**BUSINESS CASE FOR 5G CONNECTIVITY FOR BORDER CROSSING CHALLENGES FOR GORDIE HOWE INTERNATONAL BRIDGE**

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**Summary:**

This business case focuses on the problem of traffic congestion during peak hours on the Gordie Howe International Bridge and at ports of entry between Canada and the United States. The objective is to apply queuing theory to minimize wait times for commuters and commercial transport vehicles, optimize resource utilization, and reduce costs. The scope includes data collection and analysis, determining the appropriate number of operational booths during peak hours, conducting a cost-benefit analysis, and developing an implementation plan. To ensure the effectiveness of the proposed solution, simulation modelling will be used to evaluate its performance.

The proposed solution aims to improve traffic flow and reduce congestion, benefiting commuters, commercial transport companies, and the economy. By using queuing theory, we aim to identify the optimal number of operational booths required during peak hours and reduce wait times for users. The cost-benefit analysis will evaluate the feasibility and return on investment of the proposed solution. The implementation plan will include a timeline, milestones, resource requirements, and a risk management plan to mitigate potential risks.

Overall, this business case aims to provide a comprehensive analysis of the problem of traffic congestion during peak hours and a proposed solution that applies queuing theory and simulation modelling to optimize traffic flow, reduce wait times, and improve efficiency.

**Problem Statement:**

Traffic congestion during peak hours on the Gordie Howe International Bridge and at ports of entry between Canada and the United States is causing significant delays for commuters and commercial transport vehicles, resulting in decreased efficiency and increased costs that negatively impact the economy. To address this issue, the solution involves applying queuing theory to determine the optimal number of booths required during peak hours, further will try to examine any alternative techniques that can be used to succeed in our goal. The goal is to minimize wait times and optimize resource utilization, leading to improved traffic flow and reduced congestion. This approach is expected to benefit commuters, commercial transport companies, and the economy.

**Business Case Objectives:**

* To identify the peak times of traffic on the Gordie Howe International Bridge and at the ports of entry.
* To determine the appropriate number of booths that should be operational during peak hours to minimize wait times for commuters and commercial transport vehicles.
* To optimize the utilization of available resources, such as staff and equipment, to improve efficiency and reduce costs.
* Discussing alternate strategies other than queueing theory

**Business Case Scope:**

* Collect data on traffic patterns and wait times at the Gordie Howe International Bridge and at the ports of entry.
* Conduct an analysis of the data using queuing theory to identify the peak times of traffic and estimate the expected wait times during these periods.
* Determine the appropriate number of booths that should be operational during peak hours to minimize wait times, based on queuing theory calculations.
* Conduct a cost-benefit analysis to determine the feasibility and return on investment of the proposed solution, taking into account the costs of implementing additional booths, staff, and equipment.
* Develop a detailed implementation plan that outlines the timeline, milestones, and resource requirements for the proposed solution.
* Identify the key stakeholders and conduct a stakeholder analysis to ensure their needs and interests are incorporated into the proposed solution.
* Develop a risk management plan that identifies potential risks associated with the proposed solution and outlines strategies for mitigating these risks.

**Analysis:**

Based on the data analysis of the Windsor-Detroit Ambassador Bridge, it is evident that the bridge experiences significant congestion only on Wednesdays, Mondays, and Tuesdays. During these days, peak wait times range from 31 to 27 minutes. Therefore, a reasonable conclusion can be drawn that the bridge primarily requires additional manpower and infrastructure support during these peak hours. By effectively allocating resources during these times, we can enhance operational efficiency and maintenance cost-effectiveness, leading to reduced wait times for travellers. To determine the appropriate number of resources needed, we will employ Queueing Theory, A subfield of mathematics focuses on the analysis of waiting lines or queues. It offers mathematical models and methods to analyse and optimise systems including customer or entity arrival, response times, and the number of servers or resources available. Businesses and organisations can efficiently cut wait times and boost system efficiency by comprehending and utilising queue theory**.**

**Fig. 1 Average wait times**

The following list includes the main elements of queue theory:

**Arrival Process**: The pattern or distribution of clients entering the system is referred to as the arrival process. Different statistical models, like the Poisson or exponential distribution, could be used to describe it. It is possible to predict the rate of client arrivals and the chance of many arrivals taking place at once by understanding the arrival process.

**Service Time:** The length of time needed to serve each customer is known as the "service time." Service times can be modelled using several statistical distributions, such as exponential, normal, or gamma distributions, just like the arrival process. One can determine the typical amount of time needed to serve a customer by studying service times, and then allocate resources accordingly.

**Queue Discipline**: The procedures or guidelines that establish the sequence in which clients are served are referred to as the queue discipline. First-come, first-served (FCFS), last-come, first-served (LCFS), shortest processing time (SPT), and priority-based queuing are some of the different disciplines. The discipline chosen for the queue can influence wait times and customer satisfaction.

**Number of Servers:** The number of servers reflects the persons or resources that are available to service the clients. It's essential to have the right number of servers to handle demand for services without creating long wait times. Based on arrival rates, service times, and desired performance metrics, queue theory offers methods for calculating the ideal number of servers.

**Queue Length and Waiting Time:** The number of customers in queue at any time is referred to as the "queue length," and the "waiting time" is the amount of time a customer must wait before being serviced. Based on system factors, queuing theory enables calculation and forecasting of average queue length and waiting time. Making choices that will reduce wait times requires the use of this information.

Several methods can be used, including queue theory, to shorten wait times:

**Keeping Arrival and Service Rates in Balance:** By varying the arrival and service rates, it may be possible to better match the system's capacity to consumer demand. You can avoid line-ups getting too long or resources being underutilised by appropriately regulating these rates.

**Expanding the Number of Servers:** Increasing the number of servers can help spread out the workload and shorten wait times. This strategy comes at a cost; thus, it should be carefully studied. The number of servers needed to achieve service level goals while maximising resource utilisation can be determined using queue theory.

**Optimising Queue Discipline:** Making the right queue discipline choice can have a big impact on how long customers wait. The best policy for a given system can be found by examining how several disciplines affect customer happiness and service effectiveness.

**Putting Prioritisation into Practise:** In systems with a range of customer priorities, putting a priority-based queuing system into practise helps guarantee that clients with high priorities get quick service. With this strategy, waiting periods for important clients or requests that must be fulfilled quickly are reduced.

**Implementing virtual queues:** Using a digital system that enables customers to reserve their position in queue from a distance, virtual queues replace actual waiting queues. Customers no longer have to physically wait, which reduces their perceived wait times and enhances the overall experience.

**Predictive Analysis and Real-Time Monitoring:** With the use of historical data and real-time monitoring, you can predict peak times, spot bottlenecks, and proactively manage resources to avoid long lines. You can optimise resource allocation and reduce waiting times by using predictive models and data analytics to uncover patterns.

**Queue theory approaches will be implemented, which will streamline the bridge's operations and shorten wait times. The main tactics consist of**:

* **Priority Based queuing**: Introduce a system of priority-based queuing that divides cars into several priority levels according to factors including how frequently they are used, their business traffic, and their status as emergency vehicles. To reduce wait times, higher priority vehicles will receive faster servicing.
* **Server Capacity Allocation:** To ensure that higher priority vehicles are processed quickly and efficiently, set aside a part of server capacity just for them.
* **Parallel Processing: Implement** parallel processing by breaking down service jobs into more manageable, independent subtasks that can be completed at the same time. The average service time per vehicle will be cut down, and resource usage will be optimised.
* **Streamlining Service Processes:** Streamline service procedures by streamlining document verification processes, implementing technology solutions for quicker toll collecting, and getting rid of any stages that aren't necessary.
* **Real-Time Traffic Monitoring and Adjustment:** Real-Time Traffic Monitoring and Adjustment. Based on current demand and congestion levels, this information will allow for dynamic adjustments to the distribution of server capacity, ensuring effective resource utilisation.

We discuss the following procedures in the in the below visualizations where we see different strategies (from discussed above) to process vehicles in queue by combining different methods to allocate them services.

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**Fig. 2 Overview of Queue Theory**

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**Fig. 3 (Priority Based Queuing theory)**

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**Fig. 4 (Detail Priority Queue Theory)**

**The Gordie Howe Bridge gets the following advantages from applying queuing theory strategies:**

* Reduced Wait Times: All cars crossing the bridge will have much shorter wait times because to priority-based queuing, parallel processing, and optimised service procedures.
* Increased Customer contentment: Reduced wait times would improve overall customer contentment and experience, which will support favourable opinions of the bridge's dependability and efficiency.
* Optimal Resource Utilisation: Queue theory techniques will guarantee effective server capacity and resource allocation, enhancing operational effectiveness and minimising idle time.
* Improved Regional Economic Productivity: The bridge will allow for smoother transit, increasing regional economic productivity and encouraging trade activities. It will also reduce traffic and wait times.

**Alternative solution**

We may use the ideas from queueing theory to improve the flow of traffic on the Bridge and reduce wait times during the busy afternoon hours. Here is a suggestion to shorten wait times:

* **Pre-Screening and Prepayment**: Implement a system where regular commuters or pre-approved vehicles can pre-screen and prepay their tolls online. This allows for expedited processing and reduces the time spent at toll booths, particularly during peak hours.
* **Automated Toll Collection:** Upgrade the toll collection system to use electronic toll collection methods, such as RFID-based transponders or license plate recognition systems. This eliminates the need for manual toll collection and reduces the time spent at toll booths.
* **Real-Time Traffic Information:** Provide drivers with real-time information about traffic conditions and estimated wait times at the bridge through variable message signs or smartphone applications. This allows drivers to make informed decisions about their travel plans and potentially adjust their routes or timing to avoid peak congestion.
* **Intelligent traffic management systems:** Utilize advanced traffic management systems that use sensors, cameras, and real-time data analysis to optimize traffic flow, manage lane assignments, and detect incidents promptly.
* **Dynamic lane reversal**: Implement dynamic lane reversal strategies, where the number of lanes dedicated to entering or exiting Canada can be adjusted based on the current traffic conditions.
* **Traffic signal synchronization:** Coordinate traffic signals near the bridge to facilitate smooth traffic flow and reduce congestion in the vicinity.

**Stakeholder’s List:**

The stakeholders involved in the proposed project include Government agencies, Transportation companies, commuters, Business owners, Community groups, Technology providers, and Investors.

**Possible Risks and mitigation:**

**Data accuracy risk:** There is a risk that the collected data may not accurately reflect the actual traffic patterns, leading to inaccurate results.

Mitigation**:** To mitigate this risk, we will use reliable and verified data sources and validate the accuracy of the data through statistical analysis and cross-checking with other sources. Therefore, we are using reliable data resource from link: in order to carry out our analysis as it can be seen as the reliable data source.

**Implementation risk:** There is a risk that the proposed solution may not be implemented successfully due to unforeseen technical or logistical challenges.

Mitigation**:** To mitigate this risk, we will conduct a thorough feasibility analysis and develop a detailed implementation plan that considers all potential challenges and risks. We will also assign a dedicated project team with the necessary expertise and resources to ensure the successful implementation of the proposed solution.

**Financial risk:** There is a risk that the costs associated with implementing the proposed solution may exceed the expected benefits.

Mitigation**:** To mitigate this risk, we will conduct a comprehensive cost-benefit analysis to evaluate the feasibility and return on investment of the proposed solution. We will also develop a detailed budget and regularly monitor the project expenses to ensure they remain within the allocated budget.

**Stakeholder risk:** There is a risk that the proposed solution may not meet the needs or expectations of all stakeholders, leading to resistance or opposition.

Mitigation**:** To mitigate this risk, we will engage with all stakeholders throughout the project and seek their feedback and input. We will also communicate regularly and transparently to keep stakeholders informed about the project's progress and address any concerns or issues that arise.

**Cost Estimation:**

To provide a cost estimate for this project, more detailed information about the specific requirements and resources needed would be necessary. However, some potential cost factors that could be considered include:

* Data Collection: This would involve hiring staff, purchasing equipment, and software needed for collecting and analysing traffic data. The cost for this could range from $50,000 to $100,000.
* Simulation Modelling: This would involve purchasing software and hardware needed to build and run the simulation models. The cost for this could range from $20,000 to $50,000.
* Implementation: This would involve the cost of hardware, software, and labour required to implement the proposed solution, including any necessary upgrades or changes to the infrastructure. The cost for this could range from $500,000 to $1 million or more.
* Contingency: This would involve reserving a percentage of the total project cost to cover unexpected expenses or cost overruns. A contingency of 10% to 20% is commonly used.
* Overall, the total cost for this project could range from several hundred thousand dollars to several million dollars, depending on the specific details and requirements of the project.

**Future scope of project:**

* Integration of real-time data from various sources to enhance traffic predictions and resource allocation.
* Implementation of advanced traffic management systems using AI, machine learning, and predictive analytics.
* Collaboration with stakeholders such as government agencies, transportation companies, and community groups.
* Scaling the project to address traffic congestion in other transportation corridors or border crossings.
* Continual improvement through feedback and evaluation of implemented solutions.
* Exploration of emerging technologies and innovations in traffic management
* Consideration of future trends and changes in transportation patterns.
* Emphasis on data-driven decision-making and ongoing monitoring of traffic flow and congestion levels.

**References:**

* <https://bwt.cbp.gov/historical>
* <https://www.gordiehoweinternationalbridge.com/en>
* <https://ieeexplore.ieee.org/Xplore/home.jsp>
* <https://dl.acm.org/>
* <https://drive.google.com/file/d/1DYtk-yGuod3-lWAWHjecqqlaEKq1ZqvS/view?usp=drive_link>
* Video Link: <https://youtu.be/FCuSuYJYYig>