Effect of stop skipping on passenger travel time on the Washington Metro

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EFFECT OF STOP SKIPPING ON PASSENGER TRAVEL TIME ON THE WASHINGTON METRO

The metro or subway system is a vital part of a city's infrastructure and provides affordable transit options. However, subways are often plagued with delays and overcrowding issues. This is a serious problem because disruptions in the normal operation of transit systems leads to lost productivity hours for workers. Fortunately, there have been many advancements in transportation research using math modeling to develop better schedules that take into account passenger demand and train capacity. One of these scheduling techniques is skip stopping. Skip stopping (or stop skipping) is a schedule that allows trains to skip certain low demand stops so that more passengers can be reached at the higher demand stops. By doing this, the overall operating speed can be improved, although for some passengers waiting times will increase. A balance has to be found such that the costs of a skip stop system (additional waiting times, time to change trains) are less than the benefits (decreased overall travel time). Skip stop systems have been implemented by metro systems in Santiago and Seoul (Freyss, M. et. al; Suh et. al.) Locally, the Washington Metro (WM) used stop skipping previously, but only to make up for delays instead of during normal operation. Another to improve transit speed is including express lines, but these require major infrastructure investments that may not be easily added, especially in underground stations. Skip stopping is advantageous in this regard because it only requires a change in schedule to improve speed; existing trains and tracks can continue to be used (Vuchic, 1976).

Past Research

Past research on skip stop operation consists of models optimizing skip stop schedules and models comparing skip stop efficiency to a regular stop system. In Seoul's subway, a skip stop operation was found to reduce the overall travel time (including waiting time) by nearly 8 percent. The time spent traveling only on the train was also lowered by 12 percent. The tradeoff is that a skip stop system reduces overall travel time, but increases the waiting time for certain individuals at lower demand stops. This project utilized an OD (origin-destination) matrix, which was derived from the ridership data on one of the lines (Suh et. al, 2002). A technique for skip stop termed an AB stop skipping schedule was developed in the 1970s. In this system, there are two types of trains on a line, the A train and the B train. The stops on a line are categorized into 3 types: A, B, or AB. A trains stop at A stops and B trains stop at B stops. Both the A train and the B train stop at AB stops. The designation of which station should be which type is based on factors such as the number of passengers at a station and maintaining equal amounts of A and B stations. (Vuchic, 1976). This AB skip stop model has been the foundation for many recently created scheduling algorithms. Other past research has supported the idea of not limiting the stops that are skipped to a predetermined schedule. An empirical study in Taiwan found that allowing for variation in the stops that are skipped created the best planning outcome, which minimized operating costs and travel time loss (Chang et. al, 2000). Essentially, creating an optimal schedule requires variation depending on ridership, since everyday is different in terms of the number of riders taking a particular train. The downside of such an approach is that the passengers may be confused by the lack of a standard schedule about the stops a train will take.

Present Research

Much of the recently published research has built off of the AB skip stop pattern previously mentioned. What has changed is that the optimization techniques used and the inclusion of additional variables such as passenger behavior. Genetic algorithms, which optimize a problem using a process that mimics natural selection, have been used extensively to develop skip stop schedules. Genetic algorithms have been used widely in operations research as a faster method to approximate solutions to complicated models. In the context of skip stop scheduling, genetic algorithms are useful because they can take into account many conditions, such as access modes, collision constraints, and stopping scenarios without having exceedingly high computational costs (Lee, 2012). Other present research includes taking into account the train choice behavior of passengers into a skip stop mathematical model. This research also utilized the AB skip stop pattern, and found that skip stopping can improve the service for passengers. It also showed that the elasticity (the sensitivity of the train operations to changing demand) improved under a skip stop system (Cao, 2016). This is valuable because it shows that a skip stop system is not only faster but also more resistant to sudden changes in passenger volume. Other research includes a continuous approximation model that factors in continuous variables such as the station density on a linear track in order to figure out which stops to skip. This type of model assumes an unlimited capacity on the trains and also considers the energy cost of the trains in order to optimize it. However, it does not take into account actual data from the trains (Freyss et. al, 2013). While research on AB skip stopping has focused on subways, it has also been extended to buses that traditionally have a fixed set of stops. The effect of this has been (Huang et. al, 2017). The objective functions for these types of models are minimized so that the cost is the smallest. The cost can include both energy expenses and waiting time.

Current problems in the field

In the case of modeling skip stop operations, the exact number of passengers leaving from a particular station will usually vary day by day. Since these are important to any model that calculates the cost of waiting time, perfectly optimized skip stop operations are impossible. Another limitation is the impact of other factors on travel time, such as service delays due to mechanical or weather problems (unrelated to stopping while waiting for another train). While these delays are not a part of normal operation, they can still have significant impact on the overall travel time of passengers. These are much more difficult to predict and include in the overall travel time because they are not usually a function of known variables like the speed of a train. Another problem is solving for the efficiency of skip stop operations quickly without using a more intensive analysis that includes origin and destination data. This issue has been partially resolved through approximation models, but these are limited in how precise their results will be compared to a more thorough analysis (Freyss, et. al).

Proposed Research

The proposed research will use train operation data collected from the Washington Metro Authority and input it into the continuous approximation model used by Freyss, et. al. This model will not initially utilize ridership but rather include constants such as number of trains operating in each direction, acceleration and deceleration rate of a train, track length, and cruising speed of the train. The model used makes certain assumptions, such as infinite train capacity, and identical dwell time at all stations to simplify the calculations. Once this information is input into the model, the optimal density of stations should be identified. Some parts of the model include energy costs, but these will be ignored for the purposes of simplifying the calculations. The total cost to be optimized will initially consist of only the travel time. Of note is that this model makes use of the previously elaborated AB skip stop pattern. Once this preliminary model has been developed, the goal will be to add additional parameters such as energy costs and optimize those in conjunction with the minimum waiting time.

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