CSE 564 Project Report Phase 2

Team 7

Team Member Names:

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

Table of Contents

Table of Contents

Table of Contents

Table of Contents

1. Customer Problem

1.1. Student Dissatisfaction

1.1.1. Long waiting time [1]

- Students would need to wait for shuttle a much longer time.
- Student lose their patience in taking shuttle.

1.1.2. Crowded Shuttle [1]

- Students not being able to find seats during peak hours.
- Crowded environment makes student uncomfortable.

1.1.3. Lack of feedback system [2]

- Lack of a system for students to provide feedback on shuttle services.
- Student complaints are not addressed promptly, leading to recurring issues.

1. 1. 4. Lack of Communication [2]

- Students do not receive notifications about shuttle delays or cancellations.

1.2. Inefficient Shuttle Dispatching

1.2.1. Lack of responsiveness [2]

- Shuttle can’t respond to accident quickly
- Shuttle schedule can’t respond if there’s a huge event in school

1.2.3. Poor Route Design [3]

- Unreasonable route design leads to detours
- Students need to spend more time reaching their destination

1.2.2. Lack of Real-Time Information [4]

- Students can’t get real-time shuttle information
- Unable to predict shuttle arrival times
- No collection or analysis of shuttle usage statistics to improve services.

1.2.4. Poor Coordination with Other Transport Services [3]

- Shuttle schedules do not align with public transport timings.
- Missed opportunities to collaborate with ride-sharing services for better coverage.

1.3. Waste of Resources

1.3.1. Environment impact [5]

- Inefficient usage of shuttle caused extra pollution
- The pollution might provoke resident’s anger

1.3.2. Operation Costs [3]

- School needs to spend more money due to inefficient dispatching

- This would also affect the overall sustainability of the whole shuttle system.

1.3.3. Human Resource [3]

- Drivers' work schedules are unreasonable
- High work pressure on drivers affects service quality

1.3.4. Maintenance Costs [2]

- Poor maintenance leads to frequent shuttle breakdown
- Untimely maintenance increases costs
- Takes more time to classify the data in traditional shuttle system
- Shuttles do not employ energy-saving measures, increasing operational costs.

1.3.5. Underutilized Shuttle Capacity [1]

- Shuttles run with very few passengers during non-peak hours
- More drivers than needed during low demand periods, leading to inefficiency.

1.3.6. Inefficient Scheduling [3]

- Some shuttle routes overlap, leading to redundant services.
- Shuttle schedule not based on actual demand, causing inefficiencies.

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[1] T. Arabghalizi and A. Labrinidis, "Data-driven Bus Crowding Prediction Models Using Context-specific Features," *ACM/IMS Transactions on Data Science*, vol. 1, no. 3, pp. 1–33, Sep. 2020, doi: https://doi.org/10.1145/3406962.

[2] M. W. Raad, M. Deriche, and T. Sheltami, "An IoT-Based School Bus and Vehicle Tracking System Using RFID Technology and Mobile Data Networks," *Arabian Journal for Science and Engineering*, Nov. 2020, doi: https://doi.org/10.1007/s13369-020-05111-3.

[3] A. Sharma, "Advancing School Bus Routing: A Machine Learning Approach for Enhanced Efficiency, Safety, and Sustainability." Accessed: Sep. 28, 2024. [Online]. Available: https://www.ijfmr.com/papers/2022/6/16031.pdf

[4] "Real-Time Bus Arrival Prediction: A Deep Learning Approach for Enhanced Urban Mobility," *Arxiv.org*, 2024. https://arxiv.org/html/2303.15495v3 (accessed Sep. 22, 2024).'

[5] W. Austin, G. Heutel, and D. Kreisman, "School Bus Emissions, Student Health, and Academic Performance," *National Bureau of Economic Research*, Mar. 01, 2019. https://www.nber.org/papers/w25641

2. Stakeholders

2.1. Health and Safety Regulators [6]:

- Ensures compliance with transportation safety standards, reducing accident risks.
- Oversees health protocols, especially in light of public health concerns like COVID-19.
- Audits the shuttle service for safety features, such as emergency exits and fire safety.
- Monitors emergency response procedures, ensuring timely action during accidents.

2.2. Environmental Advocacy Groups [7]:

- Promotes the use of eco-friendly shuttles to reduce the university's carbon footprint.
- Ensures that the shuttle system adheres to sustainability practices in line with city or national goals.
- Pushes for data tracking to monitor and report emissions reductions over time.
- Encourages initiatives like green energy usage, electric vehicles, and reduced fuel consumption.

2.3. Student Councils or Campus Advocacy Groups:

- Represents the voice of students in decision-making, offering valuable user feedback.
- Advocates for improved service based on the needs of the student body, such as shorter wait times.
- Acts as a liaison between students and shuttle operators for real-time issue reporting.
- Ensures the shuttle service supports campus inclusivity and access to educational events.

2.4 Insurance Providers:

- Provides coverage for shuttles, protecting against financial risks in the event of accidents or malfunctions.
- Ensures compliance with legal liability standards for both drivers and passengers.
- Helps assess risk to minimize incidents that could affect the shuttle's operation.
- Could provide risk mitigation strategies, reducing premiums based on fleet safety performance.

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[6] Wang, X., Yuen, K. F., Shi, W., & Ma, F. (2020). The determinants of passengers' safety behaviour on public transport. *Journal of Transport & Health*, *18*, 100905.

[7] Richards, R., Murdoch, L., Reeder, A. I., & Rosenby, M. (2010). Advocacy for active transport: advocate and city council perspectives. *International Journal of Behavioral Nutrition and Physical Activity*, *7*, 1-8.

2.5. Accessibility Advocates:

- Ensures that the shuttle system is fully accessible to students with disabilities.
- Advocates for features like wheelchair access, audio announcements, and clear signage.
- Ensures compliance with ADA (Americans with Disabilities Act) standards or similar laws.
- Works to create a transportation experience that is inclusive and safe for all passengers.

2.6. Public Transportation Agencies:

- Could collaborate with the shuttle service to integrate schedules with public transit systems.
- Helps avoid redundant services by aligning shuttle routes with existing public transportation.
- Helps avoid redundant services by aligning shuttle routes with existing public transportation.
- Coordinates fare-sharing or ticketing systems for seamless travel across multiple transport modes.

2.7. Faculty and University Staff [8]:

- Affected by shuttle schedules when commuting between campuses or attending meetings.
- Could provide valuable feedback on how the service impacts productivity and campus operations.
- May use the shuttle system during events or irregular work hours, requiring flexible scheduling.
- Ensures that transportation aligns with academic and administrative needs.

2.8. IT and Data Security Teams [9]:

- Responsible for securing personal data collected through the shuttle system's feedback and tracking features.
- Implements cybersecurity measures to protect against breaches, especially with real-time monitoring.
- Ensures privacy compliance, such as anonymizing travel data and securing sensitive information.

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[8] Busch-Geertsema, A., Lanzendorf, M., & Klinner, N. (2021). Making public transport irresistible? The introduction of a free public transport ticket for state employees and its effects on mode use. *Transport policy*, *106*, 249-261.

[9] Callegati, F., Campi, A., Melis, A., Prandini, M., & Zevenbergen, B. (2015). Privacy-preserving design of data processing systems in the public transport context. *Pacific Asia Journal of the Association for Information Systems*, *7*(4), 4.

- Develops and maintains the app or interface used by students and staff to interact with the shuttle service.

2.9. Students

- Improved system that allows them to reach their goal location in a reasonable time
- Allows them a combust system that allows them to feel safe when standing at the shuttle location.
- Improve time for them to arrive to class on time
- Allows them to see how many people are located at the shuttle location.
- Allowing them to avoid over crowdedness
- Allows the students to leave an alert if there's a lot of people on a particular shuttle

2.10. Drivers and Staff

- Optimized schedule to reduce stress
- Predictable workloads
- Improved job satisfaction
- Reduced Idle times
- Better work life balance
- Better coordination with maintenance team to for earlier maintenance based on usage

3. Concept of Operations

3.1. Overview

- An ASU shuttle Dispatcher system
- Dispatches buses based on crowd sizes
- Reduces students wait times, improves their satisfaction
- Calculate shortest route to reduce carbon emission
- Predict the accurate number of shuttles needed, minimize the cost

3.2. Solution Concept of Operations [10]

3.2.1. Data Collection

- Install sensor in shuttle to collect crowd size data
- Implement real-time data collection
- Use IoT devices to enhance data quality

3.2.2. Data Analysis

- Develop algorithms to analyze patterns
- Predicts crowd trends
- Implement machine learning to improve prediction accuracy

3.2.3. Bus Dispatch

- Automated dispatch based on predictions
- Ensures optimal shuttle utilization (avoid empty shuttle on the road)
- Implement dynamic routing to respond changing in crowd sizes
- Enable manual override for driver to handle unexpected events of system

3.3. Proposed Solution Summary [11]

3.3.1. Address Student Dissatisfaction

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[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] 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

- Implement real-time monitoring to optimize shuttle schedules
- Ensure more shuttle during peak hours to reduce wait times
- Increase shuttle frequency during peak times to decrease crowding shuttle
- Implement a reservation system to manage seat availability

3.3.2. Enhance Efficiency in Shuttle Dispatching

- Provide an app to show real-time shuttle information to students
- Predict shuttle arrival times and share with users for better planning
- Redesign routes based on student usage patterns to minimize detours
- Align shuttle schedules with public transportation to improve connectivity

3.4. Operational Scenarios [12][13]

3.4.1. Morning Rush Hour

- Sensors collect data of crowd sizes at bus stops
- Algorithms analyze incoming data
- System predicts increasing demand at specific stops
- Additional buses are dispatched to the most crowded stops
- Passengers receive real-time updates about new bus arrival times
- Increase shuttle availability in peak hours

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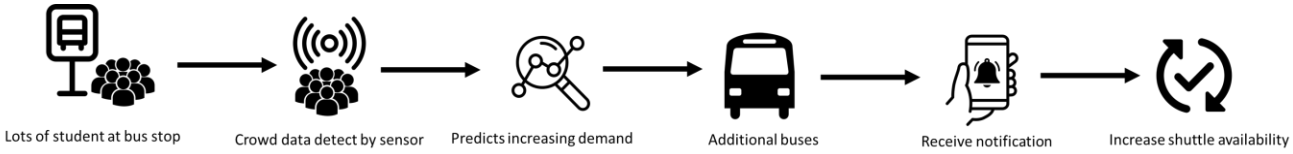

3.4.2. Special Events (Graduation Ceremony)

- Identify upcoming graduation ceremony
- Estimates the additional traffic load near the venue
- Recalculate shuttle routes to avoid congestion

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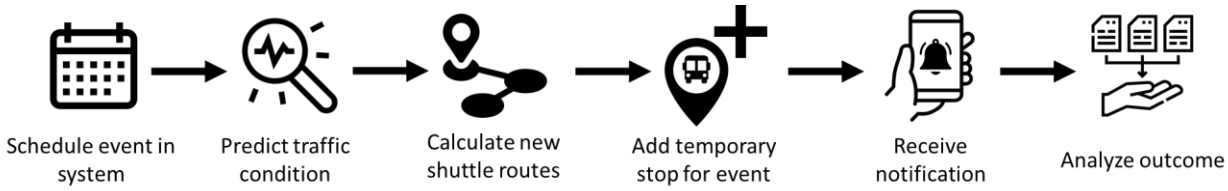
[12] P. HORAŽĎOVSKÝ, S. KOZHEVNIKOV and M. SVÍTEK, "Dynamic Public Transport in Smart City using Multi-agent system," 2019 Smart City Symposium Prague (SCSP), Prague, Czech Republic, 2019, pp. 1-5, 2019

[13] S. Lyapin, D. Kadasev and N. Voronin, "Application of Digital Control Approaches in Solving Transport Planning Problems in Road Transport," 2023 5th International Conference on Control Systems, Mathematical Modeling, Automation and Energy Efficiency (SUMMA), Lipetsk, Russian Federation, 2023, pp. 894-898

- Add temporary stops near the venue
- Allocate extra buses for the event
- Activate enhanced schedules on event day
- Provide real-time bus stop updates notification in App
- Collect and analyze outcome for future planning

Story board:



3.4.3. Unexpected Incidents (e.g., Roadblocks, Accidents)

- Identify roadblocks or accidents from Internet
- Plan alternative routes and dispatch additional buses
- Reroute buses to mitigate delays
- Provide the route change and delays notification in App
- Continuously monitor the incident situation for responses
- Review incident data to improve future responses

3.5. Constraints[14]

3.5.1. Budget

- Limit the scope of advanced features and extensive data collection systems
- Hard to always have an optimal number of shuttles available

3.5.2. Integration

- Existing infrastructure might complicate integration
- Implementation could disrupt current operations

3.5.3. Accuracy

- Predictions may occasionally be inaccurate result in delays
- Inconsistent data can impact decision-making

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[14] M. N. Islam, "Towards Designing Users' Intuitive Web Interface," 2012 Sixth International Conference on Complex, Intelligent, and Software Intensive Systems, Palermo, Italy, 2012, pp. 513-518,

3.5.4. Scalability

- Current infrastructure constraints may limit expansion

3.5.5. Environmental Impact

- Emission reduction might conflict with service quality
- Budget constraints may make it hard to implement eco-friendly practices

4. Requirements Received

4.1. Shuttle scheduling

4.1.1. As a student, I want to reach on time for classes across campus

- Schedule buses based on crowd patterns
- More buses during peak hours.

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

- The schedules shall be created using machine learning.
- Predict crowd based on historical crowd data and past trends [6].
- The system's accuracy shall improve with continued use.

4.1.3. 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.

4.1.4. 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.

4.1.5. 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.

4.2. Data Collection

4.2.1. 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.

4.2.2. 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.

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[6] 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

- Engagement will also help increase student trust in the system. [15]

4.3. Driver Schedule

4.3.1. 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.

4.3.2. 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.

4.4. School Events

4.4.1. 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.

4.4.2. 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.

4.5. Viewing Shuttle Schedule

4.5.1. 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 show the timings of the shuttle service.

4.5.2. 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

4.5.3. 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.

4.6. Shuttle Routes

4.6.1. 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.

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

- They must also be able to see how long they stay at each stop.

4.6.2. 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.

4.7. App User Interface

4.7.1. 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.

4.7.2. As a student I want an abstract map for readability and faster load time. [16]

- The map routes shall be drawn abstract (without detail) outside of campus.
- Only campus streets should be shown for navigation.
- Personalization options to tailor for individual users.
- Only the shuttles relevant to the user is displayed.

4.8. Delay Notifications

4.8.1. 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.

4.8.2. 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,

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[16] 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.

5. Requirements Elicitation

5.1. Identifying the users of the solution.

- There will be a lot of people who are directly/indirectly affected by the shuttle services.
- Shuttle service provides appropriate transportation for students and faculty
- Shuttle services employ drivers, technicians and other workers.

5.1.1. Question: Who are the primary users of the ASU Shuttle Dispatcher system?

- Identify who will be the users relying on the ASU Shuttle service.
- Identify who will be the users who support the operations of ASU Shuttle service.
- Identify any other users impacted by the success/failure of the service.

5.1.2. Rationale for the Elicitation Question

- The identified users can be classified into categories [17].
- Targeted requirements can be gathered for categories of users.
- Features & functionality can be prioritized for best user experience.
- Conformance with specified quality criteria is required to validate requirements.[18].
- The perspective & experiences of identified users can be used to set the quality criteria.
- Understanding user demographics can guide decisions for scalability & future planning.
- The inability to elicit tacit knowledge leads to loss of market opportunities & systems failure. [19]

5.2. Identifying the current challenges.

- It is important to identify the current situation of the ASU Shuttle Service experience.
- The current situation might differ based on the category of user.
- The solution must maintain all positive experience of the current system.
- The solution must work towards improving the challenges of the current system.

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[17] M. A. Iqbal and A. Shah, "Process Hierarchy for GSD Based User-Centric Requirements Elicitation Frameworks," *2020 IEEE 15th International Conference on Industrial and Information Systems (ICIIS)*, RUPNAGAR, India, 2020, pp. 528-533

[18] I. Atoum *et al*., "Challenges of Software Requirements Quality Assurance and Validation: A Systematic Literature Review," in *IEEE Access*, vol. 9, pp. 137613-137634, 2021

[19] H. A. Al-Alshaikh, A. A. Mirza and H. A. Alsalamah, "Extended Rationale-Based Model for Tacit Knowledge Elicitation in Requirements Elicitation Context," in *IEEE Access*, vol. 8, pp. 60801-60810, 2020

5.2.1. Question: What are the challenges with the current shuttle service.

- Identify the positive experiences that users have with the ASU shuttle service.
- Identify the negative experiences that users have with the ASU shuttle service.
- Identify the challenges from different categories of users.
- Classify the major and the minor challenges faced from different user perspective.

5.2.2. Rationale for the Elicitation Question

- Existing systems and processes are an important source to elicit requirements [20].
- The current challenges can help establish a baseline to measure success of solution.
- Identifying the challenges can help pinpoint areas in need of improvement.
- Prioritize features that addresses the major challenges.
- Knowing which feature to prioritize is important for resource allocation, system design.
- Prioritizing solving user challenges can guarantee better user satisfaction.

5.3. Identifying the financial constraints

- It is extremely important to have agreement on the financial aspect for the solution.

5.3.1. Question: What is the budget for the solution? What is the expected cost-savings?

- Understand the financial constraints for implementation of solution.
- Understand the expectations on cost-saving post-implementation.

5.3.2. Rationale for the Elicitation Question

- There exists a relationship between software reliability and budget [21].
- Budget helps define what can be realistically achieved within budget.
- The budget information is critical for planning & resource allocation.
- This information can be used to prioritize important features.
- Cost-effective features can be prioritized based on client expectation.
- Make important trade-off decisions.
- Financial risks can be identified early and mitigation strategies can be formulated.

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[20] S. Sharma and S. K. Pandey, "Requirements elicitation: Issues and challenges," *2014 International Conference on Computing for Sustainable Global Development (INDIACom)*, New Delhi, India, 2014

[21] V. Rattan, P. Panwar, R. Mittal, J. Singh and V. Malik, "Forecasting the Budget Required for Software under Development," *2021 8th International Conference on Signal Processing and Integrated Networks (SPIN)*, Noida, India, 2021, pp. 36-40

- Assess the return on investment of the solution based on estimated cost saving.
- Plan a long-term financial strategy based on the client expectations.

5.4. Identifying the success criteria for the solution

- Agreement on success criteria helps to align with client's needs, goals & objectives.

5.4.1. Question: How should the success of the ASU Shuttle Dispatcher service be measured?

- Define 'success' for the solution.
- Identify criteria on which the success of the solution can be measured.

5.4.2. Rationale for the Elicitation Question

- Success criteria define what the mission needs to accomplish to be successful [22].
- Ensures everyone has a shared understanding on success of the solution.
- Identify specific metrics and performance indicators to assess the solution.
- The design and development priorities decided based on contribution to success.
- The future planning and resource allocation decided to maximize success.
- Clear understanding of success can enable continuous monitoring and evaluation.
- The success criteria can be the benchmark of evaluation post-implementation.

5.5. Identifying the modes for user interaction

- User interaction is an important part of the system.
- Users might be able to communicate easily with the system.

5.5.1. Question: What are the expected user interactions and modes of interaction?

- Understand what must be communicated to the user.
- Understand what communication must be taken from the user.
- Understand types of communication to be established with the user.

5.5.2. Rationale for the Elicitation Question

- Understanding user interaction expectation helps to identify design priorities.
- User can be provided intuitive interface for better effective user experience [23].
- Identify specific functionalities to be included.

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[22] NASA Headquarters, "Expanded Guidance for NASA Systems Engineering," *March 2016*, pp. 79

[23] M. N. Islam, "Towards Designing Users' Intuitive Web Interface," 2012 Sixth International Conference on Complex, Intelligent, and Software Intensive Systems, Palermo, Italy, 2012, pp. 513-518,

- Real-time tracking & notifications can be provided to riders of the shuttle.
- Planned schedule, schedule changes can be provided to operators of the shuttle.
- Feedback mechanisms can be established to improve the system.
- Design the system to be compatible with existing workflows for smooth adoption.
- Design system to be usable for all potential users including those with disabilities.
- Identifying expected modes of interaction (e.g. web, mobile) determines technology choices.

5.6. Identifying the existing systems to integrate

- ASU will have multiple software systems for the campus shuttles.
- The existing systems must be identified and analyzed.

5.6.1. Question: What are the existing systems to integrate with?

- Identify all the relevant software systems.
- Identify the data and the scope of each system.
- Analyze the system to check of reusable components.
- Identify parts of system, data that can be reused in the solution

5.6.2. Rationale for the Elicitation Question

- Understand existing systems to ensure compatibility and prevent integration issues.
- Streamline data sharing with existing systems, databases, apps.
- Integrate and allow easy accessibility of relevant data at a single place.
- Enhance the functionality of the dispatcher system by leveraging existing solutions.
- Utilizing existing systems can save time and resources.
- Integrating with familiar systems can improve user experience.

5.7. Identifying the expected user satisfaction

5.7.1. Question: What is the targeted user satisfaction and how do we measure it?

- Identify criteria to measure user satisfaction, e.g. wait times.
- Identify how to measure the user satisfaction.
- Identify what level of user satisfaction is expected.

5.7.2. Rationale for the Elicitation Question

- Set clear expectations of user satisfaction to be met to guide design & functionality choices.
- Clear metrics helps to set benchmarks to evaluate the system performance.

6. Conclusion

6.1. Overview

6.1.1. Enhanced Efficiency and Student Satisfaction

- It mainly deals with the problem of long waiting times associated with shuttle services.
- Optimizes resource allocation to ensure shuttles are used more efficiently.
- Finds latitude for informed decision-making with real-time data collection and timely dispatching.
- Aims at ironing out and providing a good travel experience.

6.1.2. Improved Reliability and Predictive Capabilities

- Anticipate passenger demand by using data analytics and build the shuttle schedule.
- Improves the overall reliability of the shuttle service via proactive scheduling.
- Reduces the inconvenience of jam-packed shuttles by ensuring a more comfortable ride.
- This leads to smaller lines and a much more pleasant experience for all students.

6.1.3. Seamless Integration with Campus Resources

- Links shuttle services with public transit for broader transportation options.
- Coordinates shuttle times with campus events to further enhance accessibility.
- Offers a holistic approach to campus transportation needs.
- It simplifies students' planning because of its unified transportation resource.

6.2. Open Issue 1: Data Quality and Accuracy

6.2.1. Data Integrity and Reliability

- Clearly, reliable data from sensors are quite crucial for system effectiveness.
- Inconsistent data will result in imprecise predictions and lead to bad dispatching decisions.
- Accurate data supports optimal scheduling and resource allocation.
- Ensuring data integrity is critical for maintaining user trust and service quality.

6.2.2. Data Quality Assurance Strategies

- Perform structured checks for accuracy and data integrity.
- Undertake routine calibration of sensors and equipment to maintain precision.

- Establish mechanisms for detecting and correcting discrepancies in the collected data.
- Consider additional data sources to improve overall information value.

6.3. Open Issue 2: System Scalability

6.3.1. Adapting to Growing Demand

- Need to upgrade hardware to meet increased demands by students and shuttle routes.
- Improve algorithms to increase efficiency in handling demand.
- Consider cloud technology, which can provide flexibility in scaling and managing resources.
- Develop plans for future growth, considering the need for smooth expansion of systems.

6.3.2. Scalability Solutions and Strategies

- Check the capacity of existing systems for any bottlenecks.
- Consider cloud solutions that would provide greater scalability and operational flexibility.
- Offer mechanisms for equal distribution of some workload across system components.
- Develop strategies to address predicted growth and ensure smooth transitions.

6.4. Parking Lot

6.4.1. Parking Lot Item 1: Integration with External Traffic Data

- Explore relationships with city transportation agencies for real-time traffic information.
- Use real-time data to optimize shuttle routes and minimize congestion.
- Evaluate the impact of integrated traffic data on overall shuttle service effectiveness.

6.4.2. Parking Lot Item 2: Mobile App for Student Feedback

- Allow students to provide immediate feedback on shuttle services to improve responsiveness.
- Allow reporting of issues within the app itself for quicker solutions.
- Provide timely notifications and updates concerning any change in schedule or operation services to enhance the user experience.

6.4.3. Parking Lot Item 3: Pilot Program for Evaluation

- Pilot system to test the effectiveness of the system within a small scope.
- Use this pilot to reveal the most probable difficulties and gather user feedback for enhancing.
- Analyze pilot results to refine the approach before full-scale deployment.

6. Appendix A: Credit Sheet

Team Member Name	Contributions
ChiAo, Chen	• Update Operational Concept section • Story board create
Domini Baker	• Added New stakeholders • Updated the list of stakeholders
Hana Almuallem	• Identifying the Requirements Received
Jean Johnson	• Identifying Requirement Elicitations Questions • Requirement elicitation from students using campus shuttles
Aryan R. Suthar	• Added customer problem. • Updated conclusion for the document. • Added new open issues. • Discovered new parking lot items.