Project Number: 48-JFZ-BKST

A COMPARATIVE STUDY OF BANGKOK'S MASS RAPID TRANSIT SYSTEM

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science
By

Pitchaya Lekeagkarat
Vacharaporn Paradorn
Krisnapong Uampornvanich

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Approved:
Professor John F. Zeugner

AUTHORSHIP PAGE

This project was entirely a group effort. All three members equally contributed in the research, data gathering, analysis and final write-up.

EXECUTIVE SUMMARY

This project examines the feasibility of the implementation of the Bangkok Mass Transit System (BTS) in Thailand in term of applicability, history organizational structure, management, technology, financial situation, and social impact. Moreover, this project includes a comparison among BTS and three other U.S. transit systems; Metro D.C., Miami Dade Transit, and San Francisco BART. The project begins with a background history of the development of mass rapid transit in Bangkok.

The government of Thailand has concerned about the traffic crisis in Bangkok, the capital of Thailand, for at least thirty years. The best solution to the critical traffic problem with the minimum environmental impact is the construction of a mass rapid transit system. The objective of the mass rapid transit is to provide the people of Bangkok with a fast, clean, affordable transportation alternative, and to help alleviate traffic congestion in the Metropolitan Bangkok area. Many plans have been made, discussed, implemented, and rejected or cancelled. Until the 9th of April 1992, on that day the Bangkok Mass Transit System Corporation Limited (BTSC), a special purpose company formed by Tanayong Public Company Limited, signed a 30 year Concession Agreement with the Bangkok Metropolitan Administration (BMA) to build, operate and transfer an elevated mass transit railway system on two routes in central Bangkok.

The Bangkok Mass Transit System Public Company Limited (BTSC) was established with the sole aim of constructing and operating a mass transit railway system, on prudent commercial principles, in order to ease the increasingly severe traffic problem

in Bangkok. The main objectives of BTSC are to provide a safe, comfortable, fast convenient, reliable and affordable public transit system for the public.

The BTS is a heavy rail dual track elevated railway with a total length of approximately 23.5 km. The System consists of two lines, the Sukhumvit Line and Silom Line, and was built on elevated viaduct running above designated roads of Bangkok's central business district. The Sukhumvit Line starts from the East at Sukhumvit Soi 81 and ends at the Mor Chit Bus Terminal in the North. This line is approximately 17 km (10.625 miles) in length with 17 stations including one common interchange station, the Central Station. The line makes structural provision for construction of one additional station in the future. The Silom Line starts at the foot of Sathorn Bridge on the Bangkok side and ends at the East of Bangthad Thong Road near Nation Stadium. The Silom Line is approximately 6.5 km (4.0625 miles) in length with 7 stations including one common interchange station, the Central Station. Also, the line makes structural provision for construction of one additional station in the future.

In order to evaluate the BTS, a comparative study of BTS and other systems was undertaken. Among the United States mass rapid transit systems, Metro D.C., Miami Dade Transit, and San Francisco BART were chosen for this purpose.

The Metro in Washington D.C. project began in 1952 and first opening on March 1, 1976. It was more than four decades of planning and building went into creating the transit system that now serves the metropolitan Washington region. The Metro rail now has served for an area of 1,500 square miles with the population of 3.4 million. There are 78 stations, 96.6 miles (154.46 kilometers). The last two stations opened on September 18, 1999, which are Georgia Avenue-Petworth and Columbia Heights stations. In the other hand, there are 5 stations, on Green Lin to Branch Ave, which were under construction and opened on January 13, 2001.

Miami Dade Transit Agency (MDTA) has a viable four-mode system. There are bus, rail, downtown people mover, and paratransit. Nearly 300,000 passengers use these four systems daily. This special transportation service also provides mobility for people with disabilities. This project concentrated on the Metrorail system. Miami-Dade country's 21-mile rapid transit system running from Kendall through South Miami, Coral Gables, and downtown Miami, to the Civic Center/ Jackson Memorial Hospital area; and to Brownsville, Liberty City, and Hialeah, with connection to Broward and Palm Beach countries at the Tri-Rail/ Metrorail transfer station. The 21metrorail stations, which are about one mile apart, provide easy access for bus riders, pedestrians, and passengers using the Dadeland South, Dadeland North, South Miami, Martin Luther King Jr. Plaza, Earlington Heights, and Okeechobee stations.

The Bay Area Rapid Transit District (BART) is a 95-mile, automated rapid transit system with trains traveling up to 80 mph serving over 3 million people. The system connect San Francisco to Colma and other East Bay communities--north to Richmond, east to Pittsburg/Bay Point, west to Dublin/Pleasanton, and south to Fremont. Thirty-nine BART stations are located along five lines of double track. BART's basic mission is to provide safe, reliable, economical, and energy-efficient means of transportation. Since opening in September 1972, BART has safely carried over one billion and a half passengers more than 18 billion passenger miles. BART stations are fully accessible to disabled persons. BART's current weekday ridership is approximately 325,000.

The analysis of the systems was done by comparing the differences and similarities between BTS and U.S. systems. A chart has been constructed, completed and analyzed. Any acknowledged problems of BTS were examined, and the suggestions to solving these problems based on the data gathered, which were introduced later in this report. This is a preliminary study that may lead to implementation of the BTS in Thailand.

1 Introduction

The Bangkok Metropolitan District and its vicinity is perhaps one of the most populated cities in the world with a population of approximately ten million. Everyday, about three million people commute into the city, causing great congestion. The high density of vehicles in Bangkok has created an enormous traffic problem. Traffic congestion and pollution has been a horror story for Bangkokians for years. Highways, streets, and roads have been built to support the increasing numbers of vehicles but the problem still remains. Other public transportation such as buses, and taxies did not reduce the problem since they all share the same path.

However, since the beginning of the 70's era, the government of Thailand has planned to relieve the traffic crisis by exploring other alternatives. The best solution to the critical traffic problem with the minimum environmental impact is the construction of a mass rapid transit system. The objective of the mass rapid transit is to provide the people of Bangkok with a fast, clean, affordable transportation alternative, and to help alleviate traffic congestion in the Metropolitan Bangkok area.

It has come to the rescue of a city overwhelmed by traffic jams, a knight in red, white and blue armor. The elevated Skytrain, which finally opened on December 5th, 1999 - the birthday of Thailand's King Bhumipol Adulyadej - after years of bureaucratic delay and controversy, has slightly changed the traffic situation in Bangkok.

This study has been organized in the following chapters.

The Executive Summary Chapter provides a complete overview of this project study.

The Background Chapter discusses the history and information necessary to understand the contents of the study. This section focuses on the fundamentals of the BTS system, as well as the history behind the traffic problems of Bangkok. Additionally, all areas of study are discussed within the section.

The Methodology Chapter discusses the goals of this study, specifying a step-by-step approach. Also discussed, are the social impacts of the study, data collection methods, and quantification.

The Result Chapter deals with the information on Metro D.C., Miami Dade Transit, and San Francisco BART.

The Analysis Chapter contains a comparison the similarities and differences of BTS with Metro D.C., Miami Dade Transit, and San Francisco BART arranged visually in a chart. Along with this comparison, are suggestions and recommendations for the BTS system. These recommendations are intended to enhance Bangkok Mass Transit System operations and services in the future. Both advantages and disadvantages are discussed based on set criteria ratings.

The Conclusion Chapter possesses the final explanation of all the data drawn from the analysis with the underlying goal of answering the question of feasibility for implementation.

The Appendices Chapter contains technical details of the system, including automatic fare collection system, telecommunication system, supervisory control and data acquisition system, operation, station information, design & planning criteria, passenger forecasts for station design.

2 Background

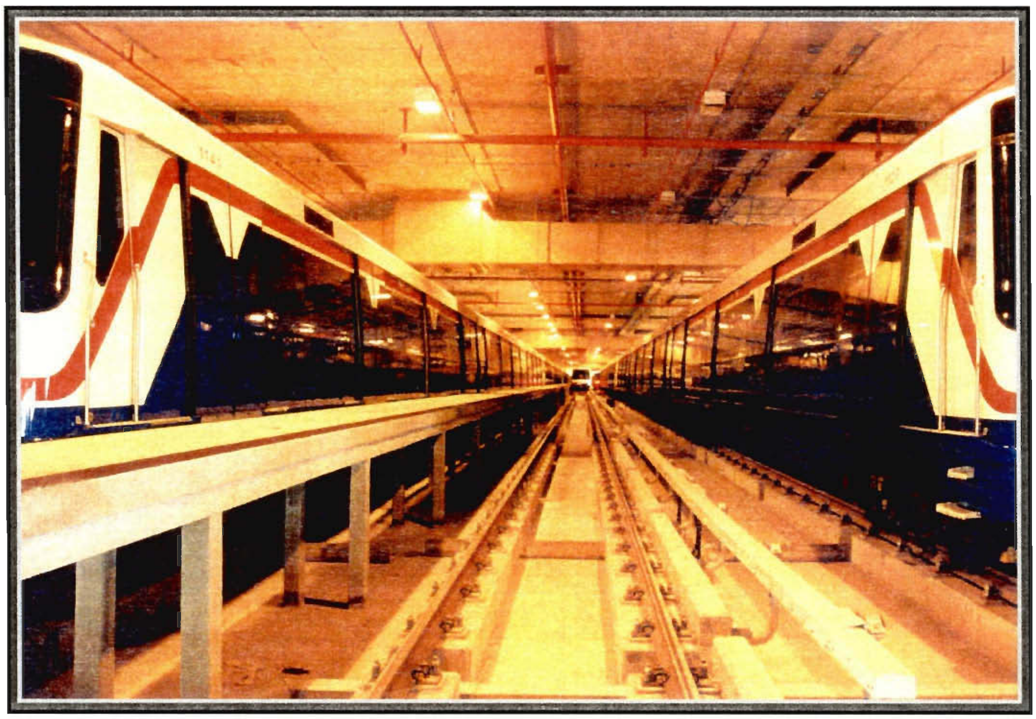
This section contains the overall information and background history of the Bangkok Sky Train project.

2.1 Bangkok Sky Train

On the 9th of April 1992, Bangkok Mass Transit System Corporation Limited (BTSC), a special purpose company formed by Tanayong Public Company Limited, signed a 30 years Concession Agreement with the Bangkok Metropolitan Administration (BMA) to build, operate and transfer an elevated mass transit railway system on two routes in central Bangkok. The concession was awarded by the BMA following a competitive tendering process and approval by the Ministry of Interior and the Thai Cabinet. The Bangkok Transit System (BTS) was opened to be operational by 1999. BTSC operates and derives revenue from the 23.5 km railway for 30 years before handing it back to the BMA.

2.1.1 BTSC Objective

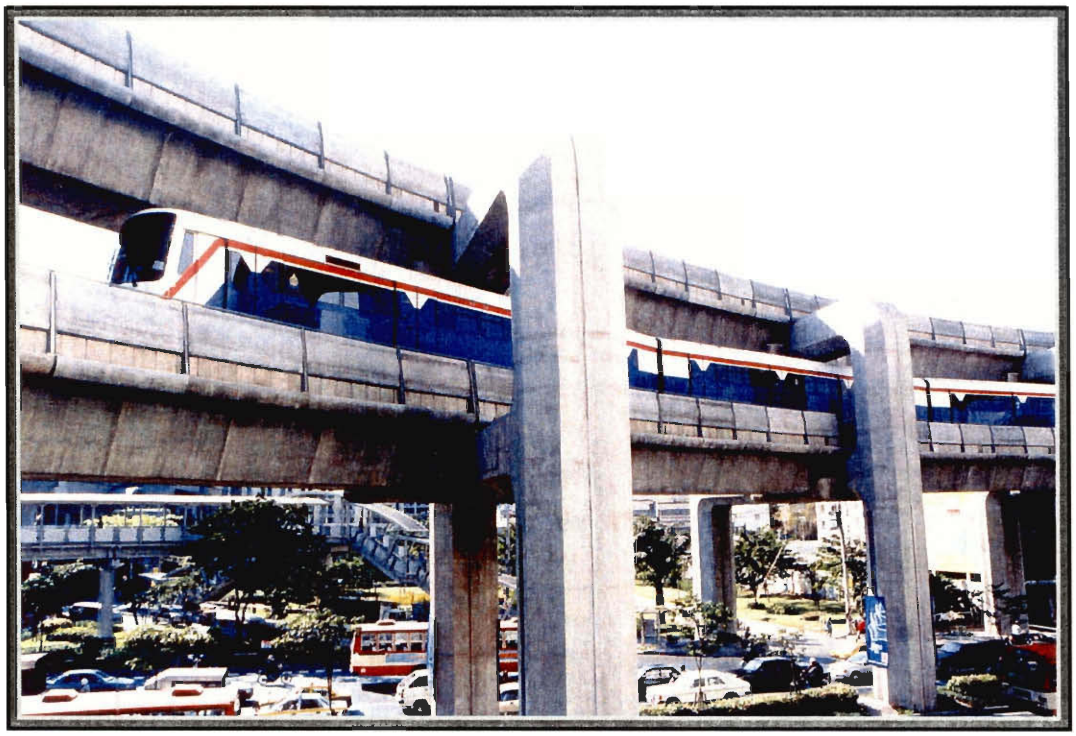
BTSC was established with the sole purpose of constructing and operating a mass transit railway system, on prudent commercial principles, in order to ease the increasingly severe traffic problem in Bangkok. The main objectives of BTSC are to provide a safe, comfortable, fast convenient, reliable and affordable public transit system for the public and to give the shareholders of BTSC a reasonable return for their investments.



2.1.2 Project Description

Bangkok Transit System

The BTS is a heavy rail dual track elevated railway with a total length of approximately 23.5 km. The system consists of two lines, the Sukhumvit Line and Silom Line, and will be built on elevated viaduct running above designated roads of Bangkok's central business district.



1. Sukhumvit Line

The Sukhumvit Line starts from the East at Sukhumvit Soi 81 and ends at the Mo Chit Bus Terminal in the North. It passes along Sukhumvit Road, Ploenchit Road, Rama I Road, Phayathai Road, Victory Monument and Phaholnyothin Road. The Sukhumvit Line is approximately 17 km in length with 17 stations including one common interchange station, the Central Station. The line makes structural provision for construction of one additional station in the future.

2. Silom Line

The Silom Line starts at the foot of Sathorn Bridge on the Bangkok side and ends East of Bangthad Thong Road near the National Stadium. From Sathorn Road, it proceeds North to the junction with Klong Chong Nonsi where it turns East to join Silom Road before running along Ratchadamri and Rama I Roads. The Silom Line is approximately 6.5 km in length with 7 stations including the common interchange station, the Central Station. The line also includes structural provision for an additional station.

Structure

The viaduct is 9 meters wide and in general the track is 12 meters above the ground. Reinforced concrete columns support the viaduct approximately 2 meters square and generally located in the median of the road. Typical span length between columns is 30 to 35 meters.

Electrical & Mechanical (E&M) System

The Siemen-supplied E&M system is designed for the ultimate capacity of the System. However, initially the power supply system, the automatic fare collection system and the train fleet have been sized to meet the initial demand of 25,000 passengers per hour per direction. The trains are powered by electric motors fed by an electrified third rail. The System incorporates a signaling system that continuously advises the train drivers of the optimum driving conditions including speed, braking, when to shut doors etc. Built-in automatic protection systems ensure that no unsafe situation can arise.

Trains

A train is formed by 3- or 6-car coupled together and is capable of running in either direction. The System uses only three-car trains on commencement of operation, and six-car trains will be used when passenger usage of the System rises to beyond the level where the three-car trains can used, a driving car and a trailer car.

Only driving cars are motorized. Motorized trailer cars may be introduced when six-car trains are needed. All cars are air-conditioned. Each car is approximately 22 meters long and 3 meters wide, with four doors on each side. Cars are joined together with gangways, which permit passengers to move freely from car to car. The car body will be constructed of stainless steel. The three-car train has 126 seats. In peak periods, 735 passengers are able to stand at a density of 6 passengers per square meter. Applying a crush-loading factor (a density of 8 passengers per square meter), the total number of passengers per train increases to 1,106.

Stations

Stations are built on columns erected, where possible, in the central median of the roadways. This type of construction is used so that the maximum road surface is maintained while, at the same time, minimizing diversion of existing utilities necessitated by the construction of the System. Stations are located No. 800 to 1,000 meters apart. Each station is approximately 150 meters long. With the exception of

Central Station, all stations are of the side platform type design, with two platforms located on the outer sides of the station and tracks running through the center.

The Central station is of a center platform design with two platforms, one above the other. This permits the direct transfer of passengers between lines. This type of design is a platform located at the center of the station and tracks running along the outer rims. Whilst this layout facilitates passenger transfers from one line to another, construction of stations using this design is more complicated because of the need to curve tracks around the platforms.

Access to stations can be by stairways and escalators from the street to the concourse level. In addition to providing access to the station, the station concourse will serve as a grade-separated pedestrian crossing above the roadway. At all stations, escalators are provided between concourse and platforms. All stations and lifts, both from concourses to platforms and from footpaths to concourses.

Depot

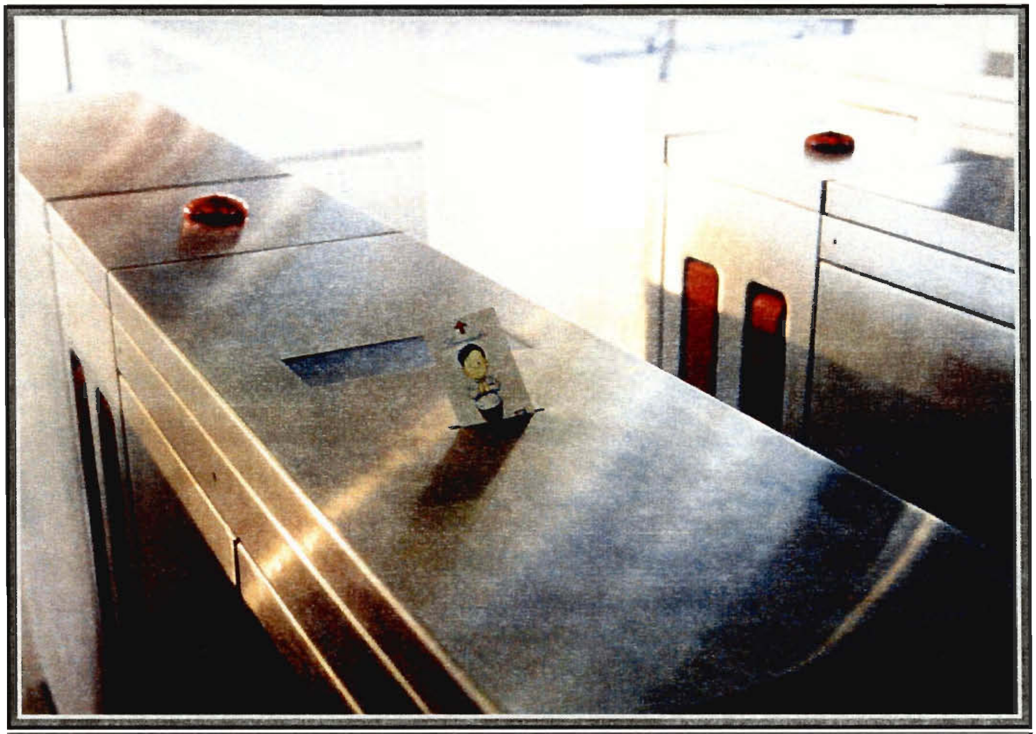
The Mo Chit depot, located on a 64,000 square meter site at the Northern end of the System, contains full workshop and maintenance facilities and the main stabling area. It also includes an administration building and the control center from which the entire System operation is monitored and controlled.

2.1.3 Operations

Operating Schedule

Train services run daily between 6:00 a.m. and 12:00 midnight. The level of patronage and specific requirements of passengers are important factors in determining the final service schedule.

Ticket and Fare Collection



An automatic fare collection system providing single ride and stored value tickets are used. The automatic fare collection system has been designed to cater for the System's possible ticketing integration with other mass transit systems that will link with BTS in the future.

Operating Costs

BTSC's Electrical and Mechanical Engineering Consultant, Kennedy & Donkin Transportation Limited have estimated the operating and maintenance costs of the System. These costs have included all maintenance, stuff, capital expenditure and general overhead costs over the life of the Concession.

2.1.4 Environmental Impact

Two environmental studies for the Project were commissioned by BTSC. Initially, at the time that the depot for the System was to be located at Lumpini, the Hong Kong-based environmental consulting firm, AXIS Consultants, conducted a study. This report was prepared and submitted to the government for comment in 1993. The change of the depot site from Lumpini Park to Mo Chit in late 1993 necessitated that BTSC conduct a further study specifically addressing the new, final alignment. This report was prepared by Kasertsart University for submission to the government and approved in mid-1995. Monthly environmental monitoring was conducted during the course of construction to the resolution required by the approved report. Further according studies shall be conducted during the operation period to monitor the impact of the System.

2.1.5 Financial Information

<u>Patronage and Revenue Estimates</u>

Revenue estimates have been based on distant related fare basis, which has been approved by Committee. The authorized fare on opening ranged from Bath 15 to Bath 45 per trip while the effective fare is charged from Baht 10 to Baht 40 per trip.

Initially, rider ship forecasts were prepared by three specialists traffic consulting firms, PADECO, TRANSMARK and Sindhu Pike Bodell Consultants. These forecasts were prepared at different phases of the project, respectively for the feasibility study in 1992 and at the time of the design of the System in 1993. For the original system alignments, the firms projected average daily patronage volume of over 500,000 passengers during the System's first year of operation. Another study carried out by MVA, the largest independent traffic consultant in Asia retained by

BTSC's financial advisers, further confirmed the basic rationale for the System and indicated a likely strong patronage demand in line with the earlier forecasts.

As a result of the relocation of the depot, economic crisis, and fare structure change, MVA updated its patronage forecast to reflect an estimated daily volume of over 491,025 passengers. This rider ship volume is forecast to increase over time to a maximum of about 1,275,158 per day during the period of the Concession. Such increased demand assumes an increase in the initial train fleet size and the adoption of a six-car train as demand requires.

Land Cost

As the viaducts were being built on BMA's right of way and land for the depot was provided by the BMA, there was no land acquisition cost for the project.

Project Cost

The total project costs of the System are estimated to be Baht 52,013 million. These costs include civil works, electrical and mechanical works, utility diversion works, project management and financing costs during the construction period. The turnkey construction contract for the System was awarded in 1995 to the Siemens – Italian-Thai Consortium for the construction of the System and supply of electrical and mechanical equipment. Under a separate maintenance contract, Siemens is also responsible for maintenance of the electrical and mechanical equipment for five years after commencement of operation.

The total project costs are to be funded on a limited recourse basis by a combination of equity, Thai Baht and US Dollar loans. Siam Commercial Bank is leading a syndicate of Thai financial institutions providing the Thai Baht loans;

Kreditanstalt fur Wiederaufbau (KFW), the German export credit bank, is arranging a syndicate of international lenders providing a large portion of the US Dollar loans. International Finance Corporation (IFC), the private sector arm of the World Bank, also participates in the financing by extending a senior loan to the project.

An initial equity amount of Baht 15,138 million or 92% of the total required equity amount has been provided by the Principal Shareholders of the Company in accordance with the requirements of the Principal Shareholders Agreement signed in October 1996. This agreement and the loan agreements with the senior lenders require the balance of the required equity amount to be in place within one year from the first draw down on the loan. First draw down under the senior loans was made in December 1997.

Principal shareholders include Tanayong Public Company Limited, Italian Thai Development Public Company Limited, The Siam Commercial Bank and Land & Houses Public Company Limited.

A breakdown of the uses and sources of funding for the project is shown below: (base on exchange rate of US$ 1 = Baht 39)

	Baht Million	US$ Million
Civil Works	17,603	451.4
E&M Works	23,452	601.4
Utilities Diversion Works	747	19.2
Pre-Operating Costs	5,811	145.0
Financing and Interest Costs	4,400	112.7
Total Uses of Funds	**54,013**	**1,333.7**
Equity	18,426	472.5
Baht Loans	11,160	286.1
US$ Loans	21,881	561.1
Other	546	14.0
Total Sources of Funds	**52,013**	**1,333.7**

Investment Rationale

BTS is one of the first privately funded Build-Operate-Transfer (BOT) transportation projects. BTSC have confidence in the project's viability for the following reasons:

a. The population of Bangkok has grown to a level such that an efficient mass transit system is vital to the continued economic growth of the city.

b. Traffic congestion in the city is so great that the problem cannot be solved without diverting road users to other means of transport.

c. A rapid transit system running along the main streets of the city will offer commuters speed and reliability and its opening will both cause a major diversion of transport-users from existing transport modes and release a very significant suppressed demand for inner-city travel.

d. The Concession Agreement provides for a mechanism for the System fare to be adjusted in line with inflation.

e. As the System is largely situated within the central business district of Bangkok, rider ship will not be subject to significant fluctuations between peak and non-peak hours throughout the day. As a result, the equipment and energy consumption in the BTS will be effectively used.

Bangkok Mass Transit System Public Company Limited. "Bangkok Mass Transit System Project", BTS: Bangkok, 1999.

2.1.6 Construction

BTSC have seen the year being extremely productive as the overall progress was reported at 93% -a remarkable 40% increase from the previous year, including the completion of BTS Building and operational in October 1998. Additionally, nearly all traffic surfaces have been reinstated to the public to alleviate traffic congestion. Civil works and Electrical and Mechanical works in the past year can be briefly summarized in the subsequent paragraphs.

Civil Works

The construction of civil works focused on the critical areas including construction of civil structure in the Central Station vicinity, from Rachaprasong junction to Pratumwan junction, and the erection of the viaduct spans, particularly in the Central Station area. Viaduct erection was completed with the remaining half of viaduct spans from the previous year were erected in the first ten months. Construction of Central Station has significant progressed allowing subsequent installation of electrical and mechanical equipment and the test run of the Silom Line.

Twenty-one of twenty-three stations have been structurally completed with two terminal stations at Taksin Bridge and On-nut remains. Construction of the train Depot and the Operation and Control Center Building (OCC), BTS Building at Mo Chit area were practically completed.

Electrical and Mechanical Works

The progress of electrical and mechanical works has shifted from intensive manufacturing in the first few months to intensive installation, testing and commissioning of equipment in latter part of the year. Manufacturing of all off shore equipment has been completed with the exception of manufacturing of rolling stocks and automatic fare collection system. Manufacturing of rolling stocks is nearly finished with 5 percent remain to be completed.

Track work installation has been substantially progressing with only few sections toward the end of Silom line and Sukhumvit East line remain. Installation and commissioning of the Power Supply system significantly progressed from the previous year with over 80 percent of the system were already energized. Installation of signaling and central traffic control equipment was completed at the Central Control Room and nearly finished at the Central Station.

On the 10th of October 1998, the first train arrived at Laem Chabang Port, Chonburi and as of March 31, 1999, sixteen trains have been delivered on site for further testing and commissioning.

Train Test Run

In the past year, a major milestone in testing and commissioning was made when the first official train test run was successfully achieved on 27th October 1998. Additionally, the train test run was successfully achieved on the entire Silom Line on 27th February 1999.

As of March 31, 1999, BTSC successfully conducted train test run on the entire Silom Line, the entire north section of Sukhumvit Line and half of the east section of the Sukhumvit Line.

Operations

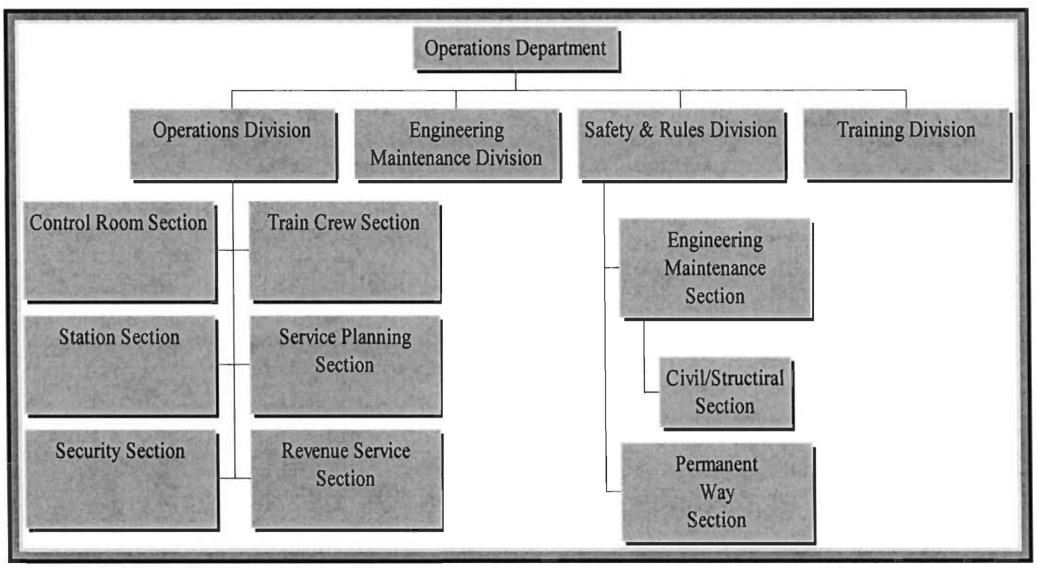
During the past year, the Company made the following preparations in order to attain maximum readiness for train operations:

Personnel

The Operations Department started staff recruitment in April 1998. Personnel is divided into 2 categories namely:

1) Training staff, who has already undergone theoretical and practical trainings and tests, locally and abroad;

2) Operations staff will be recruited before the commencement of commercial services in 1999. A chart of the Operations Department is shown below.



The progress on personnel recruitment is as follows:

- Engineering and Maintenance Division – 8 recruited out of 36 targets, equivalent to 22 percent

- Operations Division – 66 recruited out of 717 targets, equivalent to 9 percent
- Safety and Rules Division 1 recruited out of 5 targets, equivalent to 20 percent
- Training Division – 58 recruited out of 68 targets, equivalent to 85 percent

Training

The program on staff training and preparation of operations manual is as follows:

1) *Central Control Room Key Instructor and Train Crew Key instructor* - A total of 33 key instructors have received training since April 1998 and passed theoretical and practical tests in March 1999. They are currently conducting training to relevant basic staff and preparing documents and manual for operations.
2) *Station Supervisor Key Instructor* – Staff in this group have received training since January 1999. Theoretical and practical tests will be conducted in April 1999.
3) *System Administration* – Recruited in November 1998, this group is undergoing training and testing the system jointly with the system suppliers. Theoretical and practical tests will be conducted in July 1999.
4) *Line/Depot and Engineering Controller and Train Driver* - The first group of 65 Train drivers, Line/Depot Engineering controllers were recruited in February 1999 and are currently receiving training.

Preparation of Train Operations Manuals

The Operations Department is in the process of preparing operations manuals for the main divisions. The progress on this front is as follows:

Operations Procedures Manual for Central

- Control Room: 80 percent completion
- Operations Procedures Manual for Drivers: 50 percent completion
- Operations Procedures Manual for Stations: 40 percent completion
- Rule book: 100 percent completion

Electrical and Mechanical System Maintenance

For maintenance works, the Company has contracted Siemens Company who designed and built the electrical and mechanical systems. The master plan for E&M systems will comprise structure and personnel plan, maintenance plan, and safety and rule in maintenance plan.

Safety Plan

Operations Department is proceeding with preparations that will ensure the safety of operations. Meetings have been held with the Royal Thai Police to set up interfaces. Operations Rules Book is completed. The Division is setting up a team for auditing all procedures.

Finance

During 1998, in addition to ensuring that company finances such as loan disbursements and expense control were handled effectively, the Company had an on-going mission to complete an initial public offering (IPO) of its ordinary shares to fulfill the objective of the concession, to abide by the conditions of the loan agreements regarding base equity requirement and to provide contingencies in case of construction cost over-runs. Although the execution of IPO has been delay owing to the country's distressed economic and financial market conditions, the Company will utilize its best effort to successfully achieve the mission. At the same time, the Company has come up with a solution to comply with the requirement under the loan agreement as follows.

Base Equity Requirement

The loan agreement specifies that the Company must mobilize Bt 1,292 million additional funds to meet its Bt 16,430 million base equity requirement by December 1998. However, the economic crisis and unfavorable capital market conditions resulted in delay in the IPO plan. Nevertheless, through concrete financial planning, a supporting facility of Bt 1,292 million was made available from the principal shareholders in the form of an IPO Delay Loan in case the IPO fell through. So far, Bt 1,176 million of this IPO Delay Loan has been drawn down.

Share Capital Increase and Initial Public Offering

The Company is intent on achieving its IPO commitment to fulfill the objective of the concession and to pave the way for capital market access. In addition, funds derived from the IPO will provide a pool of repayment of the IPO Delay Loan to the Principal shareholders.

Capital market conditions in the past year were not conducive to fund raisings and wide market swings will likely persist. The company has therefore made plans and is ready to launch its IPO when the market turns in its favor. The company received the second approval from the Securities and Exchange Commission (SEC) on the 14th of January 1999 and applied for listing on the SET in February 1999. The application is being processed by the SET and approval is expected in the third quarter of 1999. Meanwhile, the Company is making other preparations such as selection of underwriters for its IPO.

Loan Disbursements

As at March 31, 1999, 16 out of 25 loan trenches were disbursed totaling Bt 6,884.31 million and US$ 341.86 million, representing 61 percent of the total loans, comprising Bt 11,160 syndicated loan, lead managed by Siam Commercial Bank and US$ 555.7 million loan lead managed by KFW and IFC.

<u>Marketing</u>

The year 1999 is a year for implement marketing plans for the commencement of the commercial operation at the year-end. The Company has been carrying out marketing activities to instill customer awareness, build a good image, as well as creating revenues as follows.

Shop and Advertising Areas on BTS Stations:

The Company has appointed VGI Global Media Co., Ltd. as sole concessionaire for shop and advertising management on all stations. A revenue sharing agreement has been signed.

Installation of Passenger Service Equipment:

The Company co – operated with other businesses to provide service facilities for BTS passengers, such as public telephones, ATMs. These services, besides providing convenience to passengers, will generate additional income from utilization of station areas to the Company.

Printed Advertisements on Train Tickets:

The company will also solicit advertisers by means of printed adverts on single – journey tickets and store – value tickets. Product owners will pay the

Company for rights to print adverts, the charges for which depend on the amount of tickets and duration of circulation.

In addition, the Company will issue commemorative tickets such as those for the occasion of opening Thailand's first electric train service.

Sales Promotion Activities:

The Company carried out survey studies for a variety of sales promotion activities such as economy return fare, joint promotions with other businesses, and appointed market research specialists to conduct customer research focusing on consumer behavior.

Advertising Plan:

The Company has invited advertising agencies for presentation of advertising plans and advertising budgets. Agency selection will be made in June 1999.

<u>Public Relations Activities</u>

Community Relations

A BTS rail public relation and co – ordination center was set up in front of the Siam Center station, Rama I Road, to handle complaints from people affected by the construction and contractors. Staffs deal with complaints, as well as conduct surveys of the construction sites and interviews to gauge public opinion on the project and deal promptly with problems, which arise during construction to mitigate their impact. These help foster good relations with people along the routes and reduce the airing of complaints through the media.

In addition, the Company arranged meetings between BTSC executives and shop owners in Siam Center, Siam Discovery, and Siam Square to explain and promote good understanding of the project construction to mitigate any adverse impact, which may arise during the construction.

Support of Traffic Police Activities

The Company and Radio 91 initiated a project to give awards to outstanding traffic policemen. Monthly prizes are awarded to policemen voted by Radio 91 audience for their hard work especially during the project construction, to boost their morale.

Promotion Activities

On the 10th of October 1998, the first BTS rolling stock arrived in Thailand on board Wallinius Line's AIDA ship. The Company hosted a welcome ceremony for its arrival at Laem Chabang Port. The ceremony was presided over by Mr. Prasert Samalapa, Secretary General of Bangkok Metropolitan Administration. Mr. Kasame Chatikavanij, BTSC Chairman, and Mr. Keeree Kanjanapas, BTSC Chief Executive Officer, and management of Siemens-Italian Thai consortium, the project contractor and supplier, were there to welcome the guests and the media.

On October 27, 1998, General Sanan Kachornprasas, Deputy Prime Minister and Minister of Interior, Mr. Bhijit Rattakul, Governor of Bangkok Metropolitan Administration, and Mr. Sonthaya Kunplum, Deputy Minister of Transport, were guests of honor at the official test – running of Thailand's first electric train on Paholyothin Road, from Mo Chit Station (N8) to Aree Station (N5).

The Company hold a press conference to affirm that the station in front of Mater Dei School did not cause problems and resumed construction of the station after being given a go – ahead by Mr. Bhijit Rattakul, Governor of Bangkok Metropolitan Administration, so that it would be completed in time for the commencement of commercial service on the 5th of December 1999. Some alterations were made to the station design; the entrance and exit stairs in front of the school were moved and additional noise absorbing partitions were installed.

Project Visits

Throughout the year, the Company welcomed a large number of visitors to the project who were also taken on train journeys. Some important visitors were, for instance, a group of MPs from the Republic of Iran who visited the Company on December 1, 1998.

On January 15, 1999, a group from the Cabinet Secretariat and NESDB visited the Company.

On January 20, 1999, Bangkok Metropolitan Governor, senior officials and members of Bangkok Metropolitan Council visited the Company.

On March 19, 1999, Commander of Bangkok Metropolitan police and police officials visited the Company and met with management to discuss safety measures.

Future Plans

Construction

As BTS is entering the final stage of the development, most of activities for the remaining of the year 1999 will focus on testing and commissioning of the electrical and mechanical systems and final inspection of civil works. All civil works are anticipated to complete in October 1999. System-wide integrated test is anticipated in August 1999. The project completion is expected in early December following the full service Trail Run scheduled in mid-October 1999.

Operations

Personnel

In 1999, the Operations Department expects to recruit remaining personnel to fill every position gearing up for the official service launch. The Department will also set up a permanent Training Division to provide trainings for operations staff to increase staff efficiency. The Training Division also aims to be a center for maintaining all information and database regarding the railway operations.

Training

Training programs planned by the Operations Department consist of:

1) *Line/Depot and Engineering Controller* - Seventeen Line/ Depot and Engineering Controllers will complete their trainings in August 1999.
2) *Train Drivers* - Training of 144 train drivers will be divided into 3 groups, 48 each. Separate training sessions for each group will be completed in July, August and September 1999.
3) *Station Supervisors and Station Persons* - Two training sessions for 110 Station supervisors will be completed in August and September 1999. The 220 station persons will be divided into 2 groups and separate training for each group will be concluded October and November 1999.

Training of key management positions is planned in the middle of 1999 at MTR, a mass transit system in Hong Kong, to expand their knowledge horizon on the railway operations.

Trial Runs

The full service trail run is scheduled in October 1999 prior to the commercial operations of the system in December 1999. During the trial run period the entire operations team will use this opportunity to test their readiness, trial fallback operations and address possible technical issues such as Y2K problems. The entire computer system for the railway operations will be tested and certified for Y2K compliance prior to the commercial operations.

Engineering and Maintenance Works

Detailed maintenance procedures for sub-systems of engineering and maintenance works, electrical and mechanical works will be concluded prior to the commercial launch.

Contract Administration

In addition to the operations plans, the Operations Department plans to source out contractors for various works such as station security, station cleaning work, cash and ticket transport and civil works maintenance.

<u>Safety and Rules</u>

Safety & Rules Division has planned to audit rules and procedures during Trial Run period. Joint training on incident handling with Police and Fire Brigade will also be conducted during the period. In addition, the Division has also planned to promote the organization including occupational safety.

2.1.7 Marketing

To enhance public awareness of, and familiarity with the electric train system, and to maximize revenues, the Company has made plans for continuous marketing and public relations activities. The Company will hire consultant to advice on the marketing and public relations plan.

To facilitate our train passengers, the Company experts to appoint Public telephone service providers to install both coin-operated and card-operated public phone service at all station. At the same time, the Company will consider every bank's application to install ATMs at the stations – each station can accommodate more than 5 ATMs. The machine installation can be done prior to the commencement of commercial service on December 5, 1999.

With regards to sales promotion, the Company plans to produce souvenirs carrying its logo for sales on special occasions to enhance public awareness, for example special-event ticket sales, sales of copyrighted "Nu Duan" souvenirs.

Other supplementary marketing and public relations activities include distribution of route maps, in the form of guide maps with advice on how to use the train service. The aim is to familiarize the public and foreign tourists with the train routes and services. Moreover, it plans to join with companies and shops along the routes to induce office workers and students to use train service.

Public Relations

Mobile exhibitions will be displayed at schools, colleges, universities, office buildings, and department stores along the catchments areas and in the suburbs to enhance public awareness of electric trains prior to commercial opening. Promotion materials will include videos, brochures and handouts.

On the first day of commercial service, the Company will hold an opening ceremony to announce the launch to the public and to share with them its pride in this historic day of providing the first electric train service to Thai people.

Route Extension

The government has a policy to increase public transport services and has drawn up a master plan for the construction of mass transit systems in Bangkok and surrounding provinces. Mass transit routes and implementation plans have been set. According to the master plan, for Bangkok Metropolitan mass transit system or BTS, route extensions will be carried out in 3 directions namely 1) North route, 3 km.- extension along Paholyothin Road from Mo Chit station (N8) to Rachayothin intersection. 2) South route, 3 km.- extension from Taksin station (S6), from Taksin Bridge, Bangkok side, across the river to Wong Wien Yai, and 3) East route, 27 km.- extension from On Nuch station (E9) along Sukhumvit Road to Bang Na intersection and then branching into two lines to Nong Ngu Hao Airport and Samrong. The extensions will continue to be under the supervision of Bangkok Metropolitan Administration.

According to the Company's preliminary feasibility studies, the South extension and the East extension to Bang Na intersection are more profitable. However, further technical and financial studies are needed. The commercial opening of the current project will enable the Company to find out more about user needs and evaluate future plans.

Internal Audit

As a policy of the company to have good corporate governance, the company has set up internal audit department in May 1999. The main objective is to set up an internal audit plan in accordance with international standard and to function as secretary to the Audit Committee of the company. This will also prepare the company to become a good listed company in the Stock Exchange of Thailand.

Bangkok Mass Transit System Public Company Limited. "Annual Report 1998/1999", BTS: Bangkok, 1999.

2.1.8 Time line

April 9, 1992	Concession Agreement Signed Tanayong won a 30-year concession from the Bangkok Metropolitan Administration (BMA)
August 10, 1992	Appointment of Metro Transit Consultants as general consultant
September 3, 1992	Approval by the Cabinet of granting BOI privileges to BTSC
December 9, 1992	Land delivery agreement signed with BMA Mr. Boonchu Threetong, who is the president of the Ministry of Finance assigned about 16 acres to be sky train maintenance
March 10, 1993	Turnkey tender documents released to five tendering consortia
July 19, 1993	Kennedy & Donkin appointed as E&M Technical Advisor to BTSC
September 29, 1993	BMA and Treasury Department of Ministry of Finance reached agreement to use Mor Chit Bus Terminal as BTS depot
October 6, 1993	BMA notified BTSC of the relocation of BTS depot to Mor Chit area
March 31, 1994	Utility diversion work at Phaholyothin Road started
July 15, 1994	Memorandum of Agreement awarding Turnkey construction of the project to Seimens – ITD Consortium

August 16, 1994	BMA instructed BTSC to commence test works on Ratchadamri Road as resolved by the Cabinet
October 3, 1994	H.R.H. Crown Prince presided over BTS foundation stone laying ceremony
	Test works at Ratchadamri Road Started
December 21, 1994	Construction / Transfer Contract between BMA and Treasury Department signed for the use of Mor Chit Bus Terminal
January 25, 1995	First Amendment to Concession Agreement signed (Mor Chit depot relocation)
February 18, 1995	Piling commenced at Ratchadamri Road work front
March 13, 1995	Piling commenced at Phayathai Road work front
March 21, 1995	Piling commenced at Ploenchit Road work front
May 3, 1995	Hand over of first phase of Mor Chit depot land
May 10, 1995	Piling commenced for the administration building at depot area
June 9, 1995	Casting of first segmental box girder
June 23, 1995	Cabinet approved BTS environmental impact assessment report prepared by Kasetsart University
June 28, 1995	Second Amendment to Concession Agreement signed (alignment move to Klong Chong Nonsi)
July 4, 1995	Turnkey contract signed with Siemens – ITD Consortium
August 12, 1995	Piling commenced at Phaholyothin Road work front
August 17, 1995	TOT diversion commenced in Silom Road

October 3, 1995	First segment erection at Ratchadamri Road
November 10, 1995	First segment erection at Phayathai Road
December 20, 1995	Piling commenced at Station N1
January 8, 1996	First segment erection in Phaholyothin Road
February 2, 1996	Senior loan facilities Term Sheet signed between The Siam Commercial Bank, KfW, IFC and BTSC
February 6, 1996	Piling commenced at Station N3
April 6, 1996	Piling commenced at Station E2 and Silom Road work front
July 22, 1996	Mor Chit depot site Handing-Over Ceremony
August 14, 1996	BTSC registered as public limited company
August 29, 1996	Senior loan credit facility agreements signed between The Siam Commercial Bank, KfW, IFC and BTSC
	Principal Shareholders Agreement signed
January 25, 1997	Piling commenced at Sukhumvit Road and Narathiwatrajnakrin Road
February 20, 1997	Piling Commenced at Rajprasong Intersection to Chalermpao Intersection
March 8, 1997	Piling commenced at Rama I Road and Phayathai Road
April 11, 1997	BMA Governor visit BTS Train Mock-up in Germany
April 19, 1997	Piling commenced at Phaholyothin Soi I
May 28, 1997	Commission for the Management of Road Traffic's consider to demolish Saphankwai Flyover and will reconstruct it after the construction completed
June 9, 1997	SEC Approval for IPO

June 14, 1997	Commences Construction on Ratchadumri Road from Grand Hyatt Erawan Hotel to Rajprasong Intersection
June 28, 1997	Commences Construction on Rama I Road from Sakala Theater to Pathumwan Intersection
August 4, 1997	Commences Construction at Saphankwai Intersection
August 23, 1997	Commences Construction on Rama I Road from Chalermpao Intersection to Lido Theater
August 25, 1997	SET Approval for Listing
September 13, 1997	Piling Commences at Pathumwan Intersection
September 27, 1997	Piling Commences at Victory Monument
October 18, 1997	Commences Construction on Rama I from Pathumwan Intersection to National Stadium and Sukhumvit Road from Saphanphrakhanong to Sukhumvit Soi 85
December 18, 1997	First Utilization of Senior Loans
April 17, 1998	Roll out ceremony at Vienna
October 10, 1998	First Train rolls out ceremony in Austria at Laem Chabang Chonburi
October 27, 1998	First Test Run of BTS train
December 1, 1999	Siemens – Italian Thai Consortium Handing Over Ceremony of the BTS Project
December 5, 1999	BTS Opened to Public
February 21, 2000	Her Royal Highness Princess Maha Chakri Sirindhorn chaired the Official Inauguration Ceremony of the Elevated Train Route 1 and Route 2 In Commemoration of His Majesty, the King's 6th Cycle Birthday

3 Methodology

Our team has proposed ideas for researching the project of both a physical research and a virtual, or web-based research. These required the completion of many steps. This section provides an explanation of the steps involved as well as background information about each step. Also included in this section are any thoughts that we had pertaining to specific concepts as they related to our project and the completion of our review of the BTS project.

Our goal was to study the overall story on the BTS which including background history, technical detail on how it was built, financial situation, environmental issue, accessibility to public, and most of all, the reason that they decided to build the mass rapid-transit system.

Our initial step in completing our project was a background research on the BTS. Our research and information started with the collecting data from Bangkok; by going to BTS office and gathered brochures, hand out, and various articles from Thai magazines in both English and Thai, collected many pictures of the plan, constructions sites, platform, systems including the trains, tracks, stations, ticket machines, etc.

Our next step was to gather the information from libraries, search on the Internet, which including uncover search, BTS website, various news articles from news web site (i.e. The Nation, Bangkok Post, Far Eastern Economic Review, Asia Week, New York Times Index).

It came to our attention that it was better to also observe other systems and to compare the BTS systems with other systems in the United States to see the similarities and the differences among them. We selected BART, Metro D.C., and Miami-Dade Transit from other existing systems because they seem to have some similarities as well as differences. We decided to separate the topics, focusing on each system.

The following step was for each of us to do a research and summarize on each of those three selected systems. Since we could not have visited the actual location of each systems because the lack of time, opportunity, and accessibility, we collected all the available data from the internet by browsing through each of the system's own websites; http://www.metro-dade.com/ for Miami-Dade Transit, http://wmata.com for Metro D.C., and http://www.bart.gov for BART. After collecting the information, we began to analyze and assemble them all together as well as summarize the data into the chart.

Our final step was to evaluate and consider each system extensively and comprehensively. We accumulated all the thoughts, ideas, and knowledge of all systems; BTS versus the other three systems. Our results and conclusions were then finalized into our final report.

4 Results

This section contains the information and history of the U.S. rapid transit systems. These systems are Miami-Dade Transit Agency, Metro D.C., and San Francisco Bay Area Transit.

4.1 Miami-Dade Transit Agency

[1]The Miami-Dade Transit Agency (MDTA) has a viable four-mode system. There are bus, rail, downtown people mover, and paratransit. These four systems are used by nearly 300,000 passengers daily. This special transportation service also provides mobility for people with disabilities.

4.1.1 Metrorail

[2]General Information

Fleet: 136 cars Normal capacity is 166 passengers. Crush load capacity is 250 passengers per car.

Length: 21 miles of elevated heavy rail.

Original Cost: $1.03 billion

Speed: Currently, Metrorail operates at a top speed of 55 mph.

Stations: 21 stations located throughout Miami-Dade county

Service Hours: 5:08 a.m. to midnight seven days a week. Trains arrive every six minutes during weekday peak hours; every 15 minutes during weekday midday hours, and every 30 minutes after 8 p.m. on weekdays, Saturday, and Sunday. Weekend service runs every 20 minutes before 8 p.m.

Ridership: Metrorail averaged 45,800 daily boarding for FY99.

Budget: Operating budget for FY 99, $46,272,000.

[1] http://www.metro-dade.com/mdta/allabout.html (Last updated on 01/18/00.)

Revenues: Total revenues for FY 99, $12,843,000.

[3]Miami-Dade country's 21-mile rapids transit system runs from Kendall through South Miami, Coral Gables, and downtown Miami; to the Civic Center/ Jackson Memorail Hospital area; and to Brownsville, Liberty City, and Hialeah, with connection to Broward and Palm Beach counties at the Tri-Rail/ Metrorail transfer station.

The 21 Metrorail stations, which are about one mile apart, provide easy access for bus riders, pedestrians, and passengers using at Dadeland South, Dadeland North, South Miami, Martin Luther King Jr. Plaza, Earlington Heights, and Okeechobee stations.

[4]Fares

The full fare of the Metrorail is $1.25 and $0.60 for all Medicare cardholders, other qualified elderly, people with disabilities, and youth in grades 1-12 (with permit ID). Riders 65+ rife free with a Golden Passport.

4.1.2 Transit History 1873-1948

1873- Julia B. Tuttle purchased 40 acres of land north of the river to stimulate the growth of Miami.

1891- Julia B. Tuttle offered James E. Ingraham, president of the Florida Railroad, land for a townsite if he's extend his railroad to Miami. Ingraham refused.

1895- After the big freeze in north Florida, Henry Flagler visited Miami to study the possibility of growing oranges here. Julia Tuttle offered Flagler land if he'd agree to extend his railroad to Miami. He accepted and a contract was signed.

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[2] http://www.metro-dade.com/mdta/Rail%20Information.html (Last updated on 04/20/00.)
[3] http://www.metro-dade.com/mdta/Metrorail.html (Last updated on 08/28/00.)
[4] http://www.metro-dade.com/mdta/fares.html (Last updated on 08/28/00.)

1896- April 15: Flagler's Florida East Coast Railroad (FEC) passenger service was joyously welcomed to Miami.

1900- The first wagon road was pushed in the area now known as Coconut Grove.

1905- May: three members of the Tatum family secured a street railway franchise.

1906- July 4: The Tatum brothers purchased the Miami Electric Railroad Company.

July 25: A single car began running from the old FEC depot near Avenue B (now NE 2 Avenue) and 6th Street (now Flagler Street), down to Avenue B and 12th Street, then along 12th Street to the FEC crossing at the courthouse.

1907- September 3: Miami Electric Railway Co. closed for overhaul, never to reopen.

1914- The Miami Traction Company began laying new track.

1921- The Miami Traction Co. closed down after fire wiped out its fleet. The City of Miami agreed to buy the franchise of the defunct Miami Traction Co., ordering right single-track Briney streetcars. The city leased the operation to the Miami Beach Railway Co.

1940- November 14: George B. Dunn, using the name Miami Transit Co., took over the city-owned lined and merged Dunn Bus Service into the combined operation.

1948- Pawley bought Miami transit Company upon the death of George Dunn, taking the significant step toward solving some of Greater Miami's transportation problems[5].

4.1.3 Transit History 1956-1969

1956- Pawley bought South Miami Coach Line and the Keys Transit Company.

1957- July 21: The Metropolitan Dade County Government was officially established.

1964- The Miami Urban Area Transportation Study (MUATS) began with a feasibility study on transit for Dade County.

[5] http://www.metro-dade.com/mdta/1873.html (Last updated on 01/18/00.)

1969- Construction of the Central Division complex was completed at 3300 NW 32 Avenue, consolidating four separate garage facilities and the administrative offices of the Metro transit Authority into one unit[6].

4.1.4 Transit History 1971-1979

1971- The completed MUATS studies recommended as $800 million rapid transit system, and public hearings on the entire transportation plan began.

1974- Residents of Dade County strongly opposed the planned study for construction of six new expressways. These plans were later dropped from the transportation plan.

1975- August 31: The Coral Gables Transit System merged with Dade County as part of the Metro Transit Agency.

1979- January: The Board of County Commissioners created the Downtown People Mover Policy Committee (DPMPC).

June: Groundbreaking for the Stage I system was held at the site of the University Station. The system would be known as Metrorail, and would feature 17 stations initially, with two more to be added with the extension to Hialeah[7].

4.1.5 Transit History 1980-1982

1980- The first of 260 General Motors RTS II Buses began operating on the streets of Dade County.

April: In a letter to Metro-Dade County, the Urban Mass Transportation Administration (UMTA) advised that it would commit $50 million to the DPM project subject to future congressional authorizations.

[6] http://www.metro-dade.com/mdta/1956.htm (Last updated on 01/18/00.)
[7] http://www.metro-dade.com/mdta/1970.html (Last updated on 01/18/00.)

May: Metro-Dade County received a written Full Funding Agreement from UMTA to provide 80% of the remaining construction cost for Metrorail, a first for a rapid rail project.

1982- March: UMTA granted Metro-Dade County $25.6 million additional for final design and construction of Stage I DMP.

October: The first Metrorail vehicle was completed by the Budd Company in Philadelphia and shipped to the US Department of Transportation Test Center in Pueblo, Colorado.

November: The first rail is set into place the Metrorail guide way near the Dadeland South Station[8].

4.1.6 Transit History 1983-1989

1983- February: The first Metrorail vehicle arrived at the Palmetto Yard and Shops from Pueblo, Colorado.

May 2: South Miami Station was dedicated, and the general public is given its first opportunity to ride Metrorail.

June: The Metrorail Bridge over the Miami River was completed. The rapid transit guide way was now a continuous ribbon of concrete from the Dadeland South Station to just north of the Overtown Station.

July 15: Douglas Road Metrorail station was dedicated.

August 26: Dadeland North Metrorail station was dedicated.

September 16: University and Dadeland South Metrorail stations were dedicated.

December 2: Coconut Grove and Vizcaya Metrorail stations were dedicated.

1984- February 10: Brickell Metrorail station was dedicated.

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[8] http://www.metro-dade.com/mdta/1980.html (Last updated on 01/18/00.)

April 10: Metrorail's girder #2,704 was hoisted into place at the Northside Station, marking the end of girder installation in the 20-mile Phase I Metrorail system.

May 18: Overtown Metrorail station was dedicated.

May 20: Government Center Station was officially dedicated, and Metrorail begins south-line service to ten stations from Dadeland South to Overtown Station. Rides were free to the public for the day. Over 125,000 participated in the opening-day event and rode the new system. Metrorail began operations in the Automatic Train Protection (ATP) mode.

May 21: Metrorail starts revenue service. Regular fare--$1; reduced fare--$.50 (during off-peak hours for senior citizens, people with disabilities, and youth in grades 1-12).

November 19: Allapattah Metrorail station was dedicated.

December 7: Civic Center and Santa Clara Metrorail stations were dedicated.

December 15: Earlington Heights Metrorail was dedicated.

December 17: Metrorail service was extended north to Earlington Heights station.

1985-May 1: Metrorail began a "Bikes on Train" program, a six-month demonstration allowing riders to bring their bicycles on the trains during limited hours on weekends only. A permit was required.

May 19: Service is extended to the final five Metrorail stations, thus completing service between Dadeland South ad Okeechobee.

December 9: Metrorail started Automatic Train Operations (ATO).

1989-February: Metrorail ridership reaches 40,000 per day for the first time.

March: Metrorail unofficially adds its 21st station to the system when the Tri-Rail Station opens for passenger service. The official opening of this station, which connects Metrorail with the Tri-Country Commuter Rail service, is set for June.

May: Metrorail celebrated its 40 million rider. Also, MDTA opened its first Transit Service Center at Government Center Station on May 17. Mayor Stephen P. Clark cut the ribbon to open the center, and Commissioner Charles Dusseau joined Mayor Clark in the ceremony.

June 5: Dade County officially dedicated the Tri-Rail Metrorail station, Dade County Mayor Stephen P. Clark, joined by Congressman William Lehman and Dade County Commissioner Charles Dusseau, Unveiled the plaque marking the station's official opening[9].

4.1.7 Transit history 1990-1996

1990-MDTA creates a 30-year plan to expand transit service in Dade County. Highlights of the plan include: adding 20% more bus service; upgrading the fleet and improving the access for the disabled with wheelchair accessible busses; and expanding Metrorail service an additional 39 miles. Implementation of the plan depended on securing a dedicated source of funding of transit.

November: Weekday Metrorail boardings averaged 50,3000, up from 48,400 in October. This represented a new high in ridership.

December: Metrorail carried over 101,000 passengers for the annual King Orange Jamboree Parade in downtown Miami. This marked the highest single-day total in the system's history.

1991-January 31: There were 101,000 Metrorail boardings and 43,600 Metromover boardings on New Year's Eve, the largest number of riders ever for a single event during revenue service.

1992-The Metropolitan Planning Organization (MPO) released a report proposing an Airport Multimodal Facility combining bus, Metrorail, Tri-Rail (a tri-county

[9] http://www.metro-dade.com/mdta/1983.html (Last updated on 01/18/00.)

commuter service), Amtrak, high-speed rail, car rental services, auto pick-up/drop-off areas, and parking.

1996-June: The special Transportation Services (STS) Free-Fare Pilot Program ridership was analyzed through May 1996. Under this program, certified STS riders could opt to ride free on Metrobus, Metrorail, and Metromover by showing their ID card to the bus operator or rail security officer. There was no loss of STS certification. STS ridership continued to decrease by 4.71% when compared to FY 94-94 data.

August: The preliminary design for the Metrorail extension to the Palmetto Expressway was presented to the Transportation Aesthetics Review Committee, which granted tentative approval of the design, pending a follow-up presentation to include proposed landscaping lighting, and surface treatments[10].

4.2 Metro

The Metro in Washington D.C. project began in 1952 and first opening on March 1, 1976. It was more than four decades of planning and building went into creating the transit system that now serves the metropolitan Washington region.

The Metro rail now has served for an area of 1,500 square miles with the population of 3.4 million. There are 78 stations, 96.6 miles (154.46 kilometers). The last two stations opened on September 18, 1999, which are Georgia Avenue-Petworth and Columbia Heights stations. In the other hand, there are 5 stations, on Green Lin to Branch Ave, which were under construction and opened on January 13, 2001.

4.2.1 General Information

Fleet: 764 rail cars

[10] http://www.metro-dade.com/mdta/1990.html (Last updated on 01/18/00.)

Length: 96.6 miles of line (154.46 kilometers)

Stations: 78 stations

Service Hours: 5:30 a.m. weekdays and 8 a.m. on weekends

Closes at midnight on Sunday to Thursday

Closes at 2 a.m. on Friday and Saturday

Ridership: average of 610,116 per day

The Metrorail fare is break up to be regular fare, charged during 5:30-9:30 a.m. and 3-7 p.m. weekdays, is $1.10 base (0-3 miles), maximum fare $3.25 and the reduced fare, charged at all other times, is $1.10 (0-7 miles), $1.60 (7-10 miles), $2.10 (10+ miles).

4.2.2 History

1952

July 10: Congress passes National Capital Planning Act mandating preparation of plans for movement of people and goods in the region.

1954

July 1: Congressionally funded Mass Transportation Survey presented to President Eisenhower calls for $500 million rapid rail system by 1980.

1960

July 14: President Eisenhower signs National Capital Transportation Act creating National Capital Transportation Agency (NCTA) to develop rapid rail system.

1962

November 3: NCTA submits Transit Development Program to President Kennedy proposing an 83-mile, 65-station rapid rail system.

1965

September 8: President Johnson signs legislation authorizing 25-mile, $431 million rapid transit system of future expansion.

1966

November 6: President Johnson signs bill creating Washington Metropolitan Area Transit Authority.

1967

February 20: WMATA is officially born, coexisting with NCTA for seven months. NCTA expires September 30.

1968

March 1: WMATA Board unanimously approves 97.2-mile, 38.4 miles in District of Columbia, 29.7 in Maryland and 29.1 in Virginia, Adopted Regional System (ARS).

October 1: Original groundbreaking date is postponed pending release of District of Columbia Metro funds. Congressman William Natcher, who chairs House Subcommittee on Appropriation for District of Columbia, withholds Metro funds in effort to ensure funding for federal highway projects in District of Columbia.

November 5: 71.4 percent Voters decisively commit to Metro in Arlington County, Fairfax City, Fairfax County, City of Falls Church and Prince George's County through bond referendums to help finance local shares of Metro costs.

1969

February 7: WMATA adopts revised Rapid Rail Plan and Program including relocation of three stations. System size grows to nearly 98 miles. By September 29, 1969 all jurisdictions have approved.

August 9: Council of District of Columbia approves construction of highway projects, meeting a condition of Congressman Natcher for release of District of Columbia Metro funds.

December 9: Metro breaks ground at Judiciary Square with high-ranking federal, state and local officials participating and an estimated audience of 1,500.

1970

June 11: WMATA Board realigns approximately 2.5 miles of mid-city route to improve service for inner city.

1972

May 3: WMATA awards $91.6 million contract to Rohr Corp. for first 300 Metro cars.

1973

August 13: President Nixon signs Federal Aid Highway Act of 1973, authorizing up to $65 million for construction of facilities to make Metrorail accessible for persons with disabilities.

August 16: President Nixon signs bill enabling U.S. Department of Transportation to pay WMATA $90.4 million for fiscal 1974, $7.5 million covering (1) design and construction of Arlington Cemetery station and (2) National Mall entrance to Smithsonian station.

1975

October 10: District of Columbia begins six-year transfer of $2.2 billion of interstate highway funds for Metro construction.

1976

March 27: Six years, three months and 23 days after groundbreaking, Metrorail has its opening day.

March 29: On first day of revenue service, 19,913 passengers ride on 188 train trips. System is open 6 a.m. to 8 p.m. weekdays and closed on weekends.

June 4: President Ford signs bill authorizing creation of Metro Transit Police.

1978

February 6: Red Line begins service to Silver Spring, adding four stations and 5.7 miles of line.

August 16: WMATA, at request of U.S. DOT, presents financial plan for completing and operating Metrorail system to Secretary of Transportation Brock Adams. Adams says, "The federal government agrees with the goal of completing the 100-mile system over the next several years."

September 25: Metrorail extends weekday hours from 8 p.m. to midnight.

September 30: Metrorail begins Saturday service 8 a.m. to midnight.

November 20: Orange Line opening to New Carrollton begins Metrorail service to Prince George's County.

1979

September 2: Metrorail begins Sunday service from 10 a.m. to 6 p.m.

1980

January 3: President Carter signs Stark-Harris bill authorizing $1.7 billion to finish Metrorail construction.

November 22: Benning Road, Capitol Heights and Addison Road stations open, was adding 3.5 miles to Blue Line.

1981

June 25: WMATA orders additional 200 rail cars from Breda Costruzioni Ferroviarie for about $200 million.

December 5: Van Ness-UDC, Cleveland Park and Woodley Park-Zoo stations open, was adding 2.07 miles to Red Line.

1982

January 13: First crash is preceded by a major snowstorm. Three are dead, 25 injured.

1983

April 30: Yellow Line begins operating from Gallery Place-Chinatown to National Airport, crossing Potomac on Metro's Charles R. Fenwick Bridge.

May: First of new Breda Metrorail cars arrive.

December 17: Yellow Line opens from National Airport to Huntington.

1984

August 25: Red Line begins operating 6.81-mile segment to Grosvenor.

September 13: WMATA Board adopts plan to complete 89.5 miles of 101-mile system using Stark-Harris federal funding and local matching grants.

December 13: WMATA Board selects Branch Ave terminus and St. Elizabeth's Alignment for southern portion of Green Line, increasing system mileage to 103.

December 15: Red Line opens 6.98-mile extension.

1985

April 11: Board approves 2.5-mile alignment of Green Line.

July 17: WMATA modifies safety plan to include passenger-activated escape doors in event of fire emergency aboard train.

1986

June 7: Orange Line opening East Falls Church, West Fall Church, Dunn Loring and Vienna stations in Fairfax County, which grows by 9.11 miles with

July 16: WMATA and Urban Mass Transportation Administration sign full-funding agreement to continue building 89.5-mile system.

1987

January 22 and 25: WMATA undertakes major winterization program to improve performance of rail during extreme snow and ice conditions.

June 19: Extraordinary Metro repair efforts restore service since Metrorail is not operating because of CSXT freight cars derail into Metro.

September 5: Derailing CSXT cars tear up Metrorail. Incident leads to intensive safety precautions and studies by WMATA and CSXT.

1988

January 8: Trains run without major problems in a 10-inch snowfall.

February 3: On the day that Washingtonians welcome Redskins home from Super Bowl victory with parade, Metrorail sets ridership record of 564,265 trips.

March 17: CSXT and WMATA announce joint recommendations to improve safety along shared rail corridors.

April 28: WMATA Board adopts budget with no fare increase for the fifth consecutive year

August 24: Metrorail carries one-billionth rider.

October 4: American Public Transit Association awards WMATA its top honor, the *Public Transportation System Outstanding Achievement Award*. Metro dubbed *America's Subway.*

1989

January 20: Metrorail sets ridership record of 604,000 during induction of President Bush.

1990

May 18: Metro awards $6.3 million contract to Cubic Western Data to upgrade fare card vendors, add fare machine.

June 21: WMATA Board installs pay telephones on station platforms.

September 22: Red Line begins operating north of Silver Spring to Forest Glen and Wheaton stations, adding 3.2 miles to system.

October 27: Congress gives final approval to legislation providing additional \$1.3 billion in federal funding over eight years for construction of rail system.

1991

May 11: First Green Line stations open in 1.66 mile segment north of Gallery Place-Chinatown.

June 7 and 8 (Friday and Saturday): Metrorail sets the highest ridership on a Saturday - 786,300 trips, and highest weekday ridership - 577,800 trips.

June 15: Blue Line opens, 3.57-mile extension bringing system to 79 miles and 67 stations.

December 19: WMATA Board approves financial plan that sets schedule and funding for *Fast Track* program for finishing 103-mile Metrorail system by 2001. *Fast Track* allows Metro to build remaining 13.5 miles faster and within \$2.07 billion approved by Congress and local governments.

December 28: Metrorail opens 2.88-mile Green Line segment.

1992

April 26: Metrorail begins opening at 8 a.m. instead of 10 a.m. on Sunday.

1993

January 20: Metrorail sets new ridership record, 811,000 trips, during President Clinton's Inauguration Day.

December 11: Metrorail begins service on 7.96-mile Green Line segment, which connects with Red Line at Fort Totten. This completes 89.5 miles of the 103-mile system.

December 31: Metro completes its safest year of heavy construction. Injury rate, 0.8, is fraction of industry average, 5.8.

1995

May 22: Metrorail carries two billionth riders.

September 27: Metro unveils Passes/Fare card vendors at Metro Center.

October 16: *Million Man March* yields second highest ridership in Metro's history—804,000 trips.

November 3: Metrobus carries its three billionth passenger.

November 16: The first Metro station built with private funds by an agreement of WMATA and RF&P Corporation formally signed to build Potomac Yard station with RF&P funds.

1996

March 29: WMATA celebrates 20 years of providing efficient, reliable transit.

1997

January 1: Metro offers monthly pass, which unlimited MARC-Metrorail or VRE-Metrorail travel Commuter rail to riders from Maryland and Virginia.

January 20: Rail system remains open until 2 a.m. since President Bill Clinton's second inaugural draws 620,000 passenger trips to Metro.

January 27: Green Line Shortcut begins as six-month experiment. Later, shortcut is continued because of its success in drawing new riders.

April 1: Maryland General Assembly budgets $4.7 million in FY '98 for preliminary engineering and environmental impact study on extension of Blue.

June 26: WMATA Board approves White Flint East, Metro's largest joint development project to date. To be phased in over 11 years, the 32.42-acre project includes 1.2-million sq. ft. of office space, 100,000 sq. ft. of retail space and 1,338 residences.

June 29: Service begins to Franconia-Springfield, adding 3.3 miles to Blue Line and increasing Metrorail to 75-station, 92.4-mile system.

October 4: Promise Keepers makes the system opens at 4 a.m. and causes Metrorail registers to be the fourth highest ridership, 725,900 trips.

1999

March 1: WMATA begins selling fares, passes and merchandise online.

May 18: WMATA launches SmarTrip, the permanent, rechargeable plastic fare card that is good for Metrorail trips and Metro parking.

June 23: Mayor Anthony A. Williams announces a financing plan for a New York Avenue station on the Red Line between Union Station and Rhode Island Ave station.

November 5: As part of an eight-month experiment, Metrorail extends hours to 1 a.m. on Friday and Saturday nights.

2000

January 1: As a precaution against Y2K glitches, Metrorail hours are extended to 3 a.m. The 21.5- hour day, which begins 5: 30 a. m. December 31, generates 415,000 rail trips

January 31: Metro moves customer service operations to its new Call Center near Silver Spring station.

4.3 San Francisco Bay Area Rapid Transit District[11]

The Bay Area Rapid Transit District (BART) is a 95-mile, automated rapid transit system serving over 3 million people in the three BART counties of Alameda, Contra Costa, and San Francisco, as well as northern San Mateo County.

BART, opened in September 1972, has carried over one billion and a half passengers more than 18 billion passenger miles with approximately 325,000 riders daily on weekday. BART's use of energy is three times as efficient as an automobile in its total energy consumption and ten times as efficient during rush hours in the commute direction. BART trains operate from 4 a.m. to midnight Monday through Friday, 6 a.m. to midnight on Saturday and 8 a.m. to midnight on Sunday.

BART system has 39 stations comprise 12 surface, 13 aerial and 14 subway stations featuring elevators, ramps, platform edge warning titles for the vision-impaired and specially marked parking stalls permit full access to the system by elderly and handicapped persons.

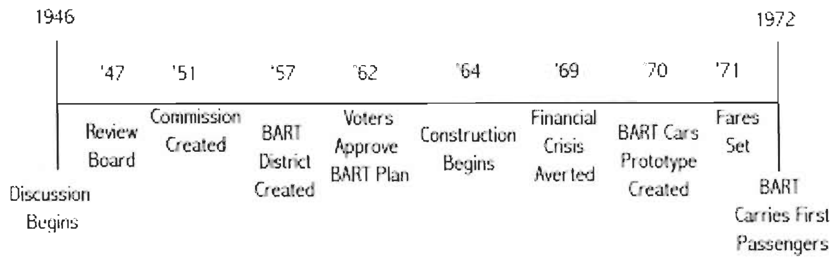
The aluminum-body train is third rail propulsion powered by 1000-volt DC electricity equipped with one 150 hp motor per axle, four motors per car. The train also has carpet, air conditioning, and tinted windows. Maximum speed for the train is 80 mph and 33 mph average, including 20-second station stops.

Estimated Cost (U.S. dollar)

Total cost of basic system (exclusive of Transbay Tube	1,443,000,000
Cost of Transbay Tube	176,000,000
Total Cost	1,619,000,000
Sources of Funding:	
1962 General Obligation Bond Referendum	792,000,000
California Toll Bridge Authority	176,000,000
Proceeds of Sales Tax Revenue	150,000,000
Earnings from Temporary Investments	111,000,000
Transit Development	24,000,000
Miscellaneous Income	51,000,000
Federal Capital Grants	330,000,000

[11] http://www.bart.org/general/history/sysfacts.htm

4.3.1 History of BART[12]



In 1946, BART concept slowly began with informal gatherings of business and civic leaders on both sides of the San Francisco Bay. Facing a heavy post-war migration to the area and its consequent automobile boom, these people discussed ways of easing the mounting congestion that was clogging the bridges spanning the Bay.

In 1947, an underwater tube concept, devoted exclusively to high-speed electric trains was born by a joint Army-Navy review Board. The result concluded that another connecting link between San Francisco and Oakland would be needed in the years ahead to prevent congestion on the Bay Bridge.

In 1951, the State Legislature created the 26-member San Francisco Bay Area Rapid Transit Commission, comprised of representatives from each of the nine counties, which touch the Bay. It was to study the Bay Area's long-range transportation needs in the context of environmental problems and then recommend the best solution.

[12] http://www.bart.org/general/history/index.htm

In 1957, The Commission advised in its final report that any transportation plan must be coordinated with the area's total plan for future development. Since no development plan existed, the Commission prepared one itself. The Commission's least-cost solution to traffic tie-ups was to recommend forming a five-county rapid transit district, comprising the five counties of Alameda, Contra Costa, Marin (which was forced to withdraw in early 1962), San Francisco and San Mateo (which voted to withdraw from the District in December 1961). Their mandate would be to build and operate a high-speed rapid rail network linking major commercial centers with suburban sub-centers.

From 1957 to 1962, engineering plans were developed for a system that would lead in a new era in rapid transit. Electric trains would run on grade-separated right-of-ways, reaching maximum speeds of 75-80 mph full of advanced functions, with sophisticated suspensions, braking and propulsion systems, and luxurious interiors. Stations would be pleasant, conveniently located, and striking architectural enhancements to their respective on-line communities.

BART had 11-member governing Board of Directors apportioned on county population size: four from San Francisco and Alameda, and three from Contra Costa. Afterward, in 1965, the District's enabling legislation was changed to apportion the BART Board with four Directors from each county, thus giving Contra Costa its fourth member on a 12-person Board. The County Board of Supervisors, hence forth, appointed two directors from each county. The other two directors were appointed by committees of mayors of each county (with the exception of the City and County of San Francisco, whose sole mayor made these appointments).

Supervisors of the three counties approved the new detailed plan and presented as the "BART Composite Report," in July 1962.

BART construction officially began on June 19, 1964, with President Lyndon Johnson presiding over the ceremonies for the 4.4-mile Diablo Test Track between Concord and Walnut Creek in Contra Costa County. The test track, completed ten months later, was used to develop and evaluate sophisticated new design concepts for BART's transit car and automatic train control system.

The District's General Engineering consultants, Parsons-Brinkerhoff-Tudor-Bechtel (PB-T-B), a joint venture enterprise formed to manage all technical, as well as construction aspects of the BART project was in charge of construction management, overall design of system facilities, equipment and monitoring of BART's major contractors.

In May 1967, the first major equipment contract was awarded, for the nation's first fully automatic train control system, to Westinghouse Electric Corporation.

In July, 1967, the first tunneling in the western U.S. done entirely under compressed air conditions, the project produced a succession of "firsts" in constructing the subway and stations in a difficult mud and water environment which required one of the greatest concentrations of tunneling crews and equipment in construction history.

In July 1969, the contract for the production and delivery of BART's electric transit cars was signed with Rohr Industries, Inc., of Chula Vista, California.

As early as 1966, it became increasingly clear that the District would fall short of funds to complete the system. The only apparent solutions were an infusion of more funds, or a drastic scaling-down of system miles to fit the original budget. Major construction contracts were rewritten and re-advertised in anticipation of the threatened cutbacks.

As the crisis deepened, BART directors refused to compromise the planned 71.5-mile system until every possible alternative could be explored. Finally, in April 1969, after three years of debate, the State Legislature granted the District's request for $150 million of authorizing the levying of a half-cent sales tax in the BART counties. The needed funds thus came from the sales of bonds pledged against the sales tax revenues.

Thus, changes and improvements increased the valuation of the system considerably from the original estimates...a cost factor that is frequently and incorrectly confused with the true project cost over-runs on specific contracts.

As the system neared completion, the construction engineers so long in charge began making way for a wide range of electronic engineers and technicians, computer experts, and other specialists. Their job was to install and prove out the automatic train control system, plus three maintenance shops and train yards at Hayward, Richmond, and Concord, a staggering array of communications and wayside equipment.

The first prototype car was delivered in August 1970. Meanwhile, IBM was readying the first group of prototype fare collection machines, which it demonstrated to District Directors in October.

In December 1971, the District Board adopted the official inter-station fare schedule, ranging from 30 cents minimum to $1.25 maximum fare. Also, approved the following month were 75 percent fare discounts for patrons over 65 or under 13 years of age, with discount tickets to be sold through local bank branches instead of at BART stations.

The 1971-72 period saw the gradual phase-out of major construction work, and the beginning of the transition from a construction-oriented organization to an operating railroad. New areas of emphasis included marketing, personnel training, planning feeder bus service to stations, and across-the-board preparations for revenue service. The District staff, up to 765 by mid-1972, had almost tripled in three years to build up the transportation and maintenance force for revenue service.

5 Analysis

This section analyzes the data that is presented in the Results section. This section also analyzes any acknowledged problems of BTS and our suggestions on solving these problems based on our data that we have gathered.

5.1 What are the acknowledged problems of BTS?

5.1.1 Price

This could be the most important problem for BTS, because the fare is still high for most riders. It cost much more compared to other transports. For instance, it costs 4.50 Baht by bus, 15 Baht by air-conditioned bus, but it cost 35 Baht by sky train for the same distance. For people who have their own cars, it is cheaper to drive than to ride the sky train over the same distance. They spend less on gas compared to the fare.

5.1.2 Lack of Ridership

The system is quite new for Bangkokians. Change is something that Bangkokians, somehow, find hard because they have become attached to how they live. People still bond to the way they have been and continue to travel same way they were. Also most of the working class people, whose have high enough salary, usually have their own cars. Normally they think that it is more convenient to drive than to travel by the mass rapid transport since they do not have to wait for the train, they have their own privacy, and they could stop on the way. Moreover, riders preferred to take the bus rather than the sky train because they could get off closer to their destination since the distance between bus stations is closer than the distance between sky train stations.

5.1.3 Lack of Stations

There are few stations available on the systems, twenty-five stations at the moment. The service area is still small but the demand for system coverage area is high. While they are expanding the coverage area, it does not satisfy people outside the area. It is hard to extent the service area because all lands are occupied and it is very hard to expropriate the land.

5.1.4 Handicap Access

They built the stations without considering on accessibility for handicapped persons. The platforms are difficult to get to, very few elevators available for handicapped people. Handicapped issue is not among the top of the "TO-DO" list in Thailand because, normally, most handicap people do not go out since it is inconvenient for them to get around. However, the BTS is trying to improve their systems to handle this handicap issue. They are installing elevators in all of the stations.

5.2 Chart Lessons

5.2.1 Time Factor

It would take some time before things settle down. All three U.S. systems have been established for more than twenty years compare to Bangkok Sky Train, which began its operation for only one year. For transportation, it would take more than one year to apprehend how things are. We can evaluate the system better in term of financial condition, economics, management, and traffic after 3-5 years of operations.

5.2.2 Peculiar Mix of Public and Private

One of the reasons why Bangkok Sky Train has trouble financially is that they would need some support from other sources. BTS is a privately own company with some government supports whereas three of the U.S. systems have a stronger government support. It seems, from the chart, that government support increase the stability of the systems, which means BTS would need more supports from the government. Government could pass some laws to assist and encourage BTS to have more riders and a better system. Public sector is another area to consider. BTS could get financial aid or loan from international bank or financial institution. A joint-business from other companies could be helpful also.

5.2.3 Fare Issue

Even though the fares of all systems cost about the same, the proportion of fare and income is different between BTS and the other U.S. systems. The income of the average BTS riders is much lower than average U.S. riders while paying the same price. For example, a U.S. rider whose pay $2.00 per day while earning $80 (fare cost 2.5% of income) compare to a Thai rider pay 80 Baht while earning 160 Baht (fare cost 50% of income). Thus, the sky train fare is relatively expensive compare to the U.S. fare.

	BART (San Francisco Bay Area Rapid Transit)	Miami-Dade Transit	Metro D.C.	BTS (Bangkok Mass Transit System)
Project Begin	1946	1873	1952	1971
Construction Begin	June 19, 1964			October 3, 1994
Opening	September 1, 1972		March 1, 1976	December 5, 1999
Years of Construction	8			5
Ridership	325,000	45,800	804,000	
Hours of Operation	4 a.m. - midnight (Mon. - Fri.) 6 a.m. - midnight (Sat.) 8 a.m. - midnight (Sun.)	5 a.m. - midnight (7 days a week)	5:30 a.m. weekdays and 8 a.m. on weekends closes at midnight on Sunday to Thursday closes at 2 a.m. on Friday and Saturday	6:00 a.m. - 12:00 a.m. everyday
Mileage	95 total		92.4 total	14.6 total
No. of Stations	39 (12 surface, 13 aerial and 14 subway)	21	78	23
Stations Features	Elevators, Ramp		Elevators, Ramp	Elevators
Stations Equipment	Automatic Fare Collection (AFC)		Farecard Vending Machine	Cash
Train System :-				
Propulsion	Third rail propulsion power (1000V DC)			Third rail propulsion power (750V DC)
Feature	Aluminum body, carpeting, air conditioning, tinted widows			Motorised trailer cars, Stainless steel body, air-conditioning, noise barrier
Track gauge	5' 6" wide compare to 4' 8" standard			1.435 meter
No. of Cars	680 total 450 A- and B-cars 150 C-cars 80 C2-cars	136 total	764 total	56 total
Speed	80 mph maximum; 33 mhp average	55 mph		50 mph maximum; 21.75 mph average
Control System	Automatic Train Control (ATC) Operations Control Center (OCC) Sequential Occupancy Release System (SORS)			Automatic Train Control (ATC) Electrical & Mechanical System Built-in automatic protection systems
Basic Fare	Minimum $1.10; maximum $4.70 (for one-way trips)	$1.25	Minimum $1.10; maximum $3.25	Minimum $0.25; maximum $1.00
Special Fare	Children 4 and under ride free. Children 5 - 12, senior citizen and person with disabilities may perchase special ticket	$0.60 for medicare card holder, elderly, people with disabilities, and youth grades 1-12	$0.50	
Total Cost	$1,619,000,000	$1,030,000,000		$1,333,700,000
Population	745,774	368,624	523,124	6,547,000

6 Conclusions

The purpose of this project was to compare the similarities and differences of various mass rapid transit system in the United Stated of America and Bangkok, and propose changes that will improve mass rapid transit system in Bangkok. The proposals will hopefully enhance the system to be more user and environmental friendly, more accessible to public, safer, more stable, higher performance, quality, and better system for Bangkokians.

The Bangkok Skytrain project was considered to be the newest technological improvement in Thailand. The system is still immature and there are some improvements that need to be done. The other systems from the U.S. were chosen for the comparison to obtain the advantages and disadvantages of the Bangkok Skytrain system. The U.S. systems were researched, studied, and summarized then compared with the Bangkok system. The similarities and differences were categorized, judged, in finding the best possible solution to improve the Bangkok system.

After an intensive study was done, the recommendations were introduced

6.1 Suggested Recommendations.

6.1.1 Time

Since the system is still new, it will become more stable eventually in a long run. In general, it usually takes some time for people to adjust themselves to get used to new things and for business to become settled.

6.1.2 Financial

Since the economy in Thailand is still unstable, BTS could get a financial support from other sources rather than rely on their own expenses. Those sources could be from banks, financial institutes, other private firm, or from government subsidies.

6.1.3 Government Supports

Government could assist on many issues such as financial, land, subsidies. They could pass a law such as parking bill, which could reduce the number of people who used their cars and increase the number of ridership in the future. They could also raise gasoline price, automobile tax. They could charge a toll for entering and exiting downtown or commercial areas.

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8 Appendix

8.1 BTS Project: Civil Work

Introduction

BTS project is to provide 23.5 km-long mass transit system to serve major commercial and business districts of central Bangkok. The project will provide trips within Central Bangkok and suburban residential areas and allow for integration with potential feeder sources and for possible future expansion. BTS system utilizes elevated pre-cast box-girder viaduct structure to support double tracks for train services. Reinforced concrete column and pilings are used for the underlying support **(see Figure 1).** There are 23 stations along with 2 BTS routes, i.e., Sukhumvit Line and Silom Line, including the Central Station at Siam Square. Depot, which consists of a workshop and stabling facilities, is located at Mo Chit to facilitate maintenance services and train stabling. The construction of the project is ongoing and is scheduled to operate on January 2, 2000.

The objective of this paper is to provide basic technical information of construction of civil works of the BTS project with the focus on the construction contracts, design criteria and construction of stations are also described for thorough understanding of the reader. The construction and project progresses are also reported.

Construction Contract

For mega-project including the BTS project, it is a common practice to adopt the Turnkey Contract paradigm. BTSC's Turnkey Contract is a fixed-price, performance guaranteed contract in the exception of utilities diversion work that diverting cost is based on unit price. The contract is turn keyed to a SITD Consortium consisting of Italian Thai Development, Siemens Limited, and Lincas for civil works, E&M works and E&M supplies, respectively. Under the Turnkey Contracts, the contractors are obligated to design, construct, test and commission the entire system. The complete system must meet pre-defined performance standards before being put into commercial operation.

There are several rationales underlying the application of this type contract. First, the Turnkey Contract allows BTSC to minimize risks for cost overrun and schedule delays. Second, the Turnkey paradigm allows the fast-track development of the system, which is, design and construction can concurrently proceed. Design-built method is preferable for the project of this magnitude to expedite project development time. The contract term is 39 months from the order to proceed on October 2, 1996.

Design Criteria

Structural designs of the entire structural system completely comply with the international standards such ACI (American Concrete Institute), AASHTO (American

Association of Stat Highway and Transportation Officials), UBC (Uniform Building Code), AISC (American Institute of Steel Construction) and British Standard.

The design of the viaduct structure is comprehensive. Design of the viaduct structure has been provided to cover all possible effects that can cause failure to the structural system such as increase of train configuration, lurching, derailment load, longitudinal force, broken rail effect, rail structure interaction collision load, wind load, collision impact of trains, thermal force, earthquake and combinations of these effects. The comprehensive design provisions ensure that the structural integrity will be maintained at all time. Station design has also been kept at the same standard with additional load provisions for escalators and surcharge pedestrian load.

The renowned J. Muller International (JMI), who pioneered and posses extensively experiences on this construction method, is appointed as the prime structural designer for the project.

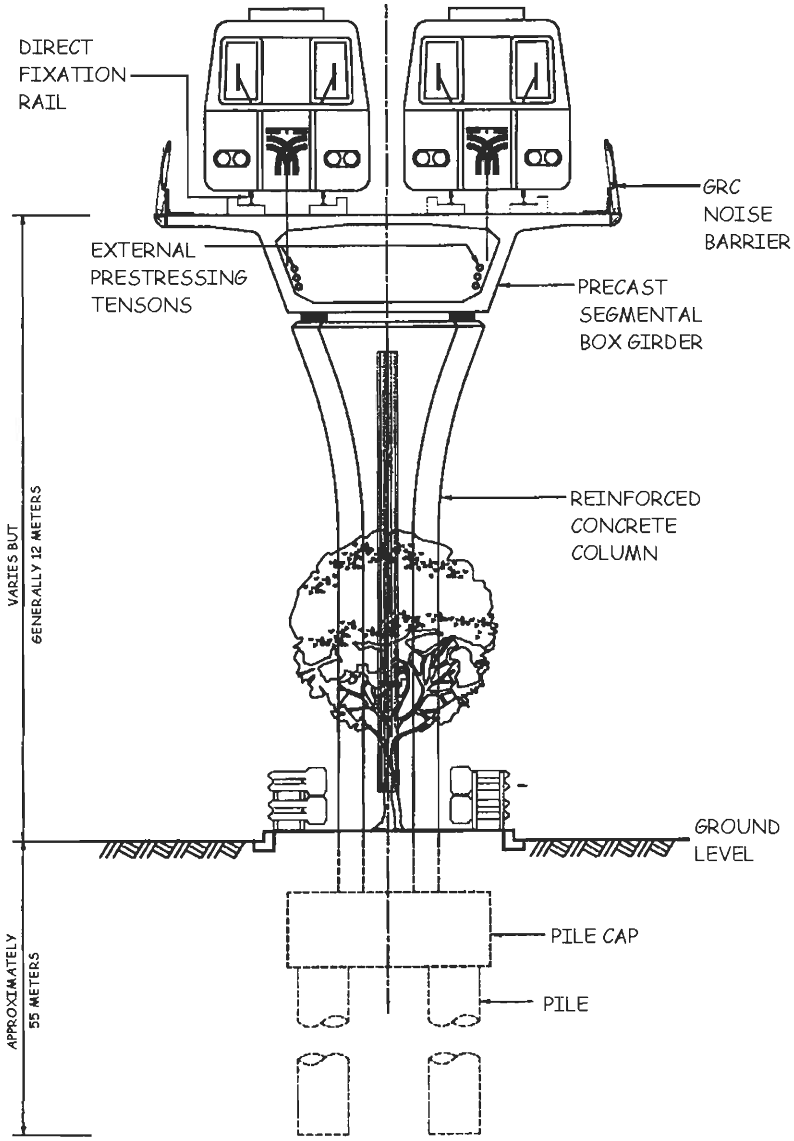


FIGURE 1: TYPICAL COLUMN AND VIADUCT

Construction Methods

Civil Works construction can be categorized into 3 major elements the Viaduct Structure, Stations, and Workshop Depot/Administration Building.

Viaduct Structure consists of piles, pile cap, column and the viaduct. The structure is typically elevated approximately 12 meters above the ground. The viaduct is supported by these column with each span is generally 35 meters long with the deck is typically 9 meters wide. The viaduct is constructed with pre-cast concrete segments erected by trusses and then externally stressed together. This pre-cast segmental construction represents a dominant aspect from construction point of view will be extensively described in the subsequent paragraph followed by construction of Station and Depot/Administration Building.

Pre-cast Segmental Construction

There are 2 primary rationales for adopting the construction paradigm. First, the construction paradigm offers the fast construction process where there is no need for false work. The speed of construction of the system derives from the ability to support an entire span, assembled at the work front and stressed in one operation. The span is then positioned and the erecting equipment moves to the next span to repeat the cycle without waiting for in-site follow up work.

Second, because false works are not placed on the street, the technique minimize disruption to traffic flows in the street of downtown Bangkok where the structure is constructed. Comparing to the use of pre-cast I-beam that has been extensively use in several infrastructure projects in Thailand, the segmental construction holds the competitive edge when transportation of these pre-cast components is a major concern. Each pre-cast segment is much shorter and lighter than a pre-cast I-beam that makes its transportation through narrow, congested downtown streets less effort. In contrast, transportation of an I-beam on a long trailer truck can impose several difficulties where curves and turns are prevalent. Additionally, because of its manufacture-like characteristics, quality of the production can be easily controlled.

The pre-cast segmental viaduct construction has the following principal steps:

- Segment casting
- Transportation
- Erection
- External post tensioning

Segment Casting

The contractor adopts the "short-line match" casting technique, which is, a segment is cast in a stationary form against a conjugate segment. The conjugate segment (which was previously cast) is the segment that is segment that is adjacent to the segment being cast when erected in position as a part of the superstructure. Match casting these segments thus creates a perfectly fit between the two segments.

There are certain sequences in casting the viaduct segments. First the starter segment, which the typical segment, is cast between the fixed bulkhead and additional moveable bulkhead since there is no adjacent previously cast segment. After casting and survey for geometry data of segment #2, it is moved to the conjugate position for casting segment #3. After casting and survey of both segment together, segment#2 is removed and segment #3 is shifted to the conjugate position for casting segment#4. The process is repeating until segment #12 is cast.

Segment#1 and segment #13, which is the "pier" segment, are cast last. Because they are pier segments, these two segments will be cast after obtaining the survey data from the "as-built" pier. The geometry data of as-built pier incorporated with as-cast conjugate segment (#2 or #12) are used to adjust position during casting this pier segment (#1 or #13)

Transportation

Based on the planned schedule, segments are transported from the casting yard to the construction sites by prime mover/trailer transporters operating in a convoy. In normal condition, all segments for each span will be transported in one batch. The transportation of segments is done at the nighttime to avoid the congested traffic during the early evening hours.

Erection

There are 5 Under-slung Trusses and 1 Overhead Truss to carry out segments erection for the BTS project. These two types of erection trusses are different in several aspects resulting in difference in their applications.

Under-slung Truss System – The under-slung truss system consists of two parallel girders 90 meters long, which are positioned under the wings of the segments adjacent to the webs and supported off brackets at the concrete columns. In general, a mobile crane will be used to lift the segments off the delivery vehicle and placed them on the girder. The segments can then be rolled to the appropriate location within the span and accurately oriented by the use of hydraulic jacks and shims. After all segments for each span have been properly positioned, the longitudinal pre-stressing tendons are placed and the span is subsequently stressed. Then a pre-stressed span is lowered onto the bearings on top of the column to complete the erection process. The girder can then be launched forward to the next span and the rear pier support.

Overhead Truss System – The overhead truss system consists of a single truss structure with front and rear supports sitting directly on top of columns. A launching trolley is suspended from the truss bottom chords and this is used to lift a segment from the delivery vehicle. Support of the segment, is transferred to vertical hanger and the trolley released to collect the next segment. Jacks on the bar supports are used to accurately position each segment. Once all segments are suspended from the hangers the longitudinal pre-stressing tendons are placed and the span is stressed and lowered onto the bearings to complete the erection process. The truss can be launched forward to the next span utilizing temporary front and rear supports.

Each Truss system posses its own advantages and disadvantages. The choice of trusty is primarily depending on the type and geometry of the superstructure. Erection by the under-slung truss is preferable and is the faster method. However, the system is only suitable for relatively straight sections of superstructure. Limited clearance below the structure and portal frame support are limiting factors.

Erection by the Overhead truss is generally slower due to the complexities of the launching process. However, for the curve span, the Overhead truss is the only viable method. Production by the Overhead along the Rama I road outpace some of the under-slung lately due to the number of viaduct decks per span (4). The rate of one span per day has been achieved on this route.

External Post Tensioning

After all segments are positioned properly, the span is longitudinally stressed by the external tend, placing inside the box of the viaduct. The tendon anchorages are located at both pier segments and the required profile of the tendons is achieved by deflecting the tendons through deviator blocks cast into a number of segments (deviator segments) located within the span. Apart form these points of contract; the tendons are freely suspended within the box section of the viaduct. The high strength steel strands bundling up tendons are enclosed in stiff polyethylene duct and are protected by injecting a cement grout into the duct to ensure long term durability.

Station Work

Stations are typically built on top beams crossing out of columns. **Figure 2** in the following pages display simplified sequences of construction of a typical station. After piles, pile cap and column are cast during step 1 to 3, a concourse cross beam (step 4) and the station column head (step 5) are cast. Then the pre-cast segmental viaducts are erected between station spans (step 6) and concourse pre-cast I-beams are placed (step 7). The platform cross beam can then is cast (step 8) and the platform pre-cast I-beams can be placed (step 9). Step 10, 11, and 12 are in restricted sequences and are adjusted during the course of construction. Pre-cast slabs for concourse and platform can be placed any time after their underlying I-beams are placed.

Depot and Administration Building

Administration building is the 11-floor building with reinforced concrete columns and post-tensioning flat slabs structure. The external shell is using the curtain wall system with insulated glass and granite. The building is nearly complete and operational.

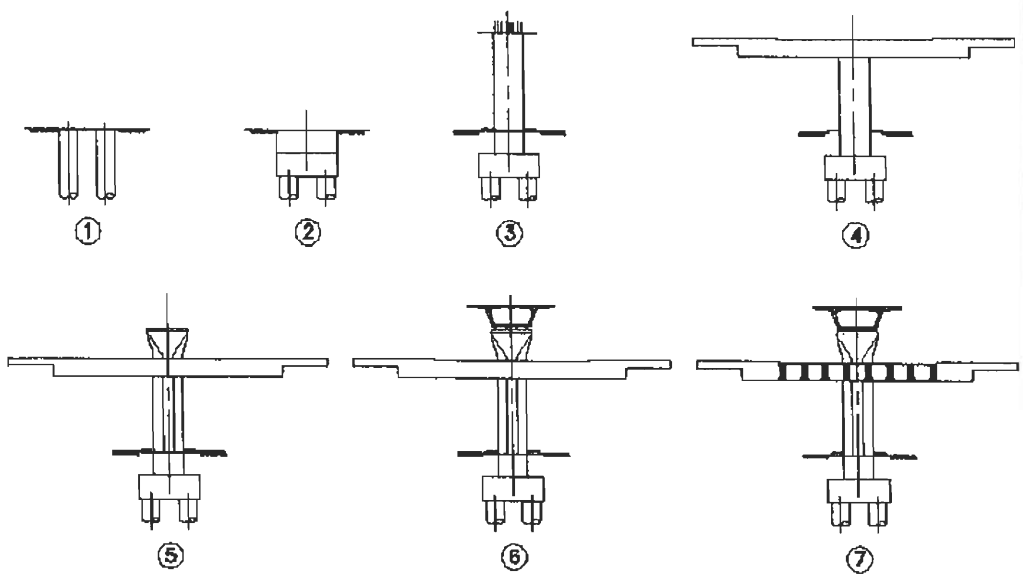
Depot consists of workshop area and stabling area. The structure is reinforced concrete with mostly post-tensioning slabs. Slabs inside the workshop area consist of train tracks, work pits and several foundation slabs for workshop equipment.

Casting Yard

Construction of the viaduct and station will not be able to proceed progressively with the industrious support from the casting yard. The main casting yard for the BTS project is located at Wihan Daeng, Saraburi. The yard is mainly responsible for casting, handling, storing, pre-stressing and testing of viaduct segment, I-beam for station concourse and platform, pre-cast slab for station concourse and platform. Steel roof structures and steel staircases for stations are manufactured in this yard, as well.

Other than manufacturing and casting structural components, the casting yard at Wihan Daeng provides a testing bed for workability of any novel erection techniques and/or new equipment that may arise during the course of construction.

FIGURE 2 : STATION CONSTRUCTION PROCESS



<u>Construction and Project Progress</u>

The progress is estimated as the following at the end of July 1998:

- Civil Progress 72.5%
- E&M Progress 63.5%
- Overall Progress 68.0%

Design for both civil works and E&M works are nearly finished with 92% and 99% complete. The progress of the project is on the appropriate pace and the commercial operation of January 1, 2000 is on target.

Viaduct Works

The viaduct structure including piles, pile cap, column and viaduct are approximately 80% complete. Stations, Depot and Administration are 37%, 89% and 83% complete respectively. A summary of viaduct construction progress is shown below in **Table 1**.

Table 1

Viaduct Construction Progress

Activity	% Completed
Piling	99.9
Pile caps	99
Columns	97
Viaduct Spans erected	65
Stations	
Conc I-Beams erected	70
Conc Crossbeams	89
Platform I-Beams	50
Platform Crossbeams	70

Pre-cast Works

A summary of pre-cast works progress at the Wihan Daeng casting yard is shown below in Table 2.

Table 2

Pre-cast Works Progress

Activity	% Completed
Double Track Segments	90
Single Track Segments	85
Concourse I-Beams	95
Platform I-Beams	67
Cable Troughs	44
Noise Barriers	71
Concourse PC Slabs	79

E&M works

Most of E&M works are still during the manufacturing phase with installation of these elements are increasing. The following Table 3 summarizes progress of major elements of E&M works for BTS project.

Table 3

E&M Works Progress

Activity	% Complete	
	Manufacturing	Installation
Track work	100	22
Third Rail	100	4
Power Supply	96	20
Signaling	84	2
SCADA	100	25
Telecommunication	93	4
Automatic Fare Collection	39	0
Rolling Stock	54	-

Conclusion

BTS project adopted the fast track, design built paradigm to expedite the project development duration. The paradigm allows the contractor to design and construct concurrently. Designs have complied with the international standards.

Construction of Civil works of the BTS project consists of three major elements: viaduct structures, stations and Depot/Administration. The construction of viaduct structure adopts the pre-cast segmental construction technique because it offers fast construction process and induces minimum disruption to traffic. Quality of the production can be controlled because of its manufacture-like characteristics. Station constructions also use pre-cast structural component to control quality and expedite construction time. Constructions of Depot and Administration building have been conventional with reinforced concrete column and post tensioning slab.

The progress of BTS system is approximately 68% overall at the end of July 1998. Civil works progress is approximately 72.5% and E&M works progress is approximately 63.5%.

Srisethanil, Chaisad, Ph.D. "BTS Project: Civil Works", Bangkok Mass Transit System Plc.: Bangkok, 2000.

8.2 BTS Project: Power Supply System

Introduction

This paper describes briefly the philosophy adopted in achieving a reliable power supply system for the BTS network.

The target of installing a reliable system has been set right from the starting point of the power network, i.e. the 24 kV MEA intake substation. Then by progressing down the line to 24 kV distribution network, various scenarios of failure modes have been considered. The system is designed to facilitate quick restoration of power. The same consideration applies to the traction power feeding scheme as well as the station's auxiliary power supply network.

Apart from having a reliable network by providing alternative feeding and certain standby equipment, consideration is also given to the importance of the continuous functioning of some essential services in the railways and the ultimate safety of passengers. For this regard, the uninterruptible to the power supply system.

Other features adopted to mitigate emergency situations include the use of flame retarding low smoke zero halogen cables along the lines and the installation of fire fighting system in the station substations.

The energy needed to operate BTS system including the traction and the service power (400 V AC) has to be derived from the power supply network. Traction power (750V DC) is uses to energize the passenger train and the service power (400 AC) is to operate the signaling equipment, station lighting and escalators etc. The power supply network for the BTS system can be divided into the following three categories:

1. The AC (24kV) high-tension distribution network.
2. The traction power (750V DC) distribution network.
3. The service power (400V AD) distribution network.

Each of the above is serving its own purposes and, hence, merits a different set of considerations in order to achieve a reliable network, which in turn will meet the ultimate goal – a reliable, and safe train service.

The AC (24kV) High Tension Distribution Network

The BTS power network obtains power from the local authority, the Metropolitan Electricity Authority (MEA), at the voltage level of 24kV. There are all together two intake sub-stations (MEA sub-stations) located strategically at Mo Chit Depot and Paisingto (1.5 Km from station E4). The power from the MEA sub-stations are fed to the two bulk sub-stations (BSS's) the 24kV power is distributed to 12 Traction Substations (TSS) and 25 Station Sub-station (SSS) including Depot (D00) and the Administration Building (A00) via the 24kV cable trenches laid along the track routes.

The station sub-stations (SSS's) transform the 24kV AC to 400V AC for the station auxiliary loads including signaling, AFC, ventilation and fire fighting system, etc.

The traction sub-station (TSS's) are located at specified stations in which the 24kV AC power is converted to 750V DC traction power for the trains. The 750V DC positive (L+) is distributed via the third rail where the train motors take the power from as the DC negative return is collected via the running rails.

It is a requirement of BTS power supply design that in the event of one MEA sub-station failure the BTS system can still be maintained and run from power supply provided from the other MEA sub-station. In other word, the two BTS bulk sub-stations are designed such that they are tied together at Central Station for this purpose. The power capacity of each the MEA sub-station for BTS usage is 40 MVA (total 80MV A with two sub-stations). It is capable of supplying all BTS's load demands in accordance with the requirements specified in the Design Criteria Specifications. The BTS distribution system is totally independent and is electrically separated from the MEA sub-station. Controls of earthling systems of MEA's and BTS' are also independent from each other.

The 24kV distribution network is separated into 2 major rings **(See Electrical Overview Diagram)**. The 24kV traction service is in the form of closed rings and in normal operation the following 3 rings are formed:

- *North bound ring* – Depot – N7 N3 – Central Station – N5 – Depot
- *East – South bound ring* – E4 – Central Station – S5 – S2 – S3 – E4
- *East bound ring* – E4 – E5 – E9 – E7 – E4

The advantage of this kind of closed ring is that a single cable fault will not interrupt the 24kV supply to the traction sub-station.

The 24kV station service is in the form of open rings with two separated ring main units (RMU's) and auxiliary transformers at each station. The advantage of open rings in the station sub-station cable network is that there will dedicate trappings in the affected ring. There are two auxiliary transformers in each station and each transformer is capable of handling all station load requirements. In normal operations three rings are formed:

•North bound ring (ring SSS1) Depot-Admin Bldg-N8 to N1-Central Station-W1

(ring SSS2) Depot-Admin Bldg-N8 to N1-Central Station-W1

•East South bound ring (ring SSS1) E4-E3-E2-E1-Central Station-S1 to S6

(ring SSS2) E4-E3-E2-E1-Central Station-S1 to S6

•East bound ring (ring SSS1) E4 to E9

(ring SSS2) E4 to E9

The Traction Power (750V DC) Distribution Network

In each traction sub-station there is one rectifier transformer (with the exception of Central Station where there are two rectifier transformers) operating to provide a 12 pulse rectified DC power to the third rail. In the future an extra rectifier transformer will be installed in the reserved a space in the traction sub-station to operate in parallel with the existing rectifier transformer to meet the additional demands of the 6-car trains. The traction sub-stations are normally designed to locate in alternative stations with a few exceptions.

Each rectifier transformer set is rated at approximately 2 MW continuous with a higher short time rating to meet the peak demand from the railway.

The traction power is transmitted to the track by the third rail system with bottom contact. An insulated cover shrouds the top three sides of the third rail. The two running rails with those from the adjacent tracks are used as return conductors. This arrangement will greatly reduce the volt drop along the rails, and, together with tail insulation as well as floating traction power system, will alleviate the stray current corrosion problem.

The traction power supply network is so designed that, with a complete outage of a single traction sub-station, the railway's normal operation will not be affected.

The Service Power (400A AC) Distribution Network

Each passenger station is equipped with two auxiliary service transformers, two main low-tension (400V AC) distribution boards and an emergency distribution board backed by a diesel generator set.

Normal building services loads are fed from the distribution boards. Essential loads such as signaling and telecommunication equipment etc. are fed from the uninterruptible power supply system (UPS), which in turn is fed from the emergency distribution board. Emergency lighting loads are also fed from the emergency distribution board that is also backed up by the diesel generator set.

Chaingam, Tin. "BTS Project: Power Supply System", Bangkok Mass Transit System Plc.: Bangkok, 2000.

8.3 BTS Project: Automatic Fare Collection System (AFC)

Introduction

BTS adopted the AFC system to ensure that the proper fare will be collected from the passenger. The BTS Fare collection System is a Closed System that all passengers are required to have ticket to enter into BTS system at the station and also when to leave the destination station.

Additionally, AFC also produces statistics of the passengers flow in-out of the BTS system. This statistical data can be used for planning and improving traffic management of BTS train services.

The AFC system consists of the following equipment:

- Ticket Issuing Machine (TIMs)
- Ticket Analyzer/Dispenser (A/D)
- Automatic Gates
- Station Computers
- Central Computer
- Tickets (SJT, SVT)

Passenger Flow

A passenger, who does not have ticket, can purchase a Single journey ticket from the Ticket Issuing Machine (TIMs) located at the unpaid area of a station, or, can purchase Stored Value Ticket at the ticket office in the station. After the passenger obtains a ticket, he will insert the ticket into the automatic gate in order to enter the BTS system. The automatic gate will check whether the ticket is valid. If the ticket is valid, the gate will open to allow that passenger to enter the BTS system. The Automatic Gate will also write date/time, gate information, station information, etc., into each ticket.

At the destination station, the passenger will insert the ticket into the automatic gate again to exit from the BTS system. For the single journey ticket, the gate will check again if the ticket is valid. If the ticket is valid, the gate will open and the passenger exit from the system as the ticket will be captured within the gate. For the stored value ticket, the gate will check the validity of ticket. If the ticket is valid, the gate will open and the ticket will be returned to the passenger and passenger can leave the BTS system. For both cases, if tickets have problems, the gates' displays will conduct the passenger to ticket offices that are at both ends of station.

Ticket Issuing Machine (TIM)

Ticket issuing Machine (TIM) will be provided in the unpaid areas at both ends of the station concourse level. A passenger can buy a single journey ticket from TIMs. TIM has 10 buttons for the passenger to select the amount of fare.

To buy a ticket, a passenger selects the fare ticket button on the TIM face. Then the display will show the required amount of money for that ticket. The passenger inserts coins into the TIM's coin entry bezel. When the number of coins is equal or more than the required fare amount, and TIM has checked that coins are not fraud, a ticket will be issued to the passenger. During this process, if the cancel button is pressed, TIM will cancel the remaining steps and return coins to the passenger.

TIM is designed to accept 1, 5, 10 and another future coin. Bank note is not accepted. In case of TIM runs out of change, the display "NO CHANGE" will light. However, the passenger still can buy the ticket (but without change).

Automatic Gate (AG)

Automatic gates (AGs) are provided on the station concourse level to separate paid and unpaid areas of station. The functions of AGs are to control passengers entering the system and to inspect, update and control passengers' tickets.

Automatic gates in station can be entry, exit, or reversible type. They are the flap barrier type. Normally, the flap barrier of each gate is closed. When a valid ticket is inserted into ticket bezel, flaps barriers will open and let passenger enter or exit from the BTS system.

Analyzer/Dispenser (A/D)

The Analyzer/Dispenser (A/D) will be provided in ticket offices at both ends of the station concourse. The function of A/D is to dispense, analyze and update passenger tickets.

The A/D will be in the dispenser mode when a passenger wants to buy ticket. Due to the policy only stored value tickets will be sold from A/D.

The A/D will be in the analyzer mode to analyze the passenger's ticket that has problem with the automatic gate. The ticket officer will use A/D to analyze ticket and update it such that the passenger can use that ticket to entry or exit BTS.

Station Computers System (SC)

Each station computer (SC) will be provided for each station. The functions of SC are as follows:

- *Control and monitor all the station AFC equipment* – The station staff can control AFC-equipment from the station computer (e.g., to switch TIMs on-off, to switch automatic gate on-off or to reverse the direction of the gate). The alarms and faults of the station AFC-equipment are also reported to the station computer.

- *Receive station AFC-equipment's parameter and fare table from Central computer and load to station equipment* – The fare table and parameter of each station AFC-equipment will be sent from the central computer to each station (e.g., fare table for the station, TIM's button parameter, function of each gate). The station computer will further send those data to the station AFC-equipment.

- *Receive transaction data from station AFC-equipment and further send them to the Central computer* – All information, traffic and sale transaction, and fault from the station AFC-equipment will be sent to station computer and further send to the central computer in the administration building.

Central Computer System (CC)

The Central Computer System (CC) will be provided the Administration building. The CC will link to station computers in stations via telecommunication-fiber optic system. The major functions of the central computer are as follows:

- *Poll and collect information from the SCs* – Central computer will periodically poll and collect data from each station computer. The data transfer from station computers is no need to be on-line. The central computer will do it periodically.

- *Input and upload operating parameters and fare tables* – The operating parameters of the station AFC-equipment can be input and updated from the central computer. Data will be sent from the central computer to each station computer via optical fiber system of the telecommunication system.

- *Generate reports from collected data* – After the central computer receives data from all station computers, it will generate reports. The reports are ticket sale, passenger statistics and equipment status and fault reports. The reports are required by financial, planning and audit departments.

- *Storage of AFC information in a relational database* – All data that sent to the central computer and being further printed out making reports are still kept in the central computer's database. The stored data will be used as backup data, and for monthly and yearly summary reports.

- *Response to A/D SV ticket queries* – The data of the stored value ticket usage will be kept in the database. These data will be sent to the station's analyzer/dispenser when required.

Tickets

Ticket used in the BTS system will be the magnetic strip – credit card size – polyester type. Every ticket will be pre-encoded with a permanent unique serial number that can be changed.

There will be only ticket serial number on a ticket before a passenger purchases it. When a ticket is used, the essential data will be written into that ticket (e.g., date and time of purchase, purchased from, the gate that this ticket enter to a station, or exit from a station, etc.).

Two types of tickets for passenger used in BTS are:

- *Single Journey Ticket (SJ)* – The Single Journey Ticket can be purchased at TIMs in each station. It is valid for a single trip, as the application fare is less than or equal to the value of the ticket.

- *Stored Value Ticket (SV)* – The passenger can purchase a stored value ticket that has prepaid value on it. The value is deducted from the ticket each time the passenger uses this ticket for BTS services.

Jirapapun, Pakdi. "BTS Project: Automatic Fare Collection System (AFC)", Bangkok Mass Transit System Plc.: Bangkok, 2000.

8.4 BTS Project: Telecommunication System

Introduction

The Telecommunications System of the BTS system comprised of the following subsystems listed below. These subsystems provide facilities that are capable of handling all voice, visual and data communications necessary to operate, maintain, and administer the BTS railway.

The Telecommunication System Comprises of:

1. Fiber Optic Transmission system.
2. Telephone system.
3. Radio system.
4. Closed Circuit Television (CCTV) system.
5. Public Address (PA.) system.
6. Time Distribution (Master Clock) system.
7. Uninterruptible Power Supply (UPS)

Fiber Optic Transmission System

In order to ensure reliable and efficient communications, all stations, Depot and Administration center will be connected by a "backbone" fiber optic transmission system that will carry voice and data signals through out the railway system.

Open Transport Network

Open Transport Network, known as OTN, is the fiber optic transmission system used to serve all the communication needed in BTS system. It is named Open Transport Network because it is "open system". It allows the system to fulfill almost all data transmission requirements for time, voice, local area network (LAN), video, Public Address and special service. Such capabilities make OTN the ideal system for the dynamic environment such as the BTS system.

OTN Architecture

Major equipment of the OTN system is as follow:

1. The Fiber Optic Backbone
2. The OTN Nodes
3. Interface Cards
4. The Network Control Center (NCC)

Each OTN node is installed at stations, administration building and Depot. They are connected together by duplicate point-to-point fiber optic rings as primary and secondary ring. In normal situation, all data in the primary ring are processed while the second ring keeps synchronized. In the case when problems happen and the primary ring cannot serve the system, the second ring will be used (in part or all the ring depends on the defective of the system).

The fiber optic transmission system for the BTS is configured into two separate rings – Silom and Sukhumvith ring. Both rings are connected to the Network Control Center at the Administration Building.

To ensure a fully resilient system, each of the fiber optic cables will only link between alternate stations and interlink cables will bypass the intervening stations on the opposite side of the track to connecting drop and insert cable. The result is known as 'hopping'.

Network Management

The OTN system will monitor the status of system and in the event that fault happens. It will reconfigure system such that minimum fault affects the system.

Interface

The various system, that need communicating within the BTS railway system, will connect to OTN system by mean of interface cards.

The example of the interface cards used in the BTS is as follows:

- Internal Telephone system - Analog voice (2 wire) Interface Card
- Radio system - 4 wire Voice E&M Interface Card
- Public Address system - High Quality Audio Interface Card
- Time Distribution system - RS 232/RS 422 Interface Card
- Automatic Fare Collection system - Thin wire Ethernet Interface Card
- SCADA system - RS 422 Interface Card

Bandwidth

The model of OTN used for BTS is OTN 150, which has a true bandwidth of 147.455 Mb/s. The current transmission requirement of BTS system is less than 30% for both Silom and Sukhumvith ring.

System Monitoring

If major faults occur, the OTN system will report to SCADA system and will be analyzed by technical controllers at the control center.

Telephone System

BTS Telephone system is to provide normal and emergency voice communication throughout the railway system including stations, Depot and the Administration Building.

The telephone system for BTS is divided into 2 functions, normal telephone and direct line telephone.

Normal Telephone

Normal Telephone includes office telephones in administration building, stations and in the Depot. These telephones are capable of making calls both within BTS as an Internal Call and outside BTS by connecting to central office trunk lines.

Direct Line Telephone

The Direct Line Telephone is for direct call to the designed destination number only e.g. the direct line telephone in the station control room can only call to the appropriate Line Controller.

The Direct Line Telephone will be provided at Control Center, Station Control room, Plant room and on the Platform – To make a call by direct line telephone, is only lift the handset the call will automatically routed to the designed destination. At the destination side e.g. Line controller; list of the incoming call will show at the operator console. The Controller can select and pick up the call.

The PABX

The PABX used for BTS will be Simens Hicom model 372 that will serve the requirement of BTS. The provided PABX performance is as follows:

- 544 Analog Telephone Lines
- 1 Maintenance and Administration Terminal
- 6 Dispatchers Terminal
- 1 Attendance Console

- 1 Call Charge Computing Terminal
- 6 Radio to PABX links
- 40 Trunk lines to the PSTN

Remark: The final performance may be amended upon the final design of the train operation.

Interface

•*Trunk lines*

BTS Telephone system will connect to TOT Trunk lines. The number of lines to serve BTS traffic is calculated to be 40 lines.

•*Radio-to-Telephone Links*

Other than connect to TOT Trunk lines, the telephone system will be interface to the BTS Radio system. To do in this way, the connection between radio user and telephone user is possible.

Public Pay Telephone

As required in the BTS's performance specification, each station of BTS will be provided with public pay telephone facility. The number of public pay telephone is appropriately calculated to match the number of the passenger flow of the particular station (1 phone/ 75 passenger/minute). The minimum requirement is 4 public telephones per station.

Radio System

The Radio System is to provide wireless communication among the fixed location radio operators such as the control center at the Administration Building, train radio users and hand-portable users throughout the BTS system.

The Trunking Radio System is chosen for the BTS because it has high efficiency to serve the railway operation environment.

The system will have a control channel for every radio sets to report to the main control of the system. The other channels are called traffic channels that may be 2-3 channels for BTS. The control channel will be used at the first time when the radio tries to establish a call. After its requirement is acknowledged the main control will manage them (conversation pair radios) to use one of the vacant traffic channel. When the conversation is finished the occupied traffic channel will be vacant again ready for the next required conversation pair.

Close Circuit Television

In order to ensure the safety of passengers, staff and vehicles and to provide security surveillance, the CCTV system is provided to BTS.

BTS-CCTV system will base on color cameras and monitors. Normally, they will configure as 1 camera to 1 monitor. They are provided in the following areas:

- Station CCTV System
- Administration Building System
- Depot CCTV System

Station CCTV System

Each surveillance camera is provided to monitor station escalators and two cameras are provided for under station area. The monitors of station cameras will be in the station control room where the station supervisor can make control and command from there.

Administration Building CCTV System

The Administration building, which is the center of BTS – operation and vital equipment, will be surveillance by CCTV system. The monitors of the administration building CCTV system will be at the building manager room where it will be 24 hours occupied.

Depot CCTV System

Each area is Depot where the road crossing the train track will be under surveillance by the CCTV camera to ensure the safety to staff, vehicles and trains. The train wash plant in Depot will also be under surveillance. The monitor of the Depot CCTV system will be at the Depot Controller Console in the Central Control Room.

<u>Public Address</u>

BTS-PA system is to provide (one way) communication to passengers and staff in BTS-station, trains and in the Depot. It will be used in case of train delay to announce necessary information and in emergency.

BTS-PA system is the modern computerized based PA system that can make announcement to BTS areas via the telecommunication fiber optic and radio system.

Station Public Address System

The PA announcement in station can be made from Line Controller Console (of the station), Station Control Room or PA-Call Station at the station platform. The Line Controller can make PA announcement to each zone in any station or all zones in all stations in his line.

Depot Public Address System

Depot-PA system will announce to the Depot workshop areas. It is possible to make announcement from the Depot Controller Console in the Central Control Room or from the PA-Call Station in Depot.

Tran Public Address System

The PA announcement in train is possibly made by the train driver or by the Line Controller via the radio and fiber optic system. The Line Controller can make PA announcement to any train or all train in that line.

Time Distribution

Master Clock System

The Master Clock System is to provide synchronized time signals for system equipment and clocks throughout the railway. The Master Clock, located in the Administration building, will be continuously updated via time signals from the GPS Receiver. The Master Clock will distribute time signal to all slave clocks in the Administration building, and via OTN to Sub-Master clocks in all stations and Depot. The Master Clock also distributes time synchronization signals to many of the railway systems.

The system consists of the following main components:

- GPS Receiver
- Master Clock
- Sub-Master Clocks
- RS Data Clocks
- Slave Clock
- System Monitoring

Uninterruptible Power Supply

TEL-UPS will be provided in Stations, Administration Building and Depot. They will supply 220 Volt, 50 Hz single-phase powers to essential systems.

Each TEL-UPS has the capacity to supply power to essential systems for 30 minutes prior to the back-up generator to take this duty.

Jirapapun, Pakdi. "BTS Project: Telecommunication System", Bangkok Mass Transit System Plc.: Bangkok, 2000.

8.5 BTS Project: Passenger Vehicle

Introduction

The characteristics and determination of the fleet size of Passenger Vehicles for the BTS System are designed to meet passenger forecast. Among other things, safety concern is given the highest priority, and incorporated into the designs of every system. The BTS train is ergonomically designed. Bangkok condition and physical attributes of Thai people are taken into account in design, materials selection and tests of subsystems, to ensure that the complete train is suitable for operations in Bangkok. Train is equipped with air conditioning unit.

The train is constructed to well-proven designs. All materials and equipment are of proven designs and furnished by experienced manufactures. Subsystems will pass specific tests as required. After assembly, the complete train will be tested as integrated systems and finally test run on the Test Track in Germany. The train can run bi-directional from either end. During normal service for the public, the train runs in automatic mode supervised and controlled by computer.

The paper outlines the major elements of rolling stock design with particular emphasis on mechanical aspects. It reviews general specified requirements for major component and systems.

Design Consideration

BTS passenger vehicle shall:

- Provide safe, energy efficient, timely and comfortable transportation
- Have a walk through capability with evacuation door at the end of the train
- Be equipped with collision protection system, voice communication facilities, emergency alarm device
- Be designed to allow safe and easy access to all major subsystems for maintenance
- Be electro-magnetically compatible with the signaling, communications and other low voltage system
- Have an aesthetically pleasing appearance
- Incorporate the latest well-proven technology
- Be designed and constructed to minimize the generation of noise and vibration

International Standards, Codes and Regulations are applied where appropriate to every phase of train making. Some are listed below:

UIC	International Union of Railways
DIN/VDE	Deutsche Industries Norm
BS	British Standards
NFPA	National Fire Protection Association
ASTM	American Society for Testing and Materials
IEC	International Electro-technical Commission
FRA	Federal Railroad Administration

Principal Dimensions

As previously started, the following train dimensions are achieved after the above requirements and passenger forecast are taken into consideration:

- Length of car	21.5 m.
- Width of car	3.2 m.
- Height from floor to ceiling	2.2m.
- Width of Side Door	1.4 m.
- Height of Side Door	1.9 m.
- Wheel Diameter	0.85 m.
- Seat	42 per car
- Design standing density	6 passenger per m^2
- Total design capacity:	A Car: 280 passengers
	C Car: 301 passengers
- Bogies	2 per car
	2 axles per bogie
	A car: 2 motor bogies

	C car: 2 trailer bogies
- Motor	2 motors per motor bogie
	Asynchronous motor 230 kW
- Maximum Speed	80 kph
- Average Speed	35 kph

Major Subsystems

Major sub-systems of the BTS train include: car-body, car interior, communication system, couplers, operator's cab, passenger door, air conditioning and lighting systems, auxiliary system, propulsion system, bogie and suspension, and braking system.

Car-body

The car-body has 4 doorways along each side ensuring equal spacing along the entire train length. To satisfy the structural requirements, whilst achieving a lightweight and efficient structure, the car-body shell is fabricated primarily from aluminum alloy. The cab end is fabricated using molded GRP. There are 6 windows on each side of the train. The top portion of the windows is a flap type that allows more ventilation when necessary.

Car-body shell structural design was checked by Finite Element Method computer analysis and verified by load testing. The test confirmed satisfactory stress levels for loads and deflections.

Car Interior

The interior of the car is pleasing in appearance and free of sharp corners and edges in order to reduce the possibility of injury to passengers. The seating arrangement is in longitudinal pattern in order to maximize the standing capacity in the car. There are 3 seat-rows on each side of the car interior located between doors. Each seat-row, which is made of a single molded fiberglass, contains 7 seats.

Communication System

The operator's cab is equipped with radio system for communication with Control Center. To allow communication between the driver and passengers, intercom system is installed in both operator's cab and passenger saloon. Information can be announced to passengers in the train by the driver via public address system.

Couplers

Coupler is the part that connects cars together. It allows connection of the electrical and control lines of each car to form a train. There are two types: Automatic coupler, which is at the cab end of A-car; Semi-permanent coupler, which is at the non-cab end of A-car and both end of C-car.

Operator's Cab

The operator's cab is located at one end of A-car. Control of the train is done from the cab. It is equipped with control console, communication system, adjustable seat, train fault annunciation panel, fire extinguisher, first aid kit and other equipment necessary for operations of the train. Cab can be accessed via cab sliding side door. The cab is air-conditioned. The operator's cab is equipped with evacuation door, which can be in either ramp or sliding mode for controlled evacuation.

Passenger Door

Passenger doors are sliding type. There are 4 doors on each side of a car. The door is designed to avoid the possibility of passenger's trapping finger. The side doors operating function are interlocked with the propulsion and brake control. Train will not leave station unless all doors are closed properly. Likewise, the doors will not automatically open unless the trains stop properly at stations. Each door is controlled by motor. At the final closure of the door, the force applied to close the door will be reduced to prevent entrapment of limbs. In case of that a door is not closed because of trapping of something in between door leaves, the door will retract a bit then re-close.

An emergency release device is provided for each doorway on the inside of the car for passenger to activate in case of emergency.

Air Conditioning and Lighting Systems

Each car is equipped with two units of roof-mounted packaged type air conditioning units and ducted throughout the car. Ventilation of each car is accomplished by the blower of the evaporator units supplied as part of the cooling system and associated duct. The ventilation will be supplied by battery in case of power loss.

In the passengers' compartment, there are two rows of fluorescent lamp sets. Two incandescent laps are installed in the cab. In case of power loss, some lighting fixtures in the passenger saloon and the operator's cab will be supplied by battery.

Auxiliary Power Supply

An auxiliary power supply equipment or static converter of a 3-car unit is installed under C-car. The auxiliary power supply is independent from the propulsion system. The input is connected to the prime power with nominal 750 VDC from Third Rail via the train's current collectors. The equipments' output will provide supply for auxiliary equipment of C-car and via couplers for both A-cars. The auxiliary equipment is air conditioning system, compressed air system, lighting system, control system and other auxiliary loads.

One of major features of the static converter is Insulated Gate Bipolar Transistors (IGBT), which is widely used semiconductor with high electrical and thermal overload capacity. The converter is controlled by PWM microprocessor control and cooled by air.

One output of the converter is for nickel-cadmium storage battery which will supply emergency loads in case of power loss: propulsion and braking control, door control, public address system, operator's console, coupler control, Automatic Train Protection, emergency lighting, ventilation control, etc.

Propulsion System

The traction system of on A-car consists of two inverters, which are housed in one container together with Traction Control Unit (TCU). The inverter generates a three-phase AC system from 750 VDC supply via third rail with variable voltage and variable frequency and supplies two traction motors.

The TCU measures the actual values of DC link voltage, motor voltages, motor currents, speeds and determines the voltage and the frequency value for the motors based on the traction effort set point and other conditions, e.g., selected running modes, temperature, etc.

The PWM modulator converts the set points voltage and frequency into trigger pulses for the pulse-controlled converter. The pulses are transmitted from the TCU modules inverter monitoring via optical fiber to the gate units. The gate units amplify the trigger pulses to the required energy level and fire the IGBTs.

Traction motor is a self ventilated three-phase asynchronous motor. It is able to withstand mechanical and electrical vibration and shock loading. The motor is designed for operation with voltage source inverter. Power of traction motor is 230 kW.

Bogie and Suspension

Equipment for car-body support, suspension, power collection, driving and braking are assembled in to a bogie. Bogie is designed to be interchangeable. Each motor bogie under A-car is equipped with traction motors, whilst trailer bogie under C-car is not.

Resilient wheels (rubber cushioned wheels) are provided to significantly reduce the noise level. Diameter of a wheel is 850 mm. Two wheels are mounted on both ends of an axle. There are two axles per bogie, two bogies per car. Wheel flange is lubricated by a solid stick lubricant to reduce noise and wheel wear.

The train suspension system consists of primary and secondary suspension systems. The former consists of a pair of cone rubber springs. The latter is equipped with two air springs. Vertical hydraulic dampers are also provided.

Each bogie, in general, is fitted with four-wheel disk and caliper brakes. Therefore, each wheel is provided with wheel brake disks on each side of the wheel cheeds. Wheel slide protection system is provided to prevent the train from stopping too fast or wheel lock when brake applied.

Each individual axle on a motor bogie is provided with one drive unit – a traction motor, a flexible coupling and a gear unit.

Current collectors are arranged on each side of a bogie. Collector shoe is made of copper impregnated carbon contacting with third rail to pick up power to supple train.

Braking System

Braking is predominantly electric brake or regenerative: the kinetic energy of the vehicle is transformed into electric energy by the traction motors working as generators. The three-phase output voltage is rectified by the inverter and fed back to the third rail.

If the third rail is not receptive because of the limitation of line voltage, the required braking effort will be provided by appropriate blending with the rheostatic brake transforming the regenerated energy into heat in the brake resistor.

At the last section of braking process or when the train almost comes to a stop, the above electric brake fades out, friction brake achieved by brake disc and caliper is applied. In case of emergency, friction brake is also applied at the force appropriate to train speeds and loads.

Train Formation

At the initial operations, a complete train will be formed by 2 A-cars and 1 C-car: A-C-A. When required, two 3-car trains can be coupled together at the Automatic Couplers to form a 6-car train for more capacity.

Safety and Driving Modes

BTS train is installed with a safety system, Automatic Train Protection under Automatic Train Control system, to control and supervise the train to run in a safe manner either in automatic or manual modes. All possible driving modes have their own preset Maximum Safe Speed.

In automatic mode or Automatic Train Operation mode, which the train is run most of the time during services all functions of the train is controlled by a redundant computer system. In manual mode the train is controlled by the driver under supervision of the safety system. Alarm to the driver, will activate if the train is reaching maximum safe speed. If the maximum safe speed is exceeded, either the emergency brake is applied or the power is cut off.

Details of the safety system can be found in the Signaling System.

Testing

Each subsystem of a train will be well tested. After assembled, integrated systems will then be tested. Finally as a complete train, test run on the Siemens test track at Wildenrath, Germany will done. Test run will also be done locally to ensure safety.

Wattanaskolpant, Nataya. "BTS Project: Passenger Vehicle", Bangkok Mass Transit System Plc.: Bangkok, 2000.

8.6 BTS Project: SCADA System

Introduction

The SCADA (Supervisory Control and Data Acquisition) system is a centralized computer control system. The system is generally utilized monitoring and controlling of system equipment at remote locations. In the BTS system, SCADA is mainly used to monitor and control the BTS power network. The system provides automatic network reconfiguration, control and monitor of power supply equipment as well as fault monitoring of such equipment. The system also provides fault-monitoring features for BTS infrastructure (E&M equipment) such as fire alarm system, air-conditioning system, etc.

The system has various subsystems, each of which has independent intelligent units to increase system reliability.

Principle

The system shall have high security, reliability and sufficient speed to control the power network of the BTS system.

System Functions

The system performs the following functions.

1. Monitor and control the equipment in various systems from CCR. Such systems are:

- Power Supply System
- DC Traction Power

2. Interface with other systems to monitor status, alarm and fault of equipment in the various systems from the CCR.

- Fire Alarm and Fighting System
- Communication System
- AFC System
- UPS System
- ACV system (Air Conditioning and Ventilation system)

3. Interface with signaling system to provide DC traction Power information to the Central Traffic Control (CTC) system.

System Configuration

The system consists of the following major components.

- Central Control System
- Remote Terminal Unit (RTU)
- Communication Network

The Central Control System consist of

- Central Computers (Server Workstation)
- Man-machine interface (MMI workstation)
- Process Connection (DAS server)
- Tele-control Interface (TIF)

The Remote Terminal Units (RTUs) are

- RTU at Bulk Service Substation (BSS)
- RTU at Traction Service Substation (TSS)
- RTU at Station Service Substation (SSS)
- RTU at Administration Building (ADM)

Communication Networks are

- LAN of the Central Control System
- Communication link to RTU

<u>Equipment Functions</u>

Remote Terminal Unit (RTU)

Remote Terminal Units (RTU) is installed at the Administration Building and at each substation over the entire BTS system. It performs the following functions.

1. Signal input and Command output
    - Process the input signal from the monitoring equipment and transmit the data back to the Central Control System

- Process the output command from the Central System and output to the control equipment

2. Interface with the control unit of other systems

    - Process the data or signal input form the monitoring equipment and transmit the data back to the Central Computer System
    - Process the output command from the Central Control System and output to the control unit of other systems

Central Control System

The Central Control System is installed in the BTSC Administration Building at Mo Chit. It enables the engineering controller to monitor and control power network of the BTS system. The system provides ease of operating functions to utilize monitoring and controlling of BTS power network. Its functions are as follow:

- Process the data receiving from RTUs in a real-time processing manner and store the data into database
- Display the process data on the MMI monitor or output to the printer
- Give alarm audible when the equipment status change and parallel output to log printer
- Give alarm audible when the equipment fault or limit violate and parallel output to log printer
- Receive information from other system regarding fault then process alarm handling similar to other equipment in the system
- Supervisory control (switching operations, check of interlocking conditions) the power supply equipment
- Process the data in the database to be archive and historical data

- Report generation as required
- Send data to the Signaling system regarding the 3rd rail live status
- Provide man-machine interface function for the Engineering Controller

Communication Network

- LAN is a local network between computers and equipment in the RTU to Central Computer system. Gateway is provided to interface with other systems.
- OTN (fiber-optic) provides data link in point-to-point mode with RTU in the substations or elsewhere.

Input/Output (I/O)

The operation of the SCADA system relates to various systems for the required functions, i.e., supervision, control and interlocking. The I/O is required from the following systems:

- Bulk substation (24 KV infeed point)
- Traction power supply i.e. rectifier transformer, rectifier
- 750 V DC Switchgear, battery charger
- Third rail system i.e. isolator
- Station power supply i.e. RMU, isolator, LV circuit breaker
- Station infrastructures i.e. air conditioning system, fire alarm system, communication system, AFC system, etc.

CCR (Central Control Room)

The Control Center will be situated in the Administration Building at Mo Chit. The center provides operating facility for the Chief Supervisor, the Line Controllers, the Depot Controller and the Engineering Controller. Spare control positions will be provided.

Engineering Control Console (SCADA)

The Engineering Controller monitors and controls the entire BTS electrical network and monitors fault alarm the electrical and mechanical systems through the SCADA system. He has all necessary information available to enable the system to be "reconfigured" in the event of a partial failure.

Abbreviations:

BTS	Bangkok Mass Transit System
SCADA	Supervisory Control and Data Acquisition
RTU	Remote Terminal Unit
LAN	Local Area Network
BSS	Bulk Service Substation
TSS	Traction Service Substation
SSS	Station Service Substation
I/O	Input/Output
A/I	Analogue Input
D/I	Digital Input
D/O	Digital Output
CV	Counter Value
MMI	Man Machine Interface
DAS	Process connection

TIF	Tele-control Interface
COMM	Communicator Server
ADM	Administrator Server
ENG	Engineering Control Console (MMI)
RESV	Reserve MMI
TFS	Time System
AFC	Automatic Fare Collection
UPS	Uninterrupted Power Supply
ACV	Air Conditioning and Ventilation

Pakpayen, Chaiwute. "BTS Project: SCADA System", Bangkok Mass Transit System Plc.: Bangkok, 2000.

8.7 BTS Project: Operations

Introduction

The paper briefly describes the operations of the BTS System. The focus will be on how the System can be accessed by the public during Normal Operations. The operations of BTS can be described into three categories: Normal Operations, Degraded/Emergency Operations and the System Maintenance. During Normal Operations, every component of the System works properly. If incidents arise and the operation is disrupted, services will be provided as planned in Degraded/Emergency operation plan. Maintenance is a significant element of the system to ensure that high service level will be maintained and avoid any disruption.

System capacity, passenger and operating program during the Normal Operation are briefly summarized to enhance thorough understanding of the System.

Normal Operations

When all required works including Civil, Electrical and Mechanical works are completed and operations stuffs are properly trained, the BTS System is ready to provide service to the public. The following performance goals are to be fulfilled by the System:

- Safety of passengers, staff and the public
- Predictable travel time
- Clean, pleasant and user-friendly system
- Affordable system
- Flexible timetable to match actual demands

The System is expected to start commercial operations on January 1, 2000. At the initial operation, the System will have 35 three-car trains including 2 spare trains. The Normal Operations of the System is defined as the scenario that all system elements are working as scheduled and no defect or incident arises. The following technical information is planned during normal operations: (the term "headway" means the frequency of the train arriving at any station that will be varied to match the actual demand in any operating periods)

• System Operating Hours	05:00 to 24:00 midnight
• No. of Stations	23 stations, Central Station inclusive
• Lines	Sukhumvit Line and Silom Line
• Average operating line speed	35 km/h
• Peak Periods	07:00 to 09:00 and 17:00 to 20:00

• Operating Headway	Sukhumvit Line,	peak hours	2:19 min.
		Off-peak	3:33 min.
	Silom Line,	peak hours	3:47 min.
		Off-peak	4:24 min.

The Operating Control Center of the System is located in the Administration Building at Mo Chit. It will house the Line Controllers who supervise train traffic on the lines. The passenger station provides the access for the public to enter the BTS System. The stations reach out to the potential passengers at every 800-1,000 meters in distance along Sukhumvit and Silom Lines.

Typical Station is a 2-storey structure consisting of Concourse Level and Platform Level. whilst the Central Station—the interchange station where passenger can transit from one line to the other with the same ticket; contains one concourse and two levels of platforms to allow interchange between the lines.

The Concourse area of each station is equipped with Ticket Issuing Machine Automatic Barrier Gate, plant rooms, and fire fighting equipment, telephone booth, information signs, Ticket Office, first aid room, Police room and stairs to the Platform Level. The Ticket Office also serves as an Information Center. Passenger can buy tickets at this level.

Located above the Concourse Level, Platforms provide the facility for passengers to board and alight from the trains. In addition to passengers waiting areas, Station Platforms are typically equipped with fire fighting equipment and Emergency Stop Plungers to stop the train in case of emergency.

Access to the BTS System

The passenger can enter the BTS System at any station as convenient. The Concourse level is where passengers can obtain tickets and the Platform level is where the passengers alight or board a train.

At the first arrival on the Concourse, before passing the Automatic Barrier Gates, the passenger is standing on the "unpaid" area. Unpaid area is separated from the "paid" area by the Gates. To get into the "paid" area a valid ticket has to be inserted to open the Gates. A single Journey Ticket can be bought automatically from the Ticket Issuing Machine, whilst the Stored Value Tickets or multiple journey tickets are available at the Ticket Office.

After the valid ticket is inserted, the Entrance Gate opens, the gate machine will return the ticket to be used again at the Exit Gate when leaving the System. After the passenger gets into the "paid" area, he or she has to go to the platform via stairs from concourse level to board the appropriate train by consulting directional and information signs. Throughout a station, various categories of sign such as

Directional signs, Identifications signs, Information signs, and Statutory & warning sings are posted to assist and control flow of passengers.

The maximum travel time on BTS System, from Mo Chit to Onnut is less than 30 minutes. Comparing to the current transportation services, BTS obviously provides a much better alternative for Bangkokians.

The passenger who wants to switch from Sukhumvit line to Silom line, and vice versa, has to alight at the Central Station to transit to a train on the other line on the appropriate platform. A new ticket is not required for the transit.

Enforcement of BTS Byelaw, with the support from the Bangkok Metropolitan Authority, is necessary to ensure proper use of the system by passengers and to ensure safety to the public, staff and equipment.

Degraded/Emergency Operations

Degraded and Emergency Operations are the operations other than the above Normal Operations. The causes of abnormal operations may be from subsystem faults or incidents occurred in the System.

Level of potential hazard will be used to define if the scenario is Degraded or Emergency. Degraded Operations is defined as any circumstances, which effect normal service or require immediate unplanned maintenance actions but are not considered potentially life threatening to any passenger or staff. Whilst Emergency Operations is defined as any scenario that is potentially life threatening.

For both abnormal operations, BTSC has properly planned for any foreseen scenarios. Safety of human's life is given the highest priority in the operations plans. Provisions of necessary equipment have been made where appropriate in BTS premises—trains and buildings. Relevant operations personnel are well trained to cope with the incident.

During either degraded or emergency operations, passengers should follow the BTS staff's instructions properly. Most of the time, the passengers are required to detrain to a station for safety. Each station is designed to allow evacuation of all passengers from platform level to the landing at the next level in less than 4.5 minutes.

Detraining can be done from a train to a station or from a train to another train then to a station. BTS train is designed to allow detraining from train to train through passenger doors or evacuation door at the end of the operator's cab.

Facilities provided within the System that may be used by passenger when necessary are:

- In train: passenger emergency release to manually open door, fire extinguisher and intercom system for communication with the driver
- At station: emergency stop plunger at platform to stop arriving or departing train in case of emergency, fire fighting equipment on platform and concourse

The use of the above facilities shall be under local regulations and BTSC Byelaw.

Maintenance

Maintenance Center of the BTS System is located at the Mo Chit Depot at the opposite of the Chatuchak Park. Maintenance is planned to be efficient and economic, to ensure availability of every element of the System: Civil, Electrical and Mechanical system.

The workshop area is compartmentalized into sub-areas specific for each subsystem. Each sub-area is installed with equipment necessary for maintenance services and testing of the parts. Storage of spare parts is also located in the workshop and supervised by computerized inventory management system.

Maintenance of the System can be categorized as: Preventive and Corrective Maintenance.

Preventive Maintenance includes:

- Regularly service
- Routine inspection
- Scheduled maintenance
- Overhaul works

Corrective Maintenance includes:

- Trouble shooting
- Non-scheduled corrective works

Major equipment necessary for maintenance of rolling stocks is: Train Wash Plant, Under floor Wheel Lathe and Mobile Lifting Jack including body jacks and bogie jacks to allow parting of the bogie from the car-body.

Conclusion

BTS Operations is scheduled to start on January 1st, 2000. The system will provide fast, reliable, safe, affordable, and convenient mode of transportation for Bangkok residents. The System generally operates in the normal situation when all system elements are working as scheduled and no defect or incident arises. However, should the incident arises, BTS will have appropriate plans to alleviate and eliminate potential hazard. In any operating circumstances, safety of passengers will be maintained at all time.

To minimize the passengers' displeasures during the ride because of possible incidents, the entire System must be properly maintained. The BTSC Maintenance

Center at Mo Chit is fully equipped to perform the task to ensure the uninterrupted services throughout.

Chandrangsu, Dr. Karoon, Chief Operating Officer. "BTS Project: Operations", Bangkok Mass Transit System Plc.: Bangkok, 2000.

8.8 MO CHIT DEPOT

The Mo Chit Depot is located on Paholyothin Rd., opposite of the Chatuchak Park. Total area is 40 Rai. The Depot consists of 2 major developments:

Operations Control Center

Depot

They will serve as the system controlling center and trains stabling, cleaning, storage, maintenance and overhaul facilities.

Operations Control Center (OCC)

The 11-storey building, built on the 6 Rai land plot, serves as the BTS Headquarter. Each floor serves different functions and houses different Departments as following:

11^{th} Board Rooms

10^{th} Finance & Accounting/Legal

9^{th} Human Resources & Admin

8^{th} Strategy & Planning/PR/Marketing

7^{th} Operations

6^{th} Project

5th Project (Siemens)

4th Canteen

3rd Training

2nd Revenue/Operations

1st Reception

The Central Control Room (CCR), SCANDA room, Telecommunication room and signaling room is also located on the first and second floor of the OCC building. They serve as the controlling center for the BTS train operation.

Depot

Depot consists of two major areas- *Workshop* and *Stabling area*, to provide facilities for stabling trains, cleaning, maintenance/overhaul of trains, maintenance of permanent way, power supply, signaling, AFC, and communication system.

Stabling Area

Trains will be stabled on the track 1-13 which is equipped with third rails. Each track power can be separately switched on/off to ensure safe operation inside the stabling area.

Track 1-8: Each track can stable maximum 4 three-car trains

Track 9-13: Each track can stable maximum 5 three-car trains

Track 1 and 2 are for heavy cleaning using the Train Wash Plant located in front of these two tracks. Interior cleaning can be done on any tracks.

Workshop

The workshop area is divided into tracks for maintenance of train system, workshops for component repair, storage area for equipment and parts, and officers for maintenance and operations staff. Trains get into the workshop tracks via access ramp from mainline. For safety reason, third rail will end in front of the workshop. Power for trains will be obtained from singer system installed on the overhead rail along every workshop track. Necessary movements of trains can be carried out by a shunting vehicle or stinger system (for short movement). All tracks in the workshop (track 14 to 20) are equipped with overhead cranes varying in capacity to lift and move heavy train components to the appropriate area.

Maintenance of train system is categorized into Light Maintenance, Heavy Maintenance and Sub-system Maintenance.

Light Maintenance

Tracks 14 to 17 are designated for light maintenance including examination 1 (running gear inspection), examination 2 (service) and visual inspections of the trains.

Track 14

For 3- or 6-car train

Major equipment: Mobile Lifting Plants

- To facilitate certain services such as resolving of bogies

Other light maintenance e.g., changing lubrication

Track 15

For 3- or 6-car train

Major equipment: Under floor Wheel Lathe

- Wheel re-profiling system

To restore wheel with normal wear or flats to the correct profile without dismantling wheels and bogies from the car body

No subsequent trial run needed

Capable of turning tires automatically to the minimum tolerances required between wheels on the same axle and between axles on the same bogie

To re-profile single wheel sets and axle brake discs

Other light maintenance if needed

Track 16 & 17

For 3- or 6-car train

Major equipment: Mobile Roof Working Platform

- To service roof mounted A/C unit

To service under frame equipment e.g., traction motor, compressor units

Heavy Maintenance

Tracks 18 to 20 are designed for heavy maintenance including regular planned overhauls and major repairs as a result of mishap's.

Track 18

For 3-car train

Function similar to track 14, except that it can serve only 3-car train

To facilitate overhaul 1, overhaul 2 and component exchange (e.g., bogie, wheel set, traction motor, A/C unit)

Major equipment: Mobile Lifting Plants

Track 19

For 3-car train

Inspect, test, heavy repair, and overhaul of train bogies and under frame equipment

Major equipment: Mobile Scaffolding

- For roof work on A/C system

Mobile Lifting Plants on the track 18 can be moved to this track for similar functions and more flexibility

Track 20

For 3-car train

Inspect, test heavy repair, and component exchange (bogie, wheel set, traction motor, A/C unit, traction container, line filter)

Major equipment: Under floor Lifting Plant

- To facilitate heavy maintenance as described above

<u>Sub-systems Maintenance</u>

The area in the south of the workshop is divided into small workshop areas dedicated for maintenance of sub-systems. Each area will be equipped with special equipment required for service, cleaning and testing of sub-systems. These workshop areas can be categorized as following:

Wheel and Axle Shop, Bogie Shop: cleaning, dismantling, repair, fitting/testing of bogies and axles

Electric Traction Shop: dismantling, cleaning, repair, exchange of bearings and for fitting of traction motors

Air Conditioning Shop: exchange of A/C unit

Machine Fitting Shop: for general repair work on all components of the BTS system and train components

Electric Shop: for overhaul and repair electric components (e.g., power switch, breaker)

Battery Shop: equipped with battery changers

Auxiliary Shop: for maintenance staff training

Electric/electronic Shop: repair of electronic components of signaling telecommunication, AFC and power supply system

Other Major Workshop Equipment

Train Wash Plant

Located in front of the stabling track 1 & 2

For cleaning exterior of train

Use recycled water

Maximum speed of train while being cleaned in the plant is 3 kph (Wash Mode)

Service Vehicle

Diesel powered

Equipped with crane and trailer

For equipment delivery on track

Track Geometry Measuring Unit

Battery powered

For measuring rail geometry, e.g., cant, corrugation

Shunting Vehicle

Battery powered rail/road vehicle

For shunting of trains

Either run on normal road surface or tracks

Stinger System

Provide electrical power to train inside the workshop area

Safe operation

Moveable in sliding motion

Rail Grinding Machine

Diesel powered

For re-profiling of rails

Stored on track 21 in the workshop area

Bangkok Mass Transit System. "Bangkok Mass Transit System: Mo Chit Depot", Bangkok Mass Transit System: Bangkok, 2000.

8.9 Station Design & Planning Criteria

Introduction

1. The location and design of the BTS Station is a challenging problem in that they are located above heavily congested roads and have to be contained within the allocated right of way between buildings along the route. Usually a Mass Transit System of this order will rely on development sites and land resumption along the route in order to be able to locate stations, station concourses and transport interchange facilities. This facility is not available on this project.

2. The architecture of the stations is important in that, together with the rolling stock design, they present a corporate image of the Bangkok Transit System to the outside world and are likely to have a significant effect in encouraging rider ship and hence the ultimate success and profitability of the system.

3. The design of the stations will respond to and be determined by the following factors:

    a) Operational requirements in the use of center and side platforms
    b) Traffic, road and pedestrian requirements
    c) Utilities
    d) Structural strength requirements
    e) Passenger forecasts and maximum vehicle capacities and the resulting entrance location and emergency evacuation requirements
    f) Environmental considerations
    g) Build ability and disruption due to construction
    h) Flexibility in design to allow stations to respond to site specific requirements

4. Due regard shall be paid to the following objectives

    a) For the public in general:

An attractive welcoming image

Urban Design Impact (including to adjoining properties)

A distinctive corporate image for the Bangkok Transit System

Provision of potential links at any point to adjoining properties and footbridges

Potential to extend the concourse to form an elevated walkway above roads

Safeguards to pedestrians and adjoining properties from noise and air pollution

Traffic safety on the roads

Limited decrease in pedestrian utility at footpath level

Opportunity cost of the proposals

b) For the Operator:

Ease of use in different conditions; normal, peak, off peak, abnormal, emergency

Quality, as a place of work

Ease of management and maintenance and the consequential effect on manning levels and responsibilities

The potential for commercial revenue earning opportunities on user routes and the capability to link into commercial developments nearby

Provision of a flexible concept of circulation to allow for substitution of escalators for stairs, additional points of vertical access (including to street level) as well as links to adjoining properties, footbridges and extended elevated walkways

The capability of increasing the number of ticket gates or changing the direction of access should future needs dictate and the ability to change to a different type of ticketing system

Services provision to internationally acceptable standards but capable of upgrading to allow for increases levels of comfort or amenity

The provision of advertising space at concourse and platform levels and the capability of providing additional space for this purpose at road side, over roads, on walkways and viaduct sides

The provision of commercial space within the stations for public amernity and revenue

c) For the passengers:

The effects of the design on passenger attitudes and behavior

The attractiveness of the facilities as measured by the following criteria:

Safety:	Intrinsic safety of the proposals including protection from fire, mechanical, electrical accidents and "worst case" projections
Time:	Perception of time, information, access time, waiting time, reliability, certainty
Cost:	Fare and value for money
Materials:	The look and feel of materials, the sensory qualities of sound, light, smell, air quality, cleanliness and lack of contaminants
Security:	The risk of assault, perceived personal threat
Amenity:	Primary provisions as specified and secondary provisions, which will reduce stress or increase utility during waiting time
Weather:	Protection from rain direct sunlight
Comfort:	Fresh air and coolness (including necessary environmental control systems)

Access: Access for disabled passengers from concourse to platform and potentially to footpath or adjoining developments

5. This document is based on standards and design criteria that have been adopted on the Hong Kong MTR, the Singapore MRT and the Taipei Rapid Transit System which are considered to be the most appropriate for the anticipated use and the environment of the Bangkok Transit System. Various standards have been adopted directly or modified to suit the particular requirements of the Bangkok Transit System in the light of experience gained on other systems.
6. This Section sets out the design criteria to be adopted in the planning and design of BTS Stations in order to ensure consistency in layout, form and identity system-wide. It is also intended that there is a consistency in construction, passenger circulation, and operation and maintenance procedures throughout the system.
7. The essential quality in a satisfactory station layout is the provision of adequate space for the movement of patrons between ground level entrances and onto trains in the most direct and logical way with the minimum delay and disruption to flow introduced by the fare collection system.
8. Important criteria that shall be applied in the development of station designs include:

    Sizing of Station Passenger Handling Facilities

    Emergency Evacuation

    Electrical & Mechanical Plant and Equipment space requirements

    Operational Accommodation

Fire Safety & Compartmentation

Stipulated Design Standards

Passenger circulation, comfort, ease of use, safety & security

Signage

Weather protection

Development of a "Kit of Parts" approach to the design of all elements

Build ability of the stations bearing in mind the site constraints in the permanent and temporary conditions

Opportunity for the maximization of commercial opportunities

9. Three types of station will exist on the system

Intermediate Stations

These will serve only one line comprising two tracks, one in each direction

Interchange Stations

These will occur where two lines converge, ideally at a single station, enabling

passengers to transfer between one line and another. It is preferable that the two lines run parallel through the station thus allowing a cross platform interchange between one line and another. This form of interchange has generally been adopted for the interchange station between the two BTS Lines.

Interchange stations with other proposed rail systems will not be of the parallel type and will generally consist of two independent stations at right angles to each other requiring a link for the transfer of passengers from one system to the other. This link shall be designed in close co-operation with the other party. However, due to the uncertainty of the design of the other system(s) the BTS Stations shall initially allow for all passenger movements to take place between ground level, concourse and platform on a stand-alone basis. A future connection to the other rail system shall not be precluded and due allowance in the station layout and structure shall be incorporated into the initial design.

Terminal Stations

These will occur at each end of each line. It is intended that, subject to government approval, the two BTS lines will be extended beyond the terminal stations of the initial system. The timing of the approval and construction of these extensions is uncertain and so the terminal stations shall be designed to allow for the maximum passenger carrying capacity consistent with the design of the standard station.

Station Layout

1. The layout of the stations is influenced by the track geometry, operational requirements, predicted passenger flows and electrical and mechanical requirements. The station can be divided into public & non-public areas (those areas where access is restricted). The public areas can be further subdivided into paid and unpaid areas.

2. Stations shall be designed around either center platform or side platform configurations. Any chosen configuration shall take into account the constraints and objectives outlined in Section 1 above.

3. The Platform level shall have adequate assembly space for passengers and will generally is a minimum of 3.5 meters wide.

4. The platform level at each station is determined by the minimum structural and spatial requirements, which allow for a concourse area to be located between street and platform. The concourse will not only allow for the ticketing and control of passengers but can also be used as a footbridge across the road on a 24 hours basis.

5. The concourse area will contain the automatic fare collection system in manner that divides the concourse into paid and unpaid area. The 'unpaid areas' are where passengers gain access to the system, obtain travel information and purchase tickets. On passing through the ticket gates the passenger enters the 'paid area' that includes access to the platforms.

6. The arrangement of the concourse area is assessed on a station-by-station basis and is determined by site constraints and passenger access requirements. However it shall be planned in such a way that maximum surveillance can be achieved by station staff over ticket machines, automatic fare collection gates, stairs and escalators. Ticket machines and AFC gates shall be positioned to minimize cross flows of passengers and provide adequate circulation space.

7. Sufficient space for passenger flow shall be allowed at the top and bottom of stairs and escalators.

8. Station entrances are located with particular reference to passenger catchment's points and physical site constraints within the right of way allocated to the Bangkok Transit System. Entrance locations and sizes are severely constrained by the need to be able to provide enough space for a minimum width of stair and pedestrian footpath space alongside. Road traffic and structural requirements have also to be taken into account.

9. Office accommodation, operational areas and plant room space is required in the non-public areas at each station. The functions, preferred locations and minimum sizes (where applicable) are given in **Appendix A1**.

Passenger Handling

1. General Criteria

Passenger handling requirements greatly influence the station design and operation of the railway. The design shall be based on a careful analysis of the requirements of the passenger and the Operator.

It is essential that the system is designed so as to maximize its attraction to potential passengers and the following criteria shall be observed:

Minimize distance of travel to and from the platform and between platforms for transfer between lines;

Adequate capacity for passenger movements;

Convenience, including good signage relating to circulation and orientation;

Safety and security, including a high level of protection against accidents

The Operator, will require that the following are taken into account:

Minimum capital cost is incurred consistent with maximizing passenger attraction;

Minimum operating costs are incurred consistent with maintaining efficiency and the safety of passengers and staff;

Flexibility of operation including the ability to adapt to different traffic conditions, changes in fare collection methods and provide for the continuity of operation during any extended maintenance or repair period, etc.;

Provision of good visibility of platforms, fare collection zones and other areas, thus aiding the supervision of operations and monitoring of efficiency and safety;

Provision of display of passenger information, advertising and commercial concessions.

2. Provision of Escalators and Stairs

The decision to provide an escalator or staircase for passenger movements shall be based upon forecast passenger flow rates, vertical travel distance, structural limitations and the availability of space.

Assuming other criteria are met, escalators will generally be provided for upward flows only and will be assessed on station-by-station basis.

The provision of escalators shall not be precluded from any station layout. Even though an escalator may not be installed in the first instance, allowance both spatially and structurally shall be made. Provision shall also be made in the electrical supply. All proposed escalator locations might initially be substituted by staircases.

The design criteria for escalators and stairs are defined in Section 7 below.

The numbers of escalators and sizes of the staircases shall be determined by checking the capacity against the peak hour flow rate for both normal and emergency conditions.

3. Passenger Movement at Stations

In order to transfer passengers efficiently between street level and train and vice versa, station planning must be based on established principles of pedestrian flow and arranged to minimize unnecessary walking distances and cross flows between incoming and outgoing passengers.

A typical flow pattern for a passenger using the system will be as follows. Upon arrival at one of the entrances the passenger will proceed to the concourse unpaid area where he can consult travel information on display and buy a ticket. The passenger will then enter the paid area by passing with a valid ticket through an automatic ticket gate and proceed to the platform where he will board the first train traveling to his destination. A journey from the platform to the entrance will be in reverse with the exception that when a passenger's ticket is invalid for the journey, it will have to be exchanged for a valid ticket and an excess fare paid before leaving the paid area.

Peak one-minute passenger flows for two cases are provided in **Appendix A2**. The Case A forecasts represent an ultimate design situation in which future Bangkok Transit System extensions, interchange with other mass transit systems, and additional growth of the central areas, are taken into account. The Case A forecasts accompany the ultimate line capacity requirement of 50,000 passengers per hour. The Case B forecasts represent the BTS stand-alone case for the year 2007. In both cases, morning peak flows are shown. The evening peak minute flows shall be assumed to be the reverse of the morning peak minute flows.

The stations shall be designed and constructed to accommodate the Case B flows as a minimum and to meet related requirements for emergency evacuation. The design and construction shall be such that whether the Case

A passenger flows are accommodated by the initial design of the station or are ultimately accommodated by further construction, modification and installation of additional facilities in the station, the related requirements for emergency evacuation shall be met. In the case of further construction to increase passenger handling capacity from Case B to Case A, this shall be done without causing disruption to the system and such that the requirements for emergency evacuation are met at all times.

Each station shall be individually assessed and a view taken to ensure ultimate passenger handling capacity is available.

Passenger handling facilities comprise the stairs, escalators and ticket gates required to process the peak traffic from street to platform and vice versa (these facilities must also enable evacuation of the station under emergency conditions, within a set safe time limit). The number of entrances from the street, and the requirements for ticket issuing machines, are also included.

The capacity of each facility is based on a percentage of the Maximum Practical Capacity (MPC) depending on location and usage. Generally the Maximum Practical Capacity is provided for a uni-directional flow of passengers. The factors to e used for other situations are:

a) Bi-Directional flow:	80% of the MPC
b) Entrance/Concourse movements	60% of the MPC to allow for the uncertainty involved in being able to predict development of the area around a station that may change

	passenger usage of entrances over a period of time
c) Concourse/Platform movements:	80% of the MPC
d) Emergency Evacuation capacities:	90% of the MPC

4. Maximum Practical Capacities

The following figures represent the maximum practical capacities that are used in conjunction with the relevant design factors to determine the practical design capacities:

Walkway (uni-directional)	88 passenger/meter/minute
Walkway (bi-directional)	70 passenger/meter/minute
Stairs Up	63 passenger/meter/minute
Stairs Down	70 passenger/meter/minute
Stairs Bi-Directional	53 passenger/meter/minute
Escalator (0.75 m/sec)	150 passenger/meter/minute

Passenger Handling Capacities – Passengers / Meter / Minute

	Maximum Practical Capacity	Entrance 60% MPC	Concourse/ Platform 80% MPC	Escape 90% MPC
Walkway (Uni-Directional)	88	53	70	79
Walkway (Bi-Directional)	70	42	56	N/A
Stairs Up	63	38	50	57
Stairs Down	70	42	56	63
Stairs (Bi-Directional)	53	32	42	N/A
Escalator (0.75 m/sec)	150	90	120	135

To facilitate passenger-handling, separation between incoming and outgoing passengers at entrances may be by a central barrier and/or by escalator up and stair down arrangements. Similarly concourses shall be divided in such a way that entrance to the paid area is to one side of the passenger handling facilities and the exit is to the other, thus reducing cross circulation to a minimum. The differing proportions of arriving and departing passengers in the morning and evening peaks may be catered for by reversing the direction of certain escalators and ticket gates, whilst still maintaining the integrity of the basic passenger flow.

Cross-flows of passengers and changes in direction shall be minimized or eliminated. Obstructions, such as columns and barriers, shall be located away from the main passenger flow. Access points between concourse and platform shall be evenly distributed along the platform and where possible, minimize the walking distances for outgoing passengers and to facilitate an even distribution of passengers waiting on the platform and boarding the train.

Public spaces shall be planned to provide open spaces allowing surveillance by station staff either visually or by closed circuit television. Narrow passageways, dead ends and visual obstructions shall be avoided.

5. Emergency Evacuation

The requirement is to evacuate people from a station platform to another location, initially the next level below and then on to street level without hindrance

The principles to be followed are:

a) The total evacuation time for the movement of all passengers from platform level to the landing at the next level shall not exceed 4.5 minutes.

b) The total evacuation time shall include a one-minute allowance to cover the time taken to reverse escalators not running in the direction of escape plus the travel time on the escalators and stairs. Evacuation by means of stairs and escalators already traveling in the direction of escape will occur during the period taken to reverse escalators.

c) The total number of passengers to be evacuated is the equivalent to a full trainload of passengers plus the maximum number of waiting passengers on the platform. For the BTS Line running with an ultimate capacity of 50,000 passengers per hour per direction running at two minute intervals, the longest and most heavily loaded train that the system is capable of operating shall be assumed. This shall not be less than the AW4 crush loading defined as 8 persons per square meter standing and all seats occupied. If only partial facilities are provided it shall be assumed that the line capacity is 25,000 passengers per hour per direction with the most heavily loaded 3-car train that the system is capable of operating at two-minute intervals.

d) The number of passengers waiting on a platform to be evacuated shall be taken to be the design headway multiplied by the peak passenger forecast and doubled to cater for the possibility of one train being cancelled.

e) The capacity of escalators and stairs in emergency evacuation conditions shall be taken as 90% of the maximum practical capacities.

f) The time required to walk from the furthest point on a platform to the escalator or stair landing must be considered. Walking speed is 1 meter/second.

g) A check shall be made to ensure that sufficient capacity exists at the level to which passengers are evacuated so that people can move freely away from stairs and escalators as they arrive.

h) The escape route capacity including stairs, escalators and passageways shall not be constricted along the exit route at any point.

I) The emergency occur in one direction of travel only.

6. Calculation Method

Total evacuation time = one minute + Queuing Time

Total Time (Minutes) = 1 + (Train Load of Passengers + Waiting Passengers) / Available Capacity

Where Available Capacity = (Number of Escalators x Emergency Escalator Capacity) + (Total Width of Stairs x Emergency Stair Capacity)

Note: Where the time for the longest walk on the platform exceeds queuing time then the walking time shall be used instead of the queuing time.

7. Provision for Fare Collection

Fare collection in the concourse areas of a station will consist of ticket issuing machines and ticket gates together with provisions for the sale of stored value tickets and the collection of excess fares. During an initial operating period after opening of the system, provision shall be made for temporary ticket issuing offices for single and multi journey tickets until such time as stored value tickets become the normal method of ticketing.

For initial planning purposes the following assumptions shall be made

Ticket gates shall be classified as entry, exit or reversible gates. For planning purposes the dimensions of the proposed ticket gates shall be used.

The following design criteria shall be adopted for the requirements of ticket gates:

If future layouts are expected to differ from the initial operating layout, provision shall be made for power and control cable connections in the initial design.

Hinged steel gates shall be provided in the barrier lines enclosing the paid area. A minimum clear opening of 1000mm shall be provided and the hinged gate shall open in the outward direction from the paid area.

The ultimate width of the barrier gate line required in the concourse will depend on the requirements for emergency escape. An automatic gate, assuming that this is of the flap type with an unobstructed passage in emergency release mode, has a capacity of 50 passengers per minute and a hinged barrier gate has the same capacity as a passageway of 79 passengers per meter per minute.

Platform Design Standards

1. The platform length shall accommodate a 6-car train and a stopping tolerance.
2. The nominal platform width measured from the platform edge to any continuous (longer than 1200mm) fixed structure shall be a minimum of 3000mm. However the preferred minimum platform width shall be 3500mm. This clearance shall be maintained for safety reasons, irrespective of passenger loading. Towards the end of the platform, clear of any main circulation areas, platforms may taper, but in no case shall they taper to a width of less than 2000 mm. In addition the absolute minimum platform width from the platform edge to any isolated obstruction shall be 2000mm. Platform widths greater than the minimum may be required at stations with large passenger flows. Each platform shall be checked for both normal operating conditions and emergency conditions.
3. Normal operating conditions require a reservoir of space for passengers waiting for a train. An average area of one square meter per passenger is

considered desirable under these circumstances. The required platform width for the design peak condition is calculated as follows:

Required platform width = 0.5 + (F x I x 1.0) / platform length

Where:

F = the peak one minute flow of boarding passengers entering onto a single platform (i.e. wishing to travel in a given direction)

I = service interval (minutes)

This formula is based upon the assumption that a 0.5m wide zone adjacent to the platform edge will remain unoccupied when there is no train at the platform.

4. When alighting passengers join boarding passengers on the platform a smaller area per passenger is acceptable and the 0.5m wide zone at the platform edge may be occupied. This situation is therefore not considered for the design of the platform width during normal operation.

5. The minimum acceptable platform width shall also be checked for emergency conditions against the following design criteria:

A delay in service of 1 missed headway amounting to 2 minutes is assumed in one direction in the peak hour;

A full train of passengers at crush loading (AW4) is required to disembark onto the same platform as the accumulated boarding passengers;

An average of 0.2 square meters per passenger is acceptable under emergency conditions;

The train will not move from the platform until passengers have begun clearing the platform and hence a 0.5m unoccupied zone adjacent to the platform edge need not be allowed for.

Thus the Required Platform Width = (4F + AW4 vehicle capacity) 0.2 / platform length (m).

6. In the case of island platforms it is assumed that if one side of the platform becomes crowded a portion of the passengers will utilize the other less crowded side of the platform. In marginal cases (i.e. those just above the minimum width requirements) some flexibility may be applied to the requirements.

7. The track alignment through a station shall be straight and level. However, consideration may be given to using horizontal curvature where required. Each location shall be judged individually.

8. A non-slip trackside platform edge strip shall be provided as part of the platform finishes. The edge strip shall extend for the full length of the platform and for a width of 500mm from the edge of the platform. The edge strip shall be designed to differ in color, texture and material from the platform paving material to aid both the sighted and visually handicapped.

9. Platforms shall be flat and level.

10. At the end of each platform an access route shall be provided from platform level down to track level for use by maintenance staff and passengers during an emergency. This access route shall have a minimum width of 1000mm. A double swing gate shall be provided at platform level to prevent unauthorized entry.

11. An under platform refuge shall be provided below the cantilevered portion of the platform for the full length of the platform. The minimum horizontal width from the side of a train to any obstruction shall be 600mm and the full height from

the track slab to the underside of the platform shall be available. Access into the under platform refuge shall be provided either through removable panels in the under platform wall or alternatively the refuge may be extended 1.5 meters beyond the platform end.

12. Manhole access shall be provided into any under platform cable duct compartment.

13. Passenger access points shall be arranged to encourage the distribution and collection of passengers evenly along the whole of the platform length. If required, access points may be offset from station to station to provide an even loading of passengers in the trains.

14. An emergency plunger shall be provided at one-third points along each platform so that a passenger on the platform may stop a train in an emergency.

15. 100mm minimum depth shall be allowed for the provision of any screed and finishes on the platform. The structural clearances above the platform finished floor level shall generally be determined by clearances above the running rail for kinematics envelope. The minimum ceiling height above finished floor level shall be 3000mm and a 2500mm clearance shall be maintained to any obstruction (sign, etc.). For design purposes the platform edge shall be taken as being 1000mm above the rail level (assuming no cant over the length of the platform) and 1675mm from the centerline of the track for straight track stations. Adjustments for horizontal clearance will be required for curved track. The final dimensions will be determined once rolling stock and its kinematics envelope have been agreed.

16. Weather protection shall be provided for all elevated stations. The roof structure shall extend for the full length of the platform and beyond the centerline of the track by at least 200mm.

17. A longitudinal planning and design module of 3.0m has been chosen for use in station design and shall be used where possible in the public area of all stations.

Concourse Design Standards

1) The size of the concourse is dependent on the passenger handling arrangement, the entrance locations, and the space requirements for offices and electrical and mechanical plant at individual stations. The layout of the concourse is mainly determined by the location of station entrances and the sitting of the access points to the platform. General standards are:

Where more than one concourse area is planned then the paid areas are connected to allow both station staff access to both areas and the passenger an alternative means of exit;

Public facilities in the concourse shall be located clear of the main passenger flow routes;

The preferred planning module of 3.0m should be adopted.

2) Within the concourse area the station ticket hall shall provide adequate space for passenger circulation and direct flow lines between ticket machines and AFC gates.

3) Space should be provided for commercial kiosk facilities within the unpaid area which, during a period at the opening of the system can be utilized as temporary ticket offices until such time as stored value tickets have become an accepted concept and the number of ticketing machines provided can cope

with the predicted demand. The location of the kiosks/temporary ticket offices shall therefore take into account their initial and intended future use.

4) Provision shall be made for a number of public telephones to be installed in each station. They shall be located away from the general passenger circulation and allocated on the basis of 1 to every 75 passengers per minute at the projected peak flow for the station with a minimum of four telephones.

5) The structural clearance in the concourse shall depend on the relationship between concourse and platform. However the preferred minimum clearance to main transverse structural members shall be 2500mm and shall be 2800mm to longitudinal structural members such as the main track viaduct. Other than these areas a minimum ceiling height of 3000mm shall be adopted with a minimum height of 2500mm to the underside of local obstructions such as signage.

6) A finishes zone of 100mm for floor finishes shall be provided. A nominal fall within the public areas towards the external faces of the concourse area shall be provided to ensure that windblown rain and water dripping from passengers and umbrellas can adequately drain from the concourse areas.

7) Means of securing and closing the station at concourse level shall be provided in the area of the ticket gates. Crowd control means will be provided at entrances but provision shall be made to allow entrances and concourse unpaid areas to be used as footbridge crossings on a 24 hour basis.

Entrances

1. Station entrances provide the link between the station concourse and the surrounding streets. They shall also cater for inter modal interchange which may include bus transfer, taxi, Tuk Tuk and motorcycle transfer, kiss and ride and park and ride facilities. Covered ground level or elevated links from such facilities may be considered if the predicted passenger flows warrant.
2. Entrances to stations shall have adequate capacity to satisfy predicted passenger flows and emergency evacuation requirements. Entrances to stations via developments are considered additional facilities and are not to be included in the assessment of minimum passenger handling facilities.
3. Entrances at Street Level shall be easily identifiable.
4. The position of entrances shall be determined by the juxtaposition of buildings, location of roadways, footpath width, space availability and flow directions of passenger traffic.
5. The selection of materials shall not radically depart from those used within stations and shall be robust, hard wearing and maintenance free.
6. Where entrances contain escalators, a protection against localized flooding to the lower machine room shall be provided by a ramp or steps.
7. The widths of entrances shall take into account predicted passenger flows, emergency evacuation requirements and available space.
8. Each entrance shall contain a temporary closure device for crowd control purposes in the event of an emergency or severe congestion. In many cases the entrance will also act as a footbridge cross to the road and shall be available on a 24-hour basis. Other measures to enable station closure and security shall be incorporated at concourse level in the area of the ticket gates.

9. Entrances within or associated with adjacent developments are additional to any required for normal passenger handling and emergency escape. Required entrances shall be within the right of way under the control of the BMA.

Escalator and Stair Design Standards

1. All escalators shall be of the heavy-duty reversible type with a design maximum practically capacity of 150 persons per minute based on a service speed of 0.75 m/sec as described in the Station Services Performance Specification. They shall be suitable for their operating environment. In addition to the technical parameters the following requirements are given for initial planning purposes:

Inclination	30^{o}
Balustrade height (step to top of handrail)	980mm
Width of truss (rise less than 12m)	1700mm

The following minimum dimensions shall be provided:

Vertical clearance from step level	2500mm
Travel distance from working point to any obstruction	8500mm
Distance between working points of escalators	
discharging into the same space	18000mm
when the number exceeds 2	20000mm
Distance between working points of escalators	
(or an escalator and stairs) operating	
in the same direction	10000mm
Distance between escalator working point and	
concourse entry point or angled passageway	5000mm

2. For design purposes escalators of less than 7000mm vertical rise shall only be supported at the top and bottom trusses. Where the rise is greater than 7000mm mid-span supports may be provided.

3. A drainage outlet or sump shall be provided in all escalator pits for the removal of water.

4. A flood landing of minimum 450mm height for all escalators at street level shall be provided to protect against localized flooding.

5. Stair access for the public shall be provided to all levels of a station. No access will be allowed from public stairs to plant areas.

6. All treads, nosings and intermediate landings shall have non-slip surfaces.

7. All stairs shall be provided with handrails on both sides. Where the width exceeds 2400mm a central handrail shall be installed. A central handrail may also be considered elsewhere where crowd control and passenger flows dictate. The handrail shall extend a minimum of 600mm beyond the bottom riser and 300mm beyond the top riser.

8. Continuous flights of stairs for use by the public shall have the following design parameters:

Pitch of stairs	30°	
Risers per flight	3	(minimum)
	14	(preferred maximum)
	16	(absolute maximum)
Height of riser (subject to pitch)	145mm	(absolute minimum)
	150mm	(preferred minimum)
	165mm	(absolute maximum)

Length of tread (subject to pitch)	250mm (absolute minimum)
	260mm (preferred minimum)
	300mm (absolute maximum)
Intermediate landing width	1800mm(absolute minimum)
	2000mm(preferred minimum)
Stair width	1800mm(absolute minimum)
(measured to the center of handrails)	2000mm(preferred minimum)

9. Minimum clear distances from the inclined line of the nosings, measured perpendicular to the incline, shall be 2.05m to any obstruction or 2.50m to any ceiling or structural bulkhead.

10. Top of handrails shall be 900 – 1000mm measured vertically from the pitch line and 1100mm vertically for landings. Where a staircase is located to an open well the balustrading will be 1100mm above FEL on the horizontal and 900mm flights.

Design For The Handicapped

1. Design for the handicapped shall not be precluded although facilities will not be provided at the initial opening of stations. The nature of the Bangkok street does not allow for the easy movement of handicapped people and so they may find it difficult to gain access at street level to stations in the first instance. However it is assumed that over a period of time conditions may improve. For design purposes it is assumed that handicapped people may gain access to the Bangkok Transit System via developments directly to concourse and/or platform levels. Space and structural provision for future installation of lifts will be provided for occasional passenger use between concourse and platform.

2. Internal dimensions of future lifts shall be 1600mm x 1500mm and 2200mm high. A minimum clear door opening of 900mm shall be provided.

3. All lift entry points shall have a clear level area of minimum dimensions 1500mm x 1500mm adjacent to the lift door.

Corridor And Ramp Design Standards

1. The width of corridors or passageways in public areas shall be determined by capacity requirements subject to the minimum dimensions give below:

Minimum for unidirectional movement	1800mm
Minimum for bi-directional movement	2000mm
Minimum for staff only movement	1200mm

2. Ramps shall only be used for small changes in level or for use by wheelchairs and the following gradients shall apply:

Preferred maximum gradient	1:20
Absolute maximum gradient	1:12

3. Ramps shall be a minimum width of 1200mm for unidirectional movement and 1500mm for bi-directional movement. Rest platforms should be considered for long ramps (exceeding 10m) provided for wheelchair users. Rest platforms should provide a level area 1800mm long at intervals of approximately 10m.

Passenger Amenities

1. General

A number of amenities shall be provided for the use of passengers within the station. Where these involve stationary passengers then the facilities shall be located clear of the main passenger flows.

2. Advertising

Advertising will be an important source of revenue but the extent of the demand for advertising will depend on market forces. Potential sites for advertising within a station shall be located so as not to conflict with the principal requirement of the provision of signage to direct passengers, especially in an emergency

There are various advertising media that can be used both within and outside the station which include:

3-Dimensional Advertising

3D Media: large models of products or company logos

Display Cabinets: for company products

2-Dimensional Electronic Advertising

Light Emitting Diode: Newscaster, information services

Neon sign: Company logo/product information

Audio Advertising

Radio style advertising, pre-recorded and played over station/train intercom.

Mechanical Advertising

Collapsible Billboards

Retractable Screen

Flipsides: Billboard with 3 times space, rotates when Required to reveal different adverts.

Q Boards:	Successor to the flipside giving space for many more advertisement

Moving Image

TV Monitors:	Used in either single units or in blocks of screens

Holograms

Lasers

Truemation

Other 2-Dimensional

Directly applied:	advertisements directly painted onto surfaces.
Superlites:	back-lit advertisements
Projection:	still image directly projected onto screens or walls
Billboards/Posters:	conventional media

A combination of many of the above means of advertising may be adopted at stations. Whatever media is used it must be integrated into the station design and not be treated as an add-on element at a later date. All wiring and fixings must be concealed. Provision shall be made for cast in conduit and fixings for advertising media at identified sites whether or not the media is installed at the opening of the railway. Attention shall be paid to ensuring maintenance access to these zones.

3. Commercial Areas within the Stations

Areas for commercial use shall be located at stations. During the initial period upon the opening of the railway system some of these areas will need to be used as temporary ticketing offices for the sale of single journey and stored value tickets.

4. Signage

Passenger information signs located at stations will be many and varied ranging from station entrance signs to train indicator panels and information panels.

Signs shall be provided in a dual language format of Thai (using Thai characters) and English with English being the subservient language.

All signage hardware shall be of a consistent range of materials and size/proportions.

5. Seating

Seats shall be located at platform level. The number of seats to be provided at individual stations will depend upon the space available and the interval between trains. Seating areas shall be protected from rain.

6. Telephones

All stations shall be provided with public telephones in unpaid areas and provision shall be made for future installation in paid areas. The number of public telephones provided will depend upon the demand but a minimum of four telephones at each concourse shall be provided.

Emergency BTS telephones shall not be provided unless hazard analysis requires them to be located in the public area of any platform or concourse that is not provided with a Station Control Room or otherwise manned by the station staff. The line shall be direct between the passenger and the station controller.

7. First Aid

First Aid and the treatment of minor injuries will be initially catered for at the First Aid Room.

8. Bins

Refuse bins shall be located throughout the station and approaches for disposal of small items of rubbish. The size of the bins shall be restricted to minimize the fire risk. The bins shall be emptied periodically and rubbish transferred to the bin store prior to removal by the public authorities.

Ash Trays/Bins shall be located adjacent to the litterbins in the unpaid area of the concourse only.

Access For Maintenance

1. All areas of the station shall be accessible for inspection and maintenance
2. Door and access panel sizes shall be of sufficient width and height for the installation/removal of the equipment within the room or rooms served. Manhole access shall have a minimum clear opening of 750 x 750mm.
3. Room layouts shall make provision for withdrawal space and circulation space around equipment where appropriate.
4. Vertical access for maintenance staff shall utilize one of the following:

1.2m minimum width of standard stair

1.0m wide 60° maximum pitch metal staircase with handrails with a maximum rise of 3.0m

0.5m minimum width of ladder access with hoops provided from a height of 2.0m for all rises above 3.0m

0.5m widths of step irons. Step irons shall only be used where the rise is less than 3.0

Electrical Systems

1. General

Work shall comply with requirements of all legally constituted authorities having jurisdiction in Bangkok.

Refer to the regulations and standards of:

a) MEA -Metropolitan Electricity Authority

b) EIT -The Engineering Institute of Thailand

c) NEC -National Electrical Code, USA

d) IEEE -The Institute of Electrical and Electronic Engineers

e) IEC -International Electro-Technical Commission

f) NFPA -National Fire Protection Association

g) NEMA -National Electrical Manufacturers Association

h) UL -Underwriters Laboratories, Inc.

i) TOT -Telephone Organization of Thailand

j) TIS -Thai Industrial Standards

k) TUV (IEC 950) Safety Standard

l) VDE 0871 Class B EMI/RFI Regulation

m) IEE -UK Institution of Electrical Engineers Regulations, 16th

n) BSS -British Standards Specifications

A low voltage (LV) 400/230V, three phase four wire, 50Hz supply shall be provided at each station. Emergency power for some designated luminaries, signs, air conditioning units and station equipment shall be provided for a minimum period specified in the Particular Design Requirements. Between mains failure and switch over and on restoration of mains power there may be a black out of a maximum of 4 seconds.

Exit signs will be of self-contained battery powered type

Separate UPS systems, which may include a diesel generator, shall be provided for the signaling system, communication systems and for control circuits of 24kV and LV switch gears and SCADA system. The duration of such backup for each system shall be defined in accordance with the provisions of the Particular Design Requirements.

2. Lighting

The lighting for the station areas shall comprise of:

Platform Area Lighting

Concourse Area Lighting

Sign Illumination

Advertising

External Lighting

Lighting shall be designed such that glare, dark recesses and areas of poor lighting levels are avoided.

A lighting design plan shall be submitted for approval to reflect a lighting system that complements the architecture and space in all the passenger areas (Platforms, Concourses and Entrances). Generally a minimum level of 200 lux is required with areas highlighted for safety purposes and visual effect. Lower lighting levels in certain areas may be acceptable and will be subject to approval.

Lighting levels in staff accommodation areas have been designated in the room descriptions scheduled in **Appendix A1**.

For signage, the illumination of station names, general information and directional signs shall incorporate fluorescent luminaries to provide back illumination or spotlights to provide front illumination. All signs required for the safety of passengers and station personnel during emergency situations shall be provided with supplies from the UPS distribution board.

Various types of advertising media will require a power supply.

External lighting for pedestrian areas and roads shall be designed and installed. Particular regard for daytime and nighttime conditions shall be considered. The power supply for external lighting requirements not directly associated with the safety of passenger movement in and out of the station shall be supplied from an independent source.

The emergency lighting system shall provide emergency lighting for the safe movement of passengers in the event of a main lighting failure and the illumination of signs. The emergency illumination level shall be 25% of the normal level. The emergency lighting system shall be provided at all station platforms, concourses, entrances, plant rooms, and equipment rooms and staff areas. Power for emergency lights shall be supplied from a central UPS system.

3. Lightning Protection

A complete lightning protection system for the station shall be provided. It shall consist of a network of roof terminals bonded to the down conductor and earth electrodes according to BS 665 or other approved standard.

4. Earthing

Earthing of the entire electrical installation shall be designed in accordance with approved regulations and MEA requirements.

Air Conditioning & Ventilation Systems

1. Design Criteria

1.1 Outside Design Conditions

Summer 35°C DB, 28°C WB

Winter 17°C DB

1.2 Inside Design Conditions

Area	Temperature °C	% Relative Humidity (HD)
Concourse	Ambient	
Platform	Ambient	
Staff Areas	24 +/- 2oC	No specific control
Station Control Room	24 +/- 2oC	No specific control
Ticket Office Signaling & Communications	24 +/- 2oC	No specific control

1.3 Ventilation Requirement

Area	Air Changes per Hour
Traction Power Substation, Equip. Room	The air change will be based on the actual pump room & machine rooms heat gain of the equipment but not less

	than 8 air changes per hour.
Battery Room	10
Toilets	12
Cleaners Room & Storage	6

2. The platform and concourse areas at elevated stations shall be architecturally and structurally designed to be open to the atmosphere. Forced ventilation systems for the area under the stations shall be designed and an allowance made for their installation at locations where mitigation measures are recommended in light of the environmental assessment.

3. Staff areas and the signaling and communication equipment rooms shall be air-conditioned.

4. The air conditioning system for the staff areas shall comprise single or multiple split type fan coil units for flexibility, low initial cost and conservation of energy. The air conditioning units that are not in use can be individually shut down. Individual zone temperature control shall also be provided for each room.

5. Exhaust Air Systems shall be provided for the following areas; traction substation, electrical rooms, cleaner's room & storage, toilets, battery room, cash and ticket room, miscellaneous operations rooms and control booth.

6. All air conditioning plant and equipment shall be concealed from view from all public areas within and outside the station area.

<u>Water Supply & Drainage</u>

1. General

All works shall be performed in accordance with all applicable municipal codes, laws and regulations issued by Government Agencies or Authorities.

The work shall be in accordance with the standards, codes and laws listed in Section 4 and 5 of Part A of the Design Standards & Criteria supplemented by:

By-laws of BMA, Control of the Building Construction, 1979

Codes issued by MWWA, Metropolitan Water Works Authority

2. Cold Water Supply System

The cold water system shall be provided at each station for general domestic use, flushing and the fire fighting system. The service pipe from a trunk city main will feed water into a storage tank. A valve chamber complete with isolating valves and water meter shall be installed in the pipeline at its entry to the station. The water tank shall be designed to provide a combined water storage capacity for domestic service and the fire fighting system.

A booster pump set shall be located in a pump room. Distribution piping shall be provided to supply water to the staff toilets and for station wash down purposes.

3. Sanitary Drainage System

The sanitary drainage system shall collect the discharge from the water closets, wash basins, showers, sink and floor drains in accordance with the Bangkok Metropolitan Authority's Building Regulations. Collected discharges shall be conveyed in a system of pipes and vents and fed into a self-contained packaged anaerobic wastewater treatment tank. The treated water shall then be discharged into a manhole and piped to the public drainage system.

The sanitary drainage system shall be completely separated from the surface water systems and shall be provided with vents and traps to prevent odors from entering the station. Pipelines shall be detailed to be neat and unobtrusive and be provided with easy facilities for ridding, particularly at bends and junctions.

4. Surface Water Drainage, except Viaducts

Rainfall intensities are provided in the Civil and Structural Engineering Design Criteria. The return shall be 100 years. Run-off shall be estimated by the Rational Method and the time of concentration shall be calculated from the modified Brans by Williams Equations.

The station drainage systems shall comprise falls, gullies and pipes to prevent ponding and not damage or impair the performance of other installations. Discharge water shall be collected and be led by gravity flow to manholes and piped to the public drainage system.

All systems shall be detailed to be neat and unobtrusive with easy facilities for ridding, particularly at bends and junctions with gullies. They shall be equipped with overflow provisions of the same capacity as the main system. Access manholes for inspection and maintenance shall be designed and detailed to be entirely waterproof.

<u>Fire Protection</u>

1. Design Considerations

The design of a station shall include the following:

Fire prevention measures

Fire control measures

Fire detection systems

Means of escape

Access for firemen

Means of fire fighting

All aspects of fire prevention and control require the close liaison with the fire fighting authority and final proposals shall be subject to the approval of the relevant authorities.

Fire prevention measures shall be designed and implemented to minimize the risk of outbreak of fire by appropriate choice, location and installation of materials and equipment.

In station planning terms, potential sources of fire can be reduced by:

- The use of non-combustible or smoke retardant materials where possible;
- Provision of layouts which permit ease of maintenance for equipment and cleaning of the station;
- Provision of special storage spaces for combustible materials such as paint such as paint and oil;
- Prohibition of gas based cooking facilities in the staff areas;
- Prohibition of smoking;
- Provision of cigarette and litter bins;
- General good housekeeping;
- Staff training and procedures.

Control of the spread of fire and smoke shall be by achieved by compartmentation of fire risk areas, smoke extraction and smoke containment.

Compartmentation is aimed at limiting the extent of a fire. A compartment consists of a portion of the station or other structure, which is separated from adjoining portions by walls, floors and/or doors. Any opening must be capable of being sealed in the event of a fire, e.g. duct openings sealed with fire dampers. Fire resistance periods (FRPs) shall be selected for spaces according to their degree of fire load and the degree of protection required for life safety, security of the system and the preservation of adjoining areas.

Openings, including ducts and passages between the System and any adjoining structure that allows free access into the System shall be protected by fire doors, fire dampers, etc., as appropriate.

The fire alarm and detection system for each station shall comprise automatic smoke/heat detectors and break glass units interconnected with the local fire alarm pane. The panel shall be located in the Station Control Room/Ticket Office together with a mimic panel indicating fire status on a zone-by-zone basis.

Upon receipt of a fire signal, the fire alarm panel shall operate audible and visual alarms within the staff areas only. The warning for the public shall be implemented by staff via the public address system. A signal shall also be sent to the control center via the SCADA system.

The automatic fire detectors of the smoke and heat sensitive type shall be installed in the staff offices, traction substation, electrical rooms, and pump room and lift machine room.

Design for evacuation of passengers from stations is described elsewhere. Standards quoted here apply to the non-public areas of offices and plant rooms. Non-public areas of stations are accessible only to BTS staff and usually only in small numbers. These areas shall be compartmented and shall be fully covered by the fire detection and alarm system.

As with the public areas of a station, escape from all non-public areas shall be possible to a place of safety. For staff-only areas a place of safety shall be an area outside the compartmented area of the fire. Staff shall be trained in fire-fighting procedures and may not require total escape from the station in a contained fire situation.

The travel distance from any point in non-public areas to an area of relative safety shall depend upon whether alternative means of escape are available. Where only one direction of escape is available travel distances shall be less than 20m. Where escape is possible in more than one direction the travel distance shall be less than 40m. Escape routes from plant areas may include manhole or ladder access.

2. Fire Protection System

All works shall be performed in accordance with all applicable municipal codes and laws and regulations issued by Government Agencies or Authorities.

The work shall be in accordance with the standards and codes listed in Section 4 and 5 of the Design Standards & Criteria supplemented by:

a) By-laws of BMA, Control of the Building Construction, 1979

b) Codes issued by MWWA, Metropolitan Water Works Authority

3. Fire Hydrant and Hose Reel System

The proposed fire protection system shall comprise the following:

Fire hydrant and hose reel system for the public areas.

Gas flooding system for the traction substation, signaling and communication equipment rooms and electrical rooms.

Portable fire extinguishers for the electrical rooms, pump rooms, staff offices and public areas.

A fire hydrant and hose reel system shall be provided at each station to protect plant, occupants and public areas as a first means of fighting the fire whilst awaiting the arrival of the local fire authority.

Fire fighting water supply shall be fed from a storage tank and duplicated pump set. The water tank shall be sized for a minimum of 30 minutes storage capacity.

Fire department connection to a standpipe shall also be provided at ground floor level as a secondary source of water supply.

A wet standpipe system shall supply water to the fire hose cabinets located at accessible locations within the station public areas.

The fire hose cabinet shall be equipped with a 40mm diameter, 30m long flexible hose with nozzle, a 65mm diameter angle value with coupling and a 4.5 kg capacity multi-purpose portable dry chemical fire extinguisher.

4. Gas Flooding System

The gas flooding system shall comprise carbon dioxide storage cylinders, pipe works, discharge nozzles, and control and alarm system. Associated with each flooding system shall be a mechanical extract purging system.

8.10 Appendix A1 – Station Accommodation

1. Station Control Room/Ticket Booth/Excess Fare Office

Function

The center for supervision of all passenger related activities on the station. Holds communication and emergency controls for station plant such as lifts, escalators, fire detection and suppression. Also supervises ticket issuing machines, ticket barriers and sells tickets, collects excess fares and holds some cash.

Location

Combined Ticket Offices and Excess Fare Offices shall be provided at concourse level in each barrier line with operating faces in both paid and unpaid areas. One such office may incorporate the Station Control Room.

Size

Minimum 12 sq.m

Desirable 16-20 sq.m

Design

It is intended that this shall be a freestanding booth with the ability to provide good visual supervision of the concourse with an allowance for at least two staff members. The floor of the office shall be elevated 300mm above the concourse floor level. It shall be fitted with "speak through" devices in the windows associated with ticketing. The layout, design and integration of all E&M control and monitoring equipment are important, as is the external appearance.

Communication

Desk with automatic and direct line telephones, electronic mail and CCTV monitors, radio, public address and passenger display facilities and associated panels. Station Master Clock.

AFC

Machines for ticket issuing and ticket verification. Concourse automatic ticket issuing machine and ticket gate control and indications (equipment monitoring and control) unit. Emergency release button. Station accounting system.

Traction Power

Traction Power Plunger

Escalators

Emergency Stop Buttons

ECS

Air conditioning: split type fan coil unit

Services

Lighting: average 500 lux at desk working level

Power: general purpose sockets

Fire protection: station fire alarm panel, automatic smoke detection system, portable fire extinguishers. Links to fire alarm panels of associated development areas that may impact on passenger access and egress.

2. Cash and Ticket Room

Function

To provide secure storage for cash, tickets, cash vaults, cash trolley, accountancy and security documents. To provide a secure area for the hand over of value items between station staff and courier or delivery staff. To house local control equipment for the automatic fare collection equipment, equipment for counting cash. This may be used for auditing purposes and shall be used for storage of cash trolleys, trolley vault transporters, vaults and document drawers. A separate cash vault with access via a vault door is required to store cash vaults for a period of time when collection services and disrupted.

Location

Preferably at concourse level and preferably within the paid area for added security but could be elsewhere. It shall be located within the area sealed off by roller blinds when the station is closed.

Size

18 - 24 sq.m. depending on the volume of traffic

Communications

Automatic telephone

AFC

Ticket magazine rack and possibly cash counting & bagging equipment

ECS

Air conditioning: split type fan coil unit

Services

Lighting: average 500 lux at desk height

Power: general purpose socket outlets

Fire protection: automatic smoke/heat detection system and portable fire extinguishers

Furnishings: Secure cupboards, safe shelving, desk & chair

3. Staff Area

Function

To provide a location where staff can change clothes, store personal items and be issued with items of documentation or equipment, relax on work breaks and eat food obtained from outside. Separate areas shall be provided for use by male and female staff for changing and storage of personal belongings.

Location

Not significant

Size

Dependent on numbers of station staff

Communications

Automatic Telephone

ECS

Air conditioning: a split type fan coil unit

Services

Power: general purpose socket outlets

Fire protection: automatic smoke/heat detection and portable fire extinguishers

Plumbing: Hot and Cold Water, sink, floor gully

Appliances: Refrigerator, electric cooker and microwave oven for meals

Furnishings

16 Full height lockers for assigned staff, 8-stacked half-height lockers for roving staff, benches, coat hooks and mirrors, table, six chairs, sink unit, clothes hanging/drying space.

4. Toilets

Function

To provide toilet and washing facilities for station staff, maintenance staff and, depending on the station and the operating rules, train drivers. The operator may permit staff from commercial units access to these facilities.

Location

Not significant

Size

To accommodate the required facilities

Ventilation

Mechanical extract system that will maintain the room at a negative pressure

Services

Lighting: average 200 lux at floor level

Plumbing: Hot and cold water, wash hand basins, showers, floor gully

Furnishings

Male: 2 urinals, 1 WC cubicle, 2 wash basins, 2 showers, mirrors, hand drier

Female: 1 WC, 1 wash basin, 1 shower, mirror, 1 electric hand drier

N.B.

At stations where train crew accommodation is provided these sizes shall be increased.

5. Station Store Room

Function

To store materials, some of which may be flammable or toxic, mops, brooms, dusters and other cleaning tools. Space for powered cleaning machines shall be provided. Mops, dusters etc. will need to be hung to dry.

Location

Not significant

Size

Approx. 10 sq.m

Ventilation

Mechanical extract system

Services

Lighting: average 100 lux at floor level

Plumbing: cold water, floor gully

Fire protection: automatic smoke/heat detection and suppression and portable fire extinguishers

Furnishings

Shelving, metal storage bins for flammable materials, cleaners sink and hanging racks

6. Refuse Store

Function

To hold refuse collected on the station until it can be disposed of by public or contract disposal agents

Location

Adjacent to a street access or at street level

Size

5 sq.m

Services

Lighting: average 100 lux at floor level

Plumbing: cold water, floor gully

Fire protection: automatic smoke/heat detection and suppression and portable fire extinguishers

Furnishings

Fireproof metal storage bins

7. Police Room

Function

To provide private accommodation for the use of the police

Location

Preferably near to staff areas and toilets

Size

18 – 24 sq.m

Communications

Automatic Telephone

ECS

Air conditioning: wall unit

Services

Lighting: average 500 lux at table height

Power: general purpose socket outlets

Fire protection: automatic smoke detection system and portable fire extinguishers

Furnishings

Store cupboards, desk and chairs

8. First Aid Room

Function

To provide a private area for rendering first aid to passengers or staff, to store first aid equipment and supplies.

Location

Not significant

Size

6 sq.m

Communications

Automatic Telephone

ECS

Air conditioning: wall unit

Services

Lighting: average 500 lux at table height

Power: general purpose socket outlets

Fire protection: automatic smoke detection system and portable fire extinguishers

Plumbing: cold water, hot water, floor gully

Furnishings

Store cupboards, desk and chair, first aid table/bed, stretcher and stretcher case, washbasin, medical inspection lamp

9. Miscellaneous Operations Room

Function

To serve as a base for on-call maintenance staff, operating supervisors and managers. One function only will be allowed at each office to be determined at a later date.

Location

Not significant

Size

12 – 16 sq.m

Communications

Automatic Telephone

ECS

Mechanical extract system

Services

Lighting: average 500 lux at desk height

Power: general purpose socket outlets

Fire protection: automatic smoke/heat detection system and portable fire extinguishers

Furnishing

Desk, chairs, storage cupboards and in some cases a workbench and shelving

10. Train Crew Supervisor's Office

Function

To provide a base for a train crew Supervisor and for train drivers to report for duty, deal with variations to duty and discipline

Location

As required by operating procedures

Size

Desirable 30 sq.m, minimum 25 sq.m

Within this area there will be a private interview room of approximately 4 sq.m, a counter dividing the remainder into a supervisor's area and a train crew area in the ratio of approximately 2:1.

Communications

Automatic Telephone

ECS

Air conditioning: split type fan coil unit

Services

Lighting: average 500 lux at desk height

Power: general purpose socket outlets

Fire protection: automatic smoke/heat detection system and portable fire extinguishers

Furnishings

Interview Room:	Desk and three chairs
Supervisor's Area:	Two desks, table, three chairs, storage cupboards and a computer workstation
Train Crew Area:	Wall mounted notice boards

11. Train Crew Room

Function

To provide accommodation for train crew to change clothing, store issued documents and equipment and personal effects. Separate rooms will be required for male and female staff

Location

At all stations where a Train Crew Supervisors Office is located. Particular location within the station is not significant

Size

To be determined in relation to distribution of train crews between location

Communications

Automatic Telephone

ECS

Air conditioning: wall unit

Services

Lighting: average 200 lux at desk height

Power: general purpose socket outlets

Plumbing: hot and cold water, sink, floor gully

Fire protection: automatic smoke/heat detection system and portable fire extinguishers

Furnishings

Wardrobe lockers for the maximum number of staff, hanging space for clothing, benches

12. Traction Substation

Function

A Traction Substation shall comprise a housing for the following equipment:

Main Transformers

Rectifier Transformers

Rectifiers

DC Switchgear

Control Equipment and Relay Panels

Battery Room

Switchgear

Location

Due to the non-availability of land outside the designated right of way, the traction substations shall be built into the stations, preferably at the extreme end where passenger movement is least

Size

Dependent on particular equipment and maintenance and access requirements

Equipment

As above

Communications

All spaces except rectifier Transformers – Automatic, power and maintenance telephones

ECS

Rectifier Transformers	-Mechanical Ventilation depending on degree of enclosure of the room
Rectifiers	-Ventilation: combined mechanical ventilation and smoke extract system
DC Switchgear	-Ventilation: combined mechanical ventilation and smoke extract system
Control Equipment & Relay Panels	-Ventilation: mechanical extract system
Battery Room	-Ventilation: individual mechanical extract system
Switchgear	-Ventilation: combined mechanical ventilation and smoke extract system

Services-Lighting

Rectifier Transformer Area	-average 200 lux at floor level
Rectifiers	-average 200 lux at floor level
DC Switchgear	-average 200 lux at floor level
Control Equipment & Relay Panels	-average 300 lux at floor level
Battery Room	-average 100 lux at floor level
Switchgear	-average 200 lux at vertical surface 600mm above floor level

Service-Power

Rectifier Transformers	-general purpose socket outlets
Rectifiers	-general purpose socket outlets
DC Switchgear	-general purpose socket outlets
Control Equipment & Relay Panels	-general purpose socket outlets
Battery Room	-general purpose socket outlets
Switchgear	-general purpose socket outlets

Services-Fire Protection

Rectifier Transformers And Rectifiers	-automatic smoke detection, CO_2 or other approved extinguishing system and portable fire extinguishers
DC Switchgear	-automatic smoke detection, CO_2 or other approved extinguishing system and portable fire extinguishers
Control Equipment & Relay Panels	-automatic smoke detection, CO_2 or other approved extinguishing system and portable fire extinguishers
Battery Room	-automatic smoke detection, CO_2 or other approved extinguishing system
Switchgear	-automatic smoke detection, CO_2 or other approved extinguishing system and portable fire extinguishers

13. Signaling Room

Function

To house signaling equipment

Location

Well separated from rooms containing transformers. Can be combined with the Communications Room

Size

As required depending on equipment requirements at specific locations

Equipment

As required

Communications

Automatic and maintenance telephones

ECS

Air-conditioning: wall unit

Ventilation: standby mechanical exhaust purging system

Services

Lighting: average 200 lux at floor level

Power: general purpose socket outlets

Fire protection: automatic smoke detection and CO_2 or other approved extinguishing system, portable fire extinguishers

14. Communications Room

Function

To house communications equipment

Location

Well separated from the station substation. Can be combined with the Signaling Room

Size

As required depending on equipment requirements at specific locations

Equipment

As required

Communications

Automatic and maintenance telephones

ECS

Air-conditioning: wall unit

Ventilation: standby mechanical exhaust purging system

Services

Lighting: average 200 lux at floor level

Power: general purpose socket outlets

Fire protection: automatic smoke detection and CO_2 or other approved extinguishing system, portable fire extinguishers

15. Station Substation

Function

To house equipment for stepping down the voltage

Location

Convenient for access to incoming and outgoing cables

Size

As required depending on equipment requirements at specific locations

Equipment

As required

Communications

Automatic and maintenance telephones

ECS

Ventilation: combined mechanical ventilation and smoke extract system

Services

Lighting: average 200 lux at floor level

Power: general purpose socket outlets

Fire protection: automatic smoke detection and CO_2 or other approved extinguishing system and portable fire extinguishers

16. Fire Tank and Pump Room

Function

Room or space to house pumps for fire fighting purposes and to provide access to the water tank

Location

Adjacent to the water tank at a level that allows the pumps to operate with a positive suction pressure

Size

As required depending on equipment requirements at specific locations

ECS

Ventilation: mechanical exhaust system

Services

Lighting: average 200 lux at floor level

Power: general purpose socket outlets

Fire protection: automatic smoke detection

Drainage: sump and mercury float level switch

8.11 Appendix A2: Passenger Forecasts For Station Design

E4 (Street)	150	41	17	134	167	175	342
E4 (Transfer)	223	66	163	217	386	283	667
E5	297	53	50	191	347	244	591
E6	138	29	15	137	153	166	319
E7	113	6	4	191	117	197	314
E8	52	0	0	53	52	53	105
E0	201	0	0	135	201	135	336
W1	0	460	212	0	212	460	672

Central

	In	Out		In	Out
Silom Line From South to West			Sukhumvit Line From North to East		
To Street	32	16	To Street	150	48
Transfers: To Sukhumvit East To Sukhumvit North		 185 194	Transfers: To Silom West To Silom South		 83 607
Silom Line From West to South			Sukhumvit Line From East to North		
To Street	112	41	To Street	146	90
Transfers: To Sukhumvit North To Sukhumvit East		 30 139	Transfers: To Silom South To Silom West		 194 57

Case B BTS Passenger Flows – Year 2007

AM Peak Passengers Per Minute

Station	Train Direction:						
	Northbound		Southbound		Both		
	In	Out	In	Out	In	Out	Total
N1	76	56	127	17	203	73	276
N2	15	69	79	7	94	76	170
N3	24	155	125	16	149	171	320
N4	11	33	58	4	69	37	106
N5	14	47	71	5	85	52	137
N6	14	35	72	4	86	39	125
N7	24	80	124	8	148	88	236
N8	0	159	155	0	155	159	314
S1	26	23	8	36	34	59	93
S2	107	39	21	65	128	104	232
S3	79	12	12	96	91	108	199
S4	30	0	0	60	30	60	90
S5	276	0	0	161	276	161	437

Station	Train Direction:						
	Northbound		Southbound		Both		
	In	Out	In	Out	In	Out	Total
E1	23	50	38	113	61	163	224
E2	79	58	45	39	124	97	221
E3	25	37	11	35	36	72	108
E4	106	26	11	101	117	127	244
E5	160	29	27	103	187	132	319
E6	75	16	8	74	83	90	173
E7	77	4	2	98	79	102	181
E8	58	0	0	44	58	44	102
E9	234	0	0	145	234	145	379
W1	0	300	113	0	113	300	413

Central

	In	Out		In	Out
Silom Line From South to West			Sukhumvit Line From North to East		
To Street	18	10	To Street	86	28
Transfers: To Sukhumvit East To Sukhumvit North		 112 138	Transfers: To Silom West To Silom South		 69 433
Silom Line From West to South			Sukhumvit Line From East to North		
To Street	66	24	To Street	83	58
Transfers: To Sukhumvit North To Sukhumvit East		 25 116	Transfers: To Silom South To Silom West		 117 48