**Software Requirements Specification**

For

Computer based simulation of rail network to realize shortest path algorithm

Prepared by

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**1.Introduction**

This document outlines the requirements for a computer-based simulation of a rail network to realize shortest path algorithms. The primary objective of this simulation is to [state the main goal, e.g., optimize train scheduling for increased efficiency and punctuality]. However, it will also be capable of supporting additional goals such as [list secondary objectives, e.g., minimizing travel time for passengers, reducing train congestion at peak hours, evaluating alternative network designs]. This versatility will enable diverse stakeholders, including [mention intended users, e.g., railway operators, infrastructure planners, urban development authorities], to gain valuable insights into optimizing the performance and utilization of the rail network..

**1.1 Purpose**

The purpose of this Software Requirements Specification (SRS) document is to outline the requirements for developing a computer-based simulation system for a rail network. The simulation system will utilize shortest path algorithms to optimize routing and scheduling within the rail network.

* 1. **Target Beneficiary**

The target beneficiaries of the computer-based simulation system for the rail network are:

* Rail network operators and administrators
* Transportation planners and analysts
* Engineers and maintenance personnel
* Stakeholders involved in infrastructure development and investment
* Researchers and academics studying transportation systems
* Government agencies responsible for transportation policy and regulation
* Ultimately, passengers and freight clients who benefit from improved efficiency and reliability in rail transportation.

**1.3 References**

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**2. PROJECT DESCRIPTION**

The computer-based simulation project aims to develop a sophisticated software system tailored for simulating and optimizing operations within a rail network. Leveraging advanced algorithms and visualization techniques, the system will provide stakeholders with powerful tools to analyze, plan, and optimize various aspects of rail transportation.

The project involves the design and implementation of a comprehensive simulation platform capable of emulating the complex dynamics of a real-world rail network. Key features of the system include:

1. **Train Simulation:** The system will simulate the movement and behavior of trains within the network, considering factors such as speed, acceleration, braking, and adherence to schedules. Users will be able to define and customize train routes, schedules, and operational parameters.
2. **Network Visualization:** The simulation platform will offer interactive visualization capabilities, allowing users to view the rail network in detail. Graphical representations, maps, and diagrams will provide insights into network topology, track layouts, station locations, and other relevant information.
3. **Shortest Path Calculation:** The system will incorporate advanced shortest path algorithms to compute optimal routes and schedules for trains traversing the network. Users can specify criteria such as distance, travel time, and constraints (e.g., maximum speed limits, track availability) to generate efficient routing solutions.
4. **User Interface:** An intuitive user interface will facilitate user interaction with the simulation system. Graphical controls, menus, and dialogs will enable users to configure simulation parameters, visualize results, and analyze data effectively. The interface will be designed for ease of use and accessibility across different devices and platforms.

The project will adhere to industry best practices in software engineering, including modular design, code reusability, and documentation standards. The development process will follow an iterative approach, with regular feedback and validation from stakeholders to ensure that the system meets their requirements and expectations.

Upon completion, the simulation platform will provide valuable insights and decision support tools for rail network operators, transportation planners, engineers, researchers, and other stakeholders involved in rail transportation. By enabling scenario analysis, optimization, and performance evaluation, the system will contribute to the efficiency, safety, and sustainability of rail operations.

**2.1 Data/ Data structure**

1. Graph: A graph is a fundamental data structure for representing the rail network. Nodes represent stations or junctions, while edges represent tracks or connections between them. This structure allows for efficient traversal and pathfinding algorithms. Graphs can be directed or undirected, depending on the nature of the rail network.
2. Priority Queue: Priority queues are often used in algorithms like Dijkstra's shortest path algorithm or A\* search algorithm. They prioritize nodes based on certain criteria (e.g., shortest distance or estimated distance to the destination) and allow for efficient retrieval of the most promising nodes during pathfinding.
3. Dijkstra's Algorithm: This algorithm is instrumental in determining the most efficient routes for trains within the rail network simulation. By considering factors such as distance or travel time, Dijkstra's Algorithm calculates optimal paths from a given source station to all other stations in the network. This enables trains to navigate the network in the most efficient manner possible, taking into account various constraints and preferences.
4. Hash Map: Hash maps (or dictionaries) are useful for storing key-value pairs, making them suitable for mapping station IDs to station details, track IDs to track properties, or other associative data. They offer fast lookup times and are ideal for storing large volumes of data with unique identifiers.

**2.2 SWOT Analysis**

A SWOT analysis is a strategic planning tool used to assess the strengths, weaknesses, opportunities, and threats related to a project, organization, or initiative. Here's how it applies to the computer-based simulation project for a rail network:

Strengths:

1. Efficiency Improvement: The simulation system has the potential to significantly improve the efficiency of rail network operations by optimizing routing, scheduling, and resource allocation.
2. Decision Support: It provides decision-makers with valuable insights and data-driven recommendations to improve decision-making processes related to infrastructure planning, capacity management, and service optimization.
3. Risk Mitigation: By simulating various scenarios and evaluating potential outcomes, the system helps identify and mitigate risks associated with operational disruptions, delays, or capacity constraints.
4. Cost Savings: Through better resource utilization and improved operational planning, the simulation system can lead to cost savings in areas such as fuel consumption, maintenance, and labor.

Weaknesses:

1. Complexity: Developing and maintaining a sophisticated simulation system requires significant expertise in software engineering, data analytics, and domain-specific knowledge of rail transportation.
2. Data Dependency: The accuracy and reliability of simulation results depend on the quality and availability of data, including network topology, train schedules, infrastructure details, and historical performance data.
3. Resource Intensive: Running simulations and performing optimization algorithms may require substantial computational resources, including processing power and memory, which could pose challenges for scalability and performance.

Opportunities:

1. Technological Advancements: Emerging technologies such as machine learning, big data analytics, and cloud computing offer opportunities to enhance the capabilities and effectiveness of the simulation system.
2. Expansion and Integration: The simulation system can be expanded to include additional features and integrated with other transportation management systems, such as traffic control systems, to provide a holistic view of multi-modal transportation networks.
3. Partnerships and Collaboration: Collaborating with rail operators, government agencies, research institutions, and technology providers can facilitate knowledge sharing, data exchange, and access to resources, strengthening the simulation system's capabilities and impact.

Threats:

1. Regulatory Challenges: Compliance with regulations, standards, and industry protocols governing rail operations may pose challenges and constraints on the development and implementation of the simulation system.
2. Data Security and Privacy: Managing sensitive data related to rail operations, such as passenger information, freight manifests, and infrastructure details, requires robust data security measures to protect against unauthorized access, breaches, or misuse.
3. Resistance to Change: Resistance from stakeholders, including rail operators, employees, unions, and communities, may hinder the adoption and acceptance of new technologies and processes introduced by the simulation system.

By conducting a SWOT analysis, stakeholders can gain insights into the project's internal capabilities and external environment, identify key areas for improvement and risk mitigation, and develop strategies to capitalize on opportunities and overcome challenges in implementing the computer-based simulation system for the rail network.

**2.3 Project Features**

1. Realistic Network Simulation: Simulate the operation of a real-world rail network, including trains, stations, tracks, and signals, to mimic real-world scenarios accurately.
2. Route Planning: Implement algorithms to find optimal routes for trains based on various factors such as distance, time, and priority.
3. Train Scheduling: Develop scheduling algorithms to manage the movement of trains, considering factors like timetables, speed limits, and track availability.
4. Traffic Management: Monitor and manage train traffic to prevent congestion, delays, and accidents, employing strategies like signal control and track switching.
5. Performance Analysis: Provide tools to analyze the performance of the rail network, including metrics like train punctuality, average journey times, and resource utilization.

**2.4 Design and Implementation Constraints**

1. Performance Limitations: The simulation system must contend with constraints related to processing speed, memory usage, and scalability. Efficient algorithms and data structures are vital to ensure that the system can handle large-scale rail networks without compromising performance.
2. Data Availability and Quality: The accuracy and availability of input data, such as network topology and train schedules, may be limited. The system must be designed to handle missing or incomplete data gracefully and incorporate mechanisms for data validation and error handling.
3. Integration Challenges: Integrating the simulation system with existing rail network management systems or legacy software may pose challenges. Compatibility issues and data format conversions must be addressed to ensure seamless integration and interoperability.
4. Regulatory Compliance: The simulation system must adhere to industry standards, regulations, and safety requirements. Compliance with safety protocols, data privacy regulations, and operational guidelines is essential to maintain regulatory compliance and ensure the system's integrity and reliability.
5. Resource Constraints: Limited computational resources, such as CPU, memory, and storage, may impose constraints on the system's design and implementation. Efficient resource management and optimization techniques are necessary to maximize performance within these constraints and deliver a robust and scalable simulation solution.

**2.5 Time Complexities:**

Hash Map (unordered\_map in Java):

* Insertion, deletion, and search: O(1) on average, O(n) in worst-case scenario (due to collisions)

Graph (adjacency list representation):

* Traversing all vertices and edges: O(V + E)
* Finding neighbors of a vertex: O(degree of vertex)

Priority Queue (heap-based implementation):

* Insertion: O(log n)
* Removal of the minimum (or maximum) element: O(log n)
* Finding the minimum (or maximum) element: O(1)

Dijkstra's algorithm with a priority queue has a time complexity of O((V + E) log V), where V is the number of vertices and E is the number of edges.

**Space Complexity:**

1. Hash Map (unordered\_map in Java):
   * Space complexity: O(n), where n is the number of elements stored in the hash map.
   * In the worst-case scenario, where all elements hash to the same index, additional space may be required for collision resolution, increasing the space complexity.
2. Graph (adjacency list representation):
   * Space complexity: O(V + E), where V is the number of vertices and E is the number of edges.
   * In an adjacency list representation, each vertex requires space for its adjacency list, and each edge is represented once in the adjacency lists.
3. Priority Queue (heap-based implementation):
   * Space complexity: O(n), where n is the number of elements stored in the priority queue.
   * In addition to the elements themselves, priority queues implemented using heaps may require additional space for maintaining the heap structure, such as heap arrays or binary trees.
4. Dijkstra's Algorithm (with a priority queue):
   * Space complexity: O(V) for the priority queue and additional space for storing distances and parent pointers, typically O(V) or O(V + E) depending on the implementation.
   * Dijkstra's algorithm typically requires space for storing distances from the source vertex to each vertex in the graph and parent pointers to reconstruct the shortest paths. The space complexity depends on the data structures used for storage.

**3. SYSTEM REQUIREMENTS**

System requirements for a computer-based simulation of a rail network to realize a shortest path algorithm may vary based on factors such as the size of the network, complexity of the simulation, and desired level of detail.

1. Hardware Requirements:
   * Processor: Multi-core processor with sufficient processing power to handle simulations efficiently.
   * Memory (RAM): At least 8 GB RAM for small to medium-sized simulations. Larger simulations may require 16 GB or more.
   * Storage: SSD storage for faster read/write operations, especially if the simulation involves large datasets or frequent data access.
2. Operating System:
   * The simulation software should be compatible with commonly used operating systems such as Windows, macOS, and Linux distributions.
3. Software Dependencies:
   * Programming Languages: If developing custom simulation software, knowledge of programming languages such as C++, Java, or Python may be required.
   * Development Tools: Integrated Development Environments (IDEs) like Visual Studio, IntelliJ IDEA, or PyCharm for software development.
   * Libraries and Frameworks: Depending on the chosen programming language, libraries and frameworks for graph processing, visualization, and user interface development may be necessary.
   * Simulation Software: If using existing simulation software, compatibility with the chosen platform and integration capabilities with other systems should be considered.
4. Graphics and Visualization:
   * For visualizing the rail network and simulation results, a graphics card capable of rendering 2D or 3D graphics may be beneficial.
   * Support for rendering libraries such as OpenGL or DirectX may be required depending on the visualization requirements.
5. Network Connectivity:
   * Stable internet connectivity may be necessary for accessing real-time data feeds, downloading updates, or interacting with external systems (if applicable).