Future Trains

Decision Paper for Phase 1.5

June 2017

DSB

Contents

1 Introduction

In recent years, decisions have been made regarding significant investment in the Danish railway infrastructure. New lines are being constructed, speed upgrades will be made to existing lines, the main network will be electrified, and the signalling systems will be replaced. These significant infrastructure improvements will change the basis of railway transportation in Denmark considerably and will also represent new demands on DSB's rolling stock.

The majority of DSB's current long-distance and regional trains face replacement before 2030 and will be replaced by new, faster electric trains in order to benefit fully from the infrastructure improvements. To this end, DSB has been tasked with the sourcing of new electric trains for Denmark by the Ministry of Transport, Building and Housing.

For the purpose of establishing a basis for a political decision regarding the commencement of train procurement, DSB has produced an executive decision paper to cover how DSB can purchase, take delivery of, and commission modern and operationally reliable electric trains with the lowest possible risk element towards the year 2030 in respect of numbers, types and delivery times to ensure that the Danish railway system can satisfy the demands resulting from future passenger number growth.[1] This points to three key questions that have all been addressed in this decision paper:

1. **Selection of train types:** What is the optimum train type combination (which and how many) to service passenger traffic on Danish railways in 2030?
2. **Purchasing strategy:** What is the overall plan for purchasing of new electrical trains (when) and the associated tendering strategy (how) and risks, given the selection of types?
3. **The next steps:** How are the next phases and the overall transformation of DSB's organisation, infrastructure, and facilities to be organised and planned as a result of the purchase and commissioning of new electric trains?

Train purchasing will fall under the remit of the programme 'Future Trains' The programme comprises two purchasing projects: 1) purchasing of new electric trains and 2) purchasing of electric locomotives. The decision paper introduces and discusses conclusions related to the purchasing of new electric trains. The purchasing of electrical locomotives has been decided in the political forum and so will not be discussed further in this decision paper. Renewal of DSB's fleet has thus already commenced and the purchasing of new electrical trains is the next natural step in the renewal process.

To form the basis for the decision paper, 15 technical reports have been prepared with relation to the central themes of the decision paper as well as a range of supporting analyses and internal notes.

The decision paper has been prepared by DSB in close collaboration with the external advisors: PA Consulting Group and SNC-Lavalin as main advisors, Boston Consulting Group as advisors on certain partial analyses, and Kammeradvokaten and the law firm Gorrissen Federspiel as legal

[1] The Ministry of Transport, Building and Housing, Commission on Rolling Stock Plan Phase 1.5 (final version January 2016).

advisors. Consulting firms Struensee & Co and McKinsey & Company have been nominated by The Ministry of Transport, Building and Housing to provide external quality assurance.

DSB believes that this decision paper creates the basis for arriving at a political decision to continue with train purchases. This shall ensure realisation of the benefits to Danish public transport promised by the investment in railway infrastructure.

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2 Summary and recommendations

The following is a summary of the main conclusions of the decision paper, including DSB's recommendations for train type selection, purchasing strategy, and the next steps for the purchase of new electrical trains and for the overall conversion of DSB's organisation, infrastructure, and facilities.

Background and starting point

DSB faces significant investments in new electrical rolling stock for Denmark to replace large portions of the current, ageing fleet towards 2030. New electrical trains are a prerequisite for being able to fully benefit from the significant railway infrastructure improvements, including the electrification of the Danish state railway network, currently being carried out. New electric trains, in consequence, form a major contribution to more environmentally friendly and efficient train operations with higher punctuality and support of future growth in passenger numbers.

DSB has created four overriding targets for the purchase of new electric trains: timely phase-in; high operational stability; lowest possible costs, and; satisfied customers. These targets have been forming the direction in relation to selection of train types, purchasing strategy, and the next steps for rolling stock acquisition.

Primary recommendation conditions

Acquisition of the new electric trains is based on the long-term DSB rolling stock plan (Rolling Stock Plan 2030) which in turn is based on a range of preconditions relating to infrastructure, passengers, operations, and rolling stock considerations. The key decision paper preconditions are:

- Adjustments to the "Train Fund"[2] means that infrastructure improvements necessary for the realisation of the so called "Hour Model"[3] probably will not be fully implemented this time around. This, among other things, leads to the elimination of any basis for acquisition of high speed trains at this point in time. DSB presumes, among other things, that the new track across West Funen will be completed. This will increase capacity in one of the worst infrastructure bottlenecks in Denmark, a prerequisite for increasing traffic volume, maintaining regional service, increasing robustness, securing capacity for freight trains, and reducing travel times.
- Central infrastructure projects are presumed completed on schedule, to include the roll-out of new signalling systems and electrification between Fredericia and Aarhus before the end of 2024 and between Aarhus and Aalborg before the end of 2025.
- A 27% growth in long distance and regional traffic is expected) for the period 2016-2030, primarily driven by the east-west traffic. This is based on a prognosis prepared by the Danish Transport, Construction and Housing Authority using the National Transport Model (Landstrafikmodellen). 89% of the passenger growth will be driven by timetable and infrastructure improvements and 11% by background societal growth. The new track

[2] Political agreement of September 2003 to allocate DKK 285bn to improve the Danish railway

[3] Model of train service that implies that the travel time between the largest cities of Denmark be reduced to one hour

between Copenhagen and Ringsted is the infrastructure project from which the greatest effect will be realised.

- DSB will not make operational coupling a mandatory requirement for the new electrical trains, meaning that the starting point is based on coupling and decoupling in Aarhus only. This has also been presumed in the train type selection calculations. If it turns out that up- and downscaling of the new electric trains works satisfactorily, DSB will be able to extend the use of up- and downscaling. This is expected to bring about a net gain of approx. DKK 90 million per annum. This is primarily due to operation cost savings as the current IC traffic needs to do more than 7% additional train kilometres without up- and downscaling to satisfy the same transport commitments, since it is not possible to adjust the train size gradually in step with passenger numbers. There will also be a capital cost saving since up- and downscaling means that fewer trains need to be acquired and gradual train size adjustment frees up trains for use on other routes. Automatic coupling is a standard functionality for all those train sets proposed in the market dialogue.
- As described in the IC4 report "IC4 Recommendation" dated 15 December 2016, the IC4 will be phased out as the first type in step with the phasing in of new electric trains beginning in 2024, and the phasing out of IC4 will be complete in 2025. This is due to operational stability challenges and high costs.
- The optimum rolling stock plan for Denmark has been identified with consideration of the expected electrification rate independently of whether DSB will continue as the operator. This means that the possibility of increased rolling stock requirements following from a potential splitting up of traffic has not been considered.
- It has been presumed that the acquisition will only include trains for national traffic. This is based on the Transport Vision (Trafikvision) from The Ministry of Transport, Building and Housing in which international traffic to Germany in 2030 no longer forms part of DSB's traffic. A number of alternative models are under consideration regarding the traffic to Sweden. If at a later date it is decided that DSB will continue its international traffic to Germany beyond 2028 and to Sweden beyond 2034, at which time the current internal traffic rolling stock is expected to be phased out, the fleet for Sweden will be acquired via separate tender. As regards the fleet for Germany, an option for electric locomotives will be included in the upcoming DSB locomotive acquisition, enabling service to Hamburg also when the Femern connection is open.

The following is a summary of recommendations related to the three key questions of the commission, on which basis the decision paper is structured:

1. **Selection of train types:** What is the optimum train type combination (which and how many) to service passenger traffic on Danish railways in 2030?
2. **Purchasing strategy:** What is the overall plan for purchasing of new electrical trains (when) and the associated tendering strategy (how) and risks, given the selection of types?
3. **The next steps:** How will the next phases and the overall conversion of DSB's organisation, infrastructure, and facilities be organised and planned as a result of the acquisition and commissioning of the new electric trains?

2.1 RECOMMENDATIONS REGARDING SELECTION OF TRAIN TYPES

The purchase of approx. 43,000 seats in new rolling stock consisting of long distance trains based on one established production platform for use in both long distance and regional traffic.

The expected passenger growth and the political desire for new tracks and more departures equate to an expected increase in passenger seats required on DSB routes from approx. 59,000 seats in 2016 to approx. 65,000 seats in 2030. This corresponds to passenger seat growth of approx. 10%.

The train acquisition investment is expected to be in the region of DKK 14.0-17.0 billion. The total investment for train acquisition, derived projects, and programme costs is estimated at DKK 17.1-21.8 billion.

Recommendation
Approx. 43,000 seats of new rolling stock is acquired.
Given the available passenger and rolling stock presumptions, a rolling stock shortfall is expected to arise in 2024, and to increase as existing rolling stock is phased out. Given that the majority of DSB's current fleet will be phased out towards 2030, it will at that time only amount to approx. 22,000 seats.

The phasing out of the current fleet is due, among other things, to fleet ageing, operational stability challenges and high costs. For example, the 96 IC3 train sets currently forming the backbone of the vast majority of Intercity and fast trains in Denmark will be phased out after approx. 35 years' operation. All IC3 train sets are expected to have been phased out by the end of 2027 and will be useful as a risk buffer against any train acquisition delays. The total phasing out means the acquisition of approx. 43,000 seats of new rolling stock is needed to satisfy the expected seating requirement of approx. 65,000 in 2030. Following this, approx. 70% of seats in new rolling stock will cover national routes and 30% will cover regional routes.

In Phase 2, and prior to making a final decision on the number of trains, DSB will further analyse the current rolling stock requirements on the basis of, among other things, an updated passenger prognosis, a detailed rolling stock plan for 2030, and any adjustment of train systems with a view to reducing the rolling stock requirements on a robust basis. At the same time, DSB has already evaluated the opportunities related to rolling stock requirement reductions. In consequence, it has been presumed, among other things, that it is realistic to adjust workshop reserves downwards and to transfer some long distance customers to regional trains via minor timetable adjustments. This has been included in the rolling stock acquisition prerequisites.

On the basis of an extensive market analysis and subsequent calculations of overall purchase and operations costs over the life cycle of the new trains, estimated at 30 years, the overriding recommendation for train type selection is as follows:

Recommendation
Long distance trains to be purchased based on a single established product platform for use both in long distance and regional traffic.
DSB recommends that the new trains are based on a single, established product platform (homogeneous fleet) for use in both long distance and regional traffic. The alternative is a fleet consisting of long distance trains for long distance traffic and regional trains for regional traffic respectively based on two different product platforms (heterogeneous fleet). Product platforms are a generic design of a train's basic technical systems and components. This means that a modern train will not have to be developed from scratch and product platforms allow for a certain scope of adjustment of the train's interior design and usage options.

Selected train type properties

Info box 2.1

The info box shows selected train type characteristics.

This info box illustrates the principal differences between the train types regional train, long distance train, and high speed train..

Property	Regional train	Long distance train	High speed train
Maximum speed (km/h)	160	200	230-250
Acceleration (m/s2)	0.8-1.25	0.7-1.0	0.5-0.9
Number of doors per side per carriage	2	1-2	1-2
Door width (mm)	1100-1950	900-1800	800-1000

The recommendation is primarily based on a weighing up of two issues: On the one hand, complexity is reduced when acquiring a fleet based on a single product platform (homogeneous fleet) for both long distance and regional traffic. This extends, for example, to maintenance, administration, and planning, as well as the tender process. On the other hand, a higher degree of adjustment to traffic type will be allowed if acquiring a fleet consisting of both long distance trains for long distance traffic and regional trains for regional traffic based on two different product platforms (heterogeneous fleet).

The calculated cost difference between the two scenarios is DKK 700 million in current values across the 30 year lifetime of the new trains. The main reason for the lower costs involved in acquiring a homogeneous fleet is the lower complexity related to purchasing, maintenance, and personnel training, of which maintenance in particular represents a large part of the cost reduction. This exceeds the advantages offered by a higher degree of adjustment to traffic type associated with a heterogeneous fleet. In addition to increased complexity costs, a heterogeneous fleet also involves increased risks (e.g. less attractive prices, as the size of the order is split in two) and programme costs.

Cost calculations for the two scenarios are based on the presumptions for rolling stock acquisition and cost estimates for new rolling stock acquired through dialogue with manufacturers and operators in the market.

The recommendation includes de-selection of high speed trains. This is due to limited travel time benefits, significantly higher purchase prices, and the likelihood that additional high speed tracks will not be established for the foreseeable future. This issue can, however, be reconsidered at a later time, provided that the infrastructure necessary to yield significant travel time reductions is established. Such considerations can be linked to future rolling stock acquisitions, for example new Øresund trains at the start of the 2030's.

Recommendation
Manufacturers should be given the opportunity to offer a homogeneous fleet consisting of either long distance trains or a combination of long distance and regional trains based on a single, established product platform.
The analysis shows that most manufacturers are capable of supplying long distance and regional trains built on the same product platform. DSB recommends allowing manufacturers the ability to offer a homogeneous fleet (long distance trains) or a combination of regional trains and long distance trains, as long as these are based on a single, established product platform. This reduces programme risks, as train manufacturers will be able to adjust their solution on the basis of the overall tender framework and at the same will keep the market open for DSB. This allows arriving at the optimum train type selection without increasing the risks, regardless of whether long distance trains or a combination of long distance and regional trains are acquired.

Recommendation
In principle, coupling and decoupling is only performed in Aarhus. If this can be satisfactorily implemented, it is recommended to extend the use of up- and downscaling to include IC traffic.
As a result of passenger flows, DSB currently uses long distance trains with up to five train sets that are operationally coupled on the main route between Copenhagen and Aalborg, and operational coupling is currently an integral part of DSB's operational concept with approx. 150 couplings per day in the long distance traffic. A total of 55,000 couplings are performed annually. The current rolling stock makes this a reliable process, and only approx. 0.3% of couplings result in delays in excess of 5 minutes.

The projected construction of new tracks on West Funen gives the potential for more direct departures across the country. At the same time, the expected lack of electrification of Vejle-Herning-Struer means that the option to service these routes with direct electric trains to and from Copenhagen will disappear. This means that in contrast with current needs, only up- and downscaling will be required in 2030 and not operational coupling.

Calculations performed in connection with train type selection show that the use of up- and downscaling in IC traffic could result in a total annual net gain of approx. DKK 90 million

compared with up- and downscaling in Aarhus only. This is primarily due to the fact that without up- and downscaling in IC traffic, more than 7% additional train kilometres have to be covered to satisfy the same transport obligations since it is not possible to gradually adjust train size to passenger numbers. There will also be capital cost savings as up- and downscaling means that fewer trains need to be acquired and a gradual adjustment of train size will release train sets for use on other routes.

To minimise risk as far as possible and because of the problems with operational coupling experienced by DSB with IC4, DSB recommends as a starting point that up- and downscaling only takes place in Aarhus. On the basis that the use of up- and downscaling in IC traffic is expected to realise a net gain of approx. DKK 90 million per annum; that automatic coupling is a standard functionality on all train sets proposed in the market dialogue; that other operators routinely use up- and downscaling, and that up- and downscaling will reduce the need for platform extensions, DSB recommends extending the use to also encompass IC traffic, provided this can be satisfactorily implemented and subject to adequate testing.

Recommendation
Acquisition of 204 train sets or 199 train sets if up- and downscaling can be implemented satisfactorily in IC traffic.
With the recommended train type selection and a seating requirement of approx. 43,000 new seats, the optimum train size for a single-deck train can be calculated from a cost perspective as 210 seats with a length of about 80 metres. This equals a total need for 204 train sets. If it were to be possible to perform up- and downscaling in locations other than Aarhus, the number of train sets can be reduced to 199.

Although 204 train sets is the expected number, there is a certain degree of uncertainty related to this estimate since the seating requirement depends on a range of preconditions, such as the development in passenger numbers and number of seats per train set in the new trains. In order to highlight the consequences of these uncertainties, a number of sensitivity calculations have been made in respect of seating requirements.

The sensitivity calculations have led to the identification of an uncertainty range for the need for new seats in 2030 equal to 110-245 train sets. This range is an expression of the lowest and highest estimate respectively, presuming a combination of the employed sensitivities. For example, both a seat pitch greater than the typical European standard and a passenger number growth higher than presumed will increase the train set need. Conversely, factors such as lower passenger number growth and outsourcing of the Øresund traffic would reduce the passenger seat requirement and therefore the train set need.

The seating requirement uncertainty range will be managed by DSB via a framework agreement involving a fixed minimum order and an in-built option to make supplemental purchases. This would oblige DSB to purchase a number of train sets equal to a minimum number taking into consideration the sensitivity analyses performed, such as lower passenger number growth.

Recommendation
The starting point to be trains with a length of 80 metres, but allowing trains up to 110 metres.
Calculations show that a train length of approx. 80 metres and with 210 seats satisfies optimum cost. The calculations are based on DSB's market analysis and an analysis of the correlation between train lengths and seat numbers. Average annual expected costs have been calculated for each train size. The calculations also demonstrate that there are limited added costs for trains up to 110 metres. In order to allow train manufacturers the opportunity to use their existing product platforms it is consequently recommended to allow train lengths up to 110 metres (with additional seats per train set). A train size of up to 110 metres will also be appropriate in light of the restrictions found in Denmark in relation to varying platform lengths. On the presumption of an acquisition of trains up to 110 metres long with a calculated number of seats of 270, the train set requirement would be 165 on the basis of up- and downscaling only carried out in Aarhus.

Recommendation
Choosing between single-deck or double-deck trains to be left open to manufacturers as long as they satisfy technical and other requirements.
Cost calculations show lower costs for double-deck trains over the life cycle of the new trains in the order of approx. DKK 80 million per annum, a difference that is not considered to be a determining factor. The lower costs can primarily be ascribed to the fact that a typical double-deck train has approx. 20-25% more seats than a single-deck train of the same length. As far as the market analysis is concerned, there are more single-deck than double-deck trains represented among the proposed product platforms.

As the cost calculations are very similar, it is recommended that the single-deck versus double-deck scenario be analysed further and that manufacturers are allowed to select the optimum solution based on the overall tender framework.

Recommendation
At this point in time, there is insufficient evidence for arriving at a final selection of train sets or train set style locomotives and coaches.[4] The recommendation therefore is to examine this element further during Phase 2 via a dialogue between the manufacturers and Banedanmark.
The information basis for calculations regarding train sets versus locomotives and coaches has significant uncertainty, one of the reasons being that the solutions proposed by manufacturers in the RFI information[5] are primarily based on train sets. The market analysis consequently indicates stronger competitiveness with train sets than with locomotives and coaches, just as the number of price points linked to locomotives and coaches is limited. Given the limited data material, the cost difference between locomotives and coaches and train sets is marginal, and the calculations suggest that locomotives and coaches could be the cheapest option. This is also the case when including coupling costs. At the same time, locomotives and coaches, like train sets, can perform operational coupling, although this is typically done manually and so must be performed by staff.

Finally, there are infrastructure conditions that Banedanmark is working to clarify. Locomotives and coaches have higher axle loads and today's main routes have significantly different permitted speeds relative to operation with train sets. The conclusions are expected to be ready during Phase 2 and DSB will refer to the analysis conclusions when selecting trains.

On this background, DSB recommends that conditions are investigated further via a dialogue with manufacturers and Banedanmark.

Recommendation
DSB formulates requirements which can be satisfied to the highest possible degree with the use of existing product platforms.
To reduce train acquisition risks as far as possible, the recommendation is to purchase a train based on an established product platform.

The product platforms offered by the market offer varying degrees of scalability as a result of differing concepts and construction principles. The market investigation shows that by formulating requirements that can be satisfied to the highest possible degree with established product platforms, manufacturers will be able to utilise these. This minimises risks for DSB and at the same time keeps the market as open as possible.

The market analysis also shows that a clear process for approval by the authorities of the new trains is a determining factor for avoiding train delivery delays and thereby a delayed phasing-in of the new trains. Additionally, both manufacturers and operators point out that design changes are a primary reason for delayed train deliveries. Train acquisition on the basis of an established product platform, a clearly defined approval by the authorities process, and a minimum of design changes are therefore important preconditions for minimising risks in the form of delivery and commissioning delays.

[4] A train set is defined as a self-propelling unit consisting of a number of cars with fixed coupling. Locomotive and coaches consists of a locomotive and a number of coaches with no propulsion capacity (push-pull).

[5] Formal market investigation (Request For Information).

2.2 RECOMMENDATIONS FOR PURCHASING STRATEGY

The new trains will be phased in with three train sets per month from 2024 to 2029, train requirements to focus on output-based requirements, and the manufacturer will potentially be responsible for maintaining the new fleet.
On the basis of the train type selection and calculation of the rolling stock requirements, a plan for the years 2016-2030 has been prepared, clarifying the optimum timing for phasing-in and phasing-out of the new and existing rolling stock respectively. The basis for the plan is the need for 43,000 new seats using train sets of 80 metres with 210 seats each, equal to 204 new train sets.

Recommendation
New rolling stock to be phased in continuously with three train sets per month from 2024 to 2029.
On the basis of the rolling stock plan, the continuous phasing-in of three train sets per month will see DSB phasing in 36 train sets per annum from 2024-2028 and 24 train sets in total in 2029. Phasing out IC3 and IR4 has been adapted to this phasing-in rate. Prior to phasing in the first train sets in 2024, a one-year period is presumed for testing and preparing of new trains and staff training, among other things.

Most manufacturers responding to the market investigation also recommend a delivery rate of 2-3 train sets per month. This is similar to the acquisition rate for new trains by many other train operators. Previous DSB acquisitions (Øresund trains, S-trains) have also followed this rate.

A steady phasing-in is recommended, both as a way to support steady delivery flow from the manufacturer and a steady phasing-in flow for DSB. This ensures better capacity utilisation with the manufacturer and DSB alike, such as in relation to preparing staff training and commissioning.

The final phasing-in rate will be determined at the time of entering into a contract in the second half of 2019 as a result of dialogue with the manufacturer and based on a total economy perspective and will therefore also be able to mitigate any additional electrification delays. In case of delayed electrification, additional electric trains can only be utilised through a change in traffic systems. If, for example, the IC system between Copenhagen and Aalborg is split up in Fredericia, new electric trains can be used on the electrified route between Copenhagen and Fredericia, isolating diesel stock to the region north of Fredericia. This would, however, involve customers having to change trains on routes that currently offer a direct connection.

Recommendation
DSB to manage the seating requirement uncertainties via a framework agreement including a fixed minimum order for a number of train sets and with an in-built option to purchase additional train sets.
As mentioned above, the 2030 seating requirement need is uncertain since it hinges on a range of presumptions, such as seat pitch, passenger growth, and the potential outsourcing of the Øresund traffic.

The uncertainty range, translated to a train set requirement of 110-245, will be managed by DSB via a framework agreement with a fixed minimum order and an in-built option for additional purchases. This would oblige DSB to a purchase of a minimum number of train sets, taking into consideration the sensitivity analyses performed, such as without background growth in the passenger prognosis. When determining the minimum order, DSB will ensure that the order size is reflected in the price. The market analysis indicates that the minimum order, allowing for uncertainties in the presumptions for rolling stock acquisition, can be leveraged to attain attractive prices.

A minimum order contract supplemented by a framework agreement with the option to supplement the order would thus enable DSB to acquire additional train sets as required once individual uncertainties are removed. This would ensure that there are no more trains acquired than necessary and would help mitigate uncertainties such as in relation to expected passenger number growth. DSB will not be required to determine the minimum order size until final manufacturer bidding in Phase 3, in the middle of 2019.

The preparation of the plan presumes the retaining of a reserve of diesel and electric rolling stock throughout the phasing-in period to be able to handle the risk of, for example, train delivery delays or delays with the railway network electrification.

Recommendation
DSB to use output-based requirements and to only specify technical requirements where necessary.
One of the fundamental principles behind the acquisition of new electric trains is that DSB wishes to acquire a product, not a project. This is intended to secure the lowest possible risks and the lowest possible life cycle costs. The market analysis shows that a significant reason for delay related to train acquisition is attributable to operators' demands for adjustment of product platforms. At the same time, a clear process for approval by the authorities of the new trains is of crucial importance to the avoidance of train delivery delays. In consequence, DSB will make only a few, necessary, technical demands and in addition make use of output-based requirements describing what the train must be able to deliver rather than how to achieve this. In this way, DSB will ensure that the new electric trains, among other things, satisfy the current infrastructure compatibility rules and current regulations that need to be satisfied for the new electric trains to be able to operate in Denmark.

The requirement process is broadly anchored throughout DSB, assured via the placing of a ambiguously requirement ownership in combination with the involvement of requirement owners and the organisation's involvement in the process. Infrastructure requirements are anchored with Banedanmark and the demands have been the subject of ongoing discussions between Banedanmark and the Danish Transport, Construction and Housing Authority.

Only a few of the set requirements require specific decisions. The following requirement areas are involved:

- *There are no specific requirements regarding optimisation of speed, acceleration, and passenger transfer, and it is left to manufacturers to adjust these to satisfy the operational patterns described by DSB as part of their existing product platforms.*
  From a customer perspective, it is important to arrive at a given timetable with a high degree of reliability. For this reason, DSB will let the manufacturer adjust, among other things, speed, acceleration, and passenger transfer in order to satisfy the time table performance described by DSB.

- *There is no requirement that the full car body and profile is to be utilised, but the manufacturer may elect to offer this.*
  The Danish infrastructure allows for a larger dimension and a wider car body profile than does the European norm. The European norm equates up to 300 mm less internal width than in existing trains, e.g. IC3/IC4. The car body and its profile and dimensions form a basic element in manufacturers' established product platforms and changes are assessed to be related to significant costs and risks. DSB has a commercial interest in maximising internal space in the train, but the Danish infrastructure is not wide enough to allow for 2+3 seats across, meaning that from a capacity point of view there are not sufficient benefits to be realised by increased width. DSB therefore recommends not requiring that the additional width allowed by infrastructure is utilised, but to leave it to the manufacturer to optimise this element. This also reduces the risks associated with rolling stock acquisition.

- *There is a requirement of non-split level entry from the platform at 550 mm and a requirement for steps on the train.*
  Level free entry from a platform is in accordance with European norms. Currently, 57% of the Danish platforms on stations that currently are electrified or will be electrified are at this level. There are 13 stations with more than 1,000 daily passengers that do not have platforms with a 550 mm level. DSB recommends that this is solved by requiring steps on the train in accordance with market standards in combination with support equipment at certain affected stations. This corresponds to current situation with DSB's existing fleet.

- *The basis for seat pitch will be the typical European norm.*
  Most Danish trains currently have greater seat pitch than in international trains. DSB

recommends a seat pitch starting point for the new electric trains based on the level found in existing double-deck coaches of a typical European norm. This will give increased seating capacity, leading to an annual financial benefit of approx. DKK 140 million and reducing the train set need by approx. 20. The reason for this is that fewer train kilometres will be required if the new electric trains have seat pitch similar to typical European norms. New seat types will enable a simultaneous reduction of seat pitch and maintaining the passenger experience since new seat types typically have narrower backrests than, e.g., IC3 seats.

→ *Decision regarding layout to be made in Phase 2.*
Product platforms offer a high degree of flexibility in relation to interior layout requirements. DSB has had dialogues with relevant interested parties, including organisations of the disabled (Danske Handicap Organisationer) and Danish Cyclists' Federation, regarding the need for a flexible and accessible layout. On the background of the market analysis, it is DSB's assessment that there are no areas of special concern with relation to access for the disabled other than the challenge represented by platforms not at 550 mm level as described above. The new trains will have low floor access and approx. 15% of the train area will be reserved for flexible areas. The size of flexible areas will not affect the number of seats on the train. The reason is that flexible areas will have flip-down seats roughly corresponding with the number of seats that would have been installed in the absence of flexible areas. This is similar to the current situation in IC3 trains. DSB expects that the layout will be sufficiently flexible that seats could potentially be removed, such as during summer, to allow room for more bicycles, just as the flexible area could be reduced where required. In Phase 2, DSB will decide on layout, to include flexible areas, following more detailed market dialogue.

→ *Any pressure protection requirements and other requirements linked to comfort will be determined during Phase 2.*
Pressure protection is normally not an element in the current market product platforms up to 200 km/h. In the Danish infrastructure it is primarily at the Great Belt that a certain degree of pressure protection could be required in order to satisfy the passenger comfort needs at 200 km/h. Pressure protection requirements could result in an additional investment of 10% of the overall purchase sum. An alternative to this would be reduced speeds at certain exposed line sections. Any pressure protection requirements will be fully clarified during Phase 2 of the rolling stock acquisition, just as requirements regarding noise, vibrations, and other comfort related elements will be clarified during Phase 2.

Recommendation
DSB assesses that outsourcing of all maintenance of the new trains will be advantageous in relation to achieving high operational stability and low maintenance costs.
International experience and maintenance cost calculations show that outsourcing both heavy and light maintenance of the new fleet will be advantageous in terms of reliability and economy. The reason is that splitting up light and heavy maintenance, as it is known, for example, in aviation, will result in increased complexity, increased costs, and reduced optimisation potential. The maintenance contract that will be given the train manufacturer in connection with the train acquisition should have a duration of at least 7-8 years, as this corresponds to a complete maintenance cycle for the fleet. DSB should continue to own the workshops and associated facilities, as workshops have a considerably longer life cycle than an outsourcing contract does.

The choice of maintenance solution affects the attainment of targets for phasing-in on time and high operational stability. The maintenance solution also affects the drive to secure the lowest possible costs since maintenance forms a significant part of the total life cycle cost of the train.

Generally speaking, DSB assesses that outsourcing is advantageous, particularly in relation to achieving operational stability quickly and the opportunity for low maintenance costs. Market maturity, however, is still developing, particularly with reference to the maintenance of larger fleets in complex networks such as the Danish one. Whatever the maintenance solution selected, maintenance work will be handled in a completely new framework, one of the reasons being that DSB recommends the establishment of new, dedicated facilities with the best possible set-up for

the new fleet. For this reason, DSB will revisit the market analysis and the technical dialogue with manufacturers during Phase 2 with a view to outsourcing maintenance of the new electric trains. At the same time, DSB will analyse the feasibility of in-house maintenance and clarify the conditions for a successful change and efficiency improvement internally in DSB on the basis of maintenance in new and more efficient surroundings.

Recommendation
One single invitation to tender under the "procurement by negotiated procedure".
The recommended train type selection, involving the acquisition of a fleet consisting of long distance trains or alternatively a combination of long distance and regional trains on the basis of a single established product platform has the effect that the process can be handled as one overall invitation to tender. The recommendation to do an invitation to tender under the "*procurement by negotiated procedure*" allows DSB the option to negotiate with the train manufacturers who put in offers. This optimises the manufacturers' offers and the tendering material throughout the negotiations, potentially leading to savings and/or better offers, just as it may contribute to reducing risks.

Evaluating offers will be based on a range of main criteria such as economy, technical solution and operational stability, passenger experience, and delivery and risks. These will be weighted to reflect the programme targets. Additionally, DSB will weight offers only including long distance trains higher than offers including a combination of regional and long distance trains. This is intended to allow for the increased complexity costs associated with a combination of long distance and regional trains.

DSB must be protected by robust contractual measures in relation to particular circumstances, e.g. delays caused by the train manufacturer or material defects with the rolling stock supplied. At the same time, DSB will seek to avoid encumbering train manufacturers with risks that could lead to increased risk premiums and thereby higher costs. This will be done, for example, with strict requirements management, ensuring that only absolutely necessary requirements are stipulated and that these will be maintained by the requirement owners throughout the acquisition period.

2.3 RECOMMENDATIONS FOR THE NEXT STEPS

Overall management of the train acquisition and derived projects must ensure that commissioning of the new trains and the re-alignment of DSB is carried out to schedule and with the minimum amount of risk.
Train acquisition is a complex and demanding task. This necessitates significant re-alignment within DSB to be able to receive, commission, and manage the maintenance of the new trains. At the same time, the new trains will enable significant structural improvements for DSB.

Recommendation
Start-up of 22 derived projects in the main areas infrastructure, facilities, processes, and organisation and IT.
Derived projects are expected to require a separate investment of DKK 2.6-4.2 billion. Early planning of the overall re-alignment will allow DSB to mobilise the company in time and enables commissioning of the new electric trains without risk to daily operations.

Infrastructure and facilities are the most investment intensive area of the derived projects, accounting for an expected investment of DKK 2.2-3.6 billion. Of this, workshops are expected to represent the greater share with expected construction costs including any land purchase of around DKK 2.0-3.3 billion. The expected construction costs are based on an estimate for new-build based on market information from similar construction projects in Europe and so have not been based on actual construction project designs. The range covers uncertainties relating to expected track capacity. The need for platform extensions and track connections to new workshops is not included in the investment.

To ensure sufficient and well-placed capacity for the handling of maintenance, preparation, and stabling of the new trains, it will be necessary to both build new and adapt existing workshops,

preparation facilities, and stabling facilities. This also includes establishing efficient access conditions for the areas used.

DSB has reviewed the existing workshops to determine whether and how they could be applied for the new fleet. Their state of maintenance and/or physical conditions makes it difficult to modify them and they are adapted to service the current fleet. In addition, when evaluating and locating new workshops for the new electric trains, DSB has, among other things, considered construction costs, operational costs, and empty driving costs.

Finally, the following principles have been used in the recommendations for workshops:

- The new electric trains must have dedicated facilities - either in the shape of existing workshops that are renovated or new workshops. Workshops dedicated to the new trains allow for optimum location selection relative to daily operations and it would be possible to locate workshops so as to reduce empty driving as far as possible. At the same time, it would be possible to lay out such workshops optimally for the new trains. Finally, dedicated workshops would mean that maintenance work on DSB's existing fleet could be carried out with a minimum of disturbance.
- At least two workshops must be dedicated to the new electric trains. If these are located in the east and west, this will ensure flexible maintenance planning across regions in order that ongoing adjustments to operational and traffic conditions, non-scheduled repairs etc. can be carried out with ease and efficiency. There would also be economies of scale as maintenance would be carried out in a small number of workshops.
- As far as the existing fleet is concerned, DSB does not wish to build new workshops, but will instead transfer the existing fleet to other, existing workshops as far as it becomes necessary.

The final locations awaits the final dialogue between DSB and the involved parties and may result in the acquisition of land as well as track capacity optimisation to and from some of the areas. DSB expects to finally determine the locations of new workshops during Phase 2, at which time it will also be decided whether the existing workshops are to be used for the new fleet.

Train acquisition also demands a substantial re-alignment of DSB's organisation and staff competencies. Seven areas have been identified in which training and skill development have to be carried out. The seven areas cover such items as education and training of locomotive and train drivers, other technical personnel, preparation personnel, and administration staff. The assessment is that 35,000 training days will be required for between 1,700 and 2,700 employees. This estimate will become more precise during the latter stages of the train acquisition process.

Finally, DSB must ensure that the new fleet is supplied with an advanced IT platform that will simultaneously satisfy future passenger needs and give DSB the flexibility required for continual renewal of the IT systems.

Recommendation
The next steps to be organised under a single overriding programme to cover both train acquisition and derived projects.
The Train of the Future consists of two acquisition projects regarding electric locomotives and new electric trains and a range of derived projects. A programme of this size and complexity, both in terms of time, economy, and risks, requires coordinated and robust programme management. Organisation and control will be based on best practice in programme management and experiences from recent international train acquisitions and other large, Danish infrastructure programmes.

The programme will be managed according to MSP® principles, a recognised method for the management of complex, public programmes. In addition, the V-model (Euronorm EN 50126) will be applied to the management of requirements and the collaboration between DSB and the manufacturer, ensuring a clear and unambiguous separation of responsibilities and enabling strict requirements management. The derived projects will be based on a distributed responsibility approach, meaning that the responsibility for execution rests with the line organisation. The

programme is intended to ensure the overall cohesion between the derived projects, follow up on progress, and approve project deliveries.

The total programme costs are expected to be approx. DKK 0.5-0.6 billion, covering internal and external costs throughout the programme duration, to include, among other things, special skills related to rolling stock, tendering and procurements.

Recommendation
The work related to preparing and executing the train acquisition is separated into five phases, cf. figure 2.1.
According to the schedule, tender material is submitted at the beginning of 2018 and contracts are expected to be entered into in the middle of 2019. The first trains are planned for delivery in 2023 and entered into commercial operations in 2024. All new trains will be fully phased in by 2029.

The programme plan includes three central, political decision portals. They cover the following:

- Middle of 2017: Political decision to commence Phase 2 on the background of the recommendations in this decision paper.
- End of 2017: Political approval of key decisions and principles of final tender material.
- Middle of 2019: Political approval of most advantageous offer and awarding of contract.

The recommended schedule is based on a full phasing-in by 2029 and has been prepared on the basis of dialogue with manufacturers. This takes into consideration the time duration for train acquisition, including among other things sufficient time for the tendering phase and entering into contract, homologation and commissioning of trains and execution of derived projects.

Overriding phase schedule for train acquisition

Figure 2.1

In accordance with the commission and the programme schedule, a number of decisions are made during later phases. Table 2.1 shows the key decisions to be made in Phase 2.

Most important decisions during Phase 2

Table 2.1

The table shows the key decisions to be made during Phase 2.

Decision	Made during Phase 2	Revisited during Phase 2	Remark
Train construction	✓		Train sets or locomotives and carriages, and axle load, and permissible speeds on selected lines.
Comfort-related requirements	✓		Layout, such as flexible areas and indoor climate.
Maintenance strategy		✓	
Location of workshops and related projects, e.g. access conditions	✓		
Investment and benefits		✓	

2.4 RISKS AND TOTAL INVESTMENT

The total investment, shown in table 2.2, has been calculated for the recommended train type selection and an acquisition plan for 204 train sets. Investments required for train acquisition have been calculated on the basis of the market analysis price estimates: Maintenance costs will form part of the contract with the train manufacturer, but have been excluded from the calculations as these costs can be predominantly ascribed as operations costs. In order to not compromise competition and price formation for the coming invitations to tender, presumptions and calculations regarding prices will not be explicitly dealt with in this document. Train acquisition costs are expected to amount to DKK 14.0-17.0 billion. The cost interval represents different price estimates for 204 train sets each with 210 seats and is based on cost estimates for new rolling stock collected during dialogue with manufacturers.

The stated estimates do not include the electric locomotives whose acquisition was decided in 2016. The estimates represent DSB's best estimates regarding the investment size and is subject to uncertainties. The estimate is based on up- and downscaling only taking place in Aarhus.

Derived projects are expected to require a separate investment of DKK 2.6-4.2 billion as also described above. This covers 22 derived projects within the main areas of infrastructure and facilities, processes and organisation and IT, of which infrastructure and facilities represent the greater investment areas of the derived projects. Platform extension requirements in Aarhus and Horsens and track connections to new workshops have not been included in the investment. Banedanmark estimates that the investment for platform extensions in Aarhus and Horsens will amount to up to DKK 400 million. Banedanmark informs that extended analyses would be required to be able to provide a useful estimate for the investment linked to track connections, which is why this is not included.

The calculated programme costs of DKK 0.5-0.6 billion covers internal and external costs for the entire programme duration, including specialised skills related to rolling stock, tendering and acquisitions.

Total investment

Table 2.2

The table shows the total investment and a preliminary estimate for external investments (2016 prices incl. VAT).

	DKK billion
Purchase of trains	14.0-17.0
Derived projects	2.6-4.2
Programme costs	0.5-0.6
Total	**17.1-21.8**
Preliminary estimate for external investments in platform extensions in Aarhus and Horsens	Up to 0.4

DSB is not covered by the budget principles related to new capital budgetting. This is thus also not the case for the Future Train programme, nor the rolling stock acquisition of new electric trains. The calculated value of the total programme risk is approx. DKK 3.7 billion across the phases. The risk value has not been included in the overall investment in table 2.2. Over the coming phases, DSB will re-visit the overall investment as well as the calculated risk value, just as DSB will seek to reduce the risk value via a range of risk mitigating actions as described below. The various risks are determined on an ongoing basis and prior to entering into contract with the selected manufacturer by the middle of 2019 several risks will have been handled.

In addition to the estimate for the overall investment, there will be expected annual operation savings of more than DKK 0.6 billion from energy and maintenance and reduced fleet complexity. The latter is expected to contribute approx. DKK 0.1 billion. The calculation operations savings are

based on the recommended train type and presumptions regarding energy and maintenance savings are based on estimates following from the market investigation carried out.

In addition to the benefits calculated above relating to energy and maintenance, other benefits linked with new electric trains are expected for which quantifying has not been attempted. Such benefits include customer orientated benefits related to new rolling stock and environmental benefits, including significantly lower noise and smell nuisance elements than those associated with the current diesel trains.

With the given presumptions, DSB expects to be able to finance the investment of the Future Train without separate state financing. The current contract payment forms the starting point.

Analysis of cost risks shows, as mentioned above, that the overall calculated risk value amounts to approx. DKK 3.7 billion. The ten largest risks amount to approx. DKK 2.0 billion, cf. table 2.3. This amounts to approx. 20% of the overall investment.

The ten largest programme risks **Table 2.3**

Risk	Strategic risk	Probability	Effect	Risk value* (DKK billion)
Delay to Banedanmark's Electrification Programme or Signal Programme (ID 131)	Delayed phasing-in	26-50%	High	0.40
Significant requirements changes after the award and contract signing (ID 36)	Cost increases	10-25%	Medium	0.35
Train manufacturer underestimates size and complexity of maintenance task (ID 202)	Lack of operational stability	10-25%	Medium	0.23
DSB's line organisation is not ready to receive the new trains (ID 1)	Delayed phasing-in	10-25%	High	0.20
Poorly functioning operational interface with manufacturer regarding maintenance (ID 139)	Lack of operational stability	5-10%	High	0.20
Costs of derived projects estimated too low (ID 12)	Cost increases	10-25%	Low	0.18
Concrete offers containing prices that deviate from the estimates used for train type selection (ID196)	Cost increases	2-5%	High	0.14
Passengers not satisfied with the new trains (ID 60)	Customer needs not satisfied	5-10%	High	0.11
Homologation and approvals take longer than scheduled (ID 14)	Delayed phasing-in	10-25%	Medium	0.10
Train manufacturer does not supply the agreed quality (ID 45)	Lack of operational stability	5-10%	Medium	0.10
Total				**2.01**

* A mean value is used within the interval of probability of a given risk to be realised. Risk value is stated in 2016 prices incl. VAT.

Risk management for the programme is based on the programme's four strategic risks:

- → Delayed phasing-in
- → Lack of operational stability
- → Cost increases
- → Customer needs not satisfied.

To reduce acquisition risk it is essential to:

- → Maintain a close dialogue with manufacturers before and during the tender process to ensure compatibility with the established product platforms on the market.

- Maintain that changes to manufacturers' established product platforms must be as few as possible and ensure that any changes are specifically assessed for advantages, costs, and risks.
- Facilitate the homologation process by ensuring close dialogue between the manufacturer and the Danish Transport, Construction and Housing Authority and base the purchase on the manufacturer being responsible for acquiring necessary approvals.
- Maintain an ongoing and close dialogue with Banedanmark during the process of the Signalling Programme and the Electrification Programme. Any delays in these two programmes represent the greatest individual risk and could lead to a need to adjust the time of commissioning. The timing of this is not to be determined, in dialogue with the manufacturer, until the middle of 2019, at which time there will be better knowledge about both programmes than is currently the case. In case of infrastructure delays, retaining the current fleet ensures a risk buffer, and traffic expansion and the increased rolling stock need in 2025 could then be delayed.
- Establish a contract regime with strong financial incentives for the manufacturer to ensure that the new electric rolling stock quickly reaches a high degree of operational stability, regardless of whether maintenance of the new fleet is outsourced or is retained in-house. Among other things, a significant part of the payment will be tied to train performance.
- As a contracting entity to focus on the avoidance of substantial changes initiated by the contracting entity after the tendering process has been started.
- Use the negotiations process to clarify the maintenance task and the interface between manufacturer and DSB in this connection.
- Ensure timely involvement of passenger interest organisations and other interested parties.
- Establish a well-functioning programme organisation with sufficient and specialised resources to ensure continuity and with a clear mandate to be able to ensure timely execution of derived projects.