Product Conversion from Manual to Automated Configuration

Parametric 3D models of existing manually configured elevator product, converted to fully automatic for utilization in an automated ordering process.

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Mechanical Engineering and Production Technology Abstract
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The goal of this product development project for Kone elevators, is to convert a deliverable products parametric 3D models and drawings, from a manual product configuration and design process (Non-Standard), to an automated one (Standard), so it can be utilized in an Automated Order Process, bringing financial value to the company.

Standard products utilize programable 3D models which receive customer order specifications as input parameters to automatically configure the 3D models. These parametric models are costly to create and are usually only created for high volume product ranges. Once taken into use however, the design process between ordering and manufacturing is fully automated. Order specific CAD models and manufacturing drawings will then be generated without the need of a design engineer which is a huge cost saving over high-volume products and greatly speeds up delivery time.

The scope of this project was to take an original non-standard product (Elevator Side Emergency Exit) and make it fully configurable using only parameters used as order specifications. The physical design of the product did not change. Every part and assembly needed to be evaluated to determine how and what was controlling the behaviour of their features and dimensions. All the components and their dimensions needed to be connected and controlled by a Top-Down Design, 3D modelling Architecture, which collects all order specific parameter values at the top of the 3D model engineering structure and distributes the values down through the structure to each configurable component that needs them. All product configurations and ranges were tested, and manufacturing drawings were checked to verify they were showing same configurations as the 3D model and aligned with the companies defined product range.

The main objective was achieved, and the product 3D models and drawings are configuring automatically using parameters and testing completed. There was no major issues during the project and all stakeholder requirements were met also. Reusing the original models and drawings was beneficial and helped to speed up the project. Unfortunately, the factory validation is still pending and no clear schedule as to when it will be made as the testing facility has limited capacity and higher priorities.

Keywords Design automation, product configuration, ordering process conversion.
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Contents

1 INTRODUCTION 1

2 KNOWLEDGE BASE AND BACKGROUND 3

2.1 Kone 3

2.1.1 Past, present, and future 3

2.2 Elevator basics 4

2.2.1 Hoisting concept 5
2.2.2 System Layout 6
2.2.3 System components overview 7
2.2.4 Car components overview 9

2.3 Kone car emergency exit - door and bridge solution 11

2.3.1 Overview 12
2.3.2 Door with extension 13
2.3.3 Door without extension 16
2.3.4 Bridge 19
2.3.5 Car interior door decoration 21
2.3.5.1 Decoration structure and weight 21
2.3.5.2 Adjusting opening clearances 22
2.3.6 EN 81-20 European Safety Requirements 22
2.3.7 Rescue Instructions 24

2.4 Product configuration 30

2.4.1 Configurable vs non-configurable products 30
2.4.2 Configurability 30
2.4.3 Benefits of product configuration 31
2.4.4 Why it's critical for global elevator manufacturers 32

2.5 Standard vs non-standard products 32

2.5.1 Standard 32
2.5.2 Non-standard 33
2.5.3 Why and when they are used by global elevator manufacturers 33

2.6 Automated Order Processing 34

2.6.1 Ordering 34
2.6.2 Product Configuration 35
2.6.3 Design automation for manufacturing 35
2.6.3.1 Top-Down Modelling 36
2.6.4 Delivery automation for supply chain 37

2.6.5 Order Orchestration 38
2.7 Data validation & testing 39
2.7.1 Continuous 3D model testing 39
2.7.2 PDM and CAD alignment 39
2.7.3 Full chain validation 39
2.7.4 Factory prototyping 40
2.8 PTC - Creo Parametric & Windchill 40
2.9 Product development process in industrial manufacturing 41
2.9.1 Stage Gate Development Process 41
2.9.2 Requirements 43
2.9.2.1 Jama Software 43
3 OBJECTIVES, PURPOSE, AND UTILITY 45
3.1 The *product* 45
3.2 The *conversion process* 46
4 PLANNING AND EXECUTION 47
4.1 Getting started 47
4.1.1 Tools used and their function 47
4.1.2 Project and product introduction 48
4.1.3 Where does this project fit into product development process 48
4.1.4 Understanding the product 48
4.1.5 Understanding the process 53
4.2 Requirements 54
4.2.1 Doors position architecture changes 54
4.2.2 Alignments required for standard process 55
4.2.2.1 New parameters needed 56
4.2.2.2 Data flow & Top-down design 57
4.2.2.3 Replace local parameters with existing 58
4.2.2.4 System attribute alignment 59
4.2.2.5 Flat state dimensions 59
4.2.2.6 Material selection from skeleton 59
4.2.3 Door opening mechanism 59
4.2.4 New parts needed 60
4.2.5 Uploading 3D models to Windchill 60
4.2.6 Drawing validation 60
4.3 Planning the work 61
4.3.1 Refining requirements into actionable steps 61

4.3.2 Order of actions 63
4.3.3 Project schedule 64
4.4 Doing the work 64
4.4.1 Doors position architecture changes 65
4.4.2 Alignments required for standard process 66
4.4.2.1 New parameters needed 67
4.4.2.2 Data flow & Top-down design 68
4.4.2.3 System attribute alignment 71
4.4.2.4 Flat state dimensions 71
4.4.2.5 Material selection from skeleton 73
4.4.3 Door opening mechanism 74
4.4.4 New parts needed 77
4.4.5 Uploading 3D models to Windchill 78
4.5 Finalizing the work 79
4.5.1 Testing of models locally in Creo 79
4.5.2 Drawing validation 80
4.5.3 Publishing drawings/PDM sync 81
4.5.4 Pilot Site Review for Global Installation 81
5 RESULTS AND CONCLUSIONS 82
REFERENCES 83

Abbreviations & terminology

AOP	Automated Order Processing.
BOM	A bill of material is a list of all components and quantities required to create a complete product.
CAD/MCAD	Computer Aided Design/Mechanical CAD.
CAR	Elevator system passenger car.
Creo Parametric	3D modelling software used to create 3D product models and manufacturing drawings.
Engineering Structure (ES)	Hierarchical decomposition of a product. Describes the product after final installation on site as it appears during its lifetime.
ERP	Enterprise Resource Planning. Data system used for large organization management.
Non-Standard Product	Generic term for products that require manual/custom engineering when ordered.
Order Bound Drawing	Manufacturing drawing of a component which has been configured and contains order specific dimensions and data.
Product architecture	Organization of a products structure.
Parameter	Term for a definable variable in data processing, which requires an input value.
PDM	Product Data Management - product information database.
PDMVC	PDM Variant Configurator.
Skeleton	3D modelling component used to locate, consolidate, define, and control critical design information withing an assembly and pass the data to other entities.
Standard Product	Predefined product which can be ordered, configured, and manufactured without manual/custom engineering.
Top-down design	Hierarchical method of organizing and processing information.
Variant Configurator	A system application using the product information database to create an order specific variation of a product.

Figures

Figure 1. Basic hoisting concept used in traction systems. (Lukaves. 2021).....5
Figure 2. Basic traction elevator system. (Archtoolbox. 2021) 6
Figure 3. Main components of a traction elevator (ElectricalKnowhow. 2012-a).....7
Figure 4. Main car components (ElectricalKnowhow. 2012-b) 9
Figure 5. Car-to-car rescue system with car doors and bridge. (KONE, 2021-d) 11
Figure 6. Door and bridge. (KONE. 2021-d).....12
Figure 7. Door with extension. (KONE. 2021-d) 14
Figure 8. Minimum car-to-car distance without bridge. (KONE. 2021-d) 15
Figure 9. Maximum car-to-car distance without bridge. (KONE. 2021-d) 15
Figure 10. Minimum car-to-car distance with bridge. (KONE. 2021-d).....16
Figure 11. Maximum car-to-car distance with bridge. (KONE. 2021-d).....16
Figure 12. Door without extension. (KONE. 2021-d).....17
Figure 13.Minimum car-to-car distance without bridge. (KONE. 2021-d).....18
Figure 14. Maximum car-to-car distance without bridge. (KONE. 2021-d) 18
Figure 15. Minimum car-to-car distance with bridge. (KONE. 2021-d).....19
Figure 16. Maximum car-to-car distance with bridge. (KONE. 2021-d).....19
Figure 17. Bridge - isometric view. (KONE. 2021-d) 20
Figure 18. Bridge - elevations. (KONE. 2021-d) 20
Figure 19. Door with modified decoration. (KONE. 2021-d).....21
Figure 20. Door with modified decoration and panel. (KONE. 2021-d).....22
Figure 21. Door opening with key. (KONE. 2019-f) 25
Figure 22. Attaching the bridge. (KONE. 2019-f).....26
Figure 23. Lowering bridge to trapped car bridge frame. (KONE. 2019-f).....26
Figure 24. Bridge car-to-car alignment. (KONE. 2019-f).....27
Figure 25. Attaching balustrades. (KONE. 2019-f).....27
Figure 26. Locking balustrade to cars. (KONE. 2019-f).....28
Figure 27. Removing the safety bars. (KONE. 2019-f).....28
Figure 28. Exterior opening mechanism. (KONE. 2019-f).....29
Figure 29. Example of top-down design in mechanical products. (Guo et al., 2012) 37
Figure 30. New product development process. (Cooper.2007).....41

Figure 31. Example of engineering instructions document. (KONE. 2021-d) 49
Figure 32. Original main assembly in Creo 50
Figure 33. Door assembly and expanded BOM in Creo.....50
Figure 34. Expanded skeleton with highlighted datums in Creo.....51
Figure 35. Sub-component BOM configuration in Creo 52
Figure 36. Relations script to configure component behaviour in Creo 52
Figure 37. Non-standard modelling method defined by Kone. (KONE.2023-g).....53
Figure 38. Standard modelling method defined by Kone. (KONE.2023-g).....54
Figure 39. Main assembly skeleton datums for door position in Creo 55
Figure 40. Example of parameters required (KONE. 2021-d).....56
Figure 41. Manual configuration noted if engineering instructions (KONE. 2021-d) 57
Figure 42. Parameters currently in the model (KONE. 2021-d) 58
Figure 43. Example of parameters used in door assemblies in Creo 58
Figure 44. Gantt chart used for project schedule 64
Figure 45. Original (left) with one door in two cars, and new design (right) with two doors in one car, rear car wall for show - in Creo 65
Figure 46. New configurable datums planes additional door position requirements - in Creo 66
Figure 47. Alignments progress and status checklist 67
Figure 48. Existing local parameters (red) and new parameters (blue) - in Creo 67
Figure 49. Door plate with configuration rules and parameters linked to skeleton – in Creo 68
Figure 50. Main assembly skeleton parameters and abbreviations 69
Figure 51. Main component BOM configuration using new parameters - in Creo.....70
Figure 52. Example of data system attributes in Creo 71
Figure 53. Example of sheet metal part in bended state - in Creo 72
Figure 54. Sheetmetal dimensions example in Creo 72
Figure 55. Manufacturing parameters in Creo 73
Figure 56. Generic Raw Material Skeleton from Car - in Creo 73
Figure 57. Example of skeleton selection rules in Creo.....74
Figure 58. Door opening sketch – in Creo 75
Figure 59. Door opening mechanism added to models - in Creo.....76

Figure 60. Connection and rotation settings for door opening - in Creo.....76
Figure 61. New parts needed to automate decoration interference issue (creo).....77
Figure 62. New parts configuration (creo).....78
Figure 63. Incomplete objects description from PTC Support (PTC. 2023-b).....79
Figure 65. Drive documents app used to test configurations (Creo).....80
Figure 64. Drawing validation checklist (Creo).....80
Figure 66. Example of 2D manufacturing drawing (Creo).....81

1 INTRODUCTION

As I started my career as a design engineer for Finnish technology service provider Etteplan Oy, I was permanently assigned to our customer KONE, a global industrial elevator manufacturer. My first position was in a custom order engineering team responsible for mechanical design work to satisfy order requirements outside standard ranges, for elevator passenger cars. My next position involved working with the interior ceilings – a subcomponent of the passenger cars. The task for these new components was different as they are designed as a Standard Product range, which do not require manual mechanical design work. The standard products are ordered through an AOP in such large organizations. The new project involved creating new 3D models and data of the existing ceiling components for a new product data management variant configuration process. Here, the new 3D models and data would be synchronized between CAD data systems and the organisations standard product data system. The input, flow of data and output would be then tested and validated. This forms some of the initial steps of building a Standard Product. Near the end of this project, I informed the project manager I was seeking a project for a bachelor's thesis. One available project was for a component which again, was closely connected with the passenger cars. It was an additional car door and bridge system, used as a side emergency exit. This was a great opportunity to learn a new component but also utilized and strengthen all my previous experience and product knowledge.

The side emergency exit is used as a rescue system when the elevator and doors are not functioning. In elevator systems which have two side by side shafts and passenger cars, an elevator technician manually controls the functioning passenger car, bringing it to the same level as the broken passenger car. The two corresponding side emergency doors are opened, and the bridge is placed between the two cars allowing passengers to escape from one to the other. This is called car to car recue and is a recue type selected during the ordering process.

It was originally designed as a Non-Standard product as at the time demand was low and creating a Non-Standard product requires much less time and cost than a Standard Product. Standard Products are much more complicated as they are part of an AOP and require a larger

initial investment. Over the years the demand has increased to the point where it is now profitable as a Standard Product – which why this project is important to Kone.

The main objective of this development project was to convert the products existing 3D models and drawings, to suit the requirements needed for a Standard Product used in the AOP. Requirements such as Design Automation and Top-Down Design modelling principals - to ensure product and order data flow, aligns with the AOP. Re-using the existing 3D models, drawings and data would be the most efficient way to meet the requirements defined by the stakeholders of the product. Data validation and testing will be carried out to ensure all changes and modifications to the 3D models and drawings are configuring correctly and outputs are aligned to the product range defined by Kone.

This thesis is also intended to function as a guide for future conversion projects. It contains an overview on all processes/steps involved and should give the reader a basic understanding of why and how to make any similar, non-standard to standard product conversion.

2 KNOWLEDGE BASE AND BACKGROUND

2.1 Kone

2.1.1 Past, present, and future

A machine repair shop named Tarmo was established in Finland's capital, Helsinki, in 1908. On October 27, 1910, it was incorporated as KONE. The machine shop started refurbishing and selling used Strömberg motors under the KONE name from a converted stable. It also imported and installed elevators from Graham Brothers in Sweden. Over the years, KONE has proven its ability to adapt to the challenges of a changing world. Its offering has ranged from industrial cranes to emergency room patient monitors, ice-skate blades, and nylon socks. But the elevator and escalator business has always been its primary focus. Breakthrough technologies, including the machine-room-less elevator and a superlight hoisting rope that enables elevator travel of up to 1 kilometre, have earned KONE a reputation as a global innovator. (Kone, 2022)

At the end of 2022, KONE had annual net sales of EUR 10.9 billion, with over 60,000 employees around the world, operating in more than 60 countries across the globe. As the urbanization megatrend shows, the world's cities are constantly growing. They attract billions of people and by 2050 more than two in every three people on the planet will live in urban areas. In this increasingly urbanizing world, Kone's mission is to improve the flow of urban life. Kone understands urbanization and can help their customers make the best of the world's cities, buildings, and public spaces. Kone's vision is to create the best People Flow experience. Their goal is to provide ease, effectiveness and experiences to their users and customers over the full life cycle of buildings. (Kone, 2023-a)

Kone has clearly defined strategies to target the biggest opportunities for growth such as:
Adapting to customer specific needs by optimizing cost efficiency and sustainability of core products and services. New solutions which will be integrated with core products and services to create added value for customers. Establishing themselves as the best partner for smart

and sustainable city development. Establishing themselves as the market leader in the fast-growing China market. (Kone, 2023-b)

KONE is investing their own development initiatives to create more 'Sustainable success with customers' by: Employing capable professionals committed to learning and succeeding in a changing world. Creating a harmonized customer experience across multiple channels. Leveraging Lean skills, practices, and leadership to eliminate waste and ensure continuous improvement. Building technology infrastructure to use data analytics and increase the efficiency, and resilience of their supply chain. (Kone, 2023-b)

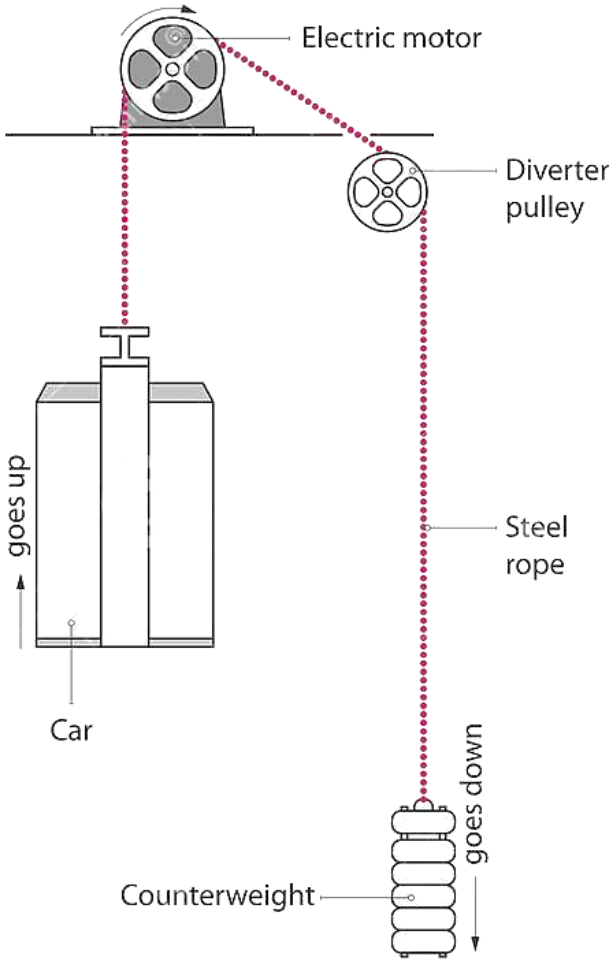
Kone was ranked as the 19th most sustainable company in the world by Corporate Knights Inc., a leading sustainable business magazine and ranking organization. KONE was the only elevator and escalator industry company to make the Corporate Knights' 2023 Global 100 Most Sustainable Corporations in the World ranking, published on the side-lines of the World Economic Forum being held in Davos, Switzerland. (Kone, 2023-c)

2.2 Elevator basics

There are only around three different types of elevator systems - Traction, Vacuum and Hydraulic. This section gives a basic overview of the most common system – the traction elevator, its hoisting concept, the system layout and components, common car design and components, and brief description of a car with a side emergency exit, car-to-car rescue type.

2.2.1 Hoisting concept

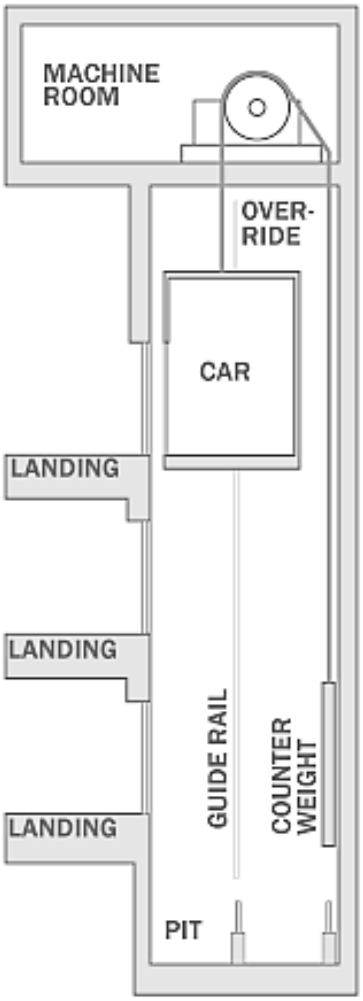
Figure 1. Basic hoisting concept used in traction systems. (Lukaves. 2021)



Traction systems lift the car using an electric motor. Steel rope is connected to the car and a counterweight. The counterweight is used to balance the load. Diverter pulleys are used to align the position of the steel rope with the counterweight.

2.2.2 System Layout

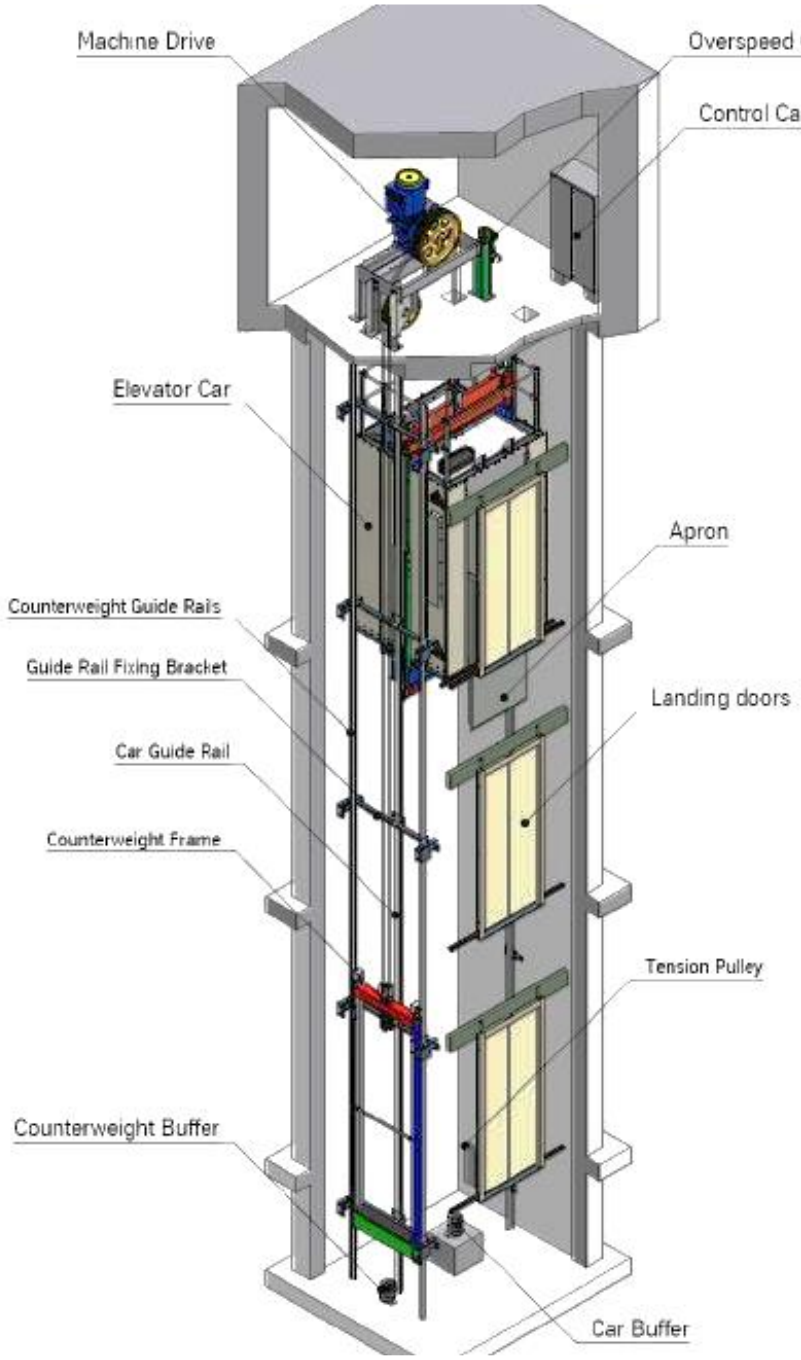
Figure 2. Basic traction elevator system. (Archtoolbox. 2021)



The electric motor lifting the car is housed in a Machine Room at the top. The car is aligned using Guide Rails, preventing movement in X and Z directions. The car is hoisted up and down the shaft as required, stopping with the Landing and Car floors being aligned. The steel rope is diverted to the side of the shaft, along with the Counterweight. The pit contains additional equipment including hydraulic Buffers which limit the travel of car and Counterweight.

2.2.3 System components overview

Figure 3. Main components of a traction elevator (ElectricalKnowhow. 2012-a)



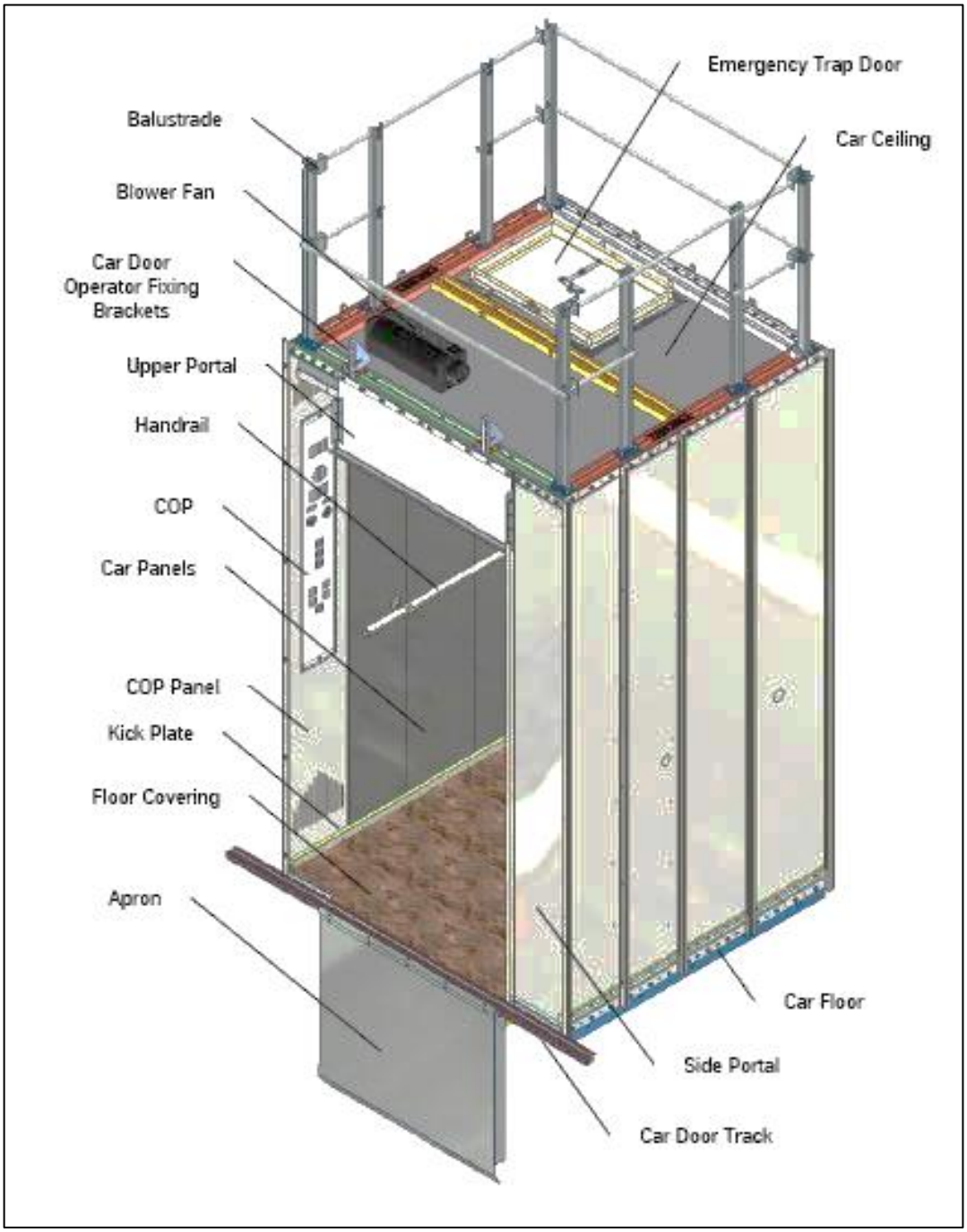
Control Cabinet: Houses a dedicated electrical controller for the entire elevator system.

Machine Drive: Electrical motor/drive unit used to lift the car. Can be with or without a dedicated machine room.

Overspeed Governor:	Safety component used to deactivate the motor and engage mechanical safety gear to stop the car if it passes a predetermined speed.
Suspension Ropes:	Ropes are connected to car sling and carry the load of the car and counterweight. They will also transfer torque to the motor if the car and counterweight are unbalanced.
Compensation Ropes:	These ropes connect to the bottom of the car and are used to compensate unbalanced load when the car is at the top or bottom of the shaft which loads the suspension rope on one side.
Elevator Car:	Used to transport passengers, vehicles, and goods.
Car Sling:	The sling is a frame which carries the car. Ropes are attached to the top cross beam of the sling frame.
Guide Shoes:	Guide shoes are part of the sling and counterweight frames and interface with the guide rails using rollers or sliders.
Guide Rails:	Attached to shaft wall. Used to guide the Car and Counterweight up and down the shaft while preventing movement in X and Z directions.
Safety Gears:	Part of Sling. The mechanical safety system used to physically stop the car by clamping the guide rails.
Counterweight:	The counterweight is used to balance the load of the car and has its own frame, guide rails, guide shoes and safety gear.
Buffers:	Hydraulic buffers in the pit limit the travel of car and Counterweight.
Landing & Car Doors:	Landing doors are on every level between building and shaft. They are opened by the car door opening mechanism and close using a weight inside the door or shaft.

2.2.4 Car components overview

Figure 4. Main car components (ElectricalKnowhow. 2012-b)



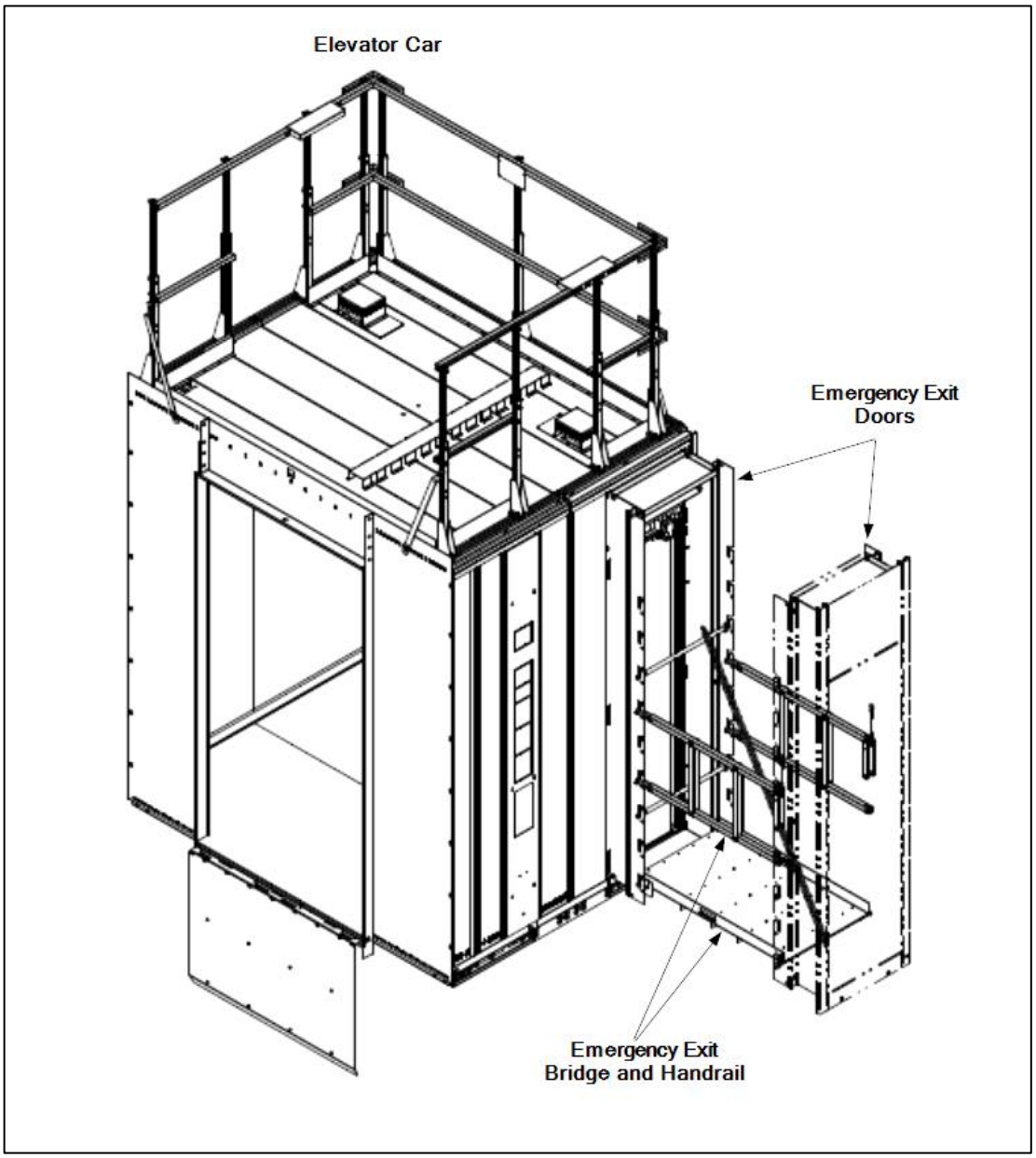
Floor: The first part of the car to be installed onto the sling and provides support for the walls.

Walls: Vertical or horizontal bended sheet metal panels form the structural car walls.

Front walls:	Front walls usually has two side panels and a top part and form the opening and position for the car doors.
Doors and Operator:	Car doors either open to one side or open from the centre to both sides. The doors are opened by a mechanism called the door operator. When a car stops at a landing, the mechanisms of both align and the car operator opens both doors.
Apron:	Aprons or Toe Guards are installed below the car door and landing doors to provide protection if the car is moving before the doors have closed.
Handrails:	Handrails are installed in all passenger elevators cars to provide support for passengers.
COP panel:	Car Operating Panel is the user interface containing the buttons to select floors, open and close doors, emergency call etc.
Kickplate:	Kickplate/toe kick/ skirting is installed at the bottom of the walls to provide protection and often has ventilation holes.
Roof:	The roof is installed on top of the walls and is designed to support maintenance personnel. Air fan, trap door, balustrade and interior ceiling are attached to roof.
Balustrade:	Installed on the roof frame to provide support and fall prevention to technicians.
Interior ceiling:	Interior ceiling or false ceiling is usually part of finishing materials and come in varying styles and designs.
Interior finish:	After the floor, walls and roof are in place, the finishing materials are installed according to customers selection.
Trap door:	The trap door can be accessed from inside or outside with a key used by technicians. It can also be used in emergencies to rescue and evacuate passengers.

2.3 Kone car emergency exit - door and bridge solution

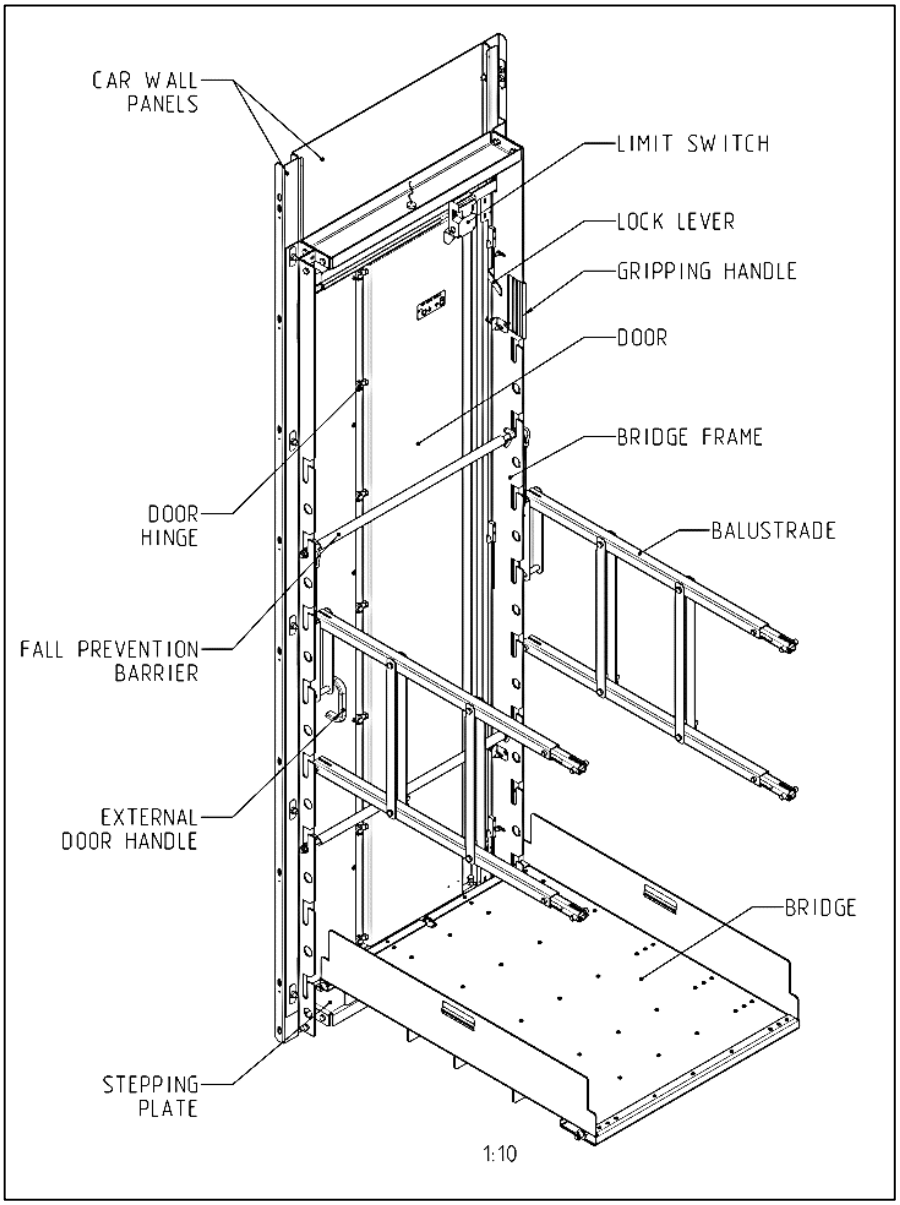
Figure 5. Car-to-car rescue system with car doors and bridge. (KONE, 2021-d)



The car emergency exit system in the car-to-car rescue configuration, uses a set of doors, one on each adjacent car. When the cars are aligned by a technician, a bridge is placed between them to allow passengers to escape from a malfunctioning car, into an operational one, and be taken to safety. This rescue system is the focus of this project.

2.3.1 Overview

Figure 6. Door and bridge. (KONE. 2021-d)



This car emergency exit system designed by Kone is compatible with all Kone elevator cars and has design instructions for engineers to make the required modifications to suit each car. It was designed as a Non-Standard product and requires design engineers to manually modify and configure the 3D models to meet each set of order specifications, ever time it is ordered.

The system has been designed in accordance with European safety regulation EN 81-20 and the maximum and minimum ranges for the design have been validated with strength

calculation. If an order requires a design outside these ranges, the design must be validated independently.

The emergency door can be used for both car-to-car, and car-to-shaft rescue and usually require the removable bridge and handrail. The bridge and handrail are not stored in or on the car, they are stored in the elevator machine room. The door open inwards into the car and can be opened from the inside using a key, or from the outside by a dedicated lever. The door lock uses a limit switch as part of a safety circuit.

There are two door types - door with extension and door without extension. The basic structure of the doors are the same and the extension version has addition wall panels on the sides, anti-step plate on top and stepping plates on the bottom. The extension depth is variable and, in some cases, negate the need for a bridge.

For car-to-car rescue type, the car-to-car distance must be available from the elevator system layout drawings. This information is used to select door types and determine if a bridge is necessary, and if so, how long it needs to be.

During the design phase, after the door has been engineered to fit the car, the car engineer needs to crosscheck with another engineering team, who designs the main elevator system layout. The layout team know the position of all other components in the shaft and can clarify that the proposed door and bridge design by the car engineer does not interfere with other components and has sufficient clearances during closed and open operation of the door.

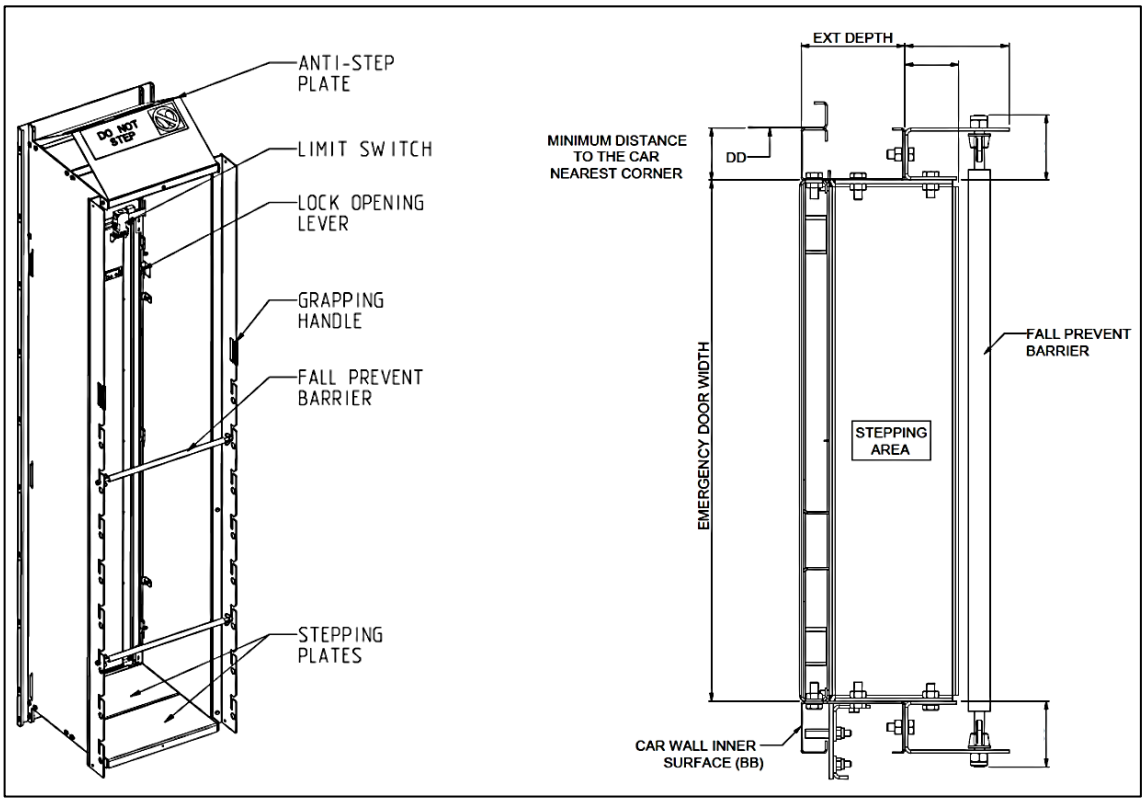
2.3.2 Door with extension

Emergency door is available with an extension towards the shaft side of the car. Maximum and minimum limitations are defined according to EN 81-20 and the door cannot be smaller than the specified minimum. If emergency door or bridge dimensions are over above limitation, strength and suitability need to be verified case by case.

Emergency door solution consist of integrated emergency door on car wall, stepping plate, fall prevent barriers and limit switch (see Figure 7). Options are for removable emergency bridge

& balustrade and light above door in shaft side. Extension depth means wall panels depth on emergency door sides (see Figure 7). Maximum and minimum extension depth is defined in Kone engineering instructions. A minimum distance from door panel to the car nearest corner must be also maintained. (KONE. 2021-d)

Figure 7. Door with extension. (KONE. 2021-d)



Without emergency bridge, car to car distance will be smaller and determines the extension depth. Without bridge free space between emergency door frame parts and distance between emergency doors stepping plates must be kept to a minimum. Shorter car to car distance and longer free space between door parts can be done case by case. Same emergency door structure is used with car to shaft rescue operations. In below figures are shown the shortest and the longest car to car configurations, without emergency bridge which are supported by the current product. (KONE. 2021-d)

Figure 8. Minimum car-to-car distance without bridge. (KONE. 2021-d)

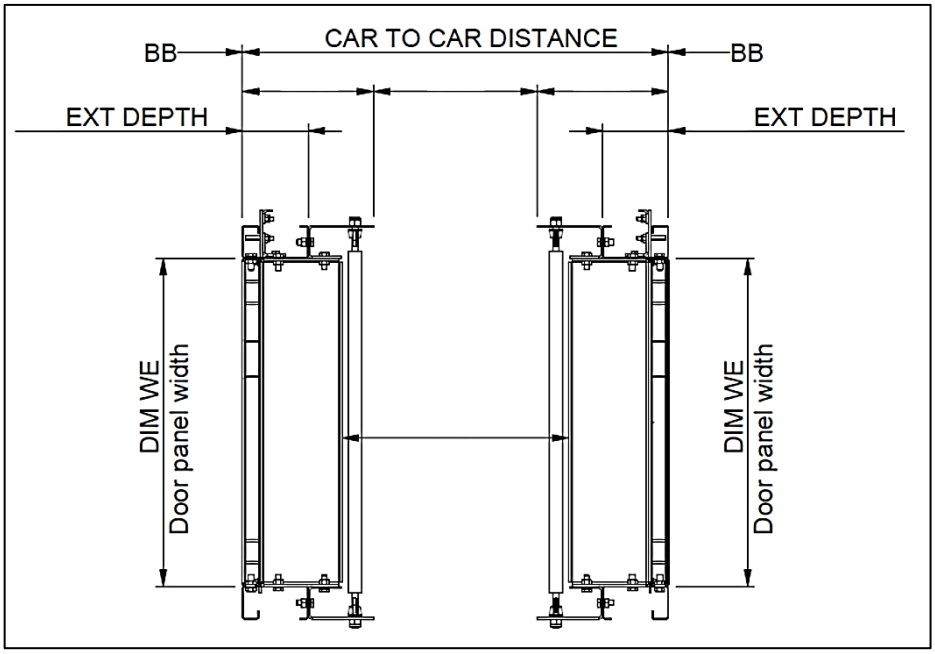
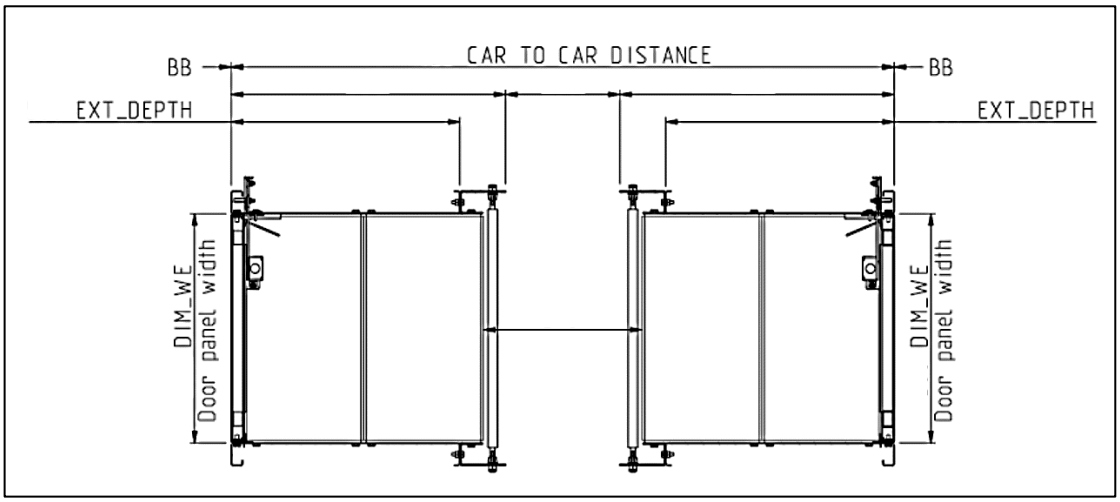


Figure 9. Maximum car-to-car distance without bridge. (KONE. 2021-d)



With emergency bridge, car to car distance can be larger and will define the extension depth and bridge length, but structural analysis is valid only up to certain size. Free space between emergency door parts is also larger. In below figures are shown the shortest and the longest car to car configurations, with emergency bridge which are supported by the current product. (KONE. 2021-d)

Figure 10. Minimum car-to-car distance with bridge. (KONE. 2021-d)

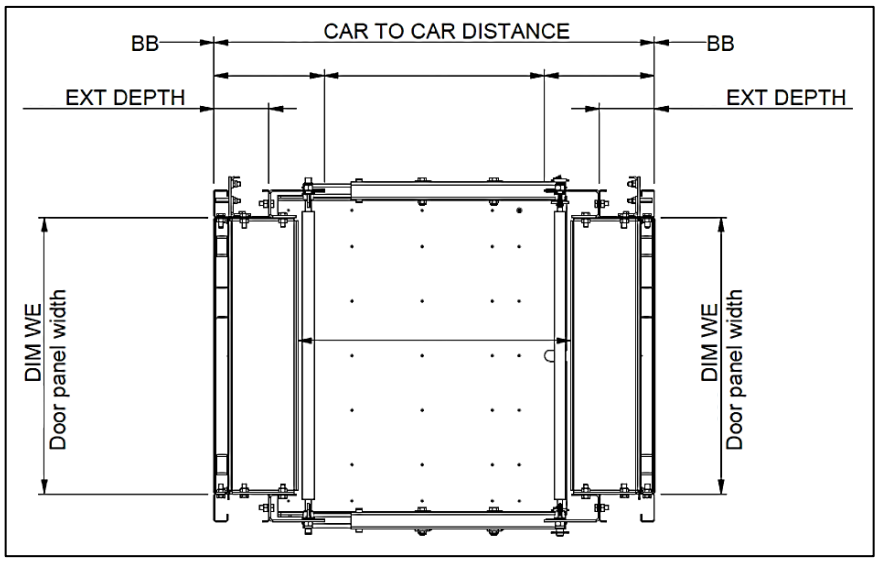
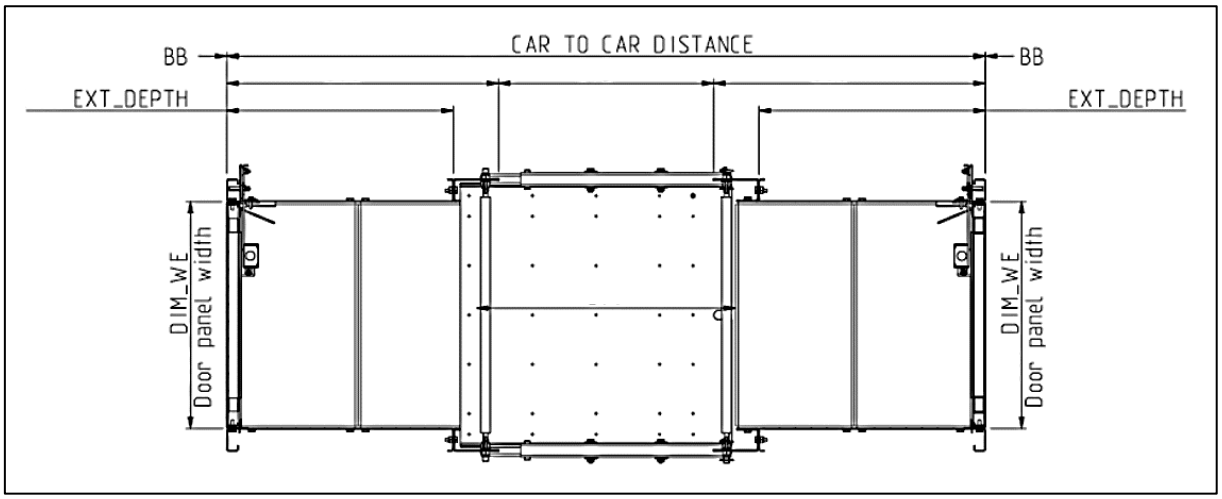


Figure 11. Maximum car-to-car distance with bridge. (KONE. 2021-d)



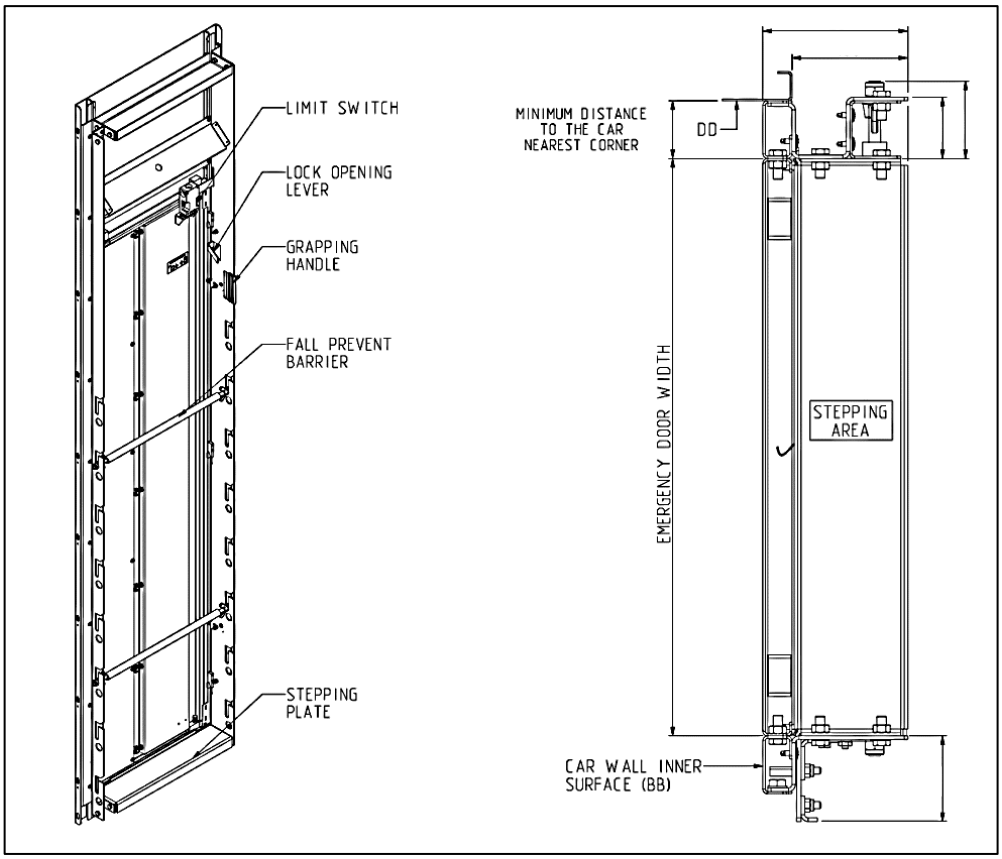
2.3.3 Door without extension

No extension - solution consists of the same components as the normal emergency door solution but is not using the extension panels. Same door, limit switch and fall prevent barriers are used. (see Figure 12). Same options for removable emergency bridge & balustrade and light above door in shaft side are also available in this solution. Depth of the no extension - solution is fixed to a minimum depth defined in Kone engineering instruction (see Figure 12).

The same door size limitations apply to the no extension - solution as for the solution with the extension panels. Due to a slightly modified design in the bridge holding panels, bridge clear

width is slightly reduced. Maximum and minimum door dimensions can be found in Kone engineering instruction.

Figure 12. Door without extension. (KONE. 2021-d)



Without emergency bridge, car to car distance is smaller than extended doors. Same rules apply to the no extension – solution, regarding without bridge free space between emergency door parts and distance between emergency doors stepping plates. Shorter car to car distance and longer free space between door parts can be done case by case. In below figures are shown the shortest and the longest car to car configurations, without emergency bridge which are supported by the current product. (KONE. 2021-d)

Figure 13.Minimum car-to-car distance without bridge. (KONE. 2021-d)

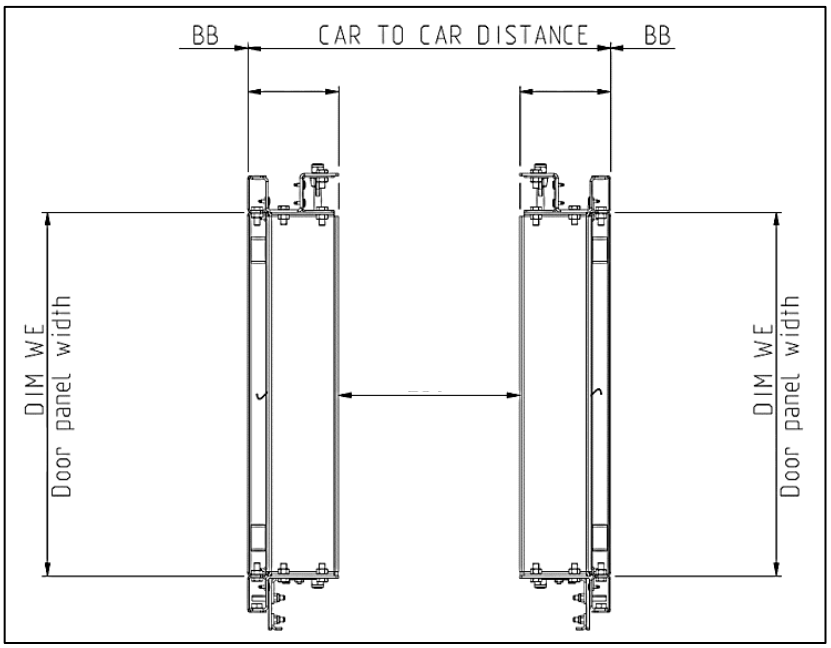
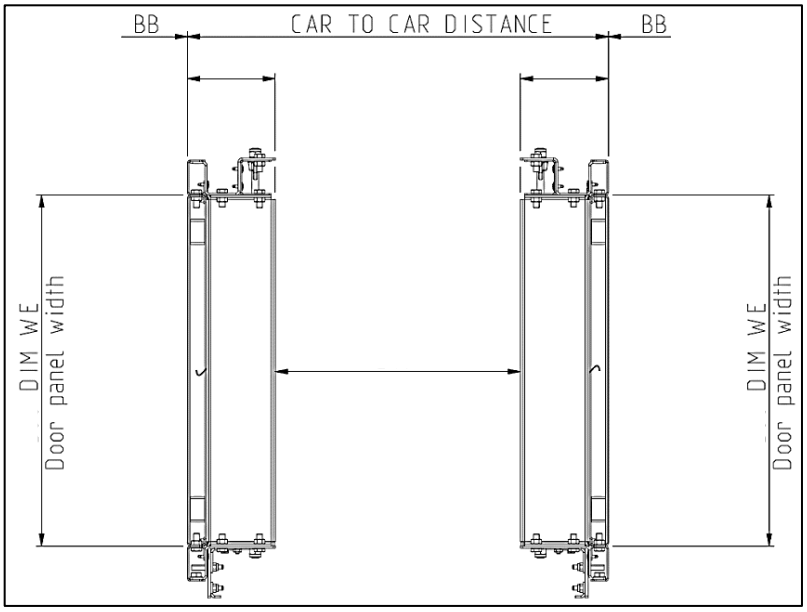


Figure 14. Maximum car-to-car distance without bridge. (KONE. 2021-d)



As with the extended version, doors with emergency bridge car to car distance can be larger. Free space between emergency door parts is also larger. In below figures are shown the shortest and the longest car to car configurations, with emergency bridge which are supported by the current product. (KONE. 2021-d)

Figure 15. Minimum car-to-car distance with bridge. (KONE. 2021-d)

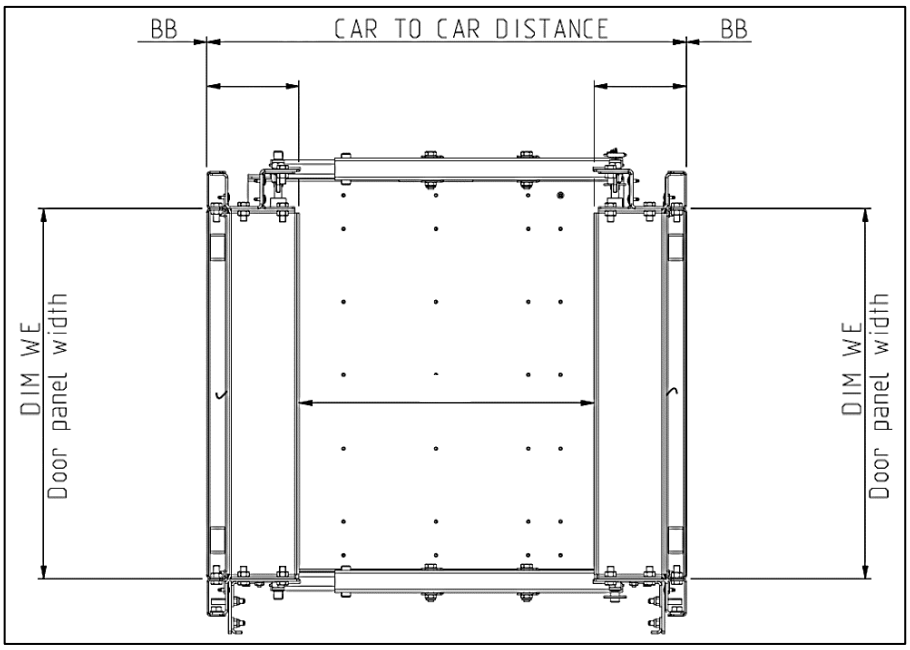
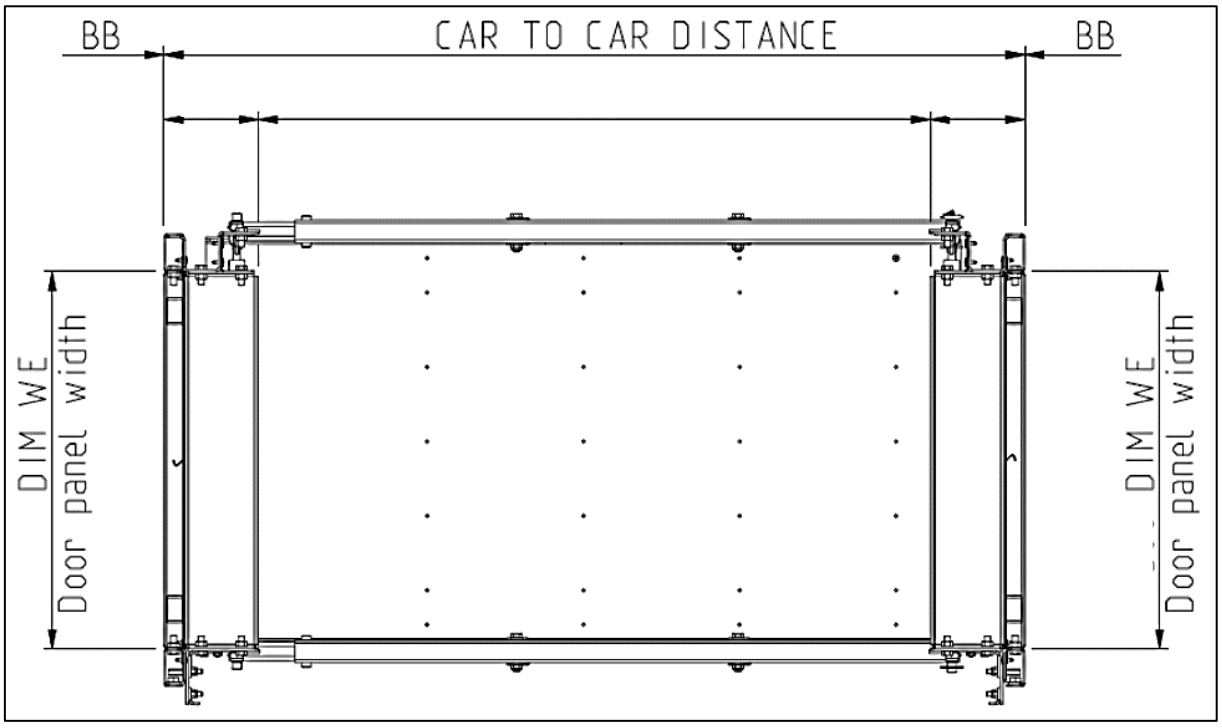


Figure 16. Maximum car-to-car distance with bridge. (KONE. 2021-d)



2.3.4 Bridge

Bridge has two versions in the model, aluminium, and steel bridge. Steel bridge is the old bridge model. Aluminium bridge is used by default. However, if extra strength is needed from

bridge and weight is not an issue, default bridge can be replaced with old bridge which uses steel frame. This can be done by changing parameter MAT_BRIDGE from “AL” into “STEEL” in main assembly. (KONE. 2021-d)

Figure 17. Bridge - isometric view. (KONE. 2021-d)

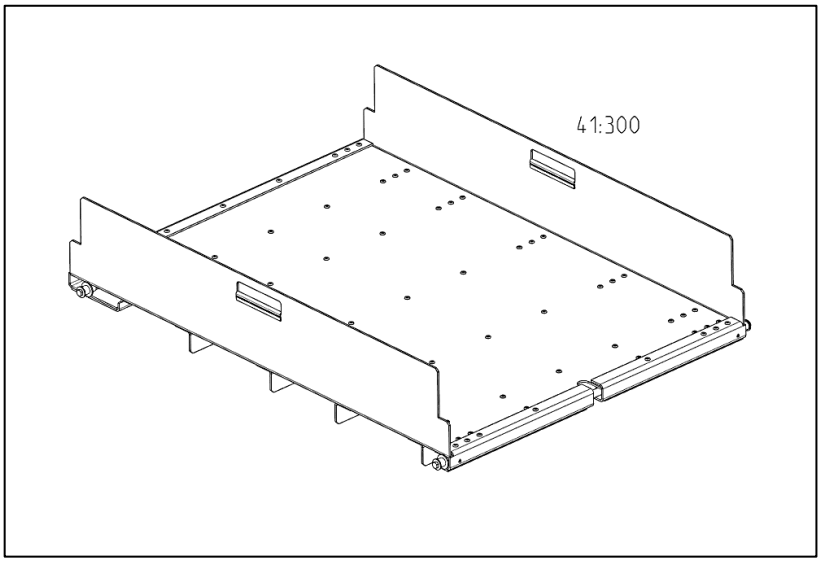
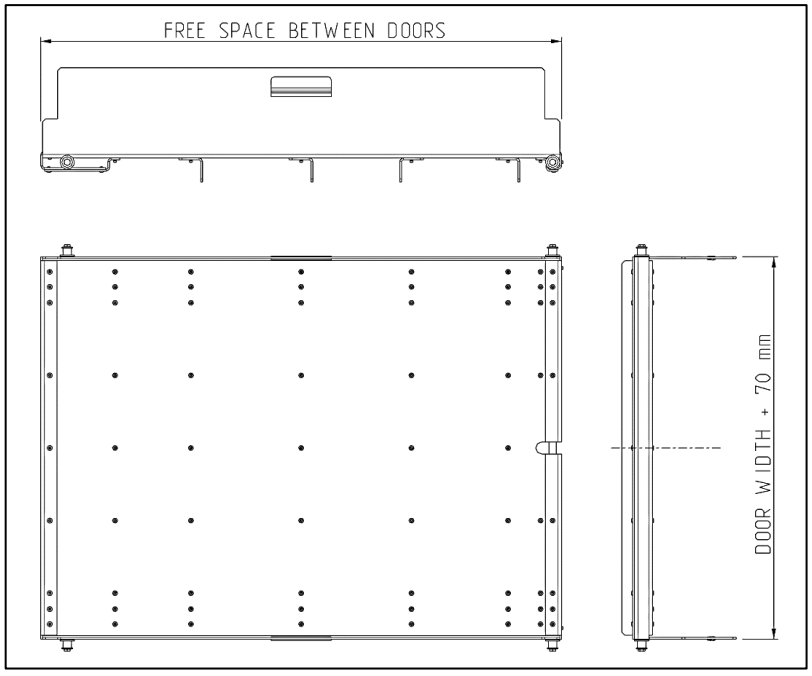


Figure 18. Bridge - elevations. (KONE. 2021-d)

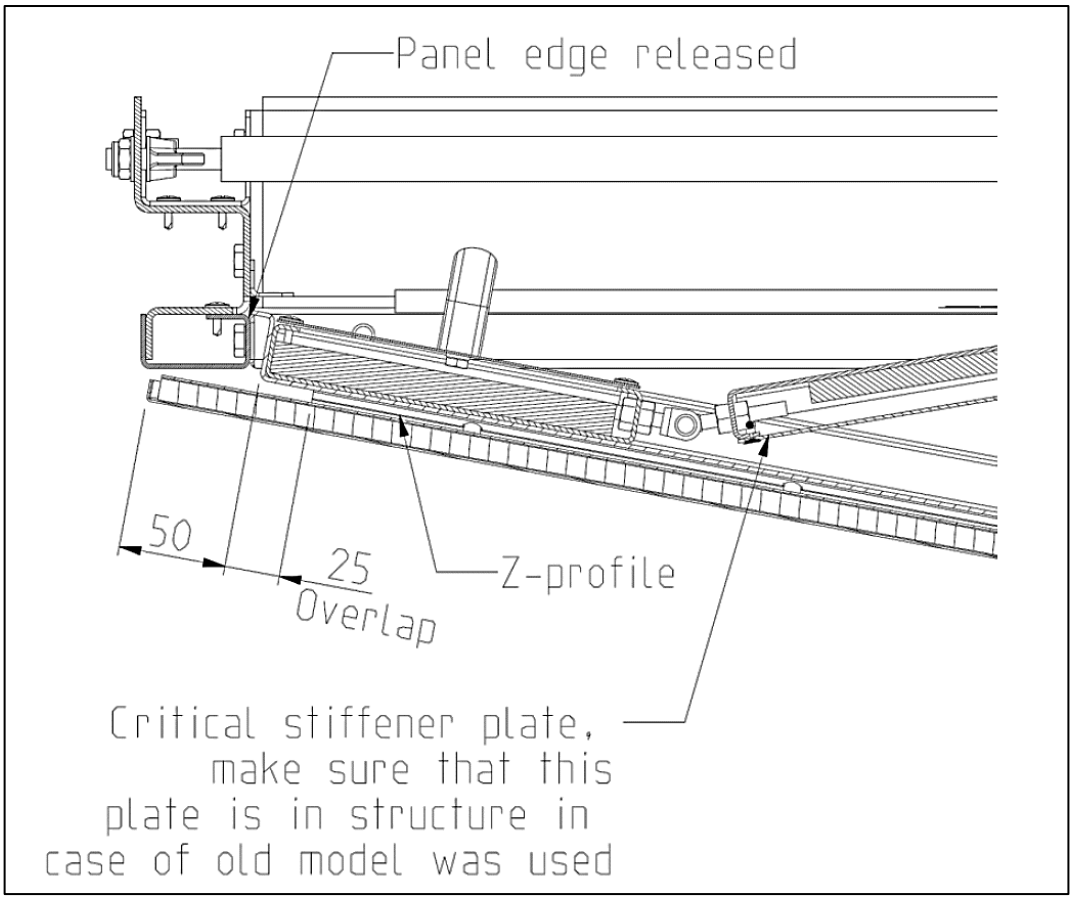


2.3.5 Car interior door decoration

2.3.5.1 Decoration structure and weight

Decoration panel is fixed to door with Z-profiles, Z-profiles to be max door width-50mm. Decoration panel can be the width of the emergency door or overlapping the door. (KONE. 2021-d)

Figure 19. Door with modified decoration. (KONE. 2021-d)

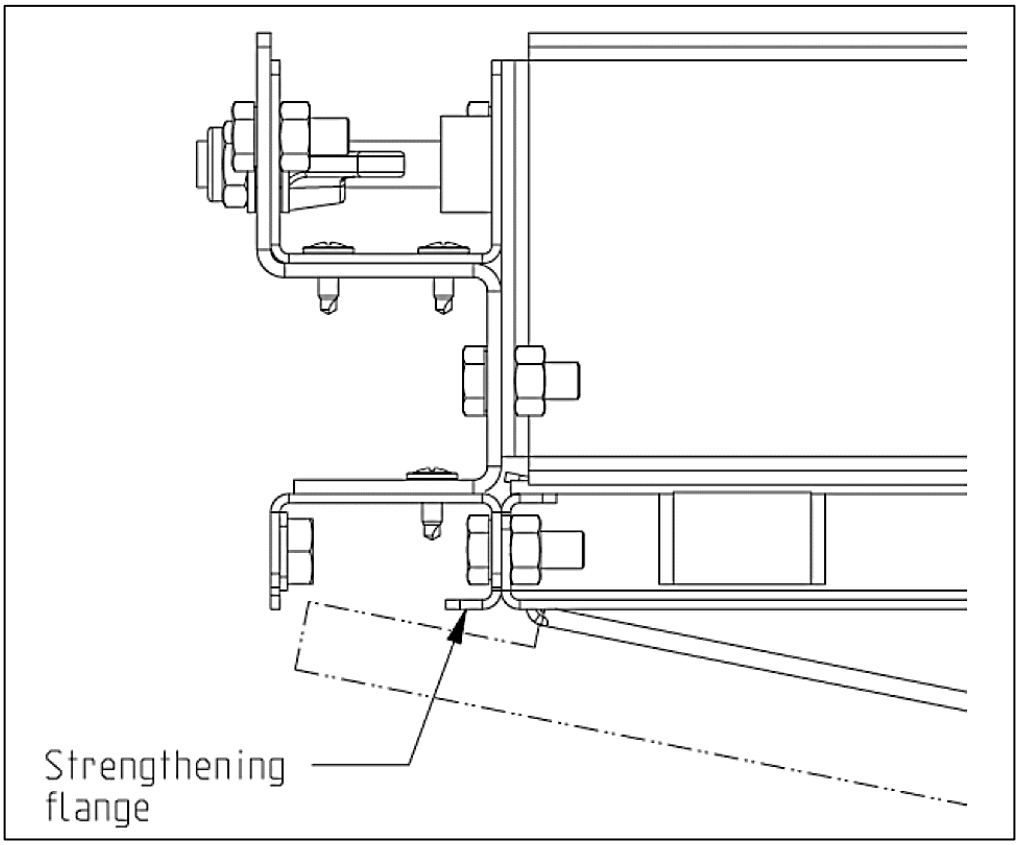


Hinging mechanism of the emergency door must be always checked (edge on the handle side releases). Hinging can be most easily checked by changing angle in 3D model. Check always also clear opening of the door with decoration and possible interference to handrail next to emergency door. Maximum weight of the decoration panel is defined in Kone engineering instructions. (KONE. 2021-d)

2.3.5.2 Adjusting opening clearances

If car has local decoration and no extension -solution is used, car engineer should replace the non-hinge-side wall panel with the copy of hinge-side wall panel. This way the decoration panel on door doesn't hit the wall panel when emergency door is opened. This solution can also be used with decoration panels provided by SL. When car engineer does this, engineer should also shorten the length of wall panel's strengthening flange into 12 mm or remove it entirely to give even more space for decoration and remove the final flange from bridge frame plate. With extension platforms, wall panels need to be re-designed. (KONE. 2021-d)

Figure 20. Door with modified decoration and panel. (KONE. 2021-d)



2.3.6 EN 81-20 European Safety Requirements

Emergency door & bridge solution fulfil EN 81-20:2014 requirements. Below is chapters from code which are taken in account in the design, and which need to be taken in account when special modifications are made to design.

EN 81-20:2014: "*5.4.6.2 Emergency doors may be used in the case of adjacent cars, provided, however, that the horizontal distance between cars does not exceed 1 m (see 5.2.3.3).*
In this case, each car shall be provided with a means of determining the position of the adjacent car to which persons will be rescued in order to allow it to be brought to a level where rescue can take place.

In the event of rescue, where the distance between car emergency doors is greater than 0,35m a portable/movable bridge or a bridge integrated into the car, with handrails and a minimum width of 0,50 m but with sufficient clearance to fit in the opening of the emergency door shall be provided.

The bridge shall be designed to support a minimum force of 2500 N.
If the bridge is portable/movable it shall be stored in the building where the rescue is to take place. The use of the bridge shall be described in the instruction manual.
If emergency doors exist, they shall measure at least 1,80 m high and 0,40 m wide."

EN81-20:2014: 5.4.3.2.2: *"Each wall of the car shall have a mechanical strength such that:*
a) when a force of 300N, being evenly distributed over an area of 5 cm² in round or square section, is applied at right angles to the wall at any point from the inside of the car towards the outside, it shall resist without:
— any permanent deformation greater than 1mm.
— elastic deformation greater than 15 mm.
b) when a force of 1000 N, being evenly distributed over an area of 100 cm² in round or square section, is applied at right angles to the wall at any point from the inside of the car towards the outside it shall resist without permanent deformation greater than 1mm.
NOTE: These forces could be applied on the "structural" wall, excluding mirrors, decorative panels, car operating panel(s), etc."

According to Kone rescue instructions, the rescue elevator car can be driven to the level of the trapped elevator by:

- using rescue drive controls inside the car (if applicable)
- using inspection drive controls on the car roof

Emergency door & bridge strength have been verified by strength analysis.

Emergency door minimum height clear opening height is 1800 mm and maximum height 2500 mm. Emergency door minimum width is 470 mm (this provides 400mm clear opening as per code) and maximum clear width is 600 mm. Emergency bridge and handrail maximum length is 1000 mm.

Distance between cars can be more when using extended emergency door frames. Thus, maximum distance between cars (from car wall inner surface BB to other car wall inner surface BB) is maximum when using largest bridge and extensions. NOTE structural analysis is valid only up to certain size defined by Kone engineering instructions.

> EN 81-20:2014: *"5.4.6.3 If emergency trap doors or doors are installed, they shall conform to the following:*
> *5.4.6.3.1 Emergency trap doors and doors shall be provided with a means for manual locking.*
> *5.4.6.3.1.1 Emergency trap doors shall be opened from outside the car without a key and from inside the car with a key suited to the triangle defined in 5.3.9.3. Emergency trap doors shall not open towards the inside of the car. Emergency trap doors in the open position shall not project beyond the edge of the car.*
> *5.4.6.3.1.2 Emergency doors shall be opened from outside the car without a key and from inside the car using a key suited to the triangle defined in 5.3.9.3. Emergency doors shall not open towards the outside of the car. Emergency doors shall not be located in the path of a counterweight or a balancing weight or in front of a fixed obstacle (except for beams separating the cars) preventing passage from one car to another.*
> *5.4.6.3.2 The locking called for in 5.4.6.3.1 shall be proved by means of an electric safety device in conformity with 5.11.2. In case of emergency doors this device shall also stop the adjacent lift when unlocked. Restoring the lift to service shall only be possible after deliberate relocking."*

Emergency door can be opened from inside the car with triangle key and from outside the car by pulling down from a red opening lever. Emergency door does not open towards the outside of the car. Emergency door lock has limit switch which is part of safety circuit according to EN81-20 code section 5.11.2. (KONE. 2021-d)

2.3.7 Rescue Instructions

The following is an extract from Kone rescue instruction document and outlines the basic procedure for the emergency exit system described in the previous sections.

Emergency rescue using emergency side doors.

NOTE: Three qualified persons needed:

- One inside the rescue car.
- One inside the trapped car.
- Optional: one on the roof of rescue car if there are no rescue drive controls installed in the rescue elevator car.

- Optional: one in the machine room if the rescue car must be moved on recall drive feature in machine room.

Rescue Procedure:

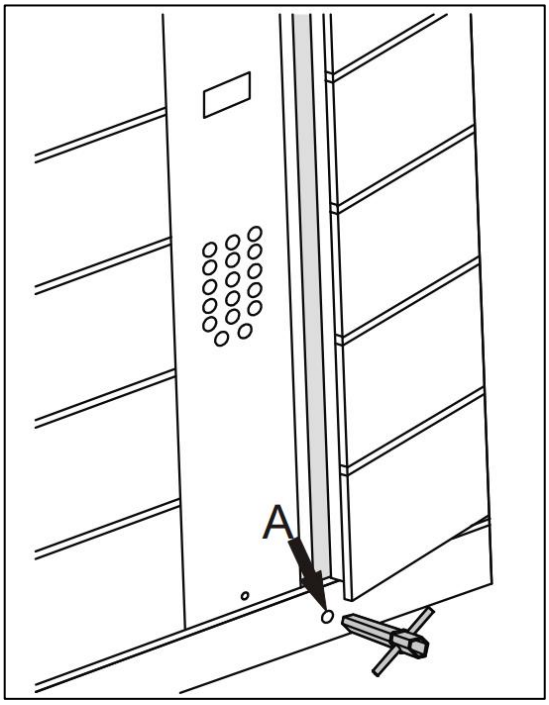
1. Secure trapped elevator car

2. Drive rescue car next to trapped car

3. Set up rescue bridge

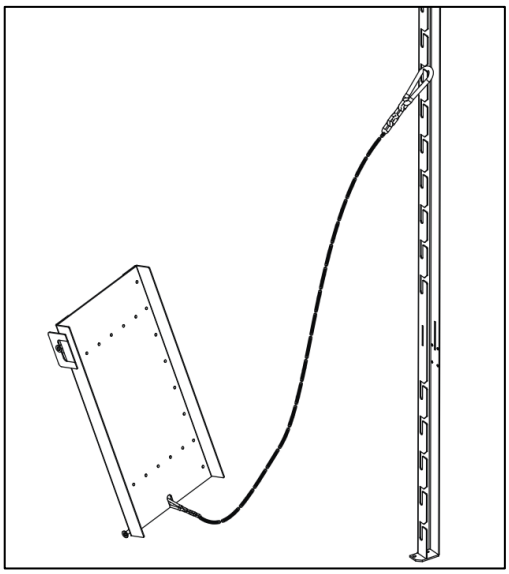
    1. Open the car emergency exit door from the keyhole (A) using an emergency opening key.

Figure 21. Door opening with key. (KONE. 2019-f)



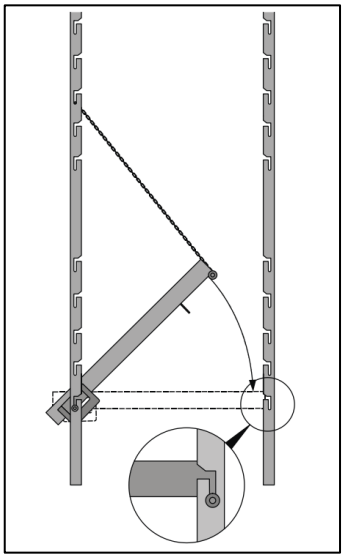
    2. Switch on the emergency lighting outside the car near the emergency exit door. If applicable.
    3. Install chain to the emergency bridge. Install the other end of the chain to the notch on vertical U-profile of the rescue car wall.

Figure 22. Attaching the bridge. (KONE. 2019-f)



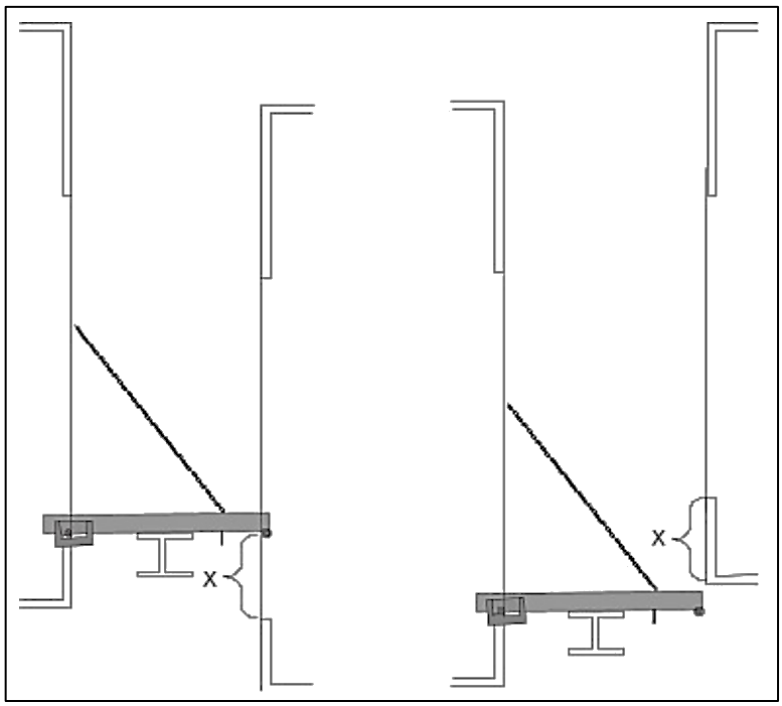
4. Fix the end of the emergency bridge to the rescue car. Make sure that there is no gap between the rescue car door sill and the bridge.
5. Lower the other end of the rescue bridge to the trapped car by using the chain. Make sure that the rescue bridge is securely attached to the trapped car.

Figure 23. Lowering bridge to trapped car bridge frame. (KONE. 2019-f)



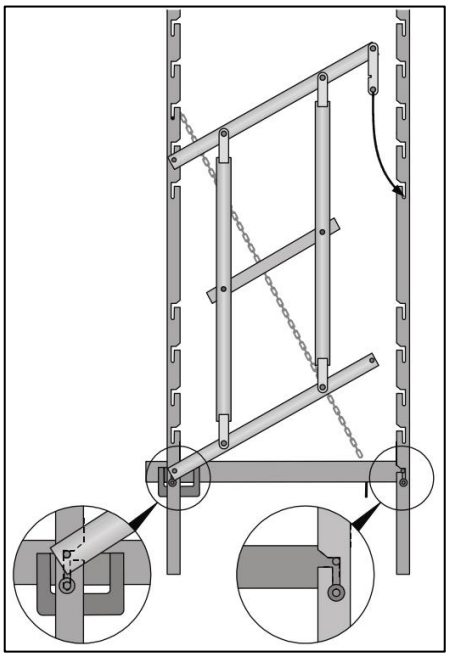
6. Make sure that the locking mechanism must be 90 degrees. (X = The gap must be lesser than or equal to 200 mm)

Figure 24. Bridge car-to-car alignment. (KONE. 2019-f)



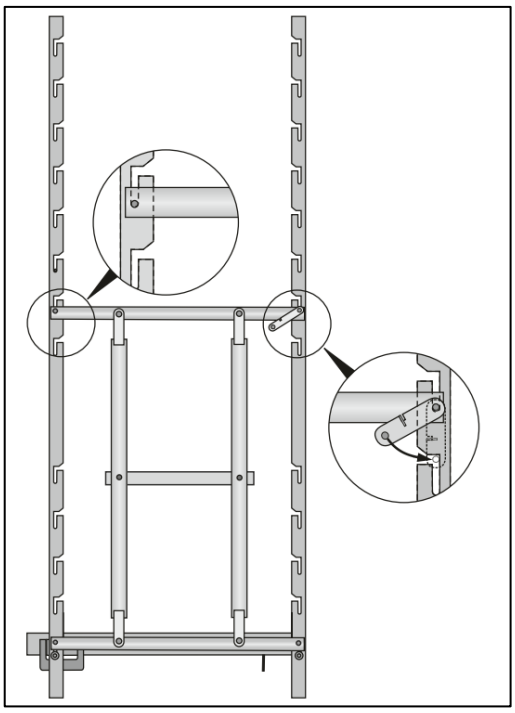
7. Attach balustrades beginning from the rescue car side.

Figure 25. Attaching balustrades. (KONE. 2019-f)



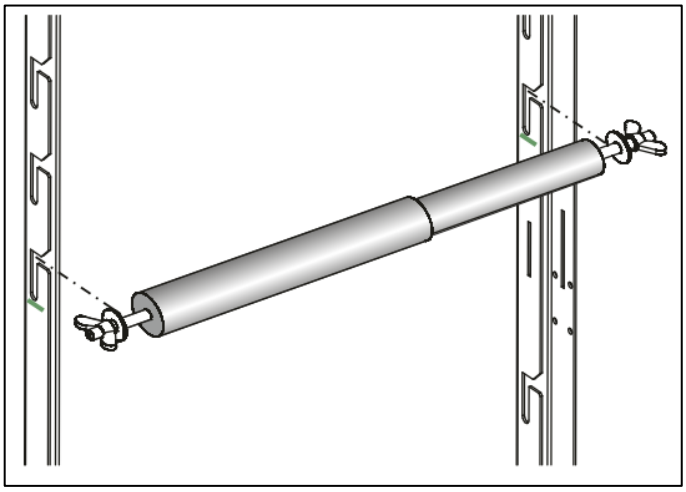
8. Lock the cotter clips on the car wall. Remove the chain from the rescue bridge. Fix the chain to the notch on the car wall.

Figure 26. Locking balustrade to cars. (KONE. 2019-f)



9. Remove the safety bars from the rescue car emergency exit door opening

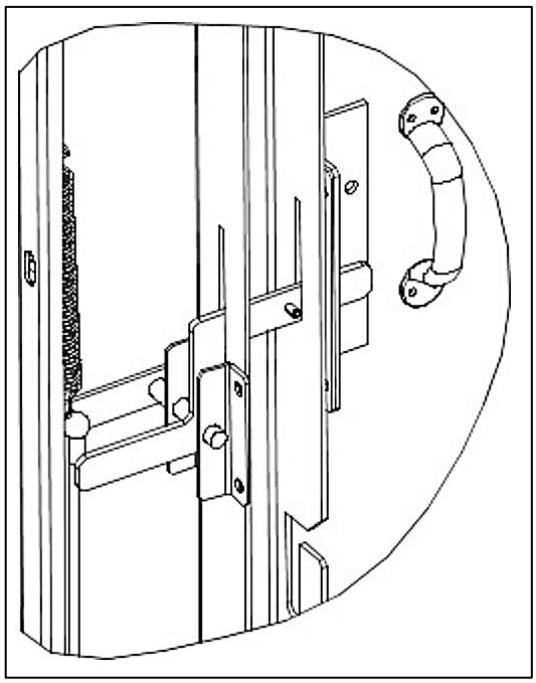
Figure 27. Removing the safety bars. (KONE. 2019-f)



4. Rescue passengers with rescue bridge

1. Open the emergency exit door outside the trapped car.

Figure 28. Exterior opening mechanism. (KONE. 2019-f)



2. If not already marked, mark the fixing points of the safety bars on the emergency exit door frame. Remove the safety bars from the trapped car emergency exit door opening (See Figure 27).
3. Enter the trapped car.
4. Help the passengers one by one across the bridge to the rescue car making sure that the other passengers keep out of the rescue door area.
5. Install safety bars to the trapped car emergency exit door opening (See Figure 27, reverse order).
6. Close and lock the emergency door of the trapped car.
7. Enter the rescue car.
8. Install safety bars (See Figure 27, reverse order).
9. Remove the balustrades of the rescue bridge. Remove the rescue bridge.
10. Close the emergency exit door.
11. Move the rescue car to the nearest landing.
12. Open the doors to let the passengers out of the rescue car.

2.4 Product configuration

Product configuration is a process where a specific combination of a product components are selected from a range of optional components, to form an order specific product, driven by the customers' requirements.

When you go to a deli to order a sandwich, you are buying a product. They will have many different ingredients to choose from, which are your product configuration options. As you are asked what type of ingredients you would like, and you make a selection, you are engaged in a product configuration process where your choices are a requirement to create the sandwich. After you have paid, you are given an order specific configuration of the product, based on your requirements and specification.

2.4.1 Configurable vs non-configurable products

Configurable products are products which have a range of optional components, sizes, shapes, colours and require the customer to make a choice before buying. The product manufacturer needs to understand the customers' requirements, to create the finished, deliverable product.

Non-configurable products do not have any options and do not require a customer to make a choice before buying. Typically, pre-defined products bought from a catalogue or off the shelf.

2.4.2 Configurability

Configurability is a measurement of how suitable the product is for configuration. It is primarily linked to:

- How the product is designed and structured.
- How the supply chain is set up to support a configurable product.
- How the product is represented in IT systems

When understood together, configurability and configuration enable the mass customization of products to meet specific and individual customer needs efficiently and effectively. (ModularManagement. 2022.)

2.4.3 Benefits of product configuration

Speed: By using a product configurator, quotes can be generated faster, in some cases instantly in front of the customer. Many companies measure the quote turnaround time, or RFQ response time, and see it is an important factor in winning the deal.

The product configurator will also generate a more precise configuration directly, meaning that the production and purchase orders can be released faster which in turn reduces the overall order-to-delivery time. In the optimal case, the exact configuration is known already when the quote is generated. (ModularManagement. 2022.)

Quality: The product configurator structures the know-how needed to transform a need into a solution. This has four major quality-related effects:

- Reduce or remove the person dependency when creating the order, by equipping every salesperson with the same necessary know-how. This ensures that the solutions are scoped and dimensioned correctly and that solutions are proposed in consistent ways according to both customer preferences and internal business criteria.
- Continuous improvement of the structured knowledge is enabled. Over time the model can be perfected, and it will always have the latest information.
- When new products, functions, features, or performance levels are introduced they can be simultaneously and instantly available to the entire sales force.
- For complex products, the configurator solver can evaluate far more possible solutions than a sales engineer. The solutions can be chosen closer to the needed specification, optimizing cost and performance. (ModularManagement. 2022.)

Cost: A product configurator can save cost in two ways:

- Person-hours for salespersons and sales engineers by automation of sales and order handling activities.

- Optimal solutions for the given need. By not over-specifying the product " just to be sure", the production cost can be minimized while keeping the required performance. (ModularManagement. 2022.)

2.4.4 Why it's critical for global elevator manufacturers

Elevator systems are highly configurable and extremely complex products which have hundreds or even thousands of parts, some of which are individually configurable in size, shape, colour, and quantity. These products are then offered and delivered to customers anywhere in the world, using many different supply chain and delivery methods, manufactured using many different processes and factories, using many different materials and prices, all the while meeting national and international standards and safety requirements. Manufacturing and delivering elevators in an enormous logistical operation.

The product data is usually maintained in a product data management system as a hierarchical structure known as a bill of materials, where the materials are simultaneously linked to dependant information such as drawings, documentation, raw materials, weight calculations, price indexes etc.

A configurator allows manufacturers to harmonize the vast amount of data between many of the IT systems, into an order specific bill of material, ready for production. This order specific BOM is then used to determine downstream supply chain activities such as make or buy material sourcing, packing and delivery logistics, and even order specific installation and maintenance documentation. Configurators maximize the accuracy of the data, and efficiency of arranging it all in and order specific BOM.

2.5 Standard vs non-standard products

2.5.1 Standard

Typically, in industrial manufacturing, companies will define a standard product range which may have many different options or configurations but have a pre-defined product design.

These are known as “standard orders” and when implemented with design automation, do not require a design engineer to create or modify the product in order to be manufactured.

2.5.2 Non-standard

Non-standard products fall outside the standard range which has been pre-defined and therefore require manual customization by a design engineer, making them “custom orders”.

2.5.3 Why and when they are used by global elevator manufacturers

Standard products utilizing automated processing are, however, extremely expensive and time consuming to create and more expensive to maintain. They are usually created for high volume products where the expense will pay itself off. They are huge product development projects requiring the creation of new product structures in the PDM systems, new configurable 3D CAD models for design automation of manufacturing drawings, aligning the configurations and constraints of PDM and CAD structures, aligning the supply chain infrastructure and creating delivery units, prototyping, conforming with safety standards and regulation. At many stages of the development, extensive testing and data validation needs to be done to ensure there are no errors as the data flows through the structures of both data systems, and the final configuration output is correct.

Non-standard products still need a similar product structure in the PDM, but the order specifications are manually modified in the 3D CAD models for creating manufacturing drawings. Delivery units are also needed but compared to standard products, non-standard products are much cheaper and faster to create as they don’t need all the complex work required for automation and data validation. Because they are usually low volume products ordered infrequently, maintenance is also less expensive.

Both product types are required but which is used in the creation of a new product is determined by feasibility study, comparing the present and future demand vs present creation and future maintenance costs.

2.6 Automated Order Processing

In the previous sections we reviewed the basics of standard vs non-standard products and how we can use a product configurator to harmonize product data between company PDM and ERP systems. This section will give a brief overview of how the product data and configurator are then utilized in AOP, which automates ordering, configuration, and manufacturing processes. This will become relevant later as the 3D models contain data used in this process.

Some manufacturers have product configurators built into their websites for customers to pre-configure their orders. This means after the customer enters their order requirements into the configurator, many of the complex processes discussed in the previous sections can be automated up to the point of factories receiving the manufacturing drawings.

A simple example can be found in the fast-food industry. McDonalds now have self-service kiosks or checkouts, where customers can review the menu, order their food, pay, and track the progress without interacting with an employee until they are handed their order. The customer configures the product and pays. Automated order processing then takes over and manages all the steps which need to be fulfilled to complete the order. Each step is a different task or process completed by each employee and the automated order processing knows in which order the steps need to be done and when they need to be started. This automation process optimizes the efficiency of the whole system.

2.6.1 Ordering

Sales Orders are created when a customer decides to buy an elevator. These sales orders collect all needed data for that specific order such as materials, quantities, prices, delivery/installation location etc. This sales order number is used to track the related information. After the sales order is created, it may contain materials which are outsourced to suppliers, in which case it will trigger the creation of Purchase Orders for those materials.

2.6.2 Product Configuration

PDM systems are where manufacturers will create and maintain most of the product data during its lifecycle and because so much of the product data is there, it is convenient to have the product configuration tool in the same data management system. CAD data usually has a separate system which is then synchronized. Customer requirement data collected during ordering is used as input for the product configuration process.

2.6.3 Design automation for manufacturing

As previously mentioned, elevators are highly configurable products, and many individual components are themselves highly configurable in their size, shape, materials, and colours etc. If individual parts vary in size and shape, how do we efficiently create all these order specific manufacturing drawings?

Manufacturing drawings are created using 2D representations of components, dependently linked to 3D models of that component. This linked dependency means that when the 3D model is modified, the 2D representations in the drawings are automatically updated.

When the 3D model of a component is being created, the ways in which is needs to be configurable are known and defined by the designers. For example, if the length of a part would need to be different for each order, its length can be defined as a parameter/variable instead of being given a specific numerical value. This parameter for example called “part_x_length”, can be given the numerical value instead and the 3D model will then update using whatever value was given to it as an input. This is the basic principle of parametric design or parametric modelling.

By applying this principle to all parts which need to be configured for each order, the order specific parameters and values are sent to the 3D model as input data instead of an engineer manually inputting the data by hand.

Defining the parameters in an intelligent way will allow manufactures to collect the parameter values as customer requirements during the ordering process. At that point, the values can be

sent to the products CAD PDM system, configuring order specific 3D models which in turn generate order specific 2D manufacturing drawings.

These order specific drawings can then be sent to the main PDM system and linked to the materials already configured there.

2.6.3.1 Top-Down Modelling

Top-down modelling is critical for product configuration and design automation.

Top-Down; from system level to substructures is preferred design approach for modular product structure when one of main goals is to manage product variation. The product architecture needs to be first defined with all necessary sub-modules that are designed to fulfil boundary conditions of the architecture.

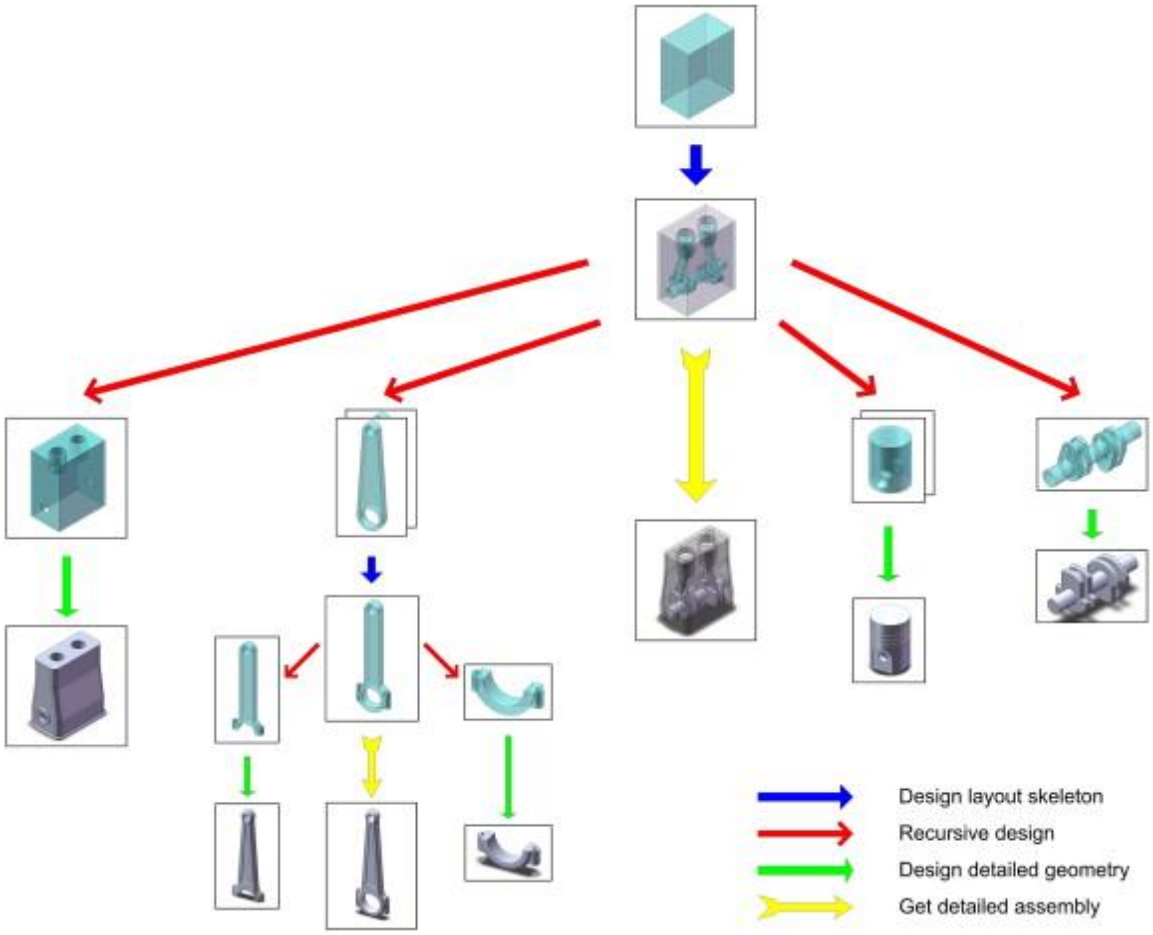
Top-Down modelling with Creo Parametric is based on skeleton technique. Skeleton is predetermined structural framework of the design. With skeleton models, it's easier to capture and define design intent.

Skeletons allow designers to pass along essential design information from one subsystem or assembly to another. This essential design information is either master definitions of geometry or copied geometry from designs defined elsewhere. Any changes made to a skeleton change its reference components as well. The use of a top-level skeleton model allows you to control the flow of information from a central, top-level location (from the top down).

Parameter information is passed from top to down as characteristics.

Individual skeleton models can be used to build the components from the bottom up. This method ensures a robust design with the design information communicated smoothly throughout the assembly. (KONE. 2019-e)

Figure 29. Example of top-down design in mechanical products. (Guo et al., 2012)



The image above shows a basic top-down design for a mechanical product. The top assembly skeleton defines the position and interfaces for lower-level assembly skeletons. The 3D model assemblies and parts are then attached to their respective skeletons. The behaviour of the entire assembly is then controlled by passing parameter configuration data from the top down.

2.6.4 Delivery automation for supply chain

After the product has been configured in the main PDM and CAD PDM systems, all the materials required for that order are known. Some materials are made by the elevator manufacturers themselves, and some are purchased from suppliers. To transport these materials, they need to be secured, wrapped, or boxed in packaging before they can be transported. Content labels, stickers and barcodes are used to track the information of what has been packed into the box, who packed it and to who and where its being transported to.

Some materials need to be transported for example, from supplier warehouses to a factory to be assembled as a complete component or product module before being delivered to the installation location. The content labels, stickers and barcodes are then scanned by the receiving factory telling them exactly what is inside. The materials can then be stocked in the factory shelves, added to the inventory records and ready to be assembled to a larger component, which in turn needs more packing materials such as wooden delivery crates, more labels, stickers, and barcodes for sender and receiver information.

Since the materials and components are different sizes and shapes for each order, that means the packaging materials and wooden delivery crates are too. One of the added benefits of having configurable 3D models is that you know exactly what size and shape your delivery packages need to be and how much they will weigh. Not only will this allow you to have your delivery packages ready in advance and with optimized size and shape - it will also allow you to plan and optimize the transportation process as the exact dimensions and weight are known in advance.

Supply Chain Management is used to manage the complex logistics outlined above and is the backbone of large industrial manufacturers. It is involved in almost every step of the entire manufacturing process, from the raw materials, to finished product. Creating and including the sourcing and delivery data required by the supply chain, to the product materials in the PDM, also allows configuration and automation of this crucial management system.

2.6.5 Order Orchestration

To effectively automate these ordering processes, data systems product configurations and complex logistical requirements, they need to be executed at the correct time, and in the correct order.

Order Orchestration manages the automation of sequential steps required to process an order and the actions which need to be fulfilled in each step.

2.7 Data validation & testing

Orchestration of these automated processes across multiple data systems requires a lot of careful testing. Major testing is done throughout the course a product development project at specific milestones, but continuous testing can also be done on day-to-day activities, especially 3D modelling.

2.7.1 Continuous 3D model testing

Design engineers creating parametric 3D models understand the requirements and function of the models and will continuously test as they design. This helps to reduce the workload in the next testing phase and creates confidence in the quality of the models they are creating. Some 3D modelling software have very powerful built-in testing capabilities, for running detailed geometric interference and constraint analysis.

2.7.2 PDM and CAD alignment

When the product structure has been created in the PDM and CAD PDM systems, order configurations first takes place in the PDM and then CAD PDM second. They are two identical structures being configured independently and must produce the same output BOM. There is dedicated software for testing exactly this, which creates test orders in the PDM systems and will compare the output BOM's of both configured structures 1 to 1 and highlight errors and inconsistencies. This testing phase also tests system level data used for other data management functions but primarily focuses on the product structure comparison.

2.7.3 Full chain validation

Full chain testing is perhaps the largest testing milestone as it tests the automated ordering process and entire range of data systems used for order handling, product configuration and manufacturing automation.

2.7.4 Factory prototyping

One of the final major testing milestones is creating a test order to be actually manufactured. This will test factory level data systems integration with full chain systems but also ensure the design automation is creating the correct data in manufacturing and assembly processes. Full scale prototypes will be created and for new products, can be used to create assembly and installation instructions.

2.8 PTC - Creo Parametric & Windchill

Creo Parametric is a 3D CAD software created by a company called PTC, used by design engineers around the world to create 3D models of products. The software is very advanced and can be used to analyse many design parameters in great detail which allows for better designing and product development. There are many advantages of using 3D models for product lifecycle management and product development and Creo allows accurate 2D manufacturing drawings to be easily created from 3D models.

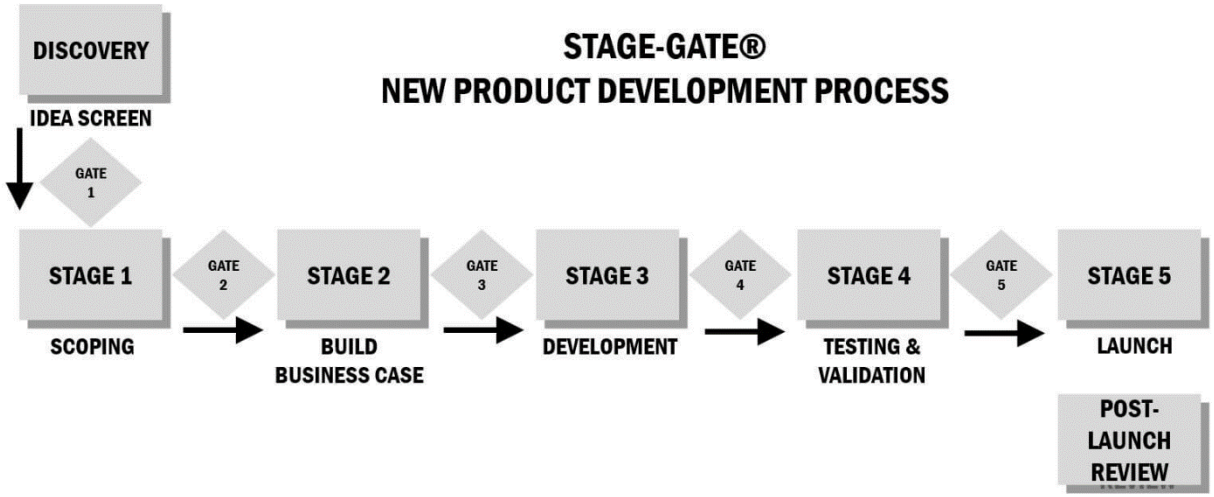
Why Creo is a market leader:

- PTC lead innovation of parametric 3D modelling software for engineering and raised the standards of quality that engineers could achieve.
- The software integrated with other software, tools, and file types.
- Creo is recognized as a leader of model-based definition (MBD) and has made advancements in related topics of generative design, real-time simulation, and additive manufacturing.
- PTC has invested heavily in creating an easy-to-use software for engineers and has a wide variety of free or paid learning tools available online.
- Creo software is available in different price ranges depending on need and size of company, making it competitively priced at each level of industry.
- Creo can be used with other PTC software solutions like Windchill PLM, ThingWorx IoT, and Vuforia AR.

PTC Windchill - Product data management platform used to store 3D models and a very powerful tool to create, develop, maintain, and revise product CAD data.

2.9 Product development process in industrial manufacturing

Figure 30. New product development process. (Cooper.2007)



2.9.1 Stage Gate Development Process

The Stage Gate Process has six main phases of product development known as Discover, Scoping, Define Business Case, Development, Testing and Validation and Launch. Between each stage is a gate where testing can be done to determine if the product development can proceed to the next stage or not.

In the Stage Gate Process, project managers and stakeholders evaluate the testing between each phase and analyse all metrics to determine to next course of action. It was developed in 1960 by The American Association of Cost Engineers and also used by NASA. It was originally created as a waterfall management process and later updated to integrate with agile and lean philosophies.

Stage 0: Idea Generation

Stage zero is the introduction to the project and the teams learns what the project objectives are. Stage zero uses qualitative, quantitative and market research, ideation processes and problem definition tools.

Stage 1: Scoping

A team creates a clear definition of the problem the project aims to solve. In this Stage, the team determines the feasibility of the project outcome. SWOT analysis is a commonly used tool which helps evaluate a project based on strengths, weaknesses, opportunities, and threats.

Stage 2: Build Business Case

Once team creates a clear definition of the solution, they can then create a product definition and analysis, a business case, a project plan, and a feasibility review. Tools like the Business Model Canvas can be used to create a clear business case and convince stakeholders of the project's viability.

Stage 3: Development

The team uses the plan and data from previous stages to create a prototype. This Stage is helped by using the SMART factors - specific, measurable, actionable, realistic, and time to keep the project moving and on time.

Stage 4: Testing and Validation

Stage is when the prototype is tested, issues are found, improvements are made, and any flaws are hopefully flushed out. After this first testing is completed and issues are fixed, the prototype can then be testing in the customer environment.

Stage 5: Launch

Once the testing is complete and all stages are finished the product can be launched/released into production and implemented to the suppliers and market etc

Description of the Gates

"*Between every two stages, a Gate is used to validate and test the outcome of each Stage and ensure it meets the requirements. The process at each Gate includes three main steps:*

- ***Input:*** *The deliveries from the previous Stage will be evaluated in this specific Gate.*
- ***Criteria:*** *The metrics and the KPIs will evaluate the deliveries.*
- ***Output:*** *The evaluation results and the decision to move to the following Stage or return to the previous.*

Based on the output of the above three steps, there are five decisions based on the Stage evaluation:

- ***Go:*** *The team can go to the following Stage.*
- ***Kill:*** *The project is not feasible enough, and it needs to end.*
- ***Hold:*** *the project will be halted because of a specific reason.*
- ***Recycle:*** *A few amendments are needed before moving to the following Stage.*
- ***Conditional Go:*** *The development can go forward based on a conditional statement (i.e., apply specific modifications)*". (designorate.2023)

2.9.2 Requirements

Requirements in product development projects are the specific needs and desires of all the stakeholders involved. They are the detailed functions, features, and design characteristics that the product is expected to have.

In global industrial manufacturing development projects, companies usually use a dedicated requirements platform to collect, define and manage all these requirements throughout the project development.

2.9.2.1 Jama Software

"*The Jama Product Development Platform is an integrated solution for guiding the strategic and operational aspects of complex product development. It supports the entire product development lifecycle from idea to launch. It gives product leaders the ability to view patterns*

of risk and opportunity across projects, teams, and time. And it integrates with the workflows and technologies teams know and enjoy best". (Ansys. 2023.)

3 OBJECTIVES, PURPOSE, AND UTILITY

The main objectives of this product development project are:

- Convert an existing product, designed for one ordering process type to another.
- Evaluate the conversion process and feasibility.
- Build a prototype to validate the manufacturing and assembly the converted product.

3.1 The *product*

Objectives:

- Convert the existing product 3D design from being manually configured to automated.
- Modify the 3D design to include the configuration and design automation requirements of the automated order management process.
- Build a prototype to validate manufacturing and assembly process.

Why the product is needed as a standard product:

- The conversion from non-standard to standard is needed to create the design automation step required to implement the product into the automated order management process.
- To be ordered, configured, and manufactured without manual/custom engineering.
- To harmonize and integrate the automated configuration of the product with existing standard elevator cars.

How and where the product be utilized:

- It will be utilized as a pre-defined emergency exit product suitable for ordering with the existing standard elevator car products, to which it is assembled.
- It can be ordered, configured, and manufactured in a single elevator system order.
- It will be utilized in the global elevator market as an emergency exit system for Kone elevator car products.

3.2 The *conversion process*

- Evaluate the product design conversion process and practices.
- Evaluate the configuration and design automation requirements of a non-standard product.
- Evaluate the feasibility for similar, future development project.
- Evaluate potential improvements to the conversion process and practices.

Why the conversion process is needed:

- The existing non-standard design does not meet the requirements for design automation and cannot be used in the automated order management process.

How and where the conversion process be utilized:

- It will be utilized to change the current product design to meet the requirements of a standard product.
- It can be utilized in any product development project needing to convert a non-standard product design to a standard design.

4 PLANNING AND EXECUTION

The following section outlines the planning and implementation phase. Understanding what needs to be done and how to do it. The collection of product, practices, and process knowledge needed to carry out the work. Formulating and prioritizing the steps and actions needed to fulfil the stakeholder requirements. Identification and mitigation of risks. Carrying out the conversion process and how it was done. Final testing of 3D models, validation, and publishing of manufacturing drawings for prototyping.

4.1 Getting started

Planning a product development project for a product that contains many technical parts and assemblies, requires a lot of reviewing before planning the actual work. Product knowledge and documentation can be extensive, even for seemingly small or simple products.

4.1.1 Tools used and their function

Creo	3D modelling software used by Kone.
Windchill	CAD product data management platform integrated with Creo.
PTC support	Technical support for Creo and Windchill.
PDM	Searching and retrieving parameters and product data.
Jama	Product development platform used for requirement management.
MS OneNote	Used to collect temporary situational data and improve workflow.
MS Excel	Used for collecting large sets of data to improve workflow.
MS Teams	Used for meetings and frequent chat with project manager and also some meetings with stakeholders.
MS Outlook	Used as main communication tool for stakeholders etc

4.1.2 Project and product introduction

The project was started with alignment meetings via Microsoft teams facilitated by the project manager from Kone. Introductions to the project and product were given by the Kone personnel responsible for the project and product. The main objectives, methods, and the tools needed to carry out the work were outlined. The technical information needed to be reviewed independently in more detail.

After the initial introduction and technical documentation review, the product and project requirements were evaluated in more detail after gaining the basic background knowledge.

After the main objectives and requirements were clearly understood, the planning then begin. Main steps to fulfil the requirements were identified and prioritized. These steps formed the structure of the workflow and order of implementation.

4.1.3 Where does this project fit into product development process

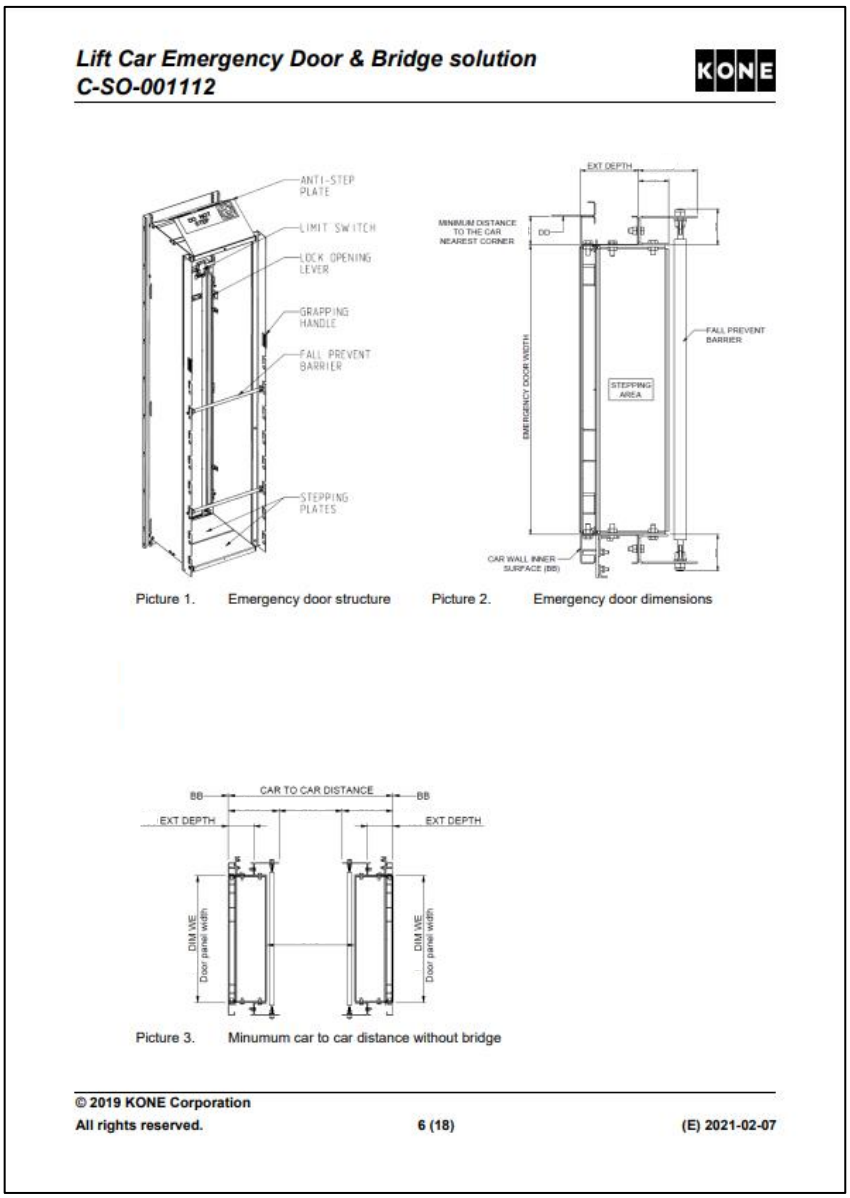
As this development project is a conversion process of an existing design, the entire product development process is not applicable. In this case, the scope for the project will re-develop the existing product from stage 3 and 4 of the stage-gate new product development process.

4.1.4 Understanding the product

C-SO-001112 – Emergency door Custom engineering instructions

After the project introduction, the product material was then available for review. The main product document used is an engineering instructions manual created by Kone for custom engineering and order instructions, C-SO-001112, which has been reviewed in section 2.3. This document gives a description of the product and information required for ordering. It also provides necessary engineering instructions needed to modify the design based on order requirements, safety codes, door types, bridge type, car to car distance, min/max constraints, interfaces with car, shaft layout interference check instructions, location of 3D models and parameter definitions.

Figure 31. Example of engineering instructions document. (KONE. 2021-d)



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Picture 1. Emergency door structure

Picture 2. Emergency door dimensions

Picture 3. Minumum car to car distance without bridge

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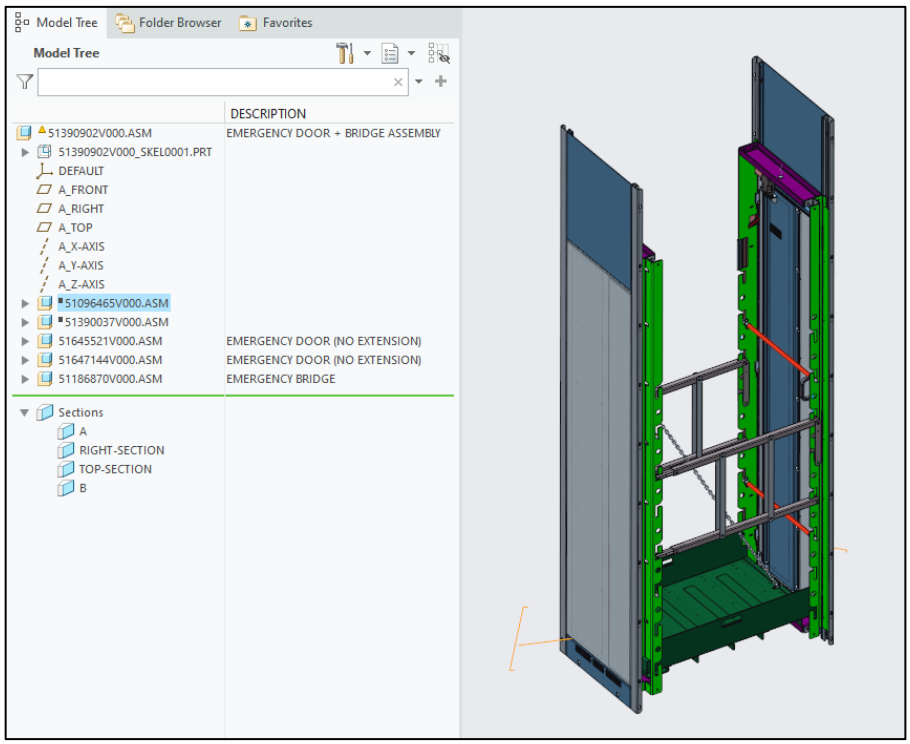
Reviewing the existing 3D model

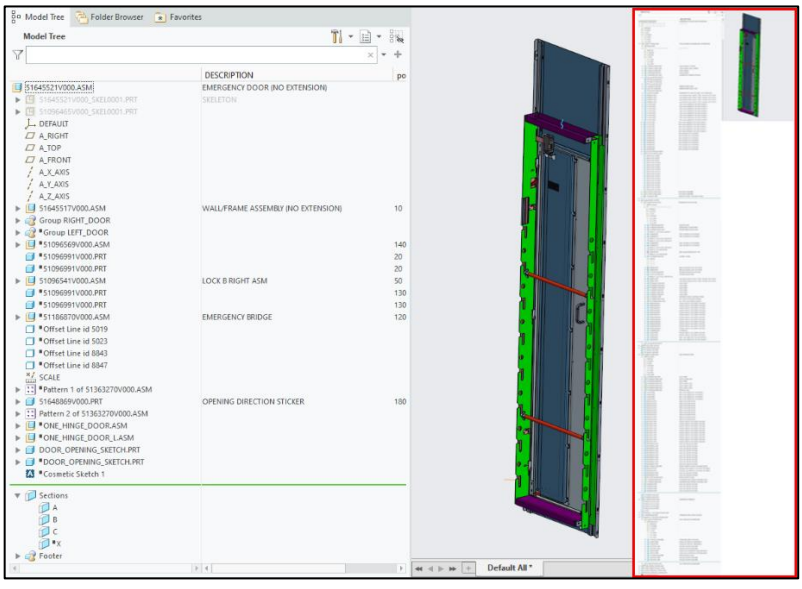
The 3D models required a lot of revision. When a product has been designed previously by another engineer, a lot of revision is required to analyse how the model architecture has been created and what existing level of configurability exists and if any, what parametric modelling practices have been used. This deep understanding of how the existing product has been created is a requirement before making any new modifications, because an engineer must understand how the design has been created, in order to identify the risks associated with changing it.

Figure 32. Original main assembly in Creo



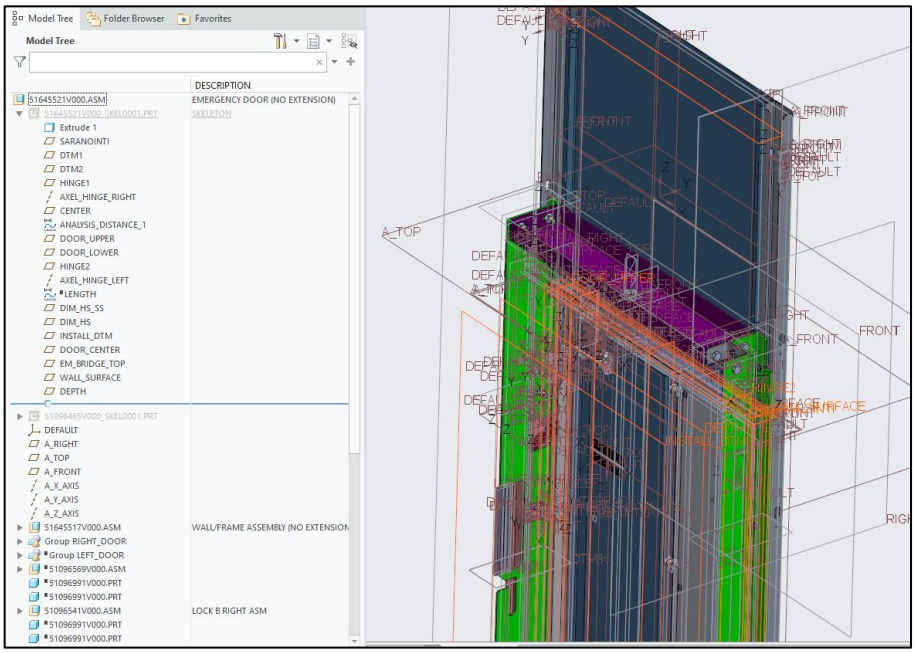
The image above shows the doors without extension, with bridge attached. Doors with extension are the first two sub-assemblies in the model tree, which are suppressed. The main assembly also has its own skeleton CAD model where the main interfaces are defined, to control the position of the sub-assemblies. This 3D model does not have the requirements needed to automatically configure to an order specific design.

Figure 33. Door assembly and expanded BOM in Creo



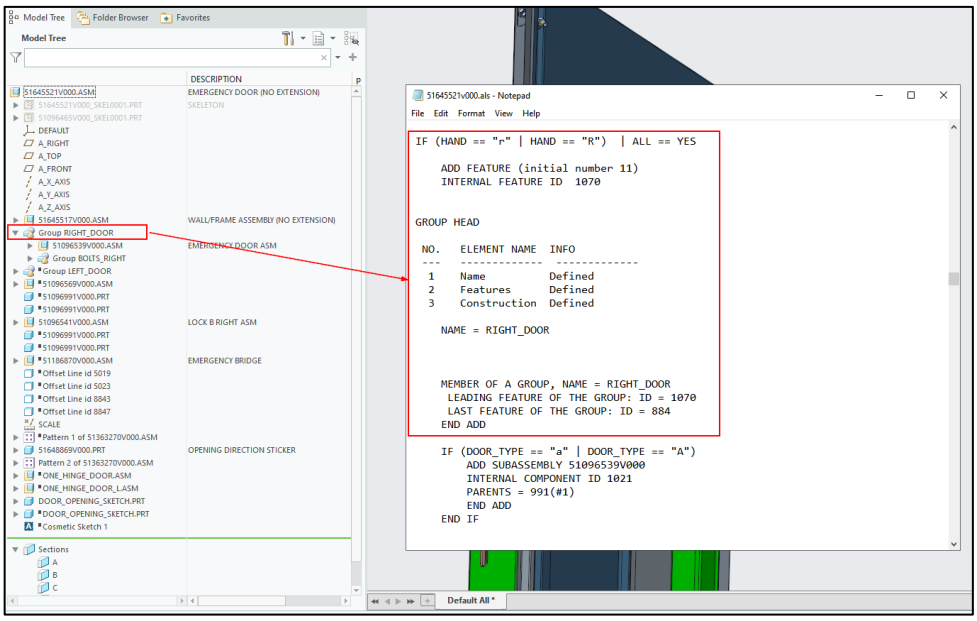
The individual door assemblies start to get complicated. Expanding some of these sub-assemblies within the door structure quickly created a long list of materials. Not all the sub-assemblies are expanded on the right image in red, and some also have left and right-handed variations.

Figure 34. Expanded skeleton with highlighted datums in Creo



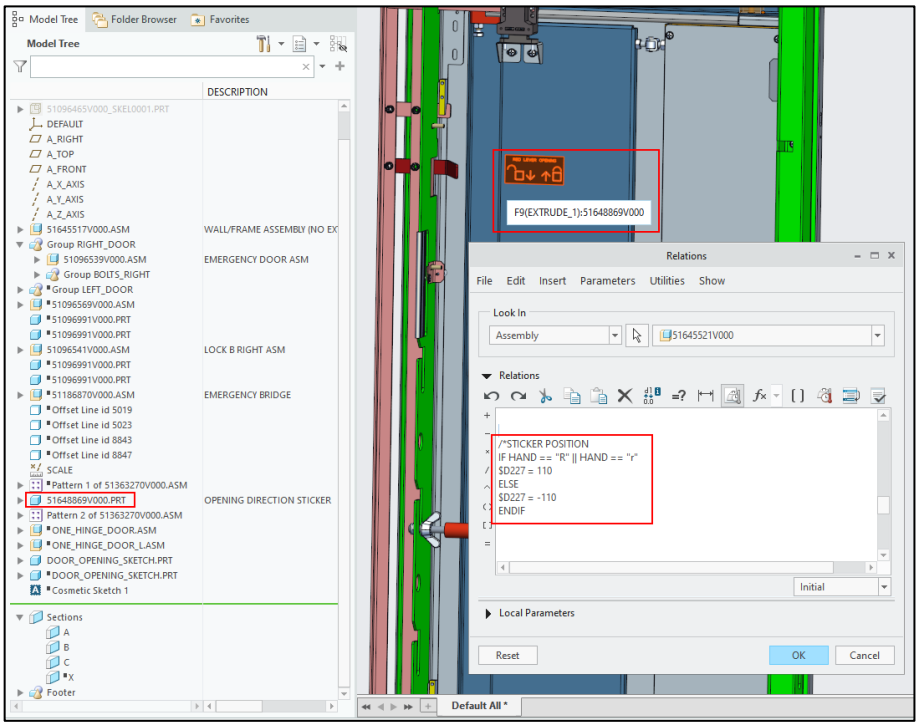
Expanding the skeletons also shows quite many datum planes and references are needed to create the interface logic of the sub-components. Here only planes and coordinate systems datums are visible. The datums highlighted in orange belong to main assembly and other belong to subassemblies. Every assembly should have its own skeleton. Skeleton models can be also inserted to other assemblies that are not its own.

Figure 35. Sub-component BOM configuration in Creo



In Creo parametric, the activation and deactivation of sub-components in an assembly in configured by an internal program script which designers can modify. Parameters are used to create simple “IF” and “ENDIF” logic statements to produce a true or false result. In the example shown above, the parameter “HAND” stands for handedness and its value was set to “R”. The statement in the program is true so the object is activated in the model tree.

Figure 36. Relations script to configure component behaviour in Creo



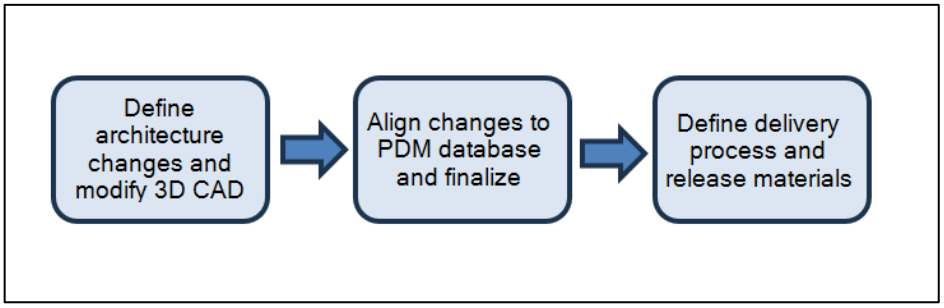
In addition to the program, Creo also has another script user interface for configuring component behaviour using the same parameters, but the logic statements are defining changes to dimensions used in the models. In the example above, the same “HAND” parameter used in program to activate the left- or right-handed component, is now used to change the position of a sticker attached to the door when the handedness changes. “D227” is the dimension identification number created by the software and refers to the distance of the sticker from a datum plane.

All these configuration rules need to be evaluated throughout the entire model. There are about 53 unique assemblies and 80 unique parts, of which many are used multiple times in various assemblies and sub-assemblies. All assemblies and parts have at least one drawing and many have two or three.

4.1.5 Understanding the process

Kone have their own internal product development processes and also well-defined 3D modelling practices and work instructions. They have created a modelling body of knowledge which defines the modelling methodology for creating both standard and non-standard product.

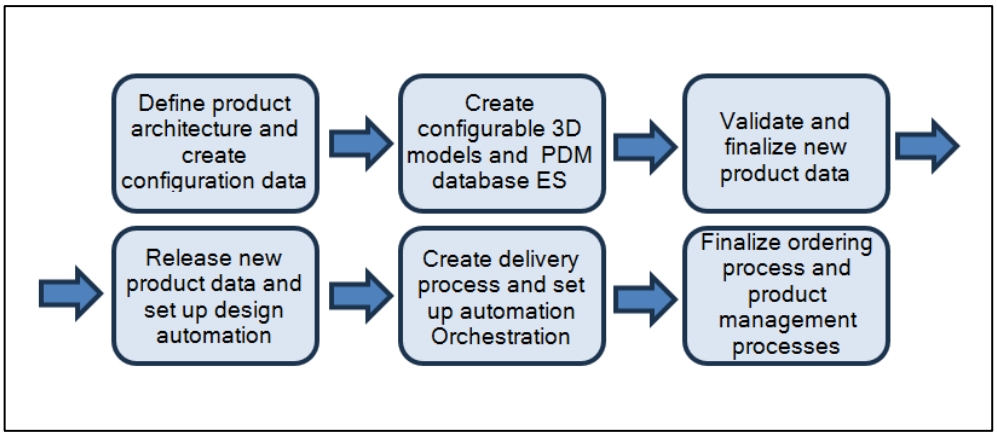
Figure 37. Non-standard modelling method defined by Kone. (KONE.2023-g)



As defined by Kone, non-standard models are usually taken from existing standard products and modified. In this case, the emergency exit system was originally design as a non-standard product, not standard.

To start the product conversion process for this project, the existing non-standard 3D models must be modified to function according to the standard modelling steps below in Figure.38.

Figure 38. Standard modelling method defined by Kone. (KONE.2023-g)



As the scope of this project is to change how the product can be ordered and configured, the actual geometrical design of physical parts should not need to be changed. The focus will be on steps 1 to 3 with local data validation of configuration rules done in Creo software.

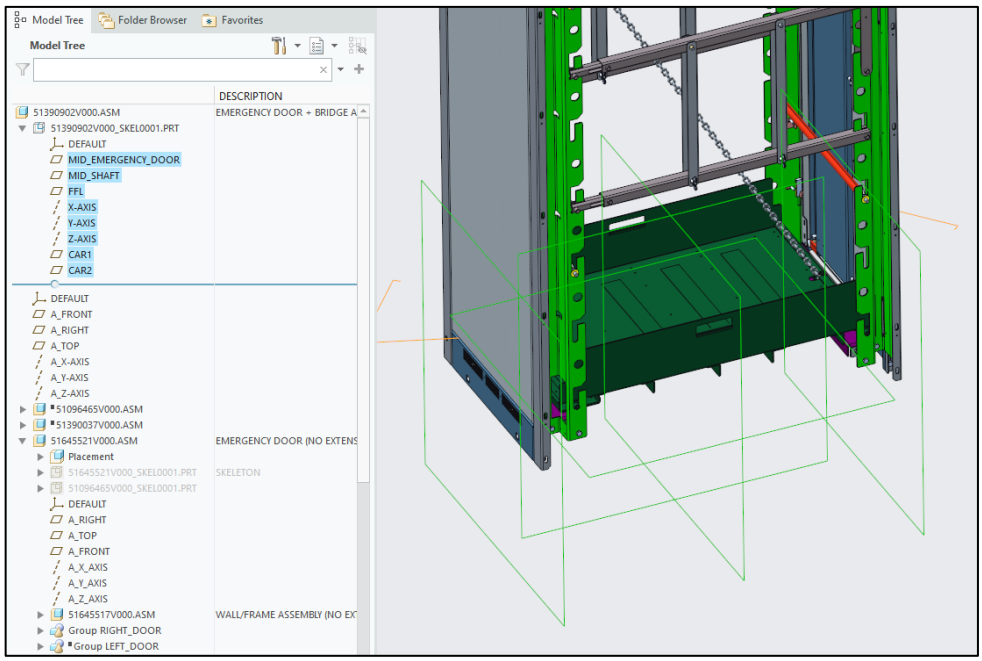
4.2 Requirements

This section reviews the requirements of stakeholders, and details what needed to change from the original non-standard design. Requirements are managed using JAMA by Kone.

4.2.1 Doors position architecture changes

Currently when the emergency door is ordered, the engineer making the modification need to know what car it will be ordered for and how it will interface with that car design. Only basic datum planes exist for positioning the doors.

Figure 39. Main assembly skeleton datums for door position in Creo



Additional datum interfaces need to be created to improve and automate the alignment and configuration of door and car 3D models. All Kone cars have defined wall panel names and position. The door should be modified so it can be configured to replace any of the wall panels. In the figure shown above, the doors are positioned as they would be if installed on two cars. The model needs to be modified so it can be included and configured as an independent modular component to each car. An additional requirement was the need to order two emergency doors, one on each side of a single car in cases where there are three shafts with three cars side by side and being able to exit from the centre to either side.

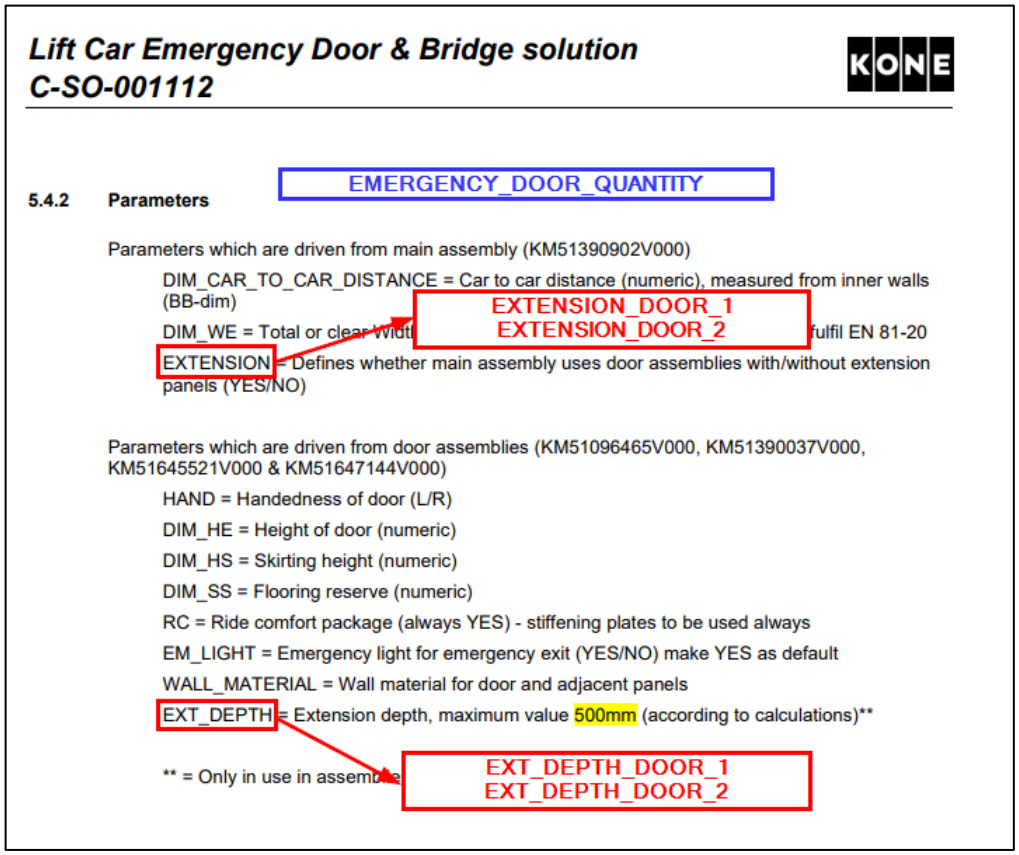
4.2.2 Alignments required for standard process

In order to utilize the product as a standard product, it must be configured using parameters used by Kone in the standard process. Some of the parameters currently used in the model are locally created parameters which exist only in the model and therefor need to be changed or replaced. The location of these parameters and how their values are passed from one assembly to another also needs to be aligned with top-down modelling practices. Specific system attribute data, material selection and flat state dimensions are also required to be aligned for all parts and assemblies.

4.2.2.1 New parameters needed

Some of the new requirements for door positioning, door quantity, bridge quantity, door extension and depth requirements, door handedness etc, require entirely new parameters to be created and added to the product database. The current parameters are also only applicable to one door. The requirements need to fulfil parameters for two doors which makes some of these existing parameters redundant in this case.

Figure 40. Example of parameters required (KONE. 2021-d)



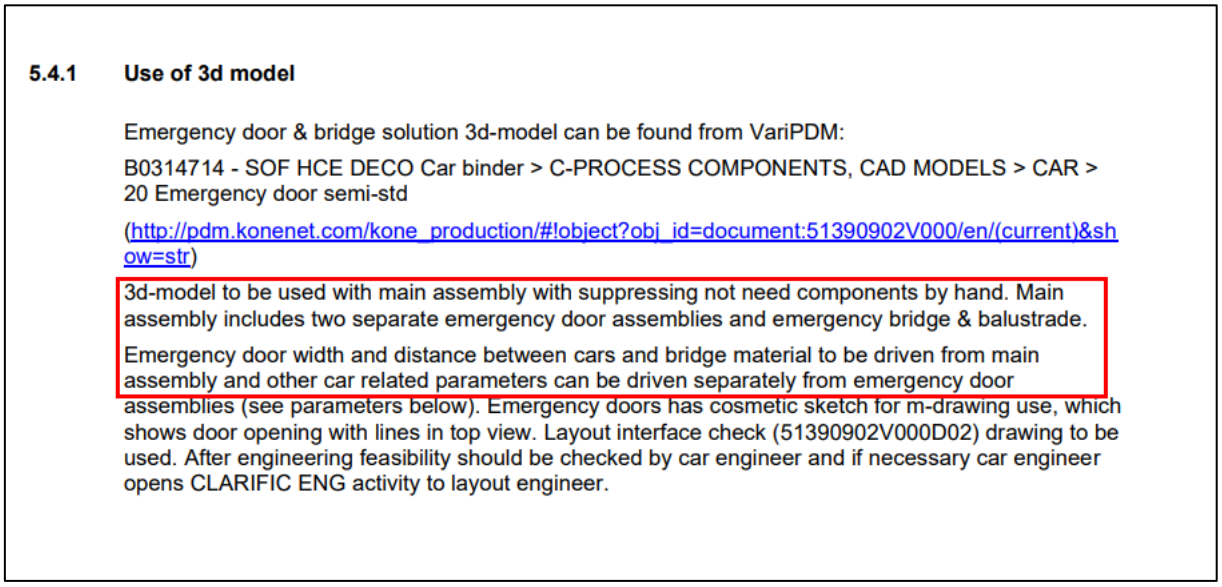
In the example above, the red parameters need to be created to replace the existing, which applies to only one door. The parameter in blue does not exist and is now needed as one or two doors could be ordered per car.

4.2.2.2 Data flow & Top-down design

To ensure the model can be configured without manually modifying any components or sub-components, all the parameter values requires in the entire model must exist on the top level or main assembly. All sub-assemblies and parts which are configurable, must receive the parameter values from the top level. This ensures consistent parameter data and values flow correctly throughout the model. When an order is placed, the parameters are first sent to the PDM product structure to configure and then sent to the 3D model, where they are received by the top level, main assembly.

The main engineering instructions for the current emergency door, review in section 2.3, states that components which are not needed should be suppressed “by hand”, as show below. This is not aligned with design automation and top-down design so configuration rules must be created for these components.

Figure 41. Manual configuration noted if engineering instructions (KONE. 2021-d)



5.4.1 Use of 3d model

Emergency door & bridge solution 3d-model can be found from VariPDM:

B0314714 - SOF HCE DECO Car binder > C-PROCESS COMPONENTS, CAD MODELS > CAR > 20 Emergency door semi-std

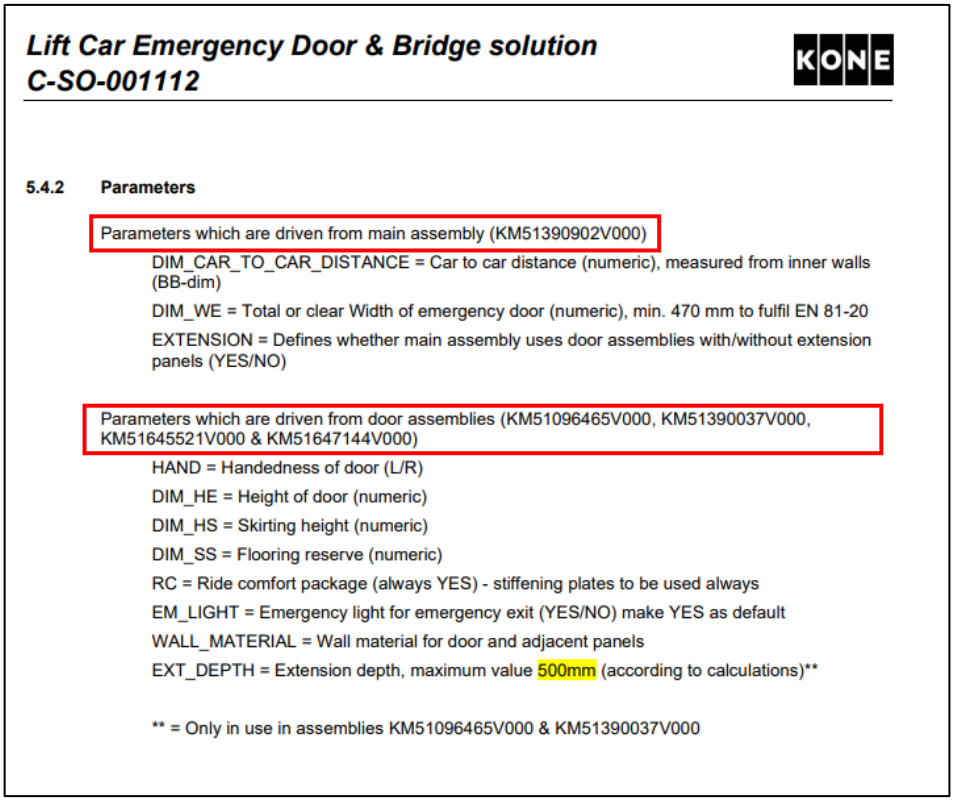
(http://pdm.konenet.com/kone_production/#!object?obj_id=document:51390902V000/en/(current)&show=str)

3d-model to be used with main assembly with suppressing not need components by hand. Main assembly includes two separate emergency door assemblies and emergency bridge & balustrade.

Emergency door width and distance between cars and bridge material to be driven from main assembly and other car related parameters can be driven separately from emergency door assemblies (see parameters below). Emergency doors has cosmetic sketch for m-drawing use, which shows door opening with lines in top view. Layout interface check (51390902V000D02) drawing to be used. After engineering feasibility should be checked by car engineer and if necessary car engineer opens CLARIFIC ENG activity to layout engineer.

The list of parameters shown below indicates which parameters are in the main assembly and door sub-assemblies. Since the parameters in door assemblies do not exist in main assembly, the values cannot be passed down. The engineering instructions also state that components which are not needed should be manually supressed.

Figure 42. Parameters currently in the model (KONE. 2021-d)



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C-SO-001112

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5.4.2 Parameters

Parameters which are driven from main assembly (KM51390902V000)

DIM_CAR_TO_CAR_DISTANCE = Car to car distance (numeric), measured from inner walls (BB-dim)

DIM_WE = Total or clear Width of emergency door (numeric), min. 470 mm to fulfil EN 81-20

EXTENSION = Defines whether main assembly uses door assemblies with/without extension panels (YES/NO)

Parameters which are driven from door assemblies (KM51096465V000, KM51390037V000, KM51645521V000 & KM51647144V000)

HAND = Handedness of door (L/R)

DIM_HE = Height of door (numeric)

DIM_HS = Skirting height (numeric)

DIM_SS = Flooring reserve (numeric)

RC = Ride comfort package (always YES) - stiffening plates to be used always

EM_LIGHT = Emergency light for emergency exit (YES/NO) make YES as default

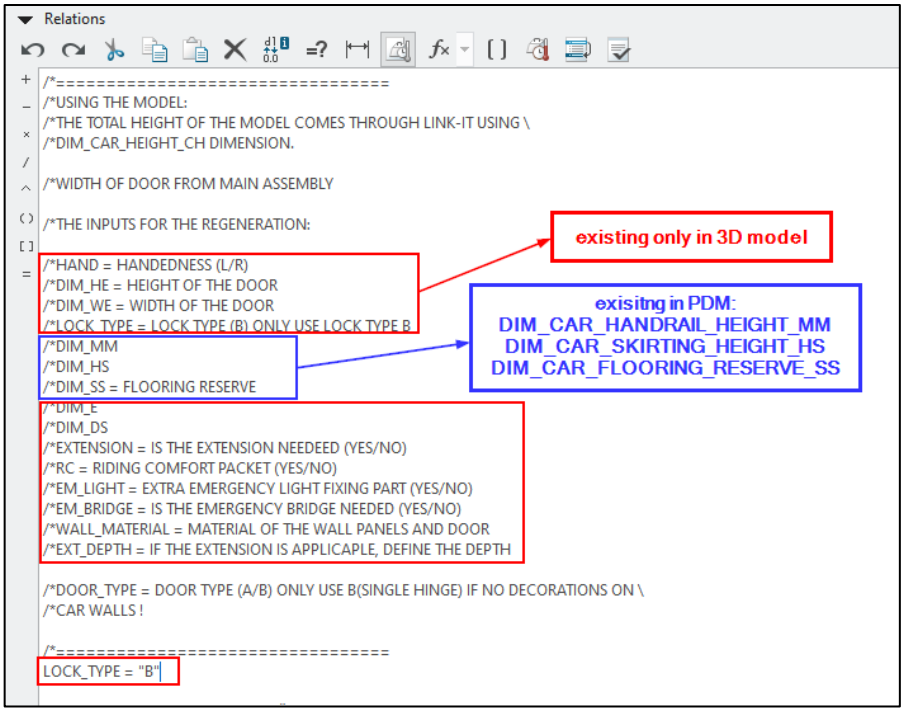
WALL_MATERIAL = Wall material for door and adjacent panels

EXT_DEPTH = Extension depth, maximum value 500mm (according to calculations)**

** = Only in use in assemblies KM51096465V000 & KM51390037V000

4.2.2.3 Replace local parameters with existing

Figure 43. Example of parameters used in door assemblies in Creo



In the example above, the parameters were searched from the company database and parameters in blue were found to already exist. Parameters in red need new parameters to be created. Creating local parameters is a normal and useful practice in non-standard modelling.

4.2.2.4 System attribute alignment

System information (attributes) for categorization of components needs to be aligned also, this data includes components type, part or assembly, unit of measure, configurability, design origin etc. These need to be checked and missing data added.

4.2.2.5 Flat state dimensions

Sheetmetal is used throughout the elevator systems, including cars and this emergency exit. Sheet thickness, length and width are critical parameter values used throughout the configuration and manufacturing process. These dimensions need to be created as parameters for every sheet metal or flat plate parts.

4.2.2.6 Material selection from skeleton

Some parts like visual wall panels have a range of different materials and surface finishes which can be used. Ideally the material selection is configured using a skeleton which lists all the available materials and makes a selection based on a parameter value as an input during configuration. Currently the model does not have this functionality. A universal skeleton already exists and needs to be added to the main assembly and parts having configurable material selection need to be able to receive the correct data from the skeleton.

4.2.3 Door opening mechanism

Currently there is no functionality in the model to show mechanical movement of the door rotating about its hinges. The engineering instruction suggest manually modifying the

connection constraints in the models, but this is very tedious manual work. This requirement will allow temporary movement of components.

4.2.4 New parts needed

As discussed earlier in section 2.3.5.2 and shown in figure 20, manual modifications need to be made to the model and in particular, panels which collide with car interior decoration when the door is being opened. The engineering instructions suggest copying an opposite panel, rotating it, and removing one of its flanges manually. The requirements will involve creating additional panels, frame supports and creating configuration rules so they will activate when needed and eliminate the need for the manual work in future.

4.2.5 Uploading 3D models to Windchill

As stated in the engineering instructions, the 3D models for this product are currently stored in the main PDM database. This database does not support the viewing or use of 3D models. The 3D models must be downloaded to an engineer's local hard drive to be modified. Kone used PTC Windchill application which is integrated with Creo as a CAD PDM where 3D models and drawings are stored.

Usually, 3D models are created in Windchill first and when ready, synchronized to the main PDM database. In this case the product CAD data in windchill can be used to build the PDM structure.

4.2.6 Drawing validation

How to get started, tools to use, collecting 3D models and understanding what the requirements mean.

4.3 Planning the work

Various meetings were held with the project manager, product owner, and engineers with previous product experience, where the requirements were refined in more detail to plan the actionable steps needed to carry out to work.

4.3.1 Refining requirements into actionable steps

Uploading 3D models to Windchill

- The models need to be first downloaded from the PDM database and location is given in engineering instructions C-SO-001112
- A new folder needed to be created in Windchill to locate the 3D models
- The models can then be uploaded from the local hard drive to the Windchill database

- During the upload process, create new CAD data files which will be sent to main PDM by selecting “auto associate” during final upload step. This creates an additional data file in windchill that contains model attribute data but no 3D data

Doors position architecture changes

- Create new datum planes in main skeleton for C, B and D wall interfaces
- Create new datums planes to define the emergency exit doors offset from C wall
- Configure the door offset datums to satisfy positions of door when it replaces the car wall panels B1, B2, D1 and D2
- Reposition the existing doors in the 3D model to the new positions defined by the new datum planes

New parameters needed

- Identify new parameters need for new requirement
- Identify existing parameters which no longer satisfy the new requirements and need to be replaced with new ones
- Create new parameter request from Kone Material Management
- When ready, add all new parameters to main assembly

Data flow & Top-down design

- Collect and define configuration rules which exist in multiple subcomponents and move rules to main assembly skeleton
- Pass the configuration result from main assembly skeleton back to original component
- Create configuration rules in program to align with new requirements

Old parameters changed new parameters

- Locate and identify the old locally created parameters and define them as being equal to newly created ones used in main skeleton
- Ensure parameters are passed correctly from skeleton to subcomponent

System attribute alignment

- Review required system attributes in Creo from manage properties of every part and assembly and align if data is missing

Flat state dimensions

- Review all sheet metal and flat bar materials and verify they have DIM1,2,3 parameters and add if missing
- Regenerate the model and verify the correct dimensions are passed back to the parameters

Material specification from skeleton

- Add “Generic Raw Material” skeleton to main assembly
- Add required newly created parameters needed to use “Generic Raw Material” skeleton
- Locate and identify all components which have visible surface and require configurable material selection from “Generic Raw Material” skeleton
- Define components local material parameter equal to required parameter from “Generic Raw Material” skeleton
- Test and verify the correct parameter values are being received by the relevant component

Mechanism opening

- Locate and identify parts which need to rotate in model
- Redefine assembly connections with "pin" connection type
- Define max and min rotation of each part
- Test opening mechanism in 3D model using Creo "grab component" function

New parts needed

- Review engineering instructions on how decoration modification are made and identify panels to be copied
- Copy the 3D models and drawings and create new material identification numbers
- Make the needed modifications to the new 3D models
- Add the new models to the existing assembly and create configuration rules

Drawing validation

- Review all part and assembly drawings for visible errors
- Test and validate the correct material code and specification is passing from skeleton to model then model drawing information table

4.3.2 Order of actions

The order in which to complete the actions need to be considered as some of the tasks are dependent on each other. For example, the drawings cannot be validated until the material selection from skeleton has been completed. After collaborating with the project manager, we agreed the tasks should be carried out in the following order:

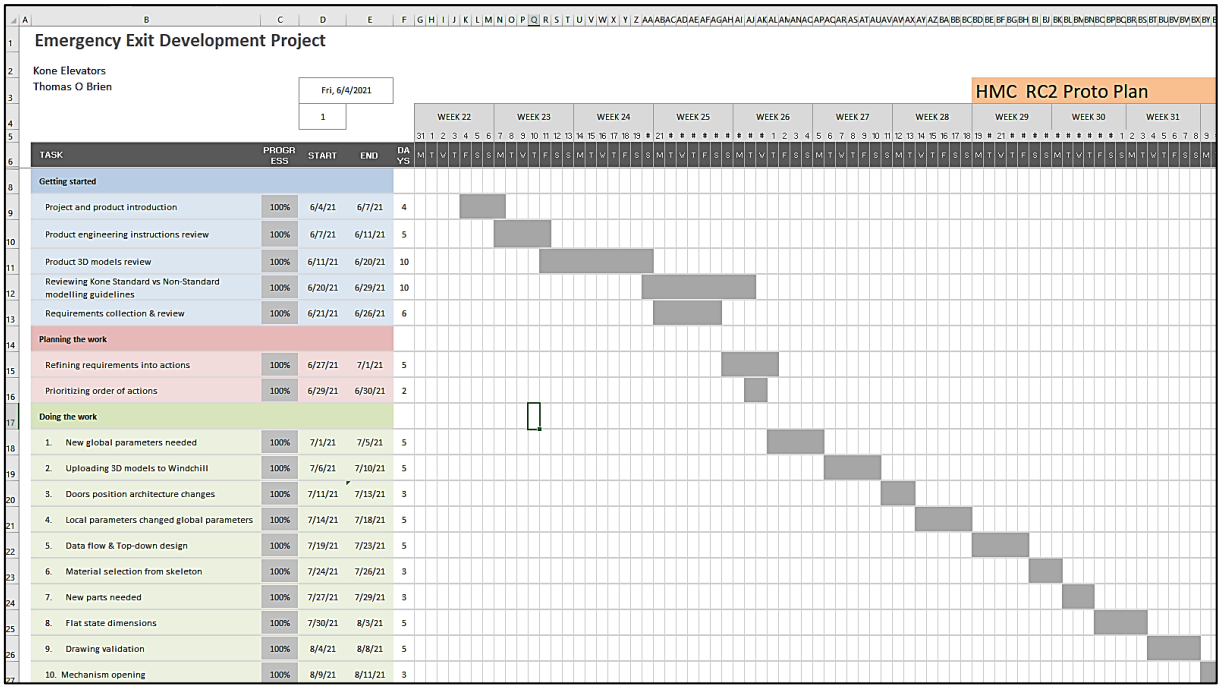
1. New parameters need to be created
2. Uploading 3D models to Windchill
3. Doors position architecture changes
4. Local parameters changed new ones
5. Data flow & Top-down design
6. Material selection from skeleton
7. New parts needed

8. Flat state dimensions
9. Drawing validation
10. Mechanism opening
11. System attribute alignment

4.3.3 Project schedule

I created a project schedule using a simple Gantt chart template from excel. The workload for each task was estimated and updated once the task was complete. The project was carried out in parallel with an internal Kone product development project which was included above the weeks. The emergency door prototype was dependant on this larger project related to the car.

Figure 44. Gantt chart used for project schedule



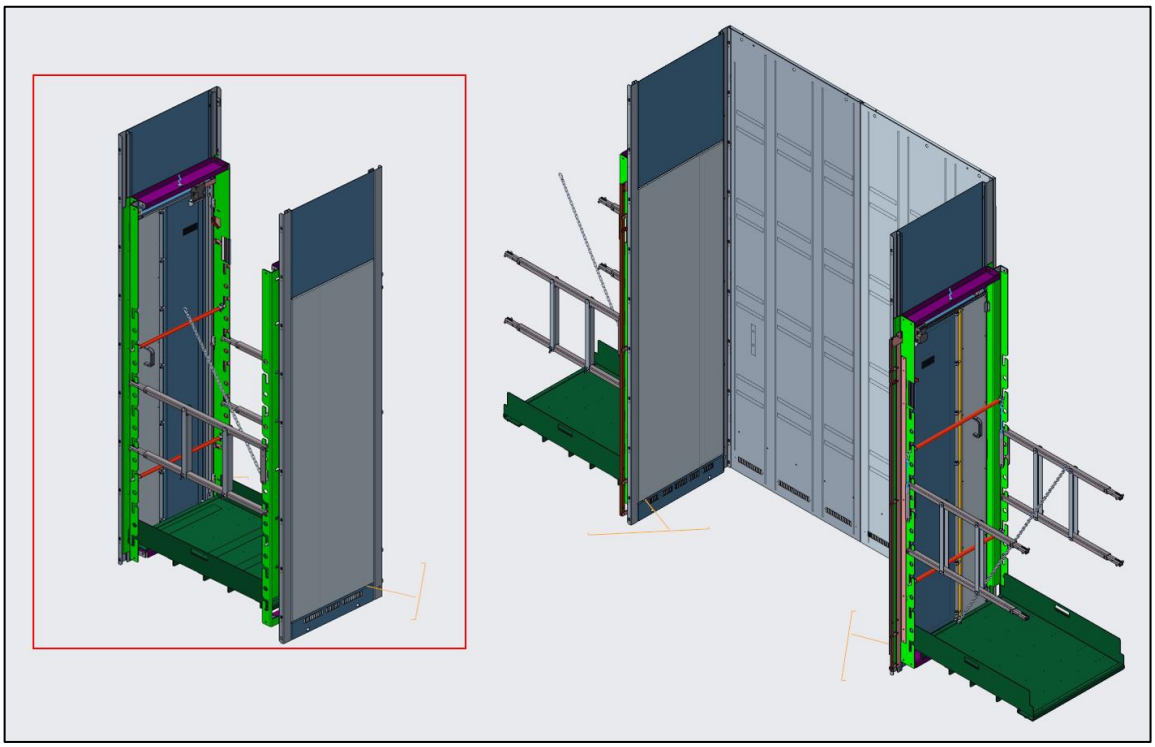
4.4 Doing the work

Detailed steps of carrying out the practical 3D model/Design engineering work

4.4.1 Doors position architecture changes

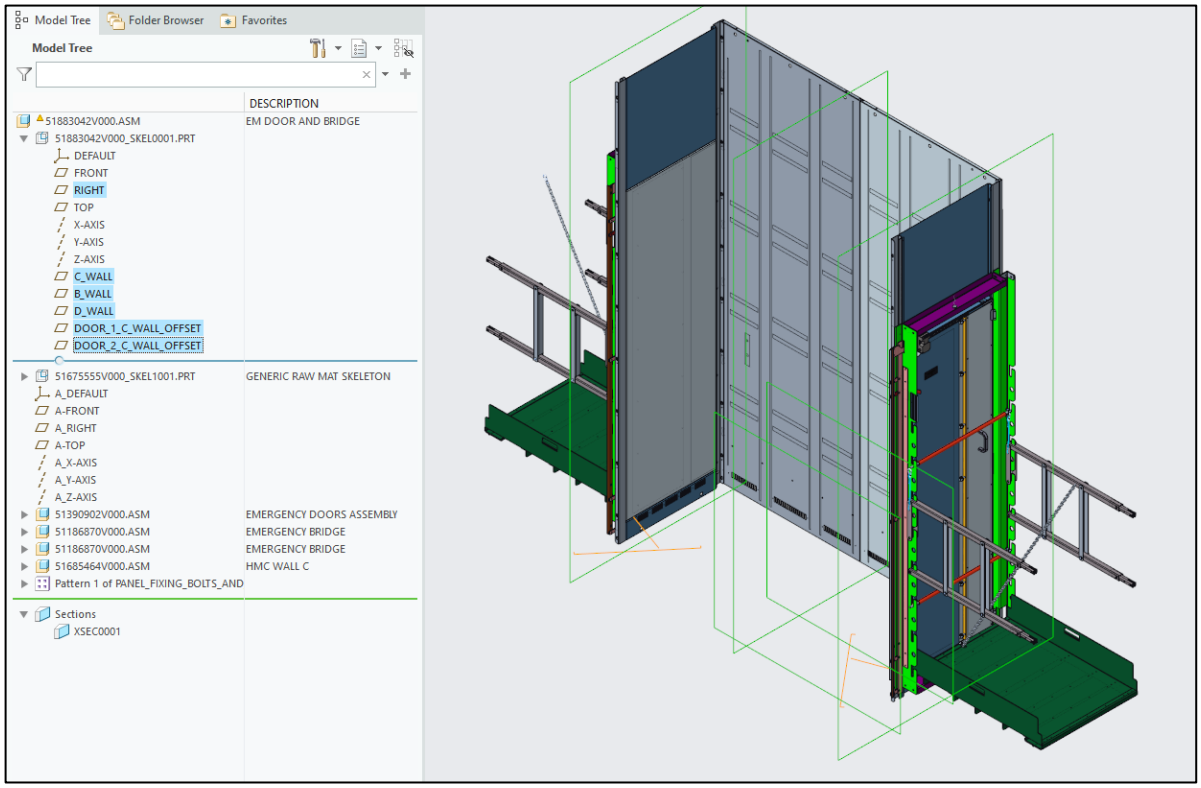
The original product was designed to be ordered as a standalone package and manually configured to the specifications determined by the car. The package included two doors and connecting bridge and would be configured ***after*** the car and can be seen below on the left where the doors are ***facing away from each other, assembled to two separate cars***. The new automated design needed to be configured ***with*** the car and so brought new requirements. Now the door is orders ***per car*** and options for number of doors were needed in case of a car needing exits on both side for example. Along with number of doors, the door position is now configurable and is aligned with standard car panel positions for modular integration. With the option of number of doors, the number of bridges in also configurable, so for example in the case of three shafts with three cars, the middle car could order two door and the outer cars needing only one. The middle car could then order both bridges, and they could be ordered with outer cars but in any case, only two bridges are needed. The new design is seen on the right where the doors are ***facing towards each other, assembled to a single car***.

Figure 45. Original (left) with one door in two cars, and new design (right) with two doors in one car, rear car wall for show - in Creo



New datum planes for doors 1 and 2, were created in the main skeleton for C, B and D car wall interfaces as shown below. The datums planes for door 1 & 2 “C_WALL_OFFSET” are configured using existing parameters from Kone which refer to wall panel positions used in car configuration and can position the doors independently to the front, rear, left or right for one or two doors.

Figure 46. New configurable datums planes additional door position requirements - in Creo



4.4.2 Alignments required for standard process

As discussed in section 4.2.2, the following alignments are required to utilize the product in the automated configuration process. I created a checklist of all parts and assemblies to keep track of progress and status as seen below. I recorded the generic raw material code, drawing status, flat dimension status and also the parameters present in each component. This made it very easy to find and replace parameters and link to top skeleton if and when needed.

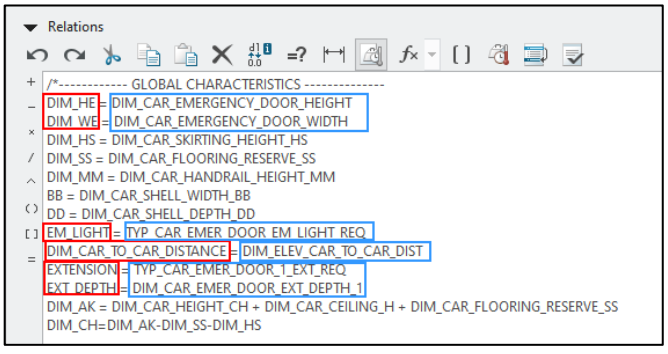
Figure 47. Alignments progress and status checklist

PART NUMBER	DESCRIPTION	LPE	MATERIAL	DWG	DIM1,2,3	NEEDED GLOBAL CHARS (taken from existing relations)
51817919v000.prt	BRIDGE END PLATE, LIGHT FIXING	C	z3			FROM: 51883042V000_SKEL0001 - DIM_WE, EXT_DEPTH, EM_BRIDGE, EXTENSION,
51817918v000.prt	BRIDGE END PLATE, LIGHT FIXING	C	z3			FROM: 51883042V000_SKEL0001 - DIM_WE, EXT_DEPTH, EM_BRIDGE, EXTENSION,
51817917v000.prt	BRIDGE END PLATE, TOP	C	z3			FROM: 51883042V000_SKEL0001 - DIM_WE
51817916v000.prt	BRIDGE END PLATE, TOP	C	z3			FROM: 51883042V000_SKEL0001 - DIM_WE
51768985v000.prt	COMPRESSION SPRING HOLDER PLATE	F	z2			none
51768897v000.prt	RIGHT SAFETY SWITCH HOLDER PLATE	f	z3			none
51768601v000.prt	ACTUATOR HOLDER PLATE	F	z1			none
51768600v000.prt	LEFT SAFETY SWITCH HOLDER PLATE	f	z3			none
51768599v000.prt	STEPPING BLOCK PLATE	C	z1			FROM: 51883042V000_SKEL0001 - EXT_DEPTH, DIM_WE,
51768303v000.prt	DO NOT STEP STICKER	F	???			none
51764219v000.prt	STEPPING BLOCK PLATE	C	z1			FROM: 51883042V000_SKEL0001 - EXT_DEPTH, DIM_WE,
51764218v000.prt	FLAT BAR	C	z1.5			none
51649061v000.prt	FLAT BAR	F	z1.5			FROM: 51883042V000_SKEL0001 - DIM_AK:1267, DIM_HE:1267, DIM_HS:1267, DIM_SS:1267
51649051v000.prt	DOOR SUPPORT PLATE	F	z2			none
51648869v000.prt	OPENING DIRECTION STICKER	C	???			none
51647091v000.prt	BRIDGE BALUSTRADE HOLDING PANEL	C	zin3 (Z3)			FROM: 51883042V000_SKEL0001 - DIM_AK, DIM_HS:, DIM_SS:,
51647034v000.prt	BRIDGE BALUSTRADE HOLDING PANEL	C	zin3 (Z3)			DIM_AK:1419, DIM_HS:1419, DIM_SS:1419, DIM_HE:1261
51646840v000.prt	WALL PANEL	C	f2			FROM: 51883042V000_SKEL0001 - DIM_AK, DIM_HS, DIM_SS, DIM_HE, MAT_WALL:
51646838v000.prt	WALL PANEL	C	f2			FROM: 51883042V000_SKEL0001 - DIM_AK, DIM_HS, DIM_SS, DIM_HE, MAT_WALL:
51646822v000.prt	LOCK HANDLE	C	3cr2			none
51646814v000.prt	BRIDGE END PLATE	C	z3			FROM: 51883042V000_SKEL0001 - DIM_WE
51645572v000.prt	WALL PANEL	C	f2			FROM: 51883042V000_SKEL0001 - DIM_AK, DIM_HS, DIM_SS, DIM_HE, MAT_WALL:
51645569v000.prt	WALL PANEL	C	f2			FROM: 51883042V000_SKEL0001 - DIM_AK, DIM_HS, DIM_SS, DIM_HE, MAT_WALL:
51645218v000.prt	BRIDGE BALUSTRADE HOLDING PANEL	C	zin3 (Z3)			FROM: 51883042V000_SKEL0001 - DIM_AK:1, DIM_HS:1, DIM_SS:1, DIM_HE:1
51645215v000.prt	BRIDGE BALUSTRADE HOLDING PANEL	C	zin3 (Z3)			FROM: 51883042V000_SKEL0001 - DIM_AK:1, DIM_HS:1, DIM_SS:1, DIM_HE:1
51644961v000.prt	BRIDGE END PLATE	C	z3			FROM: 51883042V000_SKEL0001 - DIM_WE
51643540v000.prt	FILLER PLATE	C	z2			none
51633870v000.prt	COVER PLATE	C	z1.5			FROM: 51883042V000_SKEL0001 - DIM_HE, SDIM_HE:7
51632461v000.prt	COVER PLATE	C	z1.5			FROM: 51883042V000_SKEL0001 - DIM_HE, SDIM_HE:4
51390888v000.prt	SOUND INSULATOR	C	Paroc Marine Slab 220			FROM: 51883042V000_SKEL0001 - DIM_HE

4.4.2.1 New parameters needed

As shown in section 4.2, Figure 40 & 42, some parameters were created locally in the 3D model and did not exist in the company PDM database. Parameters not found were then requested to be created through the companies' parameter creation request process. The parameters needed to be modified a little to suit the companies standardised naming convention. The figure below shows the local parameters in 3D model and newly created parameter to be used in the PDM and ordering process. Note that the original local parameters can remain in the 3D model and simply be equated to the new parameter, minimizing effort needed while maintaining required data flow from PDM through the 3D model configuration.

Figure 48. Existing local parameters (red) and new parameters (blue) - in Creo

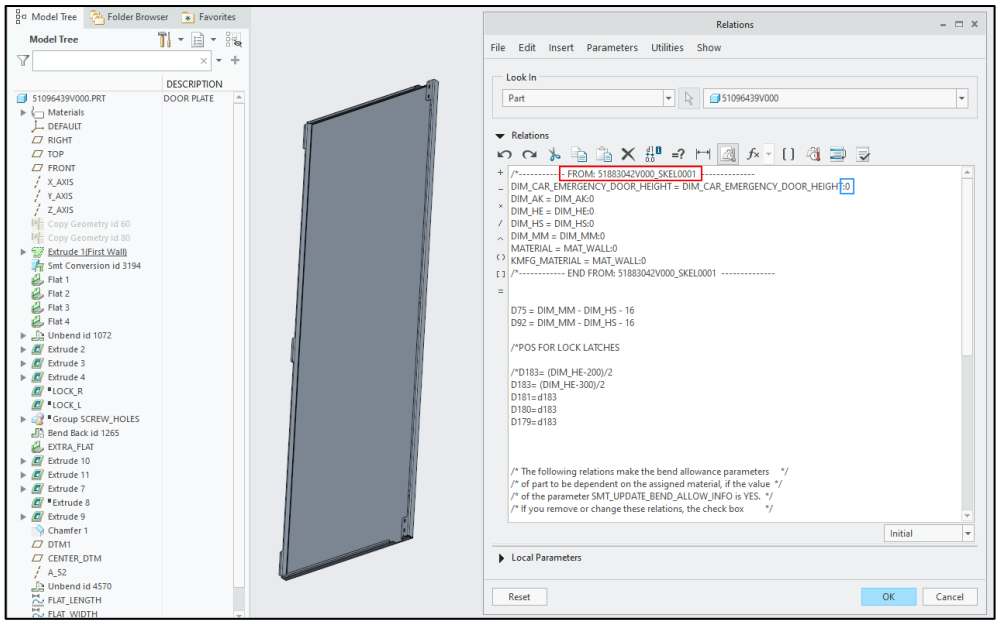


Other parameters needed to be created for new requirements such as DIM_ELEV_CAR_TO_CAR_DIST_1 & 2 as it is possible in the case of three shaft system with three cars, the distance between shafts and cars may not be the same. These parameters will allow for each bridge to be configured to the correct size. TYP_CAR_EMER_BRIDGE_1_REQ & 2 will be used to choose the correct bridge quantity.

4.4.2.2 Data flow & Top-down design

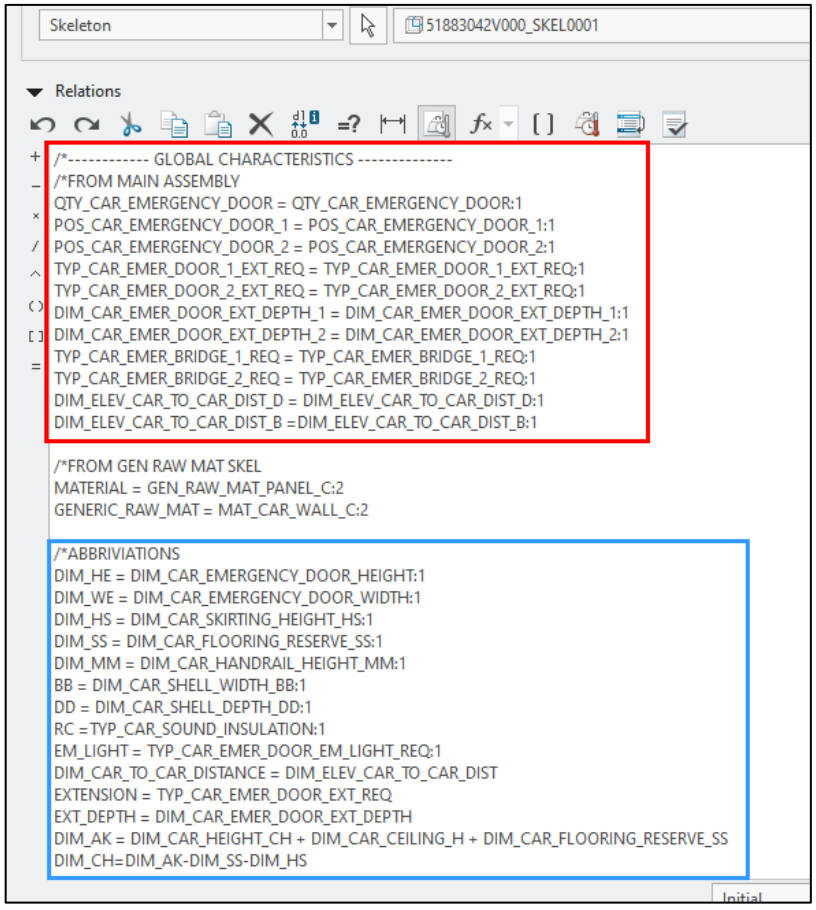
The majority of parts and practically all assemblies used in the product have some configuration rules and conditions to define the behaviour of each part and assembly. Many of the original components used local parameters and calculating and defining values independently. One of the main requirements was to modify all the configurable parts such that local parameters were equated to newly created or existing parameters from the PDM, and the values of which are linked to the top-level assembly, thus creating top-down data flow for parameter and values. The example below shows a door plate and its configuration rules. The note in red shows that the values have been linked to the top-level skeleton and ":0" in blue is the reference used to link the parameters and values. This process needs to be carried out on all components which use even a single parameter.

Figure 49. Door plate with configuration rules and parameters linked to skeleton – in Creo



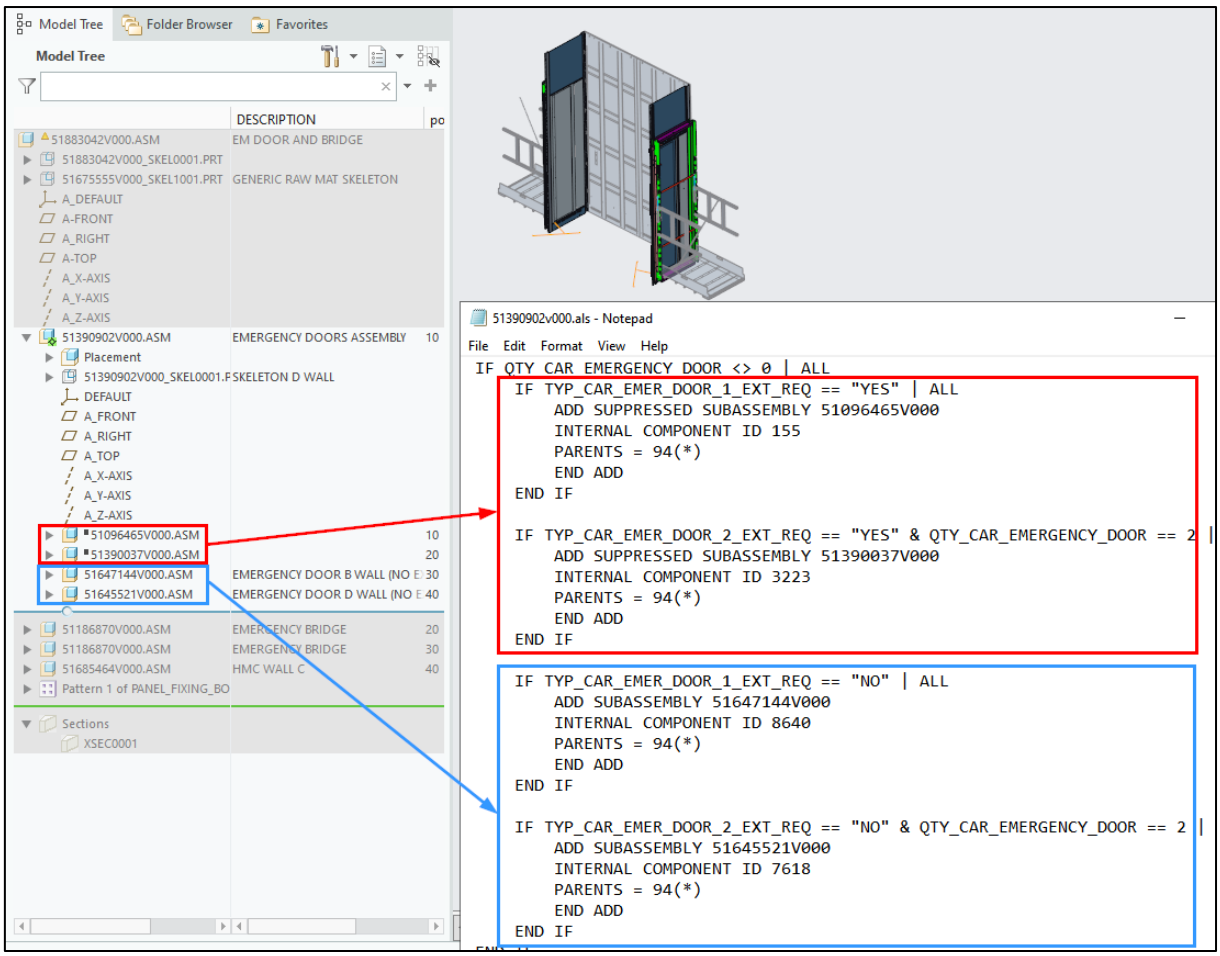
From the main level skeleton, we can see all the parameters which will receive values as input from the PDM database and then pass from top down, throughout the structure. Note that the parameters come into main assembly first and then passed to main assembly skeleton and all parameters needed in skeleton must be present in main assembly because the data will not transfer from PDM to skeleton. In the figure below the red box highlights all new parameters received directly from main assembly and blue shows some original local parameters still in use and abbreviations used as a type of shorthand text when writing rules etc. Note also that the end of the lines the reference symbol is ":1" – which is the object identification/session ID for the main assembly and in the previous example with the door plate the reference symbol was ":1" which is the object identification/session ID for the main assembly skeleton. This links the data flow like a chain throughout the structure wherever a parameter value is required, while keeping its definition on the top level.

Figure 50. Main assembly skeleton parameters and abbreviations



When the parameter data flows correctly throughout the structure, the main components can then be programmed to activate and deactivate if and when needed. Below is an example of how the new parameters and used to satisfy the new requirements of door quantity and type selection. The initial condition is “IF QTY_CAR_EMERGENCY_DOOR <> 0” meaning not 0, then deferring to the next condition “IF TYP_CAR_EMER_DOOR_1_EXT_REQ == "YES"” which if it is satisfied, will “ADD SUPPRESSED SUBASSEMBLY 51096465V000”, in this case is the door type which has extension. The next condition is used to add the second door with extension. The conditions in blue work in the same way but will configure the use of door type without extension, which is the models mostly used for illustration in this document.

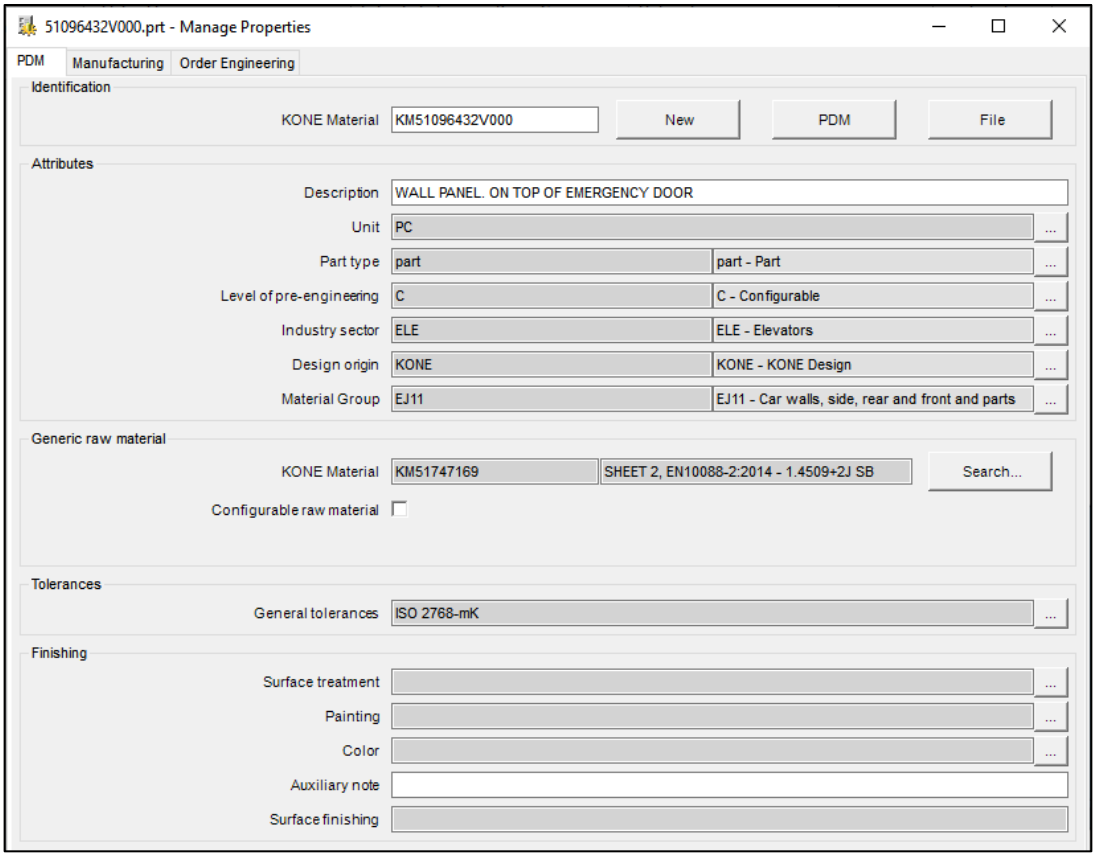
Figure 51. Main component BOM configuration using new parameters - in Creo



4.4.2.3 System attribute alignment

System/material attributes can be modified in Creo from manage properties application. Every part and assembly need to be checked and aligned if data is missing. This data is usually filled in when creating a new 3D model and is linked to the PDM database. Non-standard products may not need all this data so it could be missing from some parts of the current product.

Figure 52. Example of data system attributes in Creo

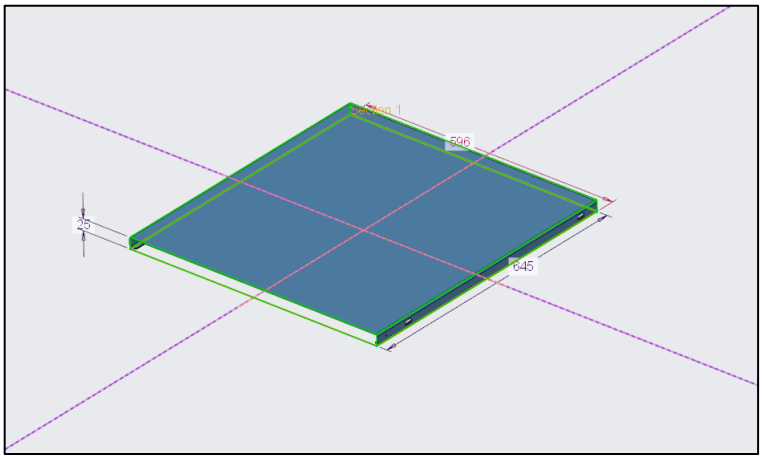


4.4.2.4 Flat state dimensions

In all sheet metal parts, the thickness, width and length need to be created as additional parameters DIM 1, DIM 2 & DIM 3. Below is an example of a panel made from sheet metal, it

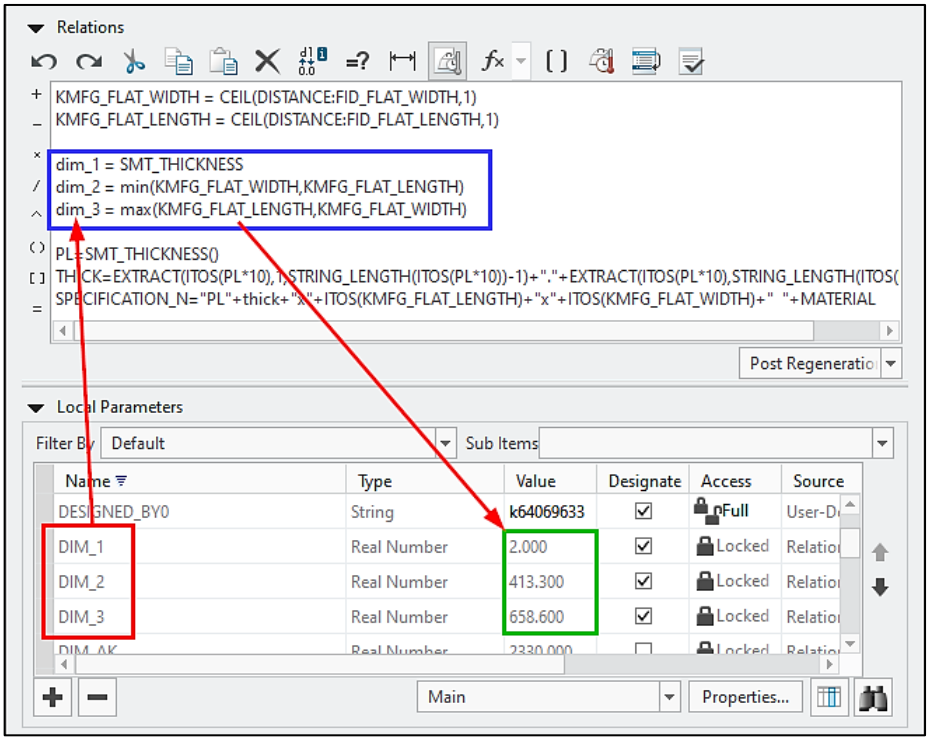
is in the bended state, but Creo will still calculate the flat state dimension and assign to DIM 1, 2, & 3 parameters.

Figure 53. Example of sheet metal part in bended state - in Creo



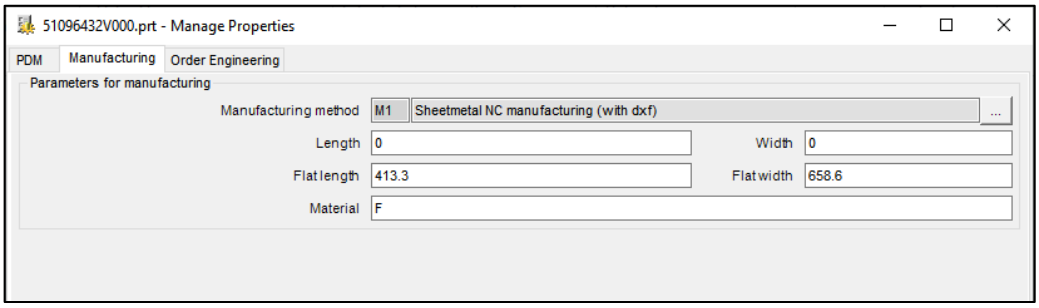
Below is the relations/programming for the part showing the reference between the parameter and the geometry definition in the 3D model. The green box shows the final calculated flat length as parameter values.

Figure 54. Sheetmetal dimensions example in Creo



The figure above shows the flat length and width dimension parameters linked to the PDM database. Also shown is the manufacturing method, in this case a DXF files for computer numerical control of automated manufacturing machines.

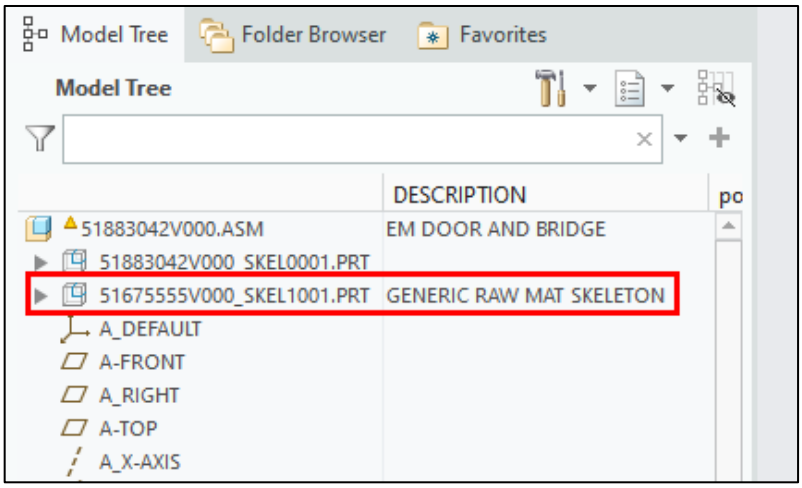
Figure 55. Manufacturing parameters in Creo



4.4.2.5 Material selection from skeleton

Below shoes the “Generic Raw Material” (GRM)skeleton used in the car to define raw materials and finishing materials for specific components. The finishing materials being the visible surfaces inside the car. In order to align the configuration with the car, the GRM Skel was added to the assembly and the selection conditions in the skeleton program define the required materials. In a real order configuration, the values are passed from the car to the door main assembly and from there down through the structure.

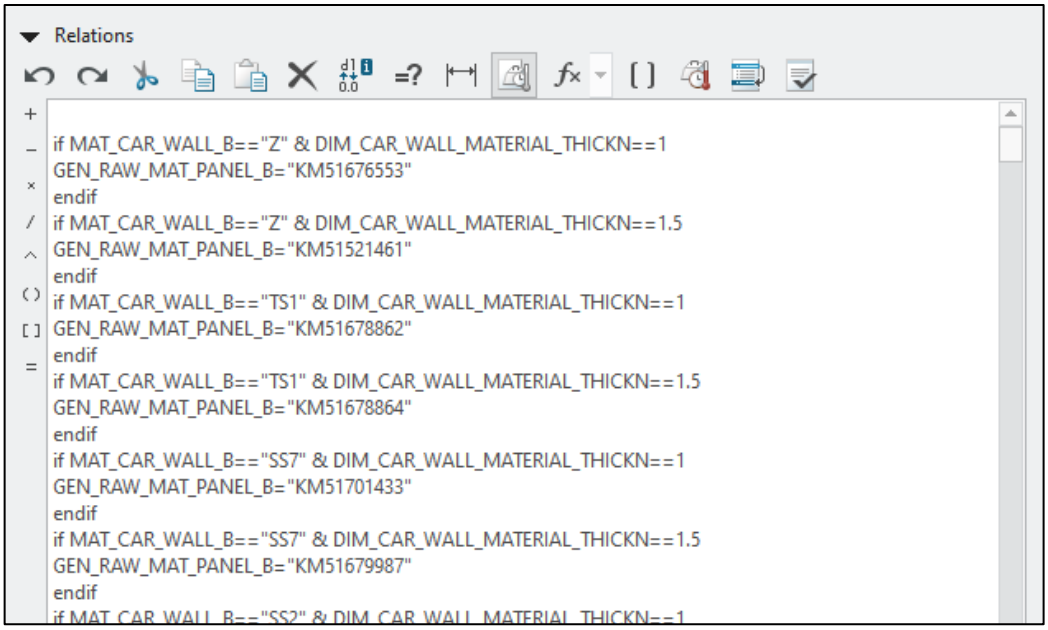
Figure 56. Generic Raw Material Skeleton from Car - in Creo



The figure below shows the configuration rules of a “Generic Raw Material” skeleton used in Creo to locate selection rules for specific materials. The first line shows a condition with two parameters and their values. If those first parameter values are given as input to the skeleton.

The condition is true and will define the parameter “GEN_RAW_MAT_PANEL_B” having a value “KM51676553” which refers to a specific type of material used as car wall panels.

Figure 57. Example of skeleton selection rules in Creo

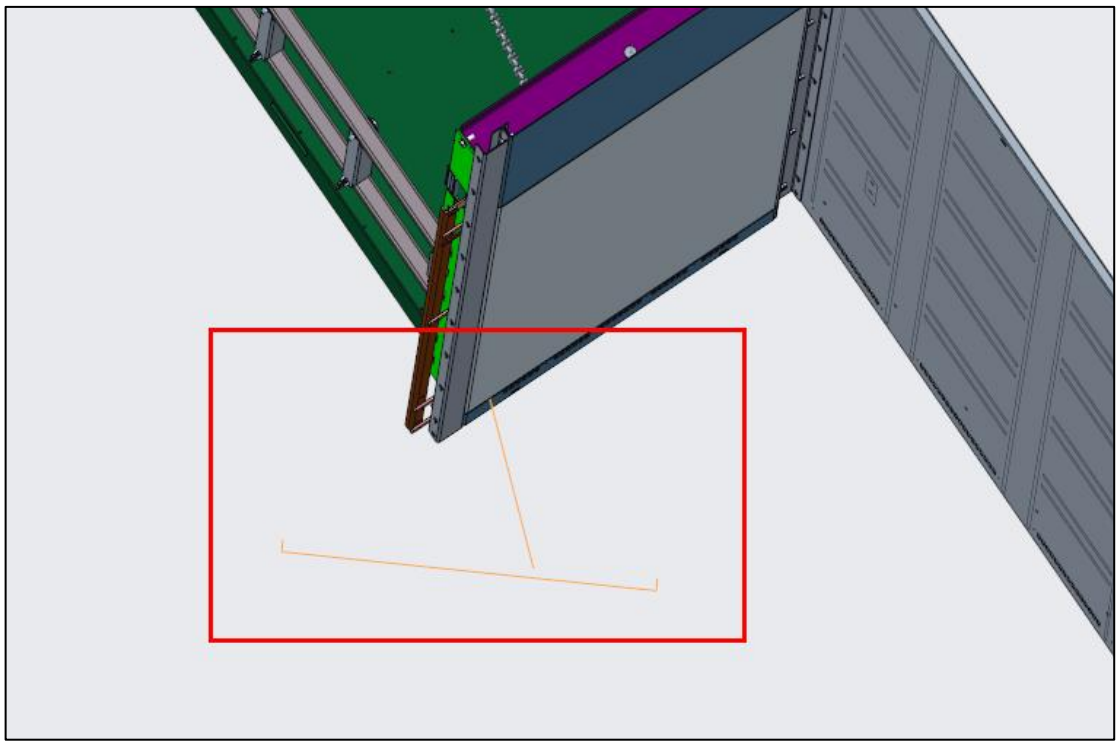


The emergency exit has some panels which replace regular car wall, so they need to be aligned with the skeleton to receive the same material specification as the rest of the car.

4.4.3 Door opening mechanism

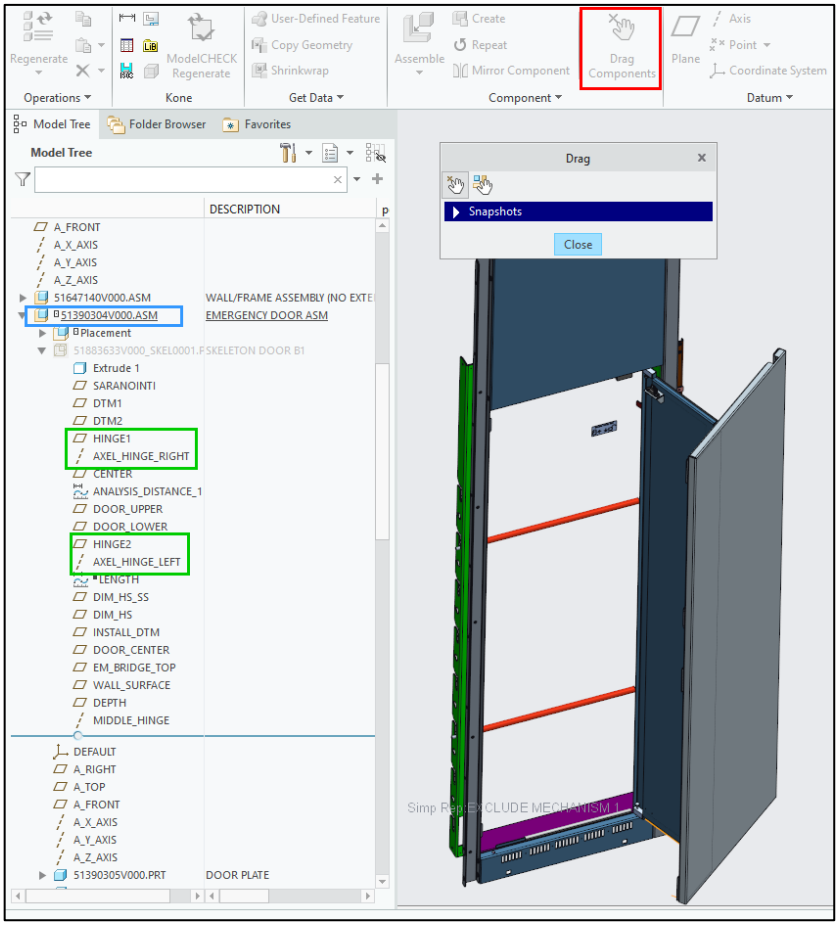
In the original model the door panel itself did not move and the open position of the door was represented by a sketch shown below.

Figure 58. Door opening sketch – in Creo



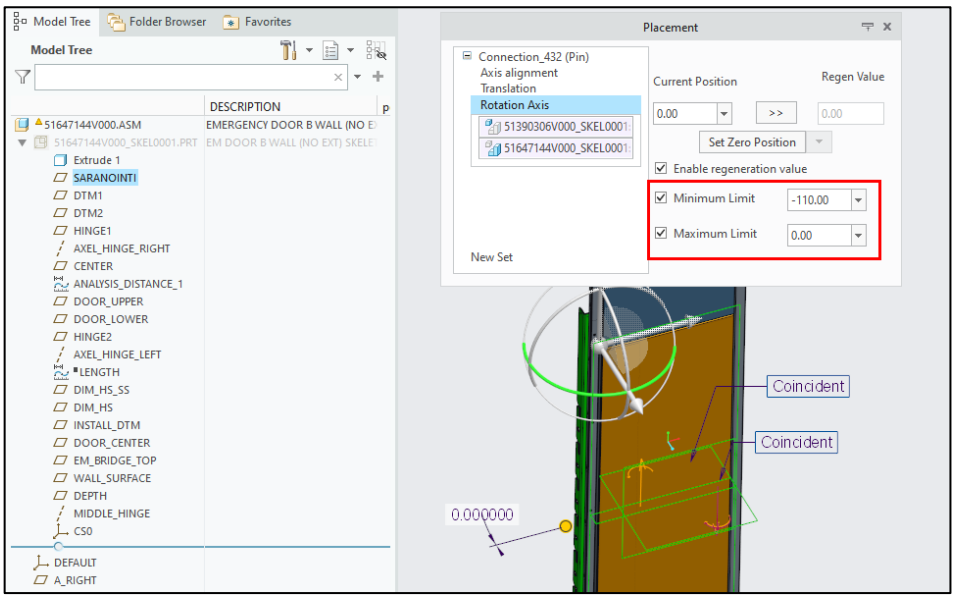
The figure bellow shows the “drag component” function in Creo which can now be used to physically rotate the door around both hinges and this function can be used to check interference with car walls when opening for example. The blue box highlights the component which has its assembly connections redefine with "pin" connection type, which allows rotational movement of the model. The green boxes highlight the datum planes and axes used to define the position and axis of rotation.

Figure 59. Door opening mechanism added to models - in Creo



Maximum and minimum rotation angles need to be determined of each part and also rotation direction as shown below, in order to function correctly.

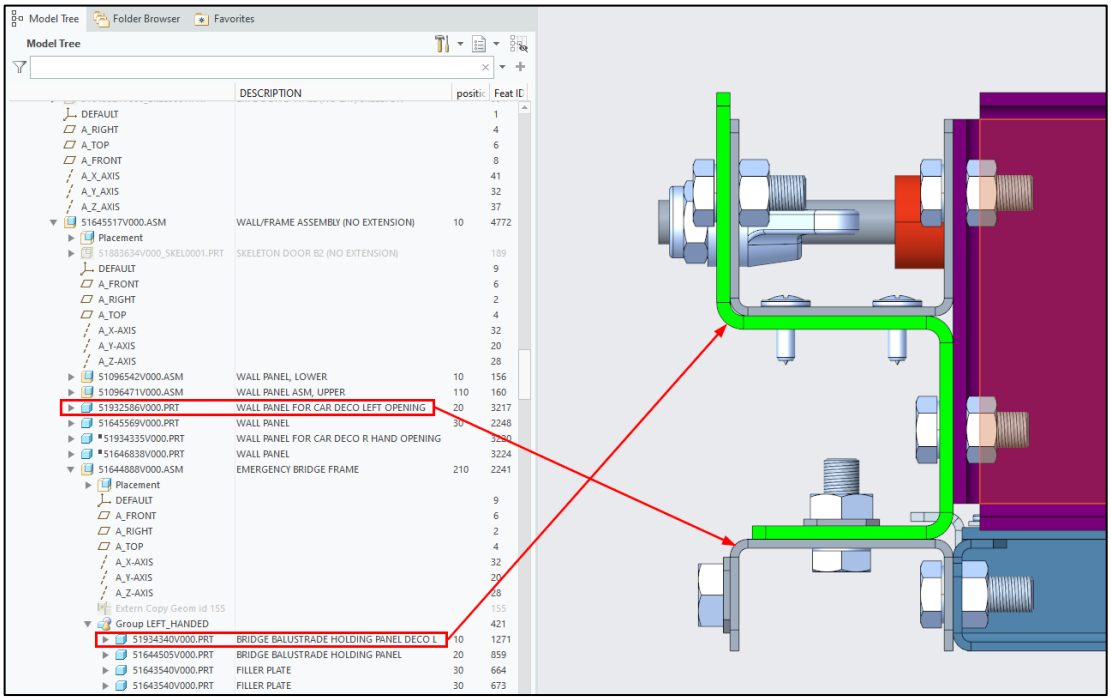
Figure 60. Connection and rotation settings for door opening - in Creo



4.4.4 New parts needed

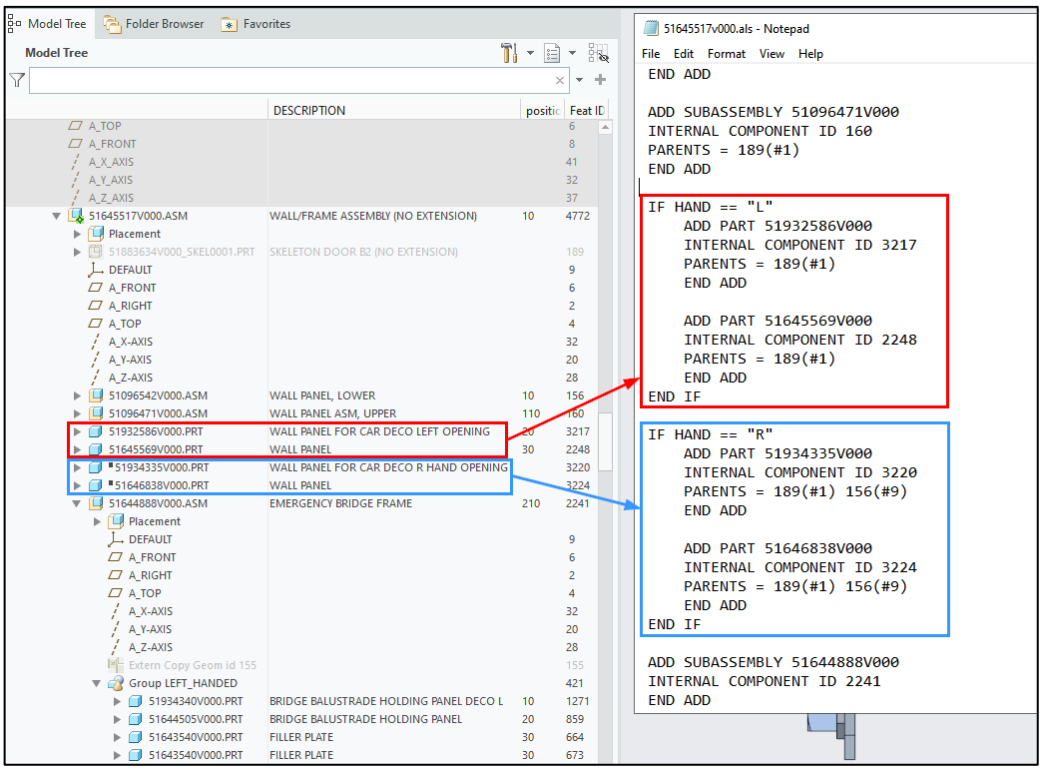
The creation of additional door adjacent panels, frame supports, and configuration rules were needed to automate a manual step in cases where decoration on door panels interfere with walls when opening, as discussed earlier in section 2.3.5.2 and shown in figure 20. The original parts were copied and given new part identification numbers to reduce workload. The two main parts are shown below in red.

Figure 61. New parts needed to automate decoration interference issue (creo)



Parts for both left and right were created and configuration rules were added to the program such that the correct parts are activated under the correct conditions, as shown below. Left-handed configuration parts in red, right-handed in blue.

Figure 62. New parts configuration (Creo)



4.4.5 Uploading 3D models to Windchill

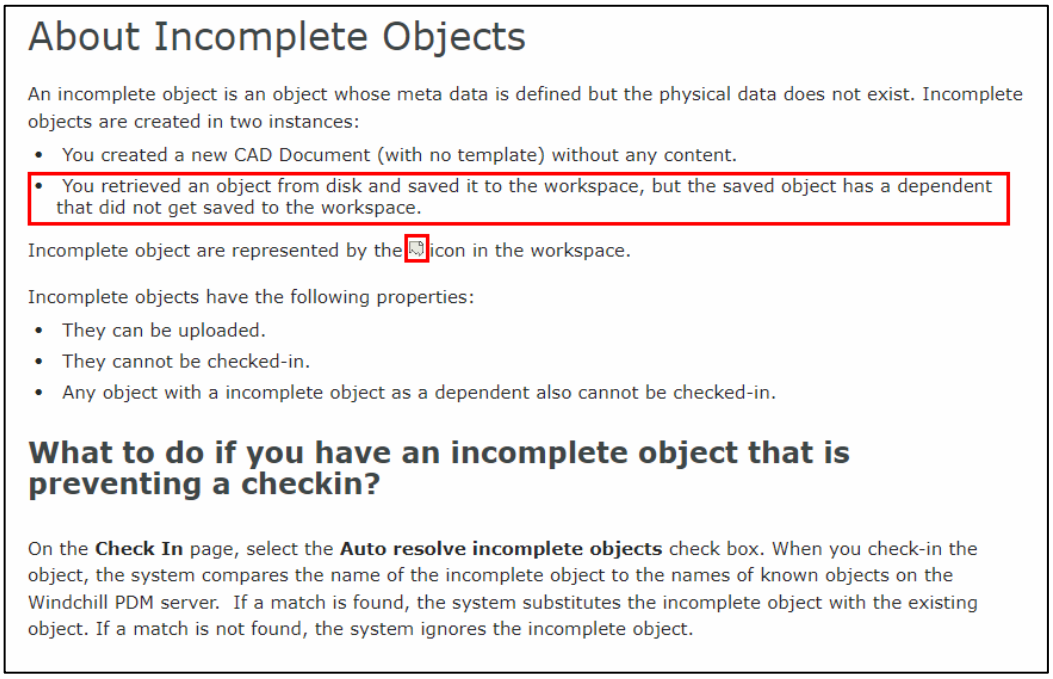
As stated in the engineering instructions, the original 3D model and product CAD data was located in the main PDM and not the CAD PDM -Windchill. In the past the 3D model was added to a single Zip file and stored there. Now the models and CAD data will be uploaded to the CAD PDM and later synchronized with the main PDM.

Adding old/existing parts to the CAD PDM can have some challenges. One of the main challenges I faced was that some of the old models has references to parts that were no longer used. Windchill recognises these parts as “” and are referenced in the 3D models stored locally and they do not exist in the Windchill PDM itself. Windchill is designed in such a way that it will not allow the upload of 3D model data which has incomplete objects.

These references to parts that do not exist anymore, had to tediously searched and located in the existing 3D models and drawings, one by one and manually deleted. Once all such references were removed, the product did not have any conflicting data and was then able to

be uploaded. Below is the description from PTC Support, note the issue I had highlighted in red. It also says incomplete objects can be uploaded but in practice this prevents the rest of the 3D model from being finally uploaded.

Figure 63. Incomplete objects description from PTC Support (PTC. 2023-b)



About Incomplete Objects

An incomplete object is an object whose meta data is defined but the physical data does not exist. Incomplete objects are created in two instances:

- You created a new CAD Document (with no template) without any content.
- You retrieved an object from disk and saved it to the workspace, but the saved object has a dependent that did not get saved to the workspace.

Incomplete object are represented by the icon in the workspace.

Incomplete objects have the following properties:

- They can be uploaded.
- They cannot be checked-in.
- Any object with a incomplete object as a dependent also cannot be checked-in.

What to do if you have an incomplete object that is preventing a checkin?

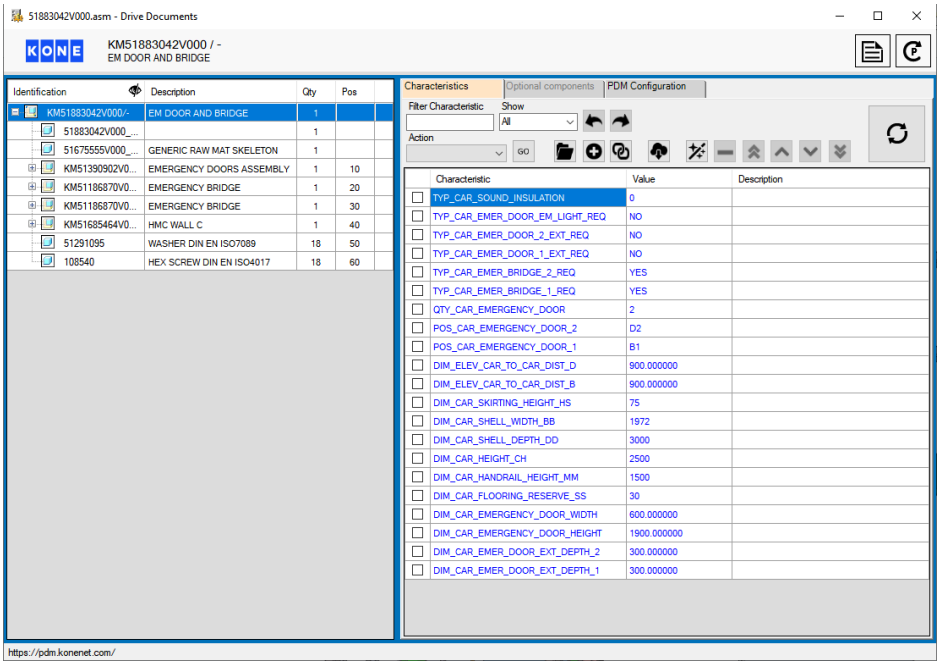
On the **Check In** page, select the **Auto resolve incomplete objects** check box. When you check-in the object, the system compares the name of the incomplete object to the names of known objects on the Windchill PDM server. If a match is found, the system substitutes the incomplete object with the existing object. If a match is not found, the system ignores the incomplete object.

4.5 Finalizing the work

4.5.1 Testing of models locally in Creo

Models where constantly testing Creo to ensure correct configurations were obtained after major modifications. Specific software is used to test configurations but in the case the component is quite small and does not have so many configurations, local test in Creo was sufficient. Testing was carried out using an application called drive documents specifically for regenerating the 3D models with all parameters. Shown below is the application and parameter list from main assembly, values can be changes and regenerated to test all sizes and variations of the product configurations.

Figure 64. Drive documents app used to test configurations (Creo)



4.5.2 Drawing validation

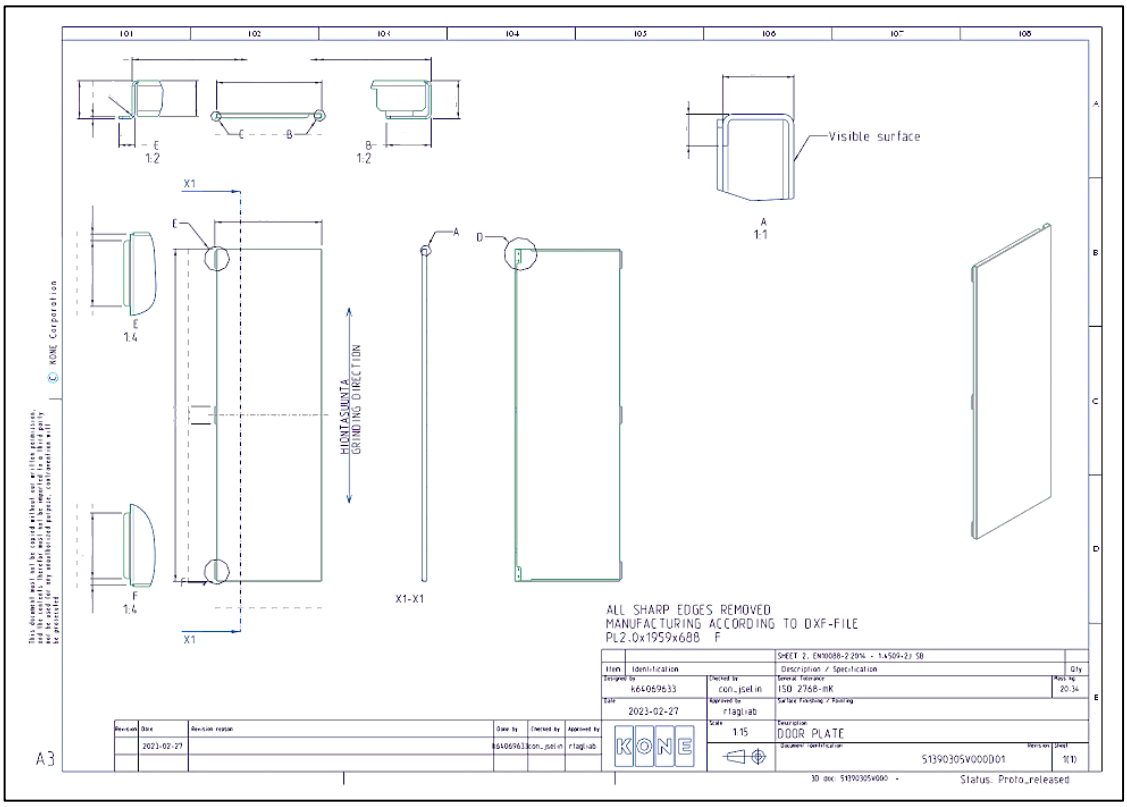
All part and assembly manufacturing drawings were reviewed for visible errors and correct manufacturing data/dimensions etc. Configurable parts and assemblies were tested to validate the correct generic raw material code, specification and dim 1,2,3 is passing from skeleton to model then model drawing information table. The drawings were checked systematically, and I used one note to record issues found and keep record of progress.

Figure 65. Drawing validation checklist (Creo)

Drawing Number	Issues found/corrected
☑ 51936110V000D01	
☑ 51936109V000D01	
☑ 51934340V000D01	☑ view states and dims updated
☑ 51934339V000D01	
☑ 51934335V000D01	
☑ 51932586V000D01	
☑ 51932579V000D01	
☑ 51844938V000D01	☑ view pos adjusted
☑ 51844929V000D01	
☑ 51844762V000D01	
☑ 51844755V000D01	
☑ 51844750V000D01	
☑ 51844749V000D01	
☑ 51844746V000D01	
☑ 51844739V000D01	
☑ 51844738V000D01	☑ view pos adjusted
☑ 51844735V000D01	

Each drawing was reviewed to ensure views and data required by factory were correctly aligned with Kone standards. Below is example of a typical 2D manufacturing drawing for a door plate. All dimensions, radius, bom balloons, notes and drawing table info needed to be validated.

Figure 66. Example of 2D manufacturing drawing (Creo)



4.5.3 Publishing drawings/PDM sync

Once drawings were validated, they could be sent to the PDM database where factory could access them and use them to build a prototype for testing manufacturing and assembly of the component. The prototype is still pending.

4.5.4 Pilot Site Review for Global Installation

The pilot site review will be a report of the manufacturing and assembly processes and will include and issues or errors which were found during factory validation. This is also still pending.

5 RESULTS AND CONCLUSIONS

Overall, the conversion process was straight forward, and I didn't find and major technical difficulties. The early phase was quite challenging as I had no prior experience with the component and understanding the original 3D model's programming logic took some time. Communication was clear with the stakeholders and requirements were all achieved. The first two main objectives were also achieved and now the component can be fully configured automatically by receiving parameter values as input from the ordering process. Reusing all the models and making the minimal changes to programming helped to speed up the project and may be beneficial to those engineers with existing experience of the original non-standard design, who may in future provide engineering and design maintenance for the new one.

Manufacturing validation by factory has been planned but unfortunately this is not a high priority so it is not clear when a prototype will eventually be made by the factory. The factory would use the drawings created by the new design to test for manufacturing and assembly issues.

During the course of the project, I learned many new aspects of the design process for manual and automated design practices, requirements, and validation. I also got a deeper understanding of the product and have some ideas to improve the existing design that could be researched further.

One area I can improve myself with in future, is to document more information when doing the work. As stated already, I had the knowledge of tools and processes needed to carry out the work and got started right away. I was focused too much on the work and it would have been better to have documented my actions more carefully and start planning the report earlier. So, the report was taking longer than expected.

In future, when the manufacturing and assembly have been validated by the factory, the product structure can be synchronized from the CAD PDM to the organizations main PDM and the product implementation phase will begin with setting up the data needed for supply chain.

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