- Displays the current location of shuttles on a map.
- Provides estimated arrival times for each stop.
- Allows users to track the shuttle's progress along its route.

3.3.2. Dynamic scheduling and Passenger Notification

- Adjusts shuttle schedules based on real-time events and passenger demand.
- Optimizes shuttle routes to minimize travel time and maximize efficiency.
- Notifies users of any changes to the schedule.

3.3.3 Data Collection and analysis and User feedback mechanism

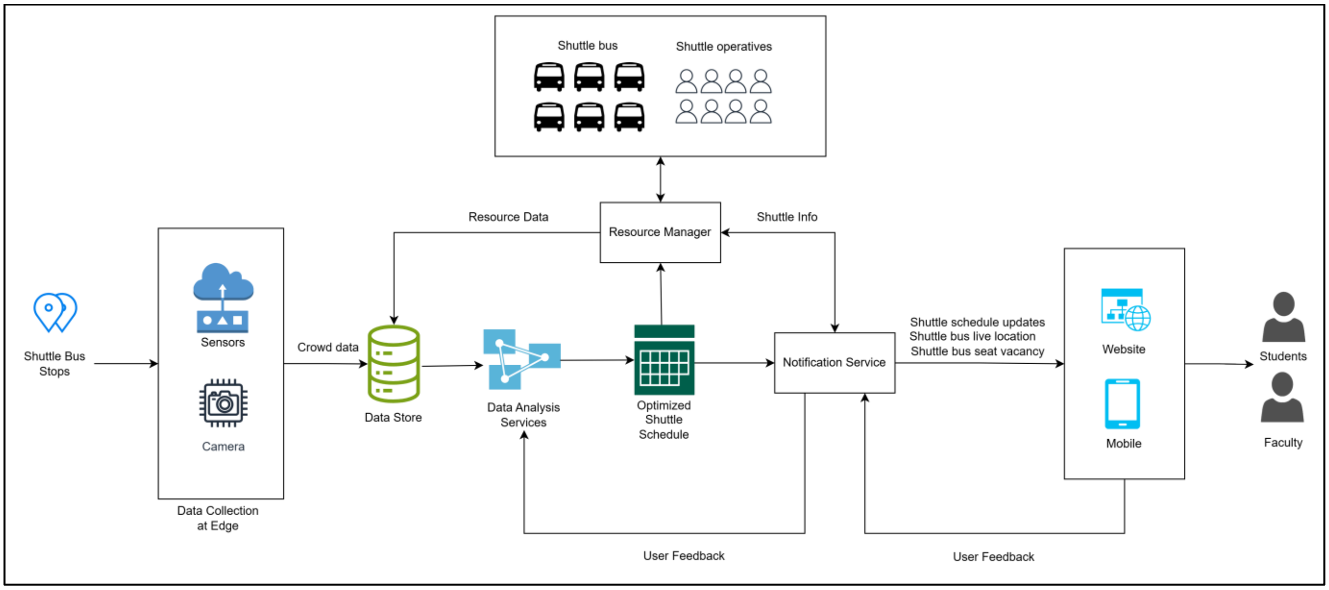
- Gathers data on ridership, wait times, and other metrics.
- Uses data to improve scheduling, dispatching, and resource allocation.
- Generates reports and visualizations to track performance.

3.4. Logical View

3.4.1. Summary for the view

- The logical view summarizes the software/hardware components, user interfaces, notification systems.
- The Resource Manager manages the shuttle and shuttle operative information.
- The Data Analysis Services analyzes the data and outputs an optimized shuttle schedule.
- The Notification service will then publish the updated schedule information to user interface.
- Website and mobile application provide & collect information from the users.

3.3.2. Graphical Representation



3.5. Process View

3.5.1. Summary for the view

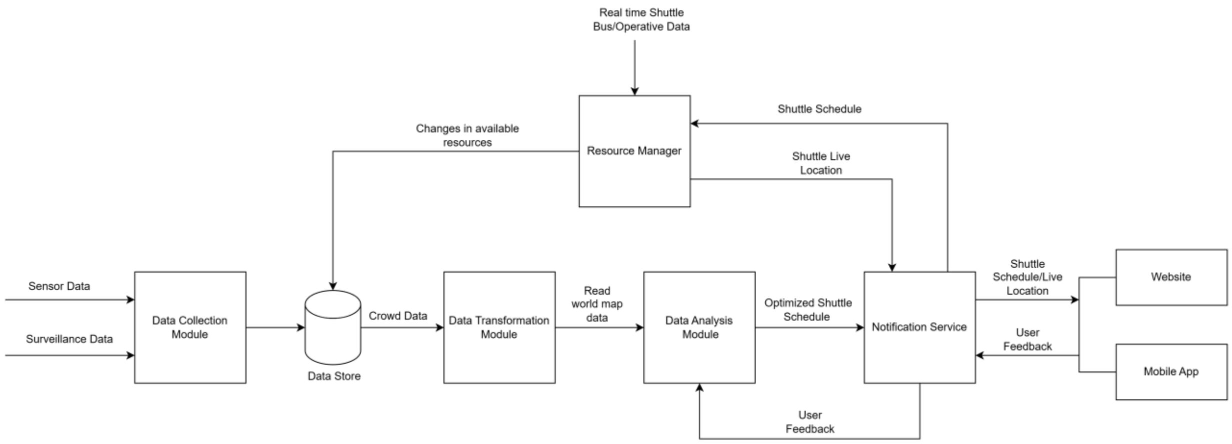
- The process view summarizes the main parts of the system.
- The Data Collection Module collects sensor data & surveillance data to track the crowd.
- The Resource Manager manages and tracks the fleet data and bus operatives' data
- The Resource Manager dispatches shuttle & bus operatives based on schedule generated.
- The Data Transformation Module transforms crowd data into real world map data for analysis [10].
- The Data Analysis Module predict the crowd trend to generate optimal shuttle schedule [11].
- The Notification Service publishes schedule information and live location information to users.
- The Notification Service publishes the shuttle schedule to the Resource Manager.
- The Notification Services collects user feedback and send it to Data Analysis module for further optimization.

---

[10] Y. Xie, J. Niu, Y. Zhang and F. Ren, "Multisize patched spatial-temporal transformer network for short- and long-term crowd flow prediction", IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 11, pp. 21548, 2022.

[11] [4] M. Z. Malik, S. Nazir and H. U. Khan, "Artificial Intelligence Based System on Enhancing the Capabilities of Transport System: A Systemic Literature Review," 2023 IEEE Symposium on Industrial Electronics & Applications (ISIEA), Kuala Lumpur, Malaysia, pp. 1-6, 2023

3.5.2. Graphical Representation



3.6. Physical View

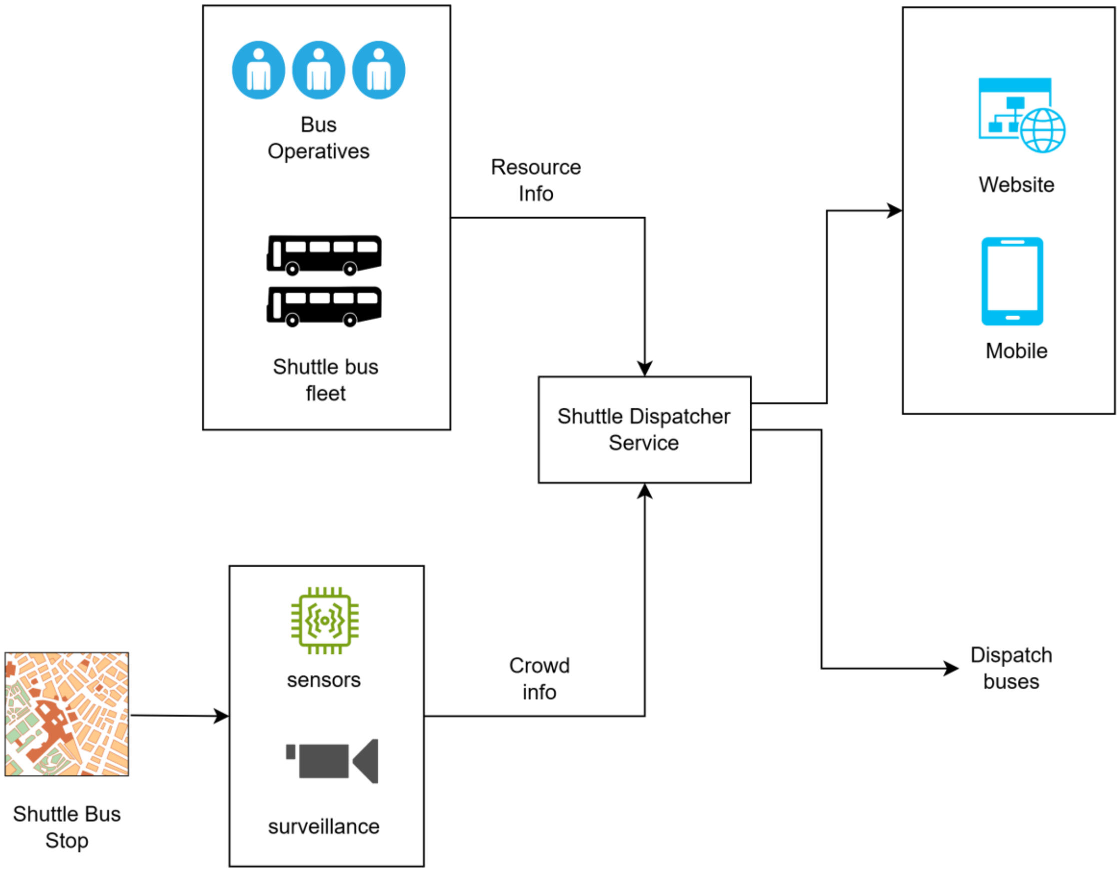
3.6.1. Summary for the view

- The physical view summarizes the hardware and infrastructure aspects.
- Sensors and surveillance equipment are set up at the bus stop to capture the crowd data [12].
- The shuttle bus fleet and the bus operatives support the operation of the shuttle service.
- The shuttle dispatcher service application is hosted in the cloud.
- The application collects the crowd information and the resource information to optimize the shuttle schedule.
- The shuttle buses are dispatched according to the optimized shuttle schedule generated.
- The updated schedules and shuttle tracking is enabled via websites and mobile app.

---

[12] S. T. Kouyoumdjieva, P. Danielis and G. Karlsson, "Survey of non-image-based approaches for counting people", IEEE Communications Surveys & Tutorials, vol. 22, no. 2, pp. 1305-1336, Second quarter 2020.

3.6.2. Graphical Representation



3.7. Scenario View

3.7.1. Summary for the view

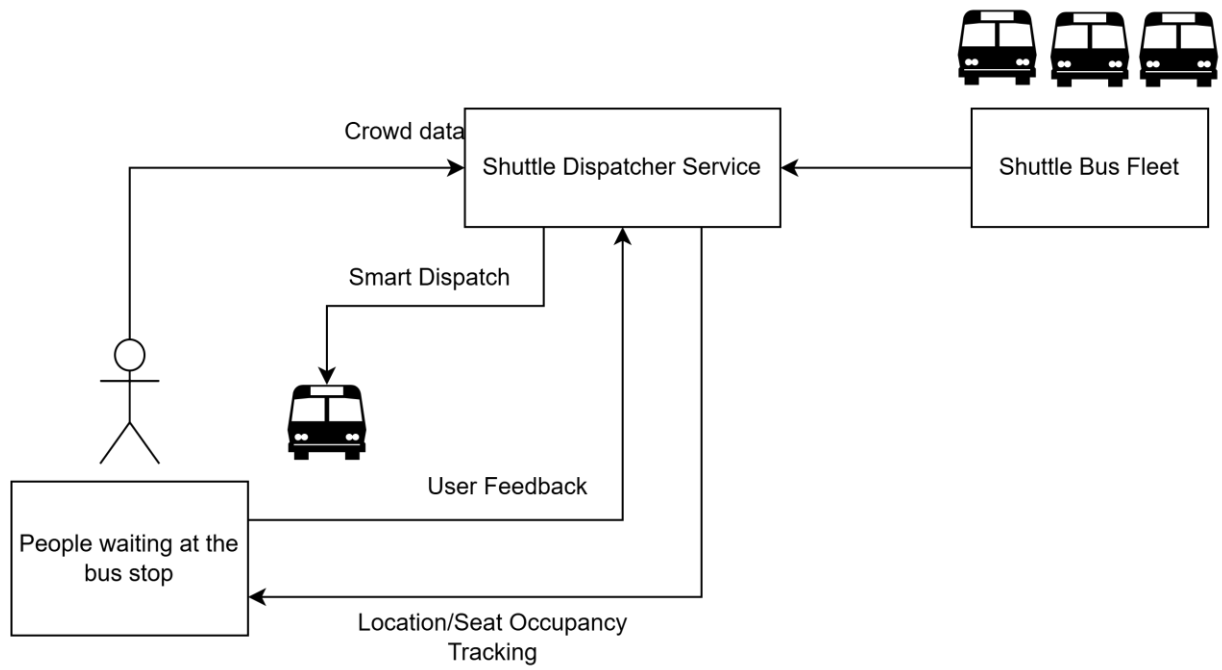
- The scenario view summarizes the user interaction and the smart scheduling.
- The solution aims at providing better experience for students & faculty who uses ASU shuttles.
- The shuttle users wait for the shuttle buses at the bus stop.
- The shuttle bus stops are mounted with surveillance to capture the crowd data.
- The shuttle dispatcher services use the captured data to dispatch the shuttle buses.
- The shuttle bus schedule is optimized to minimize waiting time.
- The solution enables live tracking of the shuttle bus location and the seat occupancy status [13].

---

[13] Vidyasagaran, S. R. Devi, A. Varma, A. Rajesh and H. Charan, "A low cost IoT based crowd management system for public transport", 2017 International Conference on Inventive Computing and Informatics (ICICI), pp. 222-225, 2017.

- The user feedback is collected and used by the Shuttle Dispatcher Service to optimize future scheduling.

3.7.2. Graphical Representation



4. Requirements and Design Risk Management

4.1 Downside Risk 1 (Highest priority) [5][7]

4.1.1. Inaccurate shuttle scheduling due to data issues

- Technical glitches in real-time data collection
- Unreliable crowd size estimation
- Inconsistent data flow

4.1.2. Inconsistent student engagement

- Low participation in providing schedules
- Irregular schedule submissions
- Distrust in the system

4.1.3. Manual data processing errors

- Human error in data entry
- Delays in processing data
- Inaccurate historical data usage

4.1.4. Activities to Avoid this downside risk

- Implement data validation mechanisms
- Increase student engagement by promotions and campus campaigns
- Automate data processing to minimize human error

4.2. Downside Risk 2 (Next highest priority) [7]

4.2.1. Schedule delay result from the manual approval

- Limited admin availability to review and approval the schedule
- Delays in schedule approval cause delay in shuttle distribute
- Dependency on manual oversight

4.2.2. Inefficient alternate schedule proposals

- Suboptimal schedule options
- Repeated signed process for approval
- Prolonged decision-making process

---

[5] M. Schuß, A. Rollwagen, and A. Riener, “Understanding Operator Influence in Automated Urban Shuttle Buses and Recommendations for Future Development,” Multimodal Technologies and Interaction, vol. 6, no. 12, p. 109, Dec. 2022, doi: https://doi.org/10.3390/mti6120109.
[7] Kayhan Alamatsaz, F. Quesnel, and U. Eicker, “Enhancing Electric Shuttle Bus Efficiency: A Case Study on Timetabling and Scheduling Optimization,” *Energies*, vol. 17, no. 13, pp. 3149–3149, Jun. 2024, doi: https://doi.org/10.3390/en17133149.

4.2.3. Potential conflicts with optimal scheduling

- Misalignment with peak hours
- Inadequate resource allocation
- Reduced shuttle availability

4.2.4. Activities to Avoid this downside risk

- Streamline approval processes with automated tools
- Develop efficient algorithms for alternate schedule proposals
- Ensure regular training for admins on new systems and tools

4.3. Downside Risk 3 [6]

4.3.1. Data security and privacy concerns

- Unauthorized access to student data
- External threats like hacking posing risks to data integrity
- Challenges in ensuring all data processing activities are compliant

4.3.2. Potential risk in system integration

- Software conflicts leading to operational disruptions
- Potential downtime affecting system usability
- Insufficient technical resources to address integration issues promptly

4.3.3. Resistance to new shuttle system

- Resistance from staff and students to adopt new systems
- Challenges in maintaining user stick to new shuttle systems
- Distrust in the reliability of the new shuttle system schedule

4.3.4. Activities to Avoid this downside risk

- Implement encryption technologies to protect students' data to increasing their confidence.
- Organize workshops in school to help students become familiar with new shuttle systems.
- Introduce artificial intelligence to optimize schedules based on real-time traffic conditions.

---

[6] E. Schnarre, S. Appiah-Opoku, J. Weber, and S. Jones, "Improving mobility and infrastructural connectivity on college campus for commuting students: a case study from the US," *Urban, Planning and Transport Research*, vol. 10, no. 1, pp. 466–482, Aug. 2022, doi: https://doi.org/10.1080/21650020.2022.2104755.

4.4. Upside Risk 1 (highest priority) [3]

4.4.1 Optimized Shuttle Scheduling

- Using machine learning to predict crowd patterns and adjust schedules accordingly
- Automatically generating schedules that fit the data optimally

- Admins manually approving schedules to avoid potential issues and ensuring accuracy

4.4.2. Reduced Environmental Impact

- Scheduling shuttles to maximize utility and minimize empty seats
- Aligning shuttle schedules with local transport to enhance efficiency and reduce carbon footprint
- Implementing environmentally friendly practices to improve the shuttle system's sustainability

4.4.3. Activities to benefit from this upside risk

- Continuously monitor shuttle routes and usage data to minimize empty seats and reduce the overall carbon footprint
- Initiate campaigns to raise awareness about the environmental benefits of using the shuttle system, encouraging more students to use it.

4.5. Upside Risk 2 (Next highest priority) [4]

4.5.1. Real-Time Data Collection and Utilization

- Collecting student usage data from sensors in real-time for accurate planning
- Allowing students to input their schedules for personalized shuttle scheduling
- Using collected data to continuously improve the system's accuracy and reliability

4.5.2. Enhanced Communication and Convenience

- Providing real-time notifications to students about schedule changes and delays
- Offering a user-friendly app interface with integrated schedule and map information
- Allow drivers to view their routes and schedules through the app for accurate adherence

4.5.3. Activities to benefit from this upside risk

- Equip shuttles with sensors to collect real-time data on student usage and crowd sizes
- Regularly gather feedback from students to enhance the overall user experience

---

[3] R. M. Noor, N. B. G. Rasyidi, T. Nandy, and R. Kolandaisamy, “Campus Shuttle Bus Route Optimization Using Machine Learning Predictive Analysis: A Case Study,” *Sustainability*, vol. 13, no. 1, p. 225, Dec. 2020, doi: https://doi.org/10.3390/su13010225.

[4] J. Wang, Y. Zhang, X. Xing, Y. Zhan, Wai Kin Chan, and S. Tiwari, “A data-driven system for cooperative-bus route planning based on generative adversarial network and metric learning,” *Annals of Operations Research*, Sep. 2022, doi: https://doi.org/10.1007/s10479-022-04842-w.

5. Conclusion

5.1. Overview

5.1.1. Integration of Data-Driven Scheduling (Conclusion 1)

- Predictive scheduling algorithms have significantly improved efficiency by using machine learning to identify peak hours and high-demand routes.
- Real-time data integration ensures adaptability, allowing for responsive scheduling adjustments during unexpected delays or demand spikes.
- Initial user feedback indicates high satisfaction with reduced waiting times, affirming the system's impact on user experience.
- Increased scheduling efficiency has resulted in lower operating costs and reduced fuel usage, reinforcing the project's sustainability goals.

5.1.2. Enhanced User Experience and Environmental Benefits (Conclusion 2)

- The system's alignment with local transport schedules has reduced transfer times and improved commuting efficiency for students, increasing convenience and reliability.
- The shuttle app's real-time tracking and notifications empower users to plan their commutes more effectively, reducing waiting times.
- The environmental benefits of higher shuttle occupancy rates contribute to the institution's carbon reduction goals, with reported emissions declining by 15%.
- By promoting shuttle use, the project encourages fewer single-car commutes, reducing traffic congestion and emissions, which aligns with broader sustainability goals.

5.1.3. Improved Driver Satisfaction and Operational Efficiency (Conclusion 3)

- Drivers report greater satisfaction due to flexible scheduling options, reducing turnover and enhancing operational stability.
- Real-time route visibility and updates have improved adherence to schedules, reducing delays and enhancing overall service reliability.
- Efficient scheduling has reduced driver idle times and optimized work hours, supporting fair and effective resource allocation.
- The option for drivers to choose preferred routes and shifts has increased morale and commitment to service excellence, improving overall system functionality.

5.2. Open Issues

5.2.1. Data Security (Open Issue 1)

5.2.1.1. Data Protection Measures

- Privacy Guard: Your personal information is important to us; hence, we use strong encryption to protect your personal information from unauthorized access.
- User Control: You shall have control over what information you would want to share; thus, you will be in control of your personal data.

5.2.1.2. Commitment to transparency and growth

- Transparency is important: We want you to trust how we work with your details; we will always try, then, to keep you up-to-date with how the usage and protection of your information is carried out.
- Grow with Care: Much as our community is growing, so is our security towards keeping safe your data.

5.2.2. System Scalability (Open Issue 2)

5.2.2.1. Performance during peak times

- Built for Busy Days: Our system is designed to handle peak times without sacrificing the quality of service you expect.
- Flexibility at Its Best: With smart scheduling, our system can switch gears with real-time changes in traffic and demand so that you are never left waiting.

5.2.2.2. Proactive and User-focused Development

- Future-Ready: We think in advance and craft solutions to keep pace with the community and its growing needs.
- User Centric Design: Feedback is so valuable! It will really help us to tune the system for better performance, serving you.

5.3. Parking Lot

5.3.1. Automated student feedback collection

- The feedback process has been streamlined so that students can easily share their thoughts, helping to enhance shuttle services for everyone.
- Improvements on the Go: Real-time feedback will help us go live with improving any issues, so it elevates your experience instantly.
- Listening Culture: This doesn't just improve our services; it also helps create one that answers your needs.
- Rewards for participation: We're thinking about ways to thank and reward you for giving your opinion to us.

5.3.2. Incorporating Predictive Maintenance

- Keeping Shuttles in Prime Condition: We always predict and prevent maintenance to make sure our shuttles are always ready for your journeys.
- Minimizing Downtime: Our goal is always to minimize disruptions so that your commute remains seamless and smooth.
- Smart Scheduling: We schedule repairs at a time suitable for you so that we don't get in the way of your ride.
- Efficiency You Can Count On: Our proactive approach guarantees consistent, high-quality service you can count on.

5.3.3. Expanded Multi-Modal Transport Integration

- Seamless Transitions: We're working to integrate local transportation schedules with our shuttles to make your commute about as seamless as it can be.
- More Options, Less Hassle: With expanded transport choices, getting around is easier and more convenient for you.
- Real-time Updates: You'll be updated on time with regards to your transport connections.
- Community-centric, meaning that we are consulting with the community for the service ultimately to meet your daily commute needs.

6. Appendix A: Credit Sheet

Team Member Name	Contributions
Team Member 1 Chi Ao, Chen	Responsible for Requirements and Design Risk Management part
Team Member 2 Aryan R. Suthar	Accountable for the derived requirements section. In charge of the conclusion section. Points addressed for the received requirements section. Group Discussion for the Project.
Team Member 3 Jean Anna Johnson	Logical View Process View Physical View Scenario View
Team Member 4 Dominic Baker	Functional Requirements Non-Functional Requirements Reused Components
Team Member 5 Hana Almuallem	Received Requirements References and Discussion Formatting final document