Quantifying Route Quality through Viability Indices using Actual Travel Time Data

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ABSTRACT
Travel time data becomes widely available with the deployments of location-based technologies including GPS-equipped vehicles and cell phones, Bluetooth readers, Dedicated Short Range Communication devices, etc. This change has made a shift on the existing distance or historical speed based route guidance to travel time-based route guidance. For example, commercial GP-based navigation system utilizes real-travel time data for updating en-route guidance. However, the variability of link travel times was not explicitly considered.

This paper explores route viability using real-time link travel time data obtained from Dedicated Short Range Communication (DSRC) devices in Daegu City, South Korea. The purpose of this study was to quantify the quality of alternative routes by explicitly considering route travel time variability. To demonstrate the practical implication of the proposed route viability, a few origin and destination pairs were selected, the distributions of shortest travel time routes (i.e., the best and the second best routes) were generated, and the viability of the shortest routes were compared on the basis of the viability index. It was found that the shortest route based on average travel time is not always the best route due to travel time variability as such viability index will help travelers understand the quality of the routes.

Keywords: route guidance, route viability, link travel time, shortest route

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1. INTRODUCTION
Route guidance system typically provides travelers with the shortest route based on link cost such as distance, historical speed, or real-time travel time so that travelers can arrive their destinations as early as possible. Studies have shown that route guidance systems are effective in improving travel time (Sparmann, 1991; Lee and Park, 2008). In practice, when multiple routes or an alternative route are considered, the existing route guidance systems mostly rely on the average travel time without explicitly considering variability in link or route travel times. In many cases, travel time reliability is more important factor than average travel time. For example, there exist two routes to an airport. Let’s assume that the route 1 has faster average travel time but much wider variability than the route 2. A traveler would prefer to take the route 2 if the route 1 travel time variability would possibly put him/her to miss the flight. In addition, one might ask how much the route 1 is better than the route 2 if a traveler does not have to catch a flight, or how viable is the route 2 when compared to the route 1. In general, the route guidance system only provides “recommended route” without providing viability of next best route. It is noted that this has not been practiced in real world in part due to lack of available link/route travel time data.

In recent years, link travel time data becomes widely available through the deployments of various location-based technologies. One example is a Dedicated Short Range Communication (DSRC) system deployed in Daegu City, South Korea. The DSRC uses two way wireless communications between the onboard equipment (OBE) installed within the vehicle and the roadside equipment (RSE) installed at the roadside infrastructure. Each vehicle equipped with OBE sends its information (i.e., randomly generated unique vehicle ID and time stamp) whenever it passes RSE. Thus, the link travel time between RSE locations can be obtained by matching the vehicle IDs and time stamps. Given Daegu City has over 10% vehicles equipped with the DSRC, the sample size for estimating average link travel time is more than adequate. A study found that around 5% sample is more than enough to estimate average travel time for any given link (Tanikella et al., 2007).

The purpose of this study was to quantify the quality of alternative routes by explicitly considering actual route travel time variability. Of course, the travel time data obtained from Daegu City was used to generate the distributions of route travel times of the best and next best routes, and their route viability was calculated on the basis of overlaps between the two distributions. The remainder of this paper is organized as follows: Travel time data in Daegu City section presents the background of Daegu City, the DSRC system deployed and the travel time to be used in this study. The methodology section discusses proposed route viability indices based on the probability of one route being better than the other using the travel time distributions. The implementation and results section presents case studies of selected three origin destination pairs to demonstrate how the proposed route viability indices...
can be calculated and the results can be informed to travelers. Finally, concluding remarks section summarizes findings of this study and recommendations for future research.

2. TRAVEL TIME DATA IN DAEGU CITY
Daegu is one of the largest cities in South Korea and hosts a vibrant lifestyle. The abrupt growth after the economic recession in South Korea changed the paradigm and modernized the big business cities with a fast-paced lifestyle. This demands greater traffic mobility challenges across larger cities as people use urban transport facilities in a greater magnitude these days to save time. The traffic management thus plays a vital role in providing time-effective, cost-effective and secure urban mobility around these larger cities where day-to-day voyage is now always in a fast-lane.

To meet the needs of urban mobility in Daegu City, the Ministry of Land, Transport and Maritime Affairs invested about 4.2 billion Korean WON to introduce an Advanced Traffic Management System that provides commuters with real-time traffic information to experience less-congested traffic conditions in order to prevent traffic-jams [1]. The goal of traffic management system was to provide innovative services that relate to different modes of commutations that give commuters flexibility, keep them well-informed and help them to take safe and coordinated travel routes for daily life mobility. Similarly, Intelligent Transportation Systems (ITS) were deployed around Daegu Metropolitan Area where the first phase was utilizing a web-based service for travelers (http://car.Daegu.go.kr/) providing transportation network congestion levels as shown in Figure 1. The web based service also provides CCTV camera footage and the maps of VMS deployed.

Figure 2 shows the Daegu network used in this study. The locations of the roadside equipments (RSEs) deployed in the City are shown in red dots. Daegu City currently archives a short span of time (about a month) worth of individual DSRC communications data during peak hours. Thus, this study focused on the afternoon peak hours between 5 PM and 7 PM. The raw data was processed using a MATLAB code that parses randomly assigned vehicle ID, time stamp at a given RSE, matches the vehicles IDs between the adjacent RSEs, and retrieves travel time between RSEs by subtracting time stamps.
Figure 1. Web-based Traveler Information System in Daegu City

Figure 2. Daegu City network with the RSE locations
3. METHODOLOGY

As noted earlier, this paper proposed two route viability indices utilizing the distributions of two routes travel times. First is called dominancy index that is the probability of superior route being better than inferior route, while the other is called beat the average index that is the probability of the inferior route being better than average of the superior route. It is noted that superior and inferior routes are defined on the basis of average travel time.

To describe the proposed indices, the following two routes between origin node 25 and destination node 28 are considered.

- Route 1: superior route having shorter average travel time
- Route 2: inferior route having longer average travel time

As shown in Figure 4, the dominancy index indicates how good the superior route is compared to the inferior route. When there is no overlap between the two route travel time distributions (Figure 4(b)), the superior route completely dominates the inferior route with dominance index of 1. If the overlap exists, the probability shown in Figure 4(a) represents dominancy index. Similarly, the beat the average index represents the probability that the inferior route can be better than the average of the superior route as shown Figure 5.

In order to demonstrate the practical implications of these two indices, three representative origin-destination pairs were chosen from the Daegu network. For each of these three pairs, two alternative routes were generated. It is noted that one can generate two best routes using K-shortest path algorithms using average link speed. In this paper, two routes between the origin and destination were identified on the basis of network knowledge. For example, one is a habitual route and the other is an alternative route to a commuter.
Figure 4. Dominance index shown as Probability being a superior route is better than an alternative route

Figure 5. Beat the Average index shown as Probability being an inferior route is better than the average of a superior route

4. IMPLEMENTATION AND RESULTS

As noted, the proposed route viability indices were implemented on three sets of origin destination pairs within the Daegu City network. For each origin and destination (OD) pair, two alternative routes were identified and the distribution of each route travel times was developed. Both route travel time distributions were plotted together. From the distributions, the dominancy index and the beat the average index were calculated.

4.1 OD Pair 1

As shown in Figure 6, two viable routes between node 2 and node 14 are shown. As noted, these two routes are a typical traveler or commuter would take as his or her primary and secondary routes. The travel time distributions were developed by analyzing only vehicles pass through the entire routes during the PM peak hours between 5 PM and 7 PM over one month period. It is noted that the amount of data used for the analysis is likely to be more than
enough to ensure the distributions were formed in reasonable shapes. It is also noted that a much shorter interval such as 5 or 10 minutes of real-time data on the very same day or historical average, if appropriate, should be used in real world implementation.

### 4.1.1 Dominancy Index
As shown in Figure 7, the route 1 is superior to the route 2. Thus, dominancy index is the probability of the route 1 travel time is absolutely better than that of the route 2 (Please refer to Figure 4). In this OD pair 1, the dominancy index is 25.4 (or the probability of the route 1 being absolutely better than the route 2 is 25.4%) as shown in Figure 8.

### 4.1.2 Beat the Average Index
As noted, this beat the average index presents the probability of the inferior route being better than the average travel time of the superior route. In this OD pair 1, the beat the average index is 36.2 (or the probability of the route 2 travel time is faster than the route 1 average travel time is 36.2%).

![Figure 6. Origin Destination Pair 1 between Node 2 and Node 14](image-url)
Figure 7. Route Travel Time Distributions of OD Pair 1

Figure 8. Dominancy Index for OD Pair 1 (shown in yellow-shaded area)
4.2 OD Pair 2
As shown in Figure 10, two viable routes between node 28 and node 36 are shown. Again, these are two alternative routes for typical travelers.

 Unlike OD pair 1 in Figure 7, OD pair 2 has slightly distinctive average travel times. That is, the superior route average travel time and its travel time distribution are quite better than those of the inferior route.

4.2.1 Dominancy Index
As shown in Figure 11, the route 2 is superior to the route 1. Thus, dominancy index is the probability of the route 2 travel time is absolutely better than that of the route 1 (Please refer to Figure 4). In this OD pair 2, the dominancy index is 64.5 (or the probability of the route 2
being absolutely better than the route 1 is 64.5%) as shown in Figure 12.

4.2.2 Beat the Average Index
This beat the average index presents the probability of the inferior route being better than the average travel time of the superior route. In this OD pair 2, as shown in Figure 13, the beat the average index is 5.8 (or the probability of the route 1 travel time is faster than the route 2 average travel time is 5.8%).

Figure 11. Route Travel Time Distributions of OD Pair 2

Figure 12. Dominancy Index for OD Pair 2 (shown in yellow-shaded area)
4.3 OD Pair 3
As shown in Figure 14, two viable routes between node 25 and node 28 are shown. Again, these are two alternative routes for typical travelers.

As shown in Figure 15, the superior route average travel time is much shorter than that of the inferior alternative route average travel time. The travel time distributions suggest that the superior route dominates the inferior route.

4.3.1 Dominancy Index
As shown in Figure 15, the route 1 is superior to the route 2. Thus, dominancy index is the probability of the route 1 travel time is absolutely better than that of the route 2 (Please refer to Figure 4). In this OD pair 2, the dominancy index is 100(or the probability of the route 1 being absolutely better than the route 2 is 100%) as shown in Figure 16.
4.3.2 Beat the Average Index
This beat the average index presents the probability of the inferior route being better than the average travel time of the superior route. In this OD pair 3, as shown in Figure 17, the beat the average index is 0.0 (or the probability of the route 2 travel time is faster than the route 1 average travel time is 0.0%).

Figure 15. Route Travel Time Distributions of OD Pair 3

Figure 16. Dominancy Index for OD Pair 3 (shown in yellow-shaded area)
5. CONCLUDING REMARKS
This paper proposed route viability indices (i.e., dominancy index and beat the average index) and demonstrated their usages through three selected origin and destination pairs from the Daegu City using actual route travel time distributions. The case studies showed that the indices adequately reflect the variability of travel times and provide more informative knowledge on the alternative routes (in terms of how good the superior route is or how good the next best route is?). The case studies also showed the importance of utilizing travel time variability as the simple average based travel time does not provide necessary information for making the most appropriate decision.

Future research should consider developing an algorithm that identifies the best and next best routes that are acceptable by travelers. While K-shortest path algorithm that finds up to K paths can be used for this purpose, it is generally understood that K-paths, often sharing too many common links, do not serve as realistic/viable alternative paths. In addition, the real-time traffic data along with the wireless communications based technology (a.k.a., connected vehicle technology) can help deploy the feedback based route guidance system by incorporating planned routes as well as real-time updates on en-route changes.

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7. REFERENCES


