ENHANCING INTERMODAL FREIGHT TRANSPORT BY MEANS OF AN INNOVATIVE LOADING UNIT

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ABSTRACT
Within the project "TelliBox - Intelligent MegaSwapBoxes for advanced intermodal freight transport" a new intermodal loading unit was developed and built as a prototype by an international consortium. This new 45 feet long loading unit is applicable to transport on road, rail, short sea and inland waterways. It combines the advantages of currently available loading units, e.g. manoeuvrability and safety of containers, loading facilities and dimensions of semitrailers and the effective use of loading area of swap-bodies, in one sustainable transport solution. The efficient and successful usage of this new solution could be also verified on a demonstration trial within Europe.

Keywords: Intermodal freight transport, loading unit, container, swap-body

1 INTRODUCTION

In recent decades intermodal freight transport was driven by changing requirements of global supply chains. The improvement of integration and compatibility between modes provides the necessary scope for a sustainable transport system [1, 2]. The encouragement of intermodality brings about the opportunity to better use rail, inland waterways and short sea shipping, which are seldom used at present because individually they do not allow door-to-door delivery. The operation grade of carriers will increase significantly in the coming decades and the European Commission prognoses a suboptimal load of rail and waterways compared to the undue quantity of road transports [3].

Since the road transport system is nearly overloaded and currently does not offer enough potential for technological enhancement to face the future increase of traffic performance, the balancing of the modes of transport i.e. intermodal transport represents a crucial solution within the scope of European transport policies [4].

In 2003, European Parliament and Council proposed a Directive on the standardization and harmonization of intermodal loading units, with the objective to reduce inefficiencies in intermodal transport resulting from various sizes of containers circulating in Europe. Within the actual 7th Framework Program the encouragement of modal shift and intermodal transport focuses to "improve the efficiency of interfaces between modes", to "maximize cargo capacity" and to optimize "logistics services, transportation flows, terminal and infrastructure capacity within European and global supply chains".

Within the last few years new innovations and developments for intermodal transport were made (e.g., Arcus 100, HighCube Container, MegaSwapBody, craneable Semitrailers etc.), but there are still a number of economical, technical and operational obstacles to overcome to provide a beneficial usage of intermodal systems for various freight transports.

Today, the transport system has to face various challenges in terms of safety, reducing traffic congestion and improving loading processes and interoperability of available transport modes. The creation of a sustainable transportation system for Europe and Russia depends furthermore on the cooperation of operators along the transport chains. Interfaces between modes and national transport chains have to gain quality and flexibility, to make intermodality competitive [5, 6].

Additionally, transport costs may be reduced by following the trend towards high-volume loading units. Concerning the dimensions of the loading units, some transport modes may not meet the requirements of every cargo [7, 8]. The lack of standardization concerning intermodal loading units hinders the connectivity of modes and generates costs e.g. by requiring special transhipment technologies [9].

Elementary developed transport solutions concerning dimensions, like the high-cube containers or jumbo semitrailers, but also regarding facilities of loading, for example by curtain-side swap-bodies or

boxes with liftable tops, were introduced to the market. But single solutions often can only be used in special areas of applications and in fact necessitate special operational technologies [10].
The success of intermodal transport solutions compared to road transport depends significantly on cost efficiency of loading processes, improvement of interoperability and the exploitation of a maximized cargo area.

STATE OF THE ART – LOADING UNITS

Currently, many different intermodal loading units (ILU) are used in European freight transport. The three most dominant concepts ISO-containers, swap-bodies and semitrailers have been further developed for certain purposes and markets. A general tendency in the enhancement of loading units concerns the maximization of the cargo area and the facilitation of loading and transhipment processes [11].
These loading units differ amongst others in aspects like dimensions and stability as well as usability regarding handling, transport and loading processes. The following paragraph describes the chief differences and their applicability. It compares the advantages and disadvantages of containers, semitrailers and swap-bodies – focusing their applicability to intermodal transport.
Semitrailers are predominantly used in road transport. Compared to containers and swap-bodies they prove to be more flexible especially in regard to the use of their cargo area. In road haulage semitrailers are preferred because of their flexibility not only in terms of manoeuvrability but also concerning the coupling and uncoupling process. Within the last few years greater sized semitrailers, called “Mega-Trailer” or “Jumbo”, have become more and more commonly used. Because of their length and internal height (about 3m) the maximized cargo area is associated with important economic advantages leading to more lucrative transportation [12]. Compared to containers and swap-bodies however, semitrailers are only partially applicable in intermodal transport chains because they are not stackable and require special equipment for handling. In general, only less than 3% of semitrailers are permitted in intermodal transport [13].
Containers are loading units which can be carried on all transport modes and for that reason they offer many advantages for their use in intermodal transport. During the last 50 years maritime containers complied strictly with the ISO standards and were optimized with the introduction of the 40’ standard container. Advantages of standard containers are related to efficient terminal handlings and cost effective intermodal operations. Intermodal transport focuses on the use of containers, as they prove to be functional in intermodal transport chains. The stability and stackability of these carriers ensure an efficient transport and loading process. However, when it comes to road transport, containers represent very little per cent of the total tonnage per freight vehicle. The reasons are that compared to semitrailers and swap-bodies containers offer a smaller cargo area and are not adjusted to standardized pallets. They do not effectively utilize the full dimensions allowed on road transport [14].
Swap-bodies are predominantly used in intra-continental freight transport between the European member states carried on road or rail. Therefore, they are adjusted to road transport restrictions and the transport of standardized euro pallets. Swap-bodies are demountable from the chassis but more lightly constructed than containers, so that most of them cannot be stacked or top-handled. The increasing use of curtain-sided and volume-optimized swap-bodies meets the loaders requirements for wide openings on both sides and a maximized cargo area [15]. For example the swap-body “Arcus 100” from Ewals Cargo Care B.V. offers a cargo volume of 100m³ and has curtains on both sides. These commonly used curtain-sided swap-bodies, however, only resist low horizontal forces in short sea shipping. Also, curtain-sided bodies cannot be certified for TIR and therefore are not able to be transhipped to Russia. Hence, in general swap-bodies are not suitable for intermodal transport including all modes road, rail and waterborne. While European standards in terms of dimensions and general requirements [16, 17], securing of cargo [18] and the coding, identification and marking of swap-bodies [19] have been published in the last 15 years, there are still notable differences in dimensions, fitting and lifting points and other properties concerning the loading and transhipment operations.
When comparing the above listed intermodal loading units a comparison matrix of technical and technological parameters of ILU can be created. For example swap-bodies exist with an internal height of 3m, but none of them can be used for shipping or are equipped with side doors. In the following table (Table 1) the most important demands on an intermodal loading unit for the envisaged usage are summed-up and conferred to existing transport solutions on the market. At present, there is no intermodal unit on the market which meets all, or at least most, listed demands.

Table 1. Comparison of technical and technological parameters of ILUs

	Container (ISO 1A)	**Swap-body (series A)**	**Semitrailer (Jumbo)**
Trimodal	+	-	-
Stackable	+	o	-
Handling from top	+	-	-
Cargo volume (100 m³)	-	+	+
Internal height (3 m)	-	+	+
Loading port from three sides	o	o	+
Safety of cargo (theft/pilferage)	+	o	o
Liftable top	o	o	+
Legend: + standard	o purpose-build	- none	

INNOVATIVE LOADING UNIT – REQUIREMENTS AND DESIGN

For a new efficient intermodal transport system, which can face the current and future transportation, the concept of swap-bodies has to be improved by taking inspiration from the manoeuvrability and safety of containers and the loading facilities and dimensions of semitrailers. Aim should be to combine the individual advantages of the loading units by eliminating the disadvantages. To achieve these objectives innovative and intelligent constructions have to be found respectively combined.

Against this background within the project "TelliBox – Intelligent MegaSwapBoxes for advanced intermodal freight transport" a prototype of an innovative 45 feet long intermodal loading unit applicable to road, rail, short sea and inland shipping has been developed. This new ILU combines all the advantages of containers, swap-bodies and semitrailers integrated within one loading unit for the first time (Figure 1). Current available solutions have not offered such combination. The engineering design of such innovative loading units is complex and has to balance the needs and requirements of customers and users on the hand and necessary sophisticated technical solutions on the other hand. To face this challenge the work of a large consortium consisting of manufactures, freight forwarder, research institutions and associations is necessary.

Therefore, an European consortium consisting of operators, logistic enterprises, manufacturers and research institutes has worked for three years under an European grant (FP7). The scientific methodology of the project is subdivided into six dedicated phases. They follow the proposed general structure by Pahl & Beitz [20]. In the beginning of the development process an extensive analysis phase is carried out. This phase included the analysis and prioritization of all technical, operational and constructive requirements for the innovative loading unit. It results in the solution space. The solution space has to consider new approaches and technological solutions for components which are on the market or prior their introduction to create variants. In this phase all partners have to be involved.

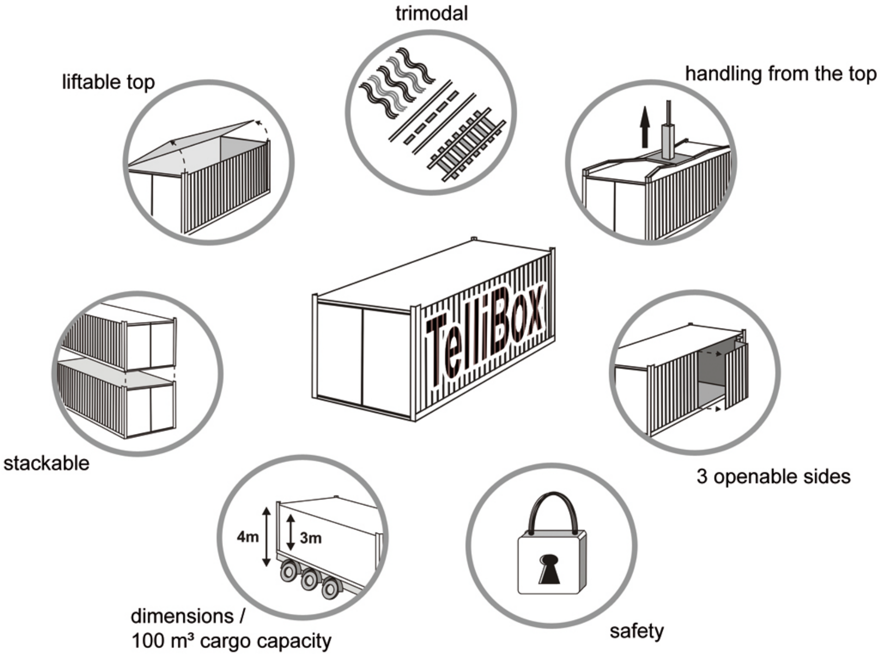

Figure 1. Requirements on the innovative loading unit

The creation of possible solutions within the second phase has been carried out in workshops of the entire consortium. A combination of methods, e.g. scientific speed dating, morphological analysis etc. was used. The result of this work phase consists of approximately three concepts, which appeared to be the most suitable (technically and operationally) for the innovative loading unit.

The elaboration of the chosen variants of the innovative loading unit and the adapted chassis comprised the third phase. Simulation methods like the 'finite element method' were used for the further analysis of the design.

In the fourth phase the solutions were evaluated. Aim of this evaluation phase has been to choose the concept with the best design. A prototype based on this design has been designed in detail. Different calculations of economic efficiency were carried out and in addition the usability of all concepts was evaluated.

The transition to the fifth phase has been the identification of the most economically, operationally and technically suitable design. One prototype of the innovative loading unit has been produced within the construction phase. The last phase, the demonstration phase comprises the testing of the prototype for all transportation modes (road, rail, short sea and inland shipping). Therefore, the handling processes in terminals have been researched. In addition, tests concerning the loading and unloading of commercial freight are carried out.

The result of the test phase has been used for an optimization loop. They also deliver an evaluation of the quality of the prototype that considers both technical and operational aspects. Therefore, an optimization loop is integrated in the scientific methodology. The recommendations out of the demonstration phase are used to improve the design. Therefore, the design process starts again in the third phase. After the needed reengineering, the prototype has been tested and evaluated again.

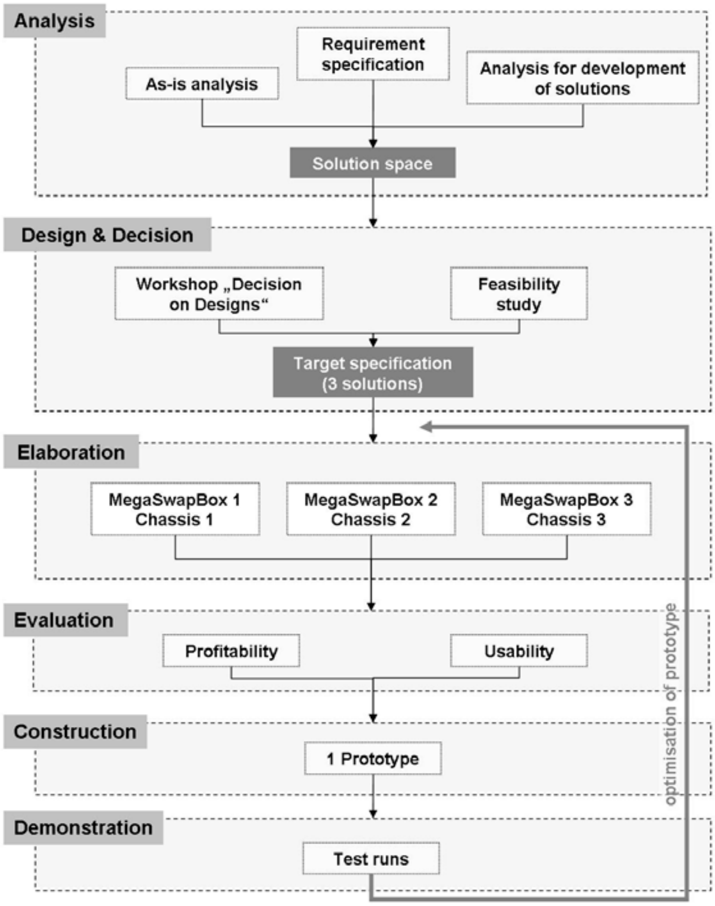

Figure 2. Methodology of design process

The initial main idea of the worked out solution of the new ILU is based on a shoe box. A closed shoe box is more stable, but if one removes the top respectively one or more sides of the shoe box, it becomes unstable. This construction principle has been further developed and applied. So, the loading unit can be stabilized if the side doors are part of the body construction (Figure 3) and in addition linked to the roof with fastening/closing elements. It is therefore important for this construction, that the door hinges and door fastening/closing elements are designed in a way that they can take part of the forces which react on the loading unit when it is being handled.

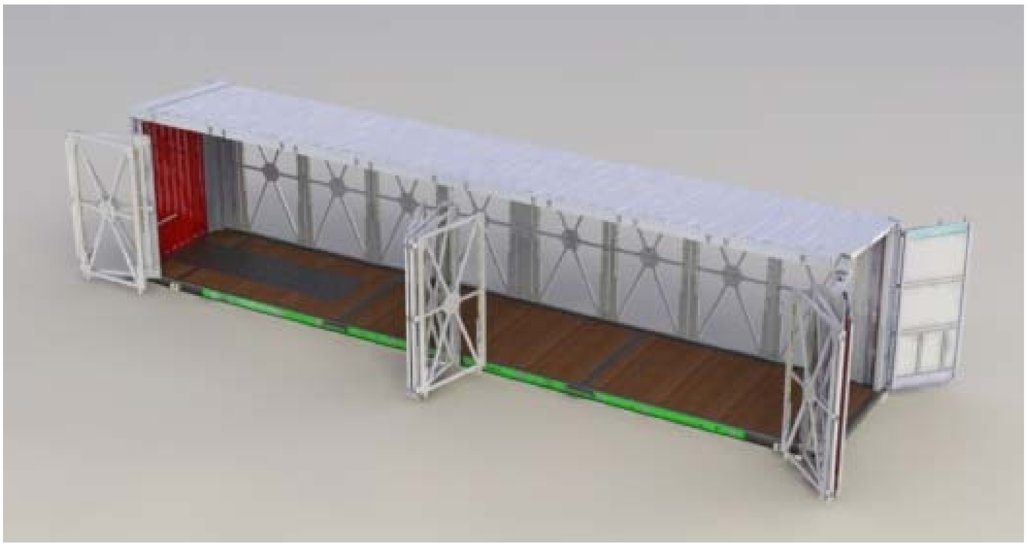

Figure 3. Simulation model of the innovative loading unit

The bottom frame is made up from a simple steel welded construction. To reduce the weight and at the same time maintaining a stable construction, the bottom frame cross members have a trapeze form (Figure 4). The top layer of the bottom frame has a steel and plywood combination as the loading platform. The bottom frame has an integrated goose neck tunnel (Figure 4). It is used for loading the container on the chassis so that the total height of chassis and container does not exceed the maximum allowed height in Europe of 4m (according to [21]).

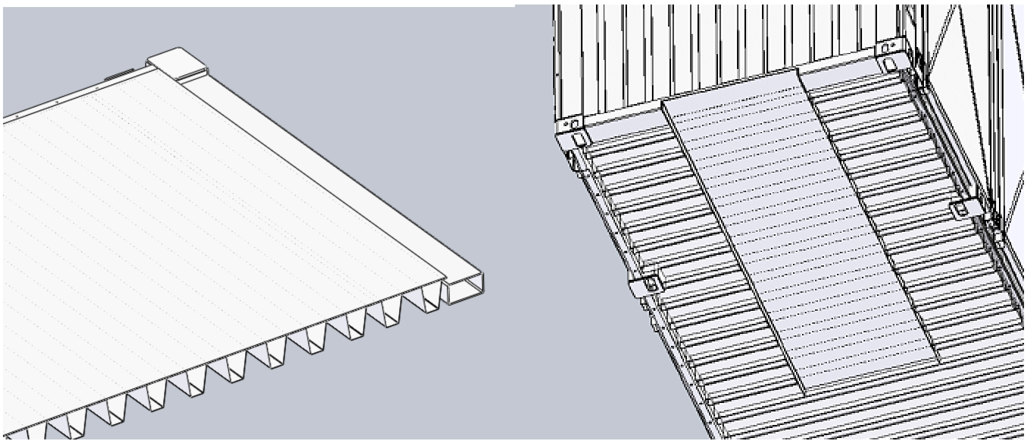

Figure 4. Loading floor and trapeze cross member (left), Goose neck tunnel (right)

The fastening system for the side doors is integrated in the side members of the bottom frame. The bottom frame fastening system is driven using a crank shaft and a gear which are integrated in the bottom frame. The system allows the fastening of one whole side door section using one gear and crank shaft. Because of this system it is possible to close the side doors and fasten them to the bottom frame construction. The front wall is a conventional container front wall of corrugated steel which is currently used also in other container constructions. The side doors are made up of 8 single doors (Figure 3). The door sections are made from a steel construction so that the loading unit is stable. The door hinge fastening systems are integrated in the side doors. The side doors are covered with an aluminium covering. Between the doors, commercial gaskets are mounted that secure the side doors against moisture and water (Figure 5). The rear doors for the new ILU are commercially available container rear doors that guarantee high security. The roof is constructed just like an ISO-Container roof. It is equipped with a rack toothed jack and a gearbox so that it can be lifted at the sides to enable loading and unloading of the system from the sides. Since the new loading unit has a liftable top it needs also a special water drainage system and is therefore included in the roof construction (Figure 5).

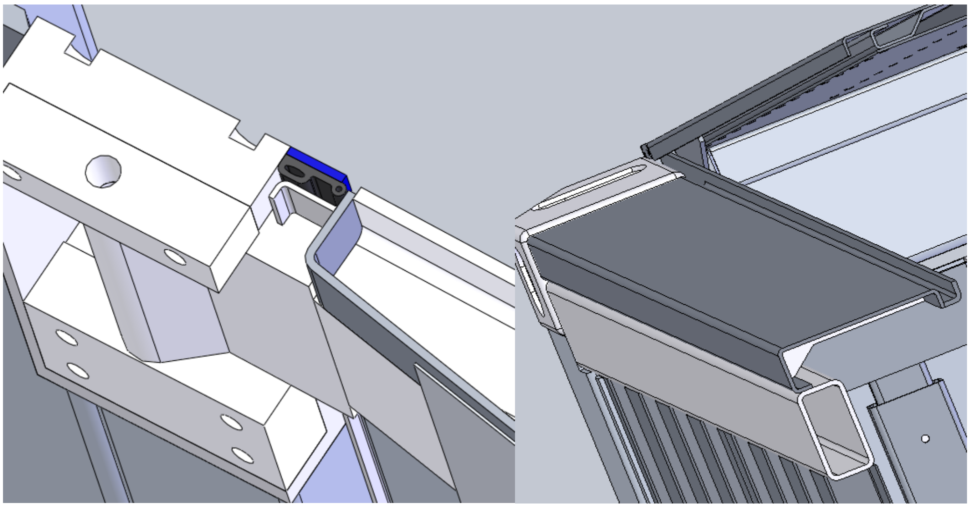

Figure 5. Side door gadget (left), water drainage system roof (right)

TESTING OF THE INNOVATIVE LOADING UNIT

The constructed prototype of the new intermodal loading unit has passed all necessary certifications for commercial use [22]. To verify also the applicability for commercial use, the transport of goods as well as the interoperability of the new intermodal loading unit it was tested and demonstrated on a 5000 km long test run. As demonstration trial a route was chosen where currently automotive goods are transported.

To identify crucial test cases for the test runs fault tree analyses have been worked out in which critical points were defined which need to be thoroughly considered. It has been essential that all project partners – from manufacturers to freight forwarders – have contributed to this process as not only the mechanical properties but also the usability and the applicability of the new loading unit have been subject of the test runs. Based on the definition of undesired events and on an extensive research of all causes with probabilities of affecting the undesired events different fault trees have been worked out (Figure 6). Afterwards the potential causes have been clustered and then used do define the test cases. The work described above was carried out in different guided workshops with members of the TelliBox consortium. From the point of view of the freight forwarders different use cases of the innovative loading unit have been identified and discussed with the manufacturers to specify critical points. For these critical points, e.g. proper door locking mechanism, undesired events have been identified in a following workshop. Based on these findings potential causes of such undesired events have been taken into account to specify test cases for the test runs of the innovative loading unit.

As test cases have been identified:

- above mentioned certifications,
- clearance tests with the tractor/trailer unit combined with the new loading unit,
- function tests of the loading unit under different loading conditions,
- test drives on a test track,
- handling operations at terminals,
- test runs with the entire combination on real roads and on ferries and
- test runs of the loading unit on short-sea ferries and inland-water barges as well as on railway wagons.

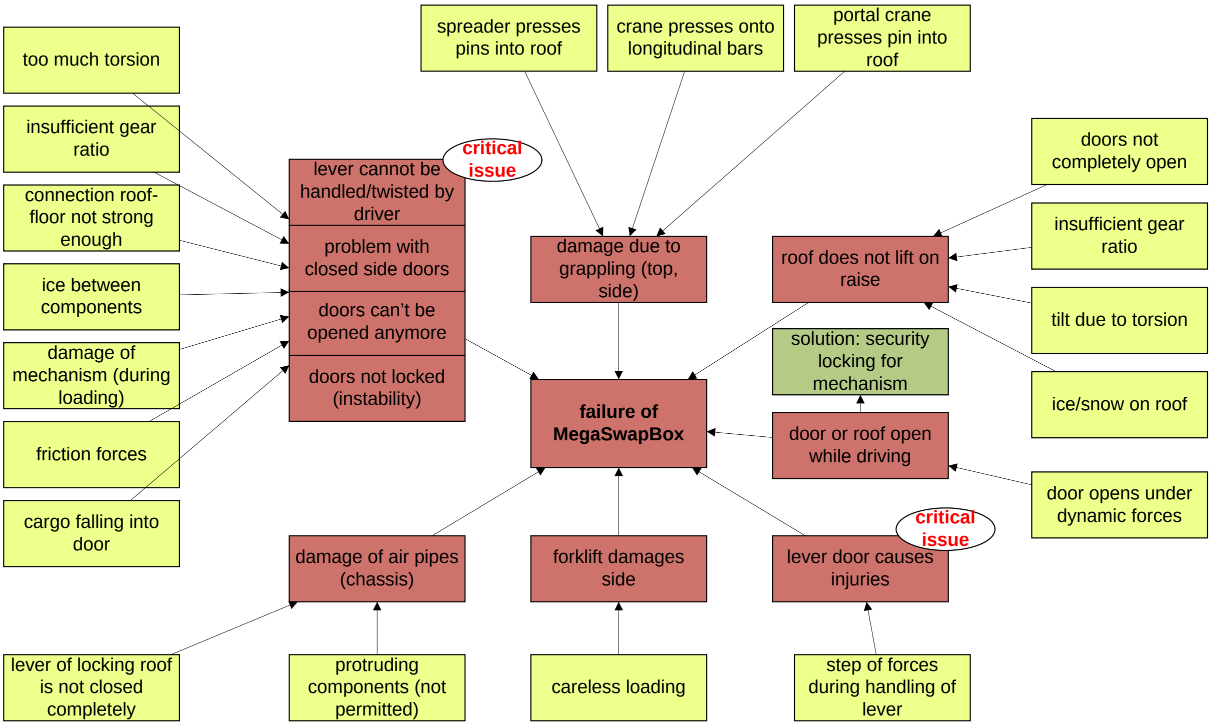

Figure 6. : Example of the analyzed fault trees

All above discussed test cases have been documented by means of photography protocols and standardized test protocols. This extensive documentation forms the basis for an optimization loop of the loading unit.

The practical execution of the test cases has been covered by the following steps (Figure 7): To perform the unloading and loading test, the new loading unit has been transported to a forwarder in Gliwice (Poland) on road. To accomplish the craning from truck onto terminal facilities and onto a railway wagon, the loading unit has been transported by road to the terminal in Katy Wroclwaski (Poland), where the loading unit has been craned onto a Megafret wagon. The subsequent forwarding was carried out by a partner on rail to Hamburg. For the next test case – transport on inland-water barges – the loading unit has been transferred to Mannheim (Germany) on road.
At a terminal in Mannheim, the loading onto the barge have been carried out so that from Mannheim, a test run on inland waters (Rhine) to Rotterdam (Netherlands) have been executed. Having arrived in Rotterdam, the loading unit has been transported on road to Calais (France) to complete the ferry trip to Dover (UK). From Dover (UK), the journey continued on road to Ellesmere Port (UK), where a test loading and unloading has been performed at an automotive company. Subsequently, the loading unit has been transported via Dover and Calais back to Eindhoven.

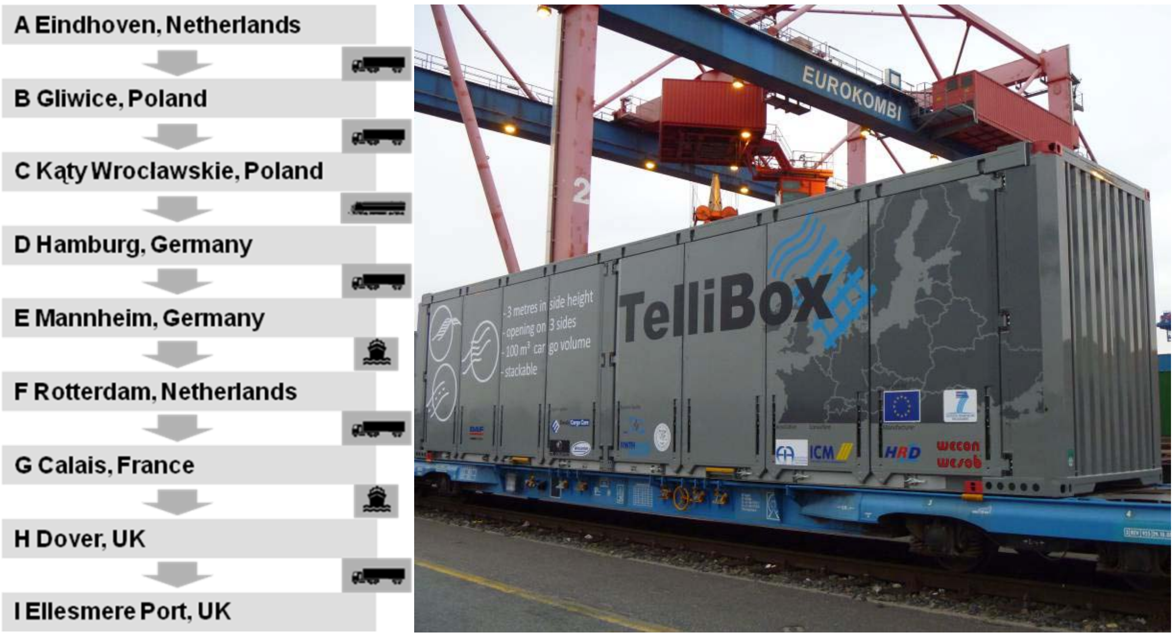

Figure 7. : Demonstration trial (left), the new ILU in use on the demonstration trial (right)

A mayor result has been that the modes road, rail, short sea and inland shipping could be used successfully within the demonstration. Before using the new intermodal loading unit the goods could not be transported trimodal on this track without exchanging loading units.

CONCLUSION AND OUTLOOK

With the development of the new intermodal loading unit an international consortium consisting of terminal operators, freight forwarders, container manufactures, research facilities, consultants and an association for intermodal transport, succeeded by creating a sustainable solution for the intermodal transport market. Through the orientation on standards and norms the new ILU offers high interoperability and easy application in transport while using the existing handling equipment and facilities. Within the above discussed demonstration trial of the prototype it could be shown that the ILU can be applied successfully commercially in trimodal transport.
For the introduction to the market it would be necessary to modify the new intermodal loading unit according to the requirements of serial production. Above it could be considered to offer the new intermodal loading unit on market in variants for special purposes and customers e.g., only one side openable, with liftable or without liftable roof. This approach would lead to a reduction of the engineering design complexity and would benefit from a modularization of the innovative loading unit introduced in this paper.

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