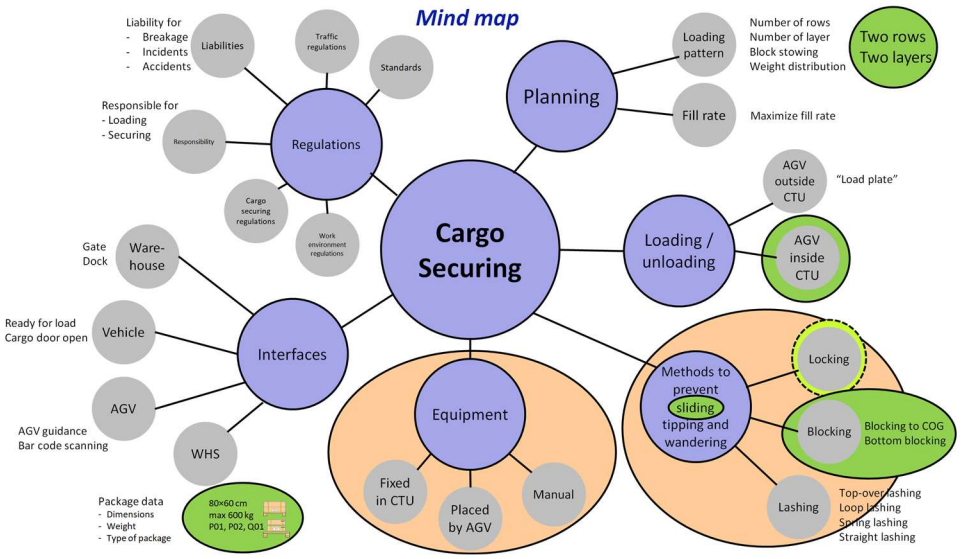
Summary of Cargo Securing methods in the Scale project

Evaluation of cargo securing methods

Workshop Cargo Securing 23rd June 2022

At a workshop the 23rd of June 2022 with nine participants from the different parties in the Scale project a Brainstorm was performed to get ideas for cargo securing in the autonomous transport chain.

There is a lot of factors that can be involved in loading and securing of the cargo, see mind map below.



Mind Map – Factors that are involved in the Cargo securing

The brainstorm was concentrated on the actual flow from the SKF D-factory to the Nordic warehouse. This means the following prerequisites for the loading and securing:

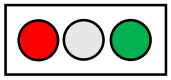
Type of cargo:	Stackable SKF-pallets (half EUR-pallets) with one or two collars. Non-stackable SKF-pallets bases loaded with single bearing boxes.
Type of loading pattern:	Two rows and two layers.
Loading method:	AGV loading the pallets into the vehicle.
Type of movement to prevent:	Mainly sliding.
Securing method:	Preferable locking or blocking

The brainstorm ended up in several ideas for the cargo securing and afterwards MariTerm has evaluated the different ideas and added some more methods during the time of the project. The advantages and disadvantages of each idea/method are listed including the need of planning in advance, securing method, required equipment and interface between systems.

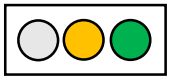
The ideas have been divided into three groups depending on the direction the actual method prevents the cargo from moving.

Summary of Cargo Securing Methods

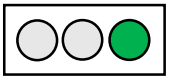
To make a visual presentation of the different methods they are classified with a “traffic light” and all methods had a green light as they are possible methods to secure the cargo. Three combinations are used with the following explanation:



Manual handling required → not autonomous.



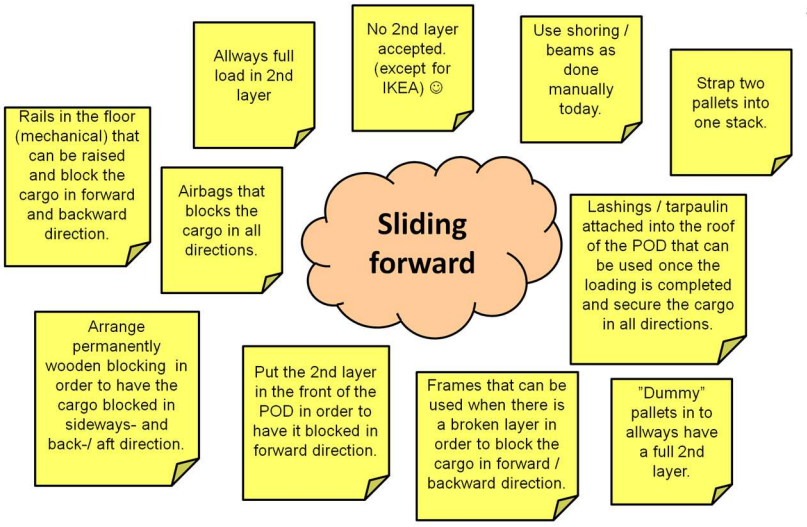
The method needs further development or have some complication that must be solved.



OK, the method can be used at once or is already available on the market.

Summary of cargo securing methods in forward direction

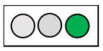
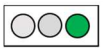
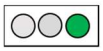
After the brainstorm the following ideas were suggested at the workshop to prevent forward sliding:



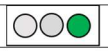
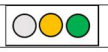
Brainstorm – Cargo securing methods in forward direction

In total 16 different ideas/methods have been evaluated. Four of the methods have got a red light as they require manual handling or was a poor solution regarding to the filling rate. Five methods have got a yellow light and four of them have been further developed and are described in next section. Two of those methods, *L-frame* and *FlexiBar*, were tested in the Dry Run and the Final Test at SKF.

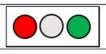
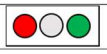
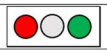
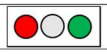
Finally, seven methods got a green light and three of them were dealing with loading empty or dummy pallets or using a specific loading pattern. Four of the methods are commercial products: *Fix Truck-Safe* from NWE, *Auto Deck* from Ancra, *Anti Slip* from LAMILUX and *Friction Paint* from several suppliers. A visit to an industry using *Fix Truck-Safe* and a test with *Friction paint* has been performed in the project, see next section.

Name	Full 2nd layer	Empty pallets (AGV)	Dummy pallet	Friction paint	Friction laminate	Tarpaulin in roof
Description	Always full load in 2nd layer	Empty pallets used when there is a broken layer to raise up section to block the cargo in forward direction.	" Dummy" pallets in to always have a full 2nd layer.	Floor painted by a paint with a high friction factor.	The floor is covered with a friction laminate with a high friction factor.	Lashings / tarpaulin attached into the roof of the POD that can be used once the loading is completed and secure the cargo.
Planning	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs no planning in advance	Needs no planning in advance	No special planning needed
Load/unload	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU
Securing method	Blocking by goods	Threshold blocking	Blocking by goods	Increase the friction	Increase the friction	Lashing (top-over)
Equipment	No equipment needed	Empty pallets placed in CTU by AGV	Dummy pallets placed in CTU by AGV	No equipment needed	No equipment needed	Lashings / tarpaulin installed inside CTU. Tightened by motors.
Interface	Planning WHS → AGV	Planning WHS → AGV	Planning WHS → AGV	No interface	No interface	Tarpaulin remote controlled
Advantages	+ No special equipment + No manual handling + Simple planning + Low cost	+ Existing equipment + Low cost + No manual handling	+ Existing equipment + Low cost + No manual handling	+ No special equipment + No manual handling + Simple planning + Low cost	+ Existing equipment, see *LAMILUX Anti-Slip* + No manual handling + Simple planning	+ No planning + Existing solution by NWE – *FIX Truck-Safe* + Can be used for all directions + No manual handling
Disadvantages	- Needs planning - Longer lead time at loading	- Needs planning - Extra handling by AGV - Return flow of empty pallets	- Needs planning - Extra handling by AGV - Return flow of dummies	- Secured only bottom layer - Friction must be at least μ = 0.8	- Secured only the bottom layer - Fixed equipment in CTU (special vehicle)- Friction must be at least μ = 0.8	- Fixed equipment in CTU (special vehicle)
Ranking						

Evaluation of Cargo securing methods in forward direction I

Name	Shoring beams (mechanical)	Frames	Shoring beams (mechanical)	Poles in rails (mechanical)	2nd layer in front	Floor Block
Description	Use mechanical shoring beams blocking second (and third) layer.	Frames that can be used when there is a broken layer to block the cargo in forward direction.	Use mechanical shoring beams blocking second (and third) layer.	Poles in rails placed in the floor that can be (mechanical) raised and block the cargo in forward direction.	Put the 2nd layer in the front of the POD to have it blocked in forward direction.	Mechanical block in floor raises up and block bottom layer
Planning	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs planning in advance of the total load
Load/unload	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU
Securing method	Blocking by equipment	Blocking by equipment	Blocking by equipment	Blocking by equipment	Blocking by goods	Blocking by equipment
Equipment	Mechanical controlled shoring beams installed in CTU in lashing rails	Frames placed in CTU by AGV	Mechanical controlled shoring beams installed in CTU in lashing rails	Rails with poles installed in CTU	No equipment needed	Floor block installed in CTU
Interface	Planning WHS → AGV Mechanical beams remote controlled	Planning WHS → AGV	Mechanical beams remote controlled	Planning WHS → AGV Poles remote controlled	Planning WHS → AGV	Planning WHS → AGV
Advantages	+ Existing equipment, see Ancra Cargo *Auto Deck*	+ No manual handling + No fixed equipment in CTU	+ No manual handling + Partly existing equipment + Low cost	+ No manual handling	+ No special equipment + No manual handling + Simple planning	+ No manual handling
Disadvantages	- Needs planning - Fixed equipment in CTU (special vehicle) - Expensive	- Needs planning - Extra handling by AGV/Forklift - Return flow of frames - Needs development, *see L-frame*	- Fixed equipment in CTU (special vehicle) - Needs development, see *FlexiBar*	- Needs planning - Fixed equipment in CTU (special vehicle) - Needs development, see *Flip Bar*	- Needs planning - Weight distribution could decrease filling rate	- Needs planning - Fixed equipment in CTU (special vehicle) - Block only bottom layer - Needs development, see *Floor Flip*
Ranking						

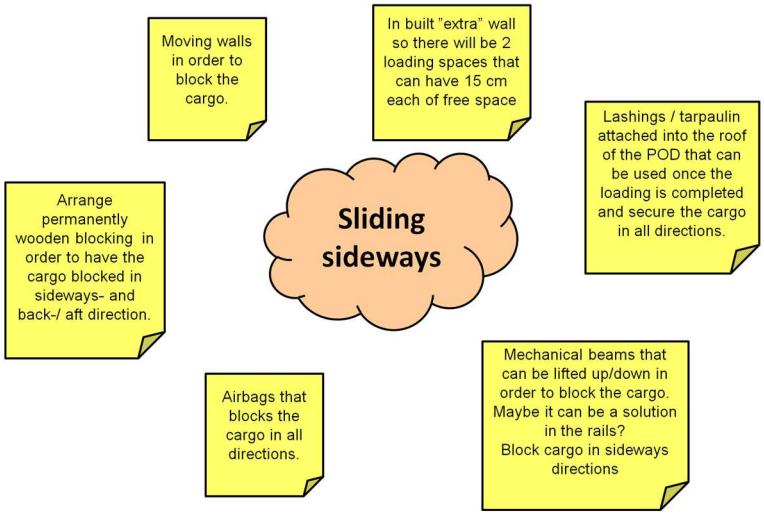
Evaluation of Cargo securing methods in forward direction II

Name	No 2nd layer	Strap 2 pallets	Empty pallets (Manual)	Shoring beams (manual)		
Description	No 2nd layer accepted.	Strap two pallets into one stack.	Empty pallets to fill void between goods and wall of CTU.	Use shoring / beams as done manually today.		
Planning	Needs planning in advance of the total load	Needs planning in advance of the total load	No special planning needed	Needs planning in advance of the total load		
Load/unload	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU		
Securing method	Blocking by goods	Blocking by goods	Blocking by equipment	Blocking by equipment		
Equipment	No equipment needed	No equipment needed	Empty pallets placed manually	Shoring beams manually placed inside CTU		
Interface	Planning WHS → AGV	Planning WHS → AGV		Planning WHS → AGV Mechanical beams remote controlled		
Advantages	+ No special equipment + No manual handling + Simple planning + Low cost	+ Existing equipment + Low cost	+ Existing equipment + No planning + Non interface involved	+ Existing equipment + Low cost		
Disadvantages	- Needs planning - Poor filling rate	- Needs planning - Limited weight prevented from sliding - Manual handling	- Return flow of empty pallets - Manual handling	- Manual handling		
Ranking						

Evaluation of Cargo securing methods in forward direction III

Summary of cargo securing methods in sideways direction

After the brainstorm the following ideas were suggested at the workshop to prevent sideways sliding:



Brainstorm – Cargo securing methods in sideways direction

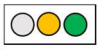
In total 12 different ideas/methods have been evaluated. Three of the methods have got a red light as they require manual handling. Six methods have got a yellow light but from the beginning of the project the loading pattern was meant to be in three rows and no securing was required in sideways direction as the pallets were going to be blocked against the sidewalls of the vehicle. Because of that reason no big efforts were done at this stage in the project to develop any of these methods.

Later in the project the loading pattern in the tests was changed to two rows instead of three which require additional sideways securing. Three of the yellow light methods are not further developed but two methods, *Flip Bar* and *Floor Flip*, are already mentioned in the previous section as they also can block cargo in forward direction. One yellow light method is an existing product *Mega Bag* from

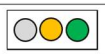
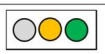
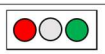
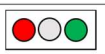
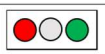
the company Checkmate, which require some development to fit in an autonomous vehicle, is described in next section.

Finally, three methods got a green light as they are ready commercial products and already mentioned as they can prevent sliding in also forward direction: *Fix Truck-Safe* from NWE, *Anti Slip* from LAMILUX and Friction Paint from several suppliers.

None of the methods to secure cargo in sideways direction was tested in the Dry Run or the Final Test at SKF. All the securing performed were done manually.

Name	Tarpaulin in roof	Friction paint	Friction laminate	Mechanical beams	Moving walls	Extra wall
Description	Lashings / tarpaulin attached into the roof of the POD that can be used once the loading is completed and secure the cargo.	Floor painted by a paint with a high friction factor.	The floor is covered with a friction laminate with a high friction factor.	Mechanical beams that can be lifted up/down to block the cargo in sideways direction. Maybe it can be a solution in the rails?	Moving walls to block the cargo in sideways direction. Maybe fixed in the shoring rails.	” Extra” wall built in CTU so there will be 2 loading spaces that can have 15 cm each of free space.
Planning	No special planning needed	Needs no planning in advance	Needs no planning in advance	No special planning needed	No special planning needed	No special planning needed
Load/unload	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU
Securing method	Lashing (top-over)	Increase the friction	Increase the friction	Blocking by equipment	Blocking by equipment	Blocking by walls
Equipment	Lashings / tarpaulin installed inside CTU. Tightened by motors.	No equipment needed	No equipment needed	Mechanical beams installed in CTU	Pneumatic/ hydraulic/ electrical (?) moving walls installed in CTU	Extra permanent wall installed in the middle of CTU
Interface	Tarpaulin remote controlled	No interface	No interface	Beams remote controlled	Walls remote controlled	
Advantages	+ No planning + Existing solution by NWE – *FIX Truck-Safe* + Can be used for all directions + No manual handling	+ No special equipment + No manual handling + Simple planning + Low cost	+ Existing equipment, see *LAMILUX Anti-Slip* + No manual handling + Simple planning	+ No manual handling	+ No planning + No manual handling	+ No planning + No manual handling + No interface involved
Disadvantages	- Fixed equipment in CTU (special vehicle)	- Secured only bottom layer - Friction must be at least $\mu = 0.5$	- Secured only the bottom layer - Fixed equipment in CTU (special vehicle)- Friction must be at least $\mu = 0.5$	- Needs planning - Fixed equipment in CTU (special vehicle) - Needs development, see *Flip Bar*	- Fixed (?) equipment in CTU (special vehicle) - Load pattern with large sideways void. - Needs development, see *Moving Bar/Wal*	- Fixed equipment in CTU (special vehicle) - Load pattern with large sideways void. - Needs development
Ranking						

Evaluation of Cargo securing methods in sideways direction I

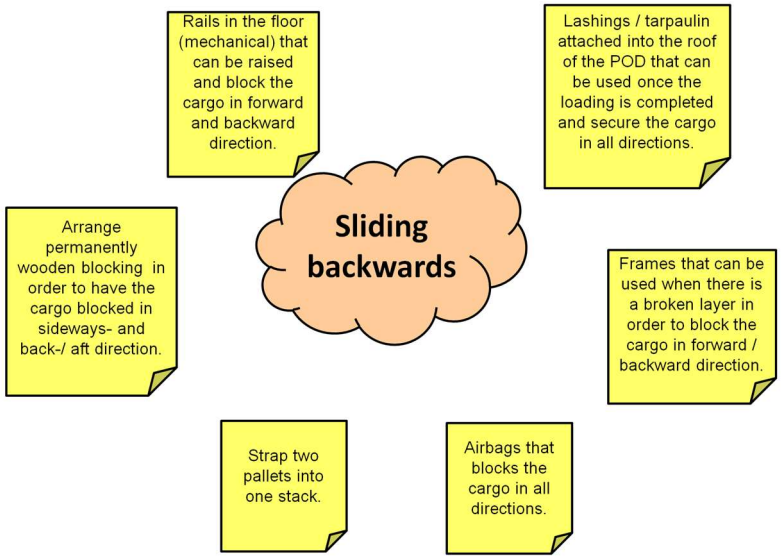
Name	Floor Block	Wooden block	Airbags (manual)	Airbags (manual)	Cargo bar	Empty pallets (manual)
Description	Mechanical block in floor raises up and block bottom layer	Arrange permanently wooden blocking up to 80 cm to have the cargo blocked in sideways direction.	Permanent airbags built in the vehicle walls that block the cargo in sideways directions.	Manually placed airbags that block the cargo in sideways directions.	Cargo bar that blocks goods in sideways direction.	Empty pallets to fill void between goods and wall of CTU.
Planning	Needs planning in advance of the total load	No special planning needed	No special planning needed	No special planning needed	No special planning needed	No special planning needed
Load/unload	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU
Securing method	Blocking by equipment	Blocking by equipment	Blocking by equipment	Blocking by equipment	Blocking by equipment	Blocking by equipment
Equipment	Floor block installed in CTU	Wooden block installed in CTU	Airbags installed in CTU	Airbags placed manually	Cargo bars placed manually	Empty pallets placed manually
Interface	Planning WHS → AGV		Airbags remote controlled			
Advantages	+ No manual handling	+ No planning + Non interface involved + Low cost	+ No planning + No manual handling + Existing solution by Checkmate – Mega Bag	+ Existing equipment + No planning + Non interface involved + Low cost	+ Existing equipment + No planning + Non interface involved	+ Existing equipment + No planning + Non interface involved
Disadvantages	- Needs planning - Fixed equipment in CTU (special vehicle) - Block only bottom layer - Needs development, see *Floor Flip*	- Fixed equipment in CTU (special vehicle) - Low filling rate - Needs development	- Fixed equipment in CTU (special vehicle) - Needs adaption of existing system	- Return flow of airbags - Manual handling	- Limited weight prevented from sliding - Manual handling	- Return flow of empty pallets - Manual handling
Ranking						

Evaluation of Cargo securing methods in sideways direction II

Summary of Cargo Securing Methods

Summary of cargo securing methods in backwards direction

After the brainstorm the following ideas were suggested at the workshop to prevent backwards sliding:



Brainstorm – Cargo securing methods in backward direction

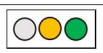
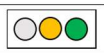
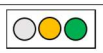
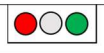
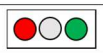
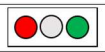
In total 13 different ideas/methods have been evaluated. Three of the methods have got a red light as they require manual handling. Four methods have got a yellow light and three of them, *Flip Bar*, *Floor Flip,* and *L-frame*, have already been mentioned. The fourth method, *Door Strap* is further developed and is described in next section. The method *L-frame* was tested in the Dry Run at SKF.

Finally, five methods got a green light and one of them was loading with empty pallets. The remaining four methods are commercial products which already have been mentioned: *Fix Truck-Safe* from NWE, *Auto Deck* from Ancra, *Anti Slip* from LAMILUX and Friction Paint from several suppliers, see further description in next section.

Name	Tarpaulin in roof	Empty pallets (AGV)	Friction paint	Friction laminate	Shoring beams (mechanical)	Shoring beams (mechanical)
Description	Lashings / tarpaulin attached into the roof of the POD that can be used once the loading is completed and secure the cargo.	Empty pallets used when there is a broken layer to raise up section to block the cargo in backward direction.	Floor painted by a paint with a high friction factor.	The floor is covered with a friction laminate with a high friction factor.	Use mechanical shoring beams.	Use mechanical shoring beams.
Planning	No special planning needed	Needs planning in advance of the total load	Needs no planning in advance	Needs no planning in advance	Needs planning in advance of the total load	Needs planning in advance of the total load
Load/unload	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU
Securing method	Lashing (top-over)	Threshold blocking	Increase the friction	Increase the friction	Blocking by equipment	Blocking by equipment
Equipment	Lashings / tarpaulin placed inside CTU. Tightened by motors.	Empty pallets placed in CTU by AGV	No equipment needed	No equipment needed	Mechanical controlled shoring beams installed in CTU	Mechanical controlled shoring beams installed in CTU
Interface	Tarpaulin remote controlled	Planning WHS → AGV	No interface	No interface	Planning WHS → AGV Mechanical beams remote controlled	+ No planning + No manual handling+ + No interface involved
Advantages	+ No planning + Existing solution by NWE – *FIX Truck-Safe* + Can be used for all directions + No manual handling	+ Existing equipment + Low cost + No manual handling	+ No special equipment + No manual handling + Simple planning + Low cost	+ Existing equipment, see *LAMILUX Anti-Slip* + No manual handling + Simple planning	+ Existing equipment, see Ancra Cargo *Auto Deck*	+ Existing equipment, see Ancra Auto Deck
Disadvantages	- Fixed equipment in CTU (special vehicle)	- Needs planning - Extra handling by AGV - Return flow of empty pallets	- Secured only bottom layer - Friction must be at least μ = 0.5	- Secured only the bottom layer - Fixed equipment in CTU (special vehicle)- Friction must be at least μ = 0.5	- Needs planning - Fixed equipment in CTU (special vehicle) - Expensive	- Vehicle with shutter door - Fixed equipment in CTU (special vehicle) - Needs development, see *Roof Bar*
Ranking						

Evaluation of Cargo securing methods in backward direction I

Summary of Cargo Securing Methods

Name	Frames	Poles in rails (mechanical)	Floor Block	Straps in rear door	Empty pallets (manual)	Shoring beams (manual)	Cargo bar
Description	Frames that can be used when there is a broken layer to block the cargo in backward direction.	Poles in rails placed in the floor that can be (mechanical) raised and block the cargo in backward direction.	Mechanical block in floor raises up and block bottom layer	Straps attached in top of headboard and bottom of rear door. When door is closed the straps are tensioned over the goods.	Empty pallets used when there is a broken layer to raise up section to block the cargo in backward direction.	Use shoring / beams as done manually today.	Cargo bar that blocks goods in backward direction.
Planning	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs planning in advance of the total load	Needs no planning in advance	Needs planning in advance of the total load	Needs planning in advance of the total load	No special planning needed
Load/unload	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU	By AGV into CTU
Securing method	Blocking by equipment	Blocking by equipment	Blocking by equipment	Lashing to avoid wandering	Threshold blocking	Blocking by equipment	Blocking by equipment
Equipment	Frames placed in CTU by AGV	Rails with poles installed in CTU	Floor block installed in CTU	Lashing belts attached int vehicle.	Empty pallets placed manually	Shoring beams manually placed inside CTU	Cargo bars placed manually
Interface	Planning WHS → AGV	Planning WHS → AGV Poles remote controlled	Planning WHS → AGV	No interface	Planning WHS → AGV	Planning WHS → AGV Mechanical beams remote controlled	
Advantages	+ No manual handling + No fixed equipment in CTU	+ No manual handling	+ No manual handling	+ No manual handling + No planning + No interface involved	+ Existing equipment + Low cost	+ Existing equipment + Low cost	+ Existing equipment + No planning + No interface involved
Disadvantages	- Needs planning - Extra handling by AGV/Forklift - Return flow of frames - Needs development, *see L-frame*	- Needs planning - Fixed equipment in CTU (special vehicle) - Needs development, *see Flip Bar*	- Needs planning - Fixed equipment in CTU (special vehicle) - Block only bottom layer - Needs development, *see Floor Flip*	- Vehicle with shutter door - Lashings could easily be stuck. - Secure only wandering - Needs development, *see Door Strap*	- Needs planning - Return flow of empty pallets - Manual handling	- Manual handling	- Limited weight prevented from sliding - Manual handling
Ranking							

Evaluation of Cargo securing methods in backward direction II

Description and development of cargo securing methods

The table below shows the different methods and ideas that have been developed and/or studied in the project.

Name	Comment	Direction that is prevented		
		Forward	Backward	Sideways
AutoDeck (mechanical bars)	Commercial product Ancra *Cargo AutoDeck*	X	X	
Door Strap (straps in rear door)	Idea		X	
Flexi Bar (mechanical bars)	Idea developed and tested in the projects Final Test	X		
Flip Bar (Poles in rails)	Idea	X	X	(X)
Floor Flip (floor block)	Idea	X	X	(X)
Friction paint (increase friction)	Commercial product tested in the project: BILTEMA *Anti-Slip Paint*	X	X	X
LAMILUX Anti-Slip (Friction Laminate) (increase friction)	Commercial product *LAMILUX Anti-Slip*	X	X	X
L-frame (frame)	Idea developed and tested in the projects Dry Run	X	X	
MegaBag (airbags built in)	Commercial product dunnage bags system from Checkmate that needs to be adapted.		(X)	X
Moving Bar (moving walls)	Idea			X
Roof Bar (mechanical bars)	Idea	X	X	
FIX Truck-Safe (Tarpaulin in roof)	Commercial product NWE Automated *FIX Truck-Safe*	X	X	X

Summary of Cargo Securing Methods

AutoDeck

The company Ancra Cargo has an advanced automated cargo decking called *AutoDeck*. Cargo beams are installed and placed in the ceiling of the vehicle. At loading the truck driver press buttons on the inside of the vehicle and the different beams will be placed at a level decided by the truck driver. The different cargo beams are managed with electrical motors and a guide system installed at the walls of the vehicle.

(photo: From Ancra YouTube video)

The truck drive press buttons to decide the level of the different cargo beams

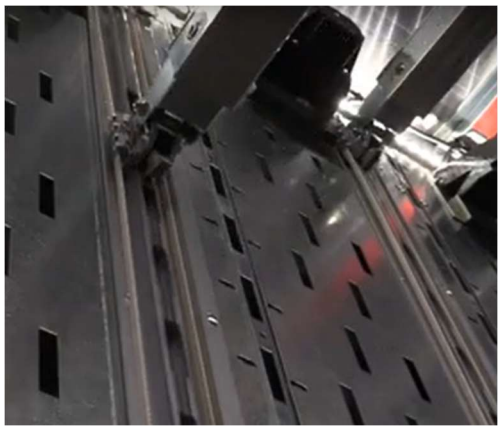
(photo: From Ancra YouTube video)

The different cargo beams move to correct position

This system could instead be possible to be used for cargo securing in lengthways direction at autonomous loading and the beams should be controlled by a remote operator.

(photo: From Ancra YouTube video)

The different cargo beams move to correct position



(photo: From Ancra YouTube video)

The cargo beams managed with electrical motors and a guide system

Advantages with *AutoDeck*:

+ The system prevents cargo movements in lengthways direction.

Disadvantages with *AutoDeck*:

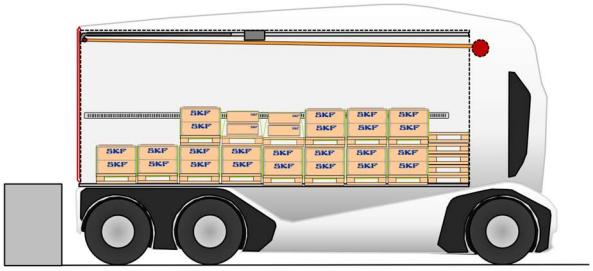
- Require planning and actions from system or remote operator
- Require system interfaces.
- Require special vehicle with a built-in system.
- Expensive.

Summary of Cargo Securing Methods

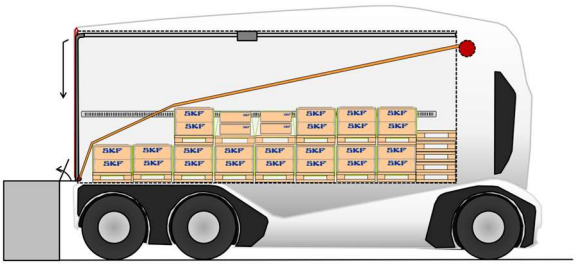
Door Strap

The idea with *Door Strap* is that several lashing belts are fastened in the bottom end of the vehicle backdoor of shutter type. The other end of the belts is connected to a motor at the top of the headboard of the vehicle. The motor can tighten the belts to a wished pre-tension.

During the loading the lashing belts are hanging in the ceiling of the vehicle. When the loading is completed the shutter door is closed and the belts are tensioned by the motor at the headboard. The lashing belts can prevent at least backward wandering of the cargo during the transport and backward sliding of a limited weight of cargo.



The belts hanging in the ceiling during loading



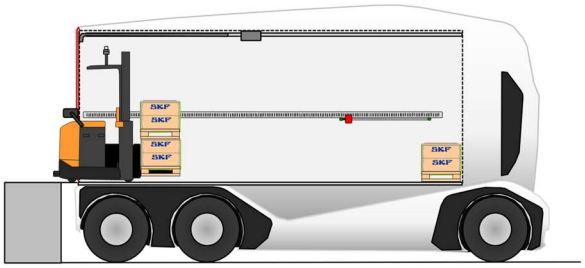
The belts are tensioned after the loading is completed and the shutter door closed

Advantages with *Door Strap*:
+ Require no manual actions.
+ Require no planning.
+ Require no system interfaces.
+ The system prevents backwards wandering.

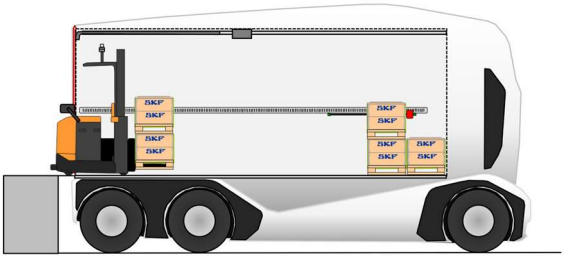
Disadvantages with *Door Strap*:
- Require special vehicle shutter back door.
- Require special vehicle with a built-in system.
- Lashings could easily be stuck.
- The system prevents backwards sliding and tipping only in limited extent.

Flexi Bar

The idea with *Flexi Bar* is that a cargo bar is placed in a shoring rail at each side of the vehicle side on a height suitable to block a second layer in forward direction. When the vehicle is empty the beams is in the back end of the shoring rails. A rubber band is running in several loops inside the beam and fastened in the back end of the rails. When the AGV is loading cargo in the first section the cargo beam moves along the rail by the push from the AGV. If no second layer was loaded the beam will return to the start position when the AGV reverses. The same procedure will happen until a second layer is loaded. Then the cargo beam will block the upper cargo layer in forward direction. Before the start of the transport the hakes on the cargo beam are automated locked.



The Flexi Bar in start position



The Flexi Bar blocks the second layer of the cargo in second section

Before unloading the cargo, the hakes on the cargo beam are unlocked.

The Flexi Bar was developed and after two tests with manual loading of cargo the Flexi Bar was ready for a test with autonomous loading by an AGV at the Final test at SKF in January 2024.

The shoring rails with the cargo beam were installed in the Einride autonomous vehicle. The rubber band was tensioned and fastened in the shoring rails. The automatic hakes are not yet developed and were therefore not tested.

One pallet in the first section is loaded and the AGV push the Flexi Bar in forward direction

The Flexi Bar is back in start position when the AGV reverses

Two sections with pallets in two rows were loaded by the AGV. The first section consists of two pallets in one layer and the second section consists of four pallets in two layers. The cargo beam was gently pushed by the AGV and return to the start position during loading the first section. When the second section in two layers was loaded the cargo beam blocked the cargo as planned. The loading and later the unloading was done without any obstacles.

The second section are loaded, and the Flexi Bar blocks the upper layer in forward direction

The result of the test was successful and a film from the test can be found the MariTerm homepage www.mariterm.se.

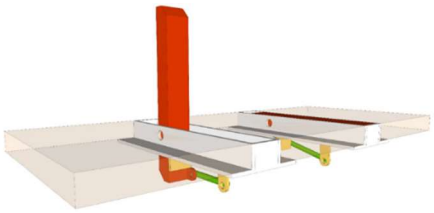
The *Flexi Bar* requires further development before it is ready to be used at autonomous loading of a CTU.

Advantages with *Flexi Bar*:
+ Require no manual actions.
+ Use of partly existing equipment.
+ Low cost.
+ The system can prevent motions of a second layer in forward direction.

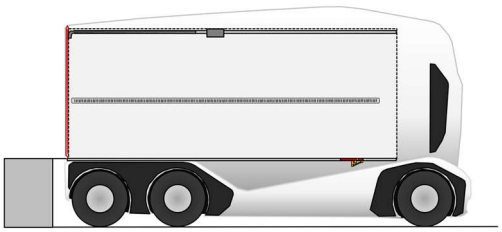
Disadvantages with *Flexi Bar*:
- Require special vehicle with a built-in system.

Flip Bar

The idea with *Flip Bar* is that several mechanical bars are mounted at the vehicle floor in strategic positions. The mechanical bars in down position don´t interfere with the cargo or the loading.



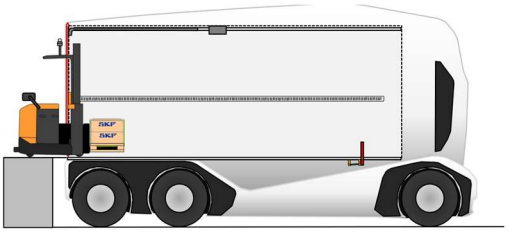
Flip Bar in upright position



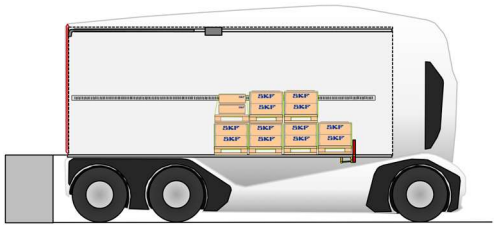
The Flip Bar is in down position when not in use

When the bars are raised to upright position the cargo can be loaded and blocked against the bars. The number of layers that can be blocked is depending on the dimensions of the cargo and the height of the bars.

The *Flip Bar* system can be installed to prevent motions in both forward, backward, and sideways directions.



The Flip Bar is in upright position when in use



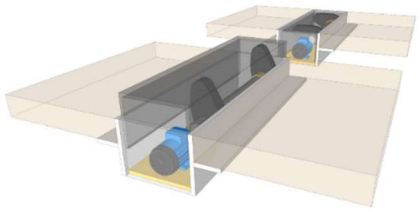
The Flip Bar block the bottom layer in forward direction

Advantages with *Flip Bar*:
+ Require no manual actions.
+ The system can prevent motions in several directions.

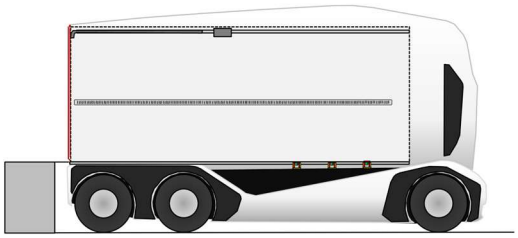
Disadvantages with *Flip Bar*:
- Require planning of the loading.
- Require special vehicle with a built-in system.

Floor Flip

The idea with *Floor Flip* is that several mechanical devises are mounted at the vehicle floor in strategic positions. The *Floor Flip* in down position don´t interfere with the cargo or the loading.



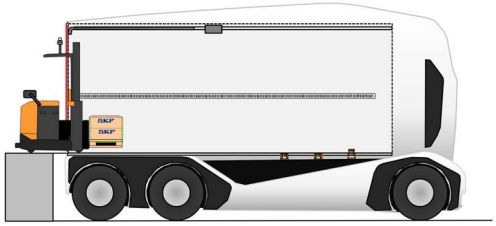
Floor Flip in different positions



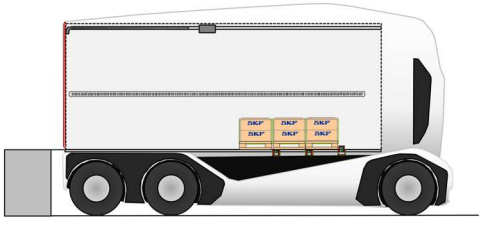
The Floor Flip is in down position when not in use

When the *Floor Flip* are raised to upright position the cargo can be loaded and bottom blocked against the blocks.

The *Floor Flip* system can be installed to prevent motions in both forward, backward, and sideways directions.



The Floor Flip is in upright position when in use



The Floor Flip block the bottom layer in forward direction

Advantages with *Floor Flip*:
+ Require no manual actions.
+ The system can prevent sliding and wandering in several directions.

Summary of Cargo Securing Methods

Disadvantages with *Floor Flip*:
- Require planning of the loading.
- Require special vehicle with a built-in system.
- The system can only block the bottom layer of the cargo.

Friction Paint (BILTEMA Anti-Slip Paint)

Several companies offer *Friction Paint* with some kind of grit to increase the friction. The wear- and tear-resistance can differ depending on the type of grit used. The type of grit will also influence the friction factor between the floor and cargo.

(photo: Biltema)
BILTEMA Anti-Slip Paint

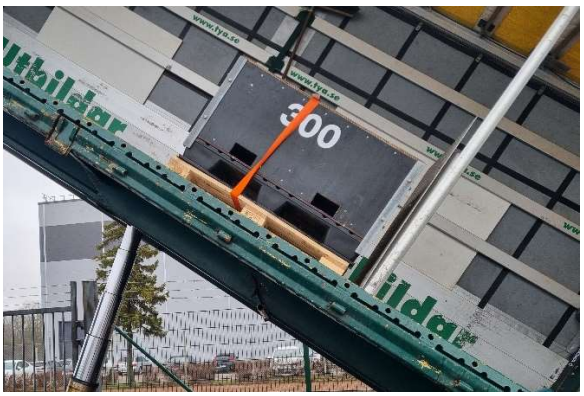
Laminate sheet painted with Anti-Slip

To investigate the influence of the *Friction Paint* on the friction factor an inclining test according to standard EN 12195-1 was performed with BILTEMA Anti-Slip Paint (art.no 30-621). The paint can be used on fiberglass, wood and steel mainly aimed for leisure boats.

The paint was painted with brush on the laminate and a second time after the first layer had dried according to the instructions on the tin. Unfortunately, the paint had the same white colour as the laminate and therefore not so easy to detect on the pictures.

The sheets were placed on the vehicle platform and blocked. Pallets with a weight of approx. 300 kg was placed on the sheets and able to slide. The vehicle platform was inclined and the angle when the pallets start to slide was observed and noted.

Wooden pallet placed on the painted laminate



The pallet starts to slide at 32°

The inclining test was done five times on each combination of material and the average friction factor was calculated according to standard EN 12195-1 with the following result:

Summary of Cargo Securing Methods

Test	1		2		3		4	
Cargo	EUR Wooden Pallet		EUR Wooden Pallet		EUR Plastic Pallet		EUR Plastic Pallet	
Surface	Laminate		Painted laminate		Laminate		Painted laminate	
Test result								
Test No.	**α**	**μ**	**α**	**μ**	**α**	**μ**	**α**	**μ**
a	22,0	0,40	36,0	0,73	11,9	0,21	20,5	0,37
b	22,5	0,41	33,8	0,67	12,1	0,21	17,0	0,31
c	24,5	0,46	32,7	0,64	12,5	0,22	16,5	0,30
d	25,0	0,47	33,0	0,65	11,7	0,21	15,9	0,28
e	24,5	0,46	32,6	0,64	11,8	0,21	15,6	0,28
Average μ_s	23,8	0,44	33,2	0,65	11,9	0,21	16,5	0,30
μ_{est} (μ_s× 0,925)	0,41		0,60		0,20		0,27	
Friction according to EN12195-1	0,41		0,60		0,20		0,27	

The friction factor is increasing and for the combination wooden pallet/Anti-Slip paint the result is good. For the combination plastic pallet/Anti-Slip paint the friction factor increased in relation to a non-painted sheet but the friction factor μ = 0.27 is too low to be useful.

Some paint remains on the plastic pallet after the inclining test

Traces of wear on the painted laminate after the inclining test

The wear-resistance was not good as traces of paint was found under the pallets and clear traces of wear on the surface of the painted laminate was observed after the inclining tests.

Note – other *Friction Paint* made for more harder environments and handling of goods like paint for the deck on sea vessels should have much better mechanical strength and resistance and goods wear-resistance.

Advantages with *Friction Paint*:
+ Require no manual actions.
+ Require no system interfaces.
+ Simple planning of loading pattern.
+ Should have a friction factor of at least μ = 0.5 up to μ = 0.8 depending on direction.
+ Low cost.
+ The system can prevent sliding and wandering in several directions.

Disadvantages with *Friction Paint*:
- Require special vehicle with platform painted with Anti-Slip paint.
- The system can only prevent sliding of the bottom layer of the cargo.

Summary of Cargo Securing Methods

LAMILUX Anti-Slip (Friction Laminate)

The company LAMILUX offers a friction laminate called *LAMILUX Anti-Slip* that can be used to cover the floor of a cargo transport unit. The *LAMILUX Anti-Slip* is a glass-fibre-reinforced laminate with high mechanical strength and resistance.

(photo: LAMILUX)

LAMILUX Anti-Slip laminate in a CTU

(photo: TUL-LOG GmbH)

Friction test according to EN 12195-1

Different grades of the *LAMILUX Anti-Slip* have been tested according to the standard EN 12195-1 with the following summary of result of the friction factors according to the certificates:

Cargo	Surface	Friction factor μ
EUR wooden pallet	AntiSlip Fein	0.64
EUR plastic pallet	AntiSlip Fein	0.50
Steel crate	AntiSlip Fein	0.54
EUR wooden pallet	AntiSlip Mittel	0.62
EUR plastic pallet	AntiSlip Mittel	0.51
Steel crate	AntiSlip Mittel	0.53

Advantages with *LAMILUX Anti-Slip*:
+ Require no manual actions.
+ Require no system interfaces.
+ Simple planning of loading pattern.
+ The Anti-Slip has a high mechanical strength and resistance.
+ The Anti-Slip has a good wear-resistance.
+ Should have a friction factor of at least μ = 0.5 up to μ = 0.8 depending on direction.
+ The system can prevent sliding and wandering in several directions.

Disadvantages with *LAMILUX Anti-Slip*:
- Require special vehicle with Anti-Slip installed.
- The system can only prevent sliding and wandering of the bottom layer of the cargo

More information regarding *LAMILUX Anti-Slip* can be found on the LAMILUX home pages:

www.lamilux.com or www.lamilux.se

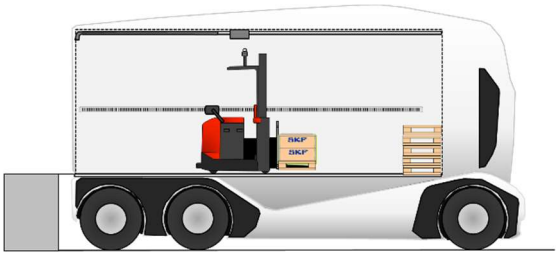
L-frame

The idea with the *L-frame* is that the AGV first picks up the frame and then one or two pallets depending on the load pattern.

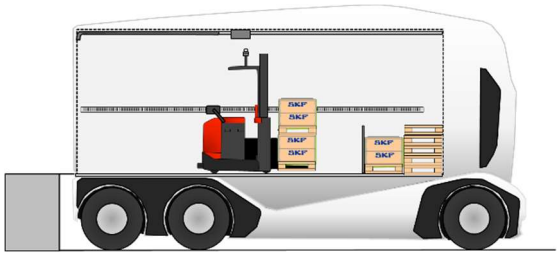
L-frame

AGV with L-frame and one pallet

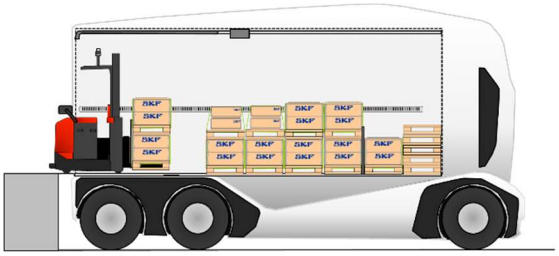
If one pallet is picked up the *L-frame* will forward block the second layer in next section to be loaded. If two pallets are picked up the *L-frame* will backwards block the second layer in that section.



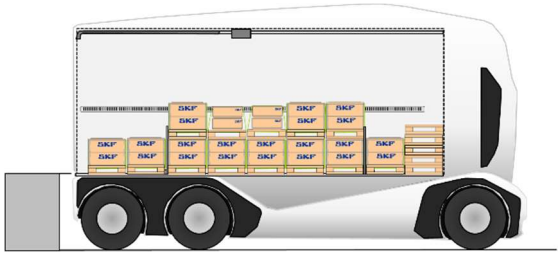
The AGV load the first section in on layer with L-frames



The next section in two layers is loaded



The last section with two layers is loaded with L-frames



The L-frames block the second layer in lengthways directions

The *L-frame* was developed and three were made to be used in the Scale tests at SKF. In a late stage of the project, it was decided not to use an AGV of counterbalance type. Instead, a Toyota AGV of walkie stacker model was chosen to be use but unfortunately not able to handle the *L-frames*. Therefore, the test with the *L-frames* was limit to the Dry Run in October 2023 when the loading and unloading was done with a manual counterbalance forklift truck.

The L-frame is picked up by the forklift

The forklift has picked up a pallet with the L-frames on the forks

Two sections with pallets in three rows were loaded by the forklift. The first section consists of three pallets in one layer and the second section consists of six pallets in two layers. The L-frames were picked up by the forklift before picking up the pallets in the first section. When the second section in two layers was loaded the L-frame forward blocked the cargo as planned. The loading and later the unloading was done without any obstacles.

The L-frames are placed in the first section of three pallets in one layer

Two rows of the next section in two layers are loaded

The second layer is forward blocked in forward direction by the L-frame

After the unloading of the pallet the L-frame is removed and placed in an own stack

The result of the test was successful and a film from the test can be found the MariTerm homepage www.mariterm.se.

Summary of Cargo Securing Methods

The *L-frame* can be used to block cargo over the bottom layer in lengthways directions. The *L-frames* are placed by the AGV and require non prerequisites from the CTU.

Advantages with *L-frame*:
+ Require no manual actions.
+ Require no fixed equipment in the CTU.
+ The system can prevent motions of a second layer in forward or backward direction.

Disadvantages with *L-frame*:
- Require planning of the loading.
- Require extra handling by the AGV/forklift.
- Require return handling of L-frames.

MegaBag

The British company Checkmate is a supplier of dunnage bags with advances valve design, strength, and quality. The company offer a dunnage bags system that can inflate and deflate the bags with a manifold system that controls the pressure in the bags during the transport. The system is made for securing cargo in large cargo holds on sea vessels. For more information see Checkmate homepage under the section heavy duty dunnage bags:

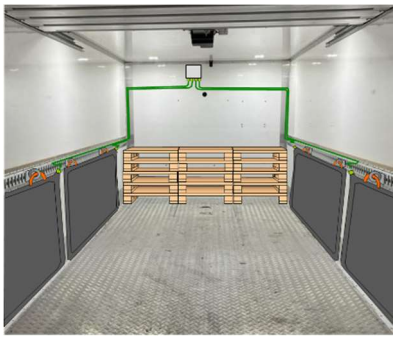
https://www.checkmateflex.com/products/heavy-duty-dunnage-bags/

Checkmate dunnage bag

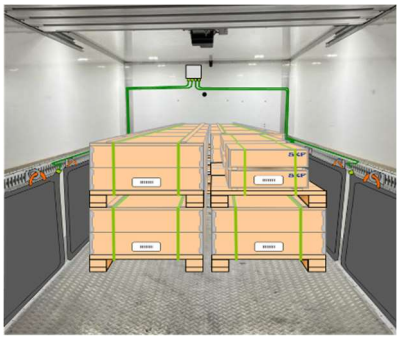
Manifold system to control the air pressure in the dunnage bags

Dunnage bags system secure pulp paper in a cargo hold

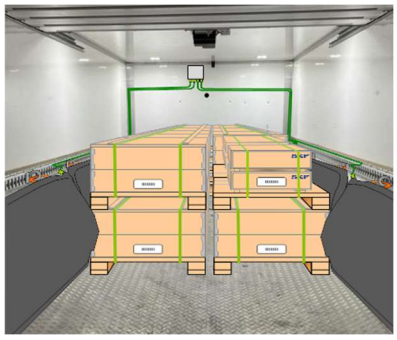
The idea, called *MegaBag,* is to use the same system of dunnage bags but adopted to a vehicle cargo hold. The main use of the system should be to hang up dunnage bags in the shoring rails on the vehicle sides to fill up void in sideway direction.



The dunnage bags are hanging in the shoring rails and connected to manifold system



During loading the dunnage bags are deflated



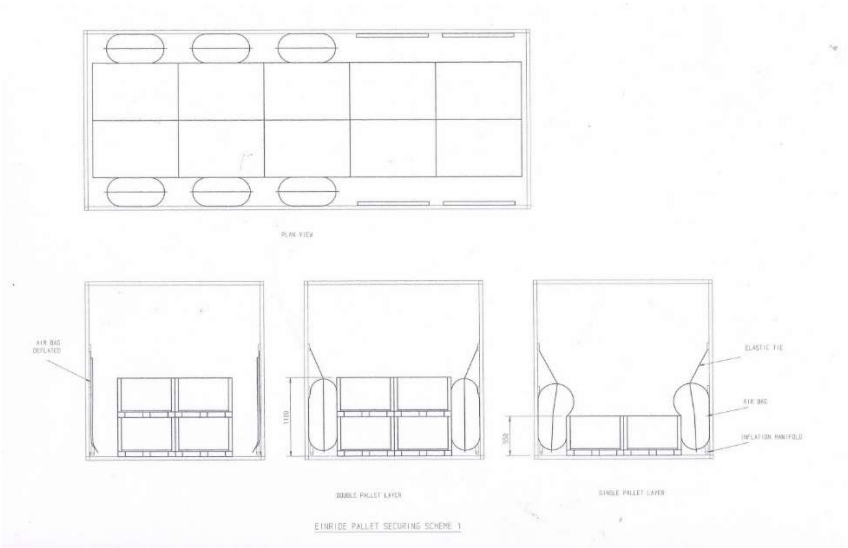
During transport the dunnage bags are inflated

The *MegaBag* idea was presented for Checkmate by Einride and MariTerm at a Teams meeting in September 2023. After the meeting Checkmate has presented the following solution:

"We believe that a system using inflatable bags could be developed for the application. A number of bags would be fitted along both side walls, probably one for each pallet as shown in the sketch below.

The primary source of power to inflate the bags would be a centrifugal air fan. An electronic or pneumatic control system would be needed to control the pressure in each bag. Opposing bags would inflate at the same rate to the same pressure and apply a known force on the side of each pallet. It is necessary to know the force or pressure that the side walls could withstand.

Bags would be deflated by either the application of a vacuum, or by the force from several elastic ties."



Sketch of the dunnage bags system in an Einride vehicle

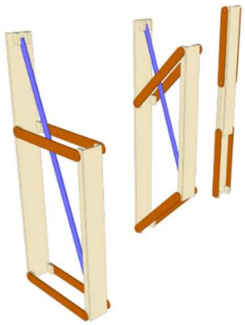
The time was too short to develop and implement the *MegaBag* system to be used on the Einride autonomous vehicle at the Final test at SKF in January 2024.

Advantages with *MegaBag*:
+ Require no planning.
+ Require no manual actions.
+ Can be installed in most vehicles.
+ The system can block cargo in sideway direction and probably motions in backwards direction. direction.

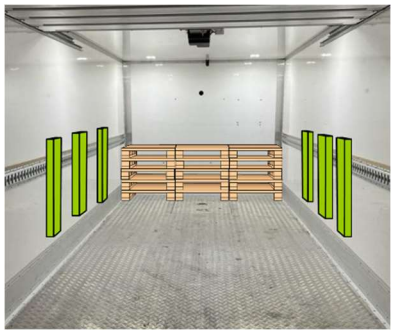
Disadvantages with *MegaBag*:
- Require air pressure system installed on the vehicle.
- Fixed equipment in the CTU.

Moving Bar

The idea with *Moving Bar* is that retractable bars are mounted in the shoring rails on each side of the vehicle. In this position the *Moving Bars* don´t interfere with the cargo or the loading. The void to deal with should be quite large and known distance in this case. The *Moving Bars* are meant to secure cargo in sideways direction.

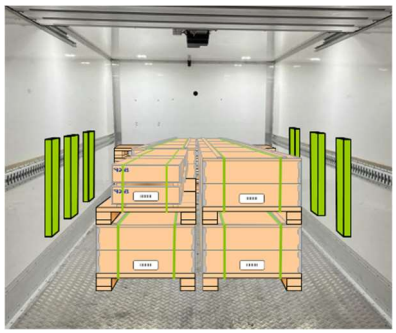


Sketch of the Moving Bar

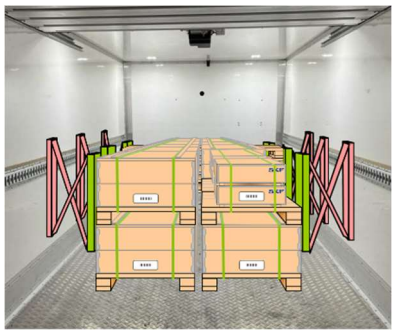


The cargo hold is ready for loading and the Moving Bars are retracted

When the loading is completed, the *Moving Bars* are fold out and prevent at movements I sideways direction.



The loading is finished



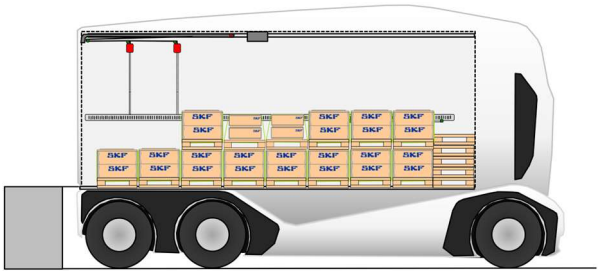
The Moving Bars are fold out and block the cargo in sideways direction

Advantages with *Moving Bar*:
+ Require no manual actions.
+ Require no planning.
+ The system can be installed in vehicles equipped with shoring rails.
+ The system can prevent motion in sideways direction.

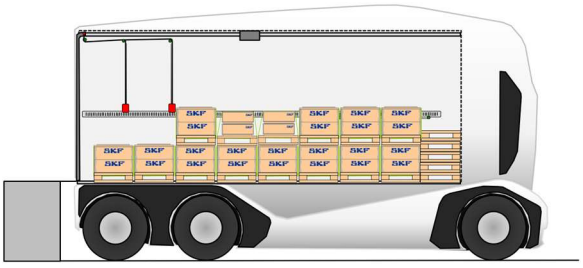
Disadvantages with *Moving Bar*:
- Require load pattern with quite large sideways void.
- Require special vehicle with a built-in system.

Roof Bar

The idea with *Roof Bar* is that several cargo beams are mounted in a guide system at the vehicle side walls and attached with rope/wire to the vehicle backdoor of shutter type. When the door is open the beams go up in the guides to the ceiling of the vehicle.



The bars are hanging in the ceiling during loading



When the shutter door is closed the bars fall and can block the cargo

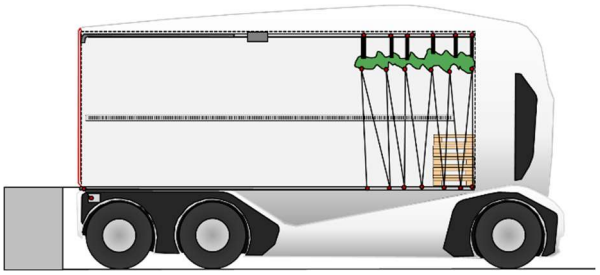
During the loading when the vehicle door is open the cargo beams are hanging in the ceiling of the vehicle. When the loading is completed the shutter door is closed and the beams will fall in the guides and are able to prevent cargo in lengthways direction.

Advantages with *Roof Bar*:
+ Require no manual actions.
+ Require no planning.
+ Require no system interfaces.
+ The system prevents mainly backwards sliding and wandering.

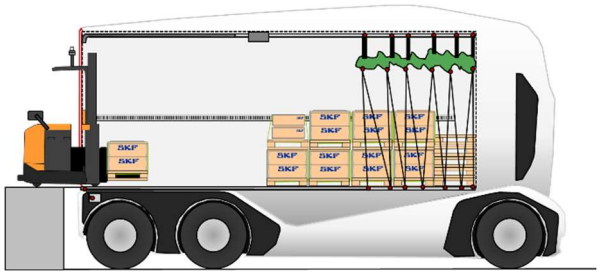
Disadvantages with *Roof Bar*:
- Require vehicle with shutter back door.
- Require special vehicle with a built-in system.
- Beams could maybe be stuck.

FIX Truck-Safe (Tarpaulin in roof)

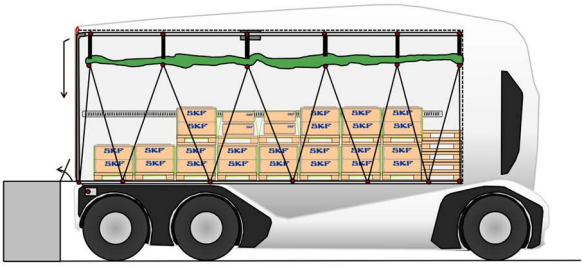
At the brainstorming in June 2022, one solution was proposed to install a tarpaulin in the roof that will be placed over the cargo after the loading was finished. The tarpaulin should be able to prevent motions in all directions. The idea was developed and adopted to the Einride autonomous vehicle which have a shutter door.



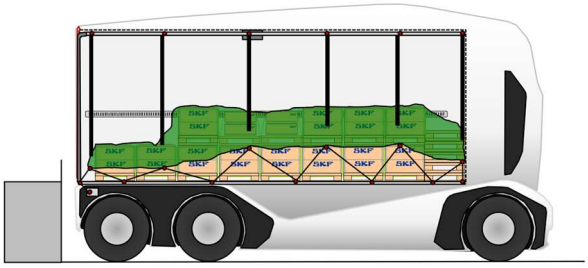
The tarpaulin is placed in the front of the vehicle before loading



Loading



Loding finished and when the shutter doors close the tarpaulin is dragged over the cargo



The tarpaulin is tensioned down against the cargo

Summary of Cargo Securing Methods

The idea to secure cargo with tarpaulin is well known and 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.

(photo: NWE)

Fix Road

(photo: NWE)

Fix Truck-Safe

(photo: NWE)

Fix Marine

NWE had developed an automated version of the cargo securing system, *FIX Truck-Safe*, that allows cargo to be quick lashed at the push of a button.

NWE 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 semi-trailer is equipped with automated NWE *FIX Truck-Safe* system that after push 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 to the start position in the ceiling.

Loading gates at Bjelin factory in Viken

Vehicle at the loading gates at Bjelin warehouse in Helsingborg

Moving floor in the semi-trailer and tarpaulin in start position

Loading the vehicle with Moving floor

Cargo loaded and straps begins to be tensioned

Tarpaulin stretched and secured the cargo

Semi-trailer connected to the gate

Vehicle driver at control panel inside factory

Control cabinet on the trailer for the FIX Truck-Safe system

MariTerm has established a good contact with Bjelin and have visited and study the automated loading, cargo securing and unloading several times. Videos from Bjelin can be found at:

NWE homepage: www.new.fi
Jolada homepage: www.jolada.com
MariTerm homepage: www.maritem.se

After several meetings between NWE, Einride and MariTerm it was decided that the *FIX Truck-Safe* system is to complicated and expensive to installed in an already built vehicle. Therefore, the automated FIX Truck-Safe system will not be tested in the Scale project. However, it is an attractive solution for new Einride projects.

Advantages with *FIX Truck-Safe*
+ Existing solution by NWE.
+ Require no manual handling.
+ Require no planning.
+ The system can prevent motion in all directions.

Disadvantages with *FIX Truck-Safe*:
- Require special vehicle with a built-in system.