

Mobilising public transport

Closing the gap to a sustainable future
Rail engineering and consultancy services

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Bright ideas.
Sustainable change.



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The Partner for Sustainable Change

Mobility and transport are essential for the development of any modern society. With people and goods crossing borders every day, globalisation has increased the importance of an efficient and sustainable transport system.

Our ambition is to become a global leader within four unifying sustainability themes:

Decarbonise for net zero

We work on accelerating the Green Energy Transition by considering renewables and new technologies. For example decarbonisation of the built environment in Buildings, Transport, Water and Energy-intensive industries via sustainable materials and reduced energy consumption.

Resilient societies and liveability

We achieve this by planning, designing, and retrofitting for resilient, healthy, safe, inclusive and socially coherent societies, cities and communities with attractive and accessible infrastructure and services, mobility, clean water and environment, and economic opportunities.

Resource management and circular economy

We focus on resource management for a transition to circular economy. This includes design for re-purposing and re-use of natural resources, building materials, lifetime extension, end-of-life and reuse of secondary materials.

Biodiversity and ecosystem

We ensure protection of natural habitats and biodiversity, restoration of nature and ecosystems, bioeconomy, biomaterials, and natural carbon sequestration in ecosystems.

With increasing urbanisation, road congestion and a focus on the environment and energy consumption, railways offer a strong alternative to road transport for people and freight. As a result, construction, upgrading and renewing of railways is rapidly increasing all over the world.

About Ramboll

Ramboll is a global architecture, engineering and consultancy company founded in Denmark in 1945. Ramboll has over 350 offices in 35 countries and our 18,000 experts create sustainable solutions across Buildings, Transport, Energy, Environment & Health, Water, Management Consulting and Planning & Urban Design.

Across the world, Ramboll combines local experience with a global knowledge base to create sustainable cities and societies. We combine insights with the power to drive positive change for our clients, in the form of ideas that can be realised and implemented. We call it: Bright ideas. Sustainable change.

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Rail engineering

Through our expertise within rail consultancy and our multifaceted rail services, Ramboll helps to improve city infrastructure and bring communities closer together.

Who we are

Ramboll provides professional engineering, design and consultancy services for all public transport systems, including the complete range of rail systems, from high-speed rail to urban transport systems, such as metro and light rail. We combine our expertise within rail consultancy with all of Ramboll's other service areas – allowing us to deliver fully integrated transport solutions.

What we do

Our technical expertise comprises permanent way, traction power, and overhead catenary systems, interlocking systems, signalling, traffic management, telecoms, and rolling stock. With our extensive expertise within railway and urban transport services, we offer planning, design, approval, operational, and commissioning services spanning the whole project cycle, from inception to evaluation upon completion.

Holistic and multidisciplinary planning

As a multidisciplinary consultancy, Ramboll is capable of delivering major complex projects requiring specialist railway expertise as well as more general capability in civil engineering, structural engineering, environmental services, commercial advice and support, IT and project management. We draw on our vast experience from local, national and international projects and can therefore deliver internationally competitive and integrated holistic

solutions that are tailored to local conditions and fully compliant with international standards.

Our approach

Our clients include all major stakeholders in the rail market, covering government departments, railway authorities, railway infrastructure agencies, operators, contractors, consultants, suppliers, rolling stock operators, private investors, banks and other financial institutions. Having a diversity of clients, we have acquired unique understanding of different stakeholder needs and this gives us valuable insight for finding solutions suitable for all stakeholders.

Bringing communities closer together



European rail traffic management system (ERTMS)

Over the next 10-15 years, all European countries will need to operate signalling systems based on the European standard, ERTMS, which will enable seamless rail travel across national borders.

Ramboll's market leading expertise in this area includes the design of the world's first and largest nationwide ERTMS system. Through many signalling and ERTMS projects, Ramboll has established extensive experience with ERTMS, ETCS and GSM-R radio.

Improving capacity, punctuality and safety

ERTMS will create significant benefits for passengers and freight companies. This includes improved capacity, better punctuality and improved safety. It will also help

ensure that rail transport systems become more competitive and a sustainable alternative to road traffic.

Many countries are developing strategies for implementing ERTMS, and face significant challenges such as obsolete and unreliable signalling systems. Ramboll can assist infrastructure managers in defining strategies, investigating business cases, planning projects, developing technical solutions, and facilitating migration from old to new signalling systems. Ramboll also has

the expertise to simulate and analyse scenarios and provide models to improve the capacity of existing lines.

Adding value throughout the project life cycle

In order to establish the most appropriate setup for ERTMS studies, ERTMS projects, and conventional signalling projects, we collaborate closely with our clients to define the best approach. By involving specialist expertise from across our disciplines and international offices, we are able to meet the individual requirements of each project.

01 ERTMS strategy in Finland

Ramboll is helping to create a comprehensive plan to support the Finnish Transport Agency's national ERTMS implementation strategy. The project includes selecting the track sections to be targeted and developing phased construction timetables.

02 Signalling Program in Denmark

The nationwide Signalling Programme in Denmark is Europe's largest re-signalling scheme. You can read more about the programme on pages 10-11.

03 ERTMS Program in Norway

Ramboll supports Bane Nor by its preparation of the nationwide ERTMS implementation by preparation of specifications for TMS systems and onboard equipment.

04 ERTMS Program in the UK

The East Coast Digital Programme (ECDP) is the first implementation programme to utilise the new Digital Railway technology specifications. Ramboll has been working as a Digital Railway Delivery Partner since early 2017, supporting Network Rail on developing the strategy and specifications.





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Feature project

The Danish Signalling Programme (Europe's largest re-signalling scheme)

The (ERTMS) is the most efficient tool to make the European railway network interoperable. Denmark is the first country in Europe to upgrade its entire signalling system, and Ramboll is heading the complicated work and the international consortium Ramboll-Atkins-Emch+Berger-Parsons.

Shorter travel times and less delays

With 60% of all Danish signalling sites reaching the end of their technical service lifespan within the next 15 years, the Danish Parliament decided to fund a EUR 2.5 billion programme to renew all railway signalling. The consultancy tender for this programme is the largest call for tender ever in Denmark.

The re-signalling scheme will ensure shorter travel times and less delays, and is the first step towards a total reorganisation of the trans-European train operation.

Replacing analogue with digital

The programme covers 2,100 km of lines and 3,200 km of tracks and encompasses all signalling equipment – from basic train detection and point machines to the overall traffic management system and on-board systems.

By implementing the common European ERTMS level 2 system on intercity and regional lines, all existing analogue radio systems will be

replaced by digital GSM-R technology for data communication between the trains and the signal control systems.

In addition, all signalling on the Copenhagen S-train network will be replaced by a CBTC metro/urban railway signalling system that is customised for driverless operation. To accomplish the task, the consortium has created a team of more than 100 experts from Denmark, Switzerland, UK and USA, to combine local knowledge of the existing system with international railway expertise.

Technology migration by 2023

The new signalling system is scheduled to be fully implemented by 2023, and Denmark will by then be the only country to have carried out a total migration to the new signalling technologies.

Throughout the roll-out of the re-signalling scheme, the entire train operation will be maintained.



Intercity and high speed railways

Efficient transport systems are absolutely essential in societies with steadily growing populations in and around large cities – and travel times for rail must be competitive compared to air traffic. In addition, the demand for sustainable transport solutions is increasing and drives the search for attractive alternatives that will make us less dependent on fossil fuels as good alternatives to air traffic.

Our competencies within intercity and high-speed railways include:

- Initial analysis and proposals regarding upgrades and new railways
- Proposals regarding operation concepts and timetable structures
- Preparation of traffic forecasts
- Analysis of capacity conditions in upgrades and new facilities
- Preparation of facility estimates following the guidelines for "New facility budgeting"
- Socioeconomic analysis
- Planning and project design of all technical rail facilities – tracks, signalling, electrification etc.
- Planning and project design of earthwork, bridges, tunnels etc.
- Planning and project design of stations and terminals
- Assistance in relation to authority approvals
- Tender and contract strategies
- Project management and construction management including inspection

Ramboll is involved in the expansion and modernisation of the main lines in the Nordic countries and in the UK. We have substantial experience and competencies in the implementation of such projects and are familiar with international standards and norms. The projects are often complex and involve many different technical disciplines, and Ramboll can provide this multidisciplinary expertise with extensive experience in assembling and working in international project teams.

Safe and fast lines in challenging terrains

At Ramboll, we conduct comprehensive mapping of environmental conditions and technical feasibility in corridors. The lines are then constructed to meet the necessary design speed. A firm curvature often demands many constructions and tunnels, especially in mountainous landscapes. Our experts possess long-term experience

within bridge-building and tunnel engineering and can calculate all parameters in order to construct safe and fast rail lines that are also operational and simple to maintain. We are also well versed in calculations of costs and the use of optimised construction methods.

We deliver reports on the potential benefits of constructing highspeed lines for society and users and we provide our clients with overviews of potential environmental consequences, time schedules and cost estimates. Our visualisation-led approach to projects is tailored to each client's requirements and employs overview maps showing where the lines will pass through the terrain as well as additional drawings of, for example, constructions and stations.





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01 Vejle Fjord – new shortcut secures faster travel time

The planning of the rail projects to realise the ambitious Danish Hour Model is in full swing. At Vejle Fjord in Denmark, studies are underway to ensure shorter travel times on the rail section between Odense and Aarhus.

02 The Norwegian National Rail Administration

Preparation for a possible Parliament decision to build a new high-speed rail line between the major Norwegian cities. Ramboll has assessed alternative routes between Oslo and Trondheim.

03 Copenhagen-Ringsted, Denmark

The new double-tracked 63 km railway from Copenhagen to Ringsted is built for speed limits up to 250 km/hour and is Denmark's first railway that can operate high-speed trains.

04 Large rail project alleviates Norway's urban pressure

Passing through and under the bustling city of Moss, the coming Sandbukta-Moss-Såstad rail link south of Oslo calls for complex rail engineering skills. The project involves the design of double-track rail tunnels in hilly terrain and a modern rail station in the city of Moss.



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Metro and Light Rail

Growing city populations require public transportation solutions that are cost-effective, reliable and sustainable. Such demands can be met through well-planned and designed metro and light rail systems.

Our competencies within Metro and Light Rail include

- Strategic concepts and planning
- Feasibility studies
- Economic analysis (cost/benefit – traffic)
- Traffic simulations
- Procurement strategies
- Tender requirements
- Detailed design
- Project management
- Building management, inspection, on-site validation

Light rail and metro transport provides an optimal solution, not only as a transport system, but also as part of urban revitalisation and development projects. Ramboll is involved in many light rail and metro projects across Europe.

Ramboll has assisted numerous cities on light rail projects covering all aspects of infrastructure, systems, rolling stock as well as operations and maintenance of a light rail system.

Our expertise within rail engineering, traffic planning, and urbanisation covers all disciplines of metro and light rail projects. We take a holistic approach and provide multidisciplinary consultancy services from regional and comprehensive planning to detailed design of railway infrastructure.

Traffic safety at all levels

Traffic safety is in focus for all infrastructure projects. Light rail system design must be integrated with the street layout to ensure traffic safety for all road users, as many light rail projects will be constructed in areas with a high density of vehicular traffic. Rail safety can be achieved by a systematic approach throughout the planning, design and construction process.

Multidisciplinary solutions

Ramboll has many years of experience and advanced technical know-how within light rail-specific technology.

Integration is not only among the sub-systems but also an overall integrated approach in Design and Build, and always considering account Operation and Maintenance. We understand how the specific sub-systems work together. Our focus is to integrate technological studies and investigations with planning processes in order to deliver optimal functionality cost-effectively. This enables us to deliver holistic and multidisciplinary consultancy solutions for our clients. Our experts also have experience with simulation in Open Track (railway) with input from Vissim (micro simulation).



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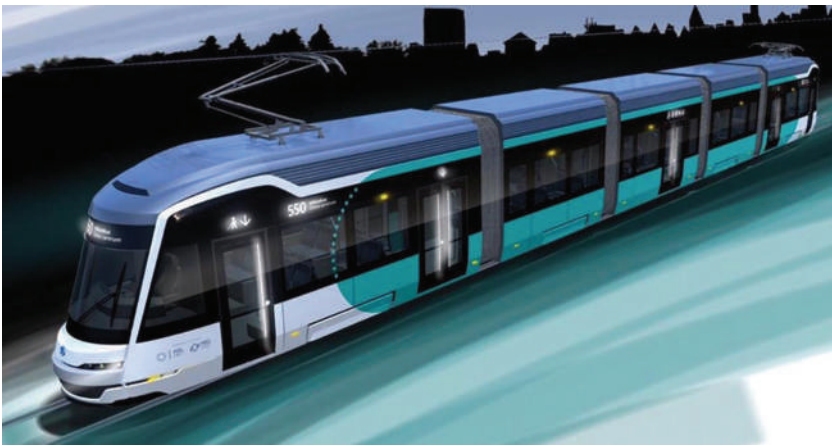
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01 Tvärbanan Light Rail, Stockholm, Sweden

Ramboll has participated in the development of the Tvärbanan Light Rail system from early feasibility studies, via multidisciplinary design, to building management.

02 Darmstadt, Germany

Ramboll carried out the feasibility study, cost-benefit analysis and demand analysis for the extension of Darmstadt's light rail network across a converted military site.

03 The Copenhagen Metro

It was a groundbreaking event when the Copenhagen Metro opened its first fully automated, driverless metro in 2002. Since then, it has become the most natural thing in the world for the citizens of Copenhagen to travel at speeds of 80 km/hour at 18 m below street level to avoid the traffic jams in the city centre.

04 The West Link unites Gothenburg

As one of Sweden's largest and most complex rail projects, the West Link meets the demand of effective public transportation and provides the city of Gothenburg with a safer, more flexible and more reliable rail system.

05 Helsinki's Jokeri Light Rail Line

The regional light rail line from Itäkeskus, Helsinki to Keilaniemi, Espoo. The goal of the project is to plan a high-standard, fast rail line, without any excessive costs. The planned length of the line is approximately 25 km (15.5 miles), of which 16 km will be in Helsinki and the remaining 9 km in neighbouring Espoo. The line will have 33 stops.

06 Tram to Tonsenhagen, designing new routes of trams in Oslo, Norway

Ramboll has headed alignment and street design for the planning programme.

07 Utrecht, The Netherlands

Ramboll has assisted in the planning of an 8 km extension of Utrecht's light rail system with nine stations, connecting a university campus to the new terminal De Uithof. Operational modelling, EMC, wheel-rail interface, permanent way, infrastructure advice.

08 Kiel, Germany

The German State Capital of Schleswig-Holstein, Kiel, will only achieve the climate protection targets for the period up to 2035 with an optimization of the existing public transport services (currently bus, ferry and regional rail services) and by eliminating capacity bottlenecks of Kiel's bus transport system. In cooperation with the municipal administration and politicians, experts of the city of Kiel and Ramboll will develop a joint recommendation for the system and the core network with a broad range of public relations work among others intensive participation of the public.

Feature project

Copenhagen Ring 3

Modern and yet well-proven technical solutions that work from day one. Those are some of the key requirements for the design, procurement and implementation of what is currently the largest light rail project in the Nordics – the future Copenhagen Ring 3 Light Rail.

From 2024, the Copenhagen Ring 3 Light Rail will form a 28 km transversal link between the five S-train lines and 11 municipalities in the western part of the Greater Copenhagen area. More than 1 million passengers a month are expected to benefit from the light rail's shorter travel times and improved comfort compared to the bus – as well as zero local emissions, since the system runs entirely on electricity.

Tested solutions and individual design

Ramboll is leading the Ramboll Arup joint venture which was responsible for developing the conceptual design and preparing the tender for the transportation system of the Copenhagen Ring 3 Light Rail. Great emphasis has been placed on creating the framework for a reliable transport system that works from day one.

“From a technical standpoint we will use proven standard components in all phases of the process. We aim for stability and predictability in the light rail service. The fact that the components are already in operation on other light rail systems is of vital importance”, says Ramboll's Senior Consultancy Director Peter Aarkrog who is project manager for the consultancy group covering the light rail transport system. Ramboll has collaborated closely with Hovedstadens Letbane, our client, and other consultants responsible

for the aspects road, civil works and architecture, forming an integrated team.

The transportation system consultancy services were provided by about 50 Ramboll experts within rolling stock, permanent way, signalling, depot and workshop design, power supply for traction and electrical equipment, safety, passenger information and control systems, radio and communication as well as operations and maintenance.

While the transport system will be based on proven technology, the objective is to add a distinctive local design element to make both the rolling stock and station infrastructure recognisable and attractive. The technical concept defines the general dimensions, maximum speed, alignment, power and gauge for the 27 vehicles, and the architectural team has developed a set of design principles describing what kind of visual design Hovedstadens Letbane is looking for. Potential suppliers will submit a specific vehicle design as part of their bid.

Dynamic simulation exposes deviations and requirements

Because of its length, various external factors will influence operations on Copenhagen's Ring 3 Light Rail. In particular, the fact that dwell times at stations will differ depending on the number of passengers alighting from and boarding the vehicles, and that

there are no less than 60 road crossings along the line, make for a high variability of runtimes. In order to determine the requirements for an attractive and robust operation, a dynamic simulation of operations was carried out, assisted by a computer model (OpenTrack).

The model serves to establish the operation of each of the 27 vehicles separately and to evaluate deviations from runtime and timetable requirements, also integrating data from traffic signal planning for all road crossings.

In parallel, operational challenges at the central node and terminal stops were analysed, and by working closely with road traffic planners, the project team developed an optimised programme to enable efficient light rail operation maintaining the needed capacity of the road nodes.

A long-term perspective on control and maintenance operations

Control and maintenance of the light rail vehicles will take place at a designated Control and Maintenance Centre (CMC) complete with stabling yard, workshop for maintenance, storage for components and a control room where all operational data will be gathered and visualised.

Ramboll has supported the architectural team in drawing up the concepts for the CMC by providing all input relating to the transportation



system and light rail operations. In order to simulate and prove the capacity of installations, the CMC operation was modelled and analysed, with internal runs as well as ramp-up and ramp-down operations in the morning and evening. The proposed solutions for the CMC focus on ensuring optimal utility and functionality of the maintenance site and equipment. The stabling yard could be extended to cater for up to 36 vehicles and the workshop for up to 54 vehicles by adding only a single track, as there is extra space prepared for further track or building extensions. This approach will safeguard an efficient operation of the Copenhagen Ring 3 Light Rail in the long term.

Operational data will form the basis for passenger information on board the vehicles, at the 28 stations and via web applications as well as for operational control and disposition in case of disruptions. The monitoring of technical systems also takes place in the CMC, where measures can be instigated immediately based on the incident log repair. Various

systems allow data exchange and communication between the control room and the driver and personnel, both radio and trackside cable-based. End of 2017 the project was awarded to the group Aarsleff (construction) and Siemens (systems and rolling stock), Ramboll is assisting the client now in the realisation.

About

Ramboll has been responsible for developing the conceptual design, preparing the tender and supporting the client in the procurement for the transportation system of the planned Copenhagen Ring 3 Light Rail.

The transportation system tender comprises

- Permanent way
- Rolling stock and required maintenance equipment in the workshop
- Power supply
- Passenger information, signalling, intelligent transport systems and communications
- Operations and maintenance
- Safety assessment

The entire project is based on BOStrab and the corresponding technical rules. Our Light Rail Competence Centre in Karlsruhe, Germany, has played a key role on this project. The consultancy was carried out in a joint venture with Arup and sub-consultants Designit and Mott MacDonald.

Rail safety

During the last 10 years, there has been a proliferation of requirements from rail authorities regarding common and standardized methods for handling and documenting railway safety. EU and national requirements based in the Common Safety Method (CSM-RA) regulation, Technical Specifications for Interoperability (TSI), CSM-Safety Management System (CSM-SMS) and the Cenelec standards now form the basis for railway safety management and documentation.

Due to the development, there is a significant client demand for assistance in developing and handling project processes of safety management as well as performing independent assessment body services as required by CSM regulations.

Tailored project delivery employing advanced tools

Ramboll assists in planning and executing the safety management process as well as safety engineering to ensure that it meets individual project requirements and considers all associated safety requirements. We have developed several advanced tools that have been specifically adapted for the safety approval process and these are an integral part of our service during project delivery.

Our safety services are strongly integrated into projects based on our expert's strong knowledge of the requirements of the 4th Railway Package, the Interoperability Directive and the Reliability, Availability,

Maintainability and Safety (RAMS) framework.

The different frameworks are the underlying mindset of our consultants in all rail-related work processes. Our expertise spans all infrastructure sub-systems, Trackside and Rolling Stock. We also have experience with building Safety Management Systems according to CSM-SMS.

A partnership approach

We ensure for our clients the documentation of and compliance with all the relevant activities to receive the required approvals in a timely manner assuring essential project milestones.

We draw on experience from a large variety of projects and have a full understanding of the approval processes required by our clients. Ramboll's partnership approach ensures that work is carried out in close cooperation with authorities, assessors, Notified Bodies (NoBo), owners, operators, infrastructure managers and contractors.

Accredited Assessment Body

Ramboll is also a Type A accredited CSM-RA Assessment Body according to DS/EN 17020 and can undertake independent assessment of all technical subsystems within infrastructure and rolling stock. With our extensive experience, we can plan and execute an assessment process tailored to each project.



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Safety Management

01 Danish Signalling Programme

Full national implementation of ERTMS and CTBC on the Copenhagen S-Bane. Ramboll provides safety management at integration level for Trackside (Thales and Alstom) and Onboard unit (Alstom) retrofit according to CSM-RA and Interoperability Directive (TSI CCS). For the S-Bane Ramboll provides safety management on integration level (Siemens CTBC system).

02 New line Copenhagen-Ringsted, Denmark

Ramboll has performed safety and interoperability consultancy for the green field high-speed line between Copenhagen and Ringsted in Denmark fully electrified with ETCS level 2. The line was commissioned in 2019.

03 Aarhus Light Rail, Denmark

Aarhus Light Rail will be the first light rail to open in Denmark in 2017. Ramboll is providing consultancy on safety and the approval process to the transportation system consortium ASAL for Aarhus Light Rail.

04 The Copenhagen Metro

Ramboll has been the client's consultant on the transportation system for the metro in Copenhagen, covering the existing as well as the coming line, "Cityringen".

Accredited Assessment Body

05 Carlsberg Station: Assessment of safety

With 12,000 passengers expected per day, the new Carlsberg Station is the gateway to the new urban area called "Carlsberg City District". Ramboll provided the assessment body service for the construction of this busy station.

06 Eglinton Crosstown Light Rail Transit

The project is a light rail transit line that will run across Toronto in Canada. It is equipped with the state-of-the-art Cityflo 650 CBTC signalling system provided by Alstom. The corridor includes a 10-kilometre underground portion. Ramboll represents the role of Assessment Body for the ECLRT Signaling system based on CENELEC standards.

07 Metro to Sydhavn

The Copenhagen Metro is completing an extension of the line that will connect the southern part of Copenhagen with the inner city. The metro will be extended with 4.5 km and five new stations. Ramboll acts as Independent Safety Assessor for Civil Works and the Mechanical and Mechanical installations.

08 Odense Light Rail Overall Assessment Body

Light Rail double track consisting of 10 subsystems. Project included above ground structures and bridges, as the line runs over and under existing bridges, as well as several retaining walls. Ramboll Accredited was contracted contractor to represent the role of overall Assessment Body.

World class train stations

Train stations in large cities are nodes for millions of passengers each day. The security of passengers is of prime concern when designing new train stations.

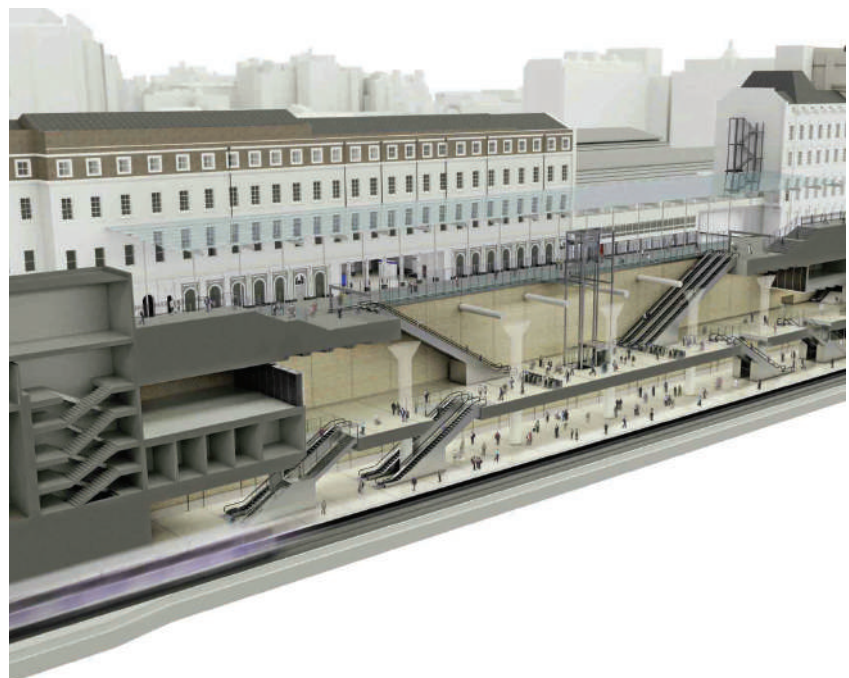
Our competencies within stations include

- Feasibility proposals regarding location of new train stations
- Environmental and heritage considerations
- Planning, design, and project management of building processes including modernisations
- Planning, design, and project management of the stations, platforms, depots and bus terminals
- Landscape planning
- Pedestrian flow analysis, multimodal travel chain analysis and concepts
- Integration of stations to surrounding urban environment
- Passenger information systems
- Accessibility
- Calculation of user movements and capacity of entrances, common areas, and platforms
- Calculation of traffic capacity of train stations
- Planning, design, and project management of technical railway facilities – tracks, signalling, electrification etc.
- Lighting systems

Stations consist of a number of user-orientated systems and traffic systems ranging from buildings, entrance/exit options, platforms, information systems, and lighting design, to rail systems including tracks, signalling works, and electrical supply facilities.

Ramboll has extensive experience in the planning, project design, and modernisation of train stations. Our solutions combine expertise from

our many specialist disciplines, e.g. transport systems, stations, urban development, telecommunication, traffic planning, project management, and construction management. Ramboll is frequently involved in projects concerning train stations for heavy rail as well as S-bane, metro and light rail.



01 Crossrail – Paddington Station
(Image: CRL and Weston Williamson Architects.)



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02 Langdon Park, Docklands Light Railway (DLR)

A new three-car DLR station built on-line around the existing Stratford link between All Saints and Devon's Road station, Langdon Park was conceived a catalyst for regeneration in the area. Work was carried out under a design and build contract with Ramboll acting as lead consultant for the designer Costain. The scheme subsequently won the British Construction Industry Regeneration Award and the APM Project Management Award for Community Project of the Year, among other honours.

03 DLR three-car enhancement

Docklands Light Railway has expanded its network to carry three-car trains. As part of this project Taylor Woodrow was awarded the design and build contract for 'Provision of Three-Car Enhancement Works'. Ramboll worked in conjunction with Arup on the detail design of the supporting structures and stations.

04 Ring 3

Modern and yet well-proven technical solutions that work from day one. Those are some of the key requirements for the design, procurement and implementation of what is currently the largest light rail project in the Nordics – the future Copenhagen Ring 3 Light Rail.

05 Holmestrand

A new fourteen km double track through the city of Holmestrand will greatly improve the rail services on the Vestfold line. Ramboll is responsible for the design of seven km of the line and Holmestrand Station.



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Feature project

Safer train stations with 3D technology

Had Holmestrand Station been completed according to the initial design, passengers would have literally been blown away. Trains passing through the Norwegian mountain where the station is located can reach speeds of over 150 km/hour – meaning a wind pressure of 15 m/second in the access tunnel, which would make it very difficult for someone to stand upright.

Facts about Holmestrand station

Holmestrand station is an important stop on the rail line connecting Oslo to the southern part of Norway. The station is part of a new double track between Holm and Nykirke. The new tracks are 14.3 kilometers long, of which more than 12 km pass through tunnels. The mountain hall is 870 m long, 35 m wide and 18 m high. The station has had unique challenges with regards to acoustics and air, due to strong air pressure from the highspeed trains passing through the tunnel and hall.

Ramboll discovered this using CFD as a planning tool. And this is just one of many examples of how this 3D technology can significantly benefit clients and society in general. “Just as meteorologists can predict the weather, we can use CFD to predict how the wind will blow, how smoke will move and what happens when a train passes into and out of a tunnel,” explains Jens Christian Bennetsen, Senior Project Manager at Ramboll Transport.

He has worked with CFD for over 20 years, initially on projects with building interiors where the technology helped to dimension ventilation systems and optimise fire safety. This gradually extended to other areas like urban planning in Hong Kong and baseball stadiums in the USA. For well over 10 years, the technology has been a fellow passenger on some of the most advanced railway and high-speed train projects in the Nordics.

A windproof station

“CFD determines how physical things operate without anyone having to build them,” explains Jens Christian Bennetsen. “We can base the design on facts and optimise it to make it cheaper, while also more accurately taking into account security

requirements from authorities, price requirements from operators and other factors. This also helps prevent unnecessary costs after commissioning because the design requires less adaptation than usual. This reduces the project risk.”

In Norway, Ramboll proposed enclosing Holmestrand station and the access tunnel with a windproof lock with two doors at each end. When the station opened to the public in November 2016, it was free of wind pressure problems. And the stakeholders were impressed: “Never before have we built a station inside a mountain with trains running at such high speeds,” said Knut Edmund Knutsen, Project Manager at Jernbaneverket to the Norwegian industry magazine Byggeindustrien.

Ramboll is working on a similar project in Sweden, where the new Barkeby station is also located in a tunnel. Ramboll experts have recommended designing platform screen doors to protect passengers from wind and to improve ventilation.

More precise measurements

CFD is also becoming more relevant in Denmark, which is phasing in highspeed trains. Ramboll has examined all the small tunnels



on the new railway line between Copenhagen and Ringsted, part of the Fehmarn Belt fixed link project to connect Denmark and Germany, and has also done calculations on a tunnel under Vejle Fjord. The findings from these projects show that the more precise calculations enabled by CFD opened the possibility of building narrower tunnels. “Without CFD you often act conservatively, making the diameter of the tunnel larger – too large, in fact – and thus putting more concrete in the tunnel. With CFD, we get detailed insight and data that can save time and money on these parameters,” Jens Christian Bennetsen points out. While CFD calculations obviously come at a cost, they pay off in the long run, especially when combined with high-performance computing. These aerodynamic analyses often provide insights that can be used in a number of other areas. At Holmestrand Station, for example, Ramboll and Jernbaneverket obtained knowledge about not only the windpressure in the tunnel but also ventilation and antifreeze precautions.

“CFD can find the optimal balance between laws, rules and requirements, on the one hand, and the operator’s demand for value-for-money on the other,” says Jens Christian Bennetsen.

“CFD determines how physical things operate without anyone having to build them.”

Jens Chr. Bennetsen,
Senior Project Manager, Ramboll Transport

About

Ramboll has been the consultant for all the building services of the gigantic mountain hall where the station is located. With a size of 130,000 cubic metres the mountain hall is one of the world’s largest. The station is reached through a 70 m high elevator, and has four tracks. Two of the tracks are by the platforms, while the two in the middle are for passing highspeed trains. One of the biggest challenges for the consultants was to calculate how to cover the ceiling of the hall with 1,000 tons of steel, to keep in place noise-reducing plates and withstand the air pressure from the high-speed trains.

Track renewals and upgrades

Demands for operational reliability and lower maintenance costs give rise to many upgrade and renewal projects. Very large sums are invested in renewing existing railways and at the same time, many lines are upgraded for higher speed or greater loading.

Our competencies within track renewal and upgrades include

- Design of permanent way system (superstructure as well as substructure)
- Signalling works
- Telecommunication
- Catenary systems and power supply
- High voltage
- Earthworks and drainage
- Embankments and cuttings
- Level crossing (road part)
- Environmental services
- Planning of execution
- Inspection and construction management

A major focus area for railway infrastructure owners is determining how to optimise their infrastructure in order to fulfil the demands for operational reliability while at the same time keeping maintenance costs down. As a result, very large sums are invested in renewing existing railways and at the same time, many lines are upgraded for higher speed or greater loading. Over more than 10 years, Ramboll has participated in a large number of renewal and upgrade projects. Among other projects we have been involved in many extensive, multidisciplinary railway projects.

Cost-effective project planning

With strong coordination between Ramboll's different disciplines and external stakeholders, the projects are carefully planned to minimise

changes in the execution phase. This ensures that the programme and budget requirements of the project are met. Our extensive experience on a range of different projects combined with the capability to provide services covering all technical disciplines also play a decisive role in achieving this. Close interaction with the relevant authorities and approval of projects prior to completion is essential. Ramboll has experts who specialise in these areas and by drawing on their skills and experience, we ensure that the projects achieve all necessary approvals and are delivered on time. We can also provide consultancy services during the development phase to assist with preparation of the business case in order to help secure investment.

01 Signalling for Norway's largest transport project prepares Oslo for future growth and a new Ski station

The 23 km Follo Line railway will connect Oslo to the commuter city of Ski. Currently the largest transport project in Norway, it features Norway's longest railway tunnel (20 km) to allow much faster and more frequent trains to Oslo from the south.

02 Upgrades and renewals in Denmark

A major focus area for railway infrastructure owners is determining how to optimise their infrastructure to fulfil the demands for operational reliability while keeping maintenance costs down. As a result, very large sums are invested in renewing existing railways. At the same time, many lines are upgraded for higher speed or axle load.



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03 Reading Station in the UK

Due for completion in 2016, the six-phased redevelopment plan for Reading Station is a hugely ambitious scheme, intended to decongest the busy railway hub, making way for more trains and ensuring a more efficient service to commuters.

04 Bermondsey Dive Under

A key component of the final stage of the Thameslink project to rebuild London Bridge station. It is a new section of railway track and infrastructure that allows Thameslink lines to cross the Kent lines unimpeded on the eastern approach to London Bridge.

05 Directing of tracks into Oslo S

The Norwegian Rail Administration (JBV) selected Ramboll to analyse the capacity of a future Oslo Central Station (Oslo S), having new lines from different directions

into the station. This was a simulation of a future situation with, among other features, a completed Follo line (from south-west, designed by Ramboll) and four tracks in tunnel (only two today) from the west into Oslo S.

06 Upgrading Aarhus - Hobro Railway

Ramboll is responsible for the screening and upgrade of the railway tracks between Aarhus and Hobro. The tracks will be upgraded and prepared for 200 km/h line speed. This project is part of "Timemodellen", which is the work designed to bring down the travel time between Aalborg and Aarhus to one hour.



06

Capacity analysis

In many countries, rail systems need to accommodate increasing volumes of trains and passengers. The optimisation of network capacity is therefore a prerequisite for efficient, reliable and punctual train services.

Competencies within capacity

- Scheduling and comparison of different timetable structures
- Analysis of passenger service levels
- Optimisation of platform and station track usage
- Simulation of railway networks, stabling yards, and station areas
- Capacity consumption calculations using the UIC 406 method
- Capacity and bottleneck analysis
- Support for capacity allocation including development of new tools and processes
- Optimisation of rolling stock and staff usage
- Optimisation of maintenance and depot usage
- Optimisation of traffic control operations
- Disturbance management
- Running time calculations
- Analysis of capacity consumption and evaluation of operator's annual capacity requests mobilising

In many countries, rail systems need to accommodate increasing volumes of trains and passengers. The optimisation of network capacity is therefore a prerequisite for efficient, reliable and punctual train services.

Railway capacity analysis plays an integral role in planning and optimising railway services as well as enabling problems to be readily identified and rail capacity to be managed effectively. Within this area, Ramboll assists rail operators and infrastructure managers and has helped create new operational models and plans for various operational scenarios. In our projects we work closely with train operating companies and other operators in the rail industry, including universities, research institutes, and other consultancies.



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01 Spårväg city to Lidingöbanan tram line

Ramboll's market-leading traffic simulation capabilities enabled a thorough understanding of client needs and the delivery of results in a short timeframe.

02 Capacity consumption and capacity calculations for the entire Finnish rail network

Ramboll's capacity evaluations combined detailed knowledge of the Finnish rail network and use of specialised analytical tools with wide-ranging capacity experience.

03 Fehmarnbelt Fixed Link

This railway capacity analysis and scheduling of various traffic scenarios draws on Ramboll's extensive experience and specialist expertise in the application of analytical tools within this field.



03

04 Light rail as enabler for urban development

The future light rail connection along the ring road 'Ring 3' just west of Copenhagen not only promotes a more coherent city infrastructure. It also has the potential to become a powerful enabler for urban growth and development.

05 Directing of tracks into Oslo S

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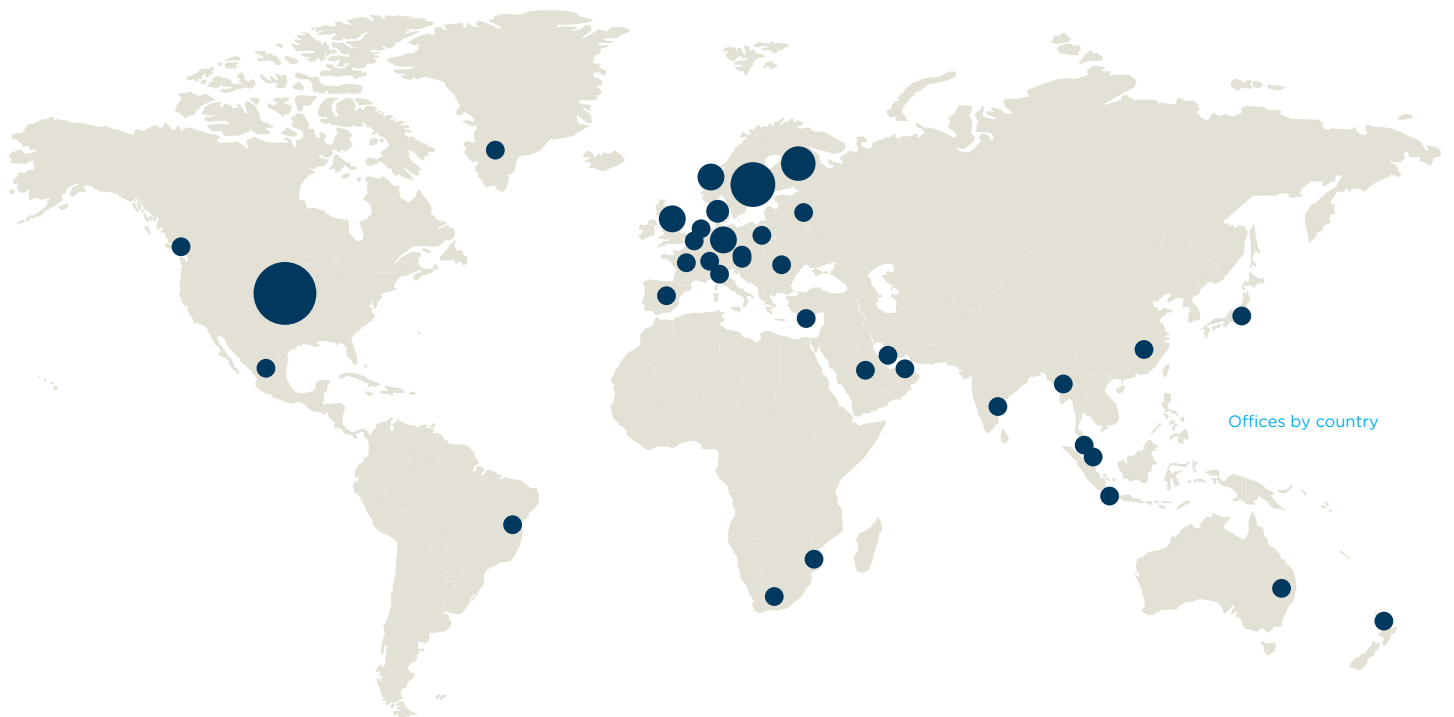


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Rail engineering and consultancy services



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Rail

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