

Modification proposals for cabin ergonomics for metro drivers in M300 series carriages

LINK Design and Development Oy

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Background

An evaluation project with the purpose of studying metro drivers' driving ergonomics was conducted between 2018-06 and 2018-12, by LINK Design and Development Oy (later referred to as "LINK Design"). Main target for possible ergonomics modifications is the M300 series of metro carriages.

This document serves as a basis for Construcciones y Auxiliar de Ferrocarriles, S.A. (later referred to as "CAF") in their evaluation of necessary procurements, acquisitions and modifications during and under the valid warranty period for the metro equipment delivered to the metro authority of the city of Helsinki, Helsinki City Transport (later referred to as "HKL").

Study methods

Ergonomics studies were conducted physically at the HKL metro depot, workshop space at LINK Design as well as on-board the metro equipment along with the drivers. The on-board study was conducted with the carriages undergoing regular traffic work while during some of the depot visits, the metro equipment remained static.

Based on these initial phase studies and findings, a 1:1 size partial mock-up version of the cabin was built into the workshop space at LINK Design. The mock-up allowed project team to validate and reproduce ergonomics situations of actual driving work while also allowing the changing of the driver's seat position and height as well as re-ordering and grouping of control buttons and switches.

HKL metro drivers and other personnel were used to test and validate findings with the mock-up. The drivers were selected in such a way, that extreme ergonomic situations were present by using as big as or as small as a driver that was available for the mock-up user test.

After initial steps in studies and findings, a set of ergonomics problems of varying degrees of severity were identified in different use cases in the daily work of the metro driver. These problem definitions were used as a basis for modifications that were sequentially introduced into the physical mock-up. HKL personnel were again used to test, comment and validate improvements presented to them by the mock-up.

Actual 3D CAD geometry and anthropometric ergonomics models were used throughout the study.

This paper is a document of the changes and differences between the original M300 cabin layout and the proposed cabin layout, according to the ergonomics studies conducted in the manner described above.

All of the stages and results of this ergonomics study has been documented in written and audio visual (photo & video) format.

Results of Field Studies

Metro drivers and their ergonomic use cases were studied *in situ* either at the metro depot or during regular metro traffic operation. According to studies, the following ergonomics issues were identified:

- Using master controller becomes non-ergonomic for some users because the stick is either too far away or in poor elevation in relation to the driver's sitting height
- Un-ergonomic master controller is pronounced when drivers use the *sifa* button
 - o Using the sifa button causes the drivers' right sided hand to go in a slight upward angle, hindering blood circulation in hand extremity
- Space underneath the control desk, reserved for the feet of the driver, becomes too small and requires some users to have their legs in an un-ergonomic angle
- Accessing some of the buttons in the angled front surface is somewhat troublesome because of the distance between driver's seating position of angled surface

Some of the minor negative observations are as follows:

- The soft hand support at the base of the master controller could be softer and it's edges could be more rounded
- The LED-luminaires' area of lighting is too limited
- Beverage/water bottle holder
- Sound emitted from the heater is considered somewhat disturbing
- Volume control of announcements affects volume also inside of cabin
- No possibility of opening any window(s) for the purposes of cleaning the windows and ventilation
- Wall between passenger and cabin spaces allows noises to come through
 - o Bottom/floor opening of wall also allows dirt and liquid to come through to cabin
- There should be a dedicated place for mirror cleaning agent and wiper cloth
- Coat rack placement is considered bad, specially in quick driver exchange situations
- A dedicated place for a bag is desired (TBD)
- An electrical socket for eg. mobile phone charging is desired
 - o Mobile phone may be stored in/nearby beverage holder



Images from an in situ user study at the Helsinki metro depot

Mock-up Validation

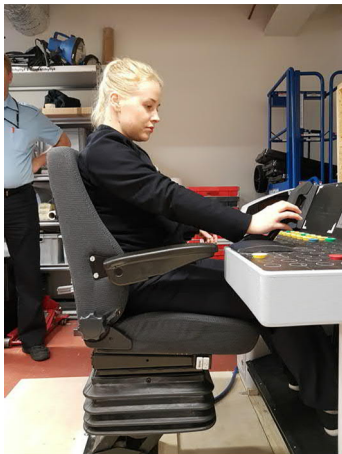
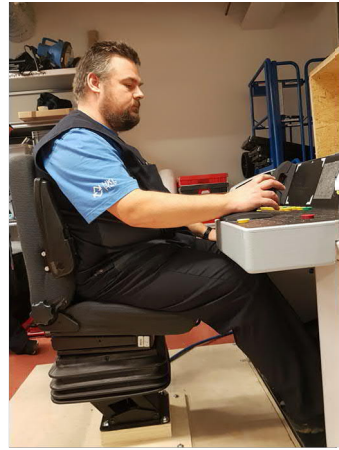
After field studies a 1:1 size mock-up was built into the workshop space at LINK Design. The mock-up was constructed in a way that allowed designers to move buttons and controls and the driver's seat into different configurations in order to identify improved ergonomics solutions. The mock-up was also used to re-produce ergonomics findings made during the field studies.

Of particular note is the chair by BE-GE, that has a rocking joint mechanism at its base. This mechanism allows the driver to swivel the entire chair backwards so that the driver is imposed with the possibility to perform their work from a standing position. Other manufacturers' seating solutions are also available; all solutions are subject to evaluation during their own selection and validation procedure, performed under HKL administration. From mock-up testing it can be postulated that the standing position is more useful to shorter drivers, as from the standing position a taller driver has to lean forward. Leaning forward is not advised from ergonomics point of view, especially when considering that the cabin is shaking due to metro rail operation.



Images of the 1:1 scale mock-up, built into the workshop of LINK Design

Images selected from video footage of the user testing and validation, with the mock-up model. Users present at the testing represent among others the P05 and P95 users. Of note are the differences between the sitting and standing use cases.



Updated 3D CAD model, modeled after the problem validation and solution ideation with the physical mock-up model. This model was used in creating the 2D drafted visualization presented later in this document. Of particular note is the re-arranged switch and button layout contra the original M300 layout. Also a proposal for a beverage holder and its placement is presented (it was reported that a driver had fallen a beverage over and the spilled liquid damaged the electrical equipment inside of the control desk).



Ergonomics Problems Definitions

In the ergonomics study, it is advisable to study people who represent the median user as well as the extreme users. This is referred to as *designing for the 95th percentile*. Designing for the 95th percentile means designing for the standard deviation of sizes found in the general population.

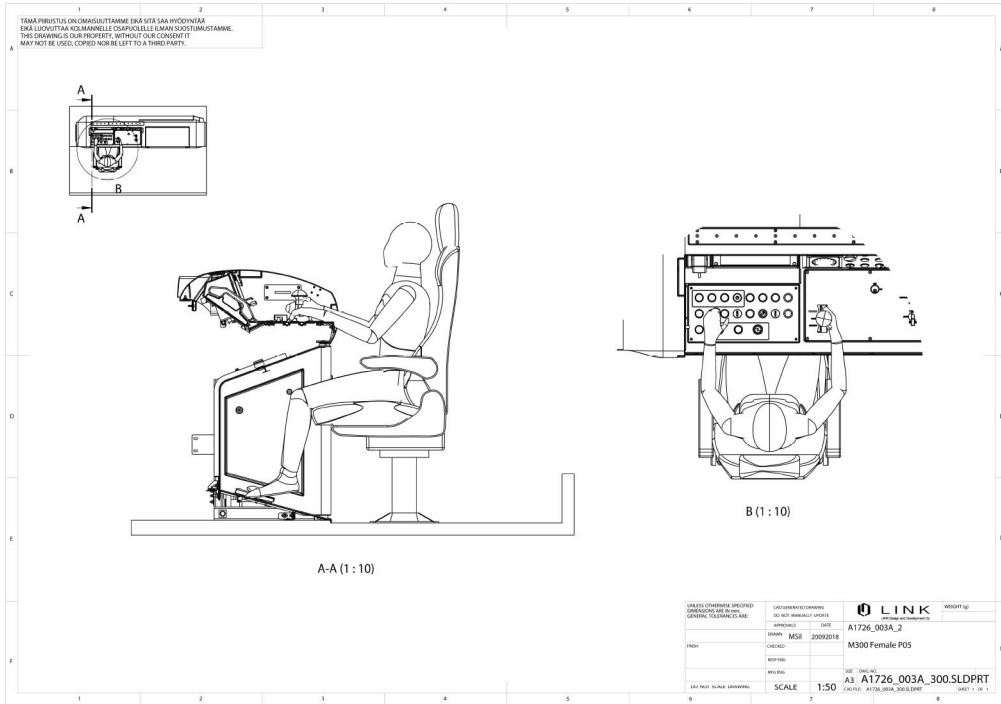
In this study, the smallest size factor user height was 150cm. This is the low-end extremum, or *P05*. The largest size factor user height was 195cm respectively. This is the top-end extremum, or *P95*.

For the shortest height P05 driver the original M300 cabin presents the following ergonomics problems:

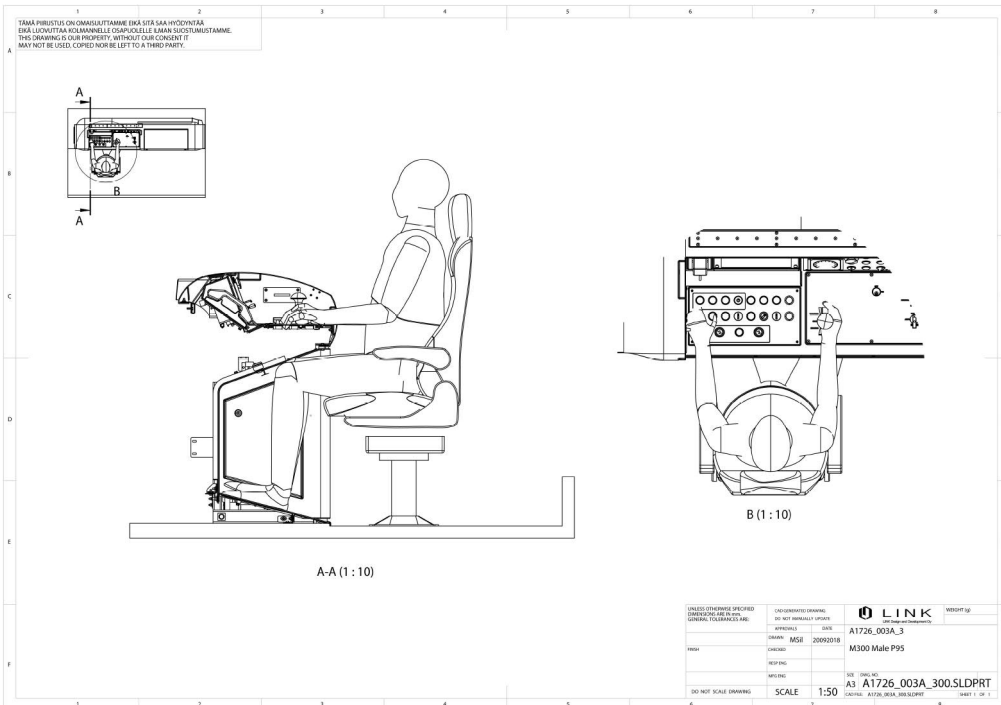
- Driver has to keep the seat in a low elevation in order to reach the feet support plane
- When seat is in low elevation, the control desk top and master controller will be positioned too high in relation to the driver

For the tall P95 driver the original M300 cabin presents the following ergonomics problems:

- Driver needs to be seated close to the control desk, in order to adequately reach the master controller
- When driver is seated close to the control desk, the driver's feet do not fit under the control desk, inside of the space reserved for feet. Additionally, the resulting angle in the driver's feet is unergonomic.



P05 / 150cm height driver, in seated driving position in original M300 cabin



P95 / 195cm height driver, in seated driving position in original M300 cabin

Proposals for Improvements

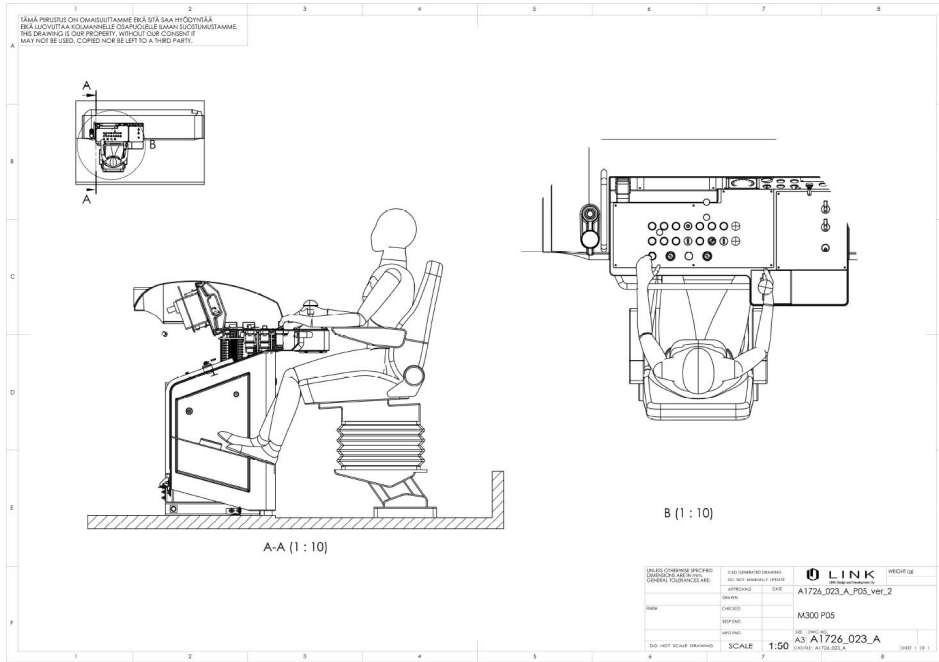
Control desk front surface offset 70mm towards the driver. The space claimed this way is reserved for a handlebar that serves as a possible point for gripping in various situations. The bar is particularly useful in situations where the driver performs metro running operations from a standing position. The standing position was found to be specifically beneficial for the shorter height driver.

Master controller moved 200mm towards the driver. This allows for a more ergonomic positioning of the master controller. In original design, the driver's hand is in a slightly upright position, thereby straining blood circulation in the hand. Situation is emphasized when driver actuates the *sifa* device via the button on the top of the controller.

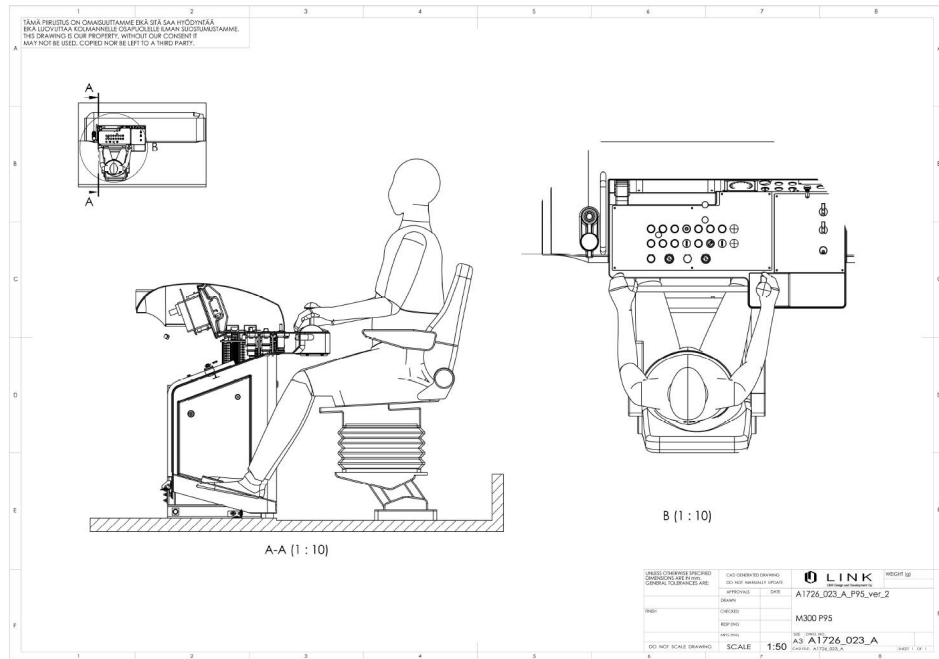
The driver's seat is offset 120mm backwards from the control desk. This modification allows the driver to position their legs in an ergonomic angle. Secondary benefit gained by offsetting the seat, prevents driver's legs and knees from contacting the inner surface of the leg space under the control desk and improves leg space usage in general.

The leg support under the driver's feet is modified so that the leg support plane's height can be adjusted. The electrically operated elevation can be controlled via a switch positioned in the angled front panel in control desk. The control switch is positioned so that it groups as a secondary function among other buttons and switches. The driver can, however, easily re-adjust support plane elevation while the metro is moving. It is recommended to advise the drivers to make their preference height elevation prior to running the metro. The other *sifa* device actuator, the foot pedal, moves along with the support plane.

The angled front panel – and thereby the buttons and switches on it - in the control desk, is moved towards the driver by 100mm. This modification allows the driver to access controls located on this surface more ergonomically, without having to lean forward.



P05 / 150cm height driver, in seated driving position in *proposed* M300 cabin



P95 / 195cm height driver, in seated driving position in *proposed* M300 cabin

Conclusions

As an overall general statement, the ergonomics study followed a very standard form of progress. It is common to study users of target group so that as close as possible group is studied that fit into the 95th percentile design principle. This ergonomics study is no exception.

Using 1:1 scale mock-ups and testing it with real users is a necessary step in validating research data and providing a platform for problem solving. By building the mock-up cleverly with the purpose of testing new ideas right away on it, and validating with real users, provides powerful means of arriving at accurate ergonomics improvements.

The main ergonomic problems for the 150cm P05 driver are: seat must be positioned to too low an elevation in order for feet to reach support plane. This also results in the master controller to be too high in relation to the driver.

The main ergonomic problems for the 195cm P95 driver are: driver must be seated too close to the control desk in order to reach the master controller. This also results in the poor placement and angle of driver's feet.

The main solutions to the ergonomics problems are: master controller moved 200mm towards driver. Angled control button/switch/screen surface moved 100mm towards driver. Adjustable foot support plane with 200mm adjustment range. Driver seat offset away from control desk by 120mm.

Appendix

Image footage from field studies; metro depot and regular traffic operation:

