

Enabling light rail solutions

Consultancy services for sustainable cities

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Bright ideas.
Sustainable change.



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Sustainable mobility

Mobility fuels economic and social development. And with more than half of the world's population now living in urban areas, efficient and sustainable transport systems are vital to ensure liveable cities.

All over the world, more and more people move to urban areas to live and work. This development puts an immense pressure on the urban infrastructure, and results in road congestion, air pollution and limited mobility. It also makes a strong case for light rail, being a high capacity, zero-emission alternative to road traffic. In recent years, a long list of densely populated cities from Stockholm to Sydney have introduced light rail transport as a means for efficient and sustainable public transport. And the fact that light rail has proven to act as a powerful enabler for urban growth and development as well, has only made the case stronger.

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. In 2014, we established the Light Rail Competence Centre in Karlsruhe, Germany, as part of the Global Rail Division. Our experts are dedicated to developing world-class light rail solutions – located in a city renowned for continuously optimising its urban and regional light rail system towards higher operational speeds and increased comfort.

About Ramboll

Ramboll is a global architecture, engineering and consultancy company founded in Denmark in 1945. Our 16,500 experts create sustainable solutions across Buildings, Transport, Energy, Environment & Health, Water, Management Consulting and Architecture & Landscape.

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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A sustainable solution on track

Light rail not only provides efficient and sustainable public transport – it also has a proven track record to vitalise the urban landscape and foster substantial urban development and growth. No wonder that cities all over the world are starting to look at light rail to relieve road congestion and improve liveability.

Why light rail and why now?

Cities all over the world are starting to look at light rail to relieve road congestion and improve liveability. Why? Because light rail systems meet some of the key requirements for today's rapidly growing cities:

- **It's electric!**

Electrically powered light rail systems can be equipped to run exclusively on renewable energy sources, thereby lightening the city's carbon footprint.

- **Zero local emissions**

Unlike petrol- or diesel-powered vehicles, electrically powered light rail systems do not emit particles that pollute the air.

- **High capacity and space efficiency**

Light rail is highly scalable to local capacity needs and generally provides a high quality as well as capacity compared to buses – thus being a real alternative to the private car.

- **The rail effect**

Light rail is a comfortable way to travel. Experience shows that people tend to prefer light rail over buses even in cases where there is no significant difference in travel time.

- **Enabler for urban growth**

Light rail and metro projects around the world have shown that permanent rail-based infrastructure potentially attracts long-term investments and influences patterns of settlement in a fundamental way.

Today's rapidly growing cities call for cost-effective, reliable and sustainable public transport solutions. And as a high capacity electrically powered transport system – that has also proven to act as a powerful enabler for urban growth – light rail seems to offer a desirable solution to these requirements in a wide range of cities around the world.

While a bus line can be changed or closed down, a rail-based transport system provides a permanent infrastructure that can attract long-term investments and influence patterns of settlement in a substantial way. In fact, Nordic cities such as Malmö, Lund, Helsingborg, Tampere, Turku, Stavanger, Copenhagen, Odense and Aarhus are all developing or considering light rail as part of urban development plans.

The light rail renaissance

While Germany still has one of the highest densities of tramway and light rail systems worldwide – counting 59 systems in total – light rail is becoming increasingly popular in particularly the Nordic countries.

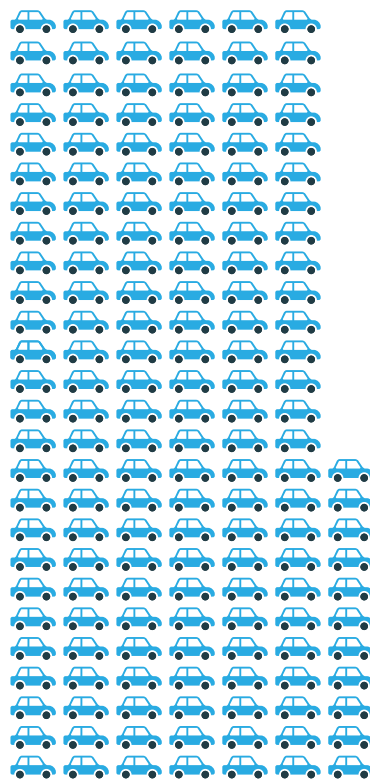
Several Norwegian and Swedish cities have already introduced light rail transportation, and cities such as Stockholm, Gothenburg, Norrköping, Helsinki, Bergen, Trondheim and Oslo are currently studying and conducting network extensions. In France, like in many other countries in Europe, tramways had almost

vanished from the streets by the late 1960s and were replaced by buses or underground metro systems. This changed with the introduction of tramways in cities such as Strasbourg, where one of the first new French light rail systems (called tramway in France) opened in 1994. Paris, Lyon, Nice, Rouen, Montpellier, Bordeaux and many others followed suit in developing modern tramway systems.

Since then, a veritable light rail 'renaissance' has spread to a large number of cities in France, in the UK, Ireland, Spain and Portugal. San Diego, California pioneered the re-introduction of light rail in the United States, with the first services of the San Diego Trolley operating in July 1981 initially with LRVs similar to those used in Frankfurt, Germany.

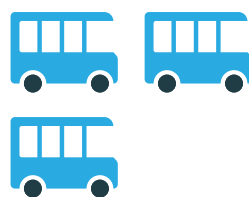
Following this spark, the US, Canada and Australia have recently introduced light rail in numerous metropolitan areas including Portland, Seattle, Phoenix, Minneapolis, Edmonton, Calgary, Melbourne, Sydney, Adelaide and the Gold Coast.

Sustainable public transportation: How to move 200 people in an efficient way



← **200 People
by car**
1.2 person per car on average

**200 People
by bus**
70 persons per bus on average



← **200 People
by tram**
200 persons per tram on average

Light rail provides efficient and sustainable public transport and is significantly more capacity-effective than a car or even a bus.

Holistic consultancy for sustainable growth

Cities have become the engines of economic prosperity and development – and the global middle class is expected to expand further over the next two decades.

Complex challenges call for an integrated approach. Consequently, our services bring together engineering, design and management consultancy to provide world-class expert knowledge, qualified guidance and support at every stage of the value chain. We advise from an early stage with strategy development and decisionmaking, provide consultancy on tendering, as well as manage and supervise the entire project to ensure that all requirements are met – at the right price, quality and time. Our breadth of resources and depth of knowledge allows us to provide services suited best for our clients' needs – from large client-based project teams to ad hoc advice

by individual specialists or any combination of the above ideally tailored to the project.

A single point of contact for everything light rail

Ramboll's Light Rail Competence Centre in Karlsruhe, Germany, serves as a single point of contact in all questions concerning infrastructure, systems, rolling stock as well as operations and maintenance of light rail systems.

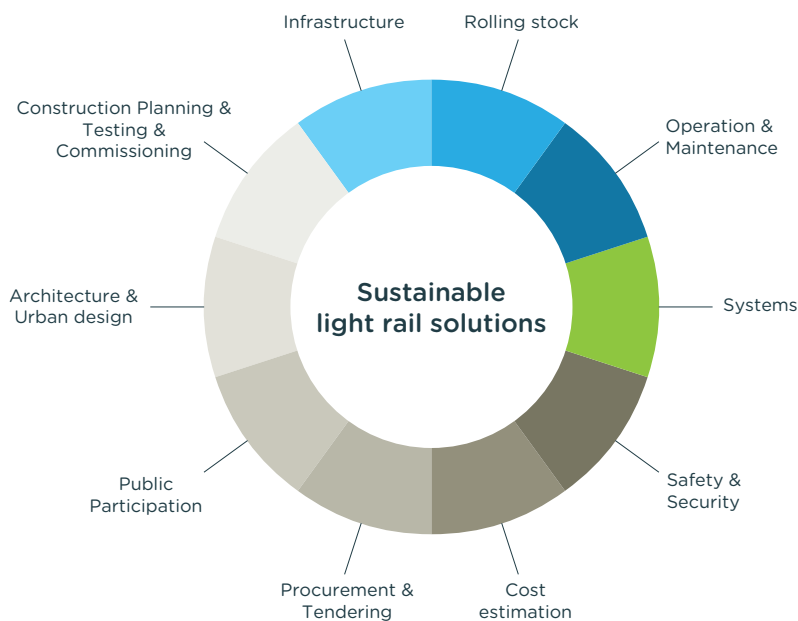
Ramboll light rail experts draw on extensive experience from light rail projects all across Europe and support the entire planning process – from feasibility studies to

the conception, design and tender of all operational and maintenance elements, not to mention life cycle cost evaluation for the light rail system as a whole.

Global project management framework

All of Ramboll's experts around the world share the same project management framework and system based on internationally recognised standards and best practices. The main objective is to exceed client expectations – consistently delivering optimised solutions and setting new standards.

Light rail projects draw on specific rail and complementary multidisciplinary services to develop truly sustainable solutions.





**01 Light rail extension Potsdam, Germany
- Project management, master planning,
rail engineering, light rail planning, traffic
planning**

The city of Potsdam just west of Berlin plans to connect a new residential area for 9,000 inhabitants to the existing public transport network and the central station in Potsdam. Ramboll in joint venture with Obermeyer is responsible for the design of a 6 km long tram line, including line planning, stations, adjustments of roads, the technical equipment of the tram as well as the integration of urban development into the current cityscape. By connecting the outskirts of Potsdam to the station citizens will have the possibility to change over to local trains direct to the centre of Berlin. Completion of the project is foreseen for 2022.

**02 LRT Sinsen, Oslo, Norway
- Preliminary design, feasibility study,
land-use planning, impact study.**

In order to improve the public transport system in Oslo, an extension of the Sinsen tramline to Tonsenhagen was initiated. Ramboll was responsible for the revised transport plan presented to Oslo's authorities, including technical feasibility and preliminary design studies as well as the corresponding impact analysis and urban land-use plan. A demand analysis completed the studies.

01



02

Feature project

What is the most sustainable public transport system?

With our feasibility study and intensive participation of the public we help the city of Kiel to find the best solution for its public transport services. Whether a tram or bus rapid transit (BRT) line is the best solution will be a key result of the study.

To achieve its climate targets by 2035, the city of Kiel, Germany, needs to optimise its public transport services. Currently the city's residents can choose between bus, ferry or regional rail services to get from A to B. But due to the location on the Kiel Fjord, travel times with public transport are long and cumbersome, which brings the entire transport system to its capacity limit. That's why the municipal administration of Kiel asked Ramboll to develop recommendations for the system and the core network.

The best option for sustainable urban transport

As a first step in this complex process a baseline study was already completed in 2019. Key finding was that two means of transportation are most likely to improve the existing public transport system: Tram or Bus Rapid Transit (BRT). However, the previous results of the mobility concept in the baseline study were only expert recommendations that do not document the derivation of the exact route of the lines under consideration. With a detailed route study Ramboll's experienced team of transport planners examine these expert recommendations and take input from local residents into account.

During a comprehensive public participation process all Kiel residents were called upon to express their wishes for future mobility. Ramboll accompanied this process with various online formats and on-site events.

Until the end of 2022 both systems will be studied in equal detail in several stages. For the ranking, i.e. the layering of all conceivable route sections in the corridors down to the core network will be derived from a formalized German route evaluation methodology (FAR: formalisiertes Abwägungs- und Rangordnungsverfahren). With a balanced selection of the evaluation criteria, this is considered to be legally watertight.

In addition to examining different routes, Ramboll is also developing, among other things, a concept for linking to other modes of transport, as well as an operational concept and operational modelling. In this way, Ramboll provides all the basics for sustainable local transport, which also includes paths for pedestrians and cyclists.

Nils Jänig, Director, Global Rail Division at Ramboll, explains:

"Evaluating the full impacts of particular transit services is vital if the goal of the system is to meet climate targets. Helping clients measure various categories of impacts allows for common errors to be identified that distort network performance. With such knowledge, transit systems can be developed for increased system efficiency, increased ridership, lower costs, and more transit-oriented land use patterns."

German engineering meets Nordic innovation

Ramboll is also contributing comprehensive and international know-how to the planning phase. In addition to traffic planners, the project team also includes experts in landscape planning, environmental aspects and public relations. Experts from Helsinki and Kiel's partner city Aarhus are also on board and will share their expertise from similar projects. In Aarhus, Ramboll has successfully planned the light rail system and will also accompany the expansion planning for the second phase over the next 10 years.



What we do

The final recommendation will among others include:

- Infrastructure planning
- Cost estimation
- Operational concept, signalisation
- Power supply
- Urban integration
- Depot planning
- Construction planning
- Financial concept
- Approval concept
- Visualisation and videos
- Environmental aspects
- Bus concept
- Inter-face to Cost-benefit-Analysis (CBA)

Infrastructure

Track superstructure, traction power, stations and depots are the key 'fixed' elements of the light rail infrastructure.

What we do

Ramboll provides consultancy on almost every aspect of light rail infrastructure:

- Alignment
- Permanent way
- Acoustics and noise
- Station design and accessibility
- Lighting design for stations and outdoor space
- Traction power
- Depot design
- Buildings
- Road design and engineering
- Tunnel and bridge engineering
- Geotechnics
- Infrastructure asset management
- Construction and contract management
- Risk and safety management

Every city has its individual character – and so has every light rail system! Sometimes high operating speed is paramount, at other times maximising system accessibility is a crucial factor. In many cases, a balance needs to be achieved between operational efficiency, the overall system's whole life cost and visual amenity. At Ramboll, we draw on international experience in developing solutions that provide just the right customisation for the unique qualities and requirements of the local environment – and that balances interests and considerations in a way that allows all parties to endorse the final solution. For instance, depots can be highly efficient in terms of track layout and arrangement of the workshop but still make up an architectural landmark and minimise noise emissions to the surrounding area.

In order to provide sustainable light rail infrastructure that leads to a better urban environment, particular attention needs to be paid to the design of various light rail infrastructure assets. This is vital to ensure that all assets are attractive, durable, safe to use, easy to maintain and economically sustainable both in investment and operation.

The interfaces between infrastructure and other systems such as rolling stock (wheel-rail contact, traction power, barrier-free stations) or operation (signal cabling, cant calculations) are also important in the alignment, station and depot

design. Mismatches in these areas may lead to reduced operating speeds, undue noise, excessive wear or an unattractive appearance of the system in the public realm.

“We have acquired a unique understanding of the different stakeholder needs and this gives us a valuable insight for finding solutions for all stakeholders in the projects we engage in.”

Director Light Rail
– Nils Jänig



01

01 City and regional train link Erlangen – Nuremberg – Herzogenaurach, Germany - Alignment study and preliminary design

The so-called “Stadt-Umland-Bahn” is the most comprehensive urban transport project in Germany today: a city and regional train link with close to 25 km of rail tracks connecting the hinterland to the existing tram network in Nuremberg transporting more than 10,000 passengers per day. In a first phase Ramboll did the vehicle planning and has now started the transport planning for the line as well as for the preliminary design for the central corridor; this includes not only the track but also the integration of the line in the urban environment. Ramboll is also responsible for the technical project management for the overall project where design partners Obermeyer and Gauff are contributing. The client will be provided with technical and operational requirements as well as implementation recommendations. In respect to regional planning and implementation the option with the lowest impact on regional space will be selected.



02

02 Bergen, Norway - Detailed planning and procurement documents for depot, civil structures and technical equipment.

Ramboll supported Mott MacDonald in the specification of a line extension of Bergen’s light rail as well as the drawing up of tender documents for a number of technical areas, especially related to civil and structural engineering for bridges, buildings and the related traffic engineering, power, geotechnical studies and investigations and environmental geology. The buildings also included the control and maintenance centre.

Rolling stock

A light rail vehicle makes a bold statement in the urban landscape and works as a visible and moving 'business card' for the light rail system as a whole. This is just one of the reasons why choosing the right rolling stock solution is crucial to ensure the success of the system.

What we do

Ramboll provides consultancy on almost every aspect of rolling stock:

- Vehicle design including interior layout and appearance
- Capacity
- Accessibility
- Energy consumption
- Technical studies and investigations for individual vehicle aspects
- Electro-magnetic compatibility
- Wheel-rail interface
- Support during the entire procurement process
- Tender design
- Offer preparation
- Contract negotiations
- Approval of delivery
- Solutions for cost-effective maintenance/life cycle cost
- Service vehicles for infrastructure maintenance

Not only does the light rail vehicle have a very visual and important interface with passengers, but the vehicle serves as the workplace for a large share of the light rail operator's workforce – the drivers.

In addition, the light rail vehicles constitute one of the most significant contributions to the system's whole life cost, as they amount to a large proportion of both the initial investment but also the ongoing maintenance cost. All things considered, choosing a rolling stock solution is anything but straightforward.

As in many other areas, a balance needs to be achieved between the desire for an attractive and presentable vehicle and the need for a vehicle that is engineered to last for the duration of its entire operational life, which generally spans about 30 years, but can be up to 40 years.

This means that the choice of rolling stock needs to be a farsighted decision that takes both the vehicle's durability and ability to adapt to future needs into consideration.

At Ramboll, we strive to find the best solutions within these potentially conflicting requirements. We draw on our experience with rolling stock technology as well as operations and maintenance to determine the unique requirements for each system and suggest the right rolling stock solution for the local environment.

As in many cases, it is of great value to consider passenger needs first, followed by requirements for the usability of the rolling stock, such as operability and maintainability.



01

01 Light rail vehicles, Jerusalem, Israel - Rolling stock procurement and tender documents

Within the Jerusalem JNET DBOM tender Ramboll was responsible for drawing up the tender material for more than 100 vehicles for the extended JNET LRT system. The objective was to ensure the procurement of vehicles that are optimally suited to the planned infrastructure. Significant challenges are the topographical and environmental conditions. Beside the rolling stock tender, Ramboll also compiled the tender for the depot equipment.

02 Utrecht, The Netherlands - Operational modelling, EMC, wheel-rail interface, permanent way, infrastructure advice.

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 terminus De Uithof - an extension that entails a modification from the current highfloor construction to a new low-floor system. Ramboll's consultancy covered disciplines within infrastructure, rolling stock, electromagnetic compatibility and operational modelling.



02

Systems

A light rail system embodies a large number of interfaces with passengers and staff, not to mention car drivers, cyclists and pedestrians in the street. All interfaces need to work seamlessly and intuitively in an integrated manner to distinguish the light rail system from the hustle and bustle of traditional mass transit.

What we do

Ramboll provides consultancy on almost every aspect of light rail systems:

- Conceptual design of communications systems
- Intermodal transport control system
- Radio and communications
- Passenger information systems
- Signalling system planning
- Control room layout
- Traction power supply
- Tender design
- Support during the entire procurement process
- Offer preparation
- Contract negotiations
- Approval of delivery

Currently Ramboll is part of the alliance (with VR Track, Sito) to compile construction design and realise the project.

Take for instance the ticket purchase and validation process, which should be self-explanatory – and definitely not feel like a ‘process’ at all. It shouldn’t hinder or hold up boarding and alighting. And passengers should be able to find information about next stops and connections both on platforms and in vehicles. In real time, of course, and ideally taking delays into account.

In order to avoid such delays in the first place, an intermodal transport control system should ensure that the operational staff at the control and maintenance centre have complete overview of the light rail operation at all times. Traffic light pre-emption at road crossings should prioritise the progress of the light rail vehicle, making sure that the only necessary stops are at the stations, while signalling ensures safe operation at single track sections, in tunnel sections and terminal stations.

To make sure that the entire light rail system and all its parts work

seamlessly and efficiently, diagnostic data from vehicles and installations should flow automatically to the control and maintenance centre to facilitate maintenance and increase the overall system availability. Power supply systems for traction and auxiliary equipment should also provide self-monitoring capabilities.

At Ramboll, we can help to determine the right balance between desired functionalities, economic investment and operation. In relation to existing systems, we can help to investigate the possibilities of increasing system reliability, user acceptance and efficiency of the light rail operation and maintenance.

In the end, technical equipment should only be used where it provides significant benefits for safety, passenger convenience or efficiency gains in operations and maintenance. The overall approach should be to implement a light rail system which as simple as possible and as technically complex as necessary.

01 Jokeri Line, Helsinki, Finland - Traffic engineering, transport planning and safety, light rail design, operational modelling, depot design.

The Raide-Jokeri line is a planned 25 km light rail line with 31 stations forming an orbital link between the outskirts of Helsinki. In a joint venture with WSP Finland, Ramboll developed the conceptual design for the line, including horizontal and vertical alignment design, urban integration, a cost-benefit analysis to underpin the project’s business case and a dynamic simulation of the intended operational programme as well as involvement of the public. Ramboll was also responsible for the conceptual design of the control and maintenance centre and stabling area.

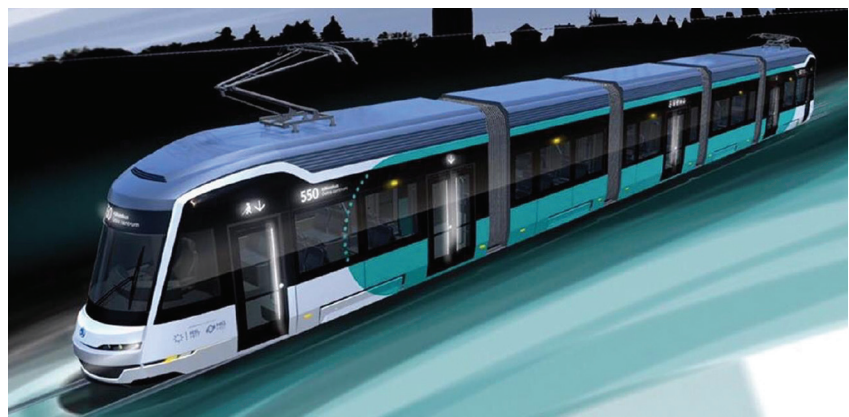




Image: Mettenhof Station in Kiel

Operations & maintenance

Operations & maintenance are essential for the entire life cycle of the light rail system guaranteeing reliable services throughout.

What we do

Ramboll provides consultancy on almost every aspect of light rail operations and maintenance:

- Operational modelling
- Runtime estimation
- Timetable planning and design
- Operational control centre
- Staffing and duty rosters
- Vehicle rosters including phasing in of service vehicle runs
- Maintenance of rolling stock, infrastructure and systems
- Key Performance Indicators (KPI)
- Performance monitoring and payment regimes

High operational performance and reliability are key to ensure that light rail poses an attractive alternative to private car use and hence becomes a driving factor for sustainable mobility and city development.

Operations bring together all elements of the light rail system – from infrastructure to rolling stock, power supply, intelligent transport systems etc. – and put them into motion and use within the urban environment.

Maintenance, on the other hand, is crucial to keep the light rail system in adequate condition to ensure safe and reliable operation and keep it in a presentable state. And together, operation and maintenance represent the light rail system's ongoing cost (opex) that is to be balanced against the initial investment cost (capex).

At Ramboll, we consider operation and maintenance right from the initial planning stages of a light rail project. This includes integrating regular operating conditions as well as possible fall backs during disturbances. In the end, it is the way the light rail operation can effectively deal with any such disturbances that to a significant extent will drive the public perception of the system.

From our experience in designing operational and maintenance concepts as well as infrastructure and rolling stock design, we identify the main issues and risks of the project and propose a tailored solution, considering the delicate balance

between capex and opex especially when these are funded by different sources.

In the end, technical equipment should only be used where it provides significant benefits for safety, passenger convenience or efficiency gains in operations and maintenance. The overall approach should be to implement a light rail system which is simple as possible and as technically complex as necessary.

01 The Hague, Netherlands - Operational modelling.

In order to find efficient ways to improve the capacity of The Hague's light rail system, Ramboll developed an operational model. Different signalling concepts were tested virtually on the track section commonly used by The Hague light rail and Rotterdam Metro. The results helped the client to develop strategies towards the future operating concept for the RandstadRail network.

02 Darmstadt, Germany - Feasibility study, cost-benefit analysis, operational advice, infrastructural advice track.

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. Ramboll was also responsible for the dynamic operational simulation and for developing the adjustments to the bus network complementary to the proposed light rail line.



01



02

World-class light rail expertise

Internationally recognised,
world leading consultancy

Combining local presence on
five continents with global knowledge

Specialists from Ramboll's Light Rail
Competence Centre collaborate closely
with local Ramboll engineers

Ramboll offices all over the world
provide a local point of contact for our clients

Key projects

01

Light rail extension Potsdam, Germany

Project management, master planning, rail engineering, light rail planning, traffic planning.

02

LRT Sinsen, Oslo, Norway

Preliminary design and feasibility study, land-use planning, impact study.

03

Feasibility study, Kiel, Germany

Feasibility study including among others infrastructure planning, cost estimation, operational concept.

04

City and regional train link Erlangen - Nuremberg - Herzogenaurach, Germany

Rolling stock concept, alignment study and preliminary design.

05

Bergen, Norway

Detailed planning and procurement documents for depot, civil structures and technical equipment.

06

Light rail vehicles and depot, Jerusalem, Israel

Rolling stock and depot equipment tender documents and procurement support.

07

Utrecht, The Netherlands

Operational modelling, EMC, wheel-rail interface, permanent way, infrastructure advice.

08

Jokeri line, Helsinki, Finland

Detailed design within alliance, traffic engineering, transport planning and safety, light rail design, operational modelling, depot design.

09

The Hague, Netherlands

Operational modelling.

10

Darmstadt, Germany

Feasibility study, cost-benefit analysis, operational advice, infrastructural advice track.

11

Light rail vehicles, Lund, Sweden

Rolling stock procurement and tender documents.

12

Tram train vehicles, Kassel, Germany

Rolling stock refurbishment concept.

13

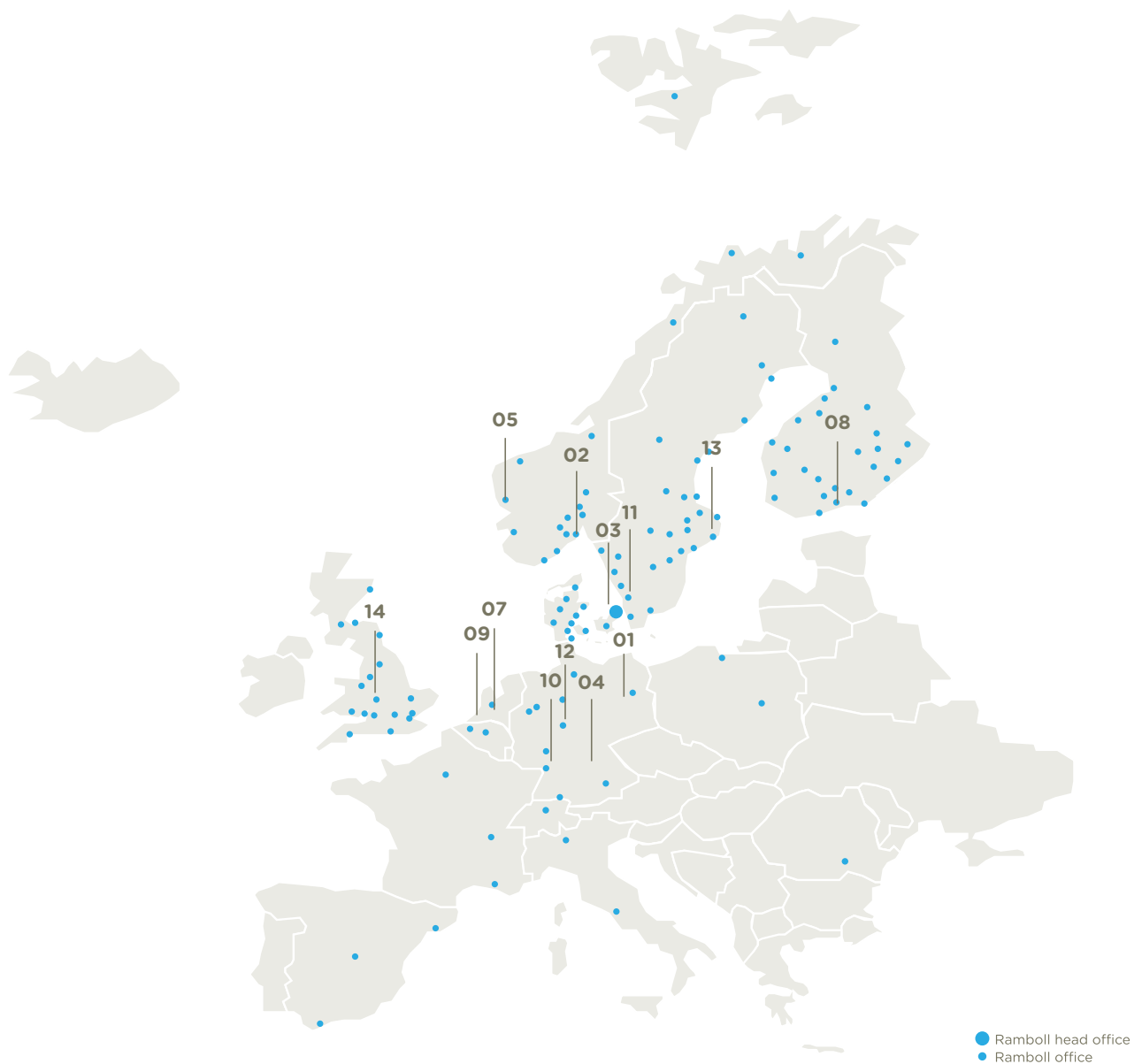
Light rail, Stockholm, Sweden

Alignment study and tender documents for the Solnagrenen branch.

14

Light rail, Birmingham, UK

Operational and power simulation.



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