

= Copenhagen Metro =

Copenhagen Metro (Danish : Københavns Metro) is a rapid transit system serving the cities of Copenhagen , Frederiksberg , and Tårnby in the Capital Region , Denmark .

The 20 @. @ 4 @-@ kilometre (12 @. @ 7 mi) system opened between 2002 and 2007 , and has two lines , M1 and M2 . The driverless light metro supplements the larger S @-@ train rapid transit system , and is integrated with DSB local trains and Movia buses . Through the city center and west to Vanløse , M1 and M2 share a common line . To the southeast , the system serves Amager , with the 13 @. @ 9 @-@ kilometre (8 @. @ 6 mi) M1 running through the new neighborhood of Ørestad , and the 14 @. @ 2 @-@ kilometre (8 @. @ 8 mi) M2 serving the eastern neighborhoods and Copenhagen Airport . The metro has 22 stations , of which nine are underground . In 2013 , the metro carried 55 million passengers .

= = Overview = =

The system is owned by Metroselskabet , which is owned by the municipalities of Copenhagen and Frederiksberg , and the Ministry of Transport . The 34 trains are of the AnsaldoBreda Driverless Metro class and stationed at the Control and Maintenance Center at Vestamager . The trains are 2 @. @ 65 m (8 ft 8 in) wide and three cars long ; their 630 @-@ kilowatt (840 hp) power output is supplied by a 750 @-@ volt third rail . The metro trains were originally planned to be four cars long , but trains were reduced to three cars per set as a savings measure . Platforms are - although shorter than originally planned - built to accommodate train with four cars , and the automatic doors can be modified accordingly should the need arise .

Operation of the system is subcontracted to Metro Service . Trains run continually , twenty @-@ four hours a day , with the headway varying from two to twenty minutes .

Planning of the Metro started in 1992 as part of the redevelopment plans for Ørestad with construction starting in 1996 , and stage 1 , from Nørreport to Vestamager and Lergravsparken , opened in 2002 . Stage 2 , from Nørreport to Vanløse , opened in 2003 , followed by stage 3 , from Lergravsparken to Lufthavnen , in 2007 . Construction of the M3 + M4 City Circle Line is underway . Scheduled to open in 2020 , this line will form a circle around the city center , be entirely underground and not share any track with M1 and M2 . Kongens Nytorv and Frederiksberg will serve as interchanges between M1 , M2 and M3 + M4 . A two @-@ station branch towards Nordhavn is planned to open in 2019 . A planned expansion towards Sydhavn will include a linkup with Ny Ellebjerg on the S @-@ train network . These stations will also be connected to the regional train network following the completion of the new Copenhagen @-@ Ringsted railway . The Sydhavn extension has been approved .

= = History = =

= = = Background = = =

The planning of the metro was spurred by the development of the Ørestad area of Copenhagen . The principle of building a rail transit was passed by the Parliament of Denmark on 24 June 1992 , with the Ørestad Act . The responsibility for developing the area , as well as building and operating the metro , was given to the Ørestad Development Corporation , a joint venture between Copenhagen Municipality (45 %) and the Ministry of Finance (55 %) . Initially , three modes were considered : a tramway , a light rail and a rapid transit . In October 1994 , the Development Corporation chose a light rapid transit .

The tram solution would have been a street tram , without any major infrastructure investments in the city centre , such as a dedicated right @-@ of @-@ way . Through Ørestad it would have had level crossings , except for a grade @-@ separated crossing with the European Route E20 and the Øresund Line . It would have had a driver and have operated at about a 150 @-@ second interval ?

twice the cycle time of the city 's traffic lights . Power would have been provided with overhead wires . Stops were to be located about every 500 m (550 yd) at street level . The articulated trams would have been about 35 m (115 ft) long and have a capacity for 230 passengers .

The light rail model would have used the same approach as the tram in Ørestad , but would instead have run through a tunnel in the city centre . The tunnel sections would be shorter , but the diameter larger because it would have to accommodate overhead wires . The system would have the same frequency as the tram , but use double trams and would therefore require larger stations . The metro solution was chosen because it combined the highest average speeds , the highest passenger capacity , the lowest visual and noise impact , and the lowest number of accidents . Despite requiring the highest investment , it had the highest net present value .

The decision to build stage 2 , from Nørreport to Vanløse , and stage 3 , to the airport , was taken by Parliament on 21 December 1994 . Stage 2 involved the establishment of the company Frederiksbergbaneselskabet I / S in February 1995 , owned 70 % by the Ørestad Development Corporation and 30 % by Frederiksberg Municipality . The third stage would be built by Østamagerbaneselskabet I / S , established in September 1995 and owned 55 % by the Ørestad Development Corporation and 45 % by Copenhagen County . In October 1996 , a contract was signed with the Copenhagen Metro Construction Group (COMET) for building the lines (Civil Works) , and with Ansaldo STS for delivery of technological systems and trains , and to operate the system the first five years . COMET was a single @-@ purpose consortium composed of Astaldi , Bachy , SAE , Ilbau , NCC Rasmussen & Schiøtz Anlæg and Tarmac Construction .

= = = Construction of lines M1 and M2 = = =

Construction started in November 1996 , with the moving of underground pipes and wires around the station areas . In August 1997 , work started at the depot , and in September , COMET started the first mainline work . In October and November , the two tunnel boring machines (TBM) , christened Liva and Bette , were delivered . They started boring each barrel of the tunnel from Islands Brygge in February 1998 . The same month , the Public Transport Authority gave the necessary permits to operate a driverless metro . The section between Fasanvej and Frederiksberg is a former S @-@ train line , and was last operated as such on 20 June 1998 .

The first section of tunnel was completed in September 1998 , and the TBMs moved to Havnegade . By December 1998 , work had started on the initial nine stations . Plans for M2 were presented to the public in April 1999 , with a debate emerging if the proposed elevated solution was the best . In May , the first trains were delivered , and trial runs began at the depot . In December , the tunnels were completed to Strandlodsvej , and the TBMs were moved to Havnegade , where they started to grind towards Frederiksberg . From 1 January 2000 , the S @-@ train service from Solbjerg to Vanløse was terminated , and work commenced to rebuild the section to metro . The last section of tunnel was completed in February 2001 .

In March 2001 , Copenhagen County Council decided to start construction of stage 3 . On 6 November 2001 , the first train operated through a tunnel section . On 28 November , laying of tracks along stage 1 , and stage 2A from Nørreport to Frederiksberg , was completed . An agreement about financing stage 3 was reached on 12 April . By 22 May , the 18 delivered trains had test @-@ run 100 @,@ 000 km (62 @,@ 000 miles) . The section from Nørreport to Lergravsparken and Vestamager was opened on 19 October 2002 . Initially , the system had a 12 @-@ minute headway on each of the two services . From 3 December this was reduced to 9 minutes , and from 19 December to 6 minutes . Operation of the system was subcontracted to Ansaldo , who again subcontracted it to Metro Service , a subsidiary of Serco . The contract had a duration of five years , with an option for extension for another three .

= = = Opening of lines M1 and M2 = = =

Trial runs on stage 2A began on 24 February 2003 and opened on 29 May . All changes to bus and train schedules in Copenhagen took place on 25 May , but to allow Queen Margrethe II to open the

line , the opening needed to be adapted to her calendar . This caused four days without a bus service along the line . Stage 2B , from Frederiksberg to Vanløse , opened on 12 October .

Forum Station was nominated for the European Union Prize for Contemporary Architecture in 2005 . On 2 December 2005 , the final agreement to build the City Circle Line was made between the local and national governments . The price was estimated at 11 @. @ 5 to 18 @. @ 3 billion Danish krone (DKK) , of which DKK 5 @. @ 4 billion will be financed through ticket sales , and the remaining from the state and municipalities . In 2006 , it was announced that the contract with Ansaldo to operate the metro had been prolonged another three years . However , the subcontract between Ansaldo and Serco Group was not extended , and the contract was instead given to Azienda Trasporti Milanesi in joint venture with Ansaldo ; they took over operations from October 2007 . The Ørestad Development Corporation was discontinued in 2007 , and the ownership of the metro was transferred to Metroselskabet I / S.

In January 2007 , the city council decided that a branch was to be built during construction at Nørrebro , to allow a future branch line from the City Circle Line towards Brønshøj . The first part of this line was intended to be constructed at the same time as the City Circle Line , to avoid a multitude @-@ higher construction cost and long interruptions of operations later . This did not involve a final decision , only an option for future construction . The Herlev / Brønshøj line was ultimately dropped as the City of Copenhagen withdrew its share of the cost of the Nørrebro branch chamber in its 2009 budget , and the state refused to continue the project . Any branch to the Herlev / Brønshøj region would now require a shutdown of the City Circle Line for an extended period of time .

In March 2007 , a proposal to establish a station at Valby , where the Carlsberg Group is planning an urban redevelopment , was scrapped . The proposal would have increased construction costs by DKK 900 million and was deemed not economical . The increased cost was , in part , due to an extra TBM being needed to complete the project on time . The City Circle Line was passed by parliament on 1 June 2007 , with only the Red ? Green Alliance voting in disfavor .

The 4 @. @ 5 km (2 @. @ 8 @-@ mile) stage 3 opened on 28 September 2007 , from Lergravsparken to the airport . It followed , for the most part , the route of the former Amager Line of the Danish State Railways . With this stage complete , the 34 trains were delivered . However , the line caused a heated debate , with several locals organized themselves into the Amager Metro Group . The group argued that the line should have been built underground , citing concerns that it would create noise pollution and a physical barrier in Amager . In April 2008 , the Copenhagen Metro won the award at MetroRail 2008 for the world 's best metro . The jury noted the system 's high regularity , safety and passenger satisfaction , as well as the efficient transport to the airport . During 2008 , the metro experienced a 16 % passenger growth to 44 million passengers per year .

An agreement made in September 2008 , the Social Democrats , the Conservative People 's Party , the Liberal Party and the Danish People 's Party agreed to not fund an expansion of the metro northwest . Initially , the system operated trains from 01 : 00 to 05 : 00 only on Thursdays through Saturdays , but , starting on 19 March 2009 , night service was extended to the rest of the week . This caused a logistical challenge , because Metro Service used the nights for maintenance . The routes were therefore set up in such a way that the system could be operated on only a single track , leaving the other free for work . In May 2009 , six companies were pre @-@ qualified to bid for the public service obligation to operate the metro . These were Serco @-@ NedRailways , Ansaldo STS , Arriva , S @-@ Bahn Hamburg , Keolis and DSB Metro ? a joint venture between DSB and RATP . The process was delayed because of a procedural error by Metroselskabet , who failed to pre @-@ qualify DSB Metro .

= = = Construction of City Circle Line = = =

An expansion of the metro , the City Circle Line , is under @-@ construction and scheduled to open in 2019 . Independent of the existing system , it will circle the city center and connect the areas of Østerbro , Nørrebro and Vesterbro to Frederiksberg and Indre By . The line will be 15 @. @ 5 km (9 @. @ 6 miles) long and run entirely in tunnel . The circle will have 17 stations , two of which are

interchanges with both the M1 and M2 lines , and it will take 25 minutes to complete a full circle . Archaeological and geological surveys started in 2007 , preferred bidders were announced in November 2010 and contracts were signed in 2011 . Preparations began by moving utilities etc. in 2010 , and construction of work sites and stations began in 2011 . Drilling of tunnels will begin in 2013 . On 7 January 2011 the new project called Cityringen started with the signature by Metroselskabet of new contracts , with Ansaldo Breda and Ansaldo Sts (Finmeccanica Group) for the supply of trains and control systems and with an Italian joint @-@ venture led by Salin Costruttori (about 60 %) and Tecnimont (about 40 %) with Seli as third partner for the construction part . In July 2013 , Natur- og Miljøklagenævnet , the environmental appeals board , ruled that the city was wrong to grant Metroselskabet permission for 24 @-@ hour work days and noise up to 78 db at the Marmorkirken site . The company is now required to stop work 6PM until a final ruling is made , which could take up to half a year , potentially delaying the completion date .

The line will operate as M3 and M4 . The former will run a full circle , while M4 will only operate on the eastern half from Copenhagen Central Station (København H) via Østerport to Nørrebro . This solution is temporary , once the metro network has been extended to Nordhavn , the M4 will start at Copenhagen Central Station but leave the City Circle Line at Østerport and service the Nordhavn branch . Later , when the Sydhavn extension has been completed , the M4 will have Ny Ellebjerg as its southern terminus . Trains will operate both ways through the circle . The line will have transfer to M1 and M2 at Frederiksberg and Kongens Nytorv . The line is estimated to carry 240 @, @ 000 daily passengers , bringing the metro 's total daily ridership to 460 @, @ 000 .

A northwestern expansion of the City Circle Line was planned , where M4 would divert at Nørrebro and run to the suburbs of Brønshøj and Gladsaxe . This project was abandoned , as the interchange chamber between any such line and the City Circle Line was scrapped as part of the City of Copenhagen 's 2009 budget . In subsequent plans , the northern extension of the M4 has instead been relocated as a Nordhavn branch which will connect with the City Circle Line at Østerport . A Nordhavn line with two stations has been approved by the Danish parliament , and is planned to open in 2019 . The southern extension of the M4 will run from Copenhagen Central Station through Sydhavn to Ny Ellebjerg , where the M4 will link up with the S @-@ train and regional train system . The Danish Transport Authority (Trafikstyrelsen) has suggested to convert the F @-@ line of the S @-@ train network to metro standard as an M5 line , but as the only linkup between the M5 and the existing network would be at Flintholm Station (interchange with M1 and M2) , this plan is dependent on the approval of a southern extension of the M4 , also providing the M5 with an interchange with the M4 at Ny Ellebjerg Station .

The City of Copenhagen has suggested two additional lines M6 and M7 , and a western extension of the M1 or M2 to Brøndbyøster has also been suggested .

In September 2011 , the local governments in Copenhagen and neighbouring Malmö in Sweden announced that they were seeking European Union funding to study a potential metro line under the Øresund to the neighbourhood of Malmö Central Station , providing faster trips and additional capacity beyond that of the existing Øresund Bridge . The study , for which the EU granted funding in the following December , will consider both a simple shuttle between the two stations and a continuous line integrated with the local transport networks on each side , and they anticipate a travel time of 15 minutes between the two city centers .

= = Route = =

The metro consists of two lines , M1 and M2 . They share a common 7 @. @ 69 @-@ kilometre (4 @. @ 78 mi) section from Vanløse to Christianshavn , where they split along two lines : M1 follows the Ørestad Line to Vestamager , while M2 follows the Østamager Line to the airport . The metro consists of a total route length of 20 @. @ 4 kilometres (12 @. @ 7 mi) , and 22 stations , 9 of which are on the section shared by both lines . M1 is 13 @. @ 9 kilometres (8 @. @ 6 mi) long and serves 15 stations , while M2 is 14 @. @ 2 kilometres (8 @. @ 8 mi) long and serves 16 stations . About 10 km (6 miles) of the lines and 9 stations are in tunnel , located at 20 to 30 m (70 to 100 ft) below ground level . The remaining sections are on embankments , viaducts or at ground level .

The section from Vanløse to Frederiksberg follows the Frederiksberg Line , a former S @-@ train line which runs on an embankment . Between Solbjerg and Frederiksberg , the line runs underground , and continues through the city center . After Christianshavn , the line splits in two . M1 reaches ground level at Islands Brygge , and continues on a viaduct through the Vestamager area . M2 continues in tunnel until after Lergravsparken , where it starts to follow the former Amager Line .

The tunnels consist of two parallel barrels ; they run through stable limestone at about 30 m (100 ft) depth , but are elevated slightly at stations . There are emergency exits every 600 m (660 yd) , so that no train is ever further than 300 m (330 yd) away from one . The outer tunnel diameter is 5 @. @ 5 m (18 ft) , while the inner diameter is 4 @. @ 9 m (16 ft) . The tunnels were excavated by the cut @-@ and @-@ cover method , the New Austrian Tunnelling method and by tunnel boring machines (TBM) . Along the elevated sections , the tracks run on alternating sections of separate reinforced concrete viaducts and joint embankments made of reinforced earth .

= = Service = =

The system operates continually (24 / 7) with a varying headway throughout the day . During rush hour (07 : 00 ? 10 : 00 and 15 : 00 ? 18 : 00) , there is a two @-@ minute headway on the common section and a four @-@ minute headway on the single @-@ service sections . During Thursday through Saturday night (0 : 00 ? 05 : 00) , the headway is fifteen minutes , and other nights it is twenty minutes on all sections of the metro . At all other times , there is a three @-@ minute headway on the common section and a six @-@ minute on the split sections . Travel time from Nørreport to Vestamager on M1 is 14 minutes , to the airport on M2 is 15 minutes , and to Vanløse on M1 and M2 is 9 minutes . In 2009 , the metro transported 50 million passengers , or 137 @, @ 000 per day ; by 2013 , the metro 's ridership increased to 55 million .

The metro operates with a proof @-@ of @-@ payment system , so riders must have a valid ticket before entering the station platforms . The system is divided into zones , and the fare structure is integrated with other public transport in Copenhagen , including the buses managed by Movia , local DSB trains and the S @-@ train . The system lies within four different zones . Ticket machines are available at all stations , where special tickets for dogs and bicycles can also be purchased . A two @-@ zone ticket costs DKK 24 , and a three @-@ zone ticket DKK 36 , and tickets are good for 60 minutes . Holders of the Copenhagen Card museum pass ride free of charge , as do up to two children under twelve years of age accompanied by an adult . As of 2012 , the metro has fully adapted to the national electronic fare card system Rejsekort .

The system is integrated with other public transport in Copenhagen . There is transfer to the S @-@ train at Vanløse , Flintholm and Nørreport , to DSB 's local trains at Nørreport , Ørestad and Lufthavnen , and to Copenhagen Airport at Lufthavnen . There are transfers to Movia bus services at all but four stations .

The system is owned by Metroselskabet , who is also responsible for building the City Circle Line . The company is owned by Copenhagen Municipality (50 @. @ 0 %) , the Ministry of Transport (41 @. @ 7 %) and Frederiksberg Municipality (8 @. @ 3 %) . The company is organized with as few employees as possible . Construction and operation is subcontracted through public tenders , while consultants are used for planning . The contract to operate the system was made with Ansaldo STS , who has subcontracted it to Metro Service , a joint venture between them and Azienda Trasporti Milanesi (ATM) , the public transport company of the city of Milan , Italy . The company has about 200 employees , the majority of whom work as stewards .

= = Stations = =

There are twenty @-@ two stations on the network , of which nine are underground and six are deep @-@ level . They were all designed by KHR Arkitekter , who created open stations with daylight . Stations have an information column in front , marked with a large ' M ' and featuring information screens . All stations have a vestibule at ground level , which has ticket and local

information , ticket machines and validators . The stations are built with island platforms and are fully accessible for people with disabilities .

The six deep @-@ level stations are built as rectangular , open boxes 60 m (200 ft) long , 20 m (66 ft) wide and 20 m (66 ft) deep . The platforms are located 18 m (59 ft) below the surface . Access to the surface is reached via escalators and elevators . The design allows the stations to be located below streets and squares , allowing the stations to be built without expropriation . Access to the track is blocked by platform screen doors . The underground stations were built as cut @-@ and @-@ cover from the top down (except Christianshavn , which was excavated as a large hole and the station built bottom @-@ up) , and the first part of construction was building a water @-@ tight wall on all sides . There are glass pyramids on the roof of the stations permitting daylight to enter . Inside the pyramids , there are prisms reflecting and splitting the light , sometimes resulting in rainbows on the walls . The light in the stations is automatically regulated to make best use of the daylight and maintain a constant level of illumination of the stations at all times .

The elevated stations are built in glass , concrete and steel to minimize their visual impact . Outside , there is parking for bicycles , cars , buses and taxis . The platforms are open , but have sheds , and automatic sensors that halt trains if obstacles are detected on the tracks .

= = Trains = =

The system uses 34 driverless electric multiple units built by AnsaldoBreda and designed by Giugiaro Design of Italy called the AnsaldoBreda Driverless Metro .

The trains are 39 m (128 ft) long , 2 @. @ 65 m (8 ft 8 in) wide , and weigh 52 tonnes (51 long tons ; 57 short tons) . Each train consists of three articulated cars with a total of six automated , 1 @. @ 6 m (5 ft 3 in) wide doors , holding up to 96 seated and 204 standing passengers (300 in total) . There are four large ' flex areas ' in each train with folding seats providing space for wheelchairs , strollers and bicycles .

Each car is equipped with two three @-@ phase asynchronous 105 @-@ kilowatt (141 hp) motors , giving each train a power output of 630 kilowatts (840 hp) . In each car , the two motors are fed by the car 's own insulated @-@ gate bipolar transistor . They transform the 750 @-@ volt direct current collected from the third rail shoe to the three @-@ phase alternating current used in the motors . The trains ' top speed are 80 km / h (50 mph) , while the average service speed is 40 km / h (25 mph) , with an acceleration and deceleration capacity of 1 @. @ 3 m / s² (4 @. @ 3 ft / s²) along the standard @-@ gauge track .

The entire metro system and the trains are run by a fully automated computer system , located at the Control and Maintenance Center south of Vestamager Station . The automatic train control (ATC) consists of three subsystems : automatic train protection (ATP) , automatic train operation (ATO) and automatic train supervisory (ATS) . The ATP is responsible for keeping the trains ' speed , ensuring that doors are closed before departure and switches are correctly set . The system uses fixed block signaling , except around stations , where moving block signaling is used .

The ATO is the autopilot that runs the trains on a predefined schedule , ensures that the trains stop at the station and open the doors . The ATS keeps track of all the components in the network , including the rails and all of the trains in the system , and displays a live schematic at the control center . The ATC is designed so that the ATP is the only safety @-@ critical system , as it would halt the trains if the other systems fail . The safety and signaling specifications are based on the German BOStrab , and controlled by TÜV Rheinland and Det Norske Veritas under supervision of the Public Transport Authority . Other aspects of the system , such as power supply , ventilation , security alarms , cameras and pumps , are controlled by a system called " control , regulating and surveillance " .

The Control and Maintenance Center is a 1 @. @ 1 @-@ hectare (2 @. @ 7 @-@ acre) facility located at the south end of M1 . It consists of a storage area for trains not in use , a maintenance area and the control facility . Trains operate automatically through the system , and can also automatically be washed on the exterior . The facility has 5 km (3 @. @ 1 mi) of track , of which 800 m (870 yd) is a test track for use after maintenance . The most common repairs are wheel grinding

; more complicated repairs are made by replacing entire components that are sent to the manufacturer . By having components in reserve , trains can have shorter maintenance time . The depot also has several maintenance trains , including diesel locomotives that are able to retrieve broken down or disabled trains .

At any time , there are four people working at the control center : two monitor the ATC system , one monitors passenger information , and one is responsible for secondary systems , such as power supply . In case of technical problems , there is always a team of linemen that can be dispatched to perform repairs . Although the trains are not equipped with drivers , there are stewards at stations and on some trains that help passengers , perform ticket controls and assist in emergency situations .