

USING BANEDANMARK'S TMS TO DEVELOP CONCEPT TIMETABLE 2030

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ABSTRACT

Banedanmark, Denmark's railway infrastructure manager, is completing an ambitious rebuilding program to create a railway for the future. The program includes installing a new ETCS (European Train Control System) signaling system on the entire railway network, increased electrification, and a set of high priority capacity and speed improvements designed to support an integrated hourly schedule. A future timetable for the year 2030 was needed to calculate minimum headway requirements for designing the ETCS.

This paper describes the process used to develop the Concept Timetable 2030. This process used a new methodology included in Banedanmark's traffic management system (TMS). This new TMS was developed by reimagining how railway planning and operations might be done if they were developed today (i.e., with current information technologies). The approach is designed to increase the quality and efficiency of railway service by using an integrated process to plan and operate railway services.

Using Banedanmark's TMS to develop Concept Timetable 2030

1. INTRODUCTION

Banedanmark, Denmark's railway infrastructure manager, is implementing an ambitious rebuilding program designed to create a railway for the future. The program includes installing a new ETCS level 2 signaling system on the entire railway network, increased electrification, and a set of high priority capacity and speed improvements designed to support an integrated hourly timetable, and a new traffic management system (TMS).

The main goal of Banedanmark's Concept Timetable 2030 (CT2030) project was to identify minimum headways for future service to guide the design of the new ETCS. A secondary goal was to manually test the schedule planning method in Banedanmark's new TMS to help identify improvements and to obtain experience on using the new process. (1)

This paper describes the new schedule planning method and how it was used to prepare the CT2030. Section 2 presents background on Banedanmark's Signalling Programme. Section 3 describes the new TMS. Section 4 describes how the new schedule planning method was used to develop the CT2030. Section 5 presents conclusions and recommendations for future research.

2. BANEDANMARK SIGNALLING PROGRAMME

In 2005 over 50% of delays on Denmark's railway network were caused by signal failures and signaling system maintenance costs were increasing rapidly. In 2006, to address these problems, Denmark's Transport Ministry commissioned a strategic study on renewing the signaling system. (2)

The study's key question was how to best implement the European Railway Traffic Management System (ERTMS) in Denmark. The ERTMS is designed to improve railway service by replacing different national-based train control systems with a single interoperable system. ERTMS also increases safety by providing full supervision of train movement and, with careful engineering design, can increase capacity by reducing train headways.

The strategic study compared piecemeal ERTMS implementation to total replacement of the entire signaling system and concluded:

- Total replacement would be more economic than piecemeal replacement because it would eliminate the need for provisional interfaces, provide economies of scale, and lower maintenance costs (including costs due to loss of know-how for maintaining legacy signaling assets).
- Total replacement would provide larger benefits much earlier, especially in terms of improving the quality of railway operations.

In 2009 the Danish government decided in favor of total replacement. The project is being implemented by the Signalling Programme, a stand-alone organization dedicated to signal system design, installation and commissioning.

The Signalling Programme signed contracts with the suppliers in 2012. Tender results confirmed the economic advantages of total replacement: by rebuilding the entire signaling system the

suppliers could achieve economies of scale in producing and installing the equipment, and it was not necessary to create interfaces with the many legacy signaling systems. The project is currently underway. It has a budget of EUR 3.2 billion and is scheduled to be fully implemented by 2023. (3) (4)

3. BANEDANMARK TRAFFIC MANAGEMENT SYSTEM (TMS)

Banedanmark is developing a new TMS as part of the Signalling Programme. The new TMS takes an integrated approach to traffic management by combining customer-oriented service planning, efficient management, and entrepreneurial business practices. This approach seamlessly integrates processes and data from the start of timetable planning to the final execution of operations. It is designed specifically to help railways succeed in today's highly competitive transport market.

Banedanmark's TMS is based on advanced computing and communications technologies. However, the system does not simply apply new technologies to old railway operating practices – most of which were standardized well before the information age – but rather re-imagines how railways might be managed if they were being invented today, in an age of ubiquitous data, advanced computing and instantaneous communications. In other words, the TMS rethinks old railway practices in light of new technologies. (5)

The key innovation was recognizing that advanced information technology could be used to integrate railway planning and operations. Integration enables railways to plan and provide services that are more attractive to customers and more efficient to operate. For example, dispatching decisions can explicitly consider customer needs since dispatching is directly connected to planning. Similarly, investment decisions can be based on a precise understanding of how new infrastructure or rolling stock will operate, since planning is directly connected to dispatching. Banedanmark's new TMS takes advantage of advanced IT to make these dispatching decisions and planning analyses fast and easy.

The process of designing Banedanmark's new TMS started by examining how current railway management systems could be improved, this led to timetables.

3.1 Problems with Existing Timetables

Timetables are the key tool used to manage railways. They provide instructions for staff and describe services offered to customers. But timetables are a compromise: not precise enough for staff and too precise for customers.

For staff, timetable information (arrival and departure times) do not sufficiently describe what's necessary to operate service. For example, if the departure time is 10:15:00 when does the train guard lock the doors? If the guard starts the process at 10:15:00, then the train won't be able to depart until 10:15:15. In practice operating personnel rely on rules-of-thumb, experience, and their own timetables to translate railway timetables into operating instructions – but these are undocumented and not shared across the organization. This ad-hoc approach wastes capacity (e.g., the track above was reserved from 10:15:00 but not needed until 10:15:15) and creates unpredictability.

In contrast, timetables are too precise for customers. Most customers are more concerned with arriving on time to participate in an activity at the destination than exact departure and arrival

times. This is illustrated by customer behavior; at frequencies of less than 10-minutes, customers do not consult the timetable, they simply show up at the station. (6) Of course, customers do rely on precise timetable departure times to decide when to arrive at the railway station, but they make their initial mode choice decisions based on perceived service qualities.

Using timetables to provide instructions for staff and describe services for customers made good sense when data was limited and hard to analyze, but today the opposite is true. Advanced computing and communications technologies enable railways to re-imagine timetables by adding more precise instructions for staff and more descriptive information on the functional needs of customers. This is the approach used in Banedanmark's new TMS.

3.2 Production Plans: Precise Staff Instructions

The difficulty of providing precise instructions to staff is a key cause for adding buffer times and reserves – which currently use from 15-30% of capacity. Recapturing this capacity begins by precisely describing the activities needed to provide service. This so-called production plan:

- Precisely describes all tasks needed to provide service;
- Assigns tasks to “task owners” (people);
- Allocates resources (e.g. track sections) to tasks;
- Uses tolerance bands to define task performance windows; and,
- Provides real-time updates in case of divergences.

Production plans enable railways to reduce reserves by simplifying, rationalizing and more closely coordinating staff activities (tasks).

Advanced information technology means production plans can be created quickly and efficiently. For operations this means the TMS can monitor task performance and create new production plans as soon as it identifies a divergence (using the large amount of real time data made available from the ETCS), and then immediately communicate the revised production plan to staff and customers in the field, thereby helping minimize the divergence's impacts on service. (7) For planning this means production plans can be used more frequently for service design and investment analysis, thereby increasing the quality of railway planning.

3.3 Service Intentions: Managing for Customer Needs

Service Intentions systematically describe the functional needs of railway customers and are used as an objective function in the process of creating production plans.

Using service intentions to help create production plans improves railway service by linking operations to customer needs. For example, when a divergence occurs, the TMS creates a new production plan designed to best achieve the service intentions (i.e., customer needs) for the entire network and all customers. In contrast, standard timetables don't provide sufficient information to help dispatchers understand what to do when there is a delay or divergence – they only contain scheduled arrival and departure times.

Service Intentions also improve schedule planning by fully considering all customers from the start, including, for example, maintenance departments. In contrast, today the needs of many customers are only considered in supplemental processes after creating the timetable (e.g., possessions for maintenance). This reduces operating efficiency and adds complexity to the schedule development process. Focusing on functional needs also enables railways to improve

efficiency by eliminating duplicative services and increase quality by shifting resources to more productive uses.

3.4 Service Planning with Banedanmark's New TMS

This section presents a very brief description of Banedanmark's new TMS. The TMS is illustrated schematically in Figure 1.

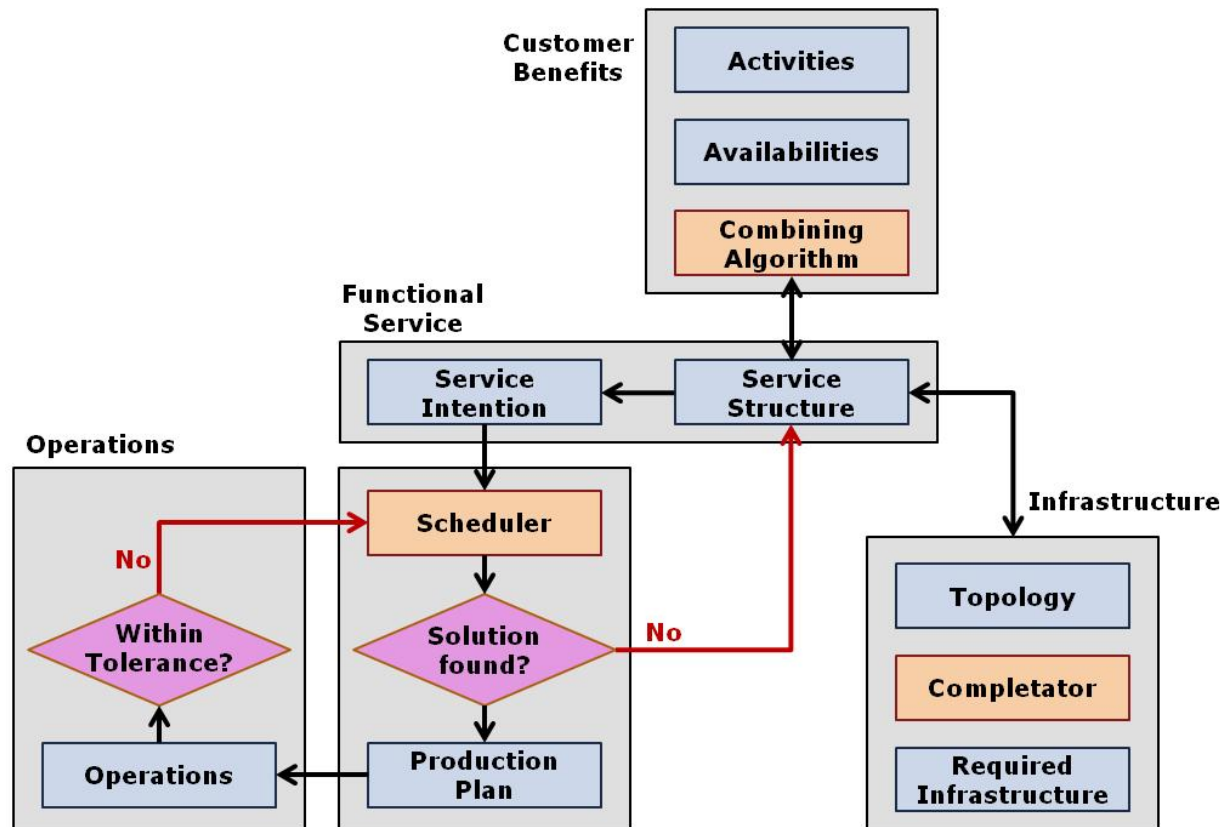


FIGURE 1 Railway management with Banedanmark's new TMS.

Customer Benefits – The new TMS starts by examining customer benefits. This consists of determining what customer “activities” should be provided with transport service, and what service qualities (“availabilities”) are needed to adequately serve these activities. The combining algorithm combines availabilities from different access points (stations) to increase railway production efficiency (i.e., availabilities from several access points can be served by the same train run).

The activities are the reasons people travel, for example shopping, going to work, going to a concert etc. By focusing on the activities it is possible to better understand the customer needs (i.e., determining what type of transport service needs to be provided for a particular activity).

The term availabilities has been defined to provide a language for precisely describing transport services in terms that are important to customers (frequency, travel time and transfers). The new TMS planning system's objective is to define availabilities that give customers the perception

they can use the transport service to participate in an activity. For example, the level of service needed to give people the perception that they can use the train to travel to work may be different from the level of service needed for shopping.

The activities and availabilities are defined by planners in an iterative process. They are then combined to create Availabilities and Activity Times (A & ATs). These represent the customer needs (markets for railway services).

Functional Service Plan – The second step in the new TMS process is developing a functional service plan. The functional service plan consists of a service structure (which defines the basic schedule pattern) and service intentions (which define the railway functions needed to fulfill the service structure). The arrow on Figure 2 is shown in both directions between the combining algorithm and functional service because the A & ATs developed in the combining algorithm may need to be revised to fit the service structure or due to infrastructure constraints.

The service intentions provide input on customer benefits into the scheduler algorithm. In fact they form the objective function for the scheduler. This enables customer benefits to be fully considered when developing production plans.

Infrastructure Analysis – The arrow between infrastructure and service structure also points in both directions because it is possible to either:

- 1) define the service structure and then determine the infrastructure requirements needed to enable the railway to operate this service structure; or,
- 2) use pre-defined infrastructure assumptions to inform the service structure, in which case the service structure will be constrained.

The topology and completator boxes are processes in the new TMS for determining an infrastructure from a desired service structure (i.e., option (1) above).

Production Plan – The third step in the new TMS process is developing the production plan. As outlined in Section 3.2, the production plan is a detailed description of all the tasks needed to operate the railway. Developing the production plan starts with feeding the service intentions into the scheduler algorithm. If a feasible solution is found it becomes the production plan. If there are no feasible solutions, then the service structure must be revised and new service intentions developed.

A feasible production plan can then be placed into operation or used in the planning process (e.g., to inform an investment analysis).

Operations – During operations the production plan is constantly compared to the actual operations. If there is a divergence (i.e., if any tasks are out of their tolerance range) then the TMS scheduler uses the current status and service intentions to develop a new production plan which can then be put into operation.

4. CASE STUDY: DEVELOPING BANEDANMARK'S CT2030 USING TMS

This section describes how the planning method in Banedanmark's new TMS was used to develop the 2030 Concept Timetable and calculate the minimum headway requirements for use in designing the new ETCS signaling system.

4.1 Future Service and Infrastructure Assumptions

The first step in developing the CT2030 was to assemble the policy level service and infrastructure assumptions. Banedanmark's goal is to significantly increase service quality and customer demand by providing:

- Highly connected passenger services throughout the entire country;
- Strengthened suburban service in the Copenhagen area;
- Improved perception of service reliability by passengers; and,
- Improved quality of freight service especially for international connections.

An especially important service improvement is the Timemodellen program ("one-hour model"). This is a regular interval timetable for 3 fast passenger train lines serving 10 Danish cities (Copenhagen, Odense, Aarhus, Aalborg, Kolding, Esbjerg, Randers, Frederica, Vejle, and Horsens). (8) The Timemodellen is designed to help create a coherent nationwide system by linking the three fast lines to regional services at the hub stations similar to Switzerland's highly successful Taktfahrplan. (9)

Another service assumption included in the project was the new TMS objective of supporting customer perception of service benefits. This means creating a timetable that helps customers create a cognitive map of transport service so that they have the feeling that they can use the service for all types of trips. This is done by serving similar markets the same way and by using regular interval timetables.

Finally, Banedanmark's capital improvement program was used as input for the infrastructure definition assumptions. These improvements are designed to help achieve Banedanmark achieve its policy level service goals. They include:

- ERTMS Level 2 signaling system for the entire network;
- 3 new high speed lines (in total 67 km) for Timemodellen;
- Electrification of a major part of the network (around 1.500 km additional electrified track kilometers resulting in a total of 2.800 km of 3.300 km); and,
- Speed upgrades on all parts of the network.

These infrastructure improvements were assumed to be in place for the CT2030.

4.2 Methodology for Developing CT2030

Banedanmark's Conceptual Timetable 2030 was developed by manually applying the new TMS process with the future service and infrastructure assumptions outlined above. Figure 2 compares the manual process with the full process shown in Figure 1. The process follows the purple arrows. The grayed-out boxes indicate processes that were not used in the CT2030 project.

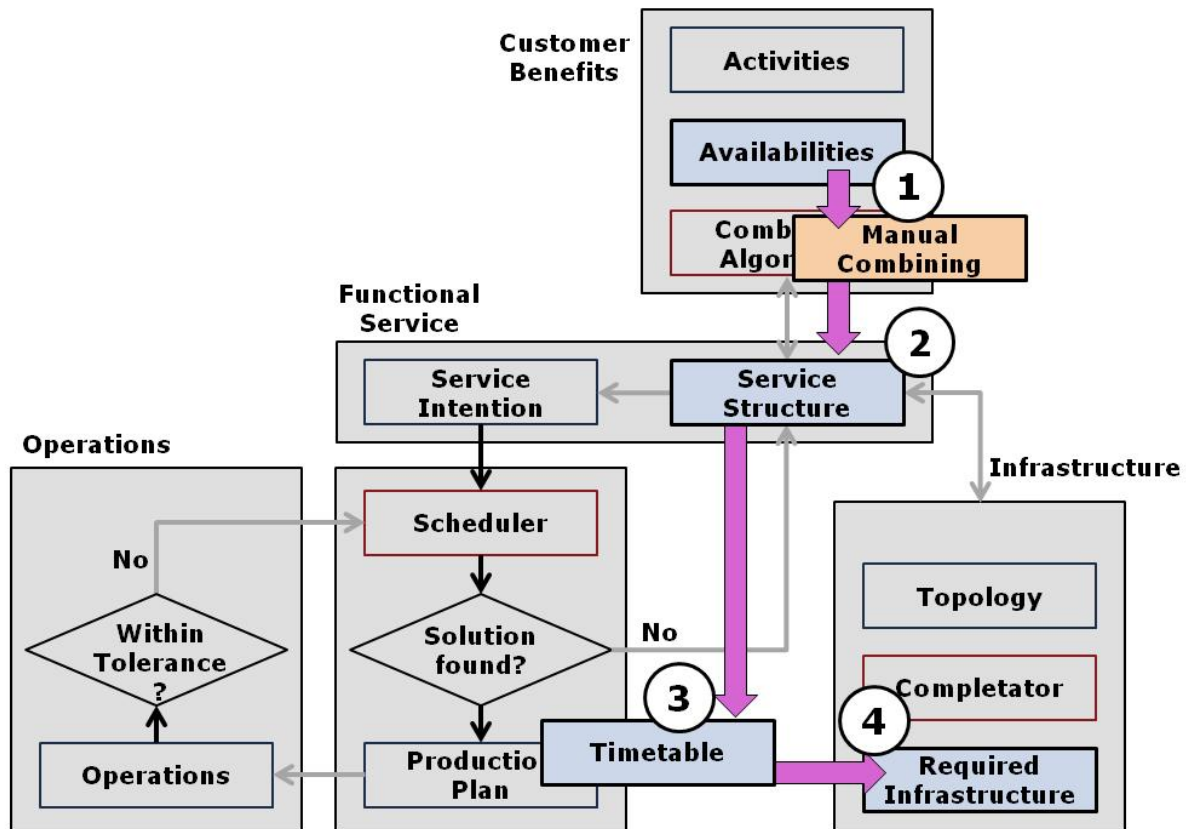


FIGURE 2 Manual application of Banedanmark's TMS for CT2030.

Three simplifications were made in developing the timetable manually. First, it was not necessary to consider activities because the CT2030 goal was to define the minimum headway requirements. Therefore it was possible to use the maximum availabilities as defined in the iterative schedule planning process. These availabilities represent service requirements during the peak period.

Second, the availabilities were combined using a manual process. The TMS will include tools to automate this process. Performing this task manually was helpful for teaching planners how the process works.

Third, there was no need to develop service intentions because the timetable was being developed manually (the scheduler was not being used to prepare a production plan). It was not necessary to create a production plan because the only output needed were minimum headway times, not precise task-based descriptions of activities.

These simplifications do not affect the essential approach being implemented in the TMS, only the level of detail. The following sections describe each step in the process (circled numbers in Figure 2 refer to the steps).

4.3 Step 1: Define Availabilities

Availabilities define the transport service between network access points (stations). Defining availabilities represents a conscious decision about what services should be provided between all access points on the network. The focus is on travel relations (access point to access point) that matter most to customers and stakeholders.

The availabilities for CT2030 were defined in an iterative process that combined information about travel demand with the policy objectives outlined above (e.g., the Timemodellen service plan, half-hourly basic service interval, minimum connectivity requirements, TMS objective of schedule consistency, etc.). This process relied partly on the subjective judgment of planners in placing access points in similar categories (e.g., major hub stations, suburban station, etc.) and considering data such as catchment area population, density, activity mix, etc.

The first step consisted of bundling the 320 access points into 86 aggregated access points to reduce the travel relation matrix. Bundling access points reduces the number of availabilities that must be defined and is a common practice in railway scheduling. Bundling combines access points that are served in approximately the same way into aggregated access points. For example, all regional stations on a line between City A and City C can be bundled into one aggregated access point called Town B. The availability defined for Town B then represents the availability for all the stations on this line.

Next, planners identified the most important travel relations in the resulting 86-by-86 matrix. This resulted in approximately 400 travel relations for which specific availabilities needed to be defined. Many of these availabilities could be taken directly from policies (e.g., Timemodellen specifies one direct service per hour between Aarhus and Aalborg with a one-hour maximum travel time) while others needed to be developed by the planners to meet more loosely defined policy objectives (e.g., provide good connectivity at local hubs).

Table 1 presents a portion of the Availabilities table used in developing the CT2030. An important point in reading Table 1 is that the TMS uses a time unit of 7½ minutes (i.e., an octant of an hour) to express availabilities. Octants are used to account for customer flexibility in their long term travel planning (as outlined in Section 3.1 above). Octants are a particularly good choice because they enable schedulers to divide hours evenly in half (4 octants) and also into quarters (2 octants). In contrast, 10-minute time blocks can only be divided evenly into half (three 10-minute blocks). This makes octants more useful for developing fixed interval timetables.

As an example consider the relation Aalborg – CPH (Copenhagen airport) which is shaded in gray. Table 1 shows 26/4/0 for this relation. This means that the travel time is 26 octants (= 3 hours and 15 minutes), there are 2 trains per hour (interval between trains is 4 octants), and these are direct trains (zero transfers required). It is important to remember that the availabilities listed in this table do not represent trains but rather functional requirements for service; how these functional requirements are actually implemented is determined in the next steps.

TABLE 1 Availabilities, Partial List

Origin (Aggregated Access Point)	Destination (Aggregated Access Point)	Travel time / Interval /Transfer (Octants/Octants /Number of transfers)
Frederikshavn	Aalborg	9/8/0
Frederikshavn	Randers	13/8/0
Frederikshavn	Køge Nord	33/8/1
Frederikshavn	Aalborg Lufth	9/8/1
Hjørring	Aalborg	5/4/0
Hjørring	København H	29/8/0
Hjørring	Køge Nord	29/8/1
Aalborg	Aarhus	8/4/0
Aalborg	Skanderborg	11/4/1
Aalborg	Roskilde	24/8/1
Aalborg	København H	24/4/0
Aalborg	Nørreport	25/4/1
Aalborg	Helsingør	31/4/1
Aalborg	CPH	26/4/0
Hobro	København H	24/4/1
Hobro	Aalborg Lufth	7/4/0
Randers	Langå	1/4/0
Randers	Aarhus	4/4/0
Randers	København H	20/4/0
Langå	København H	20/4/1
Aarhus	Roskilde	16/4/1
Aarhus	København H	16/4/0
Aarhus	CPH	18/4/0
Skanderborg	Horsens	2/4/0
Skanderborg	Vejle	5/4/0

4.4 Step 2: Develop Service Structure

The service structure is a generic description of service patterns that can be used to implement the functional requirements (availabilities). The service structure is developed by combining availabilities into “generic” trains (e.g., a train running every 30-minutes that stops at all stations on the line between A and C). The objective of combining availabilities is to increase railway production efficiency (e.g., make better use of capacity).

The goal in defining service structures is to find a balance between providing non-stop service between all stations and providing services that stop everywhere. In traditional schedule planning this means identifying opportunities for express trains. In the new TMS, availabilities make this process more transparent and analytical by explicitly defining availabilities for “trip time saving relations” where lower travel times are needed to meet specific functional requirements.

For example, the availability between two major cities might be set for a fast travel time (e.g., hourly Timemodellen). But, more interestingly, a trip time saving relation could be defined specifically to enable the connections needed to achieve other availabilities. By explicitly defining availabilities, the TMS planning method makes the customer needs for faster trains clear and therefore supports highly transparent railway scheduling.

The first step in developing the service structure for CT2030 consisted of dividing the railway network into geographical regions and then developing service structures for each region. One region covered the whole country to include long-distance trains in the process. These regional service structures became the building blocks for creating the national service structure. The regional service structures are designed to fulfill all the availabilities for the region. They were developed in an iterative process by planners working around a white board using a schematic graphical format that illustrates how services can be integrated and linked (Figure 3).

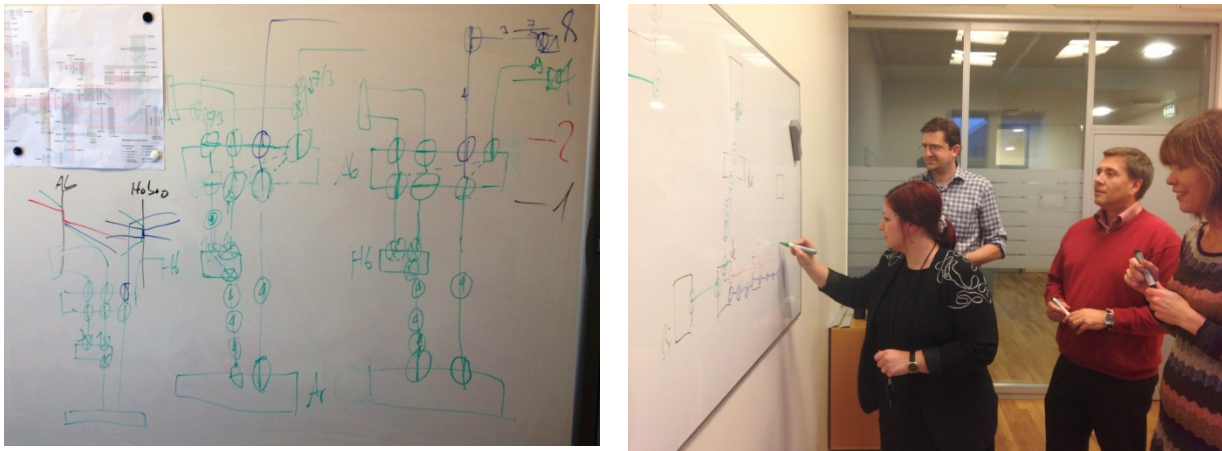


FIGURE 3 Planners developing functional timetable.

The second step in developing the service structure for CT2030 consisted of combining the optimum regional service structures. In some cases it was necessary to make trade-offs due to conflicts between the optimum regional service structures.

There were two types of conflicts. Most of the conflicts were inconsistencies between the regional service structures at the border points (e.g., the optimal service structure might have

services in one region leaving in octant 5 while the other had services arriving in octant 3). In this case one of the regional service structures was shifted to be consistent with the other (e.g., services arrive in octant 5 and leave in octant 5).

The second type of conflict was two trains trying to use the same track at the same time. This happened very rarely. These conflicts were addressed by reconsidering parts of the service structure, which, in some cases, required adaptation of the availabilities. At the end of this process the regional building blocks were combined into a coherent national service structure.

Figure 4 presents a small portion of the national service structure showing the Copenhagen region (Figure 5 shows the full national service structure). The pale brown boxes represent main access points. The lines represent two-way services. The colors highlight the number of services per hour (yellow = 8 trains/hour, green = 4 trains/hour, red = 2 trains/hour, single blue lines indicate one train per hour). The small numbers on either side of the access points on the lines represent the octants when the services leave and arrive (octants are numbered 0 – 7).

The circled numbers at the main access points indicate the headway (in octants, so 1 = every $7\frac{1}{2}$ minutes). The circled numbers outside main access points show headway at intermediate access points. The circles with crosses are octant identifiers; these indicate the octants when services are provided (e.g., for 4 services per hour: even octants: 0, 2, 4, 6; or odd octants: 1, 3, 5, 7).

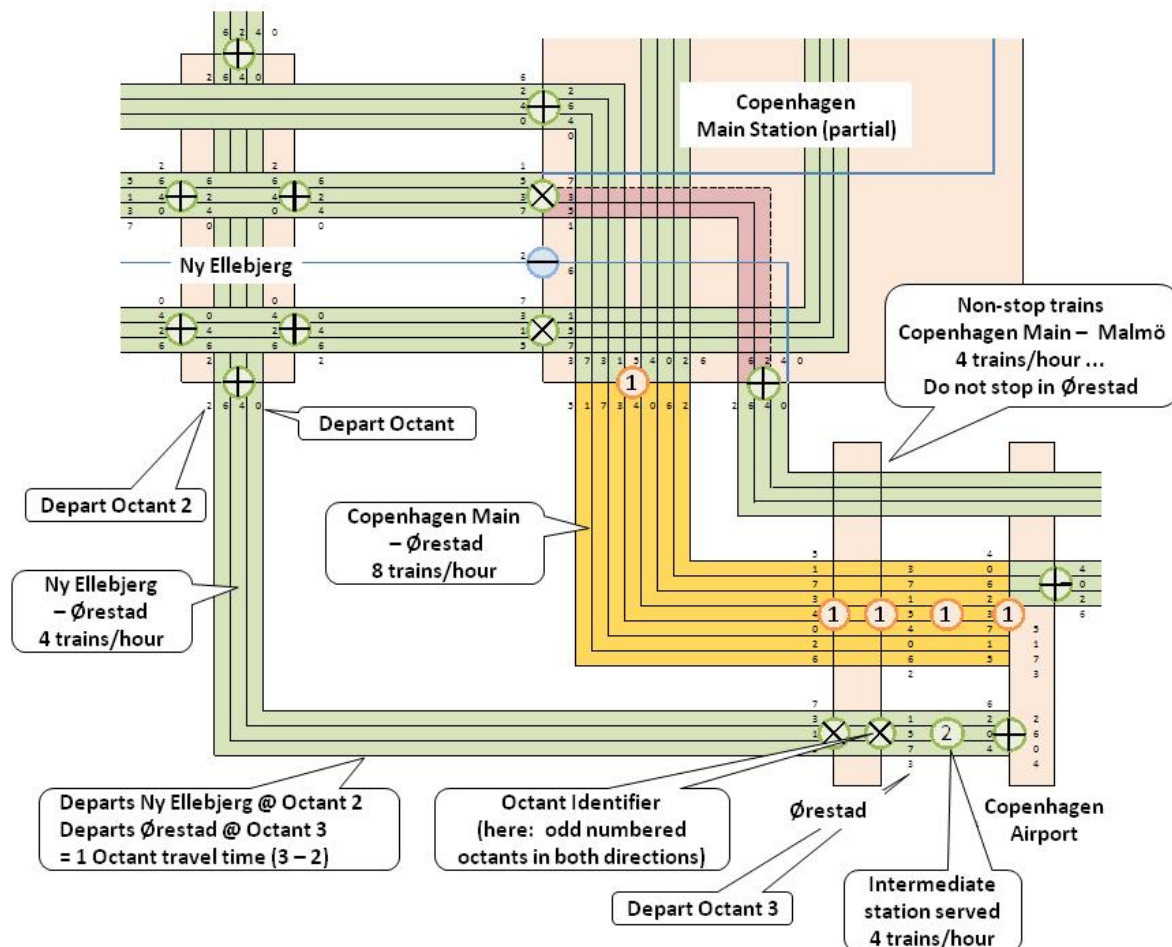


FIGURE 4 Portion of functional timetable (Copenhagen area).

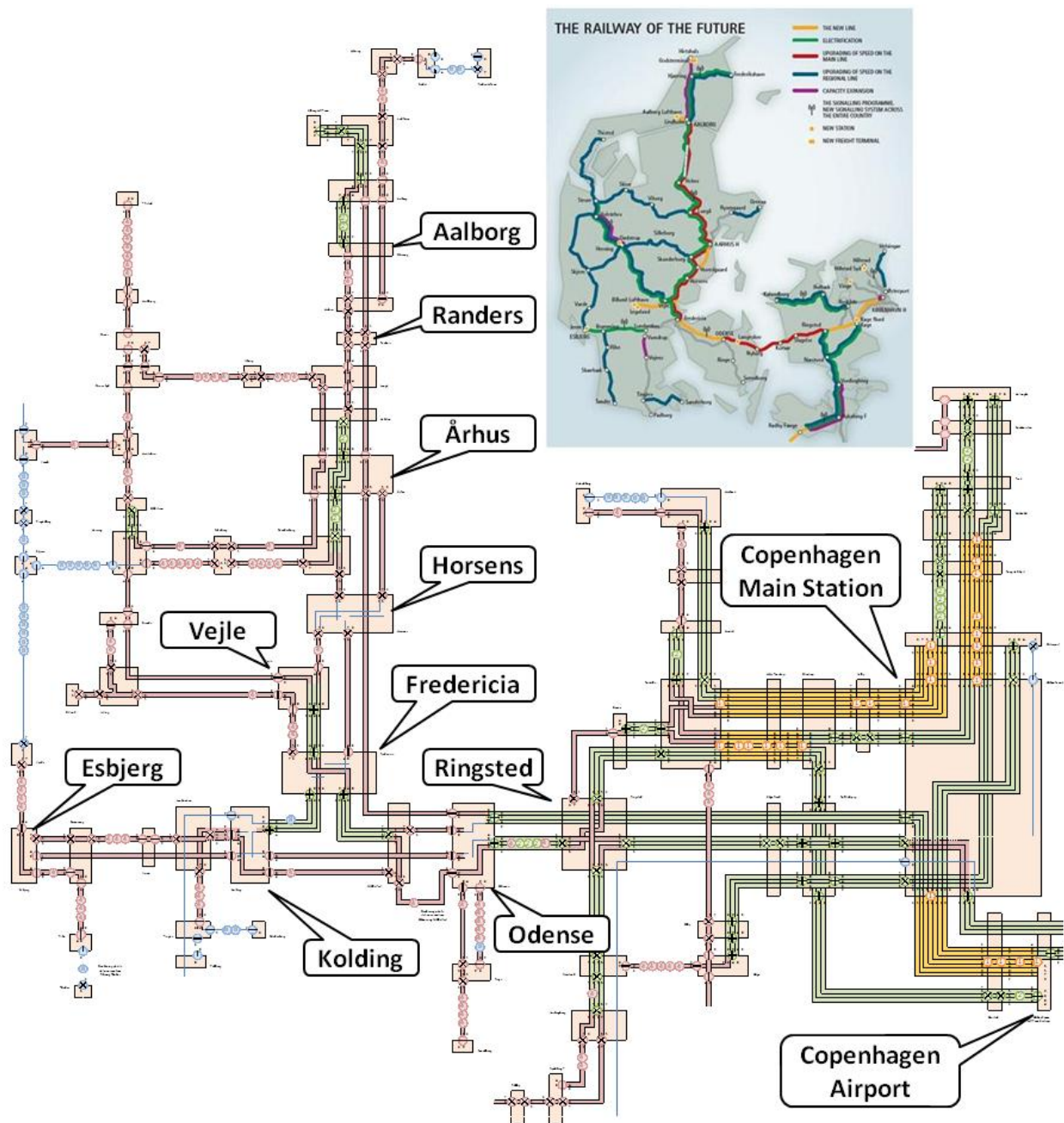


FIGURE 5 National service structure.

4.5 Step 3: Develop Detailed Timetable

The process of developing a detailed timetable for CT2030 consisted of identifying specific times for operating all services within their specified octants. This is an iterative process with the planners shifting train times until all the trains meet their functional requirements (octant, travel time, transfers) and do not violate the infrastructure capacity constraints. The analysis was done for the peak period because the project goal was to identify minimum headways.

In developing the CT2030 the planners took as given the major infrastructure improvements planned to be implemented by 2030 (described in Section 4.1). However, in situations where quite minor infrastructure improvements (e.g., a crossover) could enable a service intention to be achieved, these were assumed to be available. As outlined in the next section very few new improvements were necessary.

Capacity was checked graphically using time-distance diagrams for line segments and junction graphs for complex nodes (e.g., main stations). The process was highly iterative, so when problems were identified, the planners first attempted to eliminate the conflict by shifting the precise times, but in some cases they needed to revise service structures. As outlined above, in some cases they identified minor new infrastructure improvements and assumed they could be implemented.

Time-distance diagrams were developed for the entire Banedanmark network. Figure 6 illustrates the final time-distance diagram for the line between Copenhagen Main Station and Helsingør. The green lines indicate elementary relations (services between neighboring access points) and the red lines indicate trip time savings relations (services that connect non-neighboring access points with the goal to fulfill availabilities with shorter trip times than chaining up a series of elementary relations).

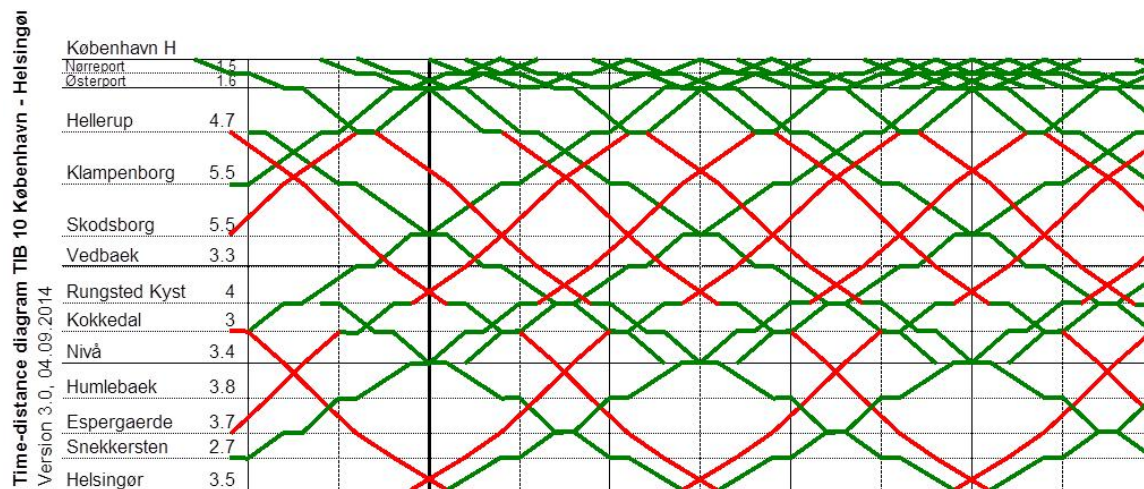


FIGURE 6 Time Distance Diagram Copenhagen Main Station – Helsingør.

Figure 7 illustrates the junction graph prepared for the Kastrup area. This is a busy junction serving trains between Copenhagen-H (main station) and Malmö, with a stop at Copenhagen Airport (CPH). The physical configuration consists of two tracks coming from Copenhagen-H, with two sets of points leading to a double track airport bypass line and a double track airport station, then another set of points leading to a double track line to Malmö and double track line into a depot located outside the airport station.

The junction graph diagram format was designed as part of TMS development to schematically illustrate track sections and points areas in complex junctions. It shows time, distance and infrastructure on the same figure.

Time moves from the top of the page to the bottom. Train paths are shown in colored lines. Points areas are shown in the shaded blue squares, each square represents 100-seconds (1-minute)

and 40-seconds), the planned minimum headway in the Kastrup junction area. The vertical lines between the points areas represent the track between the points areas. For example, in the center points area there are three tracks on the left side and four tracks on the right side (this corresponds to the second turnout to the bypass tracks).

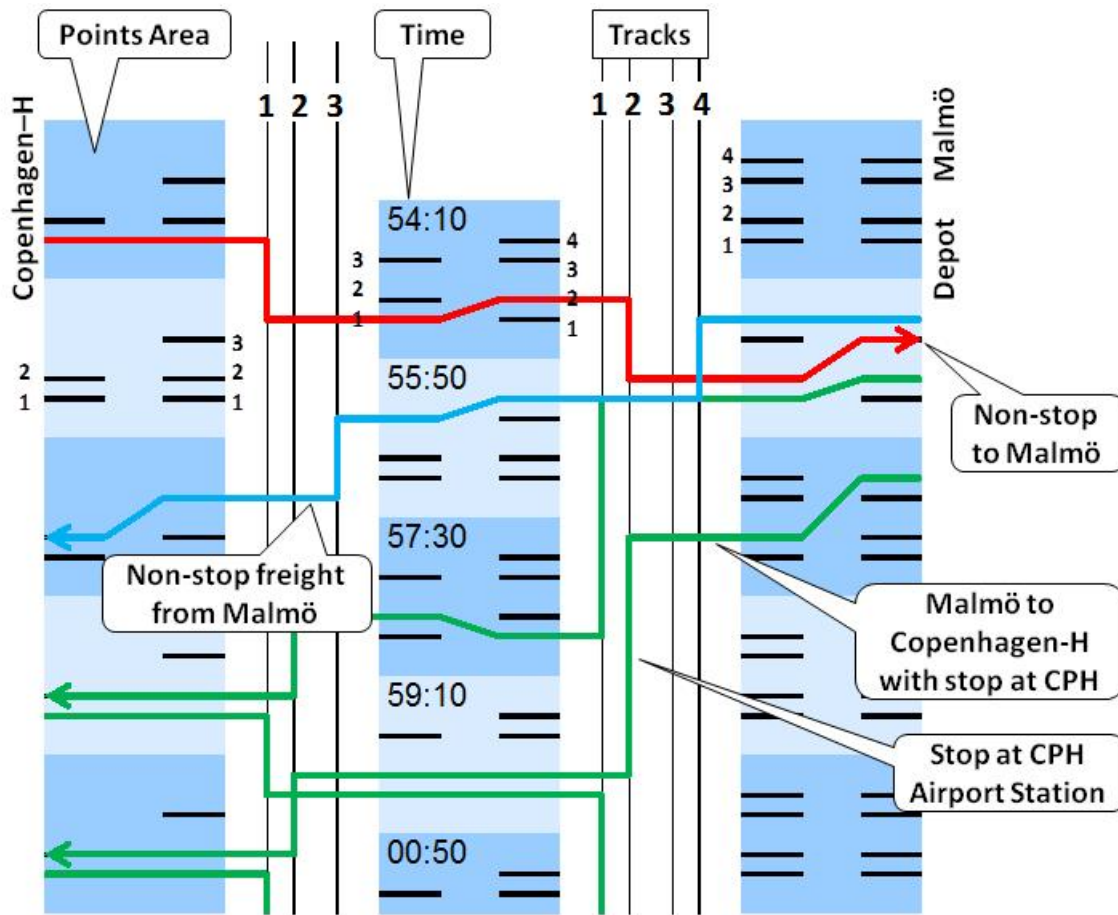


FIGURE 7 Junction Graph Kastrup area (headway: 100 seconds).

Four types of services (trains) are shown in the junction graph: a travel time savings relationship service traveling non-stop through the junction area bound for Malmö (red line), a non-stop freight service from Malmö (blue line), an elementary relationship service from Malmö to Copenhagen-H with a stop at the airport (green line), and an elementary relationship service from the airport to Copenhagen-H originating from the depot (also in green).

There are two rules for using the junction graph to plan service: (1) trains cannot cross paths within a points area; and, (2) trains cannot simultaneously occupy the same track sections.

4.6 Step 4: Infrastructure Requirements for Concept Timetable 2030

Once the detailed timetable had been created it was possible to calculate the minimum headways for the Banedanmark network and the minor infrastructure improvements needed to provide the CT2030 timetable. The headway requirements define how the ETCS should be designed and are essentially an infrastructure requirement. Figure 8 presents these minimum headways.

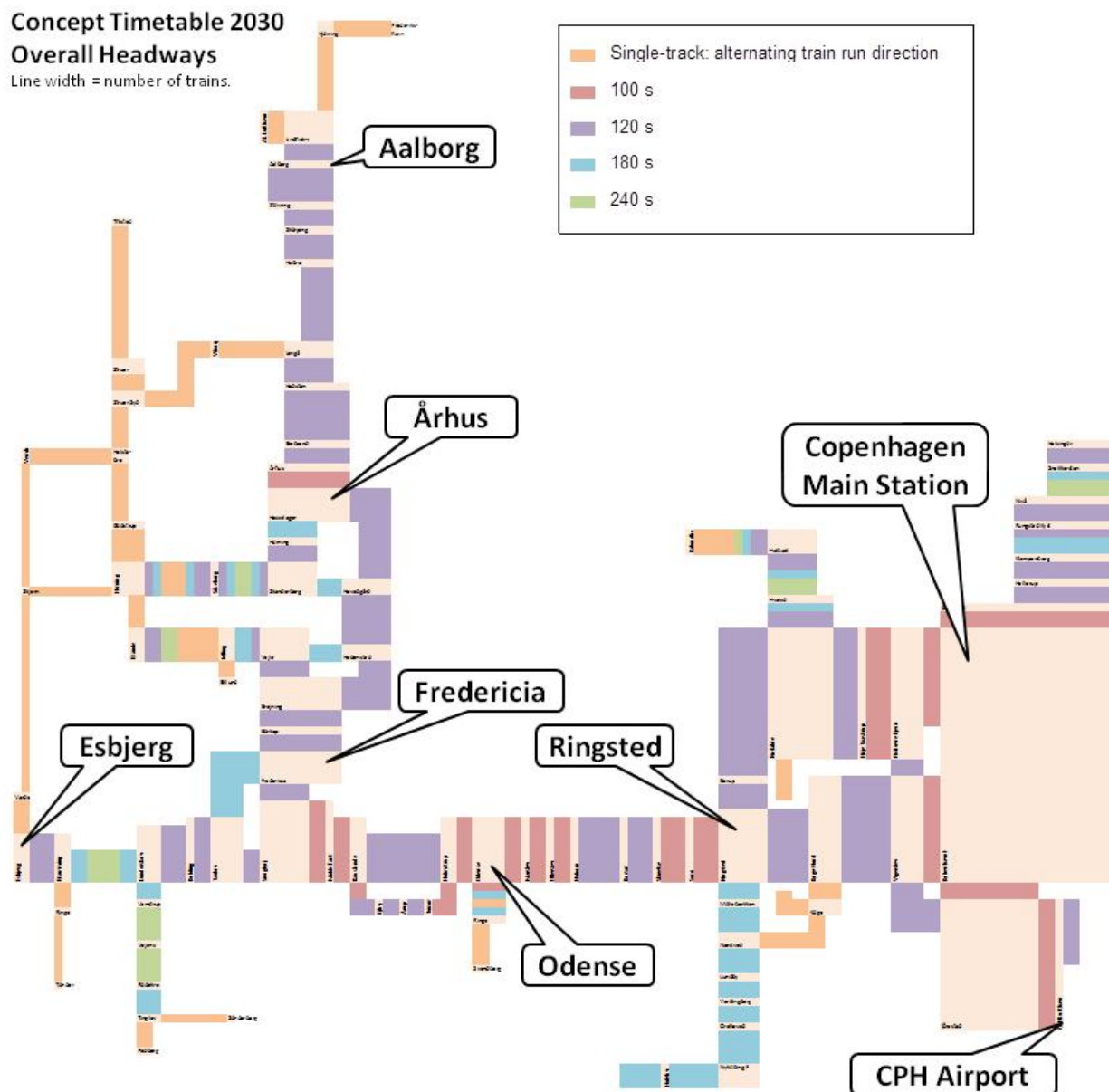


FIGURE 8 Banedanmark network headway requirements – Concept Timetable 2030

5. CONCLUSIONS

This paper describes the schedule planning process in Banedanmark's new TMS and how it was manually applied to develop a new Concept Timetable 2030. The CT2030 was then used as a design basis for planning Banedanmark's new ETCS level 2 signaling system.

Banedanmark's new TMS is designed to take full advantage of the digital data generated by the new signaling system. The new TMS integrates railway planning and operations – something not possible before advanced information technology. It replaces a process that relied on many different tools, databases and approaches with a consistent system that seamlessly integrates processes and data from the start of timetable planning to the final execution of operations. This

enables Banedanmark to plan schedules that better meet customer needs and operate services more efficiently.

Banedanmark's CT2030 was developed by manually applying the service-based traffic planning process used in the new TMS. This method starts by considering customer needs and then builds up a schedule based on those needs. The process of developing the CT2030 using the new approach was an important proof-of-concept for the new approach.

Recommendations for future research include: (1) comparing the results of manual application of the TMS methods with automated results, including the efficiency and quality of the timetables; (2) developing a more detailed understanding of the service-based approach to transport planning; and, (3) improving the ability to define and assess customer perception of transport services.

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