The PRT Project
Phase 1 Design & Engineering

Test Track

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Company:	Pantarei AS
Author:	Nils Jacob Berland
Approved by:	Jan Magnussen
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1. Summary

A test track is necessary for the PRT JV of two reasons:

- Demonstration - e.g. tolerance to ice and snow, user acceptance, government and regulating bodies
- Technical - e.g. validating switch design, LIM propulsion and control system

The test track must be in operation at Fornebu by January 2004 in order to prove winter capabilities for the decision-makers. It is assumed that the test track will be in operation until the first real JV PRT system is in operation.

The proposed test track will consist of about 600 meters of track, one station and two switches. A total of 5 vehicles will operate on the tracks – all with complete bogies but only one with a complete cabin and four with simplified cabins.

The estimated cost for establishing the test track will be ~ 49 million NOK.

These are the recommendations regarding the test track:

- Immediately build a test jig in order to test wheel materials, wheels and brakes
- Build a fully operational test track in order to convince potential clients that PRT is proven and safe technology.
- Timing is crucial if a PRT system should be considered for Fornebu. A test track – located at Fornebu – should be operational by January 2004.
- The necessary and sufficient scale of the test track is one station, two switches related to the station, about 600 meters of tracks and 5 vehicles. 5 vehicles are needed for testing merging situations.
- The test track must be available to decision makers worldwide for demonstration purposes until a full-scale system becomes operational. To facilitate this, a program for visitors must be developed.

1. Introduction

The PRT JV has as a goal to develop and deploy PRT systems worldwide. An integral part of the development of a PRT system is to build a full scale test track. The present document is the result of work carried out in Phase One of the "Design and Engineering" project.

The purpose of this document is to present the recommendations related to the test track and an overview of the suggested solutions as well as the cost estimates for the development and construction of the test track. The focus of this document is what should be done in Phase Two of the project.

A test track is necessary for the PRT JV of two reasons:

- Demonstration - e.g. tolerance to ice and snow, user acceptance, government and regulating bodies
- Technical - e.g. validating switch design, LIM propulsion and control system

The project group believes that the test track configuration described in this document is a minimal configuration needed for achieving the stated goals. However, it may be desired to add more features to the test track for demonstration purposes but not necessary from a technical standpoint.

The test track will be an integral part of the total efforts to develop a working system. This document assumes that the test track will be but a part of the present overall plans for the PRT JV and the time schedules are according to this. However – we emphasise that the test track should never become a part of an operational PRT system at Fornebu. We assume that the test track will be operational until the Fornebu PRT system, or any other PRT system built by the JV, becomes operational. In practice this implies that the test track will be operational for several years. During this period the test track should also be available as a demonstration site for potential customers and decision makers worldwide.

Results from the test track may result in changes in the design of the PRT system planned to be deployed at Fornebu and other places. It is however expected that the most probable changes are related to the control of the vehicles and propulsion systems. The tracks and bogies are not assumed to change much from test track version to production system.

The test track will attract quite a lot of attention and the PRT JV must have a plan for how to address this attention. Specifically, visitors must be handled professionally and be given relevant information.

The cost estimates for the test track is given at the end of this document as well as a separate detailed cost calculation for the entire Phase Two. The detailed cost calculations are based on the same model used for calculating the Fornebu SPC track.

Related documents:

DocID 1-AB-1-11-1.0	PRT Continued – Next Phases
DocID 1-ABC-3-4-1.0	Overall System Design
DocID 1-BCD-13-6-1.0	Mechanical Design
DocID 1-BCD-5-13-1.0	LIMs in PRT
DocID 1-BCD-3-7-1.0	Information, Communication and Control Systems (ICCS)
DocID 1-CDE-9-5-2.2	Control Strategy
Dated 24.04.03	Quotation from WGH – tracks, guideways, vehicles, LIMs
Dated 25.04.03	Quotation from Noventus – Supervisory Control System
Dated 24.04.03	Quotation from Kitron – middleware – sensors - communication

2. Purpose and scope of test track

There are two scopes for the test track – one external and one internal.

The external scope is evaluation by potential customers. The test track must appear real in order to convince potential customers that PRT is "proven and safe technology in new wrapping". We expect several of our potential clients to be risk adverse. The customer demonstration requires that the site is accessible and that it is easy to get an overview of the system, its functionality and appearance. In due time there will also be developed a program for handling visitors.

The internal scope for the test track is a technical validation. We expect the hardware for the test track to be very close to the hardware that will be used in the commercial versions of PRT. The software and operating parameters will need tuning and testing.

2.1. Customer demonstration

The main issues related to customer demonstration are:

- **Security.** Ability of the system to keep the distance between vehicles, braking ability and dependable switches.
- **Ride perception**. Jerk, speed, "perceived scare factor". The vehicles on the test track will be available for "test pilots" and potential customers who assume the risk of travelling on a system that is not yet approved by the Railroad Authorities.
- **Government requirements.** The system should be made available for authorities to evaluate related current regulations.
- **Aesthetics and environmental impact.** At least one vehicle should be as close to the expected end-product as possible. In addition the elevated rails must be demonstrated both for visual impact and noise.

2.2. Technical validation

The main issues related to technical validation are:

- **Snow and ice.** It is imperative to test all aspects of snow and ice for the system and measures for keeping the tracks and vehicles free from ice.
- **Test switch design.** The switches need testing related to functionality, sideways jerk and wear.
- **Max retardation.** Determining the maximum advisable retardation for the vehicles will have significant impacts on the headway and control system.
- **LIM dimensioning.** The LIMs must be optimised in a final system to reduce the total system cost. Hence a necessary and sufficient power level for each LIM must be determined.
- **Doors.** Different modes of operation. Test cycles with thousands of open-close operations.
- **Wheel wear.** The test vehicles should run more or less continuously for months. Wheel wear will also be tested in a separate test rig with WGH Ltd.
- **Ride perception.** Ride perception is really about deciding on a parameter envelope for speed, jerk, acceleration/retardation, etc. In addition several hardware-related parameters such as camber and inclination must be evaluated.

2.3. Test program

The test track is closely related to the development of a working PRT system. The test program will have at least the following elements:

- Low level control system features
- Mid-level and High Level Control system features
- Vehicle scheduling in and out of station
- Tests for dimensioning the LIM sizes
- Fatigue / wheel tests
- Passenger loading/unloading

2.4. Expected results

Results from the test track may involve changes in the design for the PRT system planned to be deployed at Fornebu and other places. It is however expected that the most probable changes are related to the control of the vehicles and propulsion systems. It is at present believed that there will be few and minor changes to the track and bogie design.

The results we expect are primarily as follows:

- Feedback from customers on the system as such, e.g. visual impact, appearance, functionality and ride perception.
- Feedback from regulators on the safety and functionality of the system.
- LIM dimensioning
- Results related to the operating parameter envelope.
- Design of the control system

2.5. Consequences of results

It is however very probable that the experience obtained from the test track will result in the following changes of the systems to be deployed:

- Changes in design of stations. Stations are crucial for the flow of vehicles.
- Structural changes in track configuration. Flow of vehicles.
- Changes in the control system.
- Changes in the operational parameters such as speed, headway, retardation, acceleration, etc.

3. Location

The test track should preferably be located at Fornebu. It should however not be attempted to be integrated with the system that may be deployed there later.

The requirements for the area of the test track are as follows:

- Easy access for visitors and test personnel
- Easy to erect and maintain fences around the tracks
- Easy to install concrete foundations and one station area
- Sufficient size for the proposed track and station configuration
- Road access
- Permission to run vehicles day and night for several years

4. Project management for test track

Refer to the document DocID 1-AB-1-11-1.0 PRT Continued – Next Phases.

5. Process and schedule

The design and construction of the test track will consist of the following steps:

- Detailed design
- Test Jig
- Component manufacturing and construction
- Operation

The schedule for this should be:

What	When
• Decision to commence detailed design	May 1^{st} 2003
• Detailed Test Track Design	May 1^{st} - June 30^{th} 2003
• Decision to start construction	June 1^{st} 2003
• Detailed Generic Design	July 1^{st} - December 31^{st} 2003
• Construction and manufacturing in UK	July 1^{st} - September 30^{th} 2003
• Shipment to site	October 1^{st} 2003
• Test track ready for first trial runs	December 1^{st} 2003
• Test Track in operation	January 1. 2004

By "in operation" it is to be understood that the guideway and switches are working and bogies are able to run. Basic software for operating and testing the bogies should also be operational.

6. Test Track Specifications

A more detailed hardware description for the test track is given in the engineering documentation of this project.

The test track will have a given physical configuration. This physical configuration will probably not be changed during the operation of the test track. The software is expected to change several times during the operation of the test track.

The test track will have the following logical sub-systems:

- **Facility:** Facility preparation, infrastructure, fences, buildings and concrete foundations
- **Hardware:** Hardware including guideways, LIMs, inverters, LIM controllers, vehicles, stations and low-level control system.
- **Mid-level control:** System integration, sensors, automatic vehicle braking system, zone control subsystems, cabling, abstractions and interfacing to the high-level software.
- **High-level control:** System operation control system

6.1. Communication and control system

The communication and control system is one of the more difficult issues of the test track and probably embody the biggest uncertainties. The control system will consist of several parts:

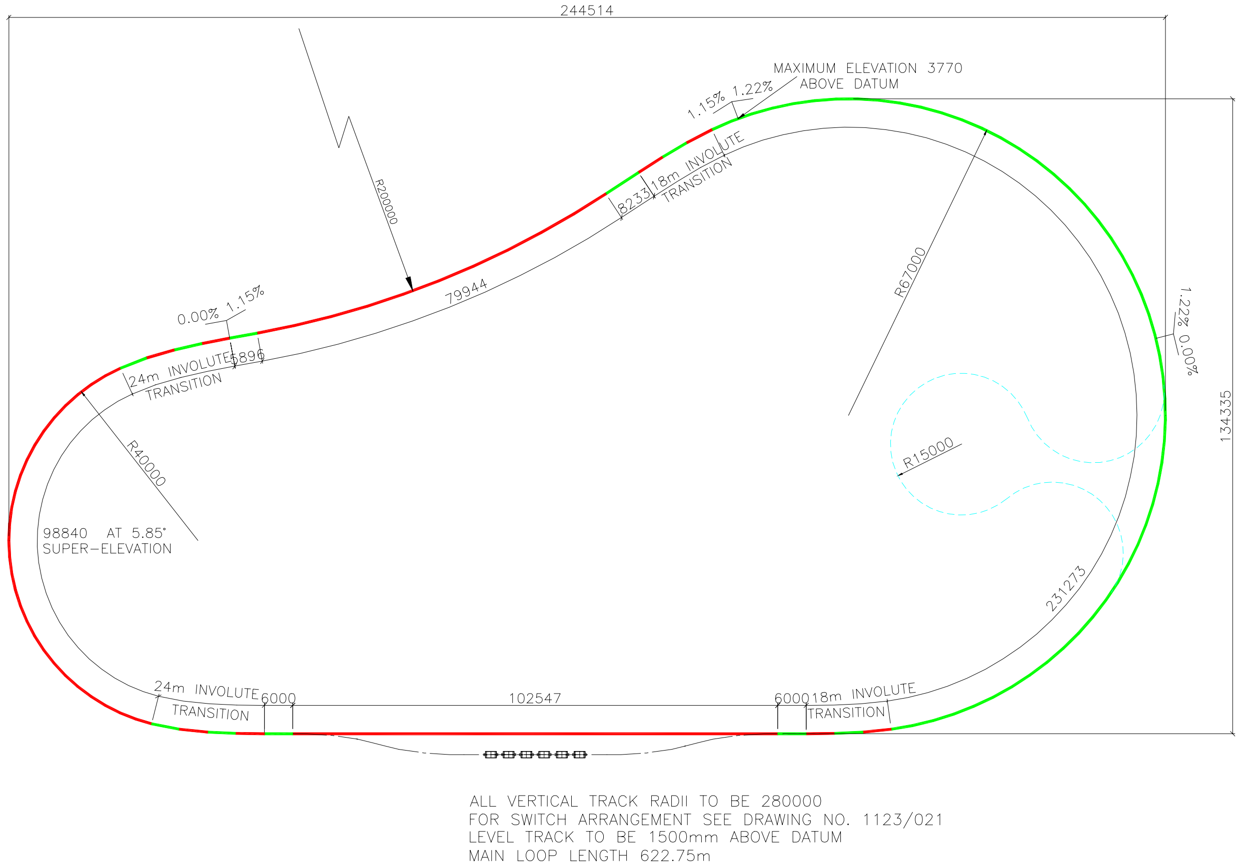
- Low level control of sensors, LIMs and vehicles
- Zone/station controllers
- Communication system
- Mid-level software acting as the glue and abstraction between the low-level and high level central controller software.
- High level central controller

So far we have a fixed price quotation for the high level control system from Noventus AB in Sweden. Their quotation comprises the following:

- Control of 4-5 vehicles on a 600 meters long track.
- Communication with 200 LIM controllers.
- PRT Control Software controls the vehicles by the by assigning force (which results in a certain speed) to the LIM controllers via communicated messages.
- Communication with 200 sensor equipments (could be the LIM controllers), that reports presence and speed of passing vehicles plus identification and destination of the vehicles.
- Programming, via LIM controllers, of ID-units in the vehicle with information about destination.
- Control of merge points by calculation of time slots for vehicles that pass the merge points and regulation of vehicle speeds to make the vehicles pass crossings in the planned sequence at planned times and speed.
- Control of entry at and start from station.
- A simple system for disposition vehicles and road map control.
- Windows screens for viewing of vehicles status and location.
- Communications trace software.

During May we shall work intensively to clarify the interfaces between Noventus and WGH, find the potential "holes" and then find partners to provide what is missing.

6.2. *Track Configuration*

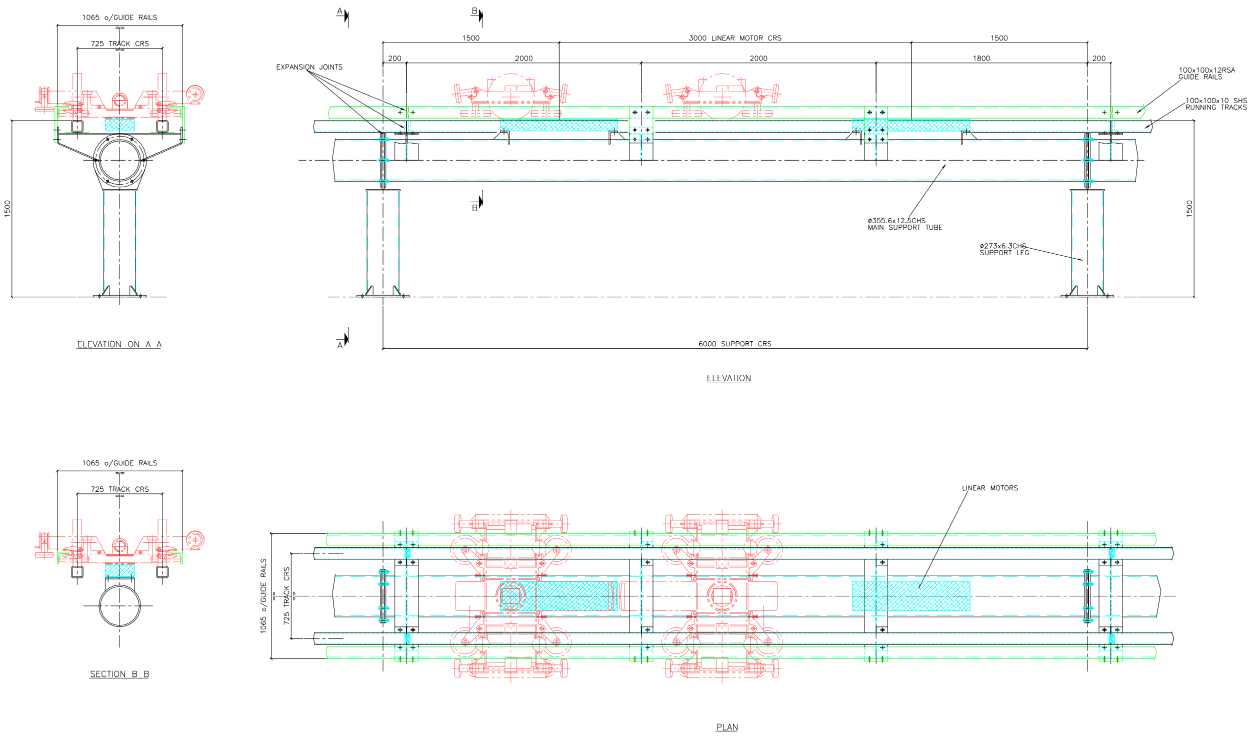


The test track will have the following attributes:

- About 600 meters tracks including/excluding station
- 200 meters elevated rail (about 2.5 meter distance up to construction).
- 400 meters ground rail (about 1 meter elevated to avoid snow accumulation)
- 1 station
- 3 turns with a radius of 40, 60 and 80 meters
- 2 switches – but only related to the station

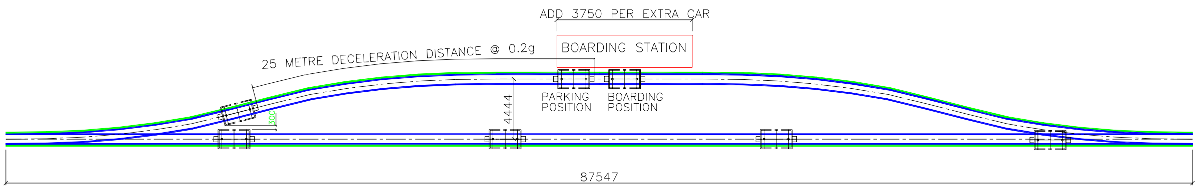
The station area will be covered by a roof and the tracks at the station will be mounted on a concrete floor. The test track configuration is as given in the figure below.

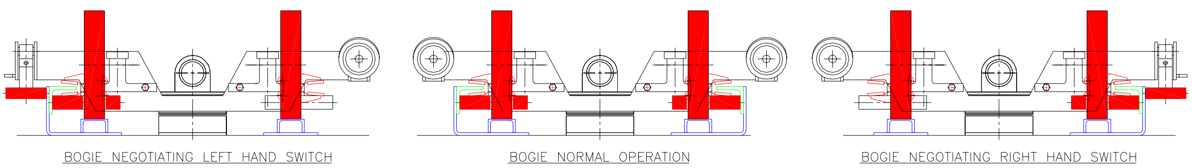
6.3. Track details



6.4. Switches

The switches for the test track should be as proposed in the Hardware documentation prepared by WGH Ltd.





6.5. *Propulsion system*

There will be LIM-drives embedded in the guideway with reaction plates for each and every vehicle. For safety and comfort reasons all vehicles will at all times be “connected” to a LIM. There will be an inverter for each and every LIM.

6.6. *Vehicles*

There should be 5 vehicles for the test track – enabling the specific test of 2 vehicles entering the main track from a station and getting “in between” 3 vehicles circling the main track.

The bogies are the primary test object in terms of technology. There should be one cabin with an exterior as close to the planned for Fornebu and 4 cabins with the physical size, but probably made with GRP exterior – looking like real vehicles. It is not decided yet who shall build the real prototype vehicle body.

6.7. *Stations*

The station should have room for 5 simultaneous vehicles. The unloading/loading area of the station will be covered or inside a building. The station will consist of a simple steel platform with handrails.

7. Cost for Test Track

The cost estimates are based on prices provided by WGH, Noventus Systems AB and Kitron Development AS. The costs given here are only related to the cost of the phase two part of the development and engineering project.

The costs are as follows:

What	Cost in NOK
Facility and offices	4 500 000
Hardware	37 700 000
Mid-level control	4 700 000
High-level control	2 400 000
SUM	49 300 000

In addition there will be a yearly cost related to the operation of the test track. A more detailed description of the cost components are given in the following.

7.1. *Cost for facility*

Facility preparation, infrastructure, fences, building for control room and concrete foundations. If possible we will use some of the old buildings at the site – specifically the aircraft

The project group has estimated this to 4.5 million NOK for Phase Two.

7.2. Prices for hardware

Hardware including guideways, LIMs, LIM controllers, vehicles, stations and low-level control system. The prices are according to price quotation from WGH Ltd dated 24.4-2003.

7.3. Costs for mid-level control

System integration, sensors, automatic vehicle braking system, zone controls subsystems, cabling, abstractions, interfacing, etc.

The mid-level software may be delivered by Kitron Development AS and the cost estimates are made by the project group and Kitron Development AS.

What	Cost in NOK
200 sensors @ NOK 2000,-	400 000
5 radio systems @ NOK 50.000,-	250 000
2 zone controllers @ NOK 50.000,-	100 000
Networking sensors	100 000
Server HW	100 000
Development	2 550 000
Installation	1 180 000
Sum	4 680 000

7.4. Costs for high-level control

The price quote from Noventus AB in Sweden is SEK 2.400.000,-. With some extra work related to interfacing their system to the test track system we estimate the cost to NOK 2.400.000,-. (SEK/NOK ~0.8)

7.5. Concluding remarks regarding Cost for Test Track

WGH Ltd. is instrumental for getting the test track up and running. They will deliver a working system with vehicles actually running – but without intelligent handling of vehicles. There are at present no alternatives for WGH Ltd.

For the mid-level control and high level control there may be alternatives to Kitron Development and Noventus AB, but the price estimates are still valid.

8. Wheel and brake test facility / jig

Phase One of the project has identified wheel life and emergency braking as major challenges associated with the bogie design. Hence the need for a separate test rig becomes apparent. The most practical site of the test jig is close to WGHs facilities in the UK as it is WGH that will need the results from the test jig immediately.

As wheels are required to travel up to 120,000 km/year in all weather conditions it is necessary to determine the wheel width to life ratio in order to establish the minimum rail width. The narrower the rail the more difficult it will be for the ice, snow or dust to form on its surface and the easier it will be to keep it clean.

The rig will be used to identify the effects that different materials and wheel constructions have on wheel life, noise generation and vibration.

The 6.4m diameter rig is designed to simulate a 20 metre track section including the expansion joint and guide rail. Located around the rim are six wheel testing stations permitting the angle and load to be adjusted and varied to simulate the expected wheel duty cycle.

It is intended that the rig be run 24 hours/day, 7 days/week in order to predict wheel performance prior to the construction of a full operational system.

The test rig also serves as a platform for the development of the emergency braking systems. The rim of the rig representing the mass of the vehicle will enable the calliper brake performance

The price for the Test Jig is included in the test track hardware above.

9. Scope of delivery from WGH Ltd.

The scope of delivery from WGH is guideway, LIMs and LIM-Controllers, Vehicles, Station and Low-Level Control System. WGH shall design, supply, install and commission a test track and five vehicles fitted with outline bodies. WGH has not quoted a fully operational prototype vehicle. Building a complete prototype will be decided during May 2003.

WGH's quotation includes:

- Project Management and Technical Support
- Mechanical Design & Electrical Design
- Independent Design Check & FE Analysis
- Shipping
- Installation
- Technical Support
- Insurance
- Travelling and accommodation

- Plugs and Moulds for Outline Body
- Track and Supports and
- Platform with Handrail and Stairs

- Vehicles
    - Cabins Outline Profile – GRP Construction
    - Bogies including:
        - Buffers
        - Emergency Brakes
        - Copper LIM reaction plate
        - 24v alternator and regulator

    - 2 x 12 volt 55 ampere hour batteries and monitor
    - Track switching
    - System management and control
    - Air gap monitoring

- Radio Control to switch 1 car only (verification of delivery from WGH)
- Low level control system

- LIM Electrical Supply
  - GRP weatherproof sub-stations (10) including:
    - installing 24 inverters fitted with isolators
    - and contactors connected by a BUS system
    - located within 2 control panels fitted with
    - locking doors
    - 630 amp main isolator
    - Interior lighting and heating

- Power and Control Cable Assemblies (244) Including:
    - LIM mountings
    - Junction Box IP55
    - 10mm power cable pre-made with numbered cores

- LIM's, Inverters and Eddy Current Magnetic Brakes

- Test Jig

Test track as described above will be a negotiated turn key, fixed price delivery from WGH Ltd with Force Engineering Ltd as sub supplier.