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# Damage to palletized loads in road transport

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**Abstract:** Manufacturers and operators of the logistics market are constantly looking for ways (opportunities) to reduce the costs of their operations. This also applies to all types of packaging. A conflict arises here between manufacturers and carriers. Producers will try to reduce the costs of collective packaging as much as possible (this packaging does not affect customers' purchasing decisions), while for transport operations, this packaging will determine the safety and quality of transported cargo. Preparing the load for transport - properly selected packaging (its shape, resistance to pressure, etc.), and above all, the proper way of forming and securing PSU (pallet load units) is a very important issue for the manufacturer/sender (as the first link in the distribution chain). It has a huge impact on the formation of cargo damage during its transport. As part of the research conducted by the authors in the area of optimization of cargo securing costs and minimization of cargo damage, the lack of a systemic approach to the problem of cargo damage in road transport was observed. The article discusses the causes of damage to palletized loads during road transport and illustrates some of these damages. Identification of the causes of damage made it possible to classify damage to palletized loads, and in the future, it will allow the development of ways to limit them, the so-called good practices for securing palletized loads.
**Keywords:** cargo, cargo safety, cargo damage, sustainable development

## 1. Introduction

Manufacturing companies constitute a significant part of ordering transport services. The products offered are usually shipped to recipients as homogeneous loads, in packages selected appropriately to the product and formed on pallet loading units (PLU) per the company's standards. We have observed a significant increase in the transport of heterogeneous loads for some time. It is related to the constantly growing e-commerce market and changes in cargo distribution (in distribution chains). In the first situation, we can talk about the full homogeneity of the packaging components of loads and methods of forming pallet load units (PLU). In the second case, we deal with the lack of any dimensional or strength consistency of shipping packaging. This situation is particularly difficult for carriers, as it prevents them from properly forming the unit. In such a situation, it is difficult

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to predict the effects of the impact of the upper layers of the load on the pallet on the lower layers.

All logistics market operators and manufacturers of various goods are looking for ways to reduce the costs of their activities. A conflict arises here between producers and carriers. Producers will try to reduce the costs of outer cases as much as possible (these packaging components do not affect the purchasing decisions of customers), while for transport operations, these packaging will determine the safety and quality of the external appearance of transported cargo. Preparation of cargo for transport - properly selected packaging (its shape, resistance to squeeze, and above all, the correct method of forming and securing the loading unit are very important issues for the manufacturer/sender (as the first link in the distribution chain) The final preparation has a huge impact on the damages of cargo during its transport. An important activity at this stage is logistics planning, which significantly reduces operations costs in the logistics market [23].

The issue of damage to palletized loads is discussed in many publications, where one can find fragmentary information about damage to palletized loads, among others [16]. However, there is a need to organize and systematize knowledge in this area based on the existing literature analysis and the authors' experience. The authors' research work in optimizing the costs of securing the load and minimizing damage to the load in transport [27] confirmed the need to organize information on damage to the palletized load. The article's purpose is only to determine the causes of damage to palletized loads during transport. No research method and results were presented, limited to illustrating and describing the damage, which allowed for their classification. Due to the extensiveness of the issue, the article was divided into two parts. Identification and description of the damage made it possible to fill the gap in the area of cargo damage and to propose an original classification of damage to palletized loads [25].

## 2. Safety in road transport

There are many factors that influence damage and losses in road transport (Fig. 1). Apart from a few factors independent of man (forces of nature, natural disasters), most of them arise as a result of intentional (theft, improper securing of goods) and unintended actions (road accidents, human errors) [4], [15]. This article will discuss only loss-making errors and damages during cargo transport caused by the human factor, i.e., improper unit load preparation. The transport services market expects the provision of services with a guarantee of safety and timely deliveries. The transport contract obliges the carrier to deliver the cargo entrusted to him cargo in the original and undamaged condition for the agreed remuneration. Therefore, the carrier should strive to maintain unchanged utility values of the transported cargo in all phases of the transport process.

According to research [19], the most important criteria for assessing the quality of cargo transport are:

- on-time deliveries (93% of respondents),
- no damage to the cargo (73%),
- failure-free means of transport (69%),
- no accidents (52%).

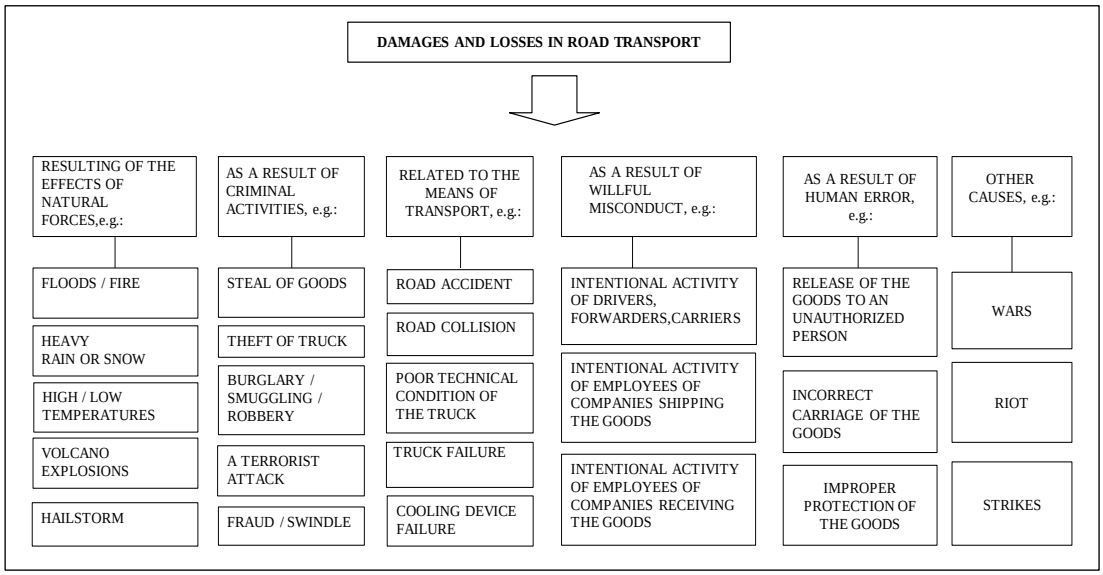


Fig. 1. Factors causing losses and damages in road transport [4]

The carriers also expressed opinions on the important factors for shaping high-quality services. The above-mentioned criteria were rated on a scale from 1 (weakest) to 6 (highest). The most important entrepreneurs considered the factors determining the safety and punctuality of transport services, with their average rating above 5.00 (Table 1).

Table. 1. The most important criteria shaping the quality of road transport services [19]

| Quality factors | Factor evaluation (average of grades on a scale of 1-6) |
|---|---|
| On-time delivery | 5,55 |
| No damage in shipments | 5,34 |
| No accidents in the transport process | 5,75 |
| No packaging damage | 4,97 |
| Reliability of means of transport | 5,37 |

Moreover, they assessed the possibility of choosing the delivery date (4.51), modern rolling stock (3.87), the appearance of drivers (2.84), and the possibility of choosing the means of transport (3.64).

## 3. Damages and packing of the load

During the performance of the transport task in the distribution chain (transport, handling, and storage), there is a risk of damage or destruction of the cargo. The cargo is exposed to mechanical, climatic, and biological damage. Mechanical damage is the main cause of damage during transport, handling, and storage operations in all modes of transport (road, rail, sea, and air transport). However, the most damage occurs in road transport, where the transported cargo is affected by dynamic loads caused by braking, acceleration, and change of direction resulting from excessive traffic and changing weather conditions [30], as well as unevenness or significant road inclination (Fig. 2). Each load must withstand undistorted

horizontal acceleration: 0.8 G in the direction of travel, 0.5 G sideways and 0.5 G to the rear [6]. On the other hand, static loads do not have a large impact on damage to the cargo due to the relatively low height of its possible stacking on the vehicle, with the application of appropriate rules of stacking the load (minimizing the weight of the load in the upper layers).

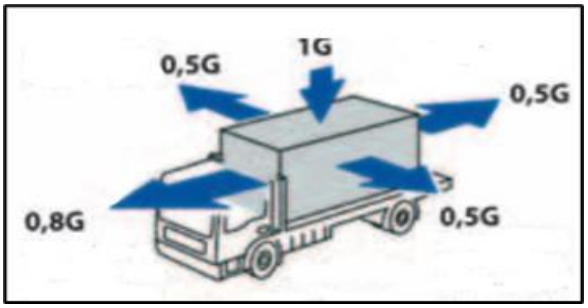


Fig. 2. Influence of dynamic forces on transported cargo [6]

A significant influence on possible damage to the cargo is also the proper storage of the cargo. The cargo should not change its physical or chemical properties during storage. It is also exposed to changing weather conditions (humidity, rain, changing temperature, or sunlight). The most important factor that allows you to protect the cargo from damage or destruction is the correct packaging and formation of the cargo units at the sender.

Very often, damage during transport is caused by improperly selected or made packaging (e.g., corrugated cardboard in the outer packaging) and/or a poorly formed pallet unit. (without spacers, stiffeners, wrapping with stretch foil, etc.).

In particular, it should be noted whether collective packages (e.g., flap cardboard boxes) are placed on the pallet to maximize its surface area, whether the load does not extend beyond the outline of the pallet, whether the pallet has a load of the same physical properties, uniform or similar shape of the collective packaging, and whether the unit shape is close to a cuboid. In the case of heterogeneous cargo per unit, it is recommended that each layer should consist of packages of similar dimensions and that packages of greater weight should be placed at the bottom of the unit. Carriers do not influence incorrect packaging or badly formed units at the sender [20], [26]. Seeing improperly packed/secured loads, they do not have many options in their offer. They can refuse to load such cargo on the truck or use the dunnage tools available to them. A reasonable solution is to provide the sender with instructions/recommendations and load requirements, according to which the sender should properly prepare the load (form pallet units). However, they only apply to securing the load on the vehicle [9], [18]. However, there are no guidelines directly regarding the proper securing of cargo on a pallet. Another solution is to transfer the responsibility (e.g., financial) for possible damage during transport from the carrier to the sender for a load that is not properly prepared for transport.

## 4. Fastening the load for transport

Securing the cargo (storage) consists of properly distributing the cargo in the formed load unit and adequately securing it against displacement and damage during transport. The arrangement also includes filling voids between cargo spaces. This issue is widely discussed

in the literature [21], [12], [13] and many other industry guides [31], [28]. Therefore, based on the literature review and the author's experience, it can be concluded that the damage to the transported loads is caused by improper arrangement and securing of the goods on the means of transport. The most common errors include:

- packaging insufficiently securing products or poorly formed loading units directly at the sender (impeding the proper placement of units on the means of transport, e.g., too large spaces between units),
- too large, unsecured spaces between loads, causing the cargo to move on the means of transport, which often leads to its damage,
- too much stacking of cargo,
- incorrect weight distribution inside the load, e.g., placing heavier loads on lighter ones,
- selection of inappropriate fixing methods
- The following methods are most often used for securing loads on means of transport:
- block - with filling empty spaces,
- threshold and plate,
- lashing systems.

In practice, loads most often have various shapes, dimensions, and weights, so it is necessary to use several securing methods at the same time.

The loads require additional protection depending on the types of fastening used. The auxiliary equipment includes:

- edge protectors - to distribute the forces acting on the lashings,
- corners - help in the proper distribution of forces when girdling the load,
- thermos shrink foil - for securing pallet loading units; stiffens and protects the load against external conditions),
- stretch film - for securing the load; quick and simple stiffening of the load and protection against external conditions,
- anti-slip mats - serve as a base for the cargo to prevent it from shifting and also as a separator between successive layers of cargo,
- plastic straps (with clamping buckles) binding the load on the pallet, • protective tarpaulins - protect the cargo against external conditions,
- moisture absorbers - prevent damage to the load in high humidity (lumps, mold, wetting, decay).

# 5. Packaging

In the literature, we can find many different definitions, features, functions, and divisions of packaging. As a packaging, we can understand the shell of the packed goods that can be separated, protecting and securing the goods against the effects of mechanical energy during transport and environmental influences. According to another definition, packaging is a product intended to protect other products against damage, as well as to protect the environment against the harmful effects of packed goods [8], [22], [29].

The package consists of:

- packaging component - it is a product made of packaging material, intended to cover the packed goods or keep it in its entirety,

- packaging auxiliaries - used for packing, closing, and preparing the packaged goods for shipment.
- The following features of the goods are distinguished:
- sensitivity to weather conditions,
- susceptibility to multi-stacking,
- susceptibility to explosion, flammability, and self-heating,
- harm to human health,
- the possibility of damage or destruction of other materials that are in contact with the given type of product or are nearby.

The difficulty of selecting a packaging increases with the number of features and sensitivities of the product.

From the logistic point of view, the most important thing is to protect the goods against damage or deterioration (during transport and/or storage). Unit packages (1st row), and then collective (2nd row) and transport (3rd row) packages, created in the process of goods distribution, must meet the requirements of standardization and dimensional coordination. Unit packaging is mainly required to protect the product against changing its required properties. On the other hand, the collective and transport packaging should protect against mechanical damage (e.g., vibrations, impacts, squeeze when multi-stacked) and climatic damage (e.g., rain, temperature, humidity, air pressure) during transport and handling [24].

Secondary packaging includes those packaging materials and components responsible for grouping unit packaging and creating a complete shipping unit. Thus, there will be outer cases, films forming bundles or so-called packs, adhesive and bonding materials, and basic information carriers (labels, tags, identifiers). Third-row packaging includes all types of cargo pallets, slip sheets (plates replacing cargo pallets), all loading pads and spacers, mats, protective corners, strapping tapes, information labels, stretch films, heat-shrinkable hoods, and other items necessary to build a pallet load.

In the era of more and more commonly used multi-level distribution networks, logistics should provide packaging that accumulates:

- strength of the structure that gives/guarantees proper protection of the packed products during transport, storage, and handling,
- proper fastening of the contents inside the package, taking into account the possibility of evenly distributing the product mass on the structural elements of the bottom and sufficient protection against shock,
- protection against weather conditions during transport appropriate for a given product and climate,
- adapting the packaging to the expected methods of storage,
- maximum reduction of the size of the package and its weight,
- rational and economical use of materials,
- technologically convenient design, ensuring easy packaging and fastening of products,
- possibly low production costs (material and labor costs),
- aesthetic appearance of the packaging and surfaces, enabling the application of the required marking.

From an economic point of view, the packaging should fulfill its functions at the lowest optimal (lowest) cost. The requirements for packaging, therefore, relate to the costs of packaging products and the efficiency of the packaging system. They should take into account the analysis of commodity losses. The packaging costs of the products are

significant and are estimated at around 15% of the value of these products on average. Proper packaging of products is a source of many savings. It can reduce the costs of transport and storage by about 6%, and it also reduces by about 8% the volume of goods losses caused by quantitative losses and deterioration of packaged products. It is worth remembering that the effects of insufficient packaging of goods are generally much worse than the effects of possible over-packaging and re-packaging [24].

The value of packaging materials accounts for approx. 50% of all product packaging costs. Losses occurring during transport or storage due to the use of inadequate packaging material or poor packaging design as a result of saving (para-saving) should be considered.

When analyzing the rationality of using packaging, one should take into account not only their cost but also the cost of the processes: packaging, transport, storage, forwarding, and losses resulting from damage to products in these packages. The optimal variant should be considered, such as a product packaging system in which the sum of packaging costs and loss of goods has the lowest value while maintaining its functionality. Thus, economically optimal packaging is considered to be the one that allows achieving the minimum value of total costs (packaging and losses).

Generally, manufacturers cannot predict the correlation between cargo and packaging components and influence the conditions of the transport task in the distribution chain. On the other hand, large transport organizations and product distributors increasingly demand the results of cargo and shipping unit tests from manufacturers. To cope with this, associations such as ISTA (International Safe Transit Association) [11] or ASTM (American Society for Testing and Materials) [1] have been established. They have developed test methods to study the behavior of loads and their components in transport processes. These methods are the source of laboratory tests of packaging, loading, transport, and storage procedures. In Europe, test results based on the ISTA test methods are most frequently expected. ISTA is an international non-profit association that is a recognized authority in the field of predictive performance testing of transport packaging. Organizations with a US-related interest are more likely to use ASTM standards. This non-profit organization works on similar principles, pursuing the same goals as ISTA.

## 6. Damage to palletized loads

In practice, we encounter many defects in palletized loads that arise on trucks during transport [5]. Based on the authors' many years of experience, all deformations or damage to the load on the pallet are presented and partially illustrated:

1.1. Offset leaving the load in the pallet area - occurs when the outline of the load is significantly smaller than the pallet. Elimination of the risk - placing the load in the middle of the pallet, with a non-slip mat or a multi-layer cardboard spacer between the pallet and the first layer of the load, properly secure the load with stretch foil in the area of binding the load to the pallet, properly selecting the size of the pallet.

1.2. Moving the load slightly beyond the pallet area - in such a situation, it is possible to repair the load. Defect elimination - anti-slip mat, multi-layer cardboard under the load, careful stacking of cartons on the pallet, taking into account the central position of the load. Strengthening the wrapping of the pallet in the area of binding the load to the pallet (Fig. 3).

Fig. 3. Offset that slightly displaces the load outside the pallet area (own pic.)

1.3. Movement significantly displacing the load behind the pallet area - the loads broke away from the load pallets and changed their form. Eliminating the risk - reducing the number of layers is an option here, or the use of sufficiently strong corners to protect the edges of the load, an anti-slip pad, and cardboard separators between the layers of outer cases, increase the number of stretch wraps for the entire load (Fig. 4).

Fig. 4. Movement that significantly displaces the load behind the pallet area (own pic.)

2.1. Tilting leaving the load in the area of the pallet - load tilted in the area provided for the pallet space, unloading without major problems, tying the load with the pallet undamaged. Eliminating the risk - dunnage tools that separate and immobilize loads on the vehicle.
2.2. Tilting slightly displacing the load outside the pallet area - the load has exceeded the area intended for the load, it is difficult to remove the pallet, and the load is tied to the pallet undamaged. Elimination of the risk - the cheapest and sufficient method in most cases is to attach multi-layer cardboard straps in the upper part of the load to compensate for empty spaces between loads on pallets (a kind of bumper ensuring that loads rest against each other on the vehicle).
2.3. Deviation significantly displaces the load outside the pallet area; however, the position of the load prevents normal unloading. The load did not „fall apart". Damage caused by

heavy braking or a relatively long-acting centrifugal force. They are very dangerous as they can deviate the load's center of gravity from the vehicle axis. Moreover, they cause deformation of the sides of the vehicle. Eliminating the hazard - even a drastic modification of the secondary and tertiary packaging components can not help much. Filling the gaps between the load and the sides of the vehicle will partially help. It will be necessary to use a tool for locking/securing the load on the vehicle. Elimination of the risk-dunnage tools that separate and immobilize loads on the vehicle (Fig. 5).

Fig. 5. Tilt significantly shifting the load behind the pallet area (own pic.)

2.4. Breaking off the load from the loading pallet with and without displacement while maintaining the correct form; no bonding: A - no displacement, B - negligible displacement, C - displacement behind the pallet area. Defect elimination - verification of the specification of the load wrapping with stretch foil - increasing the layers of foil binding the pallet to the load, central positioning of the load on the pallet (Fig. 6).

3.1. Loosening enables further operations with the load - transport vibrations are transferred to the load and consequently reduce the force of foil wrapping; further use of the load may result in displacement.

3.2. A relaxation that requires reinforcement - cargo layers are displaced but must be repaired. Elimination of the defect - the specification of wrapping with stretch foil must be reinforced, both in its lower part binding with the pallet and along the entire height of the load. Very often, the use of cardboard corners to strengthen the edges of the load will be necessary for a load arranged in a column pattern, adding inter-layer spacers and reducing displacement along the vertical axis inside the cargo (Fig. 7).

3.3. Wrapping loosening requires rebuilding the load on the pallet - the layers in the load are displaced among themselves, and no easy repair is possible. Such loads can only be built by people who do not have basic skills and knowledge about packing loads. Defect

elimination - proper pad separating the load from the pallet, the necessary amount of cardboard inter-layers, reinforcement of the edges of the load with sufficient corners along its entire height, multi-layer cardboard strips filling the free space between the load and the pallet edge, modification of wrapping with stretch film, load blocking tools on a vehicle (Fig. 8).


Fig. 6. Breaking off the load from the loading pallet (own pic.)

Fig. 7. Relaxing of the wrapping that requires reinforcement (own pic.)

Fig. 8. Relaxing requiring the load to be rebuilt on the pallet (own pic.)

4.1. Slight damage enabling further operations over the load - the lower horizontal edges of the packages are broken (but the products are still secured), indicating that the collective package structure is too weak. Eliminating the risk - the cheapest way to partially fix the situation is to use a multi-layer cardboard spacer that separates the pallet from the load.
4.2. Damage requiring local reinforcement of the load - lower layers require reinforcement of the load under the influence of the force coming from the stretch film binding the load to the pallet and the force of squeeze coming from the upper layers of the load, it crushes the vertical edge of the lower layer. Defect elimination - use corners to reinforce the edges of the load, ensure the quality of the boxes' positioning, and add a pad between the load and the pallet to reduce damage to the bottom layer of the load (Fig. 9).

Fig. 9. Damage requiring local load strengthening (own pic.)

4.3. Damage requiring building a new load - cardboard boxes crushed not only on the bottom layer but probably damaged transported product. Elimination of the defect - change the secondary packaging because they are too weak and unable to carry static loads. The dynamic loads accompanying logistics processes are much greater. Repairing the load with the simultaneous need to use the stock of existing collective packaging - inserts made of corrugated cardboard to increase the strength of the cartons against crushing. Stacking of boxes in column pattern - cardboard interlayers separating the individual layers of the load, reducing rocking and instability of the columns and pads made of multi-layer cardboard separating the load from the pallet. Corners for strengthening the edge of the load and a properly selected specification of wrapping with stretch foil ensure the load's integration and stability (Fig. 10).
5.1. Damage to the information layer of the packaging that does not affect its quality and legibility - various types of abrasions on the top and side surfaces of the collective packaging, which mainly reduce its aesthetic properties. The movement of the layers with each other causes it. They occur mainly on the walls of the secondary packaging inside the load. This type of damage, although common, is difficult to identify without carrying out a transport test in road conditions or simulated tests on appropriate vibration test stands. Eliminating the defect - immobilizing the layers of the cargo between each other, adding interlayer protective corners, and modifying the specification of wrapping the pallet with the cargo with stretch foil.

Fig. 10. Damage requiring building a new load and replacing the secondary packaging (own pic.)

5.2. Damage to the information layer of the packaging affecting its quality and legibility - significantly damaged information or advertising layer of the outer cases disqualifying its values. Elimination of the defect - immobilization of the load inside the layers, addition of interlayers, strong corners, and modification of the specification of wrapping the load with stretch foil.

5.3. Damage to the packaging structure that does not affect its further use - the supporting structure of the packaging is not damaged, and incidental damage does not affect the quality and value of the load. They do not require corrective action but should be monitored.

5.4. Damage to the structure of the packaging changing its aesthetics and strength - the possibility of permanent distortion of the product. Damage to the collective packaging resulted in a decrease in its strength or its complete loss, which means that the entire weight of the load rests on the primary packaging. Elimination of damage - a rigid spacer ensuring even transfer of forces acting on the base of the cartons, modification of the second-row arrangement of boxes in column pattern, as a last resort, reduction of the number of product layers on a pallet.

5.5. Damage requiring re-packaging due to the loss of its properties - damaged products grouped in the bottom layer of the pallet). The reason is too much space between the load units. During the transport of the load, the unbalanced forces caused by braking or the centrifugal force generated when the vehicle makes a turn deflected the load, which caused it to detach from the pallet and then shift. As a result, the entire structure collapsed. The load accumulated in the upper layers settled, crushing the goods in the lower layer. Eliminating the threat - reducing the space between the load units and between the load units and the sides of the vehicle by plates or frames permanently attached to the sides of the vehicle, limiting the ability to move the load, inflatable dunnage bags, polystyrene boards or corrugated cardboard attached to the load (Fig. 11).

5.6. Damage caused by transported products leaking out of the packaging - successive layers of cascade moisture with visible accumulation at the bottom edges. Elimination of the defect - preventing defectively prepared products from being transported, notifying the sender of the consequences, and developing protective and corrective actions (Fig. 12).

Fig. 11. Damage requiring re-packaging due to loss of physical properties (own pic.)

Fig. 12. Damage caused by leakage of products from leaky packaging (own pic.)

5.7. Damage from external flooding - cargo flooded from the outside from top to bottom; the outer cartons have damp walls starting from the top edges. The source of moisture can be flooding or exposure to direct weather conditions. Elimination of damage - if moisture did not significantly affect the packaging, the stretch film should be completely removed from the pallet, and the load should be dried in a well-ventilated, dry place. In some cases, it is necessary to disassemble part of the load to speed up the drying of cartons. Cartons that have weakened/decomposed as a result of moisture should be replaced with good and dry ones. Even slightly delaminated cardboard boxes under the influence of moisture are not suitable for further use.

5.8. Damage caused by condensate of water vapor collecting under the foil covering the load - water absorbed by cardboard packaging will significantly weaken the structure of the load. Eliminate the threat - check that the source of moisture in the load is not the product itself. Assuming that the source of water vapor is the environment, move the load to a dry and ventilated place. In the case of a very large amount of condensate, remove the stretch film completely, and after drying the load, inspect the quality of the load and packaging. After removing the defects in the secondary packaging, re-wrap the stretch film according to the wrapping specification dedicated.

5.9. Damage caused by excessively wet wooden pallets - visible moisture in the load layer adjacent to the surface of the pallet; such a load will begin to collapse. The main cause

of wet pallets is their storage in unroofed and unventilated spaces. It is advisable to use recycled paper dividers directly on the surface of the pallet as a preventive measure. The dividers absorb moisture from the wood, preventing it from spreading over the load.

6.1. Abrasions and deformations that do not affect the value of the product - minor creases, abrasions, and deformations. Elimination of the defect – observation of regularity of creation (position in secondary packaging, position of packaging in specific cargo layers, selected transport routes, seasons, etc.). The collected observations should be directed to those responsible for packaging projects in order to improve methods of designing and selecting packaging components.

6.2. Abrasions and deformations lowering the value of the product - damage affecting the lowering of the value of the goods occurs mainly in the lowest layer of the palletized unit (where the actions of forces have the highest values) are particularly exposed to destructive forces from pressures and vibrations accumulated in the layers. Such damage occurs in a way that is not signaled by breaking the walls and outer edges of the load. They are revealed when the outer cases are opened. Products transported in various types of corrugated boxes are particularly at risk of such damage. Elimination of the threat - the only protection is the use of cardboard interlayers between the layers of cardboard boxes to stop the movement of the load on the pallet.

6.3. Unsealing and cracking of the primary packaging disqualifies the product - transport damage disqualifies the product. The complete collapse of individual packaging is the result of an overloaded load. Load layers at the base cannot respond to the pressures from the layers above. Elimination of the threat - reducing the number of cargo layers or strengthening the specifications of secondary packaging, if any.

7. Damage to stacked loads - crushing caused by the base of the upper pallet. Eliminate the defect - two rules must be followed: uniform pallet loads have been built on the basis of packaging capable of transferring pressures coming from both the bottom load and the double-deck load. Stacked loads are separated from each other by a suitably rigid and strong spacer (one that does not deform under the pressure exerted by the top load). Two situations should be distinguished: uniform pallet loads intended to be stacked during storage and intended to be stacked during transport. Loads may only be stacked when multi-stacking components and packaging methods are used. The surface of these slats is only 30% of the pallet surface, which means many times greater local pressures on the upper surface of the lower pallet. Rule - the outline of the load is always slightly smaller than the outline of the load pallet (Fig. 13).

Fig.13. Damage to stacked loads (own pic.)

8. Deformations from defective pallets - deformations of the boxes that make up the load due to defective pallets. Elimination of the defect - use pallets that meet the accepted quality standards and apply the rule that the pallet is filled in at least 80% of its surface (when the filling is smaller, secondary boxes may not be able to withstand the pressure of the upper layers and the edges of the boxes will get broken and finally its contents will be destroyed) (Fig. 14).


Fig.14. Deformations from defective pallets (own pic.)

## 7. Summary

Based on the analysis of damage to palletized loads carried out in this article, due to the lack of a systematized approach to cargo damage so far, the classification of damage to palletized loads occurring during transport, often in long, multi-stage supply chains, was made. The classification of cargo damage is presented in Fig. 15 and discussed in more detail in the co-author's article [25].

The proposed systematized approach to cargo damage also made it possible to distinguish two groups of damage - those that do not change the value of the transported product and those that change the value of the transported product (Fig. 16).

Making the participants of the transport of palletized cargo - senders and recipients - as well as carriers aware of the most common damage caused by improper arrangement and securing of goods on a pallet allows you to prevent these phenomena. In addition, not every damaged load has to be returned to the sender, which results in lower costs not only on the micro-scale (costs of goods and its return and re-shipment) but also on the macro scale (less transport work and less consumption of packaging materials, therefore a smaller footprint carbon and lower consumption of raw materials).

## 8. Conclusions

Damage to cargo in drastic situations may threaten the safety of people involved in implementing a transport task in the distribution chain. These damages also affect the unplanned extension of deliveries or even prevent their further implementation. The final

and inevitable consequence is unplanned additional costs, which will be charged to the sender preparing the load for shipment.

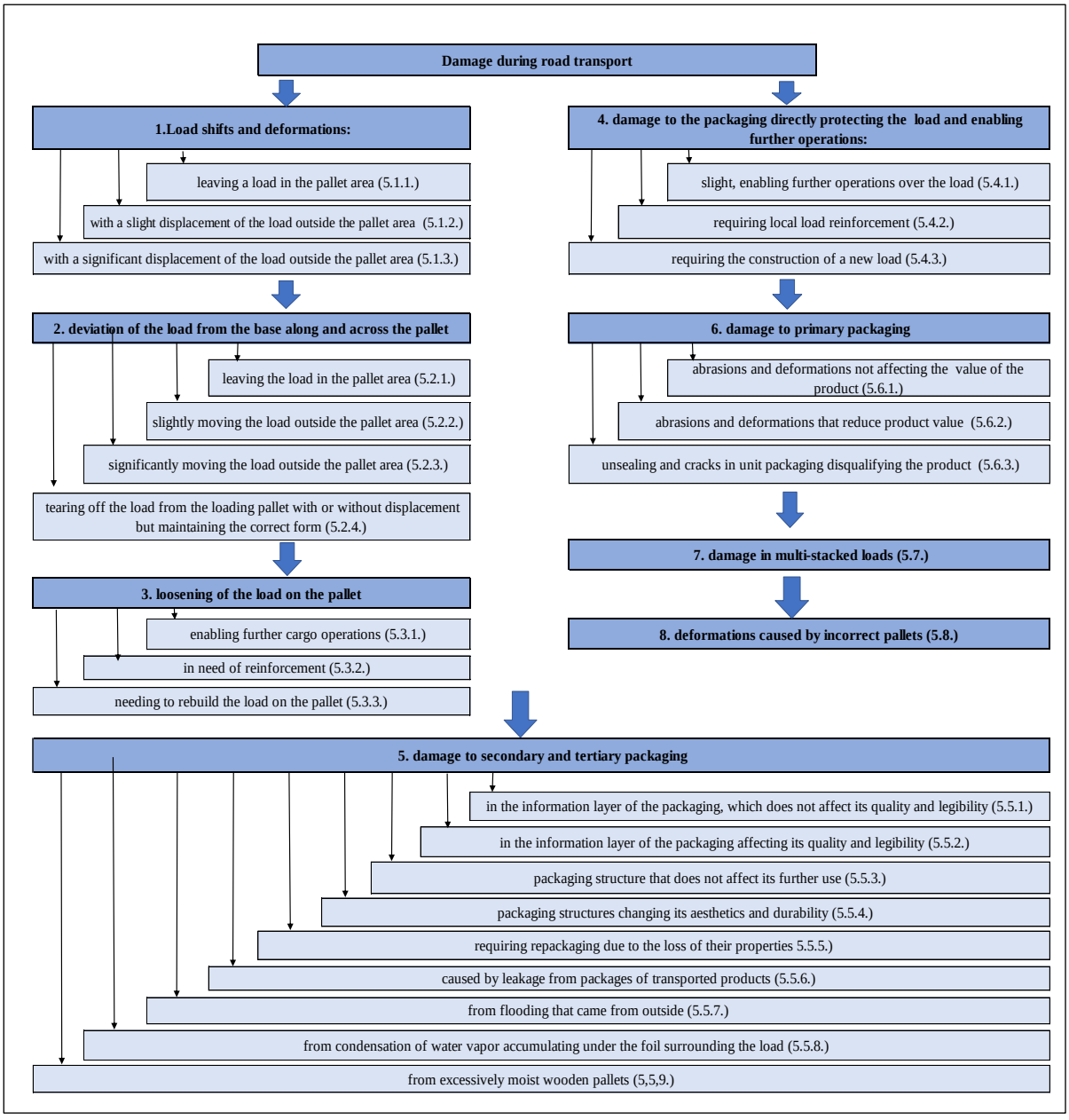


Fig 15. Classification of damage occurring during the transport of palletized loads [25]

The need to identify and classify damage to palletized loads arose as a result of a literature review and research work conducted by the authors in the area of optimization of load securing costs and minimization of load damage during transport [27].

The article does not present any results of its own research. Based on the literature review and the authors' own experiences, its purpose was only to determine the causes of damage to palletized loads during transport. An analysis of damage to palletized loads occurring in

road transport was carried out. The most common damages are illustrated and described. It has been shown that damage to palletized loads is divided into two groups:

- not reducing the value of the transported goods,
- lowering the value of the transported goods.

In addition, for each of these groups, we can distinguish two subgroups of damage:

- not generating additional costs and losses for the Producer and the Carrier,
- generating additional labor costs for the operator and/or driver and additional costs of materials to re-secure the load.

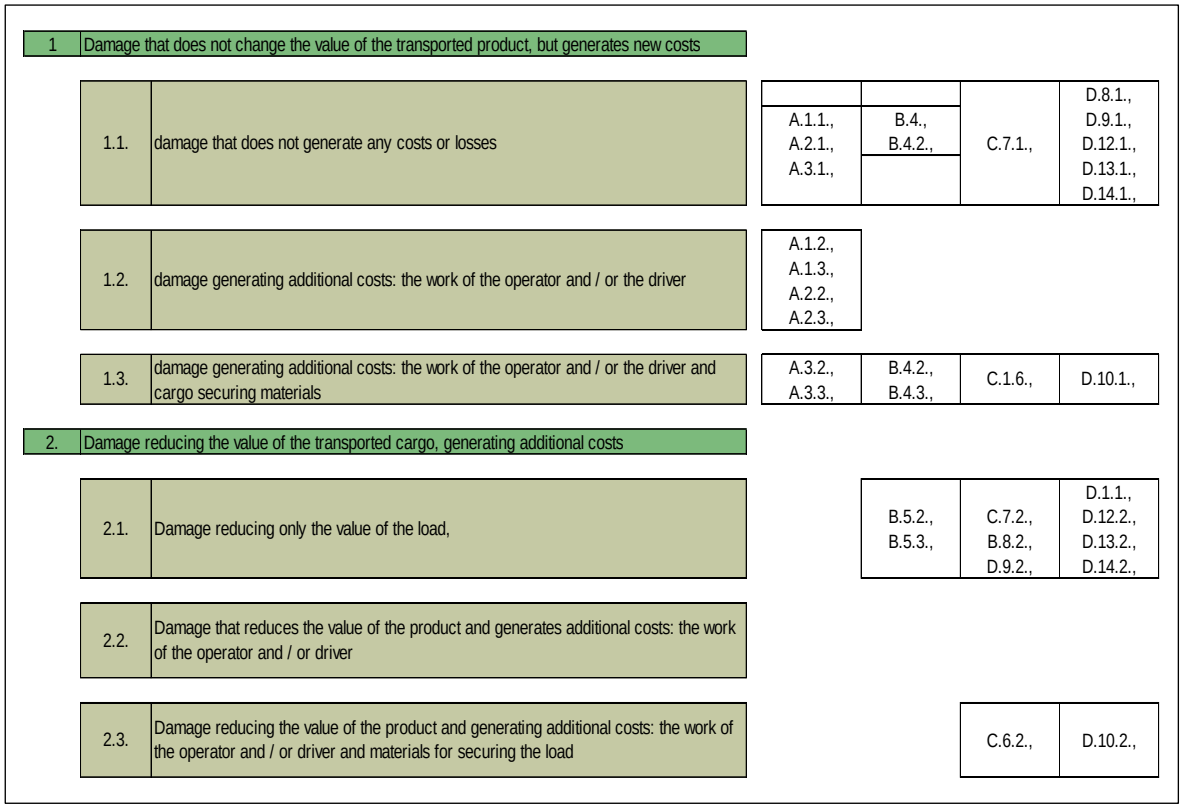


Fig.16. Split of damage to palletized loads due to the potential reduction in their value [25]

The systematized approaches to damage to palletized cargo proposed in the article allowed the development of a classification of damage to palletized cargo, which often occurs during transport in long, multi-stage supply chains. This knowledge will allow the development of procedures for properly securing cargo on a pallet, the so-called Good Practices. Currently, intensive work is being carried out on the development of such procedures, e.g., by the EUMOS Association. When analyzing cargo damage, the ecological aspect should also be considered, which should refer to activities aimed at proper material recycling [3} and activities aimed at, e.g., shaping the recycling system[2] of damaged cargo and packing materials.

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# Uszkodzenia ładunków spaletyzowanych w transporcie drogowym

**Streszczenie.** Zarówno producenci, jak i operatorzy rynku logistycznego stale poszukują dróg (możliwości) zmniejszenia kosztów prowadzonej działalności. Dotyczy to także obszaru wszelkiego rodzaju opakowań. Rodzi się tutaj konflikt między wytwórcami a przewoźnikami. Wytwórcy będą starali się maksymalnie obniżyć koszty opakowań zbiorczych (te opakowania nie wpływają na decyzje zakupowe klientów), podczas gdy dla operacji transportowych te opakowania będą decydowały o bezpieczeństwie i jakości przewożonych ładunków. Przygotowanie ładunku do transportu – prawidłowo dobrane opakowanie (jego kształt, wytrzymałość na naciski, itp.), a przede wszystkim właściwy sposób formowania i zabezpieczenia jłp (jednostek ładunkowych paletowych) jest bardzo ważnym zagadnieniem występującym u producenta/nadawcy (jako pierwszego ogniwa łańcucha dystrybucji). Ma ono ogromny wpływ na powstawanie uszkodzeń ładunków w czasie jego przewozu. W ramach prowadzonych przez autorów prac badawczych w obszarze optymalizacji kosztów zabezpieczenia ładunku i minimalizacji uszkodzeń ładunków zaobserwowano brak systemowego podejścia do problemu uszkodzeń ładunków w transporcie drogowym. W artykule omówiono przyczyny powstawania uszkodzeń ładunków spaletyzowanych w czasie przewozu transportem samochodowym oraz zilustrowano niektóre z tych uszkodzeń. Zidentyfikowanie przyczyn powstawania uszkodzeń umożliwiło dokonania klasyfikacji uszkodzeń ładunków spaletyzowanych, a w przyszłości pozwoli na opracowanie sposobów ich ograniczania tzw. dobrych praktyk zabezpieczania ładunków spaletyzowanych.

**Słowa kluczowe:** ładunek, bezpieczeństwo ładunku, uszkodzenie ładunku, zrównoważony rozwój