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# Identifying priority attributes for improving Ulaanbaatar bus services using the analytic hierarchy process

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**Abstract**

Ulaanbaatar is the capital and the biggest city of Mongolia. There has been rapid urbanization since 1990. Due to the rapid growth in population and vehicles, traffic congestion has rapidly intensified too. To mitigate the traffic congestion, uses of public transportation is strongly recommended, but the quality of public transportation is not meeting the expectations of Mongolian citizens. In this paper, the analytic hierarchy process (AHP) has been employed to identify priority attributes of Ulaanbaatar bus services. A survey was conducted for a total of 30 people including Mongolian experts and citizens and Korean experts. Results reveal that Ulaanbaatar bus service is unsafe and the bus route is inefficient. In the short term, safety and security attributes should be complemented and, in the long term, convenience and comfort for public transportation commuters should be prioritized in Ulaanbaatar.


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*Keywords:* Ulaanbaatar, Public transportation, Bus services, Analytic hierarchy process, Safety and security, Comfort and convenience

## 1. Introduction

Since 1990, there has been rapid urbanization in Ulaanbaatar, the capital city of Mongolia. Population and number of registered automobiles have rapidly increased and as a result, traffic congestion and air pollution have become a serious concern. Between 2000 to 2017, the population of Ulaanbaatar increased by 84% from 794,535 to 1,462,973 (NSO, 2018b) and the number of vehicles increased by 760% from 42,509 to 365,819 (NSO, 2018a). With due respect to population growth, vehicle-using population has grown at a much higher rate.

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The Mongolian government has implemented various policies to reduce traffic congestion and environmental degradation. The government is emphasizing on improving the public transportation. However, the quality of public transportation in Ulaanbaatar is relatively low in many aspects and in order to attract commuters towards public transportation, quality of bus services should be further improved. Due to a rapid increase in the use of private vehicles, congestion has become a severe problem in the last few decades. Public transportation plays a vital role in reducing emission level. Therefore, it is important to establish high-quality public transportation considering both environment and traffic congestion.

According to the Ulaanbaatar Transportation Department, among the public transportation users in the first half of 2018, 51% are adult, 16% children, 19% elderly people, 7% people with disability, 6% university student, 0.98% police and 0.02% blood donors. In Ulaanbaatar, the running buses and trolley buses are 937 in 88 routes. The total length of these routes covers 3874.4 km with 931 bus station. The aim of this study is to identify priority attributes for improving Ulaanbaatar bus services by using AHP. To find out the priorities, apart from the citizens, the Mongolian and Korean experts are surveyed too.

In chapter 2, important attributes for improvement of public transportation service is collected through literature review and in chapter 3, methodology used in this paper is explained. In chapter 4, survey and results are presented and in the last chapter deals with policy implications based on the survey results.

## 2. Literature review

Currently, there are 20 bus companies in Ulaanbaatar and in which 19 are operated by private sector while remaining one by the state. There are 937 buses in 88 routes and the total length of these routes covers 3874.4 km with 931 bus station. In 2015, 'USCC' (Ulaanbaatar Smart Card Company) was established to introduce new public transportation management and electronic payment system in Ulaanbaatar and the main investor in this project was 'Korea Smart Card' company from Korea.

Despite the introduction of new transportation management, public transportation still faces some serious issues. The average speed of bus during the weekdays is 10 km/h and 80% of the total fleet is over 8 years. Such a low speed of buses shows an evidence of high traffic congestion and poor transport services. To improve this situation and attract more people to use public transportation, attributes that are known to affect the public transportation services should be investigated.

A number of articles have been reviewed to understand the attributes that affect the quality of public transportation services. Through the literature review, some important attributes are found. Safety and security, reliability, frequency, comfort, and fare are the some of the most common attributes, while other attributes are also included in Table 1 too.

For a better understanding, some of the attributes are defined through the literature review. The attribute of 'safety' is about the bus safety and 'security' is about passenger's personal security. 'Reliability' is about the cancellation rates and 'timely performance' is related to punctuality. 'Frequency' is related to the headway of buses and 'availability' can be defined as whether the bus service is available or not. The attribute of 'Comfort' relates to passenger's personal comfort which can include seat comfort, noise, and temperature in the bus while 'cleanliness' can be referred as internal cleanliness which includes chair and window's cleanliness.

Some articles that included the attributes of both 'safety and security' are (Borhan et al., 2014; Leong et al., 2016; Xia et al., 2017). Articles that included only 'safety' are (Eboli and Mazzulla, 2007; Wang et al., 2010; Jain et al., 2014; Ruiz et al., 2017; Deb and Ahmed, 2018), and 'security' is (Alpopi and Manole, 2012).

'Reliability and frequency' attributes are both included in some articles, which are (Napiah, 2011; Borhan et al., 2014; (Mahmoud and Hine, 2016) and some articles that included 'reliability' are (Pérez et al., 2007; Eboli and Mazzulla, 2007; Zakaria et al., 2010; Wang et al., 2010; Jain et al., 2014; Morton et al., 2016). The articles which included 'frequency' are (Alpopi and Manole, 2012; Suman et al., 2017).

In the case of 'comfort and fare', some articles included both attributes, which are (Alpopi and Manole, 2012; Jain et al., 2014; Leong et al., 2016), and that included 'comfort' are (Eboli and Mazzulla, 2007; Ruiz et al., 2017; Xia et al., 2017; Deb and Ahmed, 2018).

Other attributes are also found in some studies. 'Tangible' (Zakaria et al., 2010), 'accessibility and timely performance' (Deb and Ahmed, 2018), 'cleanliness' (Eboli and Mazzulla, 2007), 'availability' (Kostakis and Pandelis, 2009; Mahmoud and Hine, 2016), 'speed' (Alpopi and Manole, 2012). All these attributes are described in Table 1.

Table 1. Some collections of bus service attributes.

| Studies | Tangible | Reliability | Safety | Security | Frequency | Comfort | Fare | Accessibility | Timely performance | Cleanliness | Availability | Speed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Pérez et al., 2007) | X | O | X | X | X | X | X | X | X | X | X | X |
| (Eboli and Mazzulla, 2007) | X | O | O | X | X | O | X | X | X | O | X | X |
| (Kostakis and Pandelis, 2009) | X | X | X | X | X | X | X | X | X | X | O | X |
| (Zakaria et al., 2010) | O | O | X | X | X | X | X | X | X | X | X | X |
| (Wang et al., 2010) | X | O | O | X | X | X | X | X | X | X | X | X |
| (Napiah, 2011) | X | O | X | X | O | X | X | X | X | X | X | X |
| (Alpopi and Manole, 2012) | X | X | X | O | O | O | O | X | X | X | X | O |
| (Jain et al., 2014) | X | O | O | X | X | O | O | X | X | X | X | X |
| (Borhan et al., 2014) | X | O | O | O | O | X | X | X | X | X | X | X |
| (Leong et al., 2016) | X | X | O | O | X | O | O | X | X | X | X | X |
| (Mahmoud and Hine, 2016) | X | O | X | X | O | X | X | X | X | X | O | X |
| (Morton et al., 2016) | X | O | X | X | X | X | X | X | X | X | X | X |
| (Suman et al., 2017) | X | X | X | X | O | X | X | X | X | X | X | X |
| (Ruiz et al., 2017) | X | X | O | X | X | O | X | X | X | X | X | X |
| (Xia et al., 2017) | X | X | O | O | X | O | X | X | X | X | X | X |
| (Deb and Ahmed, 2018) | X | X | O | X | X | O | X | O | O | X | X | X |

Note: O: Included; X: Not included

## 3. Methodology

AHP is a method to select the best alternative factors by layering the evaluation items and then comparing the relative importance among the factors (Saaty, 2003). The aim of this study is to identify priority attributes for improving Ulaanbaatar bus services, and therefore AHP is chosen as a suitable methodology for this study. In this research, AHP is used in three steps. The first step is constructing the hierarchy tree, and the second step is setting relative scores and computing the weights of criteria. In the third and last step, consistency and ranking is checked.

### *3.1. Constructing the hierarchy*

Based on the literature review, important attributes that influence the quality of bus services are included in this paper. Also additional attributes such as availability of card charger and traffic law violation and some others are shown in Figure 1.

There is no automatic card charger in Ulaanbaatar and card charging process can be done through a card charging terminal in a private ownership kiosk at a bus station. Because of its private ownership, if the kiosk at a bus station does not open or open the door late, public transportation users will not be able to charge their cards so, availability of card charger is very serious concern for public transportation users in Ulaanbaatar.

Sometimes bus drivers violate a defined route to make up additional revenue and it can lead to the accident. To avoid the accident, it is important to follow the traffic law. If the public transportation users feel comfortable in bus, they will use public transportation more. In this sense, air conditioning and heating, cleanliness are very important factors that influence the quality of bus services.

To attract more commuters toward public transportation, a season ticket (monthly ticket) system was introduced on 1st of April, 2017. If the fare is cheap, more people will use the public transportation, so discount schemes and season ticket system can have huge influence on public transportation users. Due to traffic congestion, public transportation users wait a long time to get on the bus. In order to improving the bus speed, bus-only lane and transit signal priority can be implemented. Also, by increasing bus frequency and changing the bus route waiting time can be decreased. Improving the bus speed and decreasing the waiting time can be a huge improvement of public transportation quality services.

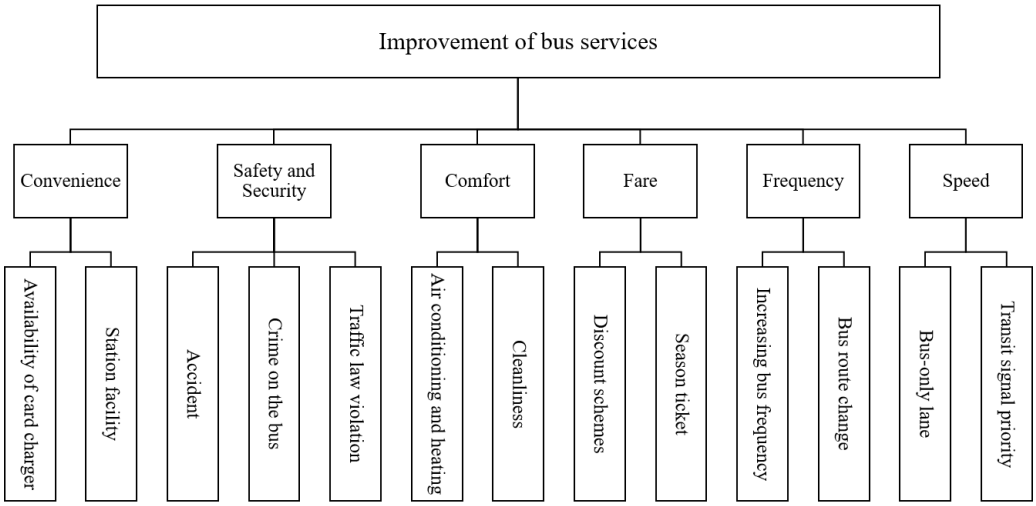


Fig. 1. AHP tree for the improvement of bus services.

### *3.2. Setting the relative scores and computing the weights of criteria*

In this study, the ranking ranges is on a scale of 1-9 (Table 2), as suggested by Saaty (Saaty, 2003).

Table 2. Relative scores.

| Scale | Definition |
|---|---|
| 1 | Equal |
| 2 | Between the equal and slightly important |
| 3 | Slightly important |
| 4 | Between the slightly important and important |
| 5 | Important |
| 6 | Between the important and very important |
| 7 | Very important |
| 8 | Between the important and absolutely important |
| 9 | Absolutely important |

In order to compute the weights of criteria, the pairwise comparison is created and it can be expressed as equation (1).

$$A=\left[a_{ij}\right]=\begin{bmatrix} 1 & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & 1 & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & 1 & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & 1 \end{bmatrix}, \left(i, j=1,2,\cdots,n\right) \tag{1}$$

where $A$ is the comparison matrix, $a_{ij}$ is the weight ratio between the evaluation factors $i$ and $j$, $w_i$ is the weight of factor $i$, and $n$ is the number of factors.

$a_{ij}$ has always a positive value. This can be expressed as equation (2)

$$a_{ij}=\frac{w_i}{w_j} \tag{2}$$

Weights are calculated through $A\cdot w=n\cdot w$. Here, $n$ denotes the eigenvalue of $A$ and $w$ is an eigenvector (Saaty, 2003). Then the comprehensive weight is derived by using geometric mean and comprehensive mean can be measured by multiplying importance from upper level to lower level.

### *3.3. Checking the consistency and ranking*

Consistency is the process of checking how logically the respondent has evaluated the factors, and consistency problem may arise in the process of measuring relative weights among the evaluation factors. Consistency Index (CI) and Consistency Ratio (CR) can be considered to examine the consistency of questionnaire. They are shown in equations (3) and (4)

$$CI=\frac{\lambda_{\max}-n}{n-1} \tag{3}$$

$$CR=\frac{CI}{RI} \tag{4}$$

where $\lambda_{\max}$ is the maximum eigenvalue. RI (Random Index) is a value obtained by randomly extracting 1 to 9 integers and creating an inverse matrix. The higher the consistency index, the value gets closer to 0. If the consistency ratio is less than 0.1(10%), it means respondents answered consistently. Otherwise, it means the opposite and filled out again or excluded from the survey.

## 4. Survey and Results

A set of questionnaire was sent to 30 people via email for participation in the survey. This survey was conducted from 16$^{th}$ to 30$^{th}$ of April, 2018 and all 30 people successfully responded to questionnaire. Among these 30 participants, 10 experts were from Ulaanbaatar Transportation Department (UTD), 10 experts from Korea Smart Card (KSCC), and the remaining 10 were the citizens of Mongolia. The Ulaanbaatar Transportation Department is the agency that operates and designs policies for Ulaanbaatar's public transportation and therefore they are fully aware of bus services.

The inclusion of the Korean experts is attributable to the fact that the Seoul has an efficient and competitive public transportation system (ARCADIS, 2017). Also, Korean experts have been in Ulaanbaatar and worked for 'Ulaanbaatar Smart Card LLC' for a while. So they have an expertise about the Ulaanbaatar public transportation services. Therefore, the expertise of Korean evaluators is expected to help in improving the Ulaanbaatar bus services in short as well as in the long term.

In the process of filling out the survey, Mongolian expert's evaluation is based on the current situation of Ulaanbaatar and Korean experts filled out the survey based on their successful transport systems experience. In addition, Mongolian citizens have responded the questionnaire on their daily experiences as they understand the area in which improvement can lead to an increase in the number of commuters due to better facilities.

The weights of the first level of criteria are compared by using AHP. Mongolian experts and citizens, as well as Korean experts, gave the highest weight to 'safety and security' and 'frequency'. It reveals that safety and security should be the first priority among the policymakers, followed by frequency, fare, convenience, comfort and then speed.

Table 3. Weights and ranks between the first level of criteria.

| Attributes | Mongolian | | | | Korean | | Overall | |
|---|---|---|---|---|---|---|---|---|
| | UTD | Rank | Citizen | Rank | KSCC | Rank | All respondents | Rank |
| Convenience | 0.07 | 4 | 0.05 | 6 | 0.17 | 3 | 0.10 | 4 |
| Safety and Security | 0.56 | 1 | 0.47 | 1 | 0.26 | 1 | 0.41 | 1 |
| Comfort | 0.07 | 5 | 0.08 | 5 | 0.14 | 5 | 0.10 | 5 |
| Fare | 0.10 | 3 | 0.11 | 4 | 0.14 | 4 | 0.12 | 3 |
| Frequency | 0.15 | 2 | 0.16 | 2 | 0.19 | 2 | 0.18 | 2 |
| Speed | 0.06 | 6 | 0.14 | 3 | 0.10 | 6 | 0.09 | 6 |

In the second level, experts from both countries recommend their first priority is to reduce the number of the accidents, followed by discount system, bus route change and increasing bus frequency. Based on the outcome of the second level, it is well understood that the Ulaanbaatar public transportation system is currently unsafe for the commuters. Experts from both countries share some common attributes, but largely they differ. This is mainly because of the level of development of the transportation system in both countries.

First of all, experts on both sides pay a lot of attention to the discount system. So it means that the Mongolian experts think that the discount scheme is important in sense of reducing the fare but the Korean experts think discount scheme should be made from the current fare rather reducing the fare. In other words, Mongolian and Korean experts see the same attribute in different way. Arguably, the difference in opinion exists because of socio-economic factors in these two countries. Korea is the member of OECD, and one of the largest economies in the world, while, Mongolia is considered developing country.

The bus route change and increasing the frequency can also be interpreted in the same context. While the Mongolian experts emphasize that there is a lack of bus routes and buses, so from the investment view, more bus routes should be established and more buses should be supplied. The Korean experts believe that the current bus route should be changed more efficiently. It can be interpreted that Mongolian experts see the 'bus route change' from the investment perspective and while, Korean experts from managemental perspective. The differences in the opinion reflects the maturity level of transport systems in these two different countries. It is well understood that Korea has developed an advanced transport system due to financial capability as well as political willingness, while, Mongolia has to grow in terms of economy as well as transport infrastructure. However, economic growth alone does not guarantee adequate infrastructure and therefore proper strategy and planning need attention of Mongolian policy makers.

In addition, the experts of both sides do not pay much attention to bus speed. The similar policy, a bus-only lane, seems to be unnecessary in the short term because it requires extensive investment costs. Also, the experts of both

countries do not pay much attention to the station facilities and cleanliness of the bus which are related to the convenience and comfort. For the Korean experts, they have given little emphasis to facilities at bus stop and cleanliness of the bus because in Seoul, most of the bus station are well equipped and the quality of bus cleanliness is very high. In other words, the Mongolian experts believe that the primary attributes such as safety and frequency should be improved rather than improving convenience and comfort in the short term.

There are other aspects in which experts opinions of both countries varies. The Korean experts see that the expansion of card charging stations in Ulaanbaatar is a critical issue but the Mongolian experts do not intend to expanding card charging stations. This shows the difference in public transportation infrastructure between the two countries. The Korean experts think that it is very necessary to construct an environment in which public transportation passengers can charge their cards easily in the same way as Korea. It also has very different views on violations of the law. In Mongolia, sometimes if there are not many people at the bus stop, buses just pass the station, which causes many complaints from the citizens. Therefore, the Mongolian experts pay attention to traffic regulations and want to improve further. In contrast, Korea is strict in crackdown and violations of laws and regulations are rare.

The Korean experts think that air-conditioning is an essential element for public transportation passengers, while the Mongolian experts differ. Mongolia does not manufacture or assembles buses. Most of the imported buses are in use for quite a long time. In reality, it is not very feasible for the Mongolian experts to expect air conditioning and heating services from the bus due to financial constraints. Some of the literature reviews mentioned above suggests the attribute of 'comfort' as one of the most important factors, which heavily affects the public transportation users. Therefore, to attract more commuters towards public transportation, improving comfort is one of the key elements and policy makers needs to address it on priority basis. Also, they have different opinions about the season ticket. The Mongolian experts want an environment in which they can use the bus more and more with the cheaper fare, but the living standard in Korea is higher and therefore transportation expenses are not that a great burden to the public transportation commuters in Korea.

The fact that the Mongolian citizens have ranked accident and crime on the bus with 1$^{st}$ and 2$^{nd}$ means that passengers do not feel safe on the bus and suggests that safety and security issues should be top most priority. Based on this, both the experts and citizens of Mongolia have emphasized the policies which ensure a reduction in the rate of accidents as well as a crime on the bus. In addition, the Mongolian experts and citizens placed importance on bus route change and increasing bus frequency. It means citizens and policy makers both think that the Ulaanbaatar bus route is inefficient.

Also, the Mongolian experts and citizens have shown very low interests in convenience and comfort. This can be explained by that they live in the same public transportation system, which they think that convenience and comfort are not the urgent issue. To improve this situation, it requires huge amount of investment and considering current situation, it looks quite difficult in short term. The Mongolian experts and citizens don't have the experience of the transit signal priority while transit signal priority has not been successfully implemented in Korea. So all parts of the respondents would have the lowest interests in transit signal priority. The Mongolian citizens' interests on bus-only lane means that they want safe, affordable and faster public transportation.

In conclusion, the inputs from the experts of both countries highlights the fact that the current Ulaanbaatar bus route is inefficient and uncompetitive. The priority can be further classified in short and long term due to economic factors. So, in short term, the first and foremost priority should be given to safety and security attributes. As safety and security gives a sense of satisfaction and confidence among the commuters and it will immensely help in attracting more people to use public bus services. However, in the long term, the policy makers should focus on attributes like convenience and comfort and these attributes will have long term benefits in terms of attracting not only ordinary commuters but it will also attract those who enjoy their privately owned vehicles.

Table 4. Ranks between the second level of criteria

| Attributes | | Mongolian | | | | Korean | | Overall | |
|---|---|---|---|---|---|---|---|---|---|
| | | UTD | Rank | Citizen | Rank | KSCC | Rank | All respondents | Rank |
| Convenience | Presence of card charger | 0.04 | 9 | 0.04 | 10 | 0.12 | 2 | 0.07 | 7 |
| | Station facility | 0.03 | 11 | 0.02 | 13 | 0.05 | 9 | 0.04 | 12 |
| Safety and Security | Accident | 0.10 | 3 | 0.14 | 2 | 0.14 | 1 | 0.16 | 1 |
| | Crime on the bus | 0.05 | 5 | 0.08 | 1 | 0.07 | 8 | 0.09 | 4 |
| | Traffic law enforcement | 0.40 | 1 | 0.32 | 7 | 0.04 | 11 | 0.15 | 2 |
| Comfort | Air conditioning and heating | 0.03 | 12 | 0.04 | 8 | 0.09 | 5 | 0.06 | 9 |
| | Cleanliness | 0.04 | 10 | 0.03 | 11 | 0.05 | 10 | 0.04 | 11 |
| Fare | Discount system | 0.05 | 4 | 0.04 | 12 | 0.11 | 3 | 0.07 | 5 |
| | Monthly ticket | 0.04 | 7 | 0.06 | 3 | 0.04 | 12 | 0.05 | 10 |
| Frequency | Increasing bus frequency | 0.04 | 6 | 0.05 | 6 | 0.08 | 6 | 0.07 | 6 |
| | Bus route change | 0.10 | 2 | 0.10 | 5 | 0.10 | 4 | 0.11 | 3 |
| Speed | Bus-only lane | 0.04 | 8 | 0.05 | 4 | 0.08 | 7 | 0.06 | 8 |
| | Transit signal priority | 0.02 | 13 | 0.02 | 9 | 0.03 | 13 | 0.03 | 13 |

## 5. Conclusion

In 1990, Mongolia shifted from a socialist to a democratic state and since then urbanization has rapidly taken place in Ulaanbaatar, the capital of Mongolia. Due to the high rate of urbanization, population and vehicles in Ulaanbaatar have been continuously increasing and as a result traffic congestion and environmental degradation have become a serious problem. In order to solve this problem, the Mongolian government has implemented various policies, and one of them is expanding public transportation use. However, the quality of Ulaanbaatar bus service is low in many aspects.

So in this study, the analytic hierarchy process has been used to identify bus service priority attributes for improving Ulaanbaatar bus services. The results show that Ulaanbaatar bus service is unsafe and the bus route is inefficient. In the short term, minimum expectations like safety and security problems must be addressed and inefficient bus routes must be improved by creating new routes or restructuring current routes. As the safety of bus passengers improve, the use of public transportation will increase too. In the long term, there is a need to establish policies that increase convenience and comfort for public transport passengers.

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