Ankara Metro: A Challenging Mix of Greenfield and Brownfield CBTC

Ankara Metro project reflects, in many ways, the strive of Hitachi Rail STS S.p.A. to continuous improvement and achievement in challenging environments. It is a story of tenacity and adaptation to mutable situations that will introduce its latest CBTC technology into the signaling systems of four Ankara Metro lines (M1 to M4) in the Republic of Turkey. When the contract was awarded, one line (M1) was in commercial operation using another company's signaling system, and the other three lines (M2 to M4) were undergoing construction planning as new lines. The contract was signed in December 2008, and commercial operation of the first line using CBTC started in 2016, while the deployment of CBTC on the last line was completed in 2018. In addition, the integration of the operation of the whole network is underway and is expected to be completed in 2021. The initial scope of work of the project included the delivery of three new CBTC (GOA2) metro lines and the technological upgrade of an existing legacy metro line and a depot, in addition to 144 onboard systems for both the newly acquired and the legacy rolling stocks. The scope of work was further extended by means of new contracts for the additional delivery of a backup ATP system (DTP) and the extension to the Macunköy depot. This article provides an overview of the Ankara Metro project and describes the project challenges that Hitachi Rail STS has faced and the efforts it has made to cope with them during this long-term large-scale project, and how it has been able to achieve its goals through continuous efforts.

Luigi Buonanno, Ph.D.
Cyril Le Foll
Omer Polat
Lorenzo Priano
Michael R. Scott

1. Introduction

The debut of the Ankara Metro project was not the most straightforward.

In 2008, the joint venture (JV) established between Ansaldo STS S.p.A. (now, Hitachi Rail STS S.p.A.: HSTS) and Alarko Holdings A.Ş. (Ansaldo STS & Alsim Alarko San. Tesisleri ve Ticaret A.Ş. Konsorsiyumu) received an order from EGO Genel Müdürlüğü (EGO), the operator of Ankara Metro, for a project to implement a communications-based train control (CBTC) on all Ankara Metro lines (M1 to M4). At the time of the order, the M1 line (14.66 km, 12 stations) was in operation with a signaling system (cross-induction loop type automatic train security system) manufactured by another company, while the M2 line (16.59 km, 12 stations), M3 line (15.36 km, 12 stations), and M4 line (9.22 km, 9 stations) were in the planning stage. The original plan was to start commercial operation using CBTC on all routes from 2014.

The contract, initially awarded by the client, EGO, to the JV, was transferred a few years later, by EGO to the current customer, Altyapı Yatırımları Genel Müdürlüğü (AYGM). On top of it, several of the contractors previously hired by the customer (e.g., civil works and rolling stock supplier) were replaced in the process. It was a clear hint that the project's lifecycle wasn't going to be a conventional one.

The delays resulting in all these changes together with some technical issues discovered during the project execution, led HSTS and the customer to adopt a different delivery strategy from the one initially agreed in the contract. The customer also requested that the start of commercial operation of the M2 and M3 lines be accelerated from the original schedule.

As a result, to accelerate the migration to the new technology provided by HSTS, a discontinuous automatic train protection (discontinuous train protection: DTP) system, which could be used also as a fallback in case of CBTC failure, was put in revenue service first. The CBTC system was introduced later, in addition to DTP, and upgraded several times over the life of the project to ensure that the final product delivered to the customer was compliant with the state of the art that the company could offer. The DTP system was designed using the same hardware required for the CBTC system so that no further installations were necessary for the upgrade to CBTC.

2. CBTC System Architecture

Figure 1 shows an overview of HSTS's CBTC proprietary technology delivered for the Ankara Metro. The system is composed by three main subsystems, the core CBTC, the computer-based interlocking (CBI), and the automatic train supervision (ATS). The design, development, and testing of each subsystem were conducted by teams in France, Italy, and the USA, respectively, coordinated in a global manner.

(1) Core CBTC

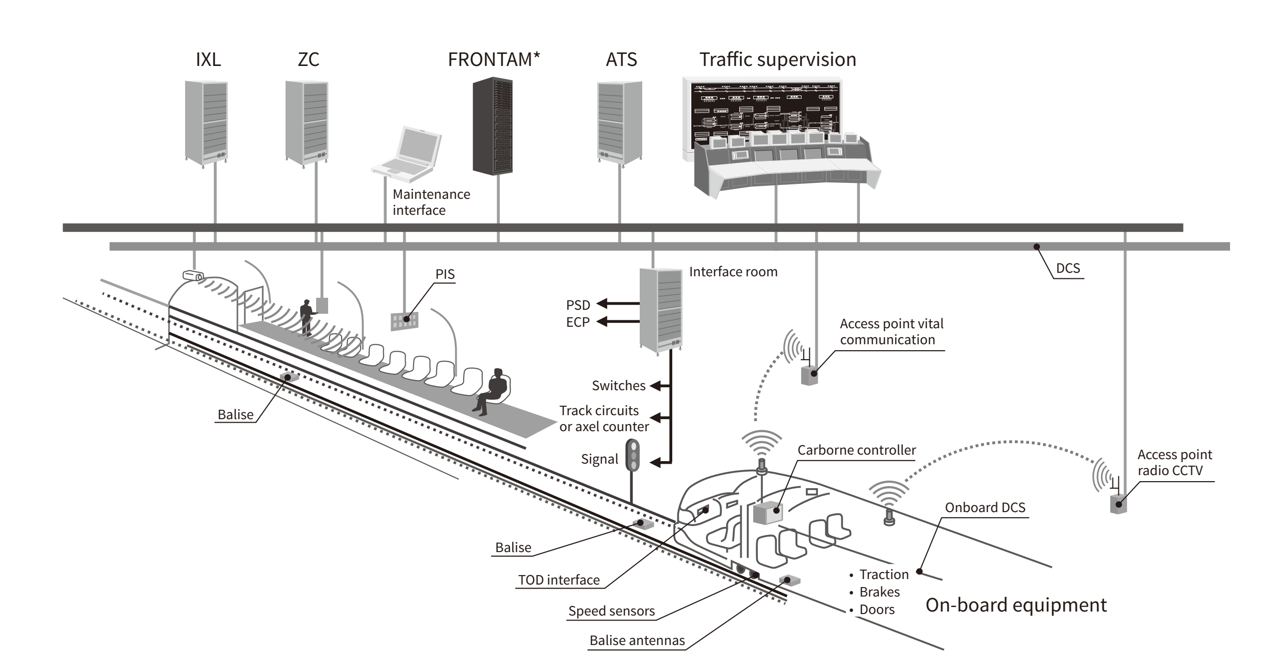
The core CBTC system consists of wayside equipment located at the control centre (called zone controllers) and onboard units (located on the trains) that dialogue through a data communication system (DCS). The core CBTC subsystem is in charge to ensure the vital separation between the operating trains considering the target headway defined. The main functions the core CBTC subsystem is responsible for are the automatic train protection (ATP) system, a protection against collisions, excessive train speeds, and other hazardous conditions, and automatic train operation (ATO), which allows automatic train driving, by using schedule and profiles set by the ATS. The design, development, and testing of the core CBTC was performed by a team from HSTS France.

(2) CBI

The CBI is the subsystem dedicated to preventing the setting up of conflicting routes by logically linking points and signal operation. It is based on a centralized CBI platform called wayside standard platform (WSP). The product implements a hierarchical architecture, in which the top layer is represented by the WSP cabinet, where interlocking safety logic runs, and the lower level is represented by peripheral post cabinets.

Figure 1 — Overview of HSTS's CBTC System

Hitachi Rail STS S.p.A.'s (HSTS's) communications-based train control (CBTC) system consists of three main subsystems, the core CBTC, IXL, and ATS.



IXL: interlocking system ZC: zone controller ATS: automatic train supervision PSD: platform screen door PIS: passenger information system ECP: emergency call point CCTV: closed circuit television DCS: data communication system TOD: train operator display

* Used for communication control of non-security systems, such as image transmission, and to function as a maintenance terminal.

Peripheral posts are installed in signaling equipment rooms in stations and house the field device controller modules that allow to interface the CBI with the wayside objects. The design, development, and testing of the CBI was performed by a team from HSTS Italy.

(3) ATS

The ATS subsystem provides the primary means by which dispatch personnel carry out their duties to monitor, supervise, and control the metro system covering the M1 through M4 lines as well as entry, exit, and movements within the Macunköy depot.

The ATS application runs on a high-availability, redundant network of commercial off-the-shelf (COTS) hardware including application and communication servers, workstations, networking equipment, and large-display wall monitors. The system is highly fault tolerant.

ATS has interfaces to several signaling and external systems that allow real-time receipt of status and control information to and from the wayside devices managed by CBI subsystem, status information from the traction power subsystem and status, control, and schedule information to and from trains managed by CBTC subsystem. The schedule mission data provided to CBTC enables the display of passenger announcements within each train car. Additionally, ATS has an interface to passenger information system (PIS) which provides information that is displayed to passengers at metro stations and platforms for arrivals of upcoming trains. The design, development, and testing of the ATS was performed by a team from HSTS USA.

It is interesting to note that the technology behind those subsystems have changed several times during the project's lifecycle, both from a hardware and software point of view. For instance, the CBI architecture has been upgraded twice, while the software baseline for all the subsystems has gone through two major releases. The reasons for those architectural upgrades have been multiple, but, in a project lasting more than 13 years, they all follow a twofold objective: to provide the customer with the most advanced product available and to standardize the solution deployed on all the HSTS CBTC projects.

3. Revenue Service Phase

The project has been characterized by a large number of revenue service phases and steps, due to the complexity of the lines and the operational needs of customer and operator, resulting in many issues to be considered and addressed by the project team.

To complete construction of the signaling system in time for the start of operation of the M2 and M3 lines, the DTP was designed and installed to have the same transport capacity as the existing signaling system in M1 line and to serve as a backup in case of CBTC failure. In March 2014, the first line (M3) was delivered in revenue service in DTP mode. Just a month later, M2 line entered into DTP revenue service as well. In addition, the M1 line required rolling stock to travel over the M1 to M3 lines, so the signaling system had to be unified for the M1 to M3 lines. As a result, DTP was introduced to the M1 line as well, and the switchover was completed and commercial operation started in 2015, with all the lines progressively activated in DTP (except of M4) first and CBTC then (see **Figure 2**).

After the switchover to CBTC was completed, the operation management functions were integrated among the railway lines so that the operations that had been carried out by each line could be unified for all of the lines as a whole. The integration of lines M1 to M3 was completed

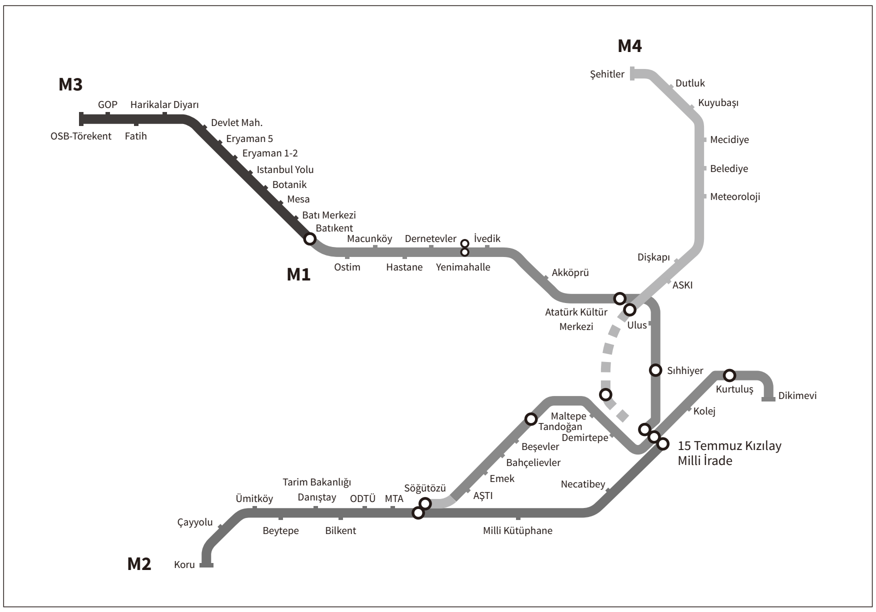


Figure 2 — Route Map of Ankara Metro M1 Line to M4 Line

Ankara Metro has route network consisting of four lines (M1 to M4), with complex operations carried out across the lines.

Table 1 — List of Main Project's Revenue Service Milestones
A phased approach was applied and the CBTC conversion was completed by the end of May 2021.

DTP mode	• M3 line (March 2014) • M2 line (April 2014) • M1 line (July 2015)
CBTC mode	• M2 line (September 2016) • M3 line (January 2017) • M4 line (April 2017) • M1 line (May 2018) • Integration of operation management functions of lines M1, M2, and M3 (February 2021) • Full integration of M4 line operation management functions (Completed in May 2021)

DTP: discontinuous train protection

in February 2021, and the integration of line M4 was completed in May 2021 (see **Table 1**).

In parallel, the commissioning of the onboard units has progressed consistently, and the conversion of all 137 trains (seven less than the original number of existing + new trains) to CBTC was completed in September 2021.

4. Challenges

Ankara Metro is a project that has posed a large number of challenges to the company in general and to the project team in particular (see **Figure 3**).

4. 1 Brownfield Project and a Large Number of Phases

First of all, the presence of a brownfield line and a brownfield depot have meant that the schedule for both construction, commissioning, and testing activities has been really compressed and has requested the continuous commitment of the involved teams to work in difficult conditions and on uncomfortable rosters: mostly on night shifts and with very limited time frames (approximately two hours per night, including the over and back procedure to shift from the existing to the new system under testing).

This situation has been further exacerbated by the different migration phases required for the full delivery of the project, in particular, the work to switch to CBTC was also congested after lines M1 to M3 were put into operation with DTP.

In general, having to design such a large metro system taking in account system migration phases such as the introduction of DTP and the switchover to CBTC, constant changes to implement the latest architectures, operational needs and constraints, etc., and minimizing at the same time costs and the operational impacts (restrictions, constraints) on the customer has been a managerial issue of massive magnitude.

4. 2 Depot Extension

At the beginning of the project, the depot extension that was already in commercial operation was not originally designed for the CBTC, and was an extraordinary challenge for the engineering team. In addition, the customer decided that the depot would have to be expanded in order to accommodate the whole fleet of new trains needed to operate the four lines, so it became larger and larger. Specifically, there are two loop lines, and including the expansion work, the facilities are twice as large as those of

Figure 3 — Members of Ankara Metro Project
In the Ankara Metro project, teams from the USA, France, and Italy collaborated with each other, working in a global system.

a normal railroad depot, so it was necessary to consider and solve various restrictions and safety issues associated with this. Its size, complexity, and the need to adapt the CBTC to the existing site configuration made this goal one of the most difficult to achieve.

4. 3 Retrofit of Legacy Trains

The retrofit on the first legacy train (in revenue service since the 80's) started in 2012. When the team approached the first prototype train, unused for years by the operator and scavenged for spares parts for the rest of the fleet, it seemed an impossible mission. But after the first moment of confusion, they put together an action plan and started to repair this train (fixing relays, wiring, etc.) with the support of old original, out of date, documentation presenting meaningful gaps with the real train situation. Thanks to the team's onboard engineering skills, the work was a success and this kept on gaining recognition for HSTS by the customer. By using the restored train, HSTS was able to proceed with the study of the conversion method to DTP and CBTC.

4. 4 The "First" by Many Means

Ankara Metro has been "the first" CBTC project from many different points of view:

- First CBTC project in which the whole signaling scope has been completely delivered by HSTS.
- First CBTC application where the worldwide team organization (USA, France, Italy) acted together and progressively improved in its processes and efficiency in interaction, providing the basis for the current consolidated way of working in quite all HSTS CBTC projects.
- First CBTC metro brownfield experience in HSTS, whose lessons learned have been extremely useful for the future projects.

4. 5 Training of Operator Personnel Used to Decades of Legacy System Operation

Operator's dispatch and maintenance personnel were accustomed to operating the system with their old, legacy system. HSTS had to cope with their expectations in terms of system operational behavior.

HSTS worked extensively with the customer early in the project to understand how the intended to operate the metro. Training sessions were repeated several times to ensure an adequate level of consciousness of how to use the new system; the design of the graphical user interface (GUI) evolved over the project's lifecycle to take in account the customizations requested by the operator and incorporate their feedback.

4. 6 COVID-19

COVID-19, which has negatively affected people and businesses all over the world, had a very serious impact on the project's schedule as well. During the first phase of the pandemic, the complete shutdowns affected the morale of the employees and caused an interruption resulting in a delay of over two months.

However, HSTS tried to make an opportunity out of the partial shutdown of the revenue service by increasing the duration of site work permits, thus recovering some delays.

4. 7 Migrating Fleet

Last but not least: the last software migration had to be performed on the entirety of the onboard fleet in a single weekend, in order not to impact the revenue service operation.

A whole fleet of almost 120 trains had to be updated in only two and half days, the time agreed with the customer. Thanks to the relentless support of the colleagues from all HSTS departments, HSTS completed a mission that was deemed impossible by preparing all the fleet ready for Monday operation.

5. Non-conventional Project

In a project of this duration and complexity, there are countless anecdotes around the vicissitudes of the people involved in the project.

In this project, many changes in plans occurred due to internal and external factors. It has been a project where the abilities of reacting and adapting to unexpected events have sometimes mattered even more than the ability to plan. Like the time HSTS had to destroy an outer wall in the operations control center (OCC) because the team needed more space for the equipment, or that other time when someone had to suddenly fly from Perth Australia to Shanghai China to negotiate an urgent cable delivery for HSTS's French team based in Turkey. The epitome of globalization.

Because Ankara Metro is not a "conventional" project by any means.

A project that has gone through changes of strategy, technology, and, most notably, people countless times. People are the real key behind the (many) successes and the (occasional) hiccups. Ankara Metro has been somehow a proof of concept of how a melting pot of teams from different nations (at some point, HSTS had teams from USA, France, Italy, Turkey, India, and Australia involved at the same time) can collaborate successfully if driven by the same integrity and objectives. A demonstration that no matter how many project managers or project engineers alternated on the job (four and five respectively), the project can keep progressing if everyone is motivated by the same passion and enthusiasm.

And people are the real legacy of the project. After a decade of work, there is a branch of talented local colleagues that are ready for new challenges. Some of them are already abroad, leading the signaling integration for HSTS's CBTC project in Lima, Peru. Others will follow.

6. Conclusions

Ankara Metro is now a system of four lines and more than 100 trains equipped with HSTS CBTC technology. It operates 18 hours a day with a minimum headway of three minutes. This result has been achieved first and foremost thanks to the tenacity and the abnegation of the many talented and committed colleagues that have made its delivery possible.

Many unexpected events happened during the lifecycle of the project, but the team has been navigating through all of them relentlessly until the achievement of all the set targets. A pool of experienced resources is now ready to move to new endeavors all around the world where new CBTC projects are under execution, and they will bring with themselves the testament to HSTS's mission to always pursue the maximum possible customer satisfaction.

Authors

Luigi Buonanno, Ph.D.
Testing and Laboratory Integration – System Validation, Hitachi Rail STS S.p.A. *Current work and research:* Project engineering for Boston NSATC project.

Cyril Le Foll
Local delivery Core CBTC EMEA, Hitachi Rail STS S.p.A. *Current work and research:* CBTC work package leader for several global projects worldwide.

Omer Polat
EMEA PE METRO Projects – EMEA PE METRO Projects Pool, Hitachi Rail STS S.p.A. *Current work and research:* Project engineering for Ankara Metro.

Lorenzo Priano
Competence Center Wayside Italy, Hitachi Rail STS S.p.A. *Current work and research:* Securing the delivery of IXL functional design for all the projects in the portfolio of the Italian LE.

Michael R. Scott
ATS WPL Pool, Hitachi Rail STS S.p.A. *Current work and research:* ATS work package leader for several global projects worldwide.