LAKAD: A PERSONALIZED MOBILE ITINERARY GENERATOR WITH FOCUS IN BULACAN TOURISM

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In partial fulfillment of the requirements for the degree Bachelor of Science in Mathematics with specialization in Computer Science, this thesis entitled **''LAKAD: A Personalized Mobile Itinerary Generator with Focus in Bulacan Tourism''** has been prepared and submitted by Bryan C. Declaro, Franniel Luigi C. Hilario, Brian Gabriel G. Magbanua, and Richard M. Manansala , who are hereby recommended for oral examination.

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DEDICATION

We dedicate this thesis for those who come after...

- The authors

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CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Itinerary planning is an important process that can enhance the experience of tourists in their travel such as how well the places interest the user and the flow in which the places are traversed. In the case of the province of Bulacan, this study created a mobile personalized itinerary generator as a possible solution to optimizing existing itineraries and providing rich and personalized itineraries of Bulacan tourism, based on the interests of the user. This chapter introduces the background, objectives, significance, and scope of the study.

Background of the Study

In the midst of advancement in technology and sciences, culture remains a vital part of many people's lives. Tourism, being a significant contributor to preservation of culture and local development, relies heavily on how well travel experiences are delivered. One of the most crucial aspects of this process is itinerary planning, a practice ensuring the maximization of multiple points of interest (POIs) efficiently without the unnecessary inconvenience. The ability to create structured travel plans does not only influence convenience but also impacts tourist satisfaction and chance of returning or recommending the destination to others.

Sustainable and authentic trends in travel experiences align with Philippines' Department of Tourism's (DOT) initiatives to develop unique cultural and natural attractions (Department of Tourism (DOT), 2023). Despite these efforts, historically active provinces like Bulacan still has some of its tourist destinations neglected, proven by how some culturally relevant sites like Barasoain Church, often attract more visitors than others like the Immaculate Conception Cathedral, with 2.6 times more visitors, despite being in the same municipality (Canet & Sunpongco, 2025). Bulacan's tourist arrival reports also show that certain municipalities acquire an uneven number of visitors for the first three quarters of the year 2025 (Provincial History, Arts, Culture, and Tourism Office (PHACTO), 2025). A problem that affects the development of Bulacan's tourism, resulting in an overlook of economic opportunities for lesser-known municipalities.

These conditions highlight the need for smarter ways to plan trips, systems that can pull together all sorts of information and offer suggestions perfectly tailored to what each person likes. This is especially important as more and more people want to explore and truly experience a destination's uniqueness, which often demands a level of planning which outdated methods often fail to deliver (Halder et al., 2022). The Bulacan Provincial Government is actively promoting their attractions through Bulacan's Pamana Pass, a checklist of certain sites, but it only acts as a guide. Technology can help people utilize it more, and make trips more satisfying ensuring tourism spots grow in a way that benefits everyone.

Creating itineraries under many constraints has become increasingly automated through a mix of both optimization algorithms and content selection processes to resolve the scheduling and relevance aspects of itinerary recommendation (Jewpanya et al., 2025; Liu et al., 2024). However, such systems are often limited to specific regions and bound by the capabilities of the model used or lack of data (Cui et al., 2025; Papadakis et al., 2024; Yulfihani & Zakariyah, 2024). Despite the drive to develop systems that simplify the complicated problems of manual itinerary planning, existing travel apps still struggle to effectively recommend itineraries as reports from Arora et al. (2022) highlights that applications may offer destination suggestions but lack the ability to offer suggestions based on user preferences. Their reports also show the demand for a personally curated service, since 30 percent of travelers responded that they are "more likely to use a travel agent now than before the pandemic". Although there are systems that already cater to this problem, a common weakness they have is overcomplexity (Postnikova, 2024). General-purpose platforms also generally do not align with the Philippines' strategic imperative to build a deeper, distinct Filipino experience (Arora et al., 2022; Department of Tourism (DOT), 2023). These weaknesses expose the need for a simple, localized itinerary recommendation system, particularly in areas with uneven destination popularity like Bulacan. This study adopts Adaptive Genetic Algorithm (AGAM) developed by Yochum et al. (2020) as a recommender algorithm to ensure suggestions does not merely list POIs, but instead consider user preferences.

Another problem of planning a travel itinerary arises when considering other constraints beyond personalization. A challenge that involves not only selecting POIs but also determining the optimal visiting order, persisting despite advances in recommendation and optimization methods (Papadakis et al., 2024; Porras et al., 2022; Yulfihani & Zakariyah, 2024). These problems demonstrate that classic ways of planning itineraries lead to unsatisfactory results, implying the inherent value in creating automated systems for planning itineraries more efficiently. From a mathematical perspective, this problem is similar to the Traveling Salesman Problem (TSP) (Wu & Fu, 2020). To address such complexity, this study uses an additional optimization algorithm that caters to TSP, which will help optimize the given routes of POIs.

These limitations, taken together, implies that manual travel planning methods in Bulacan remain inefficient due to uneven attraction popularity, lack of a personalized and optimized routing system, and the absence of accessible tools that integrate both user preferences and route optimization, which points to a need for a practical, user-centered, and localized solution.

This study proposes LAKAD to address the identified problems and provide a tourist utility app for exploring destinations in the province of Bulacan. The system will be developed to deliver two core features: a personalized itinerary generation, helping tourists better plan their trips according to their specifics, and an optimization algorithm to ensure routes are arranged in the best way possible. By combining the ideas of, and integrating personalized preference modeling and route optimization, LAKAD seeks to provide a simplified and localized solution. Ultimately contributing to DOT's strategic goals by promoting Bulacan's cultural identity and mitigating imbalance in the tourism destinations.

Statement of the Problem

The lack of systems and applications for itinerary generation in Bulacan makes it much harder for tourists to traverse the wonders the province has to offer. As such, the main objective of this study is to develop a mobile personalized itinerary generator for promoting tourist locations in Bulacan as well as providing optimized paths in the itinerary, allowing the tourist to further enjoy their trip. Specifically, this study aims to answer the following questions:

1. Which algorithm performs best in terms of run time and solution quality for solving the Traveling Salesman Problem (TSP) among the following:
   1.1. Ant Colony Optimization (ACO),
   1.2. Genetic Algorithm (GA),
   1.3. Simulated Annealing (SA),
   1.4. Particle Swarm Optimization (PSO),
   1.5. Elephant Herding Optimization (EHO),
   1.6. Grey Wolf Optimizer (GWO), and
   1.7. Hovering Scouts and Foraging Flocks Pied Kingfisher Optimizer (HSFFPKO)?
2. How can the proposed system be developed with the following functionalities:
   2.1. Tourist Spot Exploration,
   2.2. Personalized Itinerary Generation,
   2.3. Itinerary Optimization,
   2.4. Itinerary Navigation, and
   2.5. Itinerary Management?
3. How acceptable is the proposed system based on the criteria defined in the Technology Acceptance Model?
   3.1. Perceived usefulness,
   3.2. Perceived ease of use,
   3.3. Attitude towards using, and

3.4. Behavioral intention?

4. How well does the proposed system meet the ISO/IEC 25010:2023 requirements?
    4.1. Functional Suitability,
    4.2. Performance Efficiency,
    4.3. Compatibility,
    4.4. Interaction Capability,
    4.5. Reliability,
    4.6. Security,
    4.7. Maintainability,
    4.8. Flexibility, and
    4.9. Safety?

Significance of the Study

This study developed an optimized mobile itinerary planner designed to promote tourism in Bulacan as a destination for tourists while providing functional and efficient navigation support for locals and commuters. The system functions as a tool that promotes the province's tourism industry, highlights its attractions, and makes trip planning easy by combining efficiency and personalization.

Tourists. The system provides personalized and optimized itineraries according to the user's interest and preferred distance. In this way, they can enjoy both well-known and lesser-known parts of Bulacan's natural, historical, and cultural heritage while making the most of their time.

Local Establishments. The system gives them more chances to get their products and attractions seen because they can be included in the itineraries. This kind of advertising gets more customers involved and helps local businesses grow.

Local tourism sector. The system provides a tool to tourism offices and local tourism operators that enhances destination promotion, encourages tourist engagement, and improves the efficiency of travel planning.

Local Communities. The system provides residents and local communities with assistance in moving around the province and discovering nearby attractions. By improving mobility, the system helps develop the community and allows all people to appreciate the Bulacan's cultural and historical sites more.

Commuters. The system provides an alternative tool designed to enhance daily travel efficiency for commuters within Bulacan. It brings practical convenience to people who rely on mobile guidance during regular transport because it offers optimized routing and accessible location information.

Future Researchers. This research can be a reference for researchers who would want to improve or further develop the tourism recommender system. The use of AGAM and TSP algorithms provides a foundation that others may extend, compare with different algorithms, or further improve by adding other features.

Overall, this study is significant because it supports development of tourism, sustainable development, and culture enhancement in Bulacan, and provides an example of how optimized and technology-driven solutions may enhance travel and navigation experiences.

Scope and Limitation of the Study

This study focuses on the development of a mobile personalized itinerary generator, designed specifically for the province of Bulacan, to address issues in manual trip planning and limitations of existing travel apps by offering a simpler, more user-centered tool that highlights the province's cultural and historical attractions. The application is an Android-based mobile app designed to generate personalized itineraries for tourists in Bulacan. The system enhances the travel experience of tourists by providing functionalities such as itinerary optimization, personalized itinerary generation, tourist spot searching, itinerary navigation, and itinerary management. By integrating these features, the system makes traveling within Bulacan more convenient, efficient, and engaging for visitors.

The scope of the POIs is limited to natural, historical, cultural, and heritage tourist destinations of Bulacan along with the numerous “Pasalubong Centers” within the province that will be obtained from, and validated by the Provincial History, Arts, Culture, and Tourism Office (PHACTO). Tourist destinations outside Bulacan are not considered. The system does not include restaurants as POIs due to their large number and they are unfair for small and not established restaurants that are not included. The itinerary generation focuses on single-day travel sequences and users may pause or resume their visit, the system does not produce itineraries intended for multi-day tour planning. Furthermore, the system does not include public transportation routing because Mapbox, which is the mapping service used only to support walking, cycling, and driving directions, and does not provide transit or multi-modal transportation route information. Itinerary generation and recommendations will be based on weights assigned to each vertex or POI, which serve as inputs for the optimization process. Data for mapping and location will be sourced from Mapbox and PHACTO. The system excludes the implementation of additional services such as accommodation booking, ticket reservations, or guided tour arrangements. The respondents consist of tourists who are currently visiting Bulacan, regardless of whether they live within the province or in another location. These individuals are the end-user of the system and participate in the evaluation to provide feedback.

The application was developed using the React Native framework, which allows for cross-platform development and implementation. However, the mobile application is developed exclusively for the Android operating system due to feasibility and cost considerations, as development for iOS requires a MacBook and an Xcode developer account, both of which require further funding of the project. The entirety of the study which includes the planning, drafting, writing, development, evaluation, and polishing of the paper will be carried out within an eight-month timeline.

Furthermore, personalized itinerary recommendation utilize Adaptive Genetic Algorithm with Dynamic Mutation and Crossover Probabilities (AGAM), a model based on the Orienteering Problem (OP). The model is used to generate itineraries. AGAM considers multiple objectives such as POI ratings, user-defined interests, and POI popularity to recommend and generate itineraries. For route optimization, the system employs the best algorithm determined by a comparative analysis, applied within the framework of the TSP to yield the shortest possible routes for the itineraries. This ensures that the itineraries generated are both optimized and meaningful to the user's preferences.

Additionally, this study involves testing and comparing the performance of selected algorithms used to optimize routes. The comparative analysis is limited only to the algorithms chosen by the researchers. The dataset that used to compare the algorithms are obtained from existing graphs from TSPLIB, and then the results are listed accordingly with Multi-criteria decision making. To evaluate the chosen algorithms, the study focuses on two main criteria: run time and solution quality. The algorithm that performs best in these criteria is selected for implementation in the itinerary optimization feature of the mobile application.

The system's quality and acceptability was quantitatively evaluated using two standard instruments, Technology Acceptance Model (TAM) and ISO/IEC 25010:2023. The evaluation for the end-users utilize TAM to assess perceived usefulness, ease of use, and intention to use towards the application. In addition, the system was assessed against the ISO/IEC 25010:2023 software quality standards, covering functional suitability, performance efficiency, compatibility, interaction capability, reliability, security, maintainability, flexibility and safety.

CHAPTER II

THEORETICAL FRAMEWORK

This chapter combines significant findings from various literature and studies from tourism, exploration of the traveling salesman problem (TSP) in itinerary planning, and methods for recommendation for itinerary generation. This comprehensive review serves as the basis for the development of the LAKAD application by identifying relevant factors optimization algorithms for TSP in itinerary planning and factors to consider when creating personalized recommendation features of the system.

Relevant Theories

Key features of LAKAD rely on established theories of mathematics. This section examines the foundational theories and explains how they are used and related to the concept of itinerary optimization and personalized generation.

Graph Theory

Graph Theory is a branch of mathematics that is still relatively young but is developing quickly. The foundation of graph theory goes back to the 18th century, when Leonhard Euler solved the Königsberg Bridge Problem, which is often thought of as the first problem in the field. Euler's work introduced this approach of representing real-life connections through vertices and edges, which forms the basis of all network studies and relations. In the early 20th century, mathematicians like Kuratowski, Wagner, and Whitney made the field bigger by studying planar graphs and coming up with basic ideas that later became Graph Minor Theory, which connected graph structures to geometry and topology. The proof of the Four Color Theorem in 1976 made graph theory even more popular and showed how useful it could be for solving complex mathematical and computational problems (Carmesin, 2022).

A graph is a set of vertices and edges, where each edge connects exactly two vertices. Topologically, a graph can be thought of as a one-dimensional simplicial complex (Carmesin, 2022). A graph $G = (V, E)$ is composed of a set of vertices V and a set of edges E. There are two types of graphs, directed graphs, which have edges that can only go in one direction, and undirected graphs, where edges allow movement in both directions. Additionally, they can be weighted, it means that each edge has a number that represents different factors like cost, time, and distance.

In this study, the concept of graph theory will be applied to represent the points of interest (POI) as nodes and the distance between every connected vertex as the edges. This graphical representation of cities and their distances is one of the common applications of graph theory and allows access to powerful algorithms and methods for optimization.

Traveling Salesman Problem

This is a specific problem under the field of graph theory. According to Pop et al. (2024), the Traveling Salesman Problem (TSP) has been in the history of combinatorial optimization since 1930, and was properly provided a mathematical formulation by Merrill M. Flood. TSP became very popular since it is a widely investigated optimization problem, often serving as a benchmark for modern optimization algorithms. The problem states that, given a set of cities, the salesman's goal is to find the shortest possible route that visits each city exactly once. According to Wu and Fu (2020), TSP is considered a non-deterministic polynomial time problem or simply an NP-hard problem, meaning it is hard to solve efficiently and finding the exact solution takes a lot of time. Hence, one of the best way to solve it is through heuristic algorithm, where the best solution is not necessarily the optimal but the solution that takes reasonable of amount of time to solve (Sabery et al., 2023).

A Study by Violina (2021), analyzes two exact algorithms to solve TSP, the brute force algorithm and the branch and bound algorithm. They conclude that solving TSP with exact algorithm results in optimal outcome but less effective. On the other hand, independent studies by Wu and Fu (2020) and Wadi and Umar (2025), utilizes metaheuristic to solve TSP, and found that it is much better than using exact algorithms. It can easily be seen how the idea of TSP can be applied to itineraries. Each location of itineraries will be nodes and the distances between them are the edges. The goal of the system for the itinerary is to find the route which covers the least distance (Pop et al., 2024).

Orienteering Problem

The Orienteering Problem (OP) is a routing problem that aims to maximize the total rewards collected along a route within a given travel budget (Yu et al., 2022). Similar to this, Morandi et al. (2024) explains OP as the task of planning a route for one vehicle that has to follow a travel budget. The problem is depicted as a graph where the roads have distances and the locations have points or reward values. The goal in this problem is to create a path that starts and ends at the depot, stays within the travel limit, and collects as many rewards as possible from the places visited. Similarly, it originated from a sport of the same name, where participants visit check-points with pre-determined scores, in an attempt to maximize their total score within a specific time (Lim et al., 2019). Pěnička et al. (2019) described OP as a type of problem in operations research, introduced to it in 1984 by Tsiligirides. They then explained that OP is a problem that combines the combinatorial optimization problem Knapsack Problem (KP) with TSP. These two work separately as TSP, given a set of customers, seeks to find the sequence in which to visit selected customers, constrained within a budget, while also minimizing the tour path. The subset of selected customers is selected by the KP, where it maximizes the collected profit based on the selection of customers to be visited within the budget constraints. This will be used in the recommendation feature of the system where the user provides input for the time or distance constraint to generate an itinerary for the user. This is supported by two independent studies by Yochum et al. (2020) that utilize Adaptive Genetic Algorithm with Dynamic Mutation and Crossover Probabilities and, Tenemaza et al. (2020) by modeling the Tourist Trip Design Problem (TTDP) as a Time-Dependent Orienteering Problem with Time Windows (TDOPTW) in their itinerary planning systems.

Simple Additive Weighting

Simple Additive Weighting (SAW), is one of the most widely used methods for Multi-Criteria Decision Making (MCDM). It is used to evaluate and rank a set of alternatives based on multiple and often conflicting criteria. SAW works by calculating a single performance score for each alternative by summing the weighted performance ratings of those alternatives across all criteria (Taherdoost, 2023).

The implementation of SAW follows a structured process to transform diverse criteria into a comparable format. To aggregate different criteria, the data must be normalized first, this is essential because decision matrices often contain data with different units of measurement (Taherdoost, 2023). Malefaki et al. (2025) suggests that min-max normalization technique is the most appropriate for SAW, as it offers robustness regarding small variations in initial data while remaining sensitive to significant shifts in trends. Another critical component of SAW is the assignment of weights to each criterion, which reflects their relative importance in the decision-making context. These weights must sum to 1 (or 100 percent). Weighting can be derived mathematically from the data itself (objective weighting), or subjectively chosen based on the preference, knowledge, and experience of the decision-maker (Odu, 2019). The final score for each alternative is calculated by summing the products of the normalized ratings and their respective weights. The alternative with the highest or lowest total score, depending on the objective, is considered the optimal solution (Taherdoost, 2023).

In the context of this study, SAW was used to select the best algorithm for route optimization. The criteria for selection include accuracy and speed. Each algorithm was evaluated based on these criteria, and the one with the best overall score was chosen for implementation in the LAKAD application.

Technology Acceptance Model

The Technology Acceptance Model (TAM) is one of the well-known theories in explaining and predicting users' acceptance of information systems. Fred D. Davis developed this theory in 1989 to understand the psychological factors affecting individual's acceptance and usage of technology. According to Marikyan and Papagiannidis (2025), the model is based on the Theory of Reasoned Action (TRA), which highlights how an individual's attitude and subjective norms influence their behavioral intention. By concentrating on the variables that influence users' attitudes toward using a particular system, TAM modifies this framework to fit the technological environment.

The model provides a theoretical framework for assessing how likely it is that technology will be adopted in different situations. It has been one of the most widely applied models due to its simplicity and strong explanatory capacity to pinpoint the primary psychological factors influencing users' adoption of new technologies. Through this framework, researchers and developers can analyze how users perceive a system and identify where modification can be made to enhance acceptance and satisfaction (Marikyan & Papagiannidis, 2025). TAM postulates that the acceptance of technology is primarily determined by an individual's behavioral intention (BI), which is shaped by two cognitive responses: Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) (Marikyan & Papagiannidis, 2025). According to Aburbeian et al. (2022), these two constructs are considered the most critical variables influencing the use or rejection of new technology.

Software Product Assessment Framework (ISO/IEC 25010:2023)

ISO/IEC 25010:2023 is part of the Systems and Software Quality Requirements and Evaluation (SQuaRE) series, and it identifies the models to be used for describing and evaluating the quality of software and system products. It provides common terminology and concepts that enable developers, consumers, and evaluators to specify quality requirements and to determine whether a product meets the requirements. The standard emphasizes that both functional and non-functional aspects of performance should be reflected in the defined characteristics and sub-characteristics used in the evaluation of the quality of the product ("ISO/IEC 25010", 2024; "Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Product quality model", 2023).

The model states that the product quality model consists of nine primary characteristics: functional suitability, performance efficiency, compatibility, interaction capability, reliability, security, maintainability, flexibility, and safety. Each characteristic is made up of sub-characteristics which describe quantifiable components of quality, like operability, scalability, coexistence, correctness, and completeness. To keep up with changing technological contexts, the 2023 revision includes revised terminology, replacing interaction capability for usability and flexibility for portability. This system ensures that from a theoretical basis, software products are evaluated consistently to meet user expectations for performance, reliability, and safety throughout their life cycle.

Review of Related Literature

This section presents studies relevant to the development of the proposed itinerary planner. It covers works on Bulacan tourism, optimization techniques for itinerary generation, and related approaches in personalized travel planning. By reviewing these studies, the foundation for the system is established and the selection of suitable methods for itinerary construction is justified.

State of Tourism in Bulacan

According to Canet and Panaligan (2024), tourism development in Bulacan is highly influenced by accessibility, infrastructure, promotion, and the preservation of cultural and natural heritage. While Bulacan shows great potential as a tourist destination because of its rich history and heritage, the issues such as weak promotion, limited facilities, and transportation continue to limit its growth. Following this, a study by Canet and Sunpongco (2025), investigates why some historical and cultural destinations in Bulacan remain neglected despite the province's rich heritage. Their study reveals that popular landmarks like Barasoain Church and Basilica Minore de Immaculada Conception, both in Malalos City, attract the most visitors. On the other hand, attractions in other municipalities such as Meyto Shrine in Calumpit and Francisco Balagtas Museum in Balagtas, showed lower visitations. This imbalance reflects the uneven promotion of Bulacan's tourist sites.

This uneven promotion aligns with the findings of Canet and Panaligan (2024) that one of the issues is the weak promotion. Furthermore, Canet and Sunpongco (2025) examined the promotional strategies used by tourism offices and found that online promotions, social media campaigns, and partnership with bloggers and vloggers were the most effective methods of engaging younger audiences. While traditional approaches such as brochures, festivals and community-driven activities still play a role, digital strategies are better suited for Gen Z and millennial demographic. They emphasized the importance of collaboration among local government units, schools, communities, and tourism stakeholders to ensure consistent promotion and sustainable tourism development.

The local government of Bulacan has also recognized the importance of tourism in the province. In 2023, the Provincial Government of Bulacan launched the Bulacan Heritage Pass, a tourism initiative that focuses on local culture, heritage conservation, and community engagement. The Pass consists of twenty historical and cultural landmarks in the province. The landmarks include Barasoain Church, Casa Real de Malolos, the Malolos Cathedral, and the historic train stations in Guiguinto and Meycauayan, offering a structured route and incentives for completion (Velasco, 2023). While the Heritage Pass strengthens heritage preservation and promotional efforts, it does not provide optimized travel sequencing for visitors, leaving tourists to plan routes on their own. This gap underscores the need for systems that not only identify attractions but also generate efficient itineraries tailored to tourists' time and travel constraints.

Digital Adoption of Tourism in Bulacan. Digital strategies also play a critical role in Bulacan's tourism promotion, Canet et al. (2023), studied how social media content is disseminated to the users in San Rafael, Bulacan and found that 57 percent agreed that social media helped them determine their next choice of destination and 61 percent agreed that social media is a good strategy to make more tourist locations known to people. In line with this, K. C. Y. Dela Cruz et al. (2022) also surveyed 100 tourists that visited Dona Remedios Trinidad, Bulacan to determine the effectiveness of using social media in promoting a tourist destination and asked questions ranging from how social media influences traveler's decisions to the problems faced by tourists when using social media as a guide for tourism. They found that most travelers agreed that social media does influence the choice of destination of travelers. While problems reported by tourists is the spread of false or misleading information, different expectations, and inaccurate photos / videos to different tourist destinations. Clearly, the importance and role of social media in making tourist locations well-known is irreplaceable, aligning with the findings of Canet and Sunpongco (2025). However, it is also prone to misleading information, highlighting the need for verified and curated information of tourist attractions in Bulacan.

Meta-heuristic Algorithm for Routing

Route optimization can be modeled as a TSP, where it seeks the shortest possible route that visits a set of cities (nodes) exactly once. There are many algorithms that provide the solution to the TSP, one of those algorithms is the exact method. According to Violina (2021), exact methods such as Brute Force (BF) and Branch and Bound (BB) algorithms are used to solve TSP. These methods involve evaluating each possible solution one at a time until all of them are explored, then comparing each solution and then selecting the smallest one. The exact algorithm guarantees the best solution, however it becomes inefficient when the number of cities becomes large.

Another approach in solving TSP is through metaheuristic algorithms. These are often referred to as a Nature-inspired Optimization Algorithm, it is designed to find the optimal or near-optimal solutions to complex problems by mimicking the behavior of natural systems, processes, or phenomena (Sabery et al., 2023). Generally, metaheuristic algorithms begin with an initial solution and follow a set of heuristic principles to explore the search space and iteratively improve it. These guidelines help the algorithm avoid local optima and locate globally optimal or nearly optimal solutions by directing the search process toward promising areas of the search space.

In line with this, Barb-Ciorbea (2023) compared an exact method, Mixed Integer Linear Programming (MILP), with a metaheuristic approach, Ant Colony Optimization (ACO), for solving the TSP with time window constraints. The results of the exact approach shown is advantageous because it guarantees the best solution; however, its runtime becomes very high as the number of cities increases. For larger instances, the heuristic approach produced solutions much more quickly, although without the guarantee of global optimality. Despite this, both algorithms were able to achieve the best result in the tested scenario. Moreover, the metaheuristic demonstrated an additional advantage by aiming to minimize waiting duration at nodes when waiting could not be avoided. These findings emphasize that while exact methods provide precision, metaheuristic methods are better suited for larger and more time-sensitive problems (Barb-Ciorbea, 2023). This demonstrates that while exact methods are strictly optimal with respect to accuracy, their exponentially growing time complexity renders them impractical to apply to large-scale or time-constrained situations.

The goal of most metaheuristic algorithms is to find an optimal path to an instance of the TSP. The increased robustness was also found in the study of Hossain and Yılmaz Acar (2024) where they compared new optimization algorithms against old optimization algorithms for solving the TSP and concluded that the new algorithms demonstrated greater effectiveness than the old algorithms in medium-scale instances. The new algorithms used in the study which are the Artificial Bee Colony (ABC), Grey Wolf Optimization (GWO), and the Salp Swarm Algorithm (SSA) performed better routes on average compared to the classic algorithms such as the Genetic Algorithm (GA), Ant Colony Optimization (ACO), and Simulated Annealing (SA). This means that on average, the three newer algorithms produced more consistent results than the classic three. However, they also stated that although newer algorithms produced better outputs, traditional algorithms such as GA and ACO remained to demonstrate strengths for specific instances. While newer and complex algorithms outperform traditional ones in accuracy and robustness, their higher computation times may pose challenges for resource-constrained environments such as mobile devices.

On the other hand, a different comparative study by Wadi and Umar (2025) highlighted the capability of ACO and Particle Swarm Optimization (PSO) to provide a fast execution speed with minimal solution quality reduction, albeit PSO being parameter-sensitive. They also examined another swarm-based approach in the form of Elephant Herding Optimization (EHO), which consistently outperformed both ACO and PSO by achieving lower optimal costs while maintaining short execution times. Their study demonstrated the practicality of the swarm-based approaches in large-scale instances, over exact methods. There are also algorithms that focus on faster execution time at the cost of less solution quality to the route planning. These fast algorithms, however, are most suitable for hardware-related limitations such as processing power in mobile devices.

A more recent nature-inspired optimization technique related to route planning is the Hovering Scouts and Foraging Flocks Pied Kingfisher Optimizer (HSFFPKO). This algorithm enhances the original Pied Kingfisher Optimizer by adding two mechanisms that promote a better balance between exploration and exploitation in searching for a solution. The hovering scout component increases early-stage exploration by probing new regions of the solution space, while the foraging flock mechanism improves exploitation toward guiding candidate solutions to better areas. HSFFPKO showed strong performance in optimization on the CEC 2017 benchmark suite and on various engineering design problems by showing faster convergence and high solution quality compared with several swarm-based metaheuristics (A. M. Dela Cruz, 2025).

Each discussed metaheuristic algorithm demonstrates their strengths and caveats. For instance, in the study of Hossain and Yılmaz Acar (2024), new algorithms (ABC, SSA, GWO) generally have better convergence and scalability than older algorithms (GA, ACO, SA). In terms of speed and accuracy, SA and PSO show fast runtime but sacrifice accuracy. However, the algorithms in the study of Hossain and Yılmaz Acar (2024) and Wadi and Umar (2025) were tested under different tests. Hence, to find the best algorithm among them, each must be evaluated under the same test. Furthermore, the review also shows that the exact algorithm is impractical due to the time it takes to find the exact solution, thus excluding it in the algorithm to be evaluated. The best performing algorithm in terms of speed and accuracy will be the algorithm to be implemented in the study's proposed mobile application.

Itinerary Recommendation and Generation

An itinerary is defined as a structured sequence of selected places, also called Point of Interest (POI), from a set of destinations in an area. Itineraries often include activities that are offered by the POI. Every itinerary is planned accordingly under many constraints, especially in scheduling the order of visitation. These constraints include but are not limited by the route distance, time-allocation, and popularity. By planning an itinerary, tourists can utilize it to serve as a practical roadmap for their travels. These itineraries are not only useful to tourists, but are also an important application of what is called optimization algorithms and recommendation systems. Researchers often describe it as a tourist trip design problem (TTDP), a combinatorial planning task that finds the optimal visiting order of POIs under many constraints (Ruiz-Meza & Montoya-Torres, 2022).

A recommendation system is often included in itinerary generators as explored in the study of Otaki and Baba (2025) where they create a Travel recommender systems (TRSs) that recommend the most relevant itineraries for the users. One of the popular recommendation methods is the Content-based Filtering (CBF). It uses a feature list of items and compares it with items preferred by a specific user previously. The items that match in similarity are recommended to the user. CBF works by storing user profiles based on item features which are most commonly preferred by the user. These features are used to map the similarity of one item with another by similarity equation. Then, it compares each item's features with the user profile and recommends it based on the degree of similarity (Raghuwanshi & Pateriya, 2019). The other popular recommendation method is through Collaborative Filtering (CF). This method is used to predict a user's preferences or opinions by using the collective information of other users of the system. It basically analyzes the similarity between user's preferences and provides a recommendation that way (Li et al., 2024; Widayanti et al., 2023). However, both CBF and CF suffer from a cold start problem where it requires a large enough data of users.

Another approach for itinerary recommendation is based on the Orienteering Problem (OP). According to Lim et al. (2019) Tour recommendation has its roots in the OP and similar variants where a key feature is that they do not incorporate any personalization for individual users. However, a study by Yochum et al. (2020) proposed an Adaptive Genetic Algorithm with dynamic crossover and mutation probabilities (AGAM) to handle personalized multi objective itinerary planning. Their approach integrates mandatory POIs, popularity ratings, visit duration, travel time, and costs into a weighted fitness function. By using data from platforms like TripAdvisor, GoogleMaps, and Flickr, AGAM adapts during evolution to avoid stagnation and produce diverse solutions. They tested the model with a dataset for six cities namely Budapest, Edinburgh, Toronto, Glasgow, Perth, and Osaka. AGAM was compared against two baseline heuristics, MaxN a greedy approach that prioritizes the maximum number of POIs, and MaxP also a greedy approach that prioritizes POIs with the highest rating. The results show that while MaxN and MaxP performed better at including mandatory POIs, AGAM generated richer itineraries with higher-rated POIs. AGAM shows more effective use of time budgets, and improved user enjoyment, but at the expense of higher cost and fewer mandatory POIs. This study shows that an algorithmic approach can provide personalized itinerary for tourists.

The algorithmic approach of Yochum et al. (2020) highlights adaptability through genetic algorithms and diverse real world data sources to produce personalized itineraries and AGAM prioritizes richer and higher rated itineraries even at the cost of efficiency.

Additionally, this approach solves the shortcomings of CBF and CF such as: CBF doesn't have much control over route-level constraints like travel time, distance and budget. Due to the shortcomings of CF and CBF and since the proposed system is a standalone mobile application with no external server, an algorithmic approach is the desired approach for TRS. Hence, the algorithmic approach of Yochum et al. (2020) is the framework to be implemented on the proposed system because it combines recommendations and itinerary generation through the AGAM framework.

Mobile Itinerary Generator

Itinerary generators have been adopted in mobile devices, and various studies have consistently highlighted the role of smartphones in automating and personalizing trip planning. A study by Estilo et al. (2023) developed a mobile application named Destamp, it is a comprehensive planning tool that unifies itinerary generation, budget tracking, and recommendations for Iloilo city. Destamp uses Genetic Algorithm combined with CBF for recommendations. In contrast, Leong (2022) developed an itinerary planner with smart trip generation and social platform that takes a more generic tourism perspective. Loh's app includes itinerary management, autobuild route function, and optional manual editing. Rahman and Jamil (2025) work on iGuid Ipoh positioned the app as a smart-tourism solution for a heritage city, integrating itinerary management with location-based services (LBS) and interactive maps to promote local attractions.

In terms of personalization, Yulfihani and Zakariyah (2024) developed a tourism recommendation system for Batang Regency in Indonesia. Their system compares different categories based on the user's preference making the recommendation more tailored fit for the user. For Estilo et al. (2023), user's preferences are expressed through financial constraints and attraction choices within Iloilo City. Rahman and Jamil (2025) iGuide Ipoh focuses more on contextual and spatial personalization via LBS: the app helps users discover nearby attractions and manage trips while in the destination, but relies less on sophisticated preference modeling and more on location, maps, and curated city content. Loh's system offers personalization through attraction categories and trip parameters (e.g., dates, starting points), then auto-generates a route that users may rearrange, thereby balancing automation with post-generation control (Leong, 2022).

These studies complement each other, for instance the study of Estilo et al. (2023) lacks itinerary management, which Leong (2022) and Rahman and Jamil (2025) included in their study. Additionally, Yulfihani and Zakariyah (2024), although providing a great tourism recommendation system, didn't include interactive map capabilities just like the other mentioned studies. LAKAD sought to implement these features to fill the shortcomings of each mentioned study. By unifying personalized recommendations, route optimization, itinerary management, and map-based navigation; LAKAD positions itself as an improved and more holistic mobile solution for travel planning.

Review of Related Studies

This section presents different related studies that feature: itinerary optimization, where in a group of locations is selected and the order of visitation becomes an output; and personalized itinerary recommendation, where based on the user's preferences and other factors, an itinerary is generated.

Trippit: An Optimal Itinerary Generator

Trippit by Nguyen and Shoubber (2019) addresses a fundamental problem in itinerary planning which is the optimization of the itinerary itself which is a fundamental limitation of Google Maps. Although Google Maps supports multiple stops, it leaves the sequencing to the user and often resulting in inefficient trip planning. Manual planning takes time and significant effort to optimize in terms of total distance traveled and how long each location to visit for. The study also stressed the fact that most travelers would often switch between Google Maps and Yelp for planning itinerary. The system eliminates the difficulty in travel planning which makes vacation trips more time efficient and enjoyable to travelers.

The system was developed using the Waterfall method where each design phase is completed first before beginning the next. An android application was developed using React Native library and called network APIs such as the Google Places API and Foursquare Places API to calculate the optimized itinerary provided by the user. Users can input point of interests (POI) in which the application then retrieves the information from the respective APIs and calculates and outputs the optimized tour based on a greedy algorithm. Their system also calculates the best time to visit each input.

Trippit underwent several testing phases: primary testing, where they compared the results of the system to a known small list of itineraries; unit and integration testing, where they tested the logic and the correctness of the user interface; and alpha testing, with 10 users and was validated using a user satisfaction survey, in which most of the alpha users were satisfied with the resulting itinerary. However, through the selection of the algorithm and device came its limitation, which is that the application can only process up to 12 points of interest (POI). Its evaluation is also a concern as it didn't use any standard evaluation methods like ISO/IEC 25010:2023 standard or the Technology Acceptance Model (TAM). Although a small prototype, Trippit can be considered a good enough system as it was able to produce good itineraries with a simple smartphone application without the use of advanced tools like Google OR.

However, the system focuses solely on itinerary optimization and does not include any recommendation features. Users must already know which POIs they want to visit and input them into the system. There is no mechanism to suggest POIs based on user preferences or popular attractions. Additionally, the greedy algorithm used may not always yield the globally optimal itinerary, especially as the number of POIs increases. The limitation of processing only up to 12 POIs also restricts its applicability for longer trips with more destinations. Future improvements could include integrating recommendation algorithms to suggest POIs and exploring more advanced optimization techniques to handle larger sets of locations.

Optimization of Tourism Destination Recommendations in Batang Regency Using Content-based Filtering

Yulfihani and Zakariyah (2024) created a tourism recommendation system for Batang Regency in Indonesia. They applied Content-Based Filtering (CBF) for their recommendation system, using tourist preferences as their data source. Tourists interact with the system by adding destinations to a wishlist. The system then uses the wishlist to learn the tourist's preferences. The recommendation factors category similarity where it compares the categories of wishlist items like nature, culture, culinary, and leisure; and location similarity by calculating the distance between destinations using the Haversine formula, which finds the shortest distance between two points on Earth using latitude and longitude. The total similarity then calculated with 70 percent category similarity and 30 percent location similarity. The system ranks all available attractions by their total similarity score and the top 10 destinations are recommended to the tourist. The system was tested in different scenarios such as single item in wishlist, multiple items from same category with same/different locations, and multiple items from mixed categories. They use precision, recall, and F1 score as a metric for the system.

The system was designed with a three-tier architecture that includes Backend, Web Admin Panel, and Mobile Application. The backend was built using Laravel (PHP framework) and MySQL, it acts as the hub for all operations including user authentication, processing recommendations using the CBF algorithm, and managing communication between the mobile app, admin panel, and database. The Web admin panel is for administrators and also developed using Laravel, it enables admins to manage tourist destinations, categories (nature, culture, culinary, etc.). Any changes made in the admin panel updates the backend database which instantly reflects to the mobile apps. The Mobile application was developed using Android Studio and Kotlin, it connects the backend using RESTful APIs via Retrofit. The app provides tourists with Login/registration, wishlist management, personalized recommendation based on wishlist and CBF algorithm, viewing details of attractions, and

Filtering by categories and proximity.

The system provides highly accurate and relevant recommendations for tourists, especially in simple preference scenarios. The Content-based filtering approach worked well for aligning recommendations with tourists interests, and achieving a very high F1 score of 0.965. However, performance dropped slightly in complex scenarios like when the wishlist items mixed with different categories and locations. The Authors recommend future improvements such as expanding the dataset, using hybrid models (CBF + collaborative filtering), and adding user feedback mechanisms to further refine recommendations.

However, their study is solely focused on the recommendation aspect of the system, and not on the itinerary optimization. While the system can recommend destinations based on user preferences, it does not optimize the sequence of visits or consider travel constraints like time and distance. Additionally, they didn't include an evaluation for the system like ISO/IEC 25010:2023 standard or the Technology Acceptance Model (TAM), only the evaluation for the Content-based filtering was provided.

Visit Planner: A Personalized Mobile Trip Design Application based on a Hybrid Recommendation Model

Visit Planner (ViP) a mobile application prototype developed by Papadakis et al. (2024). It offers personalized recommendations for an itinerary based on user preference which are either explicitly collected by the application or assessed through the user's behavior within it. ViP utilizes an Expectation Maximization method to offer the user an itinerary that tailors to their satisfactory needs while taking into consideration time and spatial constraints that concern both the user and the destination. The application currently focuses on the city of Agios Nikolaos in Crete. The system requires a user to create a secured profile in a registration process, wherein demographic information and essential data for the algorithm is collected. After this registration process, the user is also asked to specify their preferences in three different ways of their choice, one is by rating categories of POI, another choice is by stating if they like or dislike the category, and another one is by selecting their most preferred category. These categories are carefully specified by analyzing responses collected from 150 visiting tourists, in addition to local and expert knowledge in Agios Nikolaos.

The architecture of the system consists of main components like the front-end User Interface, back-end database, the middleware for processing the information, the recommendation components, and the itinerary creation components. The front-end of the application is an android app available in Google Play. The back-end is composed of MariaDB databases for the purpose of storing necessary information of users and POIs for smooth operations and functionalities. The middleware, built upon the basis of Spring Boot Framework aims to process the controlling flow between the system components and perform the functionalities. It works by receiving queries from the front-end, and then sending those to the recommendation algorithms. The recommendation and itinerary creation components comprises four several recommendation algorithms to tender the needs of the user, where each user is assigned a different algorithm for their cases in performance evaluation wise. ViP integrates multiple, novel recommendation algorithms which can adapt to different user profiles.

The algorithms include model-based collaborative filtering that uses synthetic coordinate based system for recommendations (SCoR), hierarchical content-based similarity measures, a hybrid content-based recommendation using Weighted Extended Jaccard approach combined with the second one, and Bayesian recommendation algorithm. Any of these algorithms is applied to generate personalized POI suggestions. And once candidate POIs are retrieved, an expectation-maximization-based itinerary creation component sequences them into a feasible route by maximizing user satisfaction function constrained under temporal and spatial factors.

I-AIR: Intention-aware travel itinerary recommendation via multi-signal fusion and spatiotemporal constraints

Cui et al. (2025) developed I-AIR (Intention-Aware Itinerary Recommendation), a system based on deep learning that aimed to generate personalized and practical traveling itineraries. The two primary components of the system are an Itinerary Construction Policy, which organizes selected Points of Interest (POIs) into a logical and sequential trip, and an Intention-Aware POI Scoring Model, which assesses the relevance of possible POIs based on user preference and contextual cues. To model user preferences, I-AIR applied a Transformer-based sequential encoder that identified time patterns from check-in history, an explicit feedback encoder that synthesized long-term preferences from ratings and likes, and a Graph Convolutional Network (GCN) that represented POI relationships through co-visitation patterns. These components were integrated via a multi-signal fusion layer to generate customized POI relevance scores. In optimizing the route, the system applied a greedy algorithm that picked the top-scoring viable POI at each step while removing possibilities that violate prohibitions such as travel time, wait time, business hours, and total time budget. The model was trained using a combination of next-POI prediction and explicit feedback reconstruction on datasets including user trajectories, ratings, dwell times, and POI attributes.

During evaluation, the system was tested on eight real word datasets, including four each of theme parks and city tourism. These datasets included detailed information such as user check-in records, wait times at attractions, and tourists' reviews, and provided implicit and explicit feedback signals. The evaluation measures applied were precision, recall, and F1-scores, and comparative baseline systems included were Greedy-Popular (GPop), Greedy-Near (GNear), PersQ, EffiTourRec, DCC-PersIRE, BERT-Trip, and DLIR. Results showed that I-AIR outperformed the other systems significantly across all datasets, with higher precision in both theme park and city tourism scenarios.

Destamp: A Mobile Application for Generating Budget-Based Itineraries to Enhance Travel Planning

Estilo et al. (2023) have proposed a very similar system to the study's proposed application where itinerary generation and itinerary optimization are the main core features. The system of Estilo et al. (2023) is a mobile application that uses GA to generate an itinerary for the user. However, unlike LAKAD, the GA used in the study is univariate and does not consider other factors that may affect the user's experience on the generated itineraries such as the user's categorical preferences and POI ratings. The main objective function implied in the study is the minimizing of the itinerary travel budget depending on the maximum budget provided by the user and fitting the opening hours of each POI to the specified starting time of the user.

Destamp was developed using the AGILE methodology and the React Native framework for developing cross-platform mobile applications. Mapbox service was also used to provide mapping functions such as routing and interactive map features. While the system is split into two sections for the architecture: frontend and backend. The frontend handles all the graphical user interface and interactions which sends requests to the backend for the processing and logic such as itinerary generation.

The application has many similar features to LAKAD such as itinerary generation and live map interaction. Users can set multi-day itineraries as well as allocate budgets for the itinerary to be generated. Each POI in the app contains the map location, budget cost, opening hours, and contact information. Business owners can also use the app to submit their own shops and businesses to show up as POI in Destamp, making the whole POI list accessible and dynamic.

While very similar to LAKAD, Destamp is only bounded to the places in Iloilo City. It also implements a freemium model to its features where most features such as maximum itineraries are locked behind a subscription. It also uses GA for its itinerary generation but is lacking the option for the itinerary optimization through TSP model as their optimization refers to pair-wise optimization through Dijkstra algorithm instead. There is also a clear gap in itinerary management where itineraries cannot be edited and must be regenerated for any changes. Furthermore, the evaluation instrument of their study is not clearly defined, and the evaluators they considered consisted of ten respondents, in which they concluded that GA actually does improve travel recommendations.

Destamp limits their users from fully utilizing their application. This is different from LAKAD which allows users full access to all the available features mentioned in Destamp such as itinerary generation and optimization. The itinerary generation of LAKAD will utilize a different model, AGAM, which is a multivariate version of GA that takes into consideration factors such as POI user score through cosine similarity and POI rating from Google Maps. While the itinerary optimization aspect uses TSP applicable algorithms as mathematical foundation for minimizing the total distance traveled for the whole itinerary. Finally, users can also fully manage their own itineraries allowing them to edit the POIs included in existing itineraries.

Synthesis of the Review

The reviewed works establish valid grounds for the proposed mobile application's technical framework. Concepts such as Graph Theory, the Traveling Salesman Problem, and Orienteering Problem provide the mathematical foundation for itinerary generation and route optimization. While exact algorithms guarantee the best solution, they are often impractical for mobile devices due to high computation times. Consequently, metaheuristic algorithms have been shown to outperform exact algorithms as explored in the study of Hossain and Yılmaz Acar (2024) and Wadi and Umar (2025), offering a viable solution for mobile constraints. Furthermore, regarding personalization, literature suggests that while Content-Based Filtering is effective, it suffers from the "cold-start" problem and often provides the same recommendation as they are often deterministic in nature. In contrast, algorithmic approaches, particularly the AGAM by Yochum et al. (2020), offer greater flexibility by allowing the fitness function to account for multiple objectives such as user preferences, ratings, and time constraints. Therefore, AGAM is an applicable method for itinerary recommendation compared to content selection methods.

Mobile applications like Trippit, Destamp, and I-AIR proved the feasibility of smartphone-based route generation. However, the review highlights significant fragmentation in the current landscape as some features of existing mobile applications are mutually exclusive to each other. Some focus solely on budget (Destamp), while others prioritize simple routing without personalization (Trippit) or lack of comprehensive itinerary management features. Additionally, many existing studies fail to apply evaluation frameworks like ISO/IEC 25010:2023 or the Technology Acceptance Model (TAM). This limits the reliability of their usability claims. LAKAD intends to fill these gaps by providing a verified and rigorously evaluated generator specifically for Bulacan tourism.

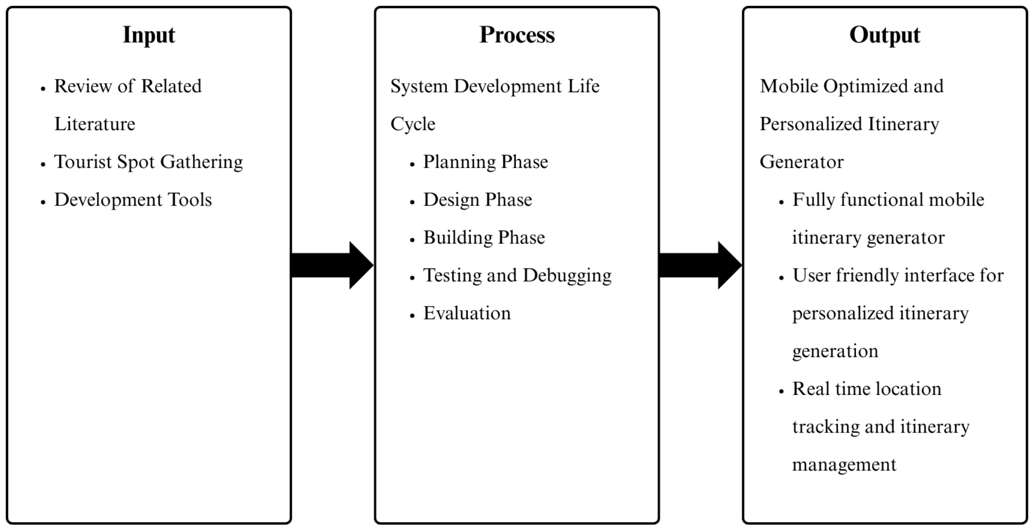
Finally, the literature highlights the needs for this system for Bulacan to exist. Although digital strategies are crucial for promotion as stated by Canet and Sunpongco (2025), but K. C. Y. Dela Cruz et al. (2022) pointed out that reliance on social media often leads to misinformation. While the Bulacan government has initiated programs like the Pamana Pass, there is currently no provincial-level system that automates and optimizes personalized itinerary planning. Existing Philippine-based studies, such as those by Estilo et al. (2023) are limited to specific cities (Iloilo city) and do not address the provincial scope required for Bulacan. Therefore, LAKAD addresses these gaps by integrating verified local data with advanced optimization algorithms to create a personalized tourism experience in Bulacan.

Conceptual Framework

This section explains the key inputs, processes, and outcomes in development of the study using an Input-Process-Output (IPO) model.

Figure 1

Input-Process-Output (IPO) Model



Input

The input contains the review of the methods used by related studies and systems, which will be used as foundation in the study. These methods consist of different algorithms used for solving the TSP and selecting which algorithm is the most applicable in the mobile platform as well as which recommendation model is a fit for itinerary recommendation. The second input is the gathering of tourist spot locations or point of interests (POI). These POIs are locations in Bulacan which can be considered as tourist attractions. These will be gathered from and verified by the Provincial History, Arts, Culture, and Tourism Office (PHACTO) to assess the correctness of the POIs included in the system. Development tools refer to the hardware and software tools that will be used to actually develop the application. These include operating systems such as Windows or Ubuntu, integrated development environments (IDE) such as Visual Studio or Android Studio, and design pieces of software like Figma or Adobe Illustrator.

Process

The AGILE methodology will be used in the software development of LAKAD, specifically the Kanban method. Kanban method is a visual process management system that can manage knowledge and work by considering the Just In Time (JIT) delivery approach Alaidaros et al. (2021). The first phase of the development will be planning and analyzing the different requirements of the system such as flow charts, entity relationship diagrams, and use cases. Afterwards, mockup user interface will be made to fully outline the look and feel of the application. Building phase will be the actual development of the core features of the application and testing and debugging will refer to the testing of the correctness of the core features' implementation. The power of AGILE methodology will be used to iteratively cycle between building phase and testing to evaluation by users and professionals to quickly enhance features and get immediate feedback. The system will go through rigorous evaluation by professionals through ISO 25010 and through TAM by its intended users.

Output

The expected output of this study is a fully functional mobile itinerary recommendation and optimization system in the scope of Bulacan. LAKAD application will be able to optimize the route to be taken for the user's itinerary as well as recommend personalized itineraries that may interest the user.

Definition of Terms

This section provides the definition of the terms used in the study, along with the operational aspects of the proposed system, to ensure clarity and a proper understanding of the concepts within the context of the research.

Algorithms. A repeated sequence of finite steps used to solve specific problems or perform calculations.

Cold Start. A problem where an algorithm has not enough necessary input data from users to perform instructions.

Itinerary. Planned sequence of tourist destinations that either reflects the user's selected preferences or is made as a recommendation by the algorithm.

Itinerary Management. A feature that allows users to organize, edit, and monitor their selected destinations and travel schedules.

Itinerary Navigation. A feature that provides users with directions and guidance throughout their travel route.

Itinerary Optimization. The process of planning the most efficient route or order of destinations for travel, determined through the use of optimization algorithms.

Personalized Itinerary Recommendation. A feature that suggests travel routes and destinations made by the algorithm tailored to the individual preferences and constraints of the user.

Provincial History, Arts, Culture, and Tourism Office (PHACTO). The government office responsible for promoting and preserving the history, arts, culture, and tourism of Bulacan province. Source of POI data.

Point of Interest (POI). A destination or tourist spot specifically preferred by a tourist, such as historical sites, natural attractions, or cultural landmarks that can be included into an itinerary.

Recommendation System. A system or algorithm that suggests destinations to users based on preferences, collected data, or other relevant parameters.

Tourist. A person traveling from place to place for pleasure or interest. The tourist serves as the end-user who interacts with the mobile application.

Tourist Spot Searching. A feature that enables users to browse, locate, and explore tourist destinations within the province.

Mapbox. An online service that provides a mapping platform to offer navigation features, interactive maps, and location information for tourist destinations in Bulacan.

Application Programming Interface (API). A set of rules and tools that allows the application to access external services, like Mapbox, in order to get the map, routing, and location information required for navigation and itinerary creation.

CHAPTER III

RESEARCH METHODOLOGY

In this chapter the research design, model adoption, process of developing the system, system evaluation, population and sample, data collection, data processing, and ethical considerations are discussed. This ensures that the research methodology is well-defined and structured, providing a clear roadmap for the execution of the study. The research design outlines the approach and framework for conducting the research, while the model adoption section delves into the specific mathematical models and algorithms that are utilized in the development of LAKAD. The process of developing the system details the steps taken to create and implement the application, while the system evaluation focuses on assessing its performance and effectiveness. The population and sample section defines the target audience for the study, and the data collection and processing sections outlines how the data was gathered and analyzed. Finally, ethical considerations ensure that the research is conducted in a responsible and ethical manner, respecting the rights and privacy of participants.

Research Design

This study primarily focuses on the development and implementation of a mobile application that generates personalized itineraries for tourists. The research design is structured to ensure that the system is developed based on empirical evidence and is evaluated for its quality, standards, and acceptability among users and professionals in the tourism industry. The quantitative aspect of the research design allows for the collection and analysis of numerical data to assess the effectiveness of the system, while the applied research approach ensures that the development of the system is grounded in real-world applications and addresses the specific needs of its intended users.

Quantitative Research

The quantitative research, specifically, descriptive research design is one of the designs in this study. This aspect of the study measure, analyze, and describe the quality, standards, and acceptability of the system using quantitative methods by collecting user and professional feedback. The researchers assess the quality and standards using the ISO/IEC 25010:2023 standard by seeking professionals to assess the system. While the acceptability of the system for tourists was analyzed using the Technology Acceptable Model (TAM). Incorporating quantitative approach for the study ensures an empirical and evidence-based support for the quality and acceptability of the developed system.

Applied Research

The applied research aspect of the study focuses on developing and implementing a system for generating personalized itineraries and optimizing existing itineraries for the interests of the user. The primary objective of this study is to create a mobile application that optimizes itineraries using the best Metaheuristic algorithm and generates personalized itineraries with travel budget using Adaptive Genetic Algorithm with Dynamic Mutation and Crossover Probabilities (AGAM) framework. The selection of the best metaheuristic algorithm was based on the performance of the algorithms in terms of solution quality and runtime efficiency. In this study, AGAM is explicitly adopted for itinerary generation and optimization even though it can also be used for route optimization. This is because the literature showed that AGAM showcased the effectiveness of AGAM for itinerary generation and optimization. The development of the system involves the use of mathematical models such as the Traveling Salesman Problem (TSP) for route optimization and the Orienteering Problem (OP) for itinerary generation. The implementation of these models in the mobile application ensures that the system is grounded in real-world applications and addresses the specific needs of its intended users, providing a practical solution for personalized itinerary generation and optimization.

Model Adoption

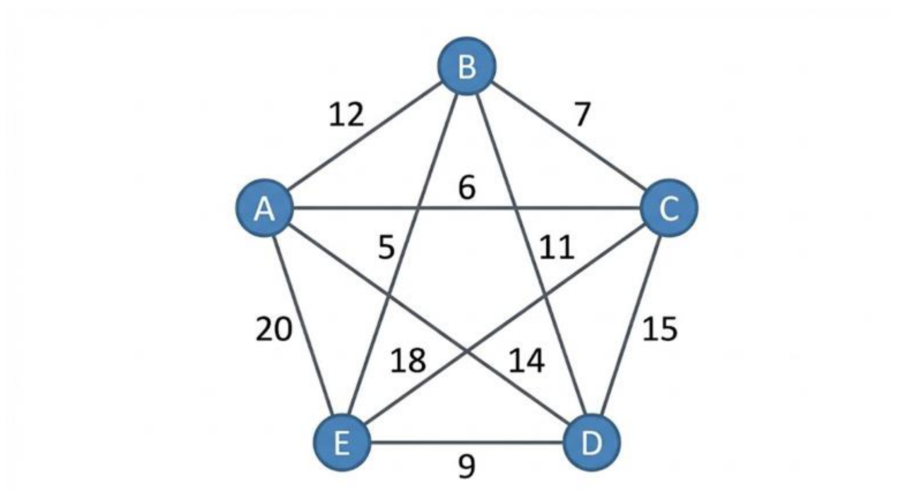
This section discusses the optimization problems such as route optimization and itinerary generation and the steps in modeling each mathematically. Specifically, the mathematical models used in the study are the traveling salesman problem (TSP) and the orienteering problem (OP).

Modeling Route Optimization with TSP

Route optimization refers to the process of finding the optimal order in visiting a set of places. This is also another definition of the TSP, where the salesman must minimize the travel cost between traveling a set of cities. In the study, the POI represents the nodes and the edges connecting each node as the distance between the shortest route, a sample graph is shown in Figure 2.

Figure 2

Sample Graph



The objective is to minimize the total travel distance by finding the best order to travel each POI from an itinerary. Using integer programming and given a graph $G = (V, E)$ where V is the set of vertices (POI) and E is the set of edges (road distance), the objective function is as shown in Equation 1:

$$\text{Minimize} \sum_{i=1}^{n} \sum_{j=1, j \neq i} c_{ij} x_{ij} \tag{1}$$

Where n is the total number of vertices (POI), c_{ij} refers to the cost of traveling from vertex i to vertex j, which in this case is the distance between the two POI, and x_{ij} refers to a binary value that indicates whether an edge directly connecting vertex i to vertex j exists in the solution (1 if it exists, 0 otherwise). The function is also constrained to the following:

1. Every city is entered and exited exactly once.
2. The solution does not contain any sub-tours.

Candidate Algorithms for TSP

The study considers several metaheuristic algorithms for route optimization for LAKAD, each with its unique approach and characteristics. These algorithms include:

1. **Genetic Algorithm (GA).** Inspired by genetics and evolution, the Genetic Algorithm is an optimization technique that works by analyzing potential solutions and generating new ones through the processes of selection, crossover, and mutation. This iterative process continues until a predefined termination requirement is met. GA is widely used across various domains because of its ability to navigate complex search spaces and identify optimal or near-optimal solutions (Hossain & Yılmaz Acar, 2024).
2. **Ant Colony Optimization (ACO).** The Ant Colony Optimization (ACO) is an optimization algorithm that mimics the foraging behavior of ants. It utilizes artificial pheromone trails to guide the search for optimal solutions. Ants in the algorithm employ probabilistic pheromones and heuristic information to address problems. The quality of the solutions determines how the pheromone trails are updated. This mechanism encourages exploration and prevents premature convergence. ACO has proven effective for various optimization difficulties (Hossain & Yılmaz Acar, 2024).
3. **Simulated Annealing (SA).** The Simulated Annealing (SA) algorithm is a

metaheuristic technique influenced by the annealing process in metallurgy. It begins with an initial solution and incorporates a mechanism that allows for the occasional acceptance of a "worse" solution based on and more thoroughly explore the solution space. The probability of accepting a worse solution is gradually reduced over time, simulating the cooling process. SA is applicable to a wide range of optimization problems (Hossain & Yılmaz Acar, 2024).

4. **Particle Swarm Optimization (PSO).** The Particle Swarm Optimization (PSO) algorithm is inspired by the social behavior of bird flocks and fish schools. In PSO, the population is made up of numerous particles, each representing a potential solution within the search space. Every particle is characterized by a velocity and a fitness value. Conceptually, PSO is very straightforward, as it relies solely on elementary mathematical operations and does not require any derived information about the optimization function (Wadi & Umar, 2025).
5. **Elephant Herding Optimization (EHO).** The Elephant Herding Optimization (EHO) algorithm is a swarm-based metaheuristic search approach for addressing optimization problems that mimics the real herding behavior of elephants, which involves organizing elephant swarms into smaller clans, each led by a matriarch and consisting of multiple female elephants and their calves, while adult male calves are expelled from the clan (Wadi & Umar, 2025).
6. **Gray Wolf Optimizer (GWO).** The Gray Wolf Optimization (GWO) algorithm is a metaheuristic technique inspired by gray wolves, simulating their leadership and cooperative hunting behaviors to locate optimal solutions. The hierarchical structure of a wolf pack (Alpha, Beta, Delta, and Omega wolves) is shown in the algorithm's design. Wolves' positions are updated based on the Alpha's location and the calculated hunting distance. GWO leverages a balance of exploration and exploitation to discover the best possible solutions. This approach has been successfully applied to various optimization challenges (Hossain & Yılmaz Acar, 2024).

7. **Hovering Scouts and Foraging Flocks Pied Kingfisher Optimizer (HSFFPKO).** HSFFPKO enhances the traditional Pied Kingfisher Optimizer by introducing multiscale search mechanisms to improve optimization performance. By adding Hovering Scouts for fine-grained local adjustments and Foraging Flocks for parallel group-based exploitation, the algorithm maintains better population diversity than its predecessor. These additions allow HSFFPKO to mitigate local optima entrapment and solve complex, high-dimensional problems more efficiently (A. M. Dela Cruz, 2025).

TSP Algorithm Selection

To determine the best algorithm to implement for LAKAD, a comparative analysis was conducted on several metaheuristic algorithms used for solving TSP. The analysis focuses on solution quality (accuracy) and runtime speed of each algorithm. The algorithms were tested on selected instances from the TSPLIB library, a standard benchmark for TSP and related problems. Table 1 presents selected instances for benchmarking.

Table 1

TSPLIB Instances for Benchmarking

TSPLIB instance	Description	Optimal Solution
burma14	Small instance with 14 cities	3323
bays29	Medium instance with 29 cities	2020
eil51	Large instance with 51 cities	426
berlin52	Large instance with 52 cities	7542

Experimental Setup. The experiments were implemented in Python because of its library support for TSPLIB, and for simplicity of the language. To ensure statistical reliability and mitigate the stochastic nature of heuristic algorithms, each algorithm was executed for 10 independent iterations on each TSPLIB instance. The results were averaged to get the baseline performance profile. Two primary metrics were defined to evaluate the algorithms:

1. **Runtime Speed (T_{avg}).** It measures the average time it takes to find the solution across the 10 iterations, measured in seconds. This metric is crucial for assessing the efficiency of the algorithm, and is calculated using the formula shown in equation 2:

$$T_{avg} = \frac{1}{10} \sum_{i=1}^{10} T_i \tag{2}$$

Where T_i is the runtime for the i-th iteration.

2. **Solution Quality (Q_{avg}).** Since the best solution for each TSPLIB instance is known, the accuracy is measured by the average relative error of the solution found by the algorithm compared to the optimal solution. The calculation is shown in equation 3:

$$Q_{avg} = \frac{1}{10} \sum_{i=1}^{10} \frac{C_i - C_{opt}}{C_{opt}} \times 100 \tag{3}$$

Where C_i is the cost of the solution found in the i-th iteration, and C_{opt} is the cost of the known optimal solution for the instance. This metric provides insight into how close the algorithm's solutions are to the optimal solution, with lower values indicating better performance.

Furthermore, each algorithm was executed on the same hardware and software environment to ensure a fair comparison. The experiments were conducted on a machine with a Ryzen 5 3400G processor, 16GB of RAM, and running Arch Linux. The algorithms were implemented with Jupyter Notebook, and the runtime was measured using Python's built-in 'time' module.

Algorithm Ranking. To select the final algorithm, the trade-off between speed and accuracy was resolved using Simple Additive Weighting (SAW).SAW was chosen because of its simplicity and interpretability, allowing for a straightforward comparison of the algorithms based on the defined metrics. Since both T_{avg} and Q_{avg} are "cost" criteria, i.e., lower values represent better performance, it is normalized relative to the maximum (worst) observed value to scale all metrics between 0 and 1. The normalization formula used was shown in equation 4:

$$r_{ij} = \frac{x_{ij}}{\max(x_{ij})} \tag{4}$$

Where r_{ij} is the normalized value of the j-th criteria for the i-th algorithm, x_{ij} is the original value of the j-th criteria for the i-th algorithm, and $\max(x_{ij})$ is the maximum value observed for the j-th criteria across all algorithms. This normalization ensures that both metrics are on a comparable scale, allowing for a fair assessment of each algorithm's performance in terms of both speed and accuracy.

The final score S_i for each algorithm i was calculated in equation 5:

$$S_i = \sum_{j=1}^{n} w_j \cdot r_{ij} \tag{5}$$

Where S_i is the final score for the i-th algorithm, w_j is the weight assigned to the j-th criteria, such that $\sum_{j=1}^{n} w_j = 1$, and r_{ij} is the normalized value of the j-th criteria for the i-th algorithm. Additionally, the

For this study, since the weights can be subjectively assigned, equal weights were assigned to both criteria, i.e., $w_1 = w_2 = 0.5$. This gives equal importance of runtime speed and solution quality, the final score is shown in equation 6:

$$S_i = 0.5 \cdot r_{i1} + 0.5 \cdot r_{i2} \tag{6}$$

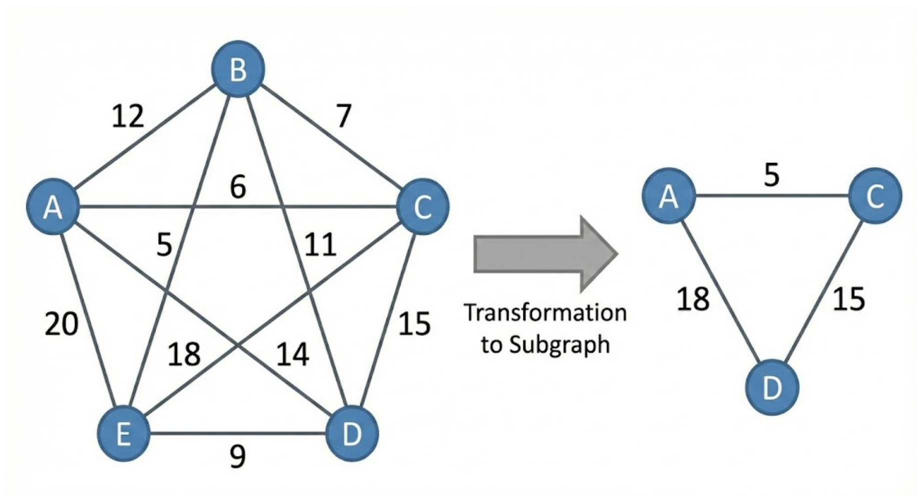
The algorithm with the lowest score S_i is considered the best choice for implementation for LAKAD. The results of the algorithm selection process are discussed in Chapter 4.

Modeling Itinerary Generation as Orienteering Problem

Another core optimization problem in the study is itinerary generation, which can be modeled as an orienteering problem (OP). In the context of the study, an itinerary refers to a plan of the user to go to two or more places. An itinerary can be modeled mathematically using graph theory similar to TSP. This would involve setting the vertices of a graph as the places and the edges as the road distance between the connected edges. A big difference of OP from TSP is the fact that it takes the whole graph or all the possible POI and outputs a subgraph instead, where TSP would use the entire graph given. An example is shown in Figure 3 where 5 POI are given as input and only three were used to generate an itinerary.

Figure 3

Subgraph result from OP



The objective of the OP is to maximize the available profit, in the case of the study: travel distance, to generate an itinerary for the user alongside other factors. Mathematically, the OP can be formulated as follows in Equation 7.

$$\text{Maximize } Z = \sum_{i=2}^{n-1} \sum_{j=2}^{n} S_i x_{ij} \tag{7}$$

Where n is the total number of vertices (POI), S_i is the score of vertex i, which can be a combination of factors such as travel distance, user preferability score, and popularity rating, x_{ij} is a binary variable that indicates whether the edge from vertex i to vertex j is included in the itinerary (1 if included, 0 otherwise), and Z is the total score of the itinerary, which the algorithm aims to maximize. The function is also constrained to the following:

1. Each vertex must only be visited once.
2. The total score must not exceed the given budget.
3. The generated path must be connected.

Adaptive Genetic Algorithm with Dynamic Mutation and Crossover Probabilities

The study also chose to adopt a modified variant of the genetic algorithm developed by Yochum et al. (2020) called Adaptive Genetic Algorithm with Dynamic Mutation and Crossover Probabilities (AGAM) for the optimization of recommended itineraries defined in terms of TSP. AGAM addresses itinerary planning as a Multi-Objective Optimization Problem, an optimization technique rooting from orienteering problems. As discussed in their work, Yochum et al. (2020) developed AGAM to generate optimal and personalized travel itineraries by balancing several objectives such as point of interest (POI) rating, and distance of POIs between the next one. Rooting from Genetic Algorithm (GA), AGAM simulates the process of natural evolution and utilizes genetic operators such as selection, crossover, and mutation to iteratively improve the quality of itineraries which, unlike traditional GA that use fixed mutation rates, also employs dynamic adjustments in parameters during the evolutionary process in a way that can maintain population diversity and therefore generate efficient and adaptive solutions.

In this implementation, the population set is defined as $P = \{p_1, \ldots, p_n\}$, where each individual p_i represents a potential itinerary. An itinerary is encoded as a sequence of POIs, $p_i = \{q_1, q_2, \ldots, q_m\}$, where each gene q_i corresponds to a specific POI visit. The length of the sequence depends on the number of POIs selected, and it is constrained by a user-defined limit $MAXN$. The total travel distance of the itinerary is constrained by $MAXD$, which ensures that the generated itineraries does not exceed the user's travel distance budget.

Fitness Function. The quality of each itinerary is evaluated by the fitness function given in Equation 8. Since factors such as popularity, rating, and interest are on different scales, a normalization process is applied to each factor so that its values is between 0 and 1.

$$f(p_i) = w_1 Ti(p_i) + w_2 Tn(p_i) + w_3 Tr(p_i) \tag{8}$$

Where w_j for $j = 1, 2, 3$, represents the weight assigned to each factor, and it is defined as follows:

- $Ti(p_i)$ is the sum of all interest values of each POI in the itinerary p_i. Each POI contains an interest value which quantifies how interested the user is in that specific POI category. The formula for calculating $Ti(p_i)$ is shown in Equation 9,

$$Ti(p_i) = \sum_{q_i \in p_i} I(q_i) \tag{9}$$

  where $I(q_i)$ is a binary value that indicates whether the user is interested in the category of POI q_i (1 if interested, 0 otherwise).

- $Tn(p_i)$ is the total number of POIs in p_i, which is calculated in Equation 10.

$$Tn(p_i) = \frac{N_{op}(p_i)}{NOP}, \quad \text{where } N_{op}(p_i) \leq MAXN \tag{10}$$

  where $N_{op}(p_i)$ is the number of POIs in itinerary p_i, and NOP is the total number of available POIs.

- $Tr(p_i)$ is the total rating of p_i given by Equation 11,

$$Tr(p_i) = \frac{\sum_{q_i \in p_i} R(q_i)}{MAXR} \tag{11}$$

  where $R(q_i)$ is the rating of a specific POI q_i in itinerary p_i obtained from Google Maps, and $MAXR$ is the best possible rating of all POIs defined as $MAXR =$ Number of POIs $*$ Maximum Rating.

Adaptive Genetic Operators. AGAM incorporates dynamic adjustments in mutation and crossover probabilities to balance exploration (searching new solutions) and exploitation (refining existing solutions). These are defined as follows:

- **Adaptive Crossover** (P_c)**.** To preserve high-quality solutions, the crossover probability decreases as the fitness of the parents exceeds the population average (f_{avg}). This is given by Equation 12,

$$PC = \begin{cases} pc_1 - \dfrac{(pc_1 - pc_2)(f' - f_{avg})}{f_{max} - f_{avg}}, & f' \geq f_{avg} \\ pc_1, & f' < f_{avg} \end{cases} \tag{12}$$

  Here, pc_1 and pc_2 are the upper and lower bounds for crossover probability,f_{max} is the largest valued fitness score among the set of populations P, f' is the larger fitness score of the two parents being crossed, and f_{avg} refers to the average fitness score of the population P.

- **Adaptive Mutation** (P_m)**.** Similarly, mutation rates are adjusted to prevent destroying optimal solutions. This is defined in Equation 13,

$$PM = \begin{cases} pm_1 - \dfrac{(pm_1 - pm_2)(f - f_{avg})}{f_{max} - f_{avg}}, & f \geq f_{avg} \\ pm_1, & f < f_{avg} \end{cases} \tag{13}$$

  where pm_1 and pm_2 are the bounds for mutation probability, and f is the fitness score of the individual being mutated.

For the parameters of AGAM, the following values were used: $pc_1 = 0.9$, $pc_2 = 0.6$, $pm_1 = 0.1$, and $pm_2 = 0.01$. These values were chosen based on Yochum et al. (2020) recommendation, which are commonly used in dynamic crossover and mutation probabilities. The procedure of AGAM is shown in Algorithm 1.

Algorithm 1 Adaptive Genetic Algorithm for Itinerary Optimization (AGAM)

Require: $MAXD$ (maximum travel distance), $MAXN$ (maximum number of POIs), N (population size)
Require: pc_1, pc_2 (crossover control parameters), pm_1, pm_2 (mutation control parameters)
Require: w_1, w_2, w_3 (fitness weights), δ (number of generations)
Ensure: Optimal itinerary p_{opt}

Initialize population P with N randomly generated itineraries
for each $p_i \in P$ **do**
Ensure $TotalDistanceCost(p_i) \leq MAXD$
end for
for iteration = 1 to δ **do**
Evaluate fitness $F(p_i)$ for each itinerary using:

$$F = w_1 Ti(p_i) + w_2 Tn(p_i) + w_3 Tr(p_i)$$

Compute $f_{\max} = \max(F(p_i))$, $f_{\text{avg}} = average(F(p_i))$
Initialize new population $P_i = \emptyset$
while $|P_i| < N$ **do**
$(parent_1, parent_2) = TournamentSelection(P, k = 2)$
$PC = calculateCrossoverProbability(F(parent_1), F(parent_2), f_{\text{avg}}, f_{\max})$
if $random(0, 1) < PC$ **then**
$(child_1, child_2) = OnePointCrossover(parent_1, parent_2)$
if $TotalDistanceCost(child_1) > MAXD$ **or** $NUMPOI(child_1) > MAXN$ **then**
Regenerate($child_1$)
end if
if $TotalDistanceCost(child_2) > MAXD$ **or** $NUMPOI(child_2) > MAXN$ **then**
Regenerate($child_2$)
end if
if $TotalDistanceCost(child_1) < MAXD$ **and** $NUMPOI(child_1) < MAXN$ **then**
InsertUnvisitedPOIs($child_1$)
end if
if $TotalDistanceCost(child_2) < MAXD$ **and** $NUMPOI(child_2) < MAXN$ **then**
InsertUnvisitedPOIs($child_2$)
end if
Add $child_1$ and $child_2$ to P_i
else
Add $parent_1$ and $parent_2$ to P_i
end if
end while
for each itinerary $p_i \in P_i$ **do**
$PM = calculateMutationProbability(F(p_i), f_{\text{avg}}, f_{\max})$
if $random(0, 1) < PM$ **then**
$Mutated\_p_i = ApplyMutation(p_i)$
if $TotalDistanceCost(Mutated\_p_i) > MAXD$ **or** $NUMPOI(Mutated\_p_i) > MAXN$ **then**
Regenerate($Mutated\_p_i$)
end if
if $TotalDistanceCost(Mutated\_p_i) < MAXD$ **and** $NUMPOI(Mutated\_p_i) < MAXN$ **then**
InsertUnvisitedPOIs($Mutated\_p_i$)
end if
$p_i \leftarrow Mutated\_p_i$
end if
end for
Recalculate fitness of all itineraries in P_i
$P \leftarrow P_i$
end for
return p_{opt} = itinerary with the highest fitness in P

Process of Developing the System

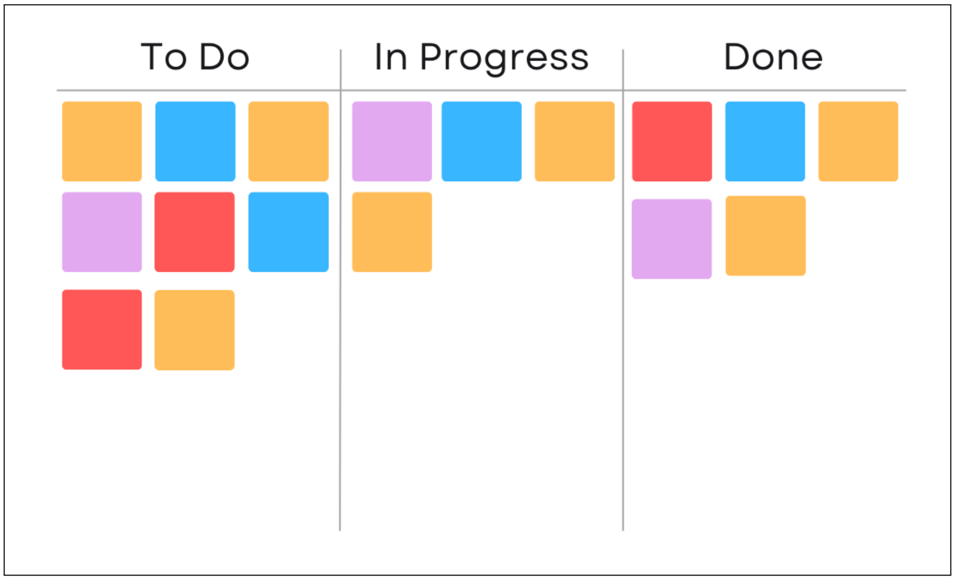
The development of the LAKAD mobile application uses the AGILE methodology, with a specific focus on the Kanban method. This approach integrates all key software development phases. These phase include analysis, planning, design, development, testing, and review, each of the phases contributes to the overall quality and functionality of the final product.

Kanban is a highly effective visual process management system designed to optimize the flow of work. It operates on the principle of Just In Time (JIT) delivery, as highlighted by Alaidaros et al. (2021), ensuring the tasks are completed and delivered precisely when needed to maximize efficiency.

This methodology offers significant advantages for the LAKAD development team. It provides a clear, visual representation of the entire workflow, allowing all team members to easily track progress from start to finish. This transparency is crucial for quickly identifying potential bottlenecks, gaps in the process, or any mishaps that might arise. By making the workflow visible, the team can proactively address issues, rather than reacting to them after they have escalated. Kanban, being a type of Agile-based methodology, is an approach that promotes flexibility which can help in an environment of software development where problems and unforeseen challenges are inevitable. Kanban's adaptability allows the team to adjust priorities and reallocate resources as needed, ensuring that progress remains steady even when obstacles are encountered. This flexibility is key to maintaining momentum and delivering a high-quality software output (Risener, 2022). The continuous flow and iterative nature of Kanban supports the team in delivering a robust and reliable system that meets user needs effectively. Figure 4 shows a graphical representation of a Kanban workflow model.

Figure 4

Kanban Software Development Life Cycle



Analysis

The analysis phase of the development involves outlining the system's scope, objectives, and requirements. This was done by reviewing the existing literature in itinerary recommendation and local tourism in the province of Bulacan. This phase establishes the key features of LAKAD, that integrates five major features designed to provide optimized, personalized, and efficient itinerary planning for tourists exploring Bulacan. Each feature combines techniques, verified local data, and user-centric design principles.

1. **Tourist Spot Exploration.** A tourist spot search feature allows the users to explore Bulacan's tourist attractions specifically through an interface where they can search through a catalog of tourist destinations that was verified by the Provincial History, Arts, Culture, and Tourism Office (PHACTO) of Bulacan. Furthermore, the system displays important and relevant information such as location and short description about the tourist spot.
2. **Personalized Itinerary Generation.** The main feature of LAKAD is the personalized itinerary generator focusing on the diverse cultural, historical and heritage tourist

destinations located across the province of Bulacan. The system developed to adapt to user-specific factors that can affect the personalization aspect of an itinerary. This feature aims to cater the personal preferences that a user has while still promoting the exploration of the rich tourism culture of the region.

3. **Itinerary Optimization.** The optimization feature of the system works in line with the personalized itinerary generator by employing the chosen best algorithm for route optimization. The optimization further helps the minimization of travel distance and constraints to visit every possible destination within the generated itinerary.
4. **Itinerary Management.** An Itinerary Management feature of the application allows users to manage and organize their itineraries. The users may add, edit, or remove destinations from their itinerary. It also allows the tracking of visited and unvisited locations so that users are informed of the status of their progress in the itinerary. Users are also able to save and reload itineraries for future use.
5. **Itinerary Navigation.** This feature assist the user during travel by providing real-time navigation support. Users are able to track their current location and visualize routes similar to Google Maps. It displays direction, travel duration, and distances between tourist spots and supports live GPS tracking to help users follow their itinerary accurately.

Furthermore, the application includes a user profile feature that allows users to create and manage their profiles, which can store their preferences, past itineraries, and other relevant information. This feature enhances the personalization aspect of the system by allowing it to learn from user behavior and preferences over time.

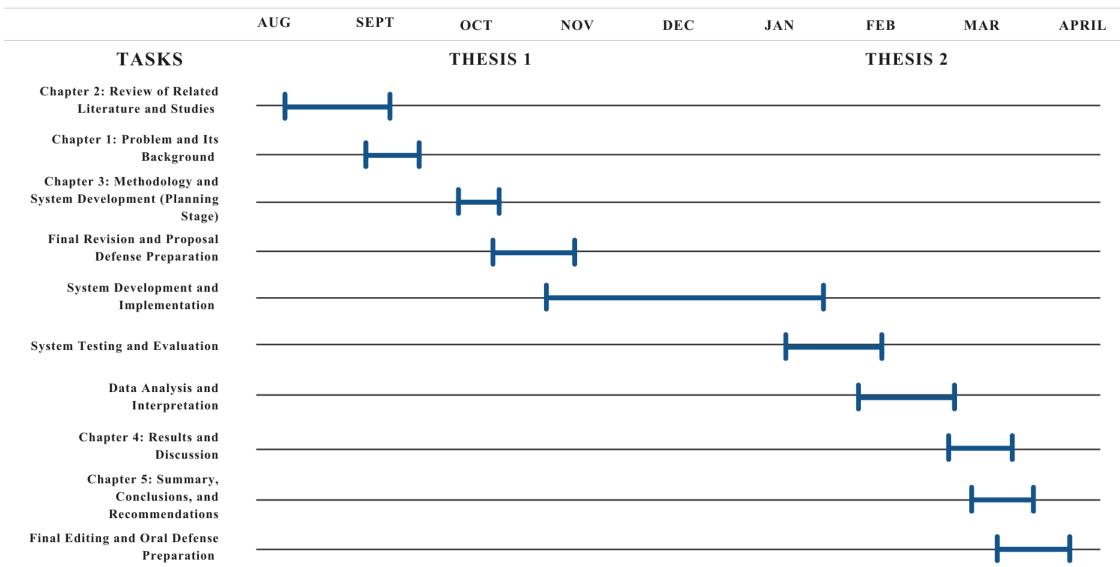
In addition, the data gathering process was also conducted in this phase, which involved collecting data on tourist destinations in Bulacan given by PHACTO. This data was used to populate the system with verified and relevant information about the tourist spots in the province, which is crucial for the functionality of the search and itinerary generation features.

Planning

The Gantt chart provides a visual timeline of the schedule of the research activity that was conducted in the process of developing LAKAD. It outlines the sequence of tasks relating to Thesis I and Thesis II, including the flow of each phase of the research from documentation and planning until system development, evaluation, and final defense.

Figure 5

Gantt Chart



The **Thesis I** output focuses on the research documentation and planning for development of LAKAD. This process begins with the Review of Related Studies (Chapter 2), in which local and foreign studies are gathered, evaluated, and organized to develop the theoretical and conceptual framework. By gathering information in Chapter 2, determining the best algorithm for the system, and the appropriate approach to execute the idea, the researchers were able to establish a solid foundation that would be the basis of the succeeding phases. After completing Chapter 1: Problem and its Background and Chapter 2, the researchers finalize the concepts, models, and methods that was utilized in Chapter 3: Methodology preparation. Chapter 3 defines the research design, the selected development model, and the desired process on creating the system, as well as the foundation on system evaluation and data gathering that was conducted on Thesis II.

For **Thesis II**, the researcher proceeds to the implementation and completion phase. The group developed and implemented the proposed system based on the design created in Thesis I.

System Development and Implementation. This phase focuses on building and integrating the components of the system based on the planned design. In the development process, the construction of the front-end, database integration, and feature implementation following the chosen development model. Testing and debugging processes was carried out on a regular basis to ensure proper functionality and performance.

System Testing and Evaluation. This phase is for testing the reliability, usability, and general quality of the system. Various testing procedures was conducted to ensure that every function works as planned and meets user needs. Feedback was collected from users and a system analyst to identify areas that need improvement.

Data Analysis and Interpretation. This stage includes data processing and data analysis that are conducted from the system evaluation. Responses collected was organized, encoded, and statistically analyzed to determine user perceptions as well as the general performance of the system.

Design

The design phase focuses on creating the overall architecture and structure of the system. This includes defining the system components, their interactions, and the data flow within the application. The system architecture was designed to ensure scalability, maintainability, and efficiency. The researchers created diagrams and models to visualize the system's structure and functionality.

Figure 6

System Architecture

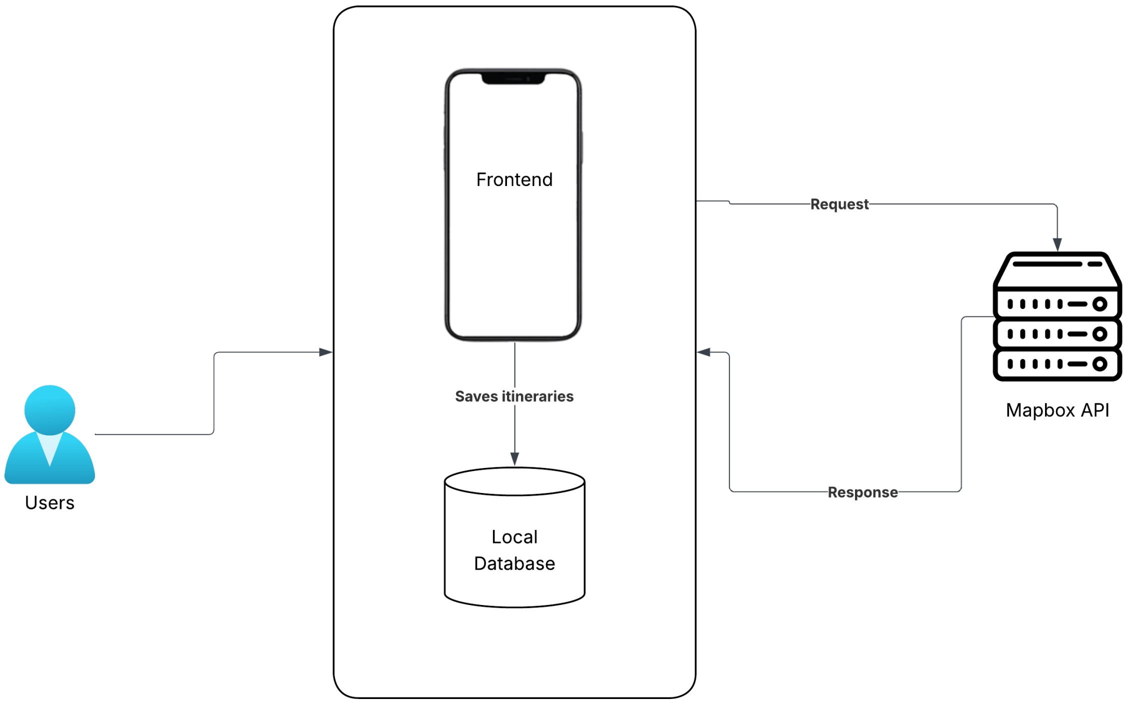
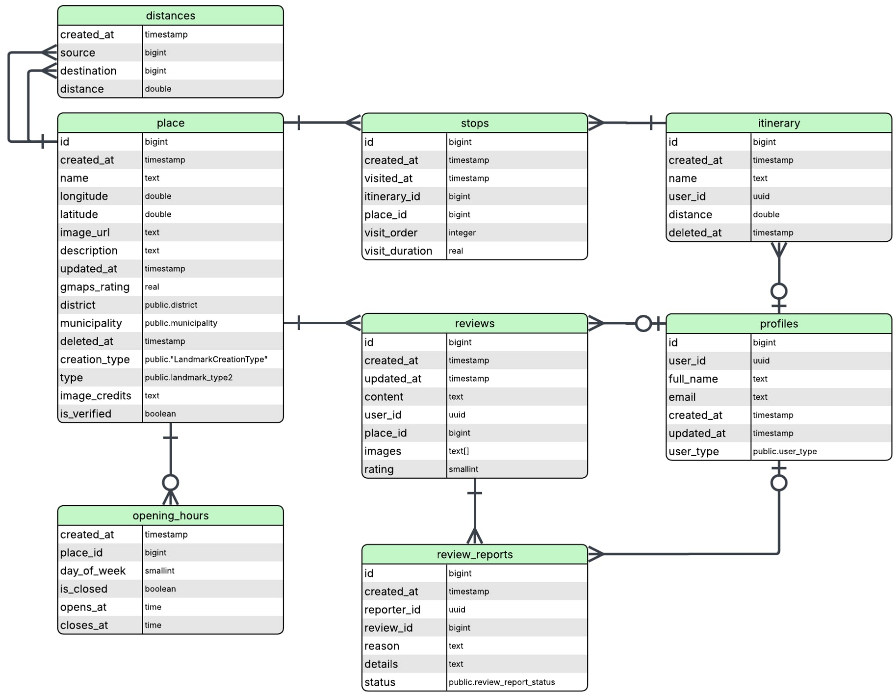


Figure 6 illustrates the system architecture of LAKAD: A Personalized Mobile Itinerary Creator and how the different components of the application interact to provide personalized and optimized travel itineraries for users. At the core of the system is the mobile frontend, which serves as the main interface where users can search for tourist destinations, generate itineraries, and manage their travel plans. When a user interacts with the application, the frontend communicates with the Mapbox API to send requests for map data, location coordinates, and optimized routes. The API processes these requests and returns the corresponding responses, which are then displayed on the user interface in the form of maps and travel routes. In addition, the application stores user-generated itineraries and relevant information in a database, allowing users to access and manage their itineraries.

Figure 7

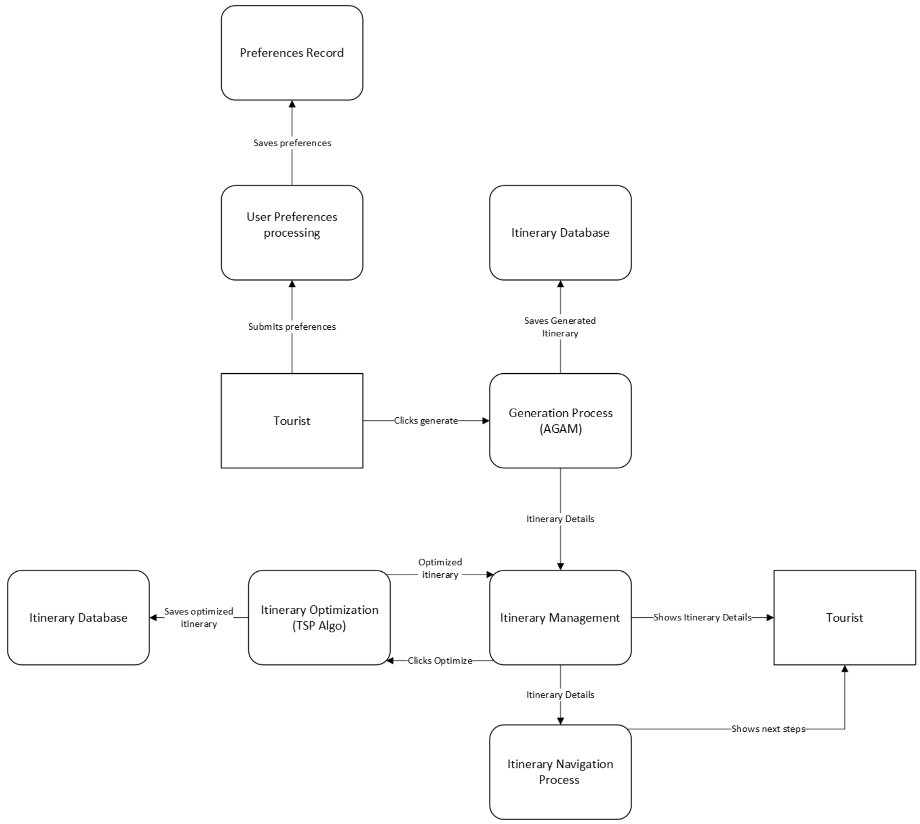
Entity Relationship Diagram



The Entity Relationship Diagram (ERD) of the system, as shown in Figure 7, consists of eight entities; `place`, `opening_hours`, `distances`, `stops`, `itinerary`, `profiles`, `reviews`, and `review_reports`. A `profiles` entity can generate many itineraries of the entity `itinerary` and provide multiple entries in the `reviews` entity. An `itinerary` entity can contain as many stops, and acts as a junction entity for a place before being organized inside an itinerary, which lets the system properly assign a `visit_order` and `visit_duration` for a location within a specific trip. `stops` entities reference a place, which serves as the central container for location data, coordinates, and ratings. Additionally, each place has at least one dedicated `opening_hours` entry to define its schedule. A place entity can be the subject of multiple reviews. A `reviews` entity may also have its own `review_reports` which are then used by the system to track moderation status.

Figure 8

Data Flow Diagram



Only one user exists for the whole system which is the tourist as illustrated in Figure 8. There are two main flows for the user actions: preferences flow and itinerary flow. The preferences flow is straightforward, the user submits the preferences per category and then is saved in the app to be used later. The itinerary flow starts from the user generating an itinerary through the AGAM process in which is saved to the database and is sent to the itinerary management process for the visualization through graphical user interface.

From itinerary management, there are two other flows: optimization and navigation flow. The optimization flow would use the best TSP algorithm selected from the analysis to optimize the itinerary visitation where the changes would be saved and flow back to the management. Navigation flow would start the navigation process, showing the tourist the directions and steps to go to the POI in the itinerary.

Development

This development phase pertains to the actual coding and implementation of the system's features inside an android application. The researchers' utilized the AGILE methodology, particularly the Kanban method for the software development life cycle. This includes weekly meetings and development checks by the researchers to ensure the system is properly developed to its intended uses. LAKAD was developed using the React Native main development framework, which uses fast and cost-efficient cross-platform mobile development, allowing a single codebase to function on both iOS and Android devices. The system utilized the JavaScript programming language for implementing the application's user interface and core functionalities due to its flexibility and compatibility with React Native framework. The main development environment for writing, editing, and debugging the program was Visual Studio Code, which provided lightweight performance and had a large selection of extensions appropriate for React Native development. Throughout the development process, Git and GitHub was used to ensure structured collaboration and version control. The list of tools used in the development is presented in Table 2.

Additionally, React Native extends the "Learn once, write anywhere" paradigm to mobile development, leveraging recent advancements like its new architecture and the JavaScript Interface (JSI). The framework's structure, represented by Fabric, aims to boost compatibility with modern React features such as concurrent rendering and synchronous data fetching. While JSI's main element allows for direct calls between JavaScript and native code. This change features a smoother interaction with the host platform and significantly reduces performance bottlenecks. JSI also allows Fabric to create UI components on the native side more efficiently. The combined adoption of JSI and Fabric offers a significant enhancement in React Native's performance, making it a good choice for developers who desire the agility of mobile development and native platform functionalities (Zhou, 2024).

This framework allows the researchers to develop the mobile application, LAKAD, as React Native's cross-platform capabilities also allow for android development.

Table 2

List of Tools for Development

Name	Description
Visual Studio Code	A lightweight and powerful source code developed by Microsoft. It supports multiple programming languages and offers built-in debugging, version control integration, and extensions suitable for React Native development.
React Native	An open-source framework developed by Meta for building cross-platform mobile applications using JavaScript and React.
JavaScript	An Interpreted, high-level programming language for building user interfaces, interaction and application logic.
Git	A software for versioning and managing software projects.
GitHub	Host for git repositories that allows online collaboration.

Testing

For the testing phase, LAKAD undergo rigorous evaluation to ensure the overall functionality and quality. The process includes system integration and user acceptance testing. System testing focuses on validating each module of the system by using test cases that evaluates the logic of the system which identifies and resolve issues affecting itinerary generation and recommendation features. Integration testing was conducted to ensure that all components of the system, such as itinerary generation and optimization, management, and user interface, operates cohesively to provide a seamless user experience.

Review

The review phase focuses on evaluating the overall functionality and usability of the system after development is completed. The researchers gather views and opinions of users, including a system analyst to determine whether the system runs efficiently and serves its desired purposes. Guided by their observation, necessary adjustments and enhancements done to refine the system.

System Evaluation

This section outlines the methods and criteria used to evaluate LAKAD, the developed mobile itinerary generator system. It details the instruments and standards for assessment, describes the target population and sampling approach, and explains the procedures for data collection and analysis. The goal is to ensure that the system meets user needs and quality benchmarks through structured evaluation using both user and expert feedback.

Evaluation Instrument

The evaluation instrument for the developed system uses Technology Acceptance Model (TAM) for the end-users and ISO / IEC 25010:2023 for IT professionals. This combination of evaluation methods allows for a comprehensive assessment of the system from both user experience and technical quality perspectives.

Technology Acceptance Model (TAM). The developed system was evaluated using the Technology Acceptance Model (TAM), as it provides a theoretical framework for understanding the process by which users accept and adopt new technologies. TAM is widely applied in system development studies for calculating the level of user acceptance based on their perceptions and intentions for using a system. To evaluate the effectiveness and acceptance of the proposed system, the following key constructs was evaluated:

1. **Perceived Usefulness**. This construct measures how much users would believe that system usage would improve their task performance. It looks at whether system functionalities like itinerary recommendation, generation, and optimal route provide concrete value and efficiency to the user.
2. **Perceived Ease Of Use**. This measures the degree of which users find the system easy to learn and operate. It singles out features including interface design, feature clarity, and the convenience of performing tasks.

3. **Attitude Toward Using**. This assesses the sentiment, satisfaction, and positive impression towards using the system. It measures how much the user enjoys interaction with the system and whether they find it useful and interesting.
4. **Behavioral Intention To Use**. This criterion measures the tendency and likelihood of the user to continue using the system in the future. It measures the intentions of the people to recommend or repeatedly use the system as their preferred tool.

The TAM questionnaire in this study was an adapted version of a TAM questionnaire, which was modified to fit the context of LAKAD. Additionally, a reliability test was conducted on the TAM questionnaire to ensure that the instrument is consistent and reliable for measuring user acceptance. The reliability test was performed using Cronbach's alpha, which assesses the internal consistency of the questionnaire items. A Cronbach's alpha value of 0.7 or higher is generally considered acceptable, indicating that the items in the questionnaire are measuring the same underlying construct effectively (Hussey et al., 2025).

ISO/IEC 25010:2023. The developed system was also evaluated by IT professionals using the ISO/IEC 25010:2023 questionnaire which evaluates the overall quality of LAKAD. The following criteria was used in the questionnaire and are based on the ISO/IEC 25010:2023 standards:

1. **Functional Suitability**. This focused on how well the proposed system meets the user's needs. The questions were about the system's main features such as itinerary optimization, personalized itinerary generation, and itinerary management.
2. **Performance Efficiency**. This assessed the system's ability to provide fast and efficient processing and its capability to handle large amounts of tasks. The questions assessed the system's response time when it comes to itinerary optimization and generation as well as managing the itineraries of the user.
3. **Compatibility**. This evaluated the system's compatibility with other external systems that the users might use. The questionnaire verified how well the developed system integrates and works alongside other mapping applications and systems.

4. **Interaction Capability**. This focused on the system's usability, accessibility, and user satisfaction. Through this, the system was assessed on how easy the system is to navigate, how intuitive and simple the user interface is for itinerary planning, and how effectively it guides the users.
5. **Reliability**. This assessed the system's dependability and consistency in performing its intended functions. The criterion assessed how well the system can operate without failure, maintain stability, and recover from unexpected errors or interruptions.
6. **Security**. This criterion ensured that all collected data remains confidential, secure, and protected. Access to the data will only be available to the researchers and authorized users. No information will be shared with third parties without proper consent.
7. **Maintainability**. This assessed the ability of the system to be updated, debugged, and improved. This criterion focused on the ability of the system to adapt to changes and its efficiency during system updates. It ensured that new features or fixes can be integrated without disrupting existing functionalities of the system.
8. **Flexibility**. This evaluated the system's ability to adapt to changing user needs, technological changes, and requirement changes. The criterion assessed how easily the system can support new itinerary features, and integrate additional modules or tools.
9. **Safety**. This focused on ensuring that the system does not cause any harm to its users. The criterion assessed how well the system protects users from potential risks, errors, or negative consequences that may arise from using the system.

Population and Sample

The respondents of this study consist of the end-users or the tourists in Bulacan and IT professionals for evaluating LAKAD. The tourists are the primary users of the application, while the IT professionals are the secondary users who evaluates the technical aspects of the system.

End-Users. The End-users or the tourists are the primary users of the application. The acceptance of the application, measured by TAM, were evaluated by the end-users.

A multi-stage non-probability sampling technique was used to select the respondents for the end-users. First, municipalities in Bulacan were classified based on their 2025 tourist arrivals (low, medium, high), see Table 3. These classifications were based on the data provided by PHACTO, such that < 100,000 arrivals is classified as low, 100,000 to 500,000 arrivals is classified as medium, and > 500,000 arrivals is classified as high. Selected municipalities were chosen from different tourist arrival classifications to ensure a diverse representation of tourists. This approach helps to reduce sampling bias and ensures that the sample reflects the diversity of tourists visiting different areas of Bulacan.

Table 3

Tourist Arrivals in Bulacan (2025)

Municipality	No. of Arrivals	Classification
Hagonoy	1,105	Low
Obando	5,190	Low
Guiguinto	7,907	Low
Plaridel	25,323	Low
San Ildefonso	40,715	Low
Baliwag	42,775	Low
Paombong	43,510	Low
Bulakan	49,078	Low
San Rafael	59,044	Low
Balagtas	85,236	Low
San Miguel	104,990	Medium
Santa Maria	110,279	Medium
Calumpit	114,000	Medium
Pulilan	130,222	Medium
Pandi	200,667	Medium
Angat	233,255	Medium
Meycauayan	278,211	Medium
Bustos	295,682	Medium
DRT	750,233	High
Malolos	816,299	High
Norzagaray	1,048,633	High
Marilao	1,116,989	High
CSJDM	1,128,736	High
Bocaue	1,335,539	High
Total	8,023,618	

The selected municipalities for the study were Baliwag, Bocaue, Bustos, Calumpit, Guiguinto, Malolos, Marilao, Plaridel, Pulilan, and San Rafael. These municipalities were chosen to represent a range of tourist arrival classifications (low, medium, high) to ensure that the sample of end-users reflects the diversity of tourists visiting different areas of Bulacan.

Within these selected municipalities, respondents were allocated proportionately based on the tourist arrivals of each municipality. This proportional allocation ensures that the sample size from each municipality is representative of the actual distribution of tourists across the region.

A total of 150 end-users was considered to be appropriate for the study. This sample size is sufficient to provide meaningful insights into user acceptance while being manageable for data collection and analysis. This is supported by previous tourism technology research by Raynera et al. (2025), which utilized the TAM with 80 respondents in similar regional tourism contexts, indicating that a sample size of 150 is adequate for achieving reliable results in this study. Additionally, methodological recommendations suggest that survey sample sizes should be justified based on research objectives, analytical approach, and practical constraints, rather than relying solely on numerical rules (Memon et al., 2020).

The 150 end-users was selected using convenience sampling because volatility in tourist arrivals and the need for timely data collection. Convenience sampling allows for the selection of respondents who are readily available and willing to participate, which is practical in a tourism context where visitor numbers can fluctuate. This approach enables the researchers to gather data efficiently while still capturing a diverse range of tourist experiences and perceptions across different municipalities in Bulacan. The allocation of the sample size for end-users is shown in Table 4.

Table 4

Allocation of Respondents for End-users

Municipality	Proportion (%)	No. of Respondents
Baliwag	1.08	2
Bocaue	33.86	51
Bustos	7.50	11
Calumpit	2.89	4
Guiguinto	0.20	1
Malolos	20.70	31
Marilao	28.32	42
Plaridel	0.64	1
Pulilan	3.30	5
San Rafael	1.50	1
Total	100.00	150

IT Professionals. IT professionals evaluates the quality of LAKAD using the ISO/IEC 25010:2023. A total of 20 IT experts were chosen based on their qualification and relevant experiences. This includes but not limited to computer programmers, UI/UX, and selected faculty members from The College of Information and Communications Technology (CICT) at Bulacan State University (BulSU). Additionally, they also provide qualitative feedback on the system's strengths and areas for improvement.

To summarize, the total sample size for the study consists of 170 respondents, with 150 end-users and 20 IT professionals as shown in Table 5.

Table 5

Summary of Population and Sample

Respondent Group	Population	Sample Size
End-users (Tourists)	Tourists visiting Bulacan tourist spots	150
IT Professionals	Software engineers, QA, UX professionals	20
Total		170

Data Collection

The data collection process of this study was divided into two parts: one for the end-users (tourists) and another for the IT professionals. Each group was evaluated using different instruments to gather relevant data for assessing the system from both user experience and technical quality perspectives. The end-users were evaluated using TAM, while the IT professionals were evaluated using ISO/IEC 25010:2023.

Both instruments utilized Likert scales to measure the responses of the respondents. The TAM questionnaire for end-users and the ISO/IEC 25010:2023 evaluation for IT professionals uses 5-point Likert scale. These scales were adopted from existing instruments and were modified to fit the context of this study especially for the TAM questionnaire. The use of Likert scales allows for quantifying the perceptions and evaluations of the respondents, providing a structured way to analyze the data collected from both groups.

Preparation and Pilot Testing. Before the actual data collection, a formal permission was requested and obtained from the local government units (LGUs) of the selected municipalities to conduct the survey among tourists. After obtaining the necessary permissions, pilot testing was conducted to ensure the reliability and validity of the TAM questionnaire. The pilot test was done with a small group of respondents who were similar to the target population. A total of 20 respondents from the municipality of Pandi were selected for the pilot test because it is excluded from the main data collection to avoid bias.

The Cronbach alpha of the pilot test results was calculated to make sure that the TAM questionnaire is reliable. The calculated Cronbach's alpha result yielded a value of 0.881 which is above the acceptable threshold of 0.7, indicating that the TAM questionnaire has good internal consistency and is reliable for measuring user acceptance. For the ISO/IEC 25010:2023, since it is a standardized evaluation method, a pilot test was not conducted for this instrument.

Administration to End-users. The data collection for end-users was conducted through face-to-face surveys in various tourist spots across the selected municipalities in Bulacan. The researchers approached tourists along with the informed consent and invited them to participate in the survey, which included a brief introduction to the LAKAD application and its features. After exploring the application, the respondents were asked to complete the TAM questionnaire, which assessed their perceptions of the system's usefulness, ease of use, attitude towards using it, and behavioral intention to use it in the future. Additionally, demographic information such as age bracket, travelling frequency, and technological proficiency was collected to analyze potential correlations between these factors and the TAM constructs.

Administration to IT Professionals. Permissions to conduct the survey among IT professionals was requested and obtained from the Information and Communications Technology Office (ICTO) of BulSU and to the dean of CICT. The data collection for IT professionals was conducted through an online survey or in-person sessions, depending on the availability and preference of the respondents. The IT professionals were provided with access to the LAKAD application and were given a brief overview of its features and functionalities. After exploring the application, they were asked to complete the ISO/IEC 25010:2023 evaluation, which assessed the system's functional suitability, performance efficiency, compatibility, interaction capability, reliability, security, maintainability, flexibility, and safety. In addition to the quantitative evaluation, IT professionals were also encouraged to provide qualitative feedback on the system's strengths and areas for improvement based on their technical expertise.

Data Processing and Analysis

The researchers conducted systematic data processing and analysis of data from the Technology Acceptance Model (TAM) questionnaire and ISO/IEC 25010:2023 system quality evaluation instrument to evaluate user acceptance rates and the total system quality of the LAKAD application.

The TAM questionnaire utilized a five-point Likert-type scale to measure respondents' perception towards LAKAD. The response categories were coded numerically as follows: 1 (Strongly disagree); 2 (Disagree); 3 (Neutral); 4 (Agree); and 5 (Strongly agree). The instrument consists of declarative statements that is designed to measure the four TAM constructs (Perceived Usefulness, Perceived Ease of Use, Attitude Towards Using, and Behavioral Intention to Use).

The ISO/IEC 25010:2023 evaluation instrument used a five-point performance rating scale to evaluate system quality constructs through expert assessment. The scale was coded as: 1 (Poor); 2 (Fair); 3 (Good); 4 (Very good); and 5 (Excellent). The experts used this instrument to assess system quality attributes which included Functional Suitability Performance Efficiency Compatibility Reliability Security Maintainability Flexibility and Safety.

Since responses to individual questionnaire items are ordinal in nature, descriptive statistics were utilized to summarize the data without assuming equal intervals between response categories. At the item level, frequency distributions and median values were computed to describe response patterns and determine the central tendency of each item.

To obtain construct-level measures, composite scores were computed by averaging responses across items corresponding to each construct. For both TAM and ISO/IEC 25010:2023 instruments, the composite score for the i-th respondent was calculated using in Equation 14,

$$X_i = \frac{\sum_{j=1}^{n} Y_{ij}}{n} \tag{14}$$

Where, X_i is the composite score for the i-th respondent, Y_{ij} is the rating of the i-th respondent on the j-evaluation item, and n is the total number of item to evaluated for a given construct.

Although individual items were ordinal, aggregating multiple items to a composite score allows the resulting construct-level scores to the treated as continuous approximation interval data. This approach was supported by the study of Huh and Gim (2025), which found that merging multiple Likert variables into a total score not only preserves the underlying correlation structures but also increases overall statistical power.

The overall mean score for each construct was computed by taking the mean of the composite scores of all respondents, this is given by Equation 15,

$$\bar{X} = \frac{\sum_{i=1}^{m} X_i}{m} \tag{15}$$

Where, $\bar{X}$ is the overall mean score for a given construct, X_i is the composite score for the i-th respondent, and m is the total number of respondents. The mean provided a summary measure of overall user acceptance (for TAM constructs) and overall system quality (for ISO/IEC 25010:2023 constructs).

The sample standard deviation was also calculated to get the variability of response among the evaluators. A lower standard deviation indicates that the respondents were in strong agreement regarding LAKAD's system acceptance and quality. The formula for sample standard deviation is given by Equation 16,

$$s = \sqrt{\frac{\sum_{i=1}^{m} (X_i - \bar{X})^2}{m - 1}} \tag{16}$$

Where, s is the sample standard deviation, X_i is the composite score for the i-th respondent, $\bar{X}$ is the overall mean score for a given construct, and m is the total number of respondents.

The interpretation of the mean scores for both TAM and ISO/IEC 25010:2023 was based on a predefined scale that categorizes the mean scores into descriptive ratings and interpretations. This scale helps to contextualize the numerical results and provides a clear understanding of what the mean scores indicate about user acceptance and system quality. The interpretation tables for both TAM and ISO/IEC 25010:2023 are presented in Table 6 and Table 7, respectively.

Table 6

Interpretation of Mean Scores for TAM

Mean Score	Descriptive Rating	Interpretation
4.21–5.00	Highly acceptable	The system is highly acceptable and meets user expectations
3.41–4.20	Acceptable	The system is generally acceptable and meets user expectations with minor issues
2.61–3.40	Fairly acceptable	The system is somewhat acceptable but has room for improvement
1.81–2.60	Slightly acceptable	The system is barely acceptable and needs significant improvements
1.00–1.80	Not acceptable	The system is not acceptable and requires major redesign

Table 7

Interpretation of Mean Scores for ISO/IEC 25010:2023

Mean Score	Descriptive Rating	Interpretation
4.21–5.00	Excellent	The quality of the system is outstanding and exceeds expectations
3.41–4.20	Very Good	The quality of the system is above average and meets expectations
2.61–3.40	Good	The quality of the system is average and meets basic expectations
1.81–2.60	Fair	The quality of the system is below average and needs improvement
1.00–1.80	Poor	The quality of the system is poor and requires major redesign

Ethical Considerations

Gemini said Ethical considerations played a crucial role in the conduct of this study, especially since it involved the participation of real people, and government institutions and offices. The ethical guidelines were strictly followed in compliance with the Data Privacy Act of 2012 (Republic Act No. 10173) and Bulacan State University's (BulSU) College of Science (CS) Ethical Committee, to uphold the integrity of the research and to ensure the privacy and security of all collected data. Obtaining informed consent, implementing data encryption, and enforcing strict access controls were observed to safeguard the rights and confidentiality of all individuals and institutions involved in the evaluation and development of the system.

Informed Consent

Participants of the study were required to give informed consent before responding to any personally identifying data or opinions that were collected for the study, usability testing, and system evaluation. Consent materials informed respondents about the study purpose, what data would be collected, how the data would be used, risks and benefits, and contact details for further questions regarding the study. The project followed recognized Philippine guidance on ethical review and informed consent processes such as the Data Privacy Act of 2012 (Republic Act No. 10173). Participants were also given the freedom to withdraw their responses at will, at which point the collected data from them would be discarded and deleted.

In addition to individual respondents, the study also involved data collection from government offices, particularly from the Bulacan Provincial History, Arts, Culture, and Tourism Office (PHACTO) and other related agencies that maintained official records on local attractions and tourism statistics. As per the request of the PHACTO, a letter required to be sent formally addressed the Provincial Governor and the Head of the Provincial Tourism Department to request permission to access relevant datasets or documents. These data included, but were not limited to, lists of Points of Interest (POIs), and visitor statistics of tourism establishments.

The request letters clearly outlined the purpose of the data use, the scope of the requested information, and the intended outcomes of the study. Only publicly shareable or officially permitted data were considered and were used in compliance with all terms set by the concerned government offices. The use of such data was limited strictly to academic and system development purposes.

Confidentiality and Privacy

All personal or sensitive information collected during the study remained confidential. Any identifiable data from participants or government records such as names or addresses were anonymized before analysis or publication by not digitizing said fields and replacing them with code or identifiers instead. Access to raw data was restricted to authorized research team members only, and all information was securely stored in digital repositories.

Data Protection

All collected data were processed and stored in compliance with the Data Privacy Act of 2012 (Republic Act No. 10173) and its Implementing Rules and Regulations (IRR). The principles of transparency and legitimate purpose in handling personal and institutional data were followed. Appropriate technical and organizational security measures, such as encrypted file storage and secure data transmission, were implemented to protect information from unauthorized access or loss. The collected physical data were safely compiled in one clearbook folder which was stored inside a vault for the duration of the study and would be disposed of one month after the final defense, and digitally collected data were encrypted in a spreadsheet file only accessible by the researchers, and would be deleted one month after the final defense.

Ethical Data Collection

The data collection process was guided by integrity and accountability. Only information relevant to the objectives of the system was gathered. The collection of data did not include sensitive personal information unless necessary and, if in any case it was, it was collected under the permission of the respondent. In compliance with Philippine regulations, the consenting respondents that were considered for the survey were strictly 18 years old and above.

For survey and usability testing activities, participation was entirely voluntary, and responses were treated as confidential. For institutional data, such as those obtained from PHACTO or other local government offices, the researchers followed the formal request procedures and upheld any data-sharing agreements or confidentiality clauses that were imposed by the office.

Transparency and Integrity

The researchers maintained transparency throughout the conduct of the study. All research methods, procedures, data sources, and analytical processes were accurately documented and reported. The team strictly avoided misrepresentation of data, selective reporting of results, or exaggeration of the system's capabilities.

Acknowledgment was given to all sources of information, including government offices and online databases. Conflicts of interest, if any, were disclosed openly. All representations made to data providers, research participants, and readers were honest and verifiable.

The study upheld the principles of academic integrity, guided by the ethical standards outlined by the Data Privacy Act of 2012 (Republic Act No. 10173), Republic Act No. 8293 (Intellectual Property Code of the Philippines), and institutional research ethics guidelines of Bulacan State University (BulSU).

CHAPTER IV

PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

This chapter presents the results of the study, including a comparative analysis of TSP algorithms, the developed application, and the evaluation of system acceptability and software quality. The findings are interpreted in the context of the research objectives and questions outlined in Chapter 1.

Comparative Analysis of TSP Algorithms

This section presents the performance evaluation of the selected metaheuristic algorithms for solving the Traveling Salesman Problem (TSP). The algorithms were tested on four standard instances from the TSPLIB library: burma14, bays29, eil51, and berlin52. The primary goal was to identify the most suitable algorithm for the LAKAD mobile application, balancing solution quality (minimizing travel distance) and runtime efficiency (minimizing user wait time).

Analysis of Solution Quality (Accuracy)

The solution quality is measured by the average relative error (%) compared to the optimal solution for each TSP instance. Table 8 summarizes the results, showing the performance of each algorithm across the four instances and their average relative error.

Table 8

Summary of Average Relative Error (%)

Algorithm	TSPLIB Instances				Average
	burma14	bays29	eil51	berlin52	
GA	0.00	0.00	0.00	0.00	0.00
SA	0.00	0.42	2.77	3.15	1.59
ACO	0.53	1.50	5.49	2.49	2.50
EHO	0.00	3.71	20.47	23.36	11.27
PSO	0.99	12.74	36.88	43.46	23.77
HSFFPKO	1.88	20.18	127.28	95.07	61.11
GWO	6.32	33.67	145.85	181.36	91.80

The results indicate that the Genetic Algorithm (GA) consistently achieved highest solution quality, with an average relative error of 0%. Simulated Annealing (SA) and Ant Colony Optimization (ACO) also performed well, with average errors of 1.59% and 2.50%, respectively. The Elephant Herding Optimization (EHO), Particle Swarm Optimization (PSO), Hovering Scouts and Foraging Flocks Pied Kingfisher Optimizer (HSFFPKO), and Grey Wolf Optimizer (GWO) showed significantly higher errors, indicating lower solution quality for the tested TSP instances.

Analysis of Runtime Efficiency

Runtime efficiency is critical for the LAKAD application, as users expect quick responses when optimizing their travel itineraries. Table 9 summarizes the average runtime (in seconds) for each algorithm across the four TSPLIB instances, along with an assessment of their growth trends.

Table 9

Summary of Average Runtime Efficiency (seconds)

Algorithm	**TSPLIB Instances**			
	burma14	**bays29**	**eil51**	**berlin52**
EHO	0.17	0.27	0.44	0.45
SA	0.49	1.04	1.82	1.90
GWO	0.51	1.02	1.73	1.75
HSFFPKO	1.16	1.42	1.78	1.76
PSO	3.36	4.77	6.30	6.84
ACO	2.51	9.67	28.62	29.23
GA	3.79	26.31	168.15	196.59

While GA achieved the best solution quality, its runtime increased exponentially with the problem size. For the berlin52 instance, GA required approximately 196.59 seconds (over 3 minutes) to complete. In contrast, EHO had the lowest runtime across all instances, with a runtime of < 0.5 seconds even for the largest instance. SA and GWO also demonstrated low runtimes, while ACO and PSO showed moderate to high runtimes, especially as the problem size increases.

Algorithm Ranking

To select the most suitable algorithm for the LAKAD application, a multi-criteria decision analysis (MCDA) approach was used to rank the algorithms based on both solution quality and runtime efficiency, particularly the Simple Additive Weighting (SAW) method. The final scores and rankings are presented in Table 10. Equal weights ($w_i = 0.5$) were assigned to both criteria.

Table 10

Final SAW Scores and Rankings of TSP Algorithms

Algorithm	TSPLIB Instances				Rank
	burma14	**bays29**	**eil51**	**berlin52**	
SA	0.06	0.03	0.01	0.01	1st
EHO	0.02	0.06	0.07	0.07	2nd
ACO	0.37	0.21	0.10	0.08	3rd
PSO	0.52	0.28	0.14	0.14	4th
HSFFPKO	0.30	0.33	0.44	0.33	5th
GA	0.50	0.50	0.50	0.50	6th
GWO	0.56	0.51	0.51	0.50	7th

Based on the SAW scores, Simulated Annealing (SA) emerged as the top-ranked algorithm, offering a strong balance between solution quality and runtime efficiency. Although GA achieved the best accuracy, its long runtime makes it resulted in a consistently high SAW score, placing it in the 6th position. EHO performed well on small instances, but its accuracy degraded on larger instances, making it less reliable for complex itineraries.

In conclusion, Simulated Annealing (SA) is the selected route optimization algorithm for LAKAD. It provides a good trade-off between solution quality and runtime efficiency, ensuring that users receive optimized itineraries in a reasonable time frame, enhancing the overall user experience of the LAKAD application.

The Developed System

The developed system, LAKAD, was developed as both a place explorer and itinerary planner with route optimization capabilities. It allows tourists to search tourists spots within Bulacan and plan their itineraries by generating one for them and gives out navigation instructions to travel. The LAKAD application has five key features, which are described in the following subsections.

Tourist Spot Exploration

Personalized Itinerary Generation

Itinerary Optimization

Itinerary Navigation

Itinerary Management

Additional Features

System Evaluation

Evaluation of System Acceptability

Software Quality Evaluation

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

REFERENCES

Aburbeian, A. M., Owda, A. Y., & Owda, M. (2022). A technology acceptance model survey of the metaverse prospects. *AI*, *3*(2), 285–302. https://doi.org/10.3390/ai3020018

Alaidaros, H., Omar, M., & Romli, R. (2021). The state of the art of agile kanban method: Challenges and opportunities. *Independent Journal of Management & Production*, *12*(8). https://doi.org/10.14807/ijmp.v12i8.1482

Arora, V., Borko, S., & Geerts, W. (2022). *State of Travel 2022: 175+ insights defining the state of travel today and the trends that will shape the future*. Skift Research.

Barb-Ciorbea, M.-A. (2023). Comparison between an exact and a heuristic-based traveling salesman problem with time window constraints. *Buletinul Institutului Politehnic Din Iaşi. Secţia Electrotehnică. Energetică. Electronică*, *69*(3), 99–112. https://doi.org/10.2478/bipie-2023-0017

Canet, L., & Panaligan, B. (2024). Examining the tourism development in bulacan province, philippines: Assessing factors shaping tourism growth. *American Journal of Tourism and Hospitality*, *2*(1), 105–123. https://doi.org/10.54536/ajth.v2i1.3297

Canet, L., Manansala, J., Cruz, M., Bernadette, P., Balingit, A., Mendiola, I., & Ramos, A. (2023). Social media as a tool for promoting tourist destinations in the municipality of san rafael, bulacan, philippines. *INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS*, *06*. https://doi.org/10.47191/ijmra/v6-i6-66

Canet, L., & Sunpongco, L. (2025). Discovering hidden gems: A comprehensive study of underrated local tourist destinations in bulacan, philippines. *International Journal of Tourism and Hospitality*, *5*, 1–20. https://doi.org/10.51483/IJTH.5.1.2025.1-20

Carmesin, J. (2022). Graph theory – a survey on the occasion of the abel prize for lászló lovász. *Jahresbericht der Deutschen Mathematiker-Vereinigung*, *124*(2), 83–108. https://doi.org/10.1365/s13291-022-00247-7

Cui, X., Wang, Z., Li, P., & Xu, Q. (2025). I-air: Intention-aware travel itinerary recommendation via multi-signal fusion and spatiotemporal constraints. *Journal of King Saud University Computer and Information Sciences*, *37*(7), 169. https://doi.org/10.1007/s44443-025-00178-0

Dela Cruz, A. M. (2025). Enhanced Pied Kingfisher Optimization Algorithm with Hovering Scouts and Foraging Flocks Mechanisms [Manuscript/Pre-print].

Dela Cruz, K. C. Y., Pangilinan, J. M., San Juan, P. V. G., Santiago, E. J. A., Santos, C. J. M. B., & Villanueva, F. C. C. (2022). Effectiveness of the use of social media in promoting a tourist destination: The case of doña remedios trinidad. *Cosmos Journal of Engineering & Technology*, *12*(1), 33–35. https://doi.org/10.46360/cosmos.et.620221006

Department of Tourism (DOT). (2023). *The National Tourism Development Plan 2023-2028* (Approved Final Report No. DOT-NTDP-23-00030). Department of Tourism (DOT), Republic of the Philippines. Manila, Philippines.

Estilo, C. B., Jondanero, S. J., & Lajo, J. C. (2023). *Destamp: A mobile application for generating budget-based itineraries to enhance travel planning* [Undergraduate Thesis]. CENTRAL PHILIPPINE UNIVERSITY. https://repository.cpu.edu.ph/bitstream/handle/20.500.12852/3365/BSSE_EstiloCB_2023_fulltext_3365.pdf?sequence=3&isAllowed=y

Halder, S., Lim, K. H., Chan, J., & Zhang, X. (2022). Efficient itinerary recommendation via personalized poi selection and pruning. *Knowledge and Information Systems*, *64*(4), 963–993. https://doi.org/10.1007/s10115-021-01648-3

Hossain, M. A. A., & Yılmaz Acar, Z. (2024). Comparison of new and old optimization algorithms for traveling salesman problem on small, medium, and large-scale benchmark instances. *Bitlis Eren Üniversitesi Fen Bilimleri Dergisi*, *13*(1), 216–231. https://doi.org/10.17798/bitlisfen.1380086

Huh, I., & Gim, J. (2025). Exploration of likert scale in terms of continuous variable with parametric statistical methods. *BMC Medical Research Methodology*, *25*(1), 218. https://doi.org/10.1186/s12874-025-02668-1

Hussey, I., Alsalti, T., Bosco, F., Elson, M., & Arslan, R. (2025). An aberrant abundance of cronbach's alpha values at .70. *Advances in Methods and Practices in Psychological Science*, *8*(1), 25152459241287123. https://doi.org/10.1177/25152459241287123

ISO/IEC 25010 [The webpage excerpt describes the product quality model.]. (2024). iso25000.com. https://iso25000.com

Jewpanya, P., Nuangpirom, P., Pitjamit, S., & Nakkiew, W. (2025). Optimized travel itineraries: Combining mandatory visits and personalized activities. *Algorithms*, *18*(2), 110. https://doi.org/10.3390/a18020110

Leong, L. W. (2022). *Itinerary planner for tourism mobile application with smart trip generation and social platform* [Undergraduate Honors Thesis]. Universiti Tunku Abdul Rahman. http://eprints.utar.edu.my/4706/1/fyp_CS_2022_LWL.pdf

Li, Y., Liu, K., Satapathy, R., Wang, S., & Cambria, E. (2024). Recent developments in recommender systems: A survey [review article]. *IEEE Computational Intelligence Magazine*, *19*(2), 78–95. https://doi.org/10.1109/MCI.2024.3363984

Lim, K. H., Chan, J., Karunasekera, S., & Leckie, C. (2019). Tour recommendation and trip planning using location-based social media: A survey. *Knowledge and Information Systems*, *60*. https://doi.org/10.1007/s10115-018-1297-4

Liu, D., Wang, L., Zhong, Y., Dong, Y., & Kong, J. (2024). Personalized tour itinerary recommendation algorithm based on tourist comprehensive satisfaction. *Applied Sciences*, *14*(12), 5195. https://doi.org/10.3390/app14125195

Malefaki, S., Markatos, D., Filippatos, A., & Pantelakis, S. (2025). A comparative analysis of multi-criteria decision-making methods and normalization techniques in holistic sustainability assessment for engineering applications. *Aerospace*, *12*(2). https://doi.org/10.3390/aerospace12020100

Marikyan, D., & Papagiannidis, S. (2025). Technology acceptance model: A review. In S. Papagiannidis (Ed.), *Theoryhub book*. https://open.ncl.ac.uk/

Memon, M., Ting, H., Cheah, J.-H., Ramayah, T., Chuah, F., & Cham, T.-H. (2020). Sample size for survey research: Review and recommendations. *Journal of Applied Structural Equation Modeling*, *4*, i–xx. https://doi.org/10.47263/JASEM.4(2)01

Morandi, N., Leus, R., & Yaman, H. (2024). The orienteering problem with drones. *Transportation Science*, *58*(1), 240–256. https://doi.org/10.1287/trsc.2023.0003

Nguyen, A., & Shoubber, O. (2019). *Trippit: An optimal itinerary generator* [Senior Thesis]. Santa Clara University. https://scholarcommons.scu.edu/cgi/viewcontent.cgi?params=/context/cseng_senior/article/1154/%5C&path_info=Thesis_Trippit_An_Optimal_Itinerary_Generator.pdf

Odu, G. O. (2019). Weighting methods for multi-criteria decision making technique. *Journal of Applied Sciences and Environmental Management*, *23*(8), 1449–1457. https://doi.org/10.4314/jasem.v23i8.7

Otaki, K., & Baba, Y. (2025). Travel itinerary recommendation using interaction-based augmented data. *Expert Systems with Applications*, *269*, 126294. https://doi.org/10.1016/j.eswa.2024.126294

Papadakis, H., Panagiotakis, C., Fragopoulou, P., Chalkiadakis, G., Streviniotis, E., Ziogas, I.-P., Koutsmanis, M., & Bariamis, P. (2024). Visit planner: A personalized mobile trip design application based on a hybrid recommendation model. *Computer Science and Information Systems*, *21*(3), 923–946. 10.21203/rs.3.rs-2731618/v1

Pěnička, R., Faigl, J., & Saska, M. (2019). Variable neighborhood search for the set orienteering problem and its application to other orienteering problem variants. *European Journal of Operational Research*, *276*(3), 816–825. https://doi.org/10.1016/j.ejor.2019.01.047

Pop, P. C., Cosma, O., Sabo, C., & Sitar, C. P. (2024). A comprehensive survey on the generalized traveling salesman problem. *European Journal of Operational Research*, *314*(3), 819–835. https://doi.org/10.1016/j.ejor.2023.07.022

Porras, C., Pérez-Cañedo, B., Pelta, D. A., & Verdegay, J. L. (2022). A critical analysis of a tourist trip design problem with time-dependent recommendation factors and waiting times. *Electronics*, *11*(3), 357. https://doi.org/10.3390/electronics11030357

Postnikova, A. (2024). *Intuitive itinerary planner* [Doctoral dissertation, IADT]. https://onshow.iadt.ie/sites/default/files/2025-05/AgnePostnikova-Thesis.pdf

Raghuwanshi, S., & Pateriya, R. (2019, January). Recommendation systems: Techniques, challenges, application, and evaluation: Socpros 2017, volume 2. https://doi.org/10.1007/978-981-13-1595-4_12

Rahman, N. H. A., & Jamil, F. (2025). Enhancing tourist engagement through mobile itinerary management and location-based services: Design and deployment experience in Ipoh, Malaysia. *Journal of Engineering, Technology and Social Sciences*, *11*(Special Issue: ICETISM), 106–111.

Raynera, G. R. A., Balasta, S. K. B., Capili, K. I. E., & Haber, S. J. T. (2025). An assessment of the effects of artificial intelligence on tourist behavior and decision-making in san jose del monte city, bulacan. *International Journal of Research and Innovation in Social Science (IJRISS)*, *9*(4). https://dx.doi.org/10.47772/IJRISS.2025.90400099

Risener, K. (2022). *A study of software development methodologies* [Undergraduate Honors Thesis]. University of Arkansas, Fayetteville. https://scholarworks.uark.edu/cseng%5C_senior/103

Ruiz-Meza, J., & Montoya-Torres, J. R. (2022). A systematic literature review for the tourist trip design problem: Extensions, solution techniques and future research lines. *Operations Research Perspectives*, *9*, 1–13. https://doi.org/10.1016/j.orp.2022.100228

Sabery, G. A., Danishyar, G. H., & Mubarez, G. S. (2023). A comparative study of metaheuristic optimization algorithms for solving engineering design problems. *Journal of Mathematics and Statistics Studies*, *4*(4), 56–69. https://doi.org/10.32996/jmss.2023.4.4.6

Systems and software engineering — systems and software quality requirements and evaluation (square) — product quality model (Second edition 2023-11) [Reference number ISO/IEC 25010:2023(E)]. (2023). ISO/IEC.

Taherdoost, H. (2023). Analysis of simple additive weighting method (saw) as a multiattribute decision-making technique: A step-by-step guide. *Journal of Management Science & Engineering research*, *6*. https://doi.org/10.30564/jmser.v6i1.5400

Tenemaza, M., Luján-Mora, S., De Antonio, A., & Ramirez, J. (2020). Improving itinerary recommendations for tourists through metaheuristic algorithms: An optimization proposal. *IEEE Access*, *8*, 79003–79023. https://doi.org/10.1109/ACCESS.2020.2990348

Velasco, S. F. (2023, May). Bulacan pamana pass, inilunsad para sa lokal na turista. *Philippine Information Agency (PIA)*. Retrieved September 30, 2025, from https://mirror.pia.gov.ph/news/2023/05/27/bulacan-pamana-pass-inilunsad-para-sa-lokal-na-turista

Violina, S. (2021). Analysis of brute force and branch & bound algorithms to solve the traveling salesperson problem (tsp). *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(8), 1226–1229. https://turcomat.org/index.php/turkbilmat/article/view/3031

Wadi, A. H. A., & Umar, S. U. (2025). Charting new routes: Comparing swarm-based approaches to the traveling salesman problem. *International Journal of Computational Methods and Experimental Measurements*, *13*(2), 371–379. https://doi.org/10.18280/ijcmem.130214

Widayanti, R., Chakim, M. H. R., Lukita, C., Rahardja, U., & Lutfiani, N. (2023). Improving recommender systems using hybrid techniques of collaborative filtering and content-based filtering [Available online September 21, 2023]. *Journal of Applied Data Sciences*, *4*(3), 289–302. https://doi.org/10.47738/jads.v4i3.115

Wu, C., & Fu, X. (2020). An agglomerative greedy brain storm optimization algorithm for solving the tsp. *IEEE access*, *8*, 201606–201621. https://doi.org/10.1109/ACCESS.2020.3035899

Yochum, P., Chang, L., Gu, T., & Zhu, M. (2020). An adaptive genetic algorithm for personalized itinerary planning. *IEEE Access*, *8*, 88147–88157. https://doi.org/10.1109/ACCESS.2020.2990916

Yu, Q., Cheng, C., & Zhu, N. (2022). Robust team orienteering problem with decreasing profits. *INFORMS Journal on Computing*, *34*(6), 3215–3233. https://doi.org/10.1287/ijoc.2022.1240

Yulfihani, I., & Zakariyah, M. (2024). Optimization of tourism destination recommendations in batang regency using content-based filtering. *Journal of Applied Informatics and Computing (JAIC)*, *8*(2), 499–508. http://jurnal.polibatam.ac.id/index.php/JAIC

Zhou, C. (2024). *Challenges and solutions in cross-platform mobile development: A qualitative study of Flutter and React Native* [Master's Thesis]. Aalto University. https://aaltodoc.aalto.fi/server/api/core/bitstreams/a96381de-2f0d-44e6-bcab-5e2424f44c66/content

APPENDICES

APPENDIX A

PSEUDOCODE OF TSP ALGORITHMS

Algorithm 2 Genetic Algorithm

Initialize population p using the INITIALIZE_POPULATION method.
Calculate the fitness for each individual in p using the EVALUATE_FITNESS method.
Set the iteration counter $T = 0$.
Set max_iterations = 1000.
while $T <$ max_iterations **do**
    Select parents from the population p using the SELECTION method.
    Perform crossover on the selected parents with a probability of 0.8 using the CROSSOVER method to generate offspring.
    Perform a mutation on the offspring with a probability of 0.2 using the MUTATION method.
    Calculate fitness for each offspring using the EVALUATE_FITNESS method.
    Replace the worst individuals in the population p with the best offspring.
    Update the best solution found so far.
    Increment iteration counter $T = T + 1$.
end while
Return the best solution found (best_individual).

Algorithm 3 Ant Colony Optimization

Initialize the pheromone matrix τ with initial_pheromone.
Set best_tour = none and best_distance = ∞.
Start timer start_time.
for $i = 1$ to num_iterations **do**
    Generate num_ants tours using the CONSTRUCT_TOUR method.
    for each generated tour k **do**
        Calculate tour_distance$_k$.
        if tour_distance$_k$ < best_distance **then**
            Update best_tour = tour$_k$
            Update best_distance = tour_distance$_k$
        end if
    end for
    Update pheromone matrix τ using the UPDATE_PHEROMONE_MATRIX method.
end for
Stop timer end_time.
Calculate computation_time = end_time − start_time.
Return best_tour, best_distance, and computation_time.

Algorithm 4 Simulated Annealing

```
function SimulatedAnnealing(cities, initial_temperature, cooling_rate, num_iterations)
    Initialize the distances matrix by calculating the distances between cities.
    Define calculate_tour_distance(tour).
    Define generate_neighbor(tour) (e.g., swapping two cities).
    Define acceptance_probability(ΔE, T) = e^(−ΔE/T).
    Initialize current_tour with a random tour.
    current_distance ← calculate_tour_distance(current_tour).
    best_tour ← current_tour.
    best_distance ← current_distance.
    T ← initial_temperature.
    start_time ← Timer.start().
    for i = 1 to num_iterations do
        new_tour ← generate_neighbor(current_tour).
        new_distance ← calculate_tour_distance(new_tour).
        ΔE ← new_distance − current_distance.
        if ΔE < 0 then
            accept ← True
        else
            prob ← acceptance_probability(ΔE, T)
            accept ← prob > random(0, 1)
        end if
        if accept then
            current_tour ← new_tour
            current_distance ← new_distance
            if current_distance < best_distance then
                best_tour ← current_tour
                best_distance ← current_distance
            end if
        end if
        T ← T · cooling_rate
    end for
    end_time ← Timer.stop().
    computation_time ← end_time − start_time.
    Return best_tour, best_distance, computation_time.
end function
```

Algorithm 5 Particle Swarm Optimization

```
Initialize parameters:
    num_particles = Number of particles
    num_iterations = Maximum number of iterations
    cities = List of city coordinates
    w = Inertia weight, c1 = Cognitive coefficient, c2 = Social coefficient

Initialize particles:
for i = 1 to num_particles do
    Initialize position X[i] randomly (random tour)
    Initialize velocity V[i] randomly
    pBest[i] ← X[i]
    pBestFitness[i] ← fitness(pBest[i])
end for
gBest ← Best particle position among all pBest
gBestFitness ← Best fitness among all particles

for t = 1 to num_iterations do
    for i = 1 to num_particles do
        // Update velocity
        Generate random numbers r1, r2
        V[i] ← w · V[i] + c1 · r1 · (pBest[i] − X[i]) + c2 · r2 · (gBest − X[i])
        // Update position
        X[i] ← UpdatePosition(X[i], V[i])
        fitnessVal ← fitness(X[i])
        // Update personal best
        if fitnessVal < pBestFitness[i] then
            pBest[i] ← X[i]
            pBestFitness[i] ← fitnessVal
        end if
        // Update global best
        if fitnessVal < gBestFitness then
            gBest ← X[i]
            gBestFitness ← fitnessVal
        end if
    end for
end for
return gBest as the best tour found
```

Algorithm 6 Elephant Herding Optimization

```
Initialize parameters:
Initialize elephants with random tours
Set number of clans, elephants per clan, and max iterations
Initialize global best (gBest)

Main loop:
for t = 1 to max_iterations do
    for each clan do
        Compute clan center E_center
        for each elephant j in the clan do
            // Update position
            X_j ← X_best + α · (X_j − E_center) · random_factor
            Ensure valid tour
            Update personal best pBest_j
        end for
        Update clan's best (gBest candidate)
    end for

    Migration step:
    Replace worst elephant with a new random tour
    Update gBest if a better solution is found
end for

Termination:
return gBest as the best tour found
```

Algorithm 7 Grey Wolf Optimizer

```
Initialize wolves
Set iteration counter
Set maximum number of iterations
while iteration_counter < max_iterations do
    Evaluate fitness for each wolf
    Update the best wolf found so far
    Determine α, β, and δ wolves
      // best, second-best, and third-best solutions
    for each wolf do
        Update the wolf's position based on α, β, and δ
    end for
    Increment iteration_counter
end while
return best wolf found (best_solution)
```

Algorithm 8 Hovering Scouts and Foraging Flocks Pied Kingfisher Optimizer (HSFFPKO)

Require: Population size N, maximum iterations T, bounds LB, UB, objective function f
Ensure: Best solution X^*
Initialize population $\{X_i\}_{i=1}^N$ uniformly in $[LB, UB]$
Evaluate fitness $f(X_i)$ and set global best X^*
for $t = 1$ to T **do**
  Compute contraction factor $o(t) = \exp(-(t/T)^2)$
  ▹ Phase 1: PKO exploration and exploitation
  for each agent i **do**
    if rand < 0.8 **then** ▹ Exploration
      Select random peer $j \neq i$
      if rand < 0.5 **then** ▹ Hovering
        $X_i' \leftarrow X_i + \alpha L_{hov}(t)(X_j - X_i)$
      else ▹ Perching
        $X_i' \leftarrow X_i + \alpha L_{per}(t)(X_j - X_i)$
      end if
    else ▹ Exploitation (Diving)
      Construct perturbed elite b_i
      $X_i' \leftarrow X_i + H_i(t)\, o(t)\, (b_i - X^*)$
    end if
    Apply bounds and greedy acceptance
  end for
  ▹ Phase 2: Commensalism
  for each agent i **do**
    if rand $> 1 - PE(t)$ **then**
      Select random peers m, n
      $X_i' \leftarrow X_m + o(t)\alpha|X_i - X_n|$
      Apply bounds and greedy acceptance
    end if
  end for
  ▹ Phase 3: Hovering Scouts
  if $t \bmod T_{HS} = 0$ **then**
    Select scout set S
    for each scout $i \in S$ **do**
      $X_i' \leftarrow X_i + X_i \odot \mathcal{N}(0, I)$
      $X_i' \leftarrow X_i' + \eta\sigma \odot (X^* - X_i')$
      Apply bounds and greedy acceptance
    end for
  end if
  ▹ Phase 4: Foraging Flocks
  if $t \bmod T_{FF} = 0$ **then**
    Partition population into flocks $\{F_k\}$
    for each flock F_k **do**
      Compute centroid C_k and leader L_k
      $T_k \leftarrow \phi L_k + (1 - \phi)C_k$
      for each agent $i \in F_k$ **do**
        $X_i' \leftarrow X_i + \xi(T_k - X_i) + \mathcal{N}(0, \rho(t)^2 I)$
        Apply bounds and greedy acceptance
      end for
    end for
  end if
  Update global best X^*
end for
  return X^*

APPENDIX B

SYSTEM EVALUATION RESULTS

APPENDIX C

SYSTEM FLOW CHART

Figure C.1

Home Page

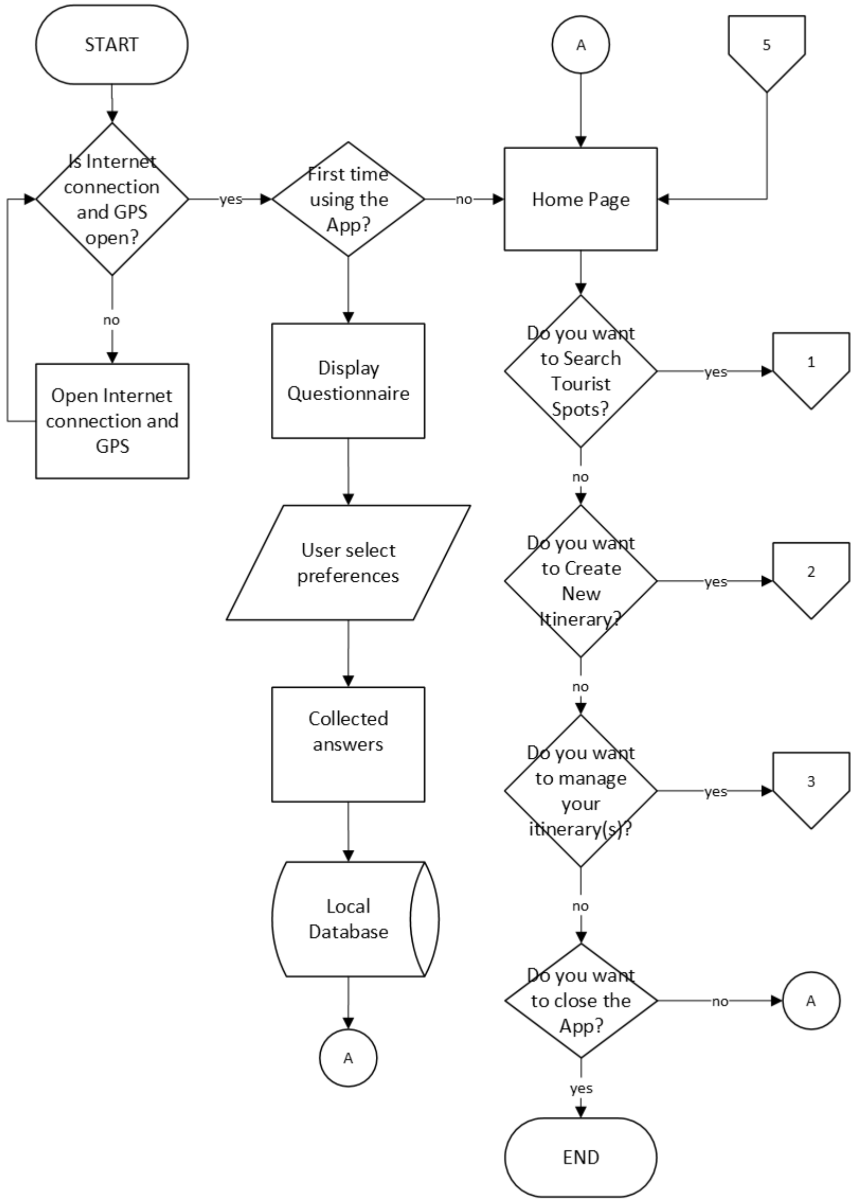


Figure C.2

Tourist Spot Searching

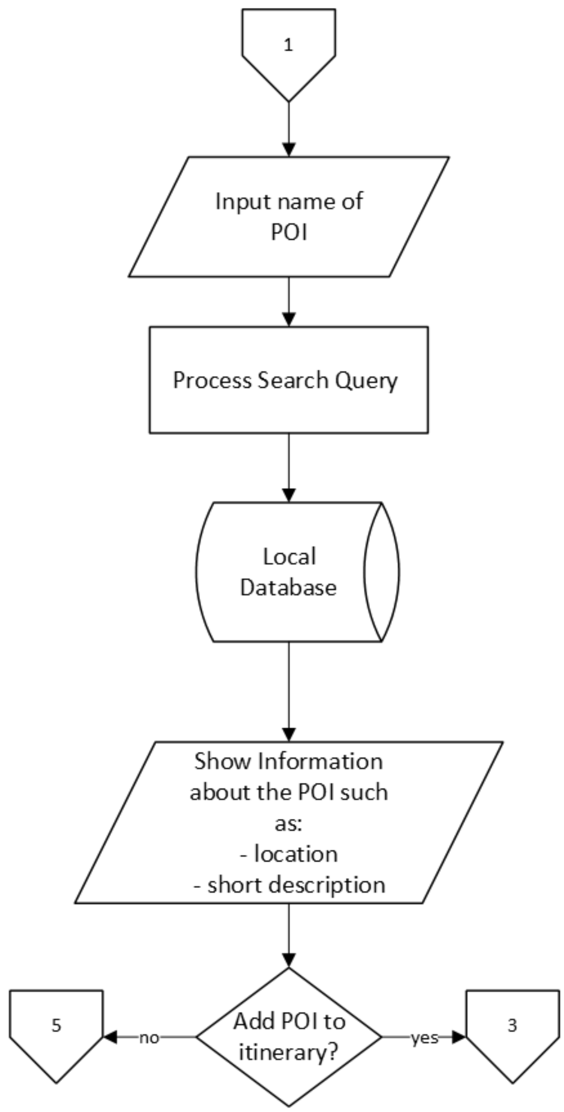


Figure C.3

Personalized Itinerary Generation

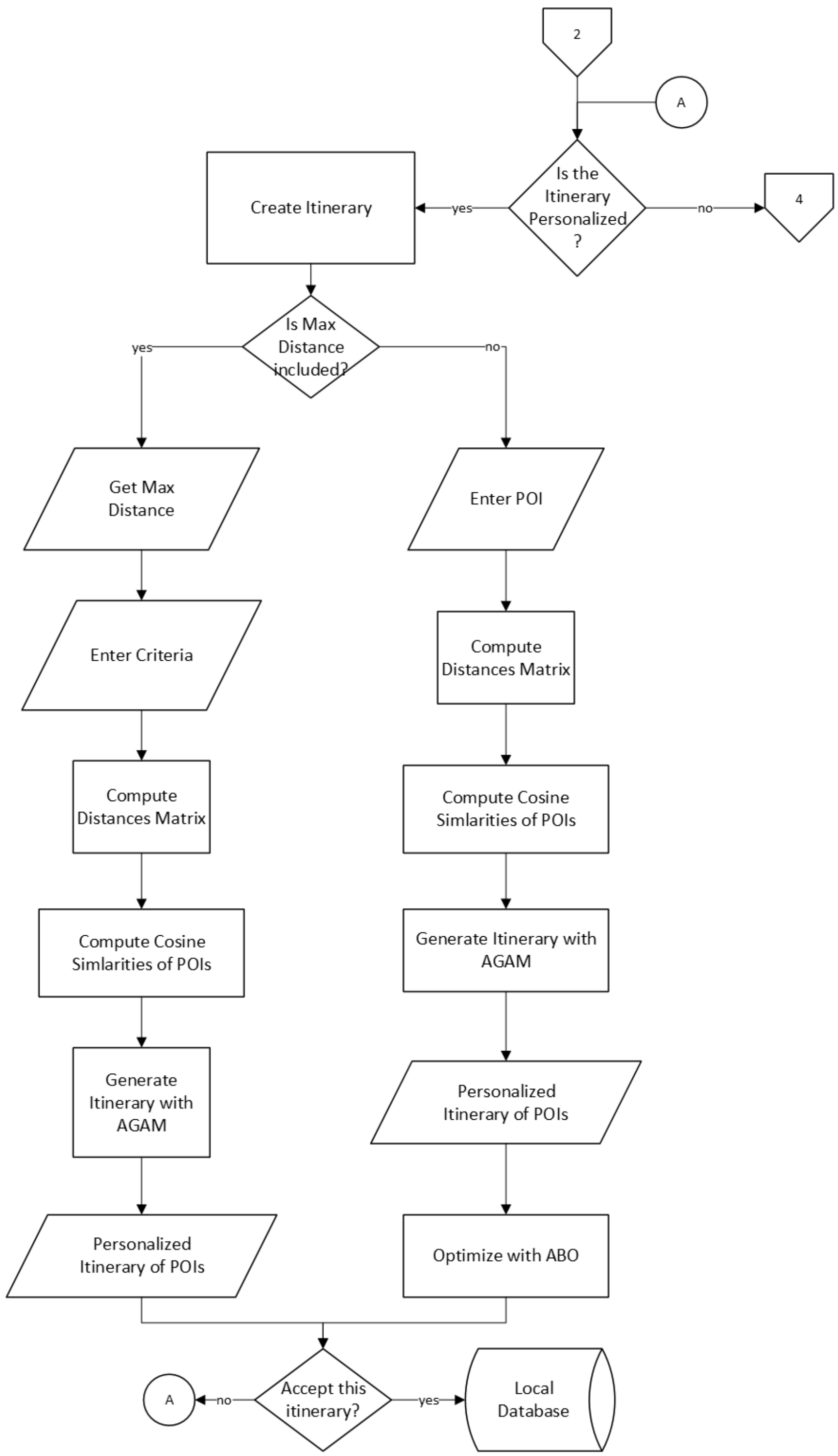


Figure C.4

Itinerary Management

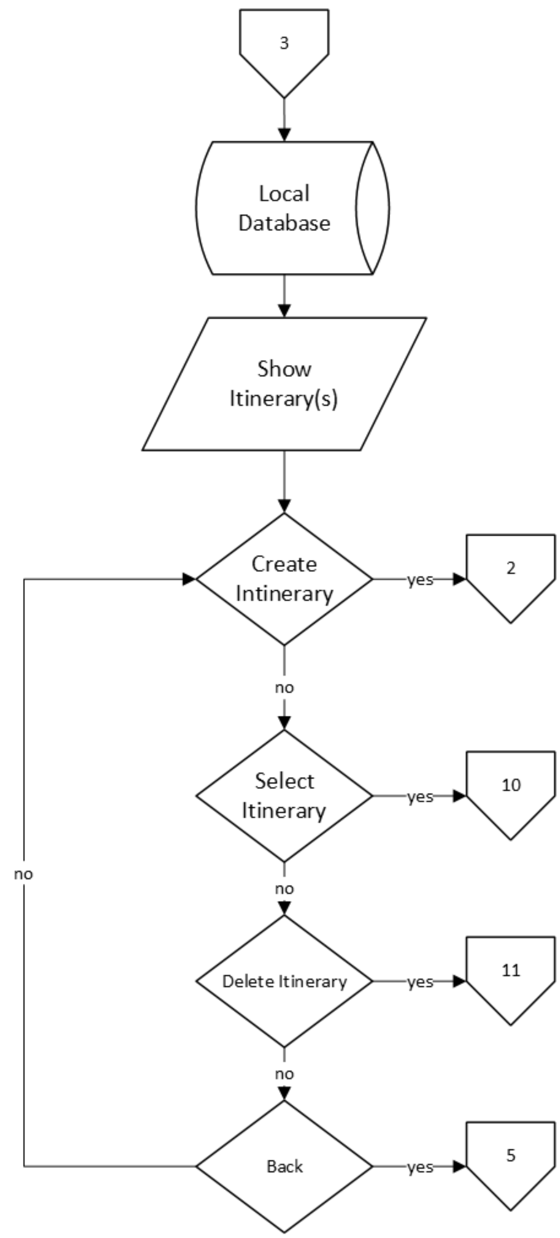


Figure C.5

Itinerary Optimization

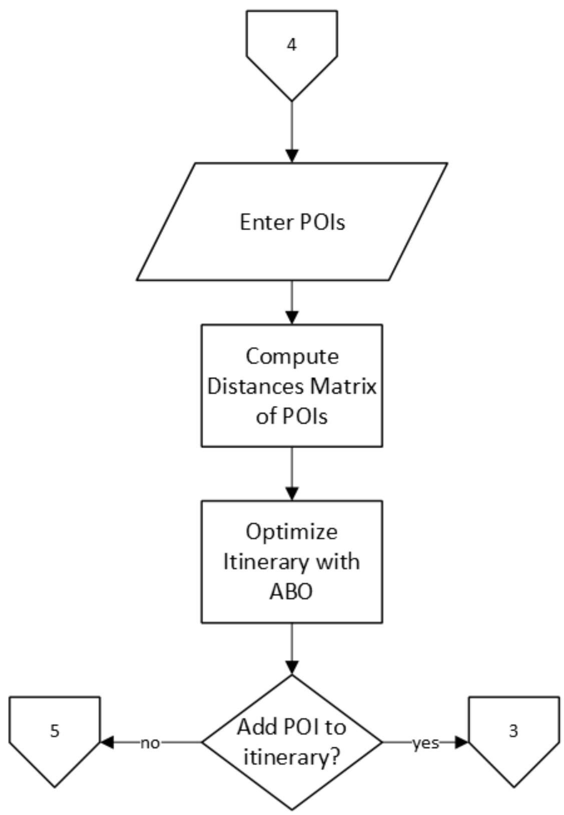


Figure C.6

Editing Itinerary

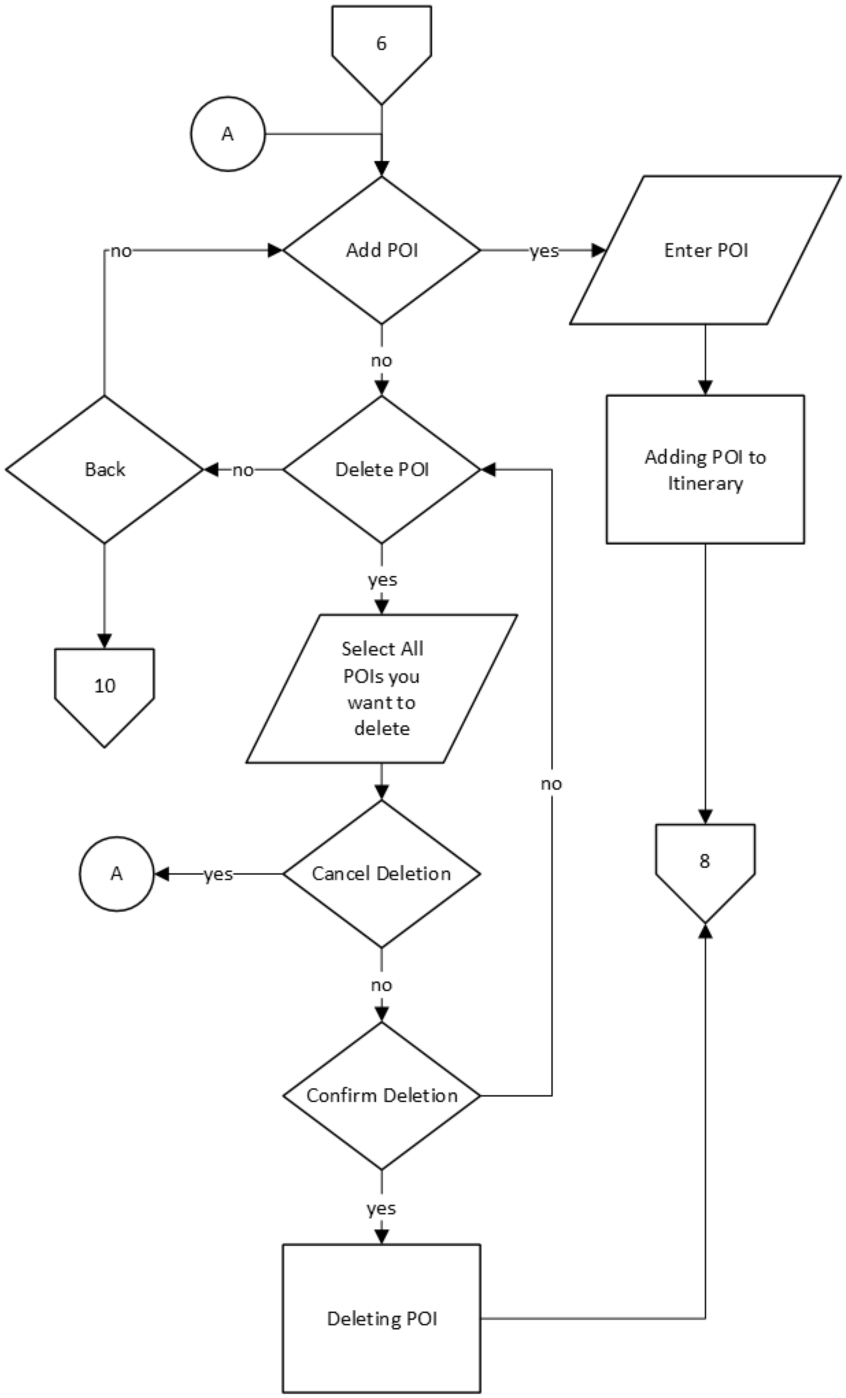


Figure C.7

Itinerary Navigation

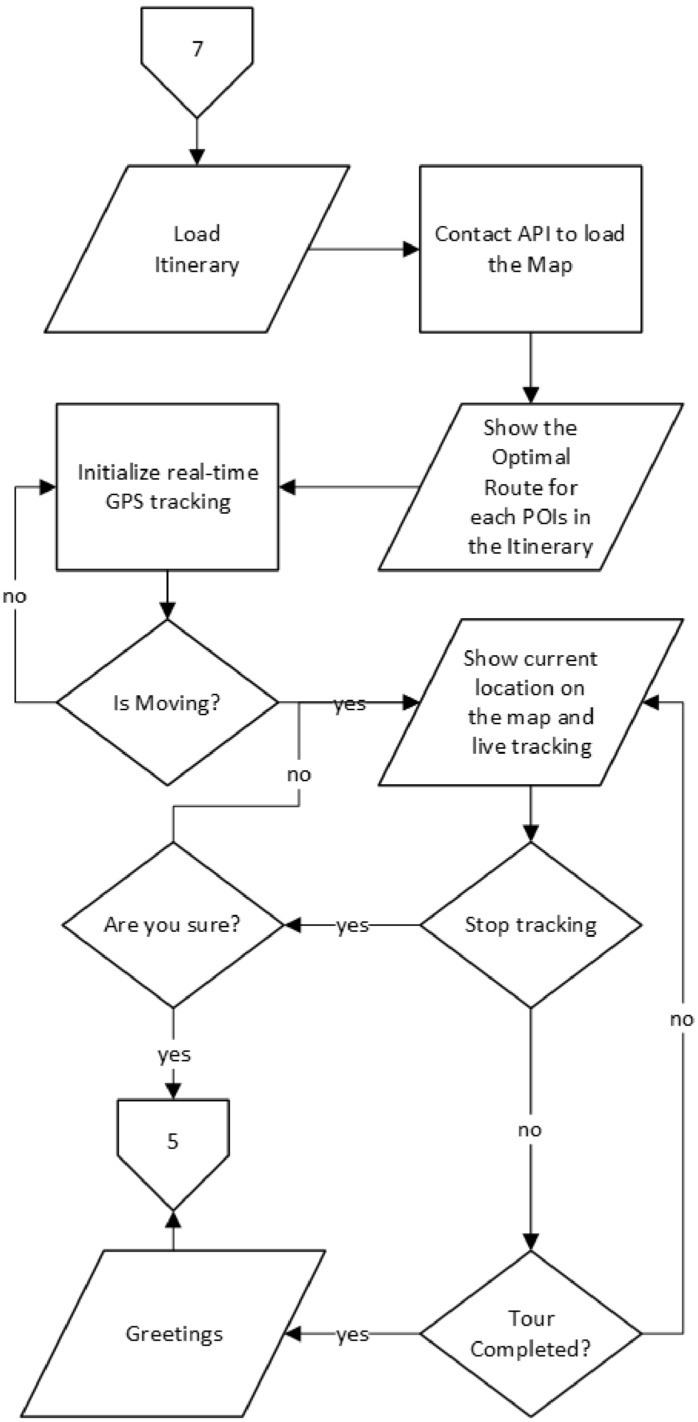


Figure C.8

Selecting Itinerary

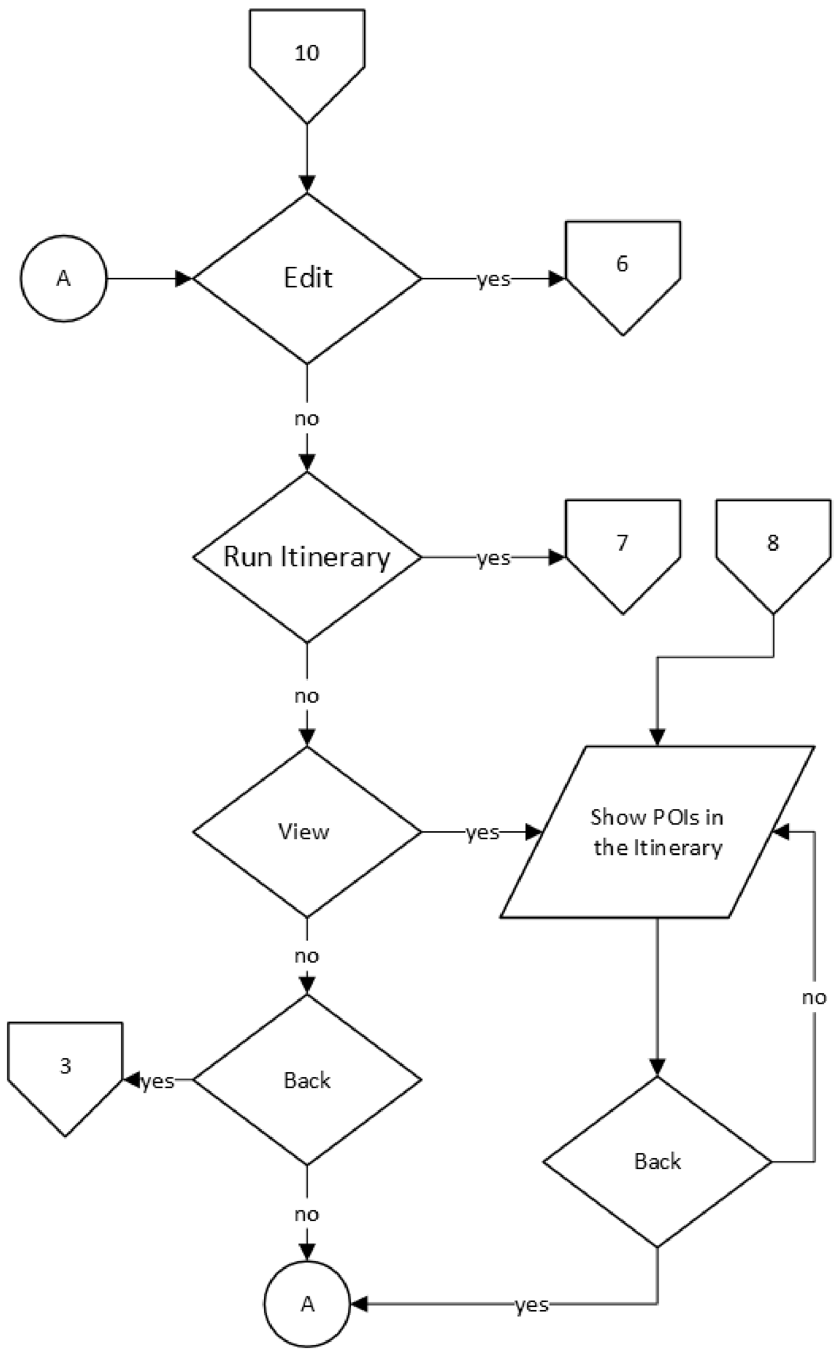
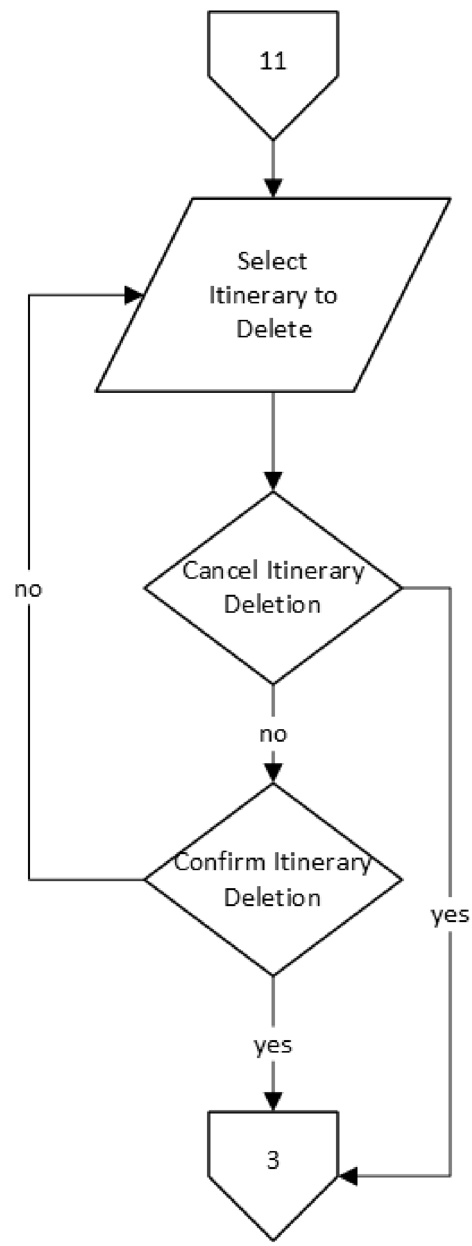


Figure C.9

Deleting Itinerary



APPENDIX D

SOURCE CODE AND PROJECT REPOSITORIES

Figure D.1

QR code for the TSP algorithms repository

https://github.com/LeinnarF/TSP-Metaheuristic-Comparative-Analysis

Figure D.2

QR code for the LAKAD application repository

https://github.com/niceWizzard/thesis-lakad-rn

Figure D.3

QR code for the thesis LaTeX repository

https://github.com/LeinnarF/Thesis-LaTex

APPENDIX E

EVALUATION INSTRUMENT

Evaluation Instrument for the System
LAKAD: A PERSONALIZED MOBILE ITINERARY GENERATOR WITH FOCUS IN BULACAN TOURISM

PERSONAL INFORMATION

Name (Optional): ______________________________

Age: ☐ 18-27 ☐ 28-37 ☐ 38-47 ☐ Above 47

Experience in Mobile Applications: ☐ Beginner ☐ Intermediate ☐ Advanced

Travelling Frequency: ☐ Rarely ☐ Occasional ☐ Frequent

Dear User,

Thank you for participating in this evaluation of our system. Your feedback is important to us and will help us improve the system. Please read each question carefully before answering and place a check (✔) in the box that represents your rating from 1 to 5, where **1 indicates "Strongly Disagree"** and **5 indicates "Strongly Agree"**.

A PERCEIVED USEFULNESS					
Indicators	**1**	**2**	**3**	**4**	**5**
1. **Improvement in Performance.** Using the system improves my performance in planning trips.					
2. **Task Efficiency.** The system helps me accomplish travel planning tasks more quickly.					
3. **Productivity.** The system increases my productivity in organizing itineraries.					
4. **Effectiveness.** The system enhances my effectiveness in planning travel activities.					
5. **Usefulness.** Overall, I find the system useful for travel planning.					
B PERCEIVED EASE OF USE					
Indicators	**1**	**2**	**3**	**4**	**5**
1. **Ease of Learning.** Learning to operate the system is easy for me.					
2. **Ease of Use.** The system is easy to use.					
3. **Clarity of Interaction.** My interaction with the system is clear and understandable.					
4. **Ease of Becoming Skillful.** I find it easy to become skillful at using the system.					

5. **Ease of Operation.** I find the system easy to operate.					
C ATTITUDE TOWARD USING					
Indicators	**1**	**2**	**3**	**4**	**5**
1. **Positive Feelings.** I have a positive attitude towards using the system.					
2. **Enjoyment.** I enjoy using the system.					
3. **Satisfaction.** I am satisfied with using the system.					
D BEHAVIORAL INTENTION TO USE					
Indicators	**1**	**2**	**3**	**4**	**5**
1. **Intention to Use.** I intend to use the system regularly.					
2. **Future Use.** I will continue to use the system in the future.					
3. **Recommendation.** I would recommend the system to others.					

Comments and Suggestions:

Please provide any additional comments or suggestions for improvement.

Thank you for your time and valuable feedback!

Name (optional): ______________________________

Role: ______________________________

Dear Expert,

We, **Bryan Declaro, Franniel Luigi Hilario, Brian Gabriel Magbanua, and Richard Manansala** are currently conducting a study entitled **"LAKAD: A personalized Mobile Itinerary Generator with Focus in Bulacan Tourism"** which aims to develop a mobile application that can help promote tourism in Bulacan by providing tourists or end-users with personalized itineraries generated through certain algorithms where user-specified preferences are the inputs.

Using a scale of 5 (Excellent) to 1 (Poor), please rate the developed system with the following criteria based on ISO/IEC 25010:2023 by marking (✔) the box.

Thank you very much.

Sincerely yours,

The researchers

A FUNCTIONAL SUITABILITY	5	4	3	2	1
Functional Completeness. The system provides a set of functions that covers all the specified tasks and intended users' objectives.					
Functional Correctness. The system provides accurate results when used by intended users.					
Functional Appropriateness. The system provides functions that facilitate the accomplishment of specified tasks and objectives.					
B PERFORMANCE EFFICIENCY	**5**	**4**	**3**	**2**	**1**
Time Behavior. The system performs its specified function under specified conditions so that the response time and throughput rates meet the requirements.					
Resource Utilization. The system uses no more than the specified amount of resources to perform its function under specified conditions.					
Capacity. The system meets requirements for the maximum limits of a product parameter.					
C COMPATIBILITY	**5**	**4**	**3**	**2**	**1**
Co-existence. The system performs its required functions efficiently while sharing a common environment and resources with other products, without detrimental impact on any other product.					
Interoperability. The system can exchange information with other products and mutually use the information that has been exchanged.					
D INTERACTION CAPABILITY	**5**	**4**	**3**	**2**	**1**

Appropriateness Recognizability. The system can be recognized by users as appropriate for their needs.					
Learnability. The system can have specified users learn to use specified product functions within a specified amount of time.					
Operability. The system has functions and attributes that make it easy to operate and control.					
User Error Protection. The system can prevent operation errors.					
User Engagement. The system presents functions and information in an inviting and motivating manner encouraging continued interaction					
Inclusivity. The system can be utilized by people of various backgrounds.					
User Assistance. The system can be used by people with the widest range of characteristics and capabilities to achieve specified goals in a specified context of use.					
Self-Descriptiveness. The system can present appropriate information, where needed by the user, to make its capabilities and use immediately obvious to the user without excessive interactions with a product or other resources.					
E RELIABILITY	**5**	**4**	**3**	**2**	**1**
Faultlessness. The system performs specified functions without fault under normal operation.					
Availability. The system is operational and accessible when required for use.					
Fault Tolerance. The system operates as intended despite the presence of hardware or software faults.					
Recoverability. The system can recover the data directly affected and re-establish the desired state of the system.					
F SECURITY	**5**	**4**	**3**	**2**	**1**
Confidentiality. The system ensures that data are accessible only to those authorized to have access.					
Integrity. The system ensures that its state and data are protected from unauthorized modification or deletion either by malicious action or computer error.					
Non-repudiation. The system can be proven to have taken place so that the events or actions cannot be repudiated later.					
Accountability. The system enables the actions of an entity to be traced uniquely to the entity.					
Authenticity. The system can prove that the identity of a subject or resource is the one claimed.					
Resistance. The system sustains operations while under attack from a malicious actor.					
G MAINTAINABILITY	**5**	**4**	**3**	**2**	**1**
Modularity. The system can limit changes to one component from affecting other components.					
Reusability. The system can be used as assets in more than one system, or in building other assets.					

Analysability. The system can be effectively and efficiently assessed regarding the impact of an intended change to one or more of its parts, to diagnose it for deficiencies or causes of failures, or to identify parts to be modified.					
Modifiability. The system can be effectively and efficiently modified without introducing defects or degrading existing product quality.					
Testability. The system can enable an objective and feasible test to be designed and performed to determine whether a requirement is met.					
H FLEXIBILITY	**5**	**4**	**3**	**2**	**1**
Adaptability. The system can be effectively and efficiently adapted for or transferred to different hardware, software, or other operational or usage environments.					
Scalability. The system can handle growing or shrinking workloads or adapt its capacity to handle variability.					
Installability. The system can be effectively and efficiently installed successfully and/or uninstalled in a specified environment.					
Replaceability. The system can replace another specified product for the same purpose in the same environment.					
I SAFETY	**5**	**4**	**3**	**2**	**1**
Operational Constraint. The system can constrain its operation to within safe parameters or states when encountering operational hazards.					
Risk Identification. The system can identify a course of events or operations that can expose life, property, or environment to unacceptable risk.					
Fail-Safe. The system can automatically place itself in a safe operating mode, or revert to a safe condition in the event of a failure.					
Hazard Warning. The system can provide warnings of unacceptable risks to operations or internal controls so that they can react in sufficient time to sustain safe operations.					
Safe Integration. The system can maintain safety during and after integration with one or more components.					

Thank you!

Comments/Suggestions/Recommendations:

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Evaluated by:

_________________________/___________

Signature/Date Signed

APPENDIX F

LETTERS

Date Sep 11, 2025

PROF. AARON PAUL DELA ROSA
Faculty, College of Information and Communication Technology

Dear Sir Paul:

We, the undersigned, are currently endeavoring on their Bachelor thesis titled, **"LAKAD: A Personalized Mobile Itinerary Creator with Focus in Bulacan Tourism"** which aims to provide personalized and optimized itineraries to promote tourism in Bulacan. In line with this, we strongly believe that your expertise and helpful guidance as the thesis adviser can greatly lead us to the success of the conduct of the said study. Thus, we would like to humbly request you to be our thesis adviser.

We hope for your positive response on this request.

Thank you very much for your support.

Respectfully yours,

Manansala, Richard M. | Declaro, Bryan C.

Hilario, Franniel Luigi C. | Magbanua, Brian G.

Noted:

RAINILYN LEONARDO-DUQUE, Ph.D.
Thesis Instructor

Conforme:

AARON PAUL M. DELA ROSA, DITC

Signature over printed name

OFFICE OF THE GOVERNOR
HON. DANIEL R. FERNANDO
R-7216-2025
RECEIVED BY
Oct. 9, 2025 DATE 11:26 TIME

October 9, 2025

Hon. Daniel R. Fernando
Provincial Governor
Provincial Government of Bulacan
2nd Floor, Provincial Capitol Building, Malolos City, Bulacan 3000 Philippines

RECEIVED
NAME WILSON
10-09-25 11:32 AM

Thru:
Gng. May Arlene DG. Torres
Department Head
Provincial History, Arts, Culture and Tourism Office (PHACTO)
Provincial Capitol Building, Malolos City, Bulacan 3000 Philippines

Dear Governor Fernando,

We, 4th year students pursuing the course BS Mathematics with Specialization in Computer Science, are currently undertaking our thesis titled **"LAKAD: A Personalized Mobile Itinerary Generator with Focus in Bulacan Tourism."** This study aims to develop a mobile application that generates personalized and optimized itineraries to promote local tourism and assist travelers in exploring Bulacan efficiently.

In line with this, we respectfully request permission to obtain statistical and informational data from the Provincial History, Arts, Culture and Tourism Office (PHACTO), specifically regarding:

1. A list of all notable tourist locations in Bulacan, along with available data on foot traffic or visitor statistics;
2. and Relevant information about these locations, including their global coordinates, short descriptions, opening hours, and tourism categories.

The requested data will be used solely for academic purposes and will contribute to the development of a system that highlights and supports the province's tourism initiatives.

Should you require any further information or clarification, you may contact us via email at 2022104499@ms.bulsu.edu.ph or through phone at 0949 326 4521.

Respectfully yours,

Manansala, Richard M.

Hilario, Franniel Luigi C.

Declaro, Bryan C.

Magbanua, Brian G.

Noted:

RAINILYN LEONARDO-DUQUE, Ph.D.
Thesis Instructor

AARON PAUL DELA ROSA, MSIT
Thesis Adviser

THELMA V. PAGTALUNAN, Ph.D.
Dean of College of Science

CURRICULUM VITAE

BRYAN C. DECLARO

Student Intern

09496580350

bryan12declaro@gmail.com

San Jose, Plaridel, Bulacan

PROFILE SUMMARY

I'm a Computer Science student who's still building my programming skills, but I have a strong background in math and problem-solving. I'm looking for an internship where I can apply my analytical thinking, learn more about tech, and get hands-on experience in a supportive environment.

EDUCATION

Bachelor of Science in Mathematics with Specialization in Computer Science

Bulacan State University (Main Campus) | Expected Graduation: 2026

- **Dean's Lister**
- **Member : Mathematics Society (A.Y. 2024 – 2025)**
- **Member : Microsoft Student Community (A.Y. 2024 – 2025)**

Relevant Coursework

- **Mathematical Modeling**
- **Object - Oriented Programming**
- **Statistics & Probability**
- **System Analysis and Design**
- **Data Structure and Algorithm**
- **Linear Algebra**

SKILLS

- Programming Languages: C++, Java, Python, C#, LaTex
- Logical thinker
- Detail-oriented
- Eager to learn
- Creative
- Team player with a collaborative mindset
- Adaptable

ACADEMIC PROJECTS

Students' Level of Awareness on the Environmental Implications of Generative AI

Research Project | Published Paper, 2025

- Conducted a quantitative study on student awareness of the environmental impact of generative AI.
- Collected data from students through surveys distributed at Bulacan State University – College of Science.
- Analyzed awareness levels and interpreted patterns in student responses.
- Published in the Journal of Education in Science, Environment and Health (JESEH) on March 26, 2025 | https://www.jeseh.net/index.php/jeseh/article/view/777

Modeling Information Diffusion on X

Research Project | Mathematical Modeling

- Developed a model to analyze and simulate how information spreads on platform X

Municipality Magazine Creation

Collaborative Multimedia Project

- Designed the magazine layout and visuals for a community-focused publication.
- Collaborated with team members who contributed additional content, research, and photography.

REFERENCES

Available upon request

Franniel Luigi C. Hilario

Pandi, Philippines | +63 995 181 8064

hilariofranniel@gmail.com | github.com/LeinnarF

Summary

Mathematics and Computer Science undergraduate specializing in algorithmic simulation and data modeling. Experienced in translating mathematical theory into practical software, demonstrated by the development of a Numerical Analysis Recommender System and custom metaheuristic solvers. Proficient in Python and Jupyter Notebooks for modeling, with strong foundation in Object-Oriented Programming (C++/Java) for implementation. Dedicated to applying rigorous mathematical logic to solve real-world engineering and optimization challenges.

Education

Bachelor of Science in Mathematics with specialization in **Computer Science**

Bulacan State University - Main Campus

Malolos, Bulacan

Academic Achievement

- Dean's Lister (A.Y. 2024-2025)

Technical Skills

Mathematical and Analysis

- Linear Algebra, Real Analysis, Graph Theory, Metaheuristic Optimization, Numerical Methods.

Programming Languages

- Python (Advanced), Kotlin, C++, C#, Java, SQL

Development Tools

- Android Development (Jetpack Compose), Unity Engine, Git/GitHub, LaTeX, Jupyter Notebooks

Research Interests

- Metaheuristic Algorithms & Optimization
- Computational Geometry
- Mobile Application Architecture
- Data Science & Analytics

Experience

UI/UX Intern

- Design the UI in Figma for BulSU ESO during internship at ISPIR Center - Bulacan State University

BRIAN GABRIEL G. MAGBANUA

Address: 328 FT. Reyes st., Sto. Rosario, City of Malolos, Bulacan
Phone: +63 9774147632
Email: magbanuabriangabriel@gmail.com
LinkedIn: linkedin.com/in/brian-gabriel

SUMMARY

A dedicated and passionate student with strong interest in technology and problem-solving. Pursuing a Mathematics-Computer Science degree. Has a solid foundation in programming and analytical thinking, supported by academic experience. Approachable, friendly, able to collaborate effectively, and can work independently. Fast learner, reliable, patient, and consistent with deadlines. Eager to apply and grow technical skills through continuous learning experience in different environments.

EDUCATION

Bulacan State University **August 2022 - Present**
- Bachelor of Science in Mathematics major in Computer Science.
- Organization: BulSU Microsoft Student Community

La Consolacion University Philippines **August 2020 - June 2022**
- Graduated Senior Highschool - STEM Strand
- Took robotics class
- Organization: Calculus Club

City of Malolos Integrated School - Sto. Rosario (Malolos Central School) **June 2010 - March 2020**
- Graduated Elementary
- Graduated Junior Highschool
- Took Visual Graphic Design class in TLE

SKILLS

Programming
- C++
- C#
- Java
- Python
- Git

Software
- MS 365
- Visual Studio Code
- Unity Editor
- Adobe Photoshop
- Canva

Others
- LaTeX

Soft Skills
- Time Management
- Team Player
- Adaptive to Change
- Resourceful

ADDITIONAL INFORMATION

- **Technical Skills:** Background knowledge in Game Development, Mathematical Modeling, Multimedia, Data Structures and Algorithms, and Database Management.
- **Languages:** Filipino, English.
- **Awards/Activities:** Graduated JHS with Honors, and SHS with High Honors. Conducted a Mathematical Modeling Group research about “*Modeling Information Diffusion on X* - Analyzing how a single influencer's post spreads using the Independent Cascade Model” - contributed to coding simulations and interpreting diffusion patterns over thousands of nodes in a network.

Character Reference available upon request

Manansala, Richard M.

4th Year BS Mathematics Student

Address: San Isidro Matua, Masantol, Pampanga | Phone: 0949-326-4521

LinkedIn: http://linkedin.com/in/richard-manansala-82a764365
Github: https://github.com/niceWizzard

Summary

Aspiring full-stack web developer leveraging proficiency in Next.js, Node.js, JavaScript, HTML, and CSS to build dynamic and user-centric applications. Developed collaborative skills through contributions to two group mathematical research papers using Python, showcasing adaptability and analytical problem-solving abilities. Eager to secure an internship where I can apply my web development expertise and contribute to a team-oriented environment. Portfolio available at https://richardmanansala.vercel.app highlights relevant projects and technical skills.

Educational Background

Bulacan State University, *Malolos,Bulacan*

Bachelor of Science in Mathematics with Specialization in Computer Science
Expected Date of Graduation: 2026
Academic Achievements

- Dean's Lister - GWA - 1.25 (A.Y. 2023-2024)
- Dean's Lister - GWA - 1.299 (A.Y. 2024-2025)

Technical Skills

1. **Web Development**
   1.1. Programming Language: Python, JavaScript/TypeScript,HTML, CSS
   1.2. Tools/Software: React/NextJS, Django, Angular
2. **Other Software and Tools:**
   - **Git** Version Control
   - **Figma/Canva**development
   - **Photoshop**

Soft Skills

- **Multi-tasking** - lead simultaneous group projects including two mathematical research projects using python.
- **Team Collaboration** - collaborated and led teams of 5-7 members for course projects.
- **Time Management** - consistently meets deadlines without fail

Experiences

Fullstack Web Developer Intern
- Created two functional websites during the internship at BMWARE Business Solutions Enterprises Inc.