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DEVELOPMENT OF COMPUTERIZED BANGKOK BUS TRANSIT ANALYTICAL SYSTEM

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Abstract: This paper presents the development of the Computerized Bangkok Bus Transit Analytical System, BBTAS, to enhance the performance evaluation of the existing bus system in Bangkok. The bus performance indicators are classified into three performance measurement groups and each group was broken down into the performance class and sub-class. The weights of each performance class and sub-class were conducted mathematically to describe the bus operating performance level. The Analytical Hierarchy Process (AHP) was applied for weighing the bus performance class and sub-class. Finally, the user gracious computerized BBTAS package was developed to evaluate the performances of all bus routes in Bangkok. To demonstrate the real world application of this developed system, this paper used the bus operating data of 88 non- air-conditioned bus routes in Bangkok to evaluate their performances. Considering all mentioned performance indicators, this developed system can rank all 88 routes from the best to the worst.

Key Words: Bus Performance Indicator, Computerized, Analytical Hierarchy Process (AHP), Bangkok

1. INTRODUCTION

The existing bus transit system in Bangkok has just recently been added up with another system locally known as "sky-train" rail transit. Ironically, this new rail transit system is not only an alternative but it can also be the competitor of the existing bus system. As the user's perspective, both systems must have adequate operation performance. Thus, the transit company must have a good evaluating system to self-evaluate their own services.

Unfortunately, the planning, management and operation of Bangkok bus system still depend on manual daily bus data collection. Everyday, bus personnel are required to manually record their entire bus operations and services on the prepared forms, which are later summarized as a monthly report. These monthly reports are then submitted to the executives for their assessment and recommendation for further bus operation, planning, and management development, which normally take place on a month by month basis.

Considering these large number of bus operations, it is significant to have a good performance evaluation system in order to obtain the system's drawback effectively. However, the existing Bangkok bus transit performance evaluation has been performed manually and straightforwardly. The manager/administrator just simply selected certain single indicators to evaluate their bus performances. Considering the large number of buses and services, it seems that these indicators cannot represent the actual bus performance in different perspectives. Therefore, this paper aims to develop the computerized system to enhance performance evaluation of the existing bus system in Bangkok.

2. CURRENT BANGKOK BUS TRANSIT

The Bangkok Mass Transit Authority, BMTA, a state enterprise under the Ministry of Transport, was established in 1976 to provide bus services to serve about two-thirds of the total public transport demand in Bangkok. Presently, BMTA operates with about 4,000 buses covering 122 bus routes (BMTA, 2003), offering services to approximately 10 million inhabitants throughout the Bangkok Metropolitan Area and its surrounding provinces. BMTA divides its operation and services into 8 bus operation zones (BOZ). However, all these 8 zones do not have much spatial relevance. Bus routes under control of any zone may operate in different zones of the city. Basically, each zone serves as an operational unit and not as spatial unit. Each BOZ normally controls around 10-20 bus routes. On the other hand, the BOZ is an important level in the decision-making process of BMTA as all planning and management decisions relating to bus operation are taken at this level. The BOZ Offices function as an implementing arm of BMTA as all tasks relating to daily bus operations are delegated to the zone offices. The Head Quarter or the Main Office functions primarily as the overall policy making, coordinating and monitoring authority while the main responsibility of a BOZ Office is to manage bus operations in its jurisdiction according to the policies set by the Head Quarter. These policies include the setting of some performance indicators. Each BOZ Office is divided into 3 bus operational divisions (BOD) and each BOD is operated under the broad policy guidelines set by the Head Quarter.

As mentioned earlier, BMTA still employs the primitive approach of manual data collection for their performance evaluation. The major instruments used in collecting relevant bus operation data in BMTA are a set of forms which include driver form, conductor form and bus operation form. Each BOD is required to prepare a daily summary for each bus route and all forms are forwarded and processed at the BOZ Office. This report is presented at a monthly meeting and an assessment is made on overall bus performance evaluation of the zone against the target for the concerned month. Also, this report is submitted to the Head Quarter for the use by BMTA executives.

In an organized management perspective, the analysis and evaluation of bus performance should be done at the organizational level instead of the independent analysis at BOZ levels through the specific performance indicators, which unfortunately are not available in the current practice of BMTA. Therefore, it is very essential that BMTA comes up with a proper analytical system and also the computerized analytical system to overcome these problems

3. DEVELOPMENT OF BANGKOK BUS TRANSIT ANALYTICAL SYSTEM (BBTAS)

Prior to develop the computerized Bangkok Bus Transit Analytical System, it is necessary to develop its bus performance analytical system. The evaluation procedure of the bus operating performance namely the Bangkok Bus Transit Analytical System (BBTAS) is demonstrated as shown in Figure 1. The characteristics of bus operating data type affecting the operating performance are specific and assorted in their nature. Therefore, these data should be hierarchically categorized into the form of the bus standard performance indicators by applying the concept of definition a community performance measurement. These indicators are classified into three groups: general performance, effectiveness measures, and efficiency measures. Each performance measurement group was broken down into the performance class and the performance sub-class based on their related characteristics and criteria.

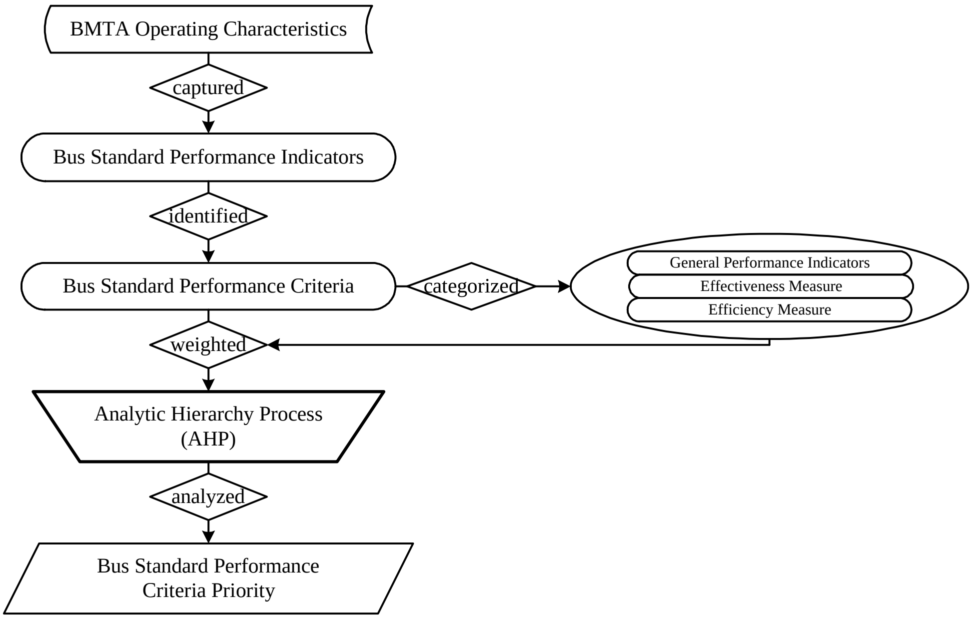

Figure 1. Overall Framework of Evaluation Procedure

The weights of each performance class and sub-class were mathematically conducted to describe the bus operating performance. Since the variables affecting bus operating performance are hierarchically organized, Analytical Hierarchy Process (AHP) (Saaty, 2000; Atthirawong and MacCarthy, 2001; Atthirawong, 2002) was then applied for weighing the bus performance classes and sub-classes. Accordingly, the questionnaire was designed for identifying the priority for the bus standard performance indicators/variables. The pilot survey was performed to assess the validity of the questionnaire. Subsequently the verified versions of questionnaires were distributed to the specialists who are the keyed managers/administrators of BMTA. Finally, the results of AHP analysis were applied to measure the relative weights of each performance measurement.

3.1 Classification of Bus Performance Indicators

As mentioned earlier, the bus performance indicators are classified into three groups, and each bus performance group is further divided into four classes while different classes explain different performance characteristics. The first performance group, the general performance indicator, composes of the passenger indicator, the revenue indicator, the expense indicator, and the personal indicator. The second group, the effectiveness measures, consists of the service consumption indicator, the quality of service indicator, the quality of human indicator and the fare indicator. The last group, the efficiency measures, contains the cost efficiency indicator, the operating ratios indicator, the vehicle utilization indicator, and the energy utilization indicator. Each bus performance class is then further divided into several sub-classes based on their related characteristics as illustrated in Table 1.

Table 1. Bus Performance Indicators

Bus Performance Indicators		
General Performance	**Effectiveness Measures**	**Efficiency Measures**
Passenger Indicator • Passenger trips • Passenger kilometers • Revenue kilometers • Route kilometers **Revenue Indicator** • Operating revenue • Total revenue **Expense Indicator** • Capital expense • Energy expense • Maintenance expense • Operating expense • Total expense **Personal Indicator** • Operating employees • Total employees	**Service Consumption Indicator** • Passenger trips per revenue kilometer • Passenger trips per route kilometer • Passenger trips per number of trips • Passenger trips per number of operating vehicle **Quality of Service Indicator** • Number of incidents • Number of vehicle system failures • Revenue kilometers between failures **Quality of Human Indicator** • Passenger trips per employee • Operating revenue per Employees • Revenue per employees • Operating expense per Employees • Expense per employees **Fare Indicator** • Average fare • Fare per operating vehicles • Fare per all vehicles	**Cost Efficiency Indicator** • Operating expense per passenger trip • Operating expense per passenger kilometer • Operating expense per revenue kilometer • Operating expense per route kilometer • Expense per passenger trip • Expense per passenger kilometer • Expense per revenue kilometer • Expense per route kilometer • Maintenance expense per passenger trip • Maintenance expense per passenger kilometer • Maintenance expense per revenue kilometer • Maintenance expense per route kilometer **Operating Ratios Indicator** • Operating revenue per operating expense • Revenue per expense **Vehicle Utilization Indicator** • Revenue kilometers per all vehicles • Revenue kilometers per operating vehicles • Revenue kilometers per route kilometers **Energy Utilization Indicator** • Revenue kilometers per fuel-Lt • Passenger trips per fuel-Lt • Operating revenue per fuel-Bht • Revenue per fuel-Bht • Operating expense per fuel-Bht • Expense per fuel-Bht

3.2 Application of Analytical Hierarchy Process (AHP) for Weighting

The application of the analytic hierarchy process (AHP) developed by Saaty (2000) is selected for weighing the bus performance indicators in this study. An overview of this AHP application on the bus performance evaluation is graphically demonstrated in Figure 2.

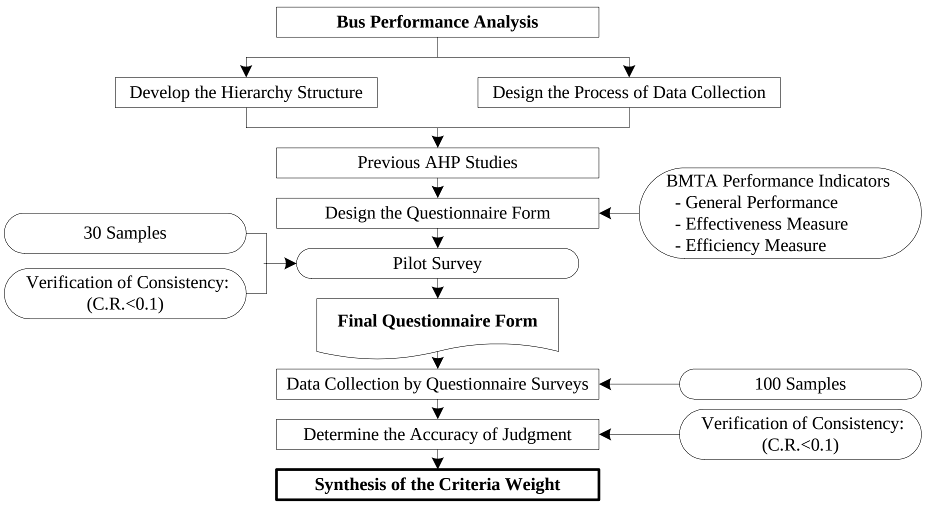

Figure 2. Determination of Weighted of Bus Performance Indicators

The principal goal of this stage is to weight the bus performance indicators, both performance classes and sub-classes, to measure the significant level of each indicator affecting the bus operating performance in the decision-making process. The measuring procedure is then divided into two steps which are Decisions Acquisition and Decisions Evaluation.

3.2.1 Decision Acquisition

The first step of performance measuring is the decision acquisition. The main objective is to acquire the decision from experts through proper mean. According to Figure 2, the decision acquisition can be broadly characterized into two objectives which are to design the hierarchy structure and to design the process of data collection. These two main objectives can be accomplished through the following process: reviewing of the previous AHP structure in order to ensure the compatibility of the bus operating performance evaluation structure and AHP structure; designing the questionnaire and finally, conducting the pilot survey.

After reviewing the AHP structure, it is found that three levels of components are appropriate to be included in AHP decision structure which are used to develop the AHP priority model in bus operating performance evaluation. These three levels of components are presented as shown in Figure 3. After the AHP structure was constructed, the questionnaire was then created based on the AHP logical requirements on bus performance evaluation which were divided into four parts;

- The performance of indicator’s group on main standard performance
- The performance of indicator’s classes on the general measure
- The performance of indicator’s classes on the effectiveness measure
- The performance of indicator’s classes on the efficiency measure

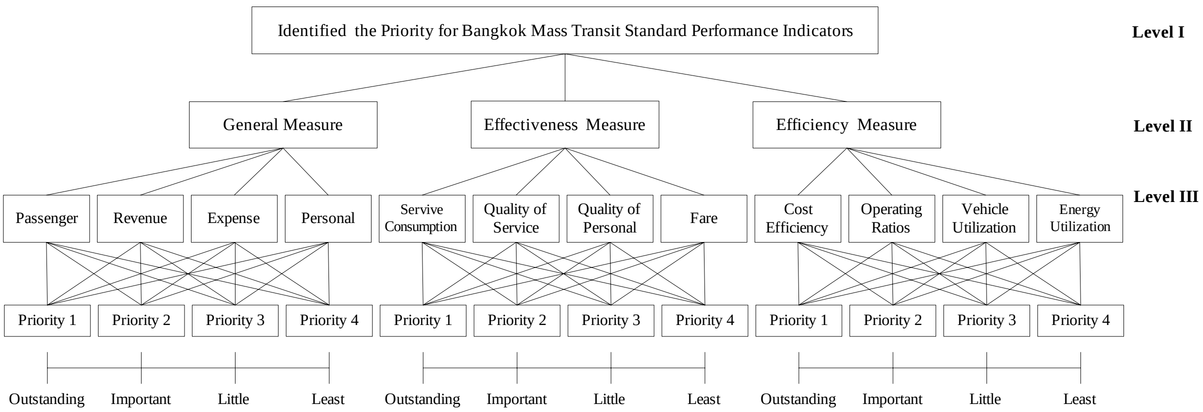

Figure 3. AHP Priority Structure for BMTA Standard Performance Decision making

The pilot survey was necessary for developing AHP model and collecting data. Thirty samples were conducted for the pilot survey. Furthermore, the Consistency Ratio (C.R.) was also determined to ensure that CR’s was equal or less than 0.1. Subsequently, the final questionnaire assessments were then conducted. The questionnaire forms were distributed to 100 authorities which are the operating superintendent personnel and administrators/managers in BMTA to weight the bus performance level. The decisions acquired from these 100 bus-operating administrators were used in the decision evaluation stage.

3.2.2 Decision Evaluation

The decisions of four performance groups obtained from the questionnaire were evaluated in order to determine the weight of performance indicators using AHP. The pair-wise comparisons of decision weight were performed for each part. The pair-wise comparison matrix of each part was developed and normalized to obtain the relative weight or eigenvector of each rating rank. The results of the decision evaluation using AHP are presented in the next section.

3.3 Determination of Weighing of Bus Performance Indicators

Each performance group was evaluated to obtain the weight parameter on each performance indicator using pair-wise comparisons. The pair-wise comparison matrix of the main standard performance group, the general measure, the effectiveness measure, and the efficiency measure are shown in Tables 2, 3, 4, and 5, respectively. Using Expert Choice software (Expert Choice, 2000), the relative weights of the bus performance level in each term were calculated. From these weight parameters, the ranking of each bus performance group on main performance indicators was illustrated.

Table 2. Pair-wise Comparison Judgment Matrix for the Standard Performance

Level 1	General	Effectiveness	Efficiency	Relative weight	Rank
General	1.000	1.287	0.546	0.293	2
Effectiveness	0.777	1.000	0.896	0.292	3
Efficiency	1.832	1.117	1.000	0.415	1
	3.610	3.403	2.441	1.000	

Table 3. Pair-wise Comparison Judgment Matrix for the General Measure Group

General	Passenger	Revenue	Expense	Personal	Relative weight	Rank
Passenger	1.000	0.935	0.841	1.078	0.238	3
Revenue	1.069	1.000	1.078	1.142	0.267	2
Expense	1.189	0.927	1.000	1.411	0.278	1
Personal	0.928	0.876	0.709	1.000	0.217	4
	4.186	3.738	3.628	4.630	1.000	

Table 4. Pair-wise Comparison Judgment Matrix for the Effectiveness Measure Group

Effectiveness	Service consumption	Quality of service	Quality of personal	Fare	Relative weight	Rank
Service consumption	1.000	0.423	0.430	0.452	0.126	4
Quality of service	2.364	1.000	1.158	1.397	0.334	1
Quality of personal	2.326	0.864	1.000	1.049	0.277	2
Fare	2.212	0.716	0.953	1.000	0.263	3
	7.902	3.002	3.541	3.898	1.000	

Table 5. Pair-wise Comparison Judgment Matrix for the Efficiency Measure Group

Efficiency	Cost efficiency	Operating ratios	Vehicle utilization	Energy utilization	Relative weight	Rank
Cost efficiency	1.000	0.613	1.111	0.599	0.195	4
Operating ratio	1.631	1.000	1.566	0.935	0.302	1
Vehicle utilization	0.900	0.639	1.000	1.047	0.215	3
Energy utilization	1.669	1.070	0.955	1.000	0.288	2
	5.201	3.321	4.632	3.581	1.000	

After pair-wise comparisons were obtained and entered into data matrices and the relative weights of each performance classes of each matrix were analyzed, then the relative weights were combined together with respect to all successive hierarchical levels in order to obtain the global weights of all 51 sub-classes. The composite relative weights of bus performance indicators were hierarchy three levels which are 3 bus standard performance measure groups, 12 bus standard performance classes, and 51 bus standard performance sub-classes. For simplicity, the weights of performance indicators are hierarchically defined by the following notations:

$$g_i = \sum_{j=1}^{a} c_j \qquad \text{Equation 1}$$

$$c_j = \sum_{k=1}^{b} w_k \qquad \text{Equation 2}$$

where

g_i = Weight of bus performance group
c_j = Weight of bus performance class
w_k = Weight of bus performance subclass
i = Group
j = Class
k = Subclass
a = Number of class in group i
b = Number of subclass in class j

3.4 Bus Performance Evaluation Procedure

The performance of bus operation must be applied in a comparative manner. The bus performance shall be compared among different operation zones, or among a finer level such as divisions, routes, or types of bus services. The weights of bus performance indicators are employed to determine the performance level of bus operation. The weights of 51 bus standard performance subclasses are selected as the key component for the evaluation. The value of performance indicator sub-class i of j bus operating route is defined as o_{ij}. All indicator sub-classes are aggregated together to create the total performance score. The procedure of performance evaluation is presented in the following sections. The attributes of bus performance for each route or each zone are divided into 51 sub-classes $(O_{1j}, O_{2j}, O_{3j}, ..., O_{51j})$ with their associated weight $(w_1, w_2, w_3, ..., w_{51})$ accruing from AHP as mentioned earlier and it is the comparison among "j" units where units can be routes, zones, etc. The attributes associated with these comparisons can be depicted in Figure 4.

ID	1	2	3	$\cdots$	j	
BOZ No						
BOD No						
Route No						
Subclass (w_i)	o_{i1}	o_{i2}	o_{i3}	$\cdots$	o_{ij}	$\bar{o}_i = \sum_{i=1}^{n} o_{ij} / n$
w_1	o_{11}	o_{12}	o_{13}	$\cdots$	o_{1j}	$\bar{o}_1$
w_2	o_{21}	o_{22}	o_{23}	$\cdots$	o_{2j}	$\bar{o}_2$
w_3	o_{31}	o_{32}	o_{33}	$\cdots$	o_{3j}	o_3
$\vdots$	$\vdots$	$\vdots$	$\vdots$		$\vdots$	$\vdots$
w_{51}	o_{511}	o_{512}	o_{513}	$\cdots$	o_{51j}	$\bar{o}_{51}$

Figure 4. Bus Performances Attribute

As mentioned earlier, the significant of attributes are different. The level of significant is measured using AHP and represented by its associated weight $(w_1, w_2, w_3, ..., w_{51})$. Therefore, the value of each attribute is then contributed in the overall performance by its associated weight. However, it is important to be noted that attributes cannot be directly aggregated due to its different characteristics. Therefore, the normalization of each attribute is undertaken. Each attribute value is divided by its mean value $(\overline{O})$ as presented in Equation 3 to provide the same value characteristics which is ready for the comparison. In addition, the normalized value is then scaled by the constant value (k) in order to force them into the same scale of comparison. It should be noted that different attributes have contributed the performance of bus in different manners. Some attributes provide positive effect to the performance (the increasing of their values will increase the performance of bus). Some attributes provide negative effect to the performance (the increasing of their values will decrease the performance of bus). Therefore, the effects of attributes must be identified prior to the determination of performance. The normalized attribute score of bus performance indicators can be determined by using the following equations:

$$\overline{o}_i = \frac{\sum_{j=1}^{n} o_{ij}}{n} \qquad \text{Equation 3}$$

$$a_{ij} = \frac{w_i \, o_{ij}}{k \, \overline{o}_i} \qquad \text{Equation 4}$$

or

$$a_{ij} = \frac{w_i \, (o_{\max} - o_{ij})}{k \, \overline{o}_i} \qquad \text{Equation 5}$$

where

i = 1, 2, 3, …, m;
j = 1, 2, 3, …, n;
k = Constant performance value

Equation 4 is derived for the determination of attribute score for positive effect attributes and Equation 5 is derived for the determination of attribute score for negative effect attributes. The summation of attribute score (S_{ij}) is calculated using equation 6. The performance evaluation scores are calculated for every unit in the comparison either for zone comparison, route comparison, or bus service comparison.

$$S_j = \sum_{i=1}^{m} a_{ij} \qquad \text{Equation 6}$$

where

S_j = Total performance score for unit " j "
a_{ij} = Normalized attribute score for sub-class " i " and unit " j "
$\overline{o}_i$ = Mean of attribute value of sub-class " i " for every unit
o_{ij} = Attribute value of sub-class " i " and unit " j "
$o_{\max}$ = Maximum of attribute of sub-class " i " for every unit
k = Constant performance value

w_i = Associated weight of sub-class " i "

The logical illustration of performance score is graphically explained in Figure 5. Applying all these mentioned step procedures, the weights of all bus performance indicators together with their effects (either positive or negative) can be determined as summarized in Table 6. Finally, the total performance scores for all indicators are determined and are used to evaluate the bus performance in Bangkok either in the zone level or route level.

ID	1	2	3	$\cdots$	j
BOZ No					
BOD No					
Route No					
Subclass (a_i)	a_{i1}	a_{i2}	a_{i3}	$\cdots$	a_{ij}
a_1	a_{11}	a_{12}	a_{13}	$\cdots$	a_{1j}
a_2	a_{21}	a_{22}	a_{23}	$\cdots$	a_{2j}
a_3	a_{31}	a_{32}	a_{33}	$\cdots$	a_{3j}
$\vdots$	$\vdots$	$\vdots$	$\vdots$		$\vdots$
a_{51}	a_{511}	a_{512}	a_{513}	$\cdots$	a_{51j}
$S_j = \sum_{i=1}^{n} a_{ij}$	S_1	S_2	S_3	$\cdots$	S_j

Figure 5. Bus Performances Score Attribute

Table 6. Illustration of Sub-classes Indicators Effects on Total Bus Performance

No	Measures	Wij 100	Performance Classes	Code	Wij 100	Performance Sub-Classes	Code	Wij 100	Direction
1	General	29.299	Passenger Indicator	C11	6.985	Passenger trips	G1	1.746	(+)
2						Passenger kilometers	G2	1.746	(+)
3						Revenue kilometers	G3	1.746	(+)
4						Route kilometers	G4	1.746	(+)
5			Revenue Indicator	C12	7.814	Operating revenue	G5	3.907	(+)
6						Total revenue	G6	3.907	(+)
7			Expense Indicator	C13	8.148	Capital expense	G7	1.630	(-)
8						Energy expense	G8	1.630	(-)
9						Maintenance expense	G9	1.630	(-)
10						Operating expense	G10	1.630	(-)
11						Total expense	G11	1.630	(-)
12			Persenal Indicator	C14	6.352	Total employees	G12	3.176	(+)
13						Operating employees	G13	3.176	(+)
14	Effectiveness	29.200	Service Consumption	C21	3.679	Passenger trips per revenue kilometer	Ef1	0.920	(+)
15						Passenger trips per route kilometer	Ef2	0.920	(+)
16						Passenger trips per number of trips	Ef3	0.920	(+)
17						Passenger trips per No of operating vehicle	Ef4	0.920	(+)
18			Quality of Service	C22	9.753	Number of incidents	Ef5	3.251	(-)
19						Number of vehicle system failures	Ef6	3.251	(-)
20						Revenue kilometers between failures	Ef7	3.251	(-)
21			Quality of Human	C23	8.088	Passenger trips per employee	Ef8	1.618	(+)
22						Operating Revenue per Employees	Ef9	1.618	(+)
23						Revenue per Employees	Ef10	1.618	(+)
24						Operating Expense per Employees	Ef11	1.618	(-)
25						Expense per Employees	Ef12	1.618	(-)
26			Fare	C24	7.680	Average fare	Ef13	2.560	(+)
27						Fare per Operating vehicles	Ef14	2.560	(+)
28						Fare per All vehicle	Ef15	2.560	(+)
29	Efficiency	41.501	Cost efficiency	C31	8.093	Operating expense per passenger trip	Eff1	0.674	(-)
30						Operating expense per passenger kilometer	Eff2	0.674	(-)
31						Operating expense per revenue kilometer	Eff3	0.674	(-)
32						Operating expense per route kilometer	Eff4	0.674	(-)
33						Expense per passenger trip	Eff5	0.674	(-)
34						Expense per passenger kilometer	Eff6	0.674	(-)
35						Expense per revenue kilometer	Eff7	0.674	(-)
36						Expense per route kilometer	Eff8	0.674	(-)
37						Maintenance expense per passenger trip	Eff9	0.674	(-)
38						Maintenance expense per passenger kilometer	Eff10	0.674	(-)
39						Maintenance expense per revenue kilometer	Eff11	0.674	(-)
40						Maintenance expense per route kilometer	Eff12	0.674	(-)
41			Operating Ratios	C32	12.533	Operating revenue per operating expense	Eff13	6.267	(+)
42						Revenue per expense	Eff14	6.267	(+)
43			Vehicle Utilization	C33	8.923	Revenue kilometers per all vehicles	Eff15	2.974	(+)
44						Revenue kilometers per operating vehicles	Eff16	2.974	(+)
45						Revenue kilometers per route kilometers	Eff17	2.974	(+)
46			Energy Utilization	C34	11.952	Revenue kilometers per fuel-Lt	Eff18	1.992	(+)
47						Passenger Trips per fuel-Lt	Eff19	1.992	(+)
48						Operating Revenue per fuel-Bht	Eff20	1.992	(+)
49						Revenue per fuel-Bht	Eff21	1.992	(+)
50						Operating Expense per fuel-Bht	Eff22	1.992	(+)
51						Expense per fuel-Bht	Eff23	1.992	(+)

4. COMPUTERIZED BANGKOK BUS TRANSIT ANALYTICAL SYSTEM

Although this paper presents the development of the Computerized Bangkok Bus Transit Analytical System (BBTAS), the comprehensive research work contains other computerized aspects of bus operations in Bangkok particularly the development of computerized database management system. As it is not possible to present all developments in this paper, thus, only the selected computerized program, the BBTAS, is presented. BBTAS is a systematic process that consists of a notation and a method. The notation used is the Unified Modeling Language (Eriksson and Penker, 1998). Also, BBTAS is developed as a user-friendly package to assist those who are not familiar with the computer program. Moreover, a customized graphical interface is also provided in this developed BBTAS for the accessibility of the non-technical users.

4.1 Authority & Security System

The Computerized Bangkok Bus Transit Analytical System (BBTAS) was developed and configured as a centralized network with a central server and several client computers. The central server is used to manage and also to analyze the performance of bus operations. Several client computers can be distributed at each BOZ as well as each BOD to permit the BMTA staff to input all bus operation data. Thus, BBTAS is especially designed for authorized users to gain access to any distributed client computers and it can also limit the access from certain users. To comply with the administrative structure of BMTA, BBTAS is accommodated three classes of users at three administrative levels as follows:

- Division Level: BOD Officers and BOD Chief
- Zone Level: BOZ Officers; BOZ Deputy Director and BOZ Director
- Executive Level: Assistant Managing Directors; Deputy Managing Directors and Managing Director

Each user can log into the system by his/her own account and password as shown in Figure 6. However, they are only permitted to access to the system in accordance with their assigned duty. By authorization, the BBTAS is protected by several levels of security so that unauthorized personnel cannot obtain certain confidential information.

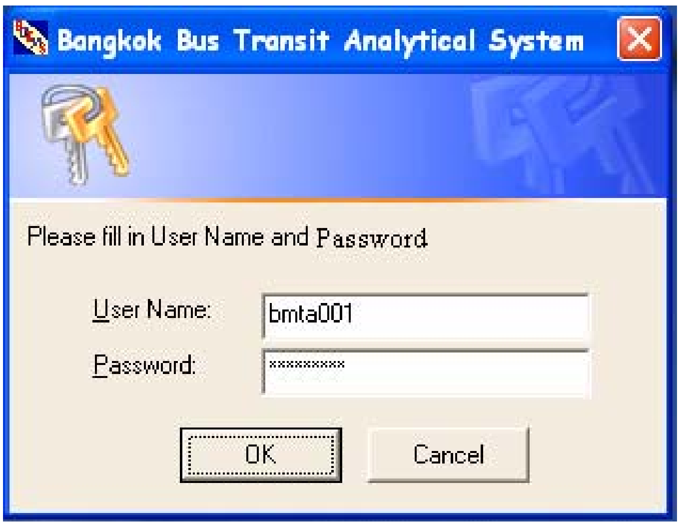

Figure 6. Authority Security Screen

Security is an important scheme in BBTAS because the privileges of the users in accessing the system have direct impact to the distributed databases. Each user is granted with special permission to access particular database files. Certain tasks such as inserting, updating, deleting and/or querying to be done on a specified database are allowed for only specific users. For instance, an operator of a division can add and modify only the tables belonging to his/her zone database. The Director of a BOZ can only view the daily and monthly reports of his/her zone. The Executives of BMTA can view the monthly reports of all eight BOZs and, in fact, can also compare the performances of these eight BOZs.

As the system is made available on the Internet, the easiest way to verify the permitted users is to assign user identification. The procedure is to identify the user name and password in order to access and log on to the system. Once the user is recognized by the system, relevant items for that particular user are displayed on the menu. Thus, the developed system must be sophisticated enough to classify the system operations suitable for each user. It should be noted that since the users can also access the system via Web browser, the system must be able to protect and prevent hackers to have a direct access to the specified URL of the system. A simple way to protect the system on this regard is to use the system logon process.

4.2 Assessing to the System

Subsequent to each user logged into the system by his/her own account and password, the system will automatically allow access to the developed computerized system displaying the BBTAS Main Menu screen as shown in Figure 7

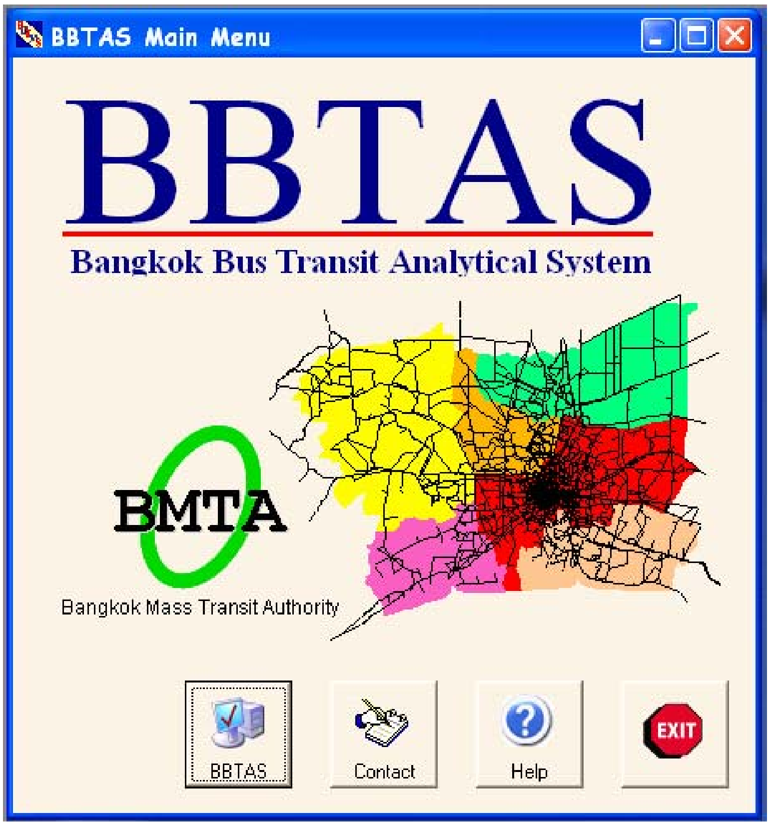

Figure 7. BBTAS Main Menu Screen

To operate the system, the user can easily assess the bus performances of his/her respond area, by simply clicking the key “BBTAS” button and an example of working screen would appear. BBTAS working screen comprises of three principle parts. The first part is designed for using the analytical hierarchy process (AHP) to determine the performance indicator weighting as previously described. Users/administrators can also input their desired weighting and the program can calculate their input information. The second part is created for selecting the bus types and bus operating data by monthly and yearly. Last part is designed for selecting the bus operation zone, division, or individual route.

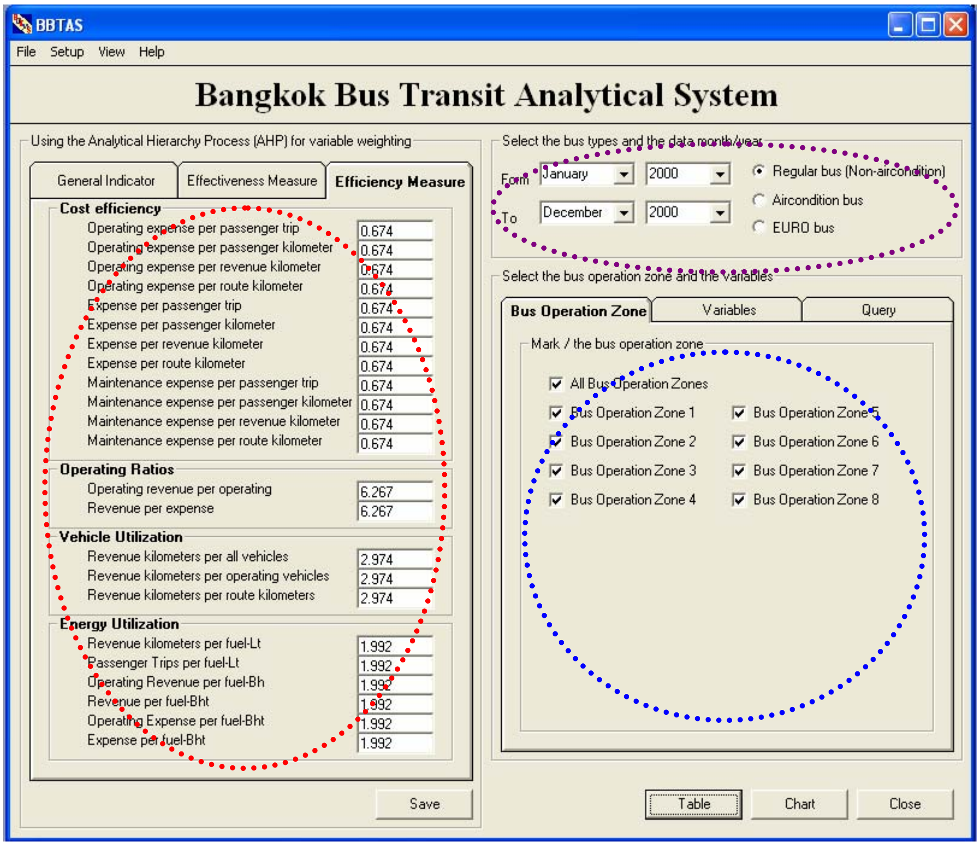

Figure 8. BBTAS Working Screen

4.3 Application of the Computerized Bangkok Bus Transit Analytical System (BBTAS)

In order to demonstrate the application of this developed system, this paper used the one year collected bus operating data of 88 non-air-conditioned bus routes in Bangkok to evaluate their performances. It was known that among all 88 bus routes, bus route number 34 is the best performance bus route while route number 140 is the worst as shown in Figure 9. In term of bus operation zone, it was found that among the 8 operating bus zones in BMTA, Zone number 3 is the best performance zone and Zone number 5 is the poorest performance zone as shown in Figure 10. All of these findings can be graphically seen in the developed computer package as user can simply click the “Table” or “Chart” button on the screen (Figure 8.) and the results would appear as presented in Figure 9 or Figure 10. Although various applications of this developed bus performance package can be further presented, due to the limitation number of pages, this paper only illustrated these above findings.

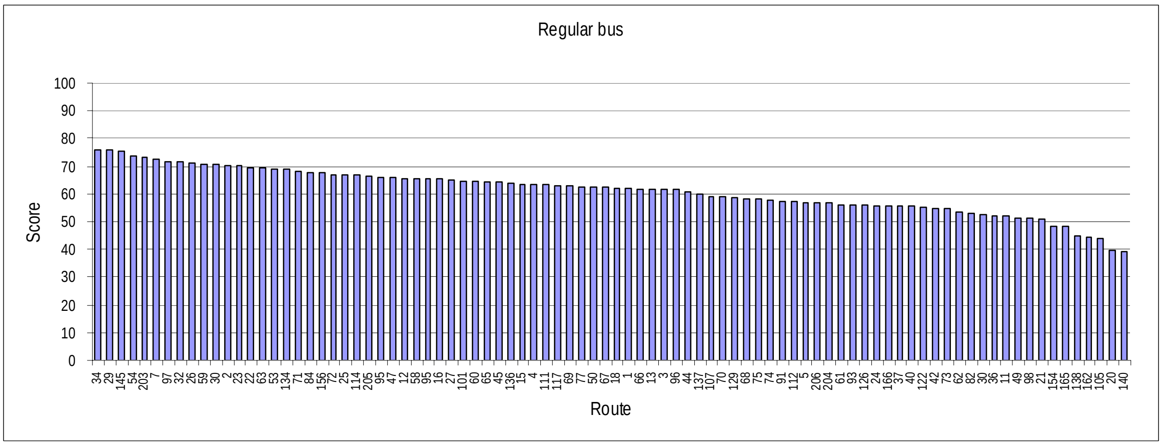

Figure 9. Report of Non Air-condition Bus Performance Evaluation

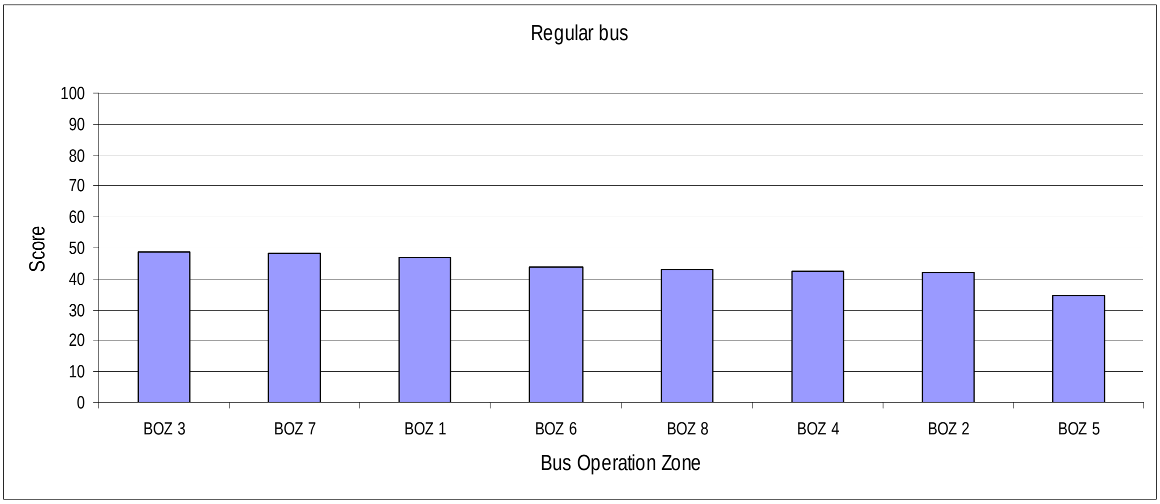

Figure 10. The Zone Performance Evaluation of the Regular bus

5. CONCLUSION

This paper presents the development of the Bangkok Bus Transit Analytical System, BBTAS, for the bus performance evaluation in Bangkok, Thailand. The BBTAS is a computerized analytical system, which can be used to evaluate bus performance through the developed bus indicators and database system by using the centralized network with a central server and the clients. The application of Analytical Hierarchy Process, AHP, was designed for weighting each bus performance indicators in term of groups, classes, and sub-classes, to measure the significant weighting of each indicator affecting the bus operating performance in the decision-making process. Furthermore, the BBTAS was especially developed to limit the access to certain levels of administrations by assigning authorization to proper users. Thus, the administrators/managers of BMTA are not only able to access the desired performance evaluation regarding their bus services/operations at their proper levels of authorization, but they are also able to evaluate the bus performances of each individual or all bus routes in their respective zones or they even can compare the performances of different bus routes or zones as well as different bus types of services.

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