









Summary of Autonomous Transport Chain Levels

Introduction

During the Scale project MariTerm AB has tried to define some kind of model to describe on which level of automation the project is dealing with. One way is to define different levels of automation in each part of the transport chain. In this case the following parts have been chosen to be described in levels of automation;

- loading,
- cargo securing,
- transport, and
- unloading.

SCALE – Transport Chain Flow – Autonomous handling							
Arrival loading gate	Loading	Cargo Securing	Departure loading gate	Transport	Arrival unloading gate	Unloading	Departure unloading gate
							
Activities							
<ul style="list-style-type: none"> - Open vehicle back door - Reverse vehicle and stop - Block wheels - Open gate door - Close dock sealing - Dock leveler down - Check - ready to load 	<ul style="list-style-type: none"> - Pick up pallet - Move into vehicle - Put down pallet - Repeat until loading finished 	<ul style="list-style-type: none"> - Secure cargo in forward direction - Secure cargo in sideways direction - Secure cargo in backward direction 	<ul style="list-style-type: none"> - Check – ready to close - Dock leveler up - Open dock sealing - Close gate door - Unblock wheels - Move vehicle and stop - Close vehicle back door 	<ul style="list-style-type: none"> - Drive to unloading gate - Check which gate to use - Reverse vehicle and stop 	<ul style="list-style-type: none"> - Open vehicle back door - Reverse vehicle and stop - Block wheels - Open gate door - Close dock sealing - Dock leveler down - Check - ready to load 	<ul style="list-style-type: none"> - Remove load securing - Pick up pallet - Move pallet to inbound area - Put down pallet - Repeat until unloading finished 	<ul style="list-style-type: none"> - Check – ready to close - Dock leveler up - Open dock sealing - Close gate door - Unblock wheels - Move vehicle and stop - Close vehicle back door
Barriers							
<ul style="list-style-type: none"> - Type of gate - Type of equipment at gate - Communication gate/vehicle 	<ul style="list-style-type: none"> - Type of autonomous loading - Type of cargo - Planning the loading - Loading pattern 	<ul style="list-style-type: none"> - Type of autonomous loading - Type of cargo - Type of method/ equipment - Loading pattern 	<ul style="list-style-type: none"> - Type of gate - Type of equipment at gate - Communication gate/vehicle 	<ul style="list-style-type: none"> - Type of vehicle - Type of equipment at gate - Communication gate/vehicle 	<ul style="list-style-type: none"> - Type of gate - Type of equipment at gate - Communication gate/vehicle 	<ul style="list-style-type: none"> - Type of autonomous loading - Type of cargo - Type of method/ equipment 	<ul style="list-style-type: none"> - Type of gate - Type of equipment at gate - Communication gate/vehicle

Transport Chain Flow – Autonomous Handling

The cargo securing has also been defined in different complexity levels depending on the characteristics of the cargo which can give an input how complex the whole automation of the transport chain can be.

Each part in the transport chain has been defined in 6 levels, 0 – 5, due to the already well accepted *SAE J3016™ Recommended Practice: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*, commonly referenced as the SAE Levels of Driving Automation™. With a taxonomy for SAE’s six levels of driving automation, SAE J3016 defines the SAE Levels from Level 0 (no driving automation) to Level 5 (full driving automation) in the context of motor vehicles and their operation on roadways.

Autonomous Loading Levels

The loading part is divided into two steps;

- how the cargo is moved to the outbound area, and
- how the cargo is loaded into the cargo transport unit (CTU)

If the cargo is uniformed or have different sizes is also a part in the complexity of the automation and in the definition of the different levels.

At **Level 0** the cargo is totally manually handled.


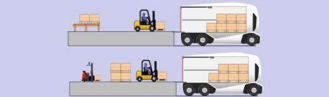
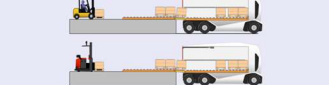
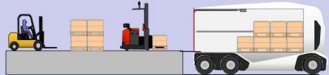
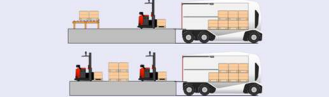

At **Level 1** the cargo is moved to the outbound area by a conveyer system or autonomous by e.g. an AGV.

At **Level 2** the cargo is loaded into the CTU by some fixed system installed at the outbound area and/or installed on the CTU e.g. Moving floors, Loading plates, conveyer systems.

At **Level 3** the cargo is manually transported to the outbound area and autonomous loaded by e.g. an AGV.

At **Level 4** uniformed cargo is fully automatic handled.

At **Level 5** cargo with different sizes is fully automatic handled.

Level	Name Type of Cargo	Loading		Example
		To outbound area	To CTU	
0	No automated handling and loading Load units with different sizes	Manual	Manual	
1	Automated handling Load units with uniformed sizes	a) Conveyer system b) Autonomous	Manual	
2	Fixed CTU loading system Load units with uniformed sizes	a) Manual b) Autonomous	Fixed loading system - Loading plate - Moving floor	
3	Manual handling and automated loading Load units with uniformed sizes	Manual	Autonomous	
4	High automated handling and loading Load units with uniformed sizes	a) Conveyer system b) Autonomous	Autonomous	
5	Full automated handling and loading Load units with different sizes	a) Conveyer system b) Autonomous	Autonomous	

Autonomous Loading Levels

Autonomous Cargo Securing Levels

The cargo securing levels are depending on the grade of manual assisted cargo securing, if the cargo securing is done by the AGV, by blocking to the boundary of the CTU or by installed equipment in the CTU and the uniformity and transport stability of the cargo.

At **Level 0** the cargo don't need additional cargo securing as the load is totally secured by blocking to the boundary of the CTU.







At **Level 1** the cargo is manually secured which normally is done by the loader of the cargo or the driver of the vehicle.

At **Level 2** some cargo securing equipment is autonomous placed by e.g. an AGV, but the securing is finalized by the driver of the vehicle.

At **Level 3** all cargo securing equipment is autonomous placed by e.g. an AGV to secure the uniformed load units.

At **Level 4** in addition to the cargo securing equipment autonomous placed by e.g. an AGV also the CTU is equipped with cargo securing system to secure the uniformed load units.

At **Level 5** all cargo securing equipment, which can handle different sizes of both rigid and non-rigid load units, is fixed installed in the CTU.

Level	Name Type of cargo	Cargo Securing	Example
0	No automated cargo securing Load units with different sizes	No cargo securing needed or entire cargo blocked by CTU boundary	
1	Manual assisted cargo securing Load units with different sizes	Cargo securing equipment manual placed by loader or remote operator	
2	Partly automated cargo securing Load units with different sizes	Some cargo securing equipment placed by AGV (autonomous) with additional help from loader/remote operator	
3	Conditional cargo securing Uniformed load units	Cargo securing equipment placed by AGV	
4	High automated cargo securing Uniformed load units	Fixed cargo securing system in CTU with additional cargo securing equipment placed by AGV	
5	Full automated cargo securing Rigid and/or non-rigid load units with different sizes	Fixed cargo securing system in CTU	

Autonomous Cargo Securing Levels

Autonomous Transport Levels (According to SEA J3016™)

The SAE J3016™ is used to define the levels of the transport part and more information is found at the SEA homepage, www.sae.org.

	SAE Level	Name	Steering, acceleration, deceleration	Monitoring driving environment	Fallback performance of dynamic driving task	System capability (driving modes)
Human monitors the environment	0	No automation the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention system				N/A
	1	Driver assistance the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about driving environment and with expectation that the human driver perform all remaining aspects of dynamic driving task.				Some driving modes
	2	Partial automation the driving mode-specific execution by one or more driver assistance system of both steering or acceleration/deceleration using information about driving environment and with expectation that the human driver perform all remaining aspects of dynamic driving task.				Some driving modes
Car monitors the environment	3	Conditional automation the driving mode-specific performance by an automated driving system of all aspects of dynamic driving task with the expectation the human driver will respond appropriately to a request to intervene.				Some driving modes
	4	High automation the driving mode-specific performance by an automated driving system of all aspects of dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.				Some driving modes
	5	Full automation the full-time performance by an automated driving system of all aspects of dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.				All driving modes

Autonomous Transport Levels according to SEA J3016

Autonomous Unloading Levels

The unloading part is divided in two steps;

- how the cargo is unloaded from the cargo transport unit (CTU), and
- how the cargo is moved from the inbound area.

If the cargo is uniformed or have different sizes has also a part in the complexity of the automation and in the definition of the different levels.

At **Level 0** the cargo is totally manually handled.

At **Level 1** the cargo is manually unloaded from the CTU and moved from the inbound area by a conveyer system or autonomous by e.g. an AGV.


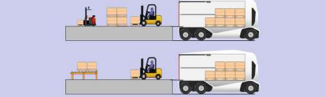
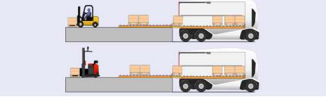

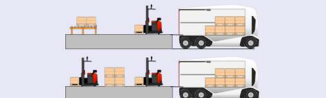
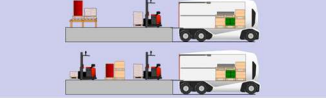
At **Level 2** the cargo is unloaded from the CTU by some fixed system installed at the inbound area and/or installed on the CTU e.g. Moving floors or conveyer systems. From the inbound area the cargo is either manually or automatic handled.

At **Level 3** the cargo is autonomous unloaded by e.g. an AGV and manually transported from the inbound area

At **Level 4** uniformed cargo is fully automatic handled.

At **Level 5** cargo with different sizes is fully automatic handled.

Summary of Autonomous Transport Chain Levels

Level	Name Type of Cargo	Unloading		Example
		From CTU	From inbound area	
0	No automated unloading and handling <small>Load units with different sizes</small>	Manual	Manual	
1	Automated handling <small>Load units with uniformed sizes</small>	Manual	a) Conveyer system b) Autonomous	
2	Fixed CTU unloading system <small>Load units with uniformed sizes</small>	Fixed unloading system - Loading plate - Moving floor		a) Manual b) Autonomous 
3	Automated unloading and manual handling <small>Load units with uniformed sizes</small>	Autonomous	Manual	
4	High automated unloading and handling <small>Load units with uniformed sizes</small>	Autonomous	a) Conveyer system b) Autonomous	
5	Full automated unloading and handling <small>Load units with different sizes</small>	Autonomous	a) Conveyer system b) Autonomous	

Autonomous Unloading Levels

Autonomous Transport Chain Levels – General

The autonomous levels of the four different parts in the transport chain can be summarized in the following chart:

Level	Loading	Cargo Securing	Transport	Unloading
0	No automated handling and loading	No automated cargo securing	No automation	No automated unloading and handling
1	Automated handling	Manual assisted cargo securing	Driver assistance	Automated handling
2	Fixed CTU loading system	Partly assisted cargo securing	Partial automation	Fixed CTU unloading system
3	Manual handling and automated loading	Conditional cargo securing	Conditional automation	Automated unloading and manual handling
4	High automated handling and loading	High automated cargo securing	High automation	High automated unloading and handling
5	Full automated handling and loading	Full automated cargo securing	Full automation	Full automated unloading and handling

Autonomous Transport Chain Levels

Summary of Autonomous Transport Chain Levels

Autonomous Transport Chain Levels – Scale test

The Scale project study the flow of finished products from the SKF D-factory to the Nordic Warehouse (NOR) starts with pallets transported from the manufacturing floor to the basement by a conveyer system including an elevator. The pallets are picked from the conveyer by an AGV and moved to the outbound area. The pallets are loaded into a vehicle by the vehicle driver (Loading Level 1). The cargo is secured by the vehicle driver mainly with cargo blocking bars (Cargo Securing Level 1).

The driver has some driver assistance in vehicle during the transport to NOR (Transport Level 1). The vehicle driver also performs the unloading to the inbound area of NOR and a forklift driver moves the pallets from the inbound area to the warehouse inbound conveyer (Unloading Level 0).

Level	Loading	Cargo Securing	Transport	Unloading
0	No automated handling and loading	No automated cargo securing	No automation	No automated unloading and handling
1	Automated handling	Manual assisted cargo securing	Driver assistance	Automated handling
2	Fixed CTU loading system	Partly assisted cargo securing	Partial automation	Fixed CTU unloading system
3	Manual handling and automated loading	Conditional cargo securing	Conditional automation	Automated unloading and manual handling
4	High automated handling and loading	High automated cargo securing	High automation	High automated unloading and handling
5	Full automated handling and loading	Full automated cargo securing	Full automation	Full automated unloading and handling

Autonomous Transport Chain Levels – Scale test Operation Today

Autonomous Transport Chain Levels – Scale Dry Run Test (HF200 – NOR)

The Scale Dry Run Test started at the outbound are at HF200 (also called NKC) where the pallets had been manually placed by a forklift driver at the outbound area. The loading of the pallets into the vehicle was also done by a forklift driver (Loading Level 0).

The cargo was secured by the vehicle driver mainly with blocking with cargo bars (Cargo Securing Level 1) and the same driver had some driver assistance in vehicle during the transport to NOR (Transport Level 1). The vehicle driver also performed the unloading to the inbound area of NOR and a forklift driver moved the pallets from the inbound area to the warehouse inbound conveyer (Unloading Level 0).

Level	Loading	Cargo Securing	Transport	Unloading
0	No automated handling and loading	No automated cargo securing	No automation	No automated unloading and handling
1	Automated handling	Manual assisted cargo securing	Driver assistance	Automated handling
2	Fixed CTU loading system	Partly assisted cargo securing	Partial automation	Fixed CTU unloading system
3	Manual handling and automated loading	Conditional cargo securing	Conditional automation	Automated unloading and manual handling
4	High automated handling and loading	High automated cargo securing	High automation	High automated unloading and handling
5	Full automated handling and loading	Full automated cargo securing	Full automation	Full automated unloading and handling

Autonomous Transport Chain Levels – Scale - Dry Run

Autonomous Transport Chain Levels – Scale Final Test (HF200 – NOR) Autonomous

The Scale Final Test started at the outbound area at HF200 (also called NKC) where the pallets had been manually placed by a forklift driver or in some case by an AGV at the outbound area. The loading of the pallets into the autonomous vehicle was done by an AGV (Loading Level 3).

At the Final Test some tests were done with some fixed cargo securing equipment (FlexiBar) in the autonomous vehicle but the final cargo securing had to be manually performed by the remote operator if needed. (Cargo Securing Level 2).

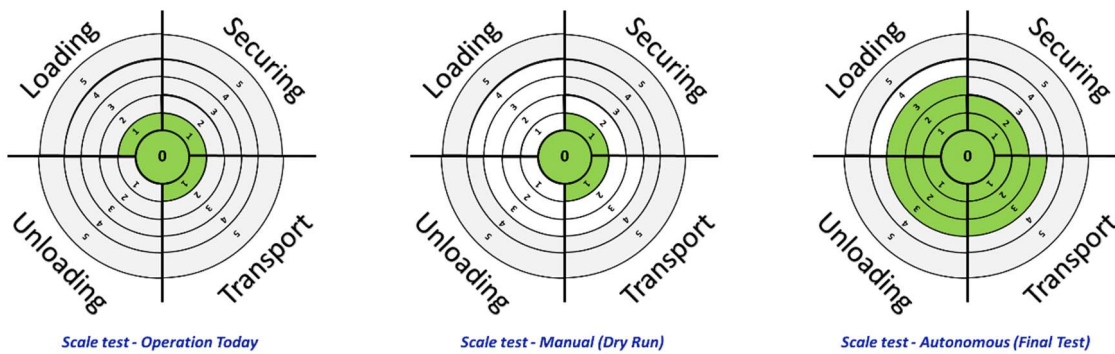
The pallets were transported in autonomous vehicle to NOR (Transport Level 3) supported by a remote operator. An AGV performed the unloading to the inbound area of NOR and a forklift driver moved the pallets from the inbound area to the warehouse inbound conveyer (Unloading Level 3).

Level	Loading	Cargo Securing	Transport	Unloading
0	No automated handling and loading	No automated cargo securing	No automation	No automated unloading and handling
1	Automated handling	Manual assisted cargo securing	Driver assistance	Automated handling
2	Fixed CTU loading system	Partly assisted cargo securing	Partial automation	Fixed CTU unloading system
3	Manual handling and automated loading	Conditional cargo securing	Conditional automation	Automated unloading and manual handling
4	High automated handling and loading	High automated cargo securing	High automation	High automated unloading and handling
5	Full automated handling and loading	Full automated cargo securing	Full automation	Full automated unloading and handling

Autonomous Transport Chain Levels – Scale - Final Test

Another way to show the different levels of automation can be done in spider diagrams which facilitate the comparison between the different tests.

Summary of Autonomous Transport Chain Levels



Autonomous Transport Chain Levels – Scale Operation Today, Scale Dry Run and Scale Final Test

Autonomous Transport Chain Levels – Case Study Bjelin Flooring Company

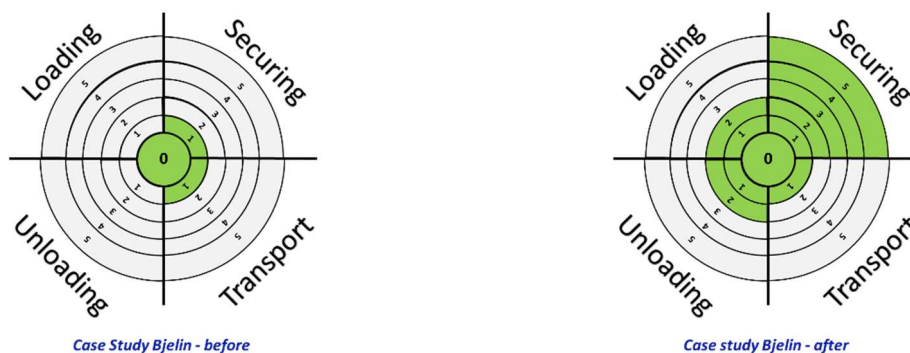
During the project MariTerm contacted the Finnish company NWE (Network Engineering Oy Ab). NWE have a lot of solutions for different modes of transport and CTUs which mainly consists of a reinforced, made-to-measure, specialized covering sheet with lashing straps sewn on.

NEW had developed and offered a complete automated transport system for the flooring manufacturing company, Bjelin, which is a good example of a Supply Chain automation.

NWE has together with their partners Joladad Hydraroll, Tyllis Oy Ab, and Hörmann developed a system that includes automatic loading and unloading and cargo securing of loads shuttled between the factory and a combined warehouse and distribution centre. The semi-trailer, built by Tyllis, is equipped with Jolada Moving Floor system for automated loading and unloading. The Moving Floor system is also installed in the factory and at the warehouse which includes loading gates from Hörmann with guide system to get the trailer in right position at the gate. The out- and incoming pallets on the Moving Floor is handled by manual counterbalance forklifts.

The semi-trailer is equipped with automated NWE *FIX Truck-Safe* system that after pushed button secures the cargo by a tarpaulin hanging in rubber straps in the ceiling tensioned by straps. The system controls the tension in the straps during the whole transport. When unloading a pushed button release the straps and the tarpaulin goes up by the rubber straps to the start position.

Before the new system was installed all handling of pallets was manual. The change of automation can be shown in the spider diagrams below:



Autonomous Transport Chain Levels – Case Study Bjelin Before and After

Summary of Autonomous Transport Chain Levels

Cargo Securing Complexity Levels

An additional view, to the different autonomous levels in the transport chain, is to understand the complexity of the cargo to load and secure depending on type of cargo, the possibility to block the cargo and the loading pattern.

The cargo securing complexity has also been divided into six levels from cargo completely blocked by the boundaries of the CTU (Level 0) to general cargo both rigid and non-rigid with different sizes with a lot of space to the boundary of the CTU (Level 5).

At **Level 0** the cargo, both rigid and non-rigid load units in different sizes, is blocked in all directions direct or indirect against the boundaries of the CTU. That means that the total void in both lengthways and sideways direction is less than 15 cm.

At **Level 1** the rigid uniformed sized cargo is at least direct or indirect bottom blocked against the headboard of the CTU. The section could have different number of layers (broken layers).

At **Level 2** the rigid cargo with different sizes is at least direct or indirect bottom blocked against the headboard of the CTU. The section could have different number of layers (broken layers).

At **Level 3** the rigid and non-rigid cargo with different sizes is at least direct or indirect bottom blocked against the headboard of the CTU. The section could have different number of layers (broken layers).

At **Level 4** the rigid cargo with different sizes may not be blocked in any direction. The section could have different number of layers (broken layers).

At **Level 5** the rigid and non-rigid cargo with different sizes may not be blocked in any direction. The section could have different number of layers (broken layers).

Level	Type of Cargo	Blocked	Loading pattern	Example
0	Rigid and non-rigid load units with uniformed size	Blocked against the CTU in all directions	Equal sections in several rows and layers stowed against the boundary of the CTU with a total void less than 15 cm in all directions.	
1	Rigid load units with uniformed size	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
2	Rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
3	Rigid and non-rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
4	Rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	
5	Rigid and non-rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	

Cargo Securing Complexity Levels

Summary of Autonomous Transport Chain Levels

SKF Today

There are two kinds of pallets from the D-factory. Either SKF-pallets (half EUR-pallets) with one or two collars or pallet bases loaded with single boxes in plastic or plywood. The pallets with single boxes are not stackable.

The cargo is normally loaded in three rows in one or two layers. Under normal circumstances the cargo is blocked by the boundary of the CTU (Level 0) but in sometimes the cargo can be loaded in broken layers (Level 1).

Level	Type of Cargo	Blocked	Loading pattern	Example
0	Rigid and non-rigid load units with uniformed size	Blocked against the CTU in all directions	Equal sections in several rows and layers stowed against the boundary of the CTU with a total void less than 15 cm in all directions.	
1	Rigid load units with uniformed size	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
2	Rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
3	Rigid and non-rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
4	Rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	
5	Rigid and non-rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	

Cargo Securing Complexity Levels – Scale test Operation Today

Scale Test – Dry Run and Final Test

The same type of cargo was used at both at the Dry Run and at the Final test. It was EUR pallets with two collars and therefore stackable.

The cargo was loaded in two rows with the short end of the pallets blocked against the headboard of the CTU. The void in sideways direction was approx. 90 cm and therefore the pallets had to be secured in sideways direction (Level 1).

Level	Type of Cargo	Blocked	Loading pattern	Example
0	Rigid and non-rigid load units with uniformed size	Blocked against the CTU in all directions	Equal sections in several rows and layers stowed against the boundary of the CTU with a total void less than 15 cm in all directions.	
1	Rigid load units with uniformed size	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
2	Rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
3	Rigid and non-rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
4	Rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	
5	Rigid and non-rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	

Cargo Securing Complexity Levels – Scale Test - Dry Run and Final Test

Summary of Autonomous Transport Chain Levels

Case study Bjelin Flooring Company

The pallets handle in the flow between Bjelin Flooring Factory and the warehouse is normal wooden pallet in different sizes stowed with wooden raw material or finished floor packages. The cargo is secured by stretch plastic into rigid pallets (Level 2) but sometimes the pallets are non-rigid (Level 3).

Level	Type of Cargo	Blocked	Loading pattern	Example
0	Rigid and non-rigid load units with uniformed size	Blocked against the CTU in all directions	Equal sections in several rows and layers stowed against the boundary of the CTU with a total void less than 15 cm in all directions.	
1	Rigid load units with uniformed size	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
2	Rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
3	Rigid and non-rigid load units with different sizes	Blocked against the headboard	Several sections with a total void more than 15 cm against the side walls of the CTU. The sections could have different number of layers (broken layers) both in forward and backward direction. Bottom layer flush stowed against the headboard.	
4	Rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	
5	Rigid and non-rigid load units with different sizes	No blocking	Several sections and/or rows with a total void more than 15 cm against the boundary of CTU. The sections could have different number of layers (broken layers) both in forward and backward direction.	

Cargo Securing Complexity Levels – Case Study Bjelin Flooring