

# TRANSPORT QUALITY ON RAILWAY REGARDING BREAKAGE



## BREAKAGE



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## **Research report by:**

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## PREFACE

In January 2004 the jvgRASLA project “Equipment for rational securing of cargo on railway wagons” was completed. In this project the result from several analysis and tests was presented that would improve the cargo securing. One of the recommendations in the summary was: “- to investigate reasons for cargo damages during railway transport and to develop means to avoid such”.

With this in mind the question was raised if there was a common interest to undertake such a project. The industry and the National Rail Administration, Banverket, showed a great interest and co-financed the project together with the Swedish Road Administration, Vägverket. The project started in the autumn 2004 as a pilot project in the Virtual Research and Demonstration Centre “Swedish Intermodal Research Centre” Sir-C.

The project is named “Transport quality on railway regarding breakage” with the acronym BREAKAGE. The work in the BREAKAGE project has been carried out in parallel with the work in the LASHCOST II project (Cost efficient Intermodal Road-Rail Transport through Developed Cargo Securing). MariTerm has coordinated and done most of the work in the BREAKAGE project, while TransportForsk AB has coordinated and done the most work in the LASHCOST II project.

The following companies and organisations have contributed to the financing of the project by direct financial support or by own work:

Ancra ABT AB	Mobitron AB
National Rail Administration, Banverket	Nordisk Transport Rail AB
BK Tåg AB	Outokumpu Stainless AB
Cyklop AB	Rail Combi AB / CargoNet AB
Eka Chemicals AB	Sandvik AB
Elektrokoppar AB	SCA Transforest AB
Green Cargo AB	SKF AB
IKEA Svenska AB	Stora Enso Transport and Distribution AB
IW Ventures AB	Sveriges Åkeriföretag
K Industrier AB	Södra Cell AB
Kappa Kraftliner AB	Tetec Trading AB
Kemira Kemi AB	Trioplast AB
Korsnäs AB	Trioplast AS
Lachenmeier AS	Swedish Road Administration, Vägverket
Länsförsäkringar	Walki Wisa, UPM Kymmene OY
Midwaggon AB	Yara AB

All financiers have been invited to the five project meetings for the two projects that have been held from October 2004 to March 2006, and the attendance in the meetings has been large or even very large. The Swedish Rail Agency (Järnvägsstyrelsen) has participated as observer in the latter part of the project. We wish to thank all involved for valuable contribution and help during the project period.

Höganäs, 2006-04-03  
MariTerm AB  
Peter Andersson  
Project manager



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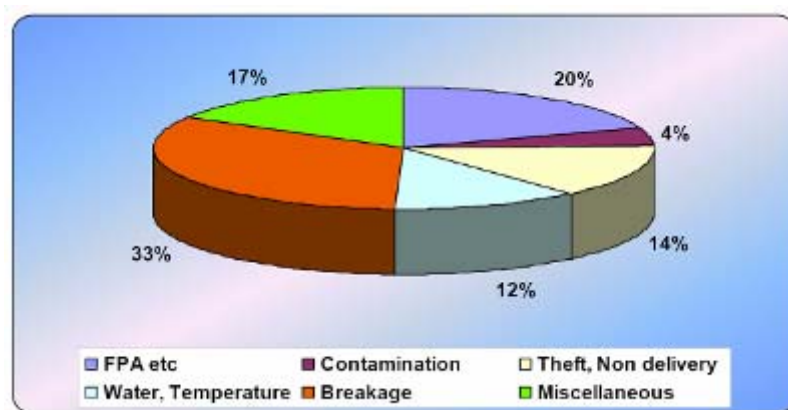
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## SUMMARY AND CONCLUSIONS

The railway has during the last decades lost market shares to other means of transportation, which could possibly be credited the harsh transport environment which generates breakage damages. The cause of breakage is believed to be the forces that arise during transport and shunting. In the project the extent of breakage, causes of breakage and means of avoiding breakage is investigated.

If the breakage problems can be reduced there is a vast market for high value goods that could be transferred to the railway.



*Cause of claim year 2004 for all modes of transport.*

A comprehensive material of statistics from The Swedish Associations of Marine Underwriters and the companies participating in the project has been studied, in order to determine the extent to which cargo is damaged in different modes of transportation. Unfortunately though, no unambiguous conclusions regarding breakage damages could be drawn since different suppliers of the statistics categories damages into groups differently, only report a minor percentage of the damages and do not indicate in what transport mode damages have occurred during intermodal transports.

One of the participating companies were however able to present excellent damage statistics, and by studying a specific transport flow in which their products are transport both by road and railway, it was concluded that transport damages caused by insufficient loading and cargo securing are more frequent during railway transports than for road and intermodal transports.

There is however no statistical evidence that the share of damages caused by breakage during rail transport is generally larger than for other modes of transport.

Apart from examination of statistics, the following different types of field studies have been carried out within the project:

- Various test transports with paper products from different producers.
- Shunting tests on four different occasions and on one of these the accelerations that both the wagon and the cargo were subjected to were measured.
- The ability of different plastic wrapping materials and methods to withstand shunting forces during rail transport.

Cost estimates for improving running and shunting characteristics for wagons have also been made.

## Test transports

The most extensive test transport, between Piteå and Vienna, included paper reels from three producers, *SCA*, *Kappa* and *Stora Enso Fors*, loaded into five different types of wagons. The reels were secured by different means and inspected in both Hallsberg and during unloading in Vienna and movements among the cargo were noted.



During the whole transport, shock recording equipment from *Mobitron AB* mounted on top of the reels registered accelerations in each wagon. The magnitude of vibrations experienced by the cargo differed significantly between the reels in the different wagons.



*The Hiqqrrs-type wagon from Kockums.*



*Cargolog sensor from Mobitron that was used to record shocks during test transports and impact tests.*

One of the wagons, a Hiqqrrs-type wagon from *K Industrier*, was equipped with a more modern type of running gear and showed an outstanding performance regarding running characteristics. The cargo in this wagon was hardly subjected to any vertical shocks at all. In sharp contrast to what was noted for the reels in three of the other wagons, the reels in the Hiqqrrs wagon had barely moved when inspected in Hallsberg. Unfortunately this wagon was the one that was subjected to the largest forces in the longitudinal direction during shunting in Maschen and Vienna, and almost all reels moved up against the end wall.

The reels supplied by Stora Enso Fors were all wrapped, low density reels with a larger diameter than the rest of the reels. They were loaded into a wagon with stripes of friction enhancing coating on the floor. No significant offset from their original positions were noted during either of the inspections. Complementary test transports were conducted with the aim of duplicating these results.

Both wrapped and unwrapped reels from Kappa were shipped from Piteå to Eslöv in a similar wagon with friction enhancing material. Most reels moved significantly regardless of the securing method used and the favourable behaviour of the Stora Enso reels in the previous test can neither be credited the wagon flooring nor the wrapping material of the reels.

A third test transport was done between Fors and Trelleborg with Stora Enso reels loaded into a wagon without the friction enhancing coating. All the stacks of reels had been dislocated approximately 10 cm in the same direction. This was most likely caused by one or several impacts during shunting. The reels had not moved around stochastically or rotated due to vibrations.



*Wrapped and unwrapped Kappa reels transported from Piteå to Eslöv.*



*Stora Enso reels transported from Fors to Trelleborg.*

From this test it can be concluded that the lack of wandering motions among the reels can not just be explained by an unfavourable height to breadth ratio. The height to breadth ratio for the stacks in this test was considerably larger than for those from Stora Enso Fors, used in the test transport between Piteå and Vienna, and yet neither of the two sets of reels showed any movements due to vibrations.

The reels from Stora Enso Fors, used in both this test transport and the transport from Piteå to Vienna had the same density, some  $600 \text{ kg/m}^3$ , which is fairly low. The reels from Kappa, which had moved a lot, had a density of about  $900 \text{ kg/m}^3$ . Some of the Kappa reels were wrapped and some were not. It is quite possible that low density reels, and especially such stowed in several layers separated by protected cardboard sheets in the end of each reel, are better at absorbing vibrations.

The repeated large movements in longitudinal direction during the tests point on the fact that the wagons in most of the test transports must have been subjected to shunting shocks in speeds up to 7,5 km/h and are clearly pointing on the Achilles heel for rail transports when it comes to transport quality for high value and damageable cargo.

For the duration of the project, several swab bodies loaded with standing paper reels have been inspected during transport, and as in the railway wagons with “standard” running gear, numerous damages caused by movements due to vibrations have been documented.



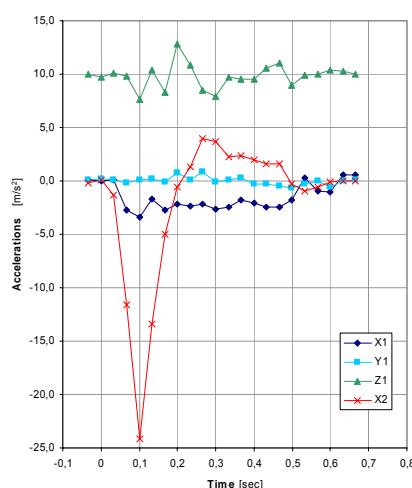
*Shaving damages on standing paper reels in a swap body.*



*Shaving damages on standing paper reels in a wagon exhibited at the Transport and Logistics exhibition in Munich in June 2005.*

## Measurement of accelerations during shunting

For the tests two freight wagons with copper and paper load respectively and three different types of wagons for intermodal transports were shunted at different speeds and directions, in accordance with the Loading Guidelines for impacts test. During the tests the accelerations were measured both on the wagon floor and at top of the cargo by two different sets of shock recording equipment.



*Accelerations measured during shunting tests*

The test data received from the tests carried out within the BREAKAGE-project indicates that, if performing impacts within the stipulated speed ranges for each type of shunting method, the dimensioning stresses of 4.0 g for hump and fly shunting and 1.0 g for intermodal transports and block trains will not be exceeded. On the other hand, the tests show that cargo secured with reasonable and commonly used methods are at risk of being damage when shunted at normative speeds.



The tests show that cargo that is not secured in any way and is allowed to slide during impacts travel great distances from its original position during shunting. If the cargo comes in contact with end or side walls and slanted roofing during movements due to shunting impacts, it would probably be damaged or deformed, as was the case for the copper coils. Thus, the UIC Loading Guidelines requires that the cargo must be loaded with sufficient free space between the cargo and the wagons fixed structure but still a reduction of impact forces would be desirable for this type of cargo as well.

A shrink filmed and bottom blocked pallet was heavily deformed during the shunting already in slow speeds even though the pallet was wrapped according to the Loading Guidelines with 150  $\mu\text{m}$  shrink film. It is thus concluded that free standing bottom blocked pallets requires quite heavier wrapping to be able to withstand shunting shocks.



By comparison between the accelerations and movements among the reels recorded in this tests and the major test transport, it has been concluded that the wagons was shunted at speeds close to 7.5 km/h during the test transport between Piteå and Vienna.

Regarding the wagons for intermodal transports loaded with swap bodies, the sliding top construction and the long stroke buffer arrangement reduced shocks considerably compared to the wagon with regular buffers, at least for impacts at greater speeds. The dimensioning longitudinal acceleration for wagons with such equipment could in the regulations be reduced to 0.5 g and thus be identical to the dimensioning stress backwards in most regulations governing road transports.



*Shock recording equipment placed directly on the floor in the middle of the wagon.*



*The wagon for intermodal transports with long stroke buffers used in the shunting tests.*

## Tests with different types of plastic packaging

Three shunting tests and two inclination tests with three different plastic packaging techniques were carried out in the project. In the tests pallets with cardboard boxes from *Stora Enso Nymölla* was wrapped in stretch film from *Trioplast AB* by *Cyklop AB* and in shrink and stretch hoods from *Lachenmeier AS*.



From the tests it has been concluded that the strength of packaging material on palletised cargo that are to be loaded sparsely and free standing on rough wooden floors, could be tested in a simple inclination test, where the pallet is inclined to about 32 degrees. It is suggested that this test replaces the current UIC requirement of a film thickness of 150  $\mu\text{m}$  for plastic packaging materials on palletised cargo, while film thickness only is not necessarily a relevant criteria.

Pallets that are bottom blocked without support for the cargo would have to be inclined to a considerable larger angle. If the pallets are closely stowed the demand for strength of the packaging material is of minor importance, as long as the goods fill out the pallets or the voids are properly filled with dunnage materials.

## Cost estimate for wagons with improved transport quality

The increased costs associated with fitting new wagons with TF25 bogies for improved running characteristics and long stroke buffer arrangements for reducing shocks during shunting have been evaluated. Estimations have also been made regarding in a near future anticipated running gear with acceptable running behaviour at reasonable prices. The costs are compared to those for a wagon equipped with standard Y25 bogies and Category A, 105 mm stroke buffers.

It has been estimated that the additional cost per transported ton goods on a wagon fitted with TF bogies and long stroke buffers would be approximately 8.75 kr/ton and 3.50 kr/ton for a concept wagon with long stroke buffers and premium running gear that are expected to be available at the market shortly.





*TF25 bogie*

This indicates that such an investment would at least be profitable for transporting middle and high value cargo and it may vary well be a necessary investment in order just to attract those types of cargo and for the railway to present itself as a competitive alternative to modern air suspended vehicles when it comes to transport quality.

## **Main conclusions**

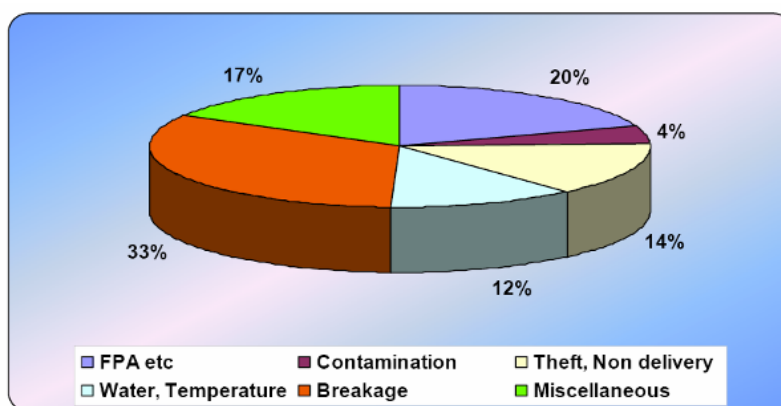
The following main conclusions have been drawn in the project:

1. From the field studies carried out it is clearly shown that rail transport with standard equipped wagons is a tough environment for the cargo. During normal rail transports the cargo is exposed to extensive vibrations and at shunting the cargo is exposed to large impacts not only exceptionally but rather as a rule.
2. Cargo damages due to vibrations and shunting impacts have in most of the field studies carried out within the project clearly been registered in normal cargo wagons as well as in intermodal cargo units.
3. During the field studies it has further been noticed that wagons with only limited improved equipment, as modern running gear and long stroke buffers give a considerably better transport environment for the cargo.
4. The use of long stroke buffers gives prerequisite for reduction of the design longitudinal acceleration to about 0,5 g, also for fly and gravity shunting. This would enable cargo in intermodal cargo units to be secured according to the road regulations also for rail transports without increased securing in any direction. It should further be possible to shunt also intermodal wagons by fly and gravity technique, which radically should increase the flexibility to mix normal and intermodal wagons.
5. The cost increase for cargo transport in a wagon with modern running gear and long stroke buffers is about 3 – 9 SEK per ton in comparison to transport in a traditionally equipped wagon.
6. It has been concluded that different types of packaging techniques for free standing palletised cargo can be tested by a static inclination test to 32 degrees.

## SAMMANFATTNING OCH SLUTSATSER

Järnvägen har under de senaste decennierna tappat marknadsandelar gentemot övriga transportslag, vilket kan bero på den tuffa transportmiljön som ger upphov till bräckageskador. Orsakerna till bräckaget antas påkänningar under transport samt påkänningar vid rangering. I projektet undersöks omfattningen av bräckage, orsakerna till bräckage och hur bräckage kan undvikas.

Om problemen med bräckage kan minskas finns en stor marknad med högvärdigt gods som kan överföras till järnväg.



*Fördelning av skadekostnader för samtliga transportslag 2004.*

Ett omfattande statistiskt underlag från Sjöassuradörerna och de i projektet deltagande företagen har studerats med avsikten att bestämma i vilken omfattning gods skadas i de olika transportslagen. Tyvärr har inga entydiga slutsatser avseende bräckage skador kunnat dras, enär olika leverantörer av statistik delar in godsskadorna i kategorier på olika sätt, vissa leverantörer enbart rapporterar en mindre andel av godsskadorna samt att det i statistiken inte alltid framgår i vilket transportslag skadan skett när det gäller intermodala transporter.

Ett av de deltagande företagen kunde emellertid presentera väldigt detaljerade sammanställningar av godsskadorna. Genom att studera skadorna i ett visst godsflöde där godset transporteras på både landsväg och järnväg, kunde det konstateras att skador orsakade av bristfällig stuvning och säkring av godset var mer vanligt förekommande på järnvägen än vid landsvägs- och intermodala transporter.

Det har dock inte gått att statistiskt belägga att järnvägen generellt skulle orsaka fler godsskador till följd av bräckage än något annat transportslag.

Utöver att utvärdera statistik har följande typer av fältstudier utförts inom projektet:

- Ett flertal testtransporter med pappersprodukter från olika leverantörer.
- Rangerprov vid fyra olika tillfällen och vid ett av dessa uppmättes de accelerationer som dels vagnen och dels godset utsattes för.
- Utvärdering av olika förpackningsmaterials förmåga att hålla samman godset och utstå de krafter som uppstår vid rangering.

De kostnader som är förknippade med att förbättra gångegenskaperna och den stötdämpande förmågan vid rangering för vagnar har utvärderats.

## Testtransporter

Den mest omfattande testtransporten företogs mellan Piteå och Wien och utfördes med fem olika vagnstyper lastade med pappersrullar från tre olika leverantörer; *SCA*, *Kappa* och *Stora Enso Fors*. Pappersrullarna säkrades med olika metoder och inspektion av dem skedde både i Hallsberg och vid avlastningen i Wien och det noterades hur rullarna förflyttat sig i vagnarna.



Under hela transporten registrerades accelerationerna i de olika vagnarna med hjälp av utrustning från *Mobitron AB* monterade uppe på rullarna. Storleksordningen på de vibrationer som rullarna upplevde skiljde sig väsentligt mellan de olika vagnarna.



*Hiqqrrs vagn från Kockums*



*Cargolog sensor från Mobitron som användes för att registrera accelerationer under testtransporterna.*

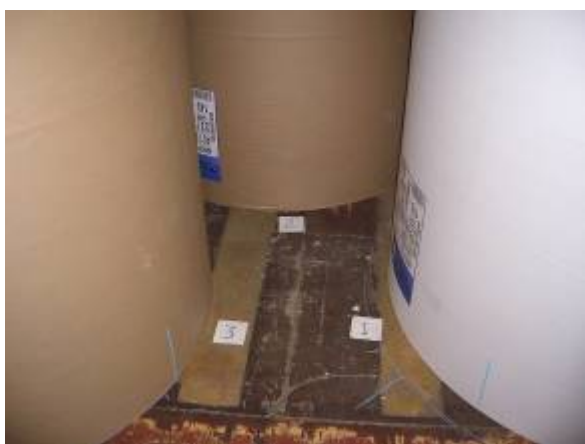
En av vagnarna, en Hiqqrrs tillhandahållen av Kockums, var utrustad med moderna löpverk och den uppvisade enastående gångegenskaper. Godset i denna vagn utsatts knappast för några vertikala stötar alls och till skillnad från godset i tre av de andra vagnarna hade det inte heller rört sig nämnvärt vid inspektionen i Hallsberg. Tyvärr var det denna vagn som utsattes för de kraftigaste rangerstötarna både i Maschen och Wien och nästan samtliga rullar hade tryckts upp emot ändgaveln.

Samtliga rullar från Stora Enso Fors var emballerade och hade en lägre densitet samt en större diameter än de övriga rullarna. De lastades alla i en vagn med band av friktionshöjande medel inbäddade i vagnsgolvet. Inga betydande rörelser noterades bland dessa rullar under någon av

inspektionerna. Kompletterande testtransporter utfördes därför med avsikt att upprepa dessa resultat.

Både emballerade och oemballerade rullar från Kappa skickades från Piteå till Eslöv i en liknande vagn med friktionshöjande material i golvet. De flesta av dessa rullar hade vid ankomsten rört sig betydande till följd av godsvandring, oberoende av hur de hade säkrats, och det fördelaktiga beteendet hos Stora Enso-rullarna i det föregående provet kan därför inte tillskrivas vare sig vagnsgolvet eller emballaget.

En tredje testtransport genomfördes mellan Fors och Trelleborg med Stora Enso rullar lastade i en vagn utan friktionshöjande material i golvet. Samtliga rullstaplar hade vid ankomsten flyttat sig ca 10 cm i samma riktning. Denna förflyttning har sannolikt orsakats av en eller flera rangerstötter. Någon förflyttning till följd av godsvandring kunde inte noteras.



*Emballerade och oemballerad rullar från Kappa transporterade mellan Piteå och Eslöv.*



*Stora Enso rullar transporterade mellan Fors och Trelleborg.*

Med utgångspunkt i dessa test kan det konstateras att den för pappersrullar vanligt förekommande omfattande godsvandringen inte kan förklaras med enbart ett ogynnsamt höjd/bredd förhållande på staplarna. Höjd/bredd förhållandet för rullarna i det tredje testet var betydligt större än för Stora Enso rullarna i transporten mellan Piteå och Wien. Trots det uppvisade ingen av uppsättningarna med rullar någon nämnvärd förflyttning till följd av vandring orsakad av vibrationer.

Rullarna från Stora Enso Fors som användes vid testtransporterna hade samma låga densitet, ungefär  $600 \text{ kg/m}^3$ . Densiteten för rullarna från Kappa, som uppvisade stora stokastiska rörelser, var ungefär  $900 \text{ kg/m}^3$  och några av dem var emballerade medan andra inte var det. Det förefaller möjligt att rullar med låg densitet och då i synnerhet sådana som staplats i flera lager med mellanliggande mjuka wellpappskivor i ändarna på varje rulle, har bättre förmåga att absorbera vibrationer.

De under fältstudierna återkommande stora rörelserna i longitudinell riktning pekar på faktumet att vagnarna i flertalet testtransporter har utsatts för rangering i hastigheter överskridande  $7,5 \text{ km/h}$ . Detta belyser järnvägens Akilleshäla vad det gäller transportkvalitet för högvärdigt och ömtåligt gods.

Under projektperioden har ett flertal växelflak lastade med stående pappersrullar inspekterats under transport och i likhet med godsvagnar med "standardlöpverk" har otaliga godsskador orsakade av vandringsrörelser dokumenterats.



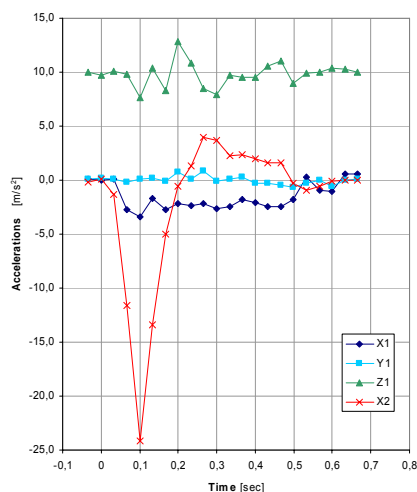
*Shaving skador på stående pappersrullar i ett växelflak.*



*Shaving skador på stående pappersrullar i en utställningsvagn på mässan Transport and Logistics i München i juni 2005.*

## Uppmätning av accelerationer vid rangering

Vid dessa test rangerades två godsvagnar lastade med pappersprodukter respektive koppartråd samt tre typer av vagnar för kombitransporter i enlighet med UIC's riktlinjer för rangerprov. Under testen uppmättes accelerationerna både på vagnsgolven och uppe på godset med två olika uppsättningar mätinstrument.



*Accelerationer uppmätta vid rangerprov.*

Resultatet av dessa mätningar indikerar att om rangering utförs inom de av UIC förskrivna hastighetsområdena för de olika växlingsmetoderna, överskrider ej de angivna dimensionerande påkänningarna på 4,0 g för rangering över vall respektive 1,0 g för rangering av kombivagnar och heltåg. Å andra sidan visar försöken att gods som säkrats med vanligt förekommande metoder riskerar att skadas även vid rangering inom tillåtna hastigheter.

Försöken visar att last som inte säkrats på något sätt utan tillåts glida rör sig avsevärda distanser under rangering. Godset riskerar då att skadas eller deformeras vid kontakt med



dörrarna eller gavlarna, vilket också skedde med koppartråden vid försöken. Lastanvisningarna för järnvägstransport föreskriver därför att godset ska lastas med tillräckligt avstånd till vagnens fasta delar men det är trots detta önskvärt med en minskning av stötkrafterna även för dessa typer av lastningsarrangemang.

En krympfilmad och bottenförstängd pall deformerades kraftig vid rangering redan vid låga hastigheter trots att emballeringen uppfyllde kravet på en filmtjocklek på minst 150 µm enligt UIC's riktlinjer. Det kan därför konstateras att betydligt starkare emballage behövs för att bottenförstängda pallar skall kunna motstå krafterna som uppkommer vid rangering.



Genom att jämföra de uppmätta accelerationerna och rörelserna vid rangerproven och under testtransporten mellan Piteå och Wien, kan slutsatsen dras att vagnarna vid denna testtransport har rangerats i hastigheter nära 7,5 km/h.

Vad gäller vagnarna för kombitransporter lastade med växelflak, reducerades påkänningarna vid rangering kraftigt för vagnskonstruktioner med glidande topp och långslagig stötinrättning jämfört med en vagn med vanliga buffertar. Detta var i synnerhet fallet vid rangering i högre hastigheter. Den dimensionerande påkänningen i longitudinell led skulle i föreskrifterna kunna sänkas till 0,5 g och således bli identisk med påkänningskravet bakåt i de flesta normerna för landsvägstransport.



*Mätutrustning för uppmätning av accelerationer.*



*Vagn med långslagig stötinrättning som användes vid försöken.*

## Test med olika typer av plastemballage

Tre separata rangerprov och två lutningstest med tre olika typer av plastfilm utfördes inom projektet. Vid testen användes pallar med kartonger med papper från *Stora Enso Nymölla* som emballerades av *Cyklop AB* med sträckfilm från *Trioplast AB* samt med huvsträcks- och krympfilmsemballering från *Lachenmeier AS* med film från *Trioplast AS*.



Utifrån dessa försök har det konstaterats att styrkan hos emballage runt palletiserat gods som stuvas utspritt och tillåts röra sig i järnvägsvagnar kan testas med ett enkelt lutningsprov. Pallarna skall då lutas till ca 32 grader. Det förslås att detta test ersätter befintligt krav på 150  $\mu$ m filmtjocklek i UIC's riktlinjer, då detta krav ensamt inte nödvändigtvis utgör ett relevant kriterium.

Pallar som är bottenförstängda skulle behöva lutas till en betydligt större vinkel. Om pallarna stuvas tätt är styrkan i emballaget av mindre intresse, så länge godset fyller ut pallarna väl eller lämpligt utfyllnadsmaterial används.

## Kostnadsuppskattning för vagnar med förbättrad transportkvalitet

Kostnader som är associerade med att utrusta vagnar med TF25 löpverk för förbättrade gångegenskaper och långslagig stötinrättning för minskade påkänningar vid rangering har utvärderats. Motsvarande uppskattningar har också gjorts för en vagn utrustad med inom en snar framtid emotsedda löpverk med acceptabla gångegenskaper till ett mer modest pris. Kostnaderna har jämförts med dem för en vagn utrustad med Y25 boggier och klass A 105 mm buffertar.

Den extra kostnaden per ton transporterat gods på en vagn utrustad med TF25 boggier och långslagig stötinrättning har uppskattats till ca 8,75 kr/ton. Motsvarande kostnad för gods i en vagn med långslagig stötinrättning och med sofistikerat framtida löpverk är 3,50 kr/ton.

*TF25 bogie*

Detta antyder att en dylik investering skulle kunna vara lönsam åtminstone vid transporter av högvärdigt gods och det kan mycket väl vara en nödvändig investering för att kunna attrahera den typen av gods och för att järnvägen skall kunna hävda sig som ett konkurrenskraftigt alternativ när det gäller transportkvalitet.

### **Sammanfattande slutsatser**

Följande övergripande slutsatser har dragits i projektet:

1. Av de genomförda fältstudierna framgår det klart att järnvägstransport med standardutrustade vagnar är en tuff miljö för godset. Under transporten utsätts godset för kraftiga vibrationer och vid rangering utsätts godset för kraftiga stötar inte bara i undantagsfall utan mer regelmässigt vid normala transporter.
2. Godsskador orsakade av vibrationer och rangerstötar har vid merparten av fältstudierna utförda inom projektet tydligt kunnat konstateras såväl i vanliga godsvagnar som i kombienheter.
3. Under fältstudierna har det vidare kunnat konstateras att vagnar med endast ringa tekniska förbättringar, såsom modernare löpverk och långslagiga stötinrättningar, ger en väsentligt bättre transportmiljö för godset.
4. Användning av långslagig stötinrättning ger förutsättning för att kraven på lastsäkring i längdled borde kunna minskas till 0,5 g, även vid rangering över vall. Detta skulle möjliggöra att gods i intermodala lastbärare lastsäkrat enligt landsvägens krav kan transporteras på järnväg utan att tilläggssäkring behöver ske. Vagnar med kombienheter skulle då också kunna rangeras över vall vilket radikalt skulle öka järnvägens flexibilitet att blanda vanliga godsvagnar och kombivagnar.
5. Kostnaderna för godstransport i en vagn med modernare löpverk och långslagig stötinrättning ökar med 3- 9 kronor per ton vid en medellång transport i förhållande till transport i en traditionellt utrustad vagn.
6. Det har konstaterats att olika typer av emballage för glidande lastsäkrat pallgods kan testas med ett statiskt lutningsprov till ca 32 grader.



# 1 INTRODUCTION

## 1.1 Background

The total freight transport performance in Sweden has increased with 30 % during the last 30 years. The freight transport performance by railway has, during the same period, only increased by about 10 %. The railway has lost market shares no matter how calculations are done. On national long distance transports the market share has decreased from 28 % to 24 % despite all support from the government. During the last 20 years the market for high processed goods has increased by more than 50 %. The railway has decreased their market share from 26 % to 19 %. It's not sound to loose market shares on a strongly growing market with good ability to pay.

Statistics from insurance companies of costs for damages indicate that high value cargo frequently suffers from breakage at railway transports and that the costs are increasing. This could be one of the reasons why consignors more and more often choose other means of transport than the railway. The causes for breakage are supposed to be the forces during transport and forces at shunting.

If the problem with breakage is reduced there is a large market with high value cargo that can be transferred from road transport to railway transport.

## 1.2 Purpose and scope of the work

The aim with the project is to develop a basis for consignors and railway operators so breakage to high value cargo can be decreased. The basis consists of the reasons of breakage and solutions to avoid it.

According to different sources, the railway has a bad reputation regarding damages on cargo. Can this reputation be washed away, the railways competitiveness will increase.

In the project the extent of breakage, causes for breakage and how breakage can be avoided is examined.

In the project the following has been dealt with:

- Analysing damage statistics
- Performing field studies with different rail transports
- Performing shunting tests with different types of cargo
- Analysing possibilities to use static tests to simulate shunting forces
- Propose solutions to reduce breakage

## 1.3 Expected field of application

By clarifying the reasons for the damages (breakage) the damages can be reduced. It will make it easier to transfer cargo to the railway from other modes of transport.

The industry and/or forwarders could use the report when deciding how to transport their goods.

## **1.4 Definition of breakage**

According to the Swedish Association of Marine Underwriters breakage is at hand where the goods by external impact have been broken, bent, dented or deformed in any other way. Superficial damage e.g. scratching or rubbing is not considered to be breakage.

In the beginning of this project the meaning of breakage was, in simple words, damages happening when the cargo carrier is moving. When starting analysing the statistics and other information it was realised that it is very difficult to extract breakage from the total of damages. Thus, breakage in this report refers to cargo damages due to inadequate stowage and securing of the cargo during transit from loading to discharge.

## **1.5 Contribution by participating companies**

Within the BREAKAGE project numerous of field studies and practical tests have been carried out. Without invaluable contribution and help from the participating companies, these activities had not been possible. To give an idea of the extent of the engagement in the project a list of contribution besides participation in the project meetings is given below.

<b>Company</b>	<b>Contribution</b>
<b>Cyklop AB</b>	Delivery of plastic packaging material for pallet tests as well as transports of pallets to and from test places and the Cyklop factory in Burseryd.
<b>Elektrokoppar AB</b>	Supply of pallets with copper for shunting tests.
<b>Green Cargo AB</b>	Wagons, locomotives and personnel for a large number of transport and shunting tests as well as supply of damage statistics.
<b>IKEA Svenska AB</b>	Supply of damage statistics.
<b>IW Ventures AB</b>	Supply of friction material for the test transport from Piteå to Vienna.
<b>K Industrier AB</b>	Supply of the company's demonstration wagon for the test transport from Piteå to Vienna.
<b>Kappa Kraftliner</b>	Supply of paper reels for the test transport from Piteå to Vienna and Eslöv as well as for shunting tests.

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<b>Lachenmeier AS</b>	Delivery of plastic packaging material for pallet tests as well as transports of pallets to and from test places and the Lachenmeier factory in Sönderborg in Denmark.
<b>Länsförsäkringar</b>	Supply of damage statistics. The research team was given free access to the files containing transport damages.
<b>Midwaggon AB</b>	Supply of lashing equipment for test transports and shunting tests.
<b>Mobitron AB</b>	<p>Supply of measuring equipment for accelerations for the test transports and shunting tests.</p> <p>Even though Mobitron AB is a small company the engagement has been large with among others mounting, dismounting and calibration of the measuring equipment along the transport route for the test transport from Piteå to Vienna.</p>
<b>Rail Combi AB</b>	Supply of wagons and swap bodies loaded with concrete sleepers for shunting tests with intermodal wagons.
<b>Sandvik AB</b>	Supply of damage statistics.
<b>SCA Transforest AB</b>	Supply of paper reels for the test transport from Piteå to Vienna.
<b>Stora Enso Fors AB</b>	Supply of damage statistics as well as paper reels and paper pallets for test transports and shunting tests.
<b>Stora Enso Nymölla AB</b>	Supply of pallets with copy paper for packaging tests.
<b>Tetec Trading AB</b>	Supply of friction material for the test transport from Piteå to Vienna.
<b>Trioplast AB</b>	Supply of plastic packaging material for packaging tests.
<b>Trioplast AS</b>	Supply of plastic packaging material for packaging tests.

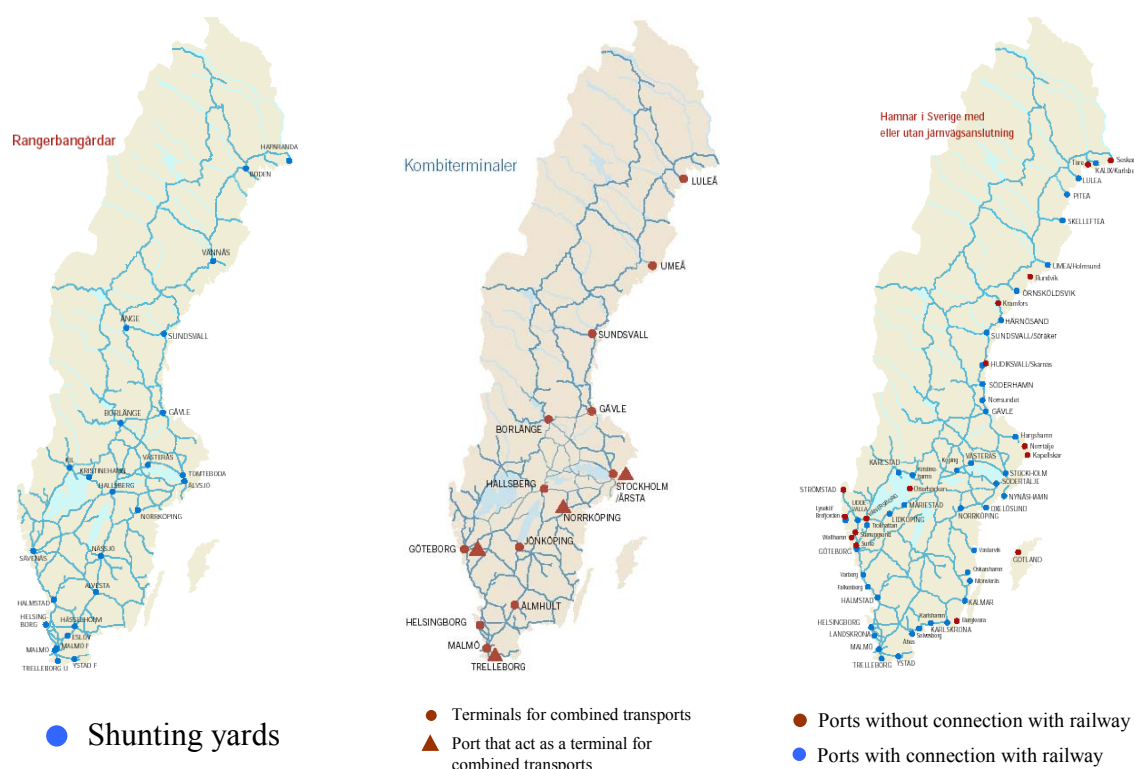


## 2 OVERVIEW OF SWEDISH TRANSPORT WORK

### 2.1 The Swedish Railway Network

The Swedish Railway Network consists of about 9882 km lines, out of which 1870 km is main lines as described in the three maps below.

In the maps shunting yards, terminals for intermodal transports and harbours are shown together with existing tracks. Sweden has today 25 shunting yards, 16 terminals for intermodal transports and 44 harbours with railway connection. [Banverket Network Statement T05.1]



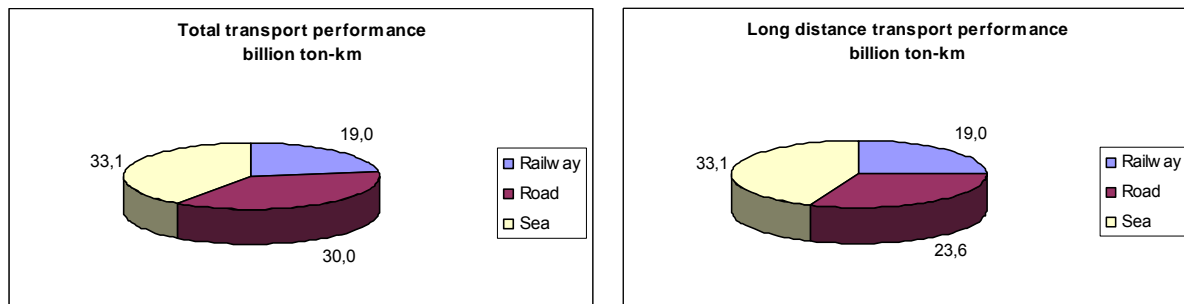
*Swedish railway network with shunting yards and intermodal terminals.*

### 2.2 Transport performance for different transport modes

The total transport work performed in Sweden during 2003 was 82 billion ton-km, with 19 billion ton-km (23%) transported on railway, 30 billion ton-km (37%) on road and 33 billion ton-km (40%) at sea.

If only road transports at long distance (> 100 km) are counted, the road transport performance decreases from 30 to 24 billion ton-km and then the split between the different modes of transport becomes; 25% on railway, 31% on road and 44% at sea.

In the statistics for transport at sea the distance on Swedish waters only is included. [SIKA]



*Swedish transport performance in billion ton-km.*

Goods transported by rail are dominated by iron-ore, metal- and forest products.

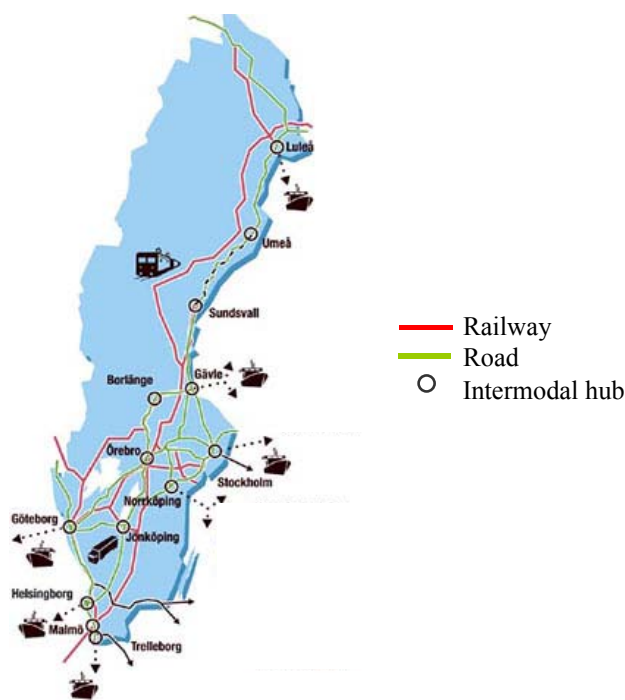
The transports of iron-ore are mainly focused to the "Malmbanan" between Luleå (Sweden) and Narvik (Norway) while the main transport routes for steel are situated between Luleå to Borlänge, Oxelösund to Borlänge and Haparanda to Avesta.

The steel export routes from Borlänge, Oxelösund, Smedjebacken, Boxholm, Hofors, Hällefors and Avesta are mainly heading southward to Gothenburg.

Routes for forest and paper products are mainly heading south from the north east coast of Sweden, Dalarna as well as Hyltebruk and reach it's destination in Gothenburg.

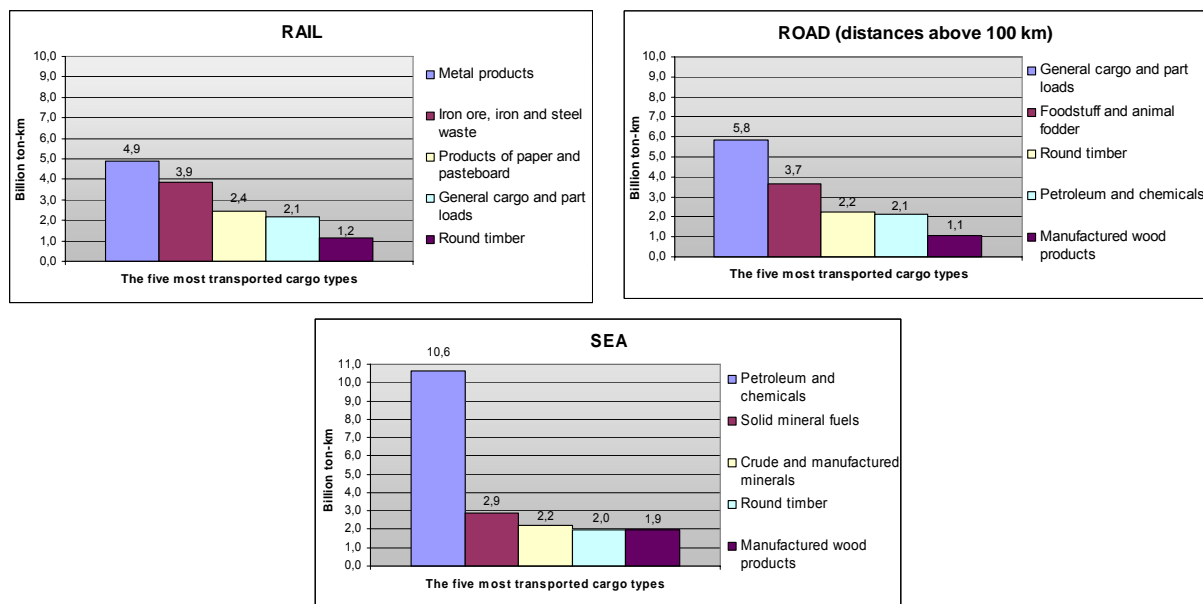
Road transports are dominated by goods as food and general cargo while petroleum products primarily are transported at sea.

The map shows main routes for domestic transports in Sweden. [Banverket Network Statement T05.1]



*Main routes for domestic transports in Sweden.*

The five largest types of products measured in transport performance (for each of the three modes of transport) are shown in the diagrams below [SIKA].



*Most commonly transported types of goods for different modes of transport.*

In transport statistics the goods are divided into 24 freight categories. These categories have, depending on the value of the goods, been classified into the three groups - “high value” - middle high value” - “low value (including bulk goods)”. [SIKA]

The categories are:

Freight category	Value group
Cereals	Low value
Potatoes, fruits and vegetables	Low value
Live animals, sugar beet	Low value
Round timber	Low value
Oil seeds and fats	Low value
Solid mineral fuels	Low value
Cement, lime, manufactured building materials	Low value
Misc. articles incl. packaging	Low value
Other waste incl. snow	Low value
Crude petroleum	Bulk cargo (Low value)
Petroleum products	Bulk cargo (Low value)
Iron ore, iron and steel waste	Bulk cargo (Low value)
Non-ferrous ores	Bulk cargo (Low value)
Crude and manufactured minerals	Bulk cargo (Low value)
Earth, sand and gravel	Bulk cargo (Low value)
Coal chemicals, tar	Bulk cargo (Low value)
Wood and cork	Middle high value
Manufactured wood products	Middle high value
Wood chip and waste wood	Middle high value
Textiles	Middle high value
Foodstuff and animal fodder	Middle high value

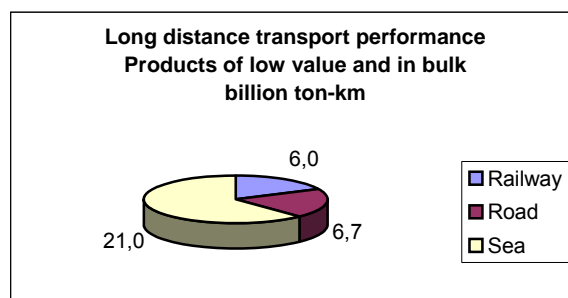
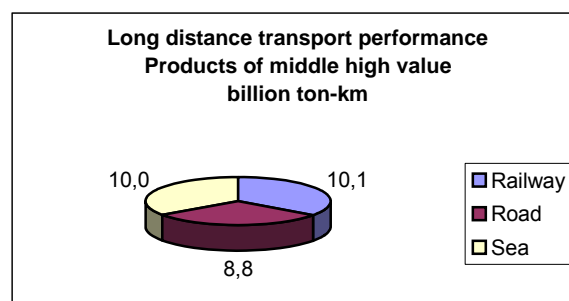
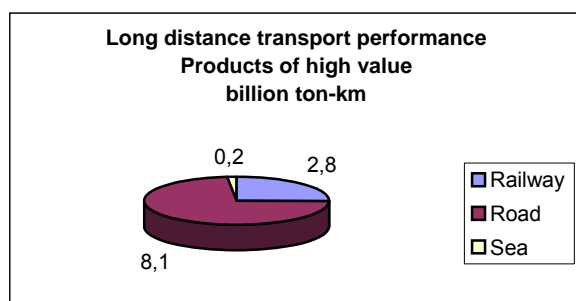
Metal products	Middle high value
Fertilisers	Middle high value
Chemicals	Middle high value
Pulp and waste paper	Middle high value
Products of paper and pasteboard	Middle high value
Transport equipment, machinery	High value
Products of metal	High value
Glass, glassware, ceramic products	High value
Leather textile, clothing, other manufactured articles	High value
General cargo and part loads	High value

Scrutinising the above statistics gives clear evidence that road transports dominates the "high value" goods sector.

In the same table it could also be noted that "low value goods" and goods in large volumes are the most commonly transported goods by sea transport. This could be explained by the fact that most oil and chemical products are considered as low value/bulk cargo and are transported in vast volumes by sea.

In the segment "Products of middle high value" the breakdown between the various transport modes are quite evenly distributed.

Please note that in transport by rail the product group "Misc. articles incl. packaging" is not specified in "Part loads" i.e. the group as whole is to be found in "Products of high value" while values in the group for road transports are divided in 90% for "Products of high value" and the remaining 10% in "Products of low value".



*Long distance transport performance for high value products in billion ton-km.*

From the figures in the statistics it can clearly be seen that only a small share (25%) of the goods of high value is transported by rail. One reason for this could be that the rail transport is considered as a harsh transport environmental for the goods compared with other means of transport.



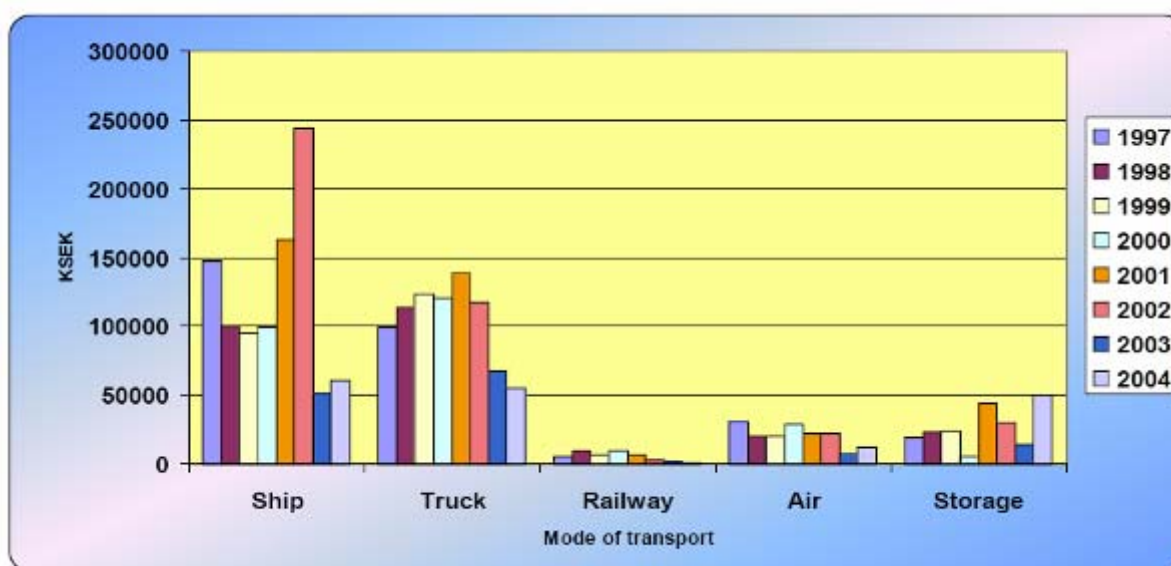
### 3 STATISTICS ON CARGO DAMAGES

#### 3.1 General statistics on cargo damages

From statistical summary of insurance fees for members of The Swedish Association of Marine Underwriters a brief summary and a broad picture of the number of claims per annum for various transport modes are given.

Anyhow, the aforementioned statistics only gives the cost for claims per type of transport mode as the total executed transports covered by the insurance are unknown. Thus, it is difficult to make any evaluation and conclusion about the quality of the actual individual transport mode from this statistical information.

Nevertheless, it can clearly be noted that the number of damages caused by rail transport is representing a very low share of the total number of damages recorded during 1997 to 2004 (see below), but it must also be noted that most damages occurred during intermodal road/rail transports are registered as a road transport damages as the statistical model consider such transports as road transport.



*Total costs in KSEK for transport damages for different modes of transport*

The Swedish Association of Marine Underwriters compiles annually all costs for transport damages for their associated members.

All damages are divided in to six categories:

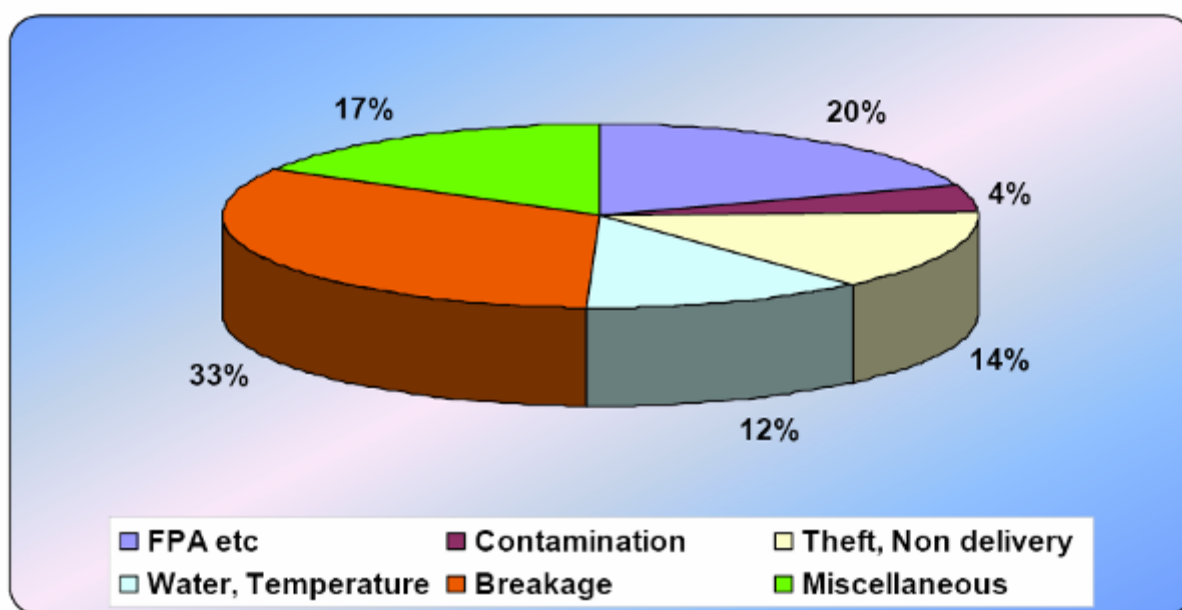
- FPA – Free from particular average (caused by accident with the transport medium)
- Contamination
- Theft and non-delivery
- Water and temperature
- Breakage
- Miscellaneous

Categorisation of damages by the associated members differs and comprises more categories than aforementioned six groups. The Swedish Association of Marine Underwriters has due to this divergence made their own evaluation and grouping of the damages reported by their associated members.

Customers to the associated members do not always report damages to their insurance company (associated members) as the cost for many low cost damages are taken by the customers themselves. It has been approximated that only 55% of the total number of damages are founding the base for The Swedish Association of Marine Underwriter's statistics.

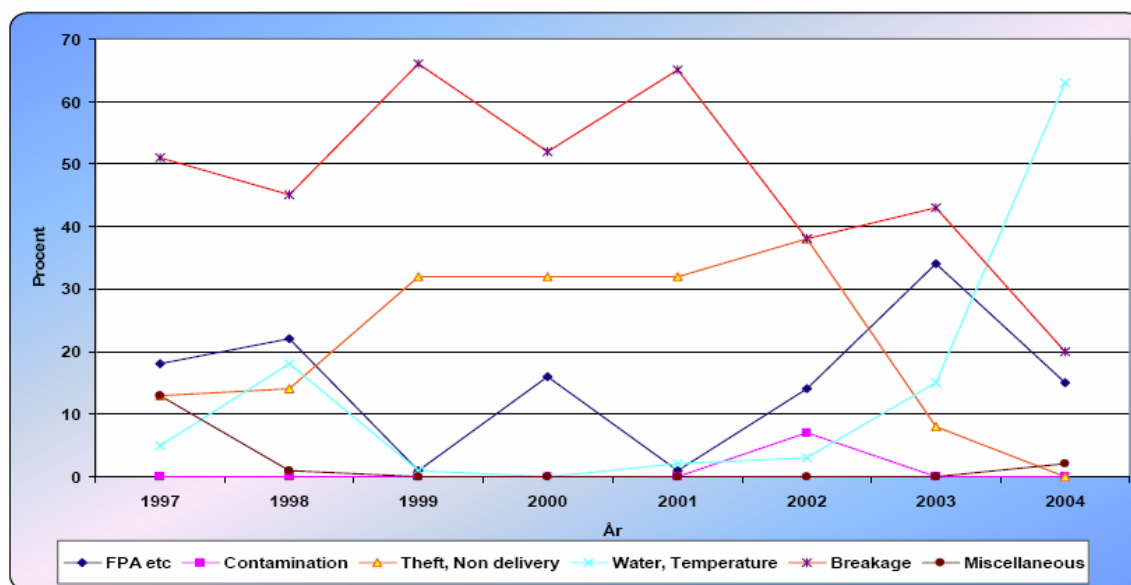
Those figures have been confirmed by one of the companies participating in the project. The company states that only a slight share from all claims are reported to their insurer and that the company themselves cover damage costs directly. This fact gives further confirmation that The Swedish Association of Marine Underwriters do not achieves a full coverage for their statistics.

Scrutinising damages from the first eight years of statistics for the different modes of transport reveals that breakage is dominating all types of transportation. According to statistics from The Swedish Association of Marine Underwriters during 2004 the total value of damages in Sweden was amounting 180,1 MSEK where from 33% (approx. 60 MSEK) was caused by breakage (see figure below).



*Cause of claim year 2004 for all modes of transport.*

The figure below shows the shares of different damage categories as percentage values during rail transport. As also shown are the costs for breakage reaching above 60% from the total cost for damages during 1999 and 2001.



*Cause of claim for rail transports 1997 – 2004.*

In the figure above only the relation between the causes of claim is shown, and not the actual costs. This means that if there is a large claim one year caused by one of the categories, the percentage of this will rise and the percentage of the other categories will simultaneously decrease.

## 3.2 Analysis of costs due to breakage

### 3.2.1 Definition of breakage

In the official statistics over cargo damages the following causes are prevailing in the category “breakage”:

1. Damage during loading
2. Damage during discharging
3. Damage during unwrapping
4. Careless handling
5. Insufficient packing
6. Improper loading and stuffing
7. Improper cargo securing
8. Damages caused by defects in/on the cargo transport unit

From the above list of reason, items 1 – 4 may be categorised as handling damages while items 5 – 8 may be categorised as transport damages.

From the group of transport damages, items 5 – 7 primarily cause mechanical damage to the goods while reason for damages in group 8 mostly causes moist or temperature damages.

Deficiencies on the cargo transport unit may however also be the reason for mechanical damage to the goods e.g. obstacles projecting from surfaces or left nails on the floor that might impair.

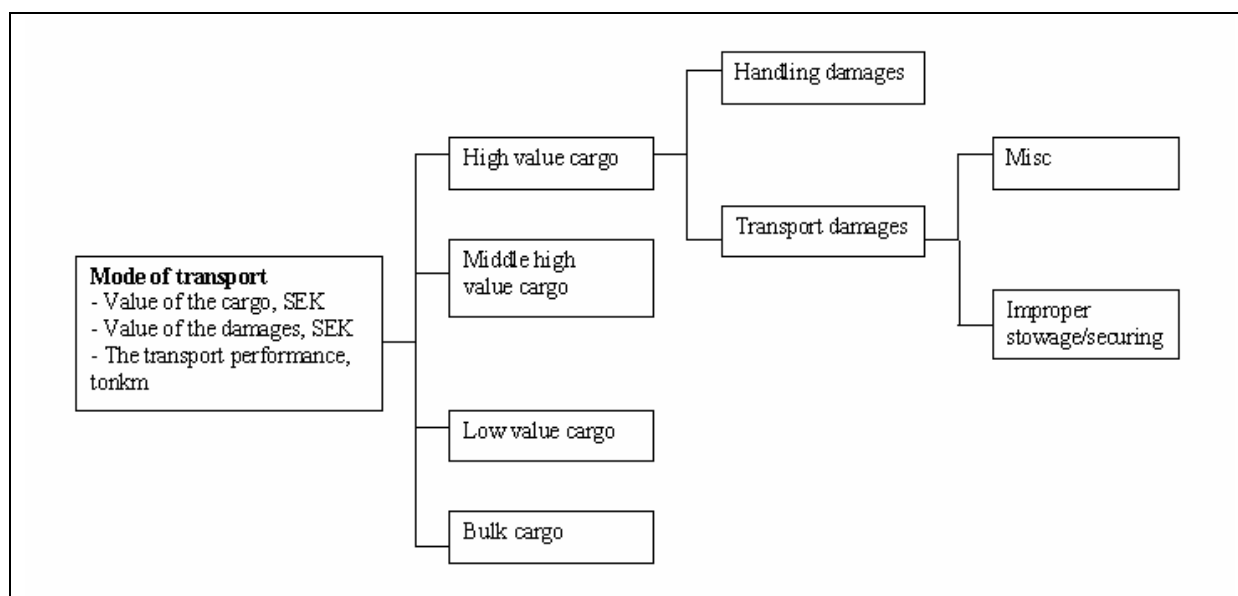
There is no demarcation of the various breakage categories in the official statistics. The BREAKAGE project will mainly focus on damages caused by category 5-7.

### 3.2.2 Costs due to breakage

Initially, the aim and focus with the project was to make a detailed analysis over the extent of breakage damages by assistance from the participating companies. This analysis should have been done by collecting and compiling information about total amount of transported goods during some years and from this material making a thorough analysis of the cost for breakage damages, reason to the damages and the total transport distance in ton-km for different transport modes.

The total cost for breakage should then have been split and categorised in handling and transport damages. Finally, the transport damages should have been divided into damages caused by improper loading/stowage including insufficient cargo securing and miscellaneous damages.

This breakdown should have been done for goods with different value in order to achieve conception if variation between goods with difference in goods value can be found, see picture below.



*Desired division and subdivision of costs for breakage damages for various transport modes and for goods with difference in value.*

This idea was brilliant but contact with the participating companies gave unfortunately information in hand that no (apart from a few exceptions) such detailed statistics existed.

From all questioned, only one company could provide the desired information. Most of the companies could only present a few out of the needed data categories and that data could not be used for the intended purpose.

Some companies only reported a few damages per transport mode and if a deeper and more thorough examination should have been made, a deep dive into the company's archives in order to scrutinise each individual case would have been necessary.

In some cases, costs for additional work load, additional transport and inspections were included in the total sum for damage costs.

One of the companies participating in the project stated that the number of actual damages was higher than the ones reported due to the company's increase of the fixed excess amount deductible from the claimed amount at damage. Thus all damages within the excess amount are not reported to the insurance company and are thus not registered in any damage statistics.

The number of transport damages reimbursed by the insurer decreased during 2003 by 2/3 because the damage value caused by breakage came under the excess amount and were thereby not recorded in the statistics.

According to statistics from SIKa, a dramatic increase in intermodal transports occurred in Sweden during 2004 but hence the increase took place from a relatively low level. Intermodal transports do only amount to some 12 – 13% of the total amount of transported goods in Sweden.

Damages during intermodal transports are hard to analyse thus shifting of goods between different transport modes takes place without handling the specific goods.

Damages that occur is normally registered as occurring during the main mode of transport and the distribution of damage registrations between the different modes of transport will be unfair. The situation is often that damages due to breakage occurring during the intermodal transport are registered as road transport damage due to the fact that the shipper in most cases also is a road transport operator.

### **3.2.3 Breakdown of breakage costs for one of the participating companies**

During the research it was revealed that one of the companies participating in the project had an outstanding system for follow up on cargo damages.

With assistance from statistics 2002 – 2004 from the actual company the opportunity was given to compare arisen damages for one customer that purely were utilising rail transport, another customer for pure road transport and another for pure intermodal road-rail transports.

The various types of damages could then, due to detailed descriptions of damage causes, be divided into the groups handling damages and transport damages.

The following reasons for damages are considered as handling damages in the company's statistics:

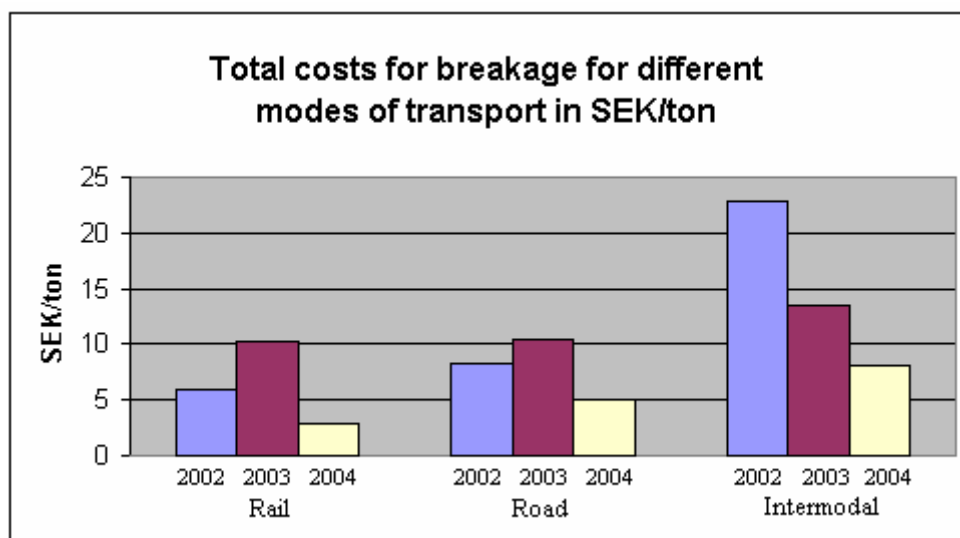
- Impact and shock during loading and discharging
- Sub-standard cargo transport unit
- Dropped cargo
- Poor flooring
- Problems with handling equipment

while the following groups are considered as transport damages:

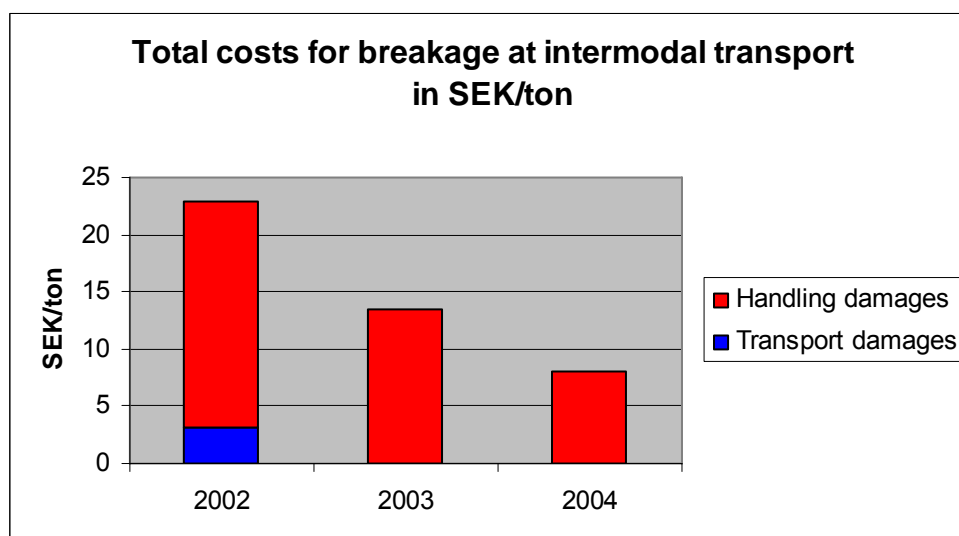
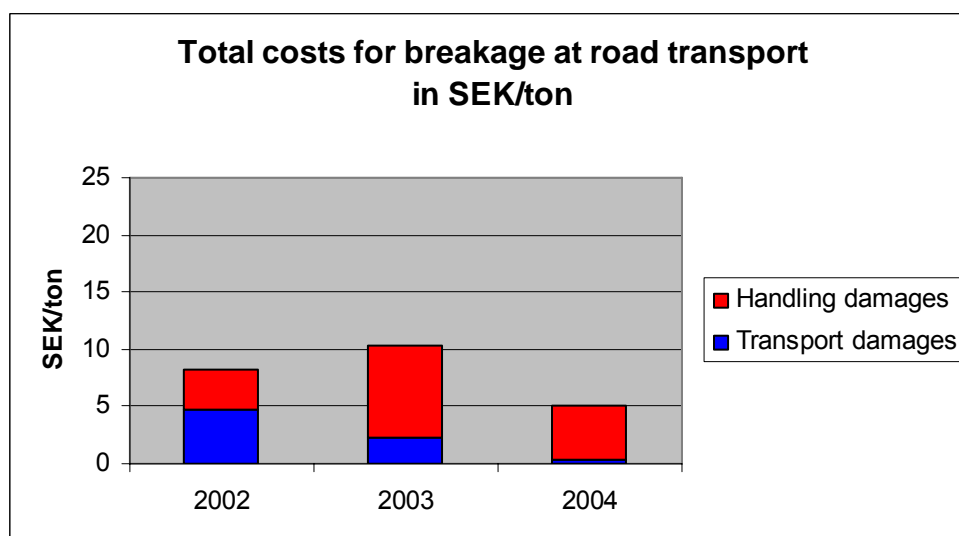
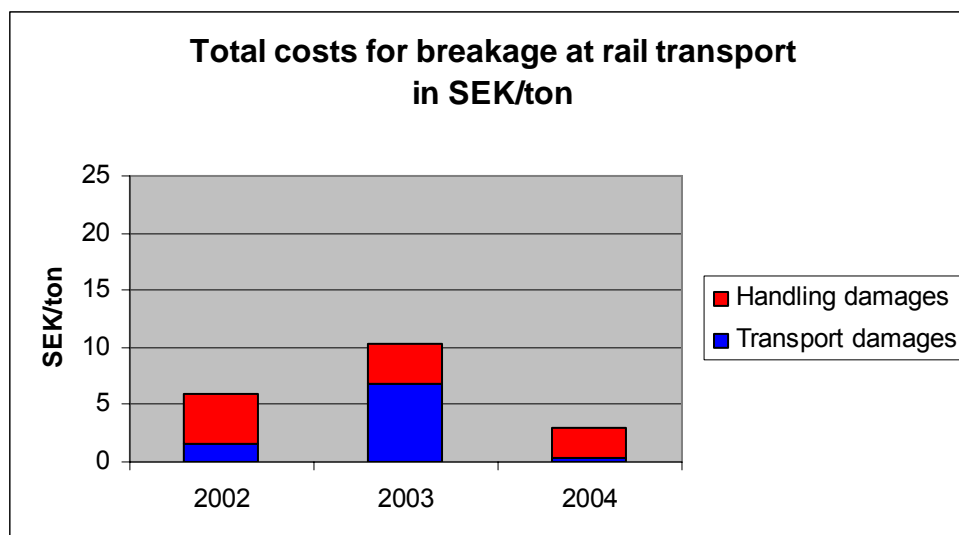
- Moisture
- Insufficient cargo securing

With information about the total delivery in ton to each individual client it has been possible to calculate the costs for handling damages expressed in SEK/ton and from distances given in km the costs for transport damages has been determined in SEK/tonkm.

The first diagram below indicates the total costs for breakage for each transport mode individually.

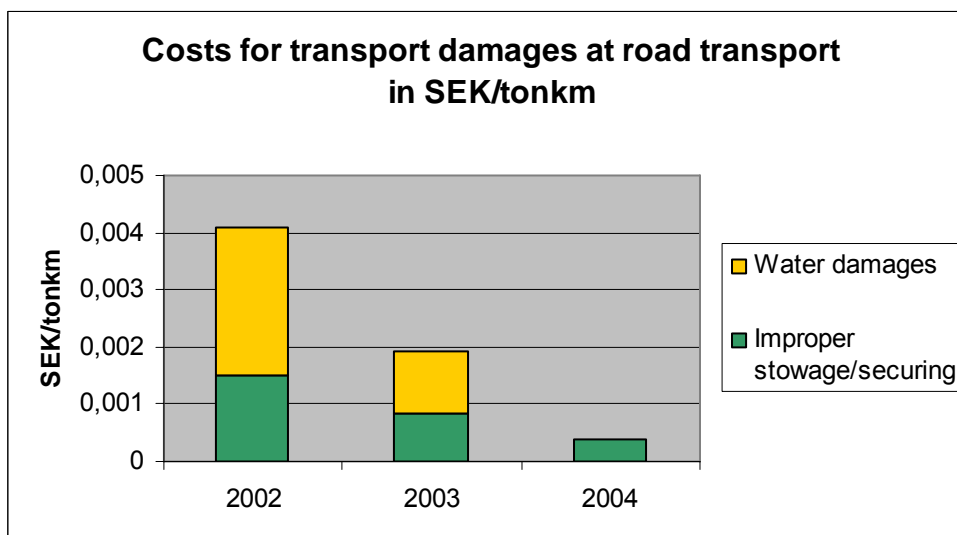
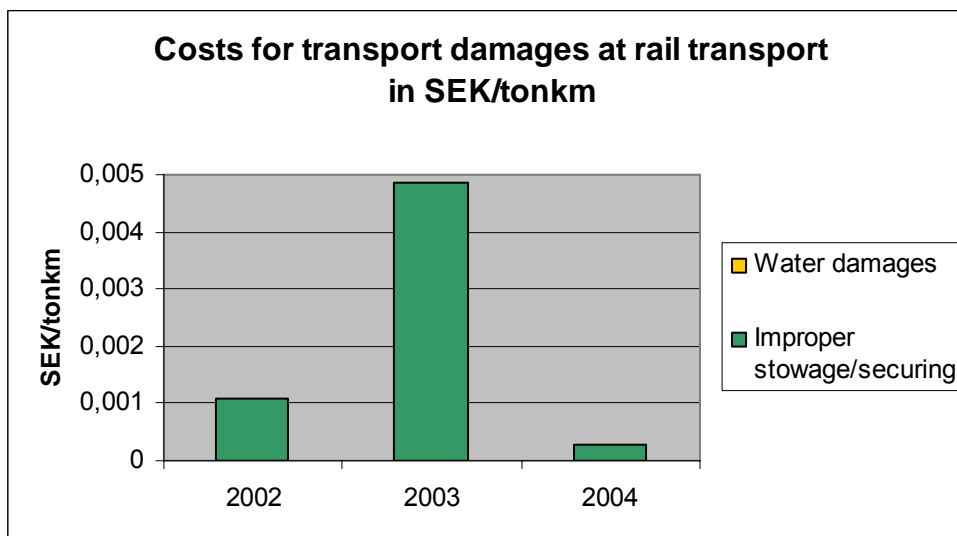


Then the total costs have been broken down in costs for handling and transport damages for the different transport modes (see introduction above). By assistance from figures over the total amount of delivered goods by each individual transport mode, costs for damages have been calculated for rail, road and intermodal road-rail transports. The results are shown in the diagrams below.

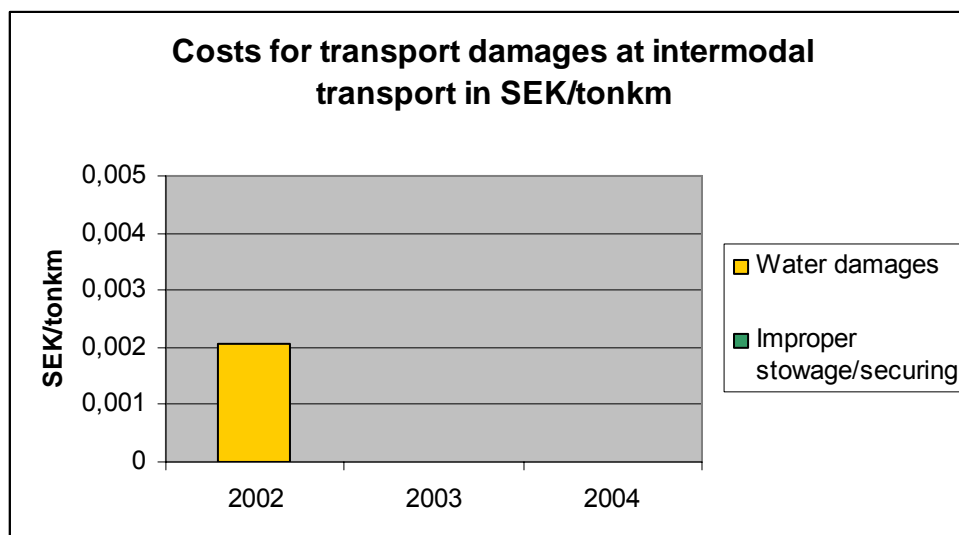


For each individual mode of transport, the transport damages has then been divided into the two groups, moisture damages and damages caused by insufficient cargo securing, where the later group is the most interesting for this project.

Below diagrams show damages caused by insufficient cargo securing for one specific company. Costs due to improper stowage and securing dominate for rail transport at the actual company while they are more or less non-existing for intermodal road/rail transport. Costs shown in the diagram are expressed in SEK/tonkm

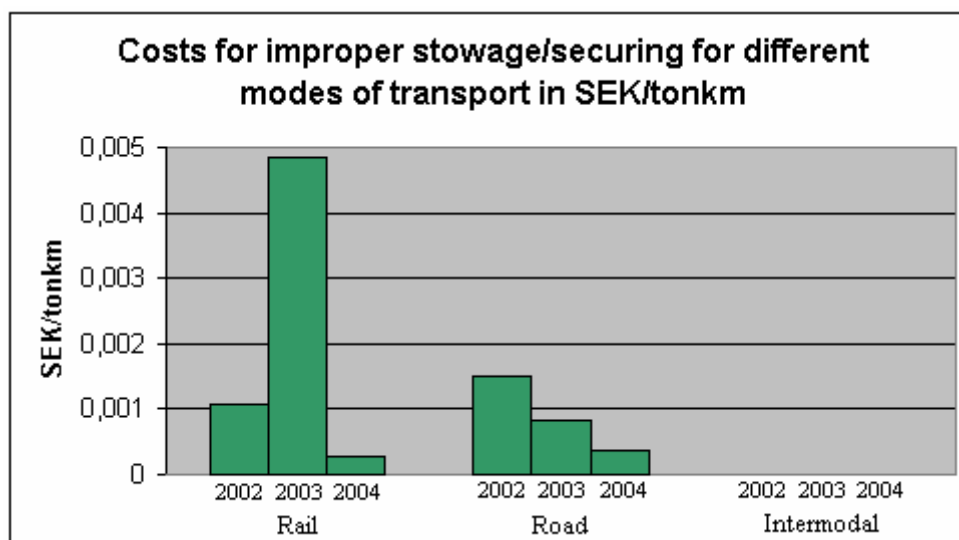






In order to achieve an overview and being able to compare costs for damages caused by insufficient cargo securing during the various modes of transport the below diagrams have been produced and show the amount for these costs during past years.

According to the company's statistics and as shown in the above diagram no damage caused by insufficient cargo securing has been reported during intermodal transports between 2002 and 2004 for the costumer in question.



It is highly interesting to compare the total amount of damage costs versus the value of the goods delivered.

According to information from the company the average value for the goods is approximately SEK 10 000/ton. The total costs for breakage damages during 2002 to 2004 was SEK 493 826 and the total amount of delivered goods to the actual clients was 59 663 ton. This gives a total value of the damages of SEK 8.28/ton.

With an average value of the goods of SEK 10 000/ton the total costs for breakage is 0.083% of the value of the delivered goods.

Using the same methodology the costs due to damages caused by insufficient cargo securing on average basis is 0.017% from the value of the goods (0.029% for rail, 0.010% for road and 0% for intermodal road-rail transport).

In this actual case, damages arised during intermodal transport has really been noted in the statistic records for intermodal transport as it is damages for each client that has been recorded and not damages caused by a certain transport mode.

### **3.2.4 Conclusions drawn from the available breakage statistics**

The statistics found in the previous section is taken from parts of the transports for **one single company with one type of goods** and are thus not fully giving possibilities for analysing the reasons behind breakage in general.

Anyhow, the aforementioned statistics seem to confirm **suspicions** that costs for breakage damages from the category insufficient loading/cargo securing is larger at rail transport than at road transport. Surprisingly the costs for such damages are close to zero at the alternative intermodal transport, but this must be considered as a coincidence for the selected flow.

Costs for handling damages are substantially higher for road and intermodal transport than for rail transport. This could eventually be explained by the fact that the pressure felt amongst the staff during the loading process for road transport is considerably higher than at the loading for rail transport due to the presence of the truck drivers on the loading berth.

The amount of damages caused by moisture is larger at road and intermodal transports than at rail transport. This fact could be explained by lower standard amongst the load carriers than the quality of the rail wagons.

Damages caused by moisture are then even higher at the intermodal transport alternative than road transport. This might have been caused by the higher speed achieved during rail transports in comparison with those achieved during road transport.

### **3.3 Examples on breakage caused during rail transport**

Even if rumours say so, there is no statistical evidence that the share of damages caused by breakage during rail transport is larger than other modes of transport.

The railway transport industry's possibility for attracting goods and thus, in line with political desires, reduce road transports is nevertheless then restricted as long as the bad reputation for the rail industry remains.

Through investigation of reasons behind factors causing breakage it would be possible to reduce the extent of those damages and thereby strengthening rail transports attraction as a strong competitor.

It is not a secret that large forces including vibrations, transverse forces during track shifting and impacts during shunting negatively affects the cargo during rail transport.

Anyhow, for the commonly transported goods of today, those forces are not occurring in such extent that it is impossible to solve the problem by different methods.

The problem occurs when new types of goods shall be transported by rail and there is a lack of knowledge and experience about the behaviour of the new type of goods. Excessive damages on the goods might be the result before suitable loading and securing methods have been developed and established and the client might during that process find damages unacceptable and has left for other transport solutions.

Below pictures show some typical breakage damages of category 5 to 7 occurred during rail transport. Many of those damages have occurred during field studies performed within the frames of this project.



*Typical cargo damage caused by inadequately stowed cargo in combination with heavy shunting forces.*



*Cargo damages caused by inadequately stowed cargo and improper use of partition wall.*



*Dangerously stowed cargo against the side doors of the wagon.*



*Improper transverse securing of palletised cargo.*



*Improper transverse securing of palletised cargo.*



*Typical shaving damage on standing craft liner reels caused by vibrations during transport of test reels from Piteå to Malmö.*



*Shaving damages on standing paper reels in a wagon exhibited at the Transport and Logistics exhibition in Munich in June 2005.*





*Shaving damage on standing paper reels in a swap body.*



*Pallet with paper sheets deformed during shunting tests.*



*Pallets falling backwards in a trailer due to improper cargo securing and heavy shunting.*



*Typical damages on intermodal cargo units caused by heavy shunting.*



*Typical damages caused by heavy shunting in freight wagons.*

## 4 ADVANCED EQUIPMENT FOR RAILWAY WAGONS

This chapter contains a review of different types of running gear and buffers that are available on the market.

During the test transports and impact tests performed within the project, the performance of these equipment categories were shown to have a great influence over the transport quality. The shocks recorded during transit were fewer and lower for the wagon equipped with modern running gear than for the wagons with older standard gear. The different impact tests that were carried out indicated great potential reductions of impact forces for wagons with more sophisticated buffer arrangements.

### 4.1 Running gear

The following possible advantages may be achieved by equipping wagons with proper running gear:

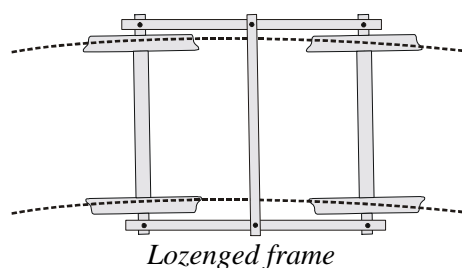
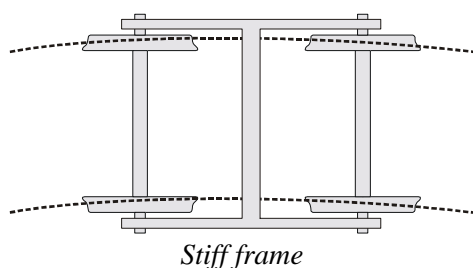
- Reduced forces on the cargo due to shocks and vibrations
- Reduced track forces
- Reduced maintenance of running gear and brakes
- Increased payload
- Higher speeds may be allowed
- Less noise

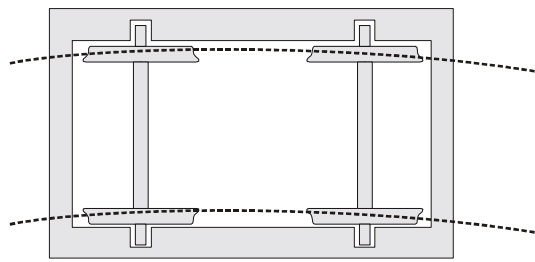
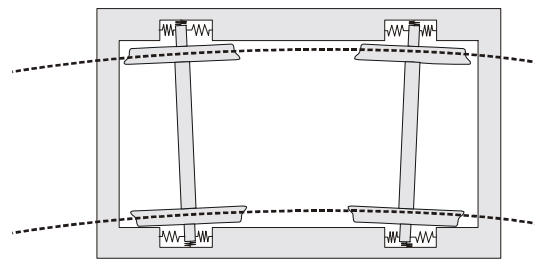
#### 4.1.1 Basic running behaviour

In order to reduce shocks, accelerations and track forces several degrees of freedom are needed for the wheel sets.

The suspension must allow for vertical movement so that unevenness of the track doesn't cause excessive vibrations to the wagon.

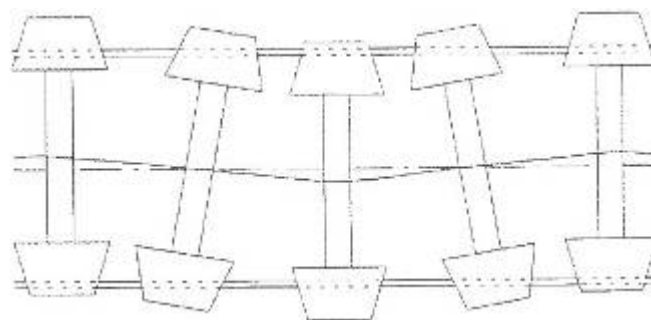
The curving performance is improved if the wheel axles are allowed to adjust to the curve radii. This is achieved by using a lozenge frame or resilient wheel set guidance.



*Stiff wheel set guidance**Resilient wheel set guidance*

There must be enough lateral clearance to allow the wheel sets to move transversely without hitting the framework and thereby cause sudden impacts.

Upon exiting the curve the wheel set must be re-centred to avoid excessive hunting motion while running at straight track.

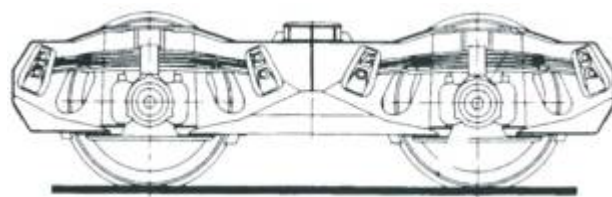
*Hunting motion for wheel set*

## 4.2 Basic types of running gear

### 4.2.1 Running gear with leaf springs and link suspension

The earliest type of suspended running gear utilized leaf springs to cushion the wagon from track forces. This type of suspension was standardised already in 1890 and though the design has undergone some changes the same design principle is still one of the most commonly found on wagons today.

The German Railway, DB, has developed several versions of link suspended bogies with leaf springs that have laid the foundation for UIC standards.

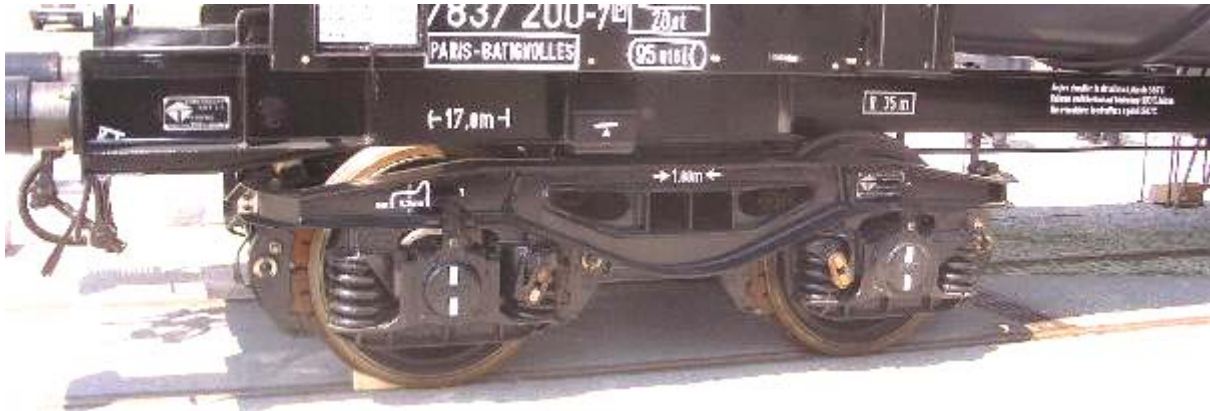
*UIC double link single axle running gear**DB bogie Type 665*



#### 4.2.2 Running gear with coil springs and friction damping

Although the main design goals of the Y25 bogie was reduced length and weight compared to the DB spring leaf bogie types, it introduced a suspension with coil spring and load depended friction damping with better capability to reduce vertical accelerations to the wagon than the link suspension bogies.

The Y25 bogie offers little freedom for lateral and longitudinal movement and can be regarded as quite stiff.



*The Y25 bogie was introduced in 1966.*

#### 4.2.3 Friction damping with wedges

Friction wedges is another way of achieving load-dependent damping of vertical motions. This concept is found on Meridian Rail's single axle running gear *Unitruck* and bogie running gear *Axle Motion*.

In curves the bogie frame displaces the friction wedges. This allows for a longitudinal movement of wheel sets and it provides stiffness and damps the motion.



*Unitruck*



*Axle Motion*

In an effort to reduce track forces and increase train speeds, the United Kingdom's privatized rail operator Railtrack PLC fitted wagons with a number of different suspension systems and among them some Axle Motion bogies. The different systems were tested during a period of 18 months with good results and the allowable wagon speeds could be increased from 70 km/h to 100 km/h.

After experiencing excessive cargo damages in forms of "flat spots" on standing paper reels, the American paper mill Bowater Inc. started shipping their reels in wagons equipped with

*Swing Motion* bogies, which is the American equivalent to the Axle Motion bogie. According to the manufacturer and their customers this got rid of nearly all breakage problems.

#### 4.2.4 Hydraulic damping

The *TF25SA* single axle running gear is designed for high speed performance and is fitted with both lateral and vertical hydraulic dampers.

Wagons used by the Swedish Postal Service operating in speeds of 160 km/h have been fitted with this type of running gear.

The Kockums wagon *Hiqrrs – vw 011* used in the test transports within this project and that has been put into service for *SCA*, is fitted with this type of running gear. Paper reels from *UPM Kymmene* are also transported in wagons equipped with *TF25SA*.

The bogie equivalent of this type of running gear is simply called *TF25*.



*TF25SA single axle running gear*



*TF25 bogie*

The test transports performed within this project has shown that it is possible to achieve excellent transport quality with this type of running gear.

### 4.3 Buffers

The test transports performed within the *BREAKAGE* project has shown that great impacts caused by shunting occur regularly and not only in exceptional cases. The performance of the buffer arrangement is a crucial factor when trying to minimize the damage to the cargo caused by these shocks.

In the shunting tests carried out within this project, two different long stroke buffer arrangements have been tested with promising results. The tests showed that shunting was possible for this type of arrangements at high speeds without exposing the cargo to unacceptable accelerations.

#### 4.3.1 Buffer categories

The performance of buffers is regulated by UIC as described in the following leaflets:

UIC 526-1 – 105 mm stroke

UIC 526-2 – 75 mm stroke (*Only allowed on wagons build before 1985-01-01*)

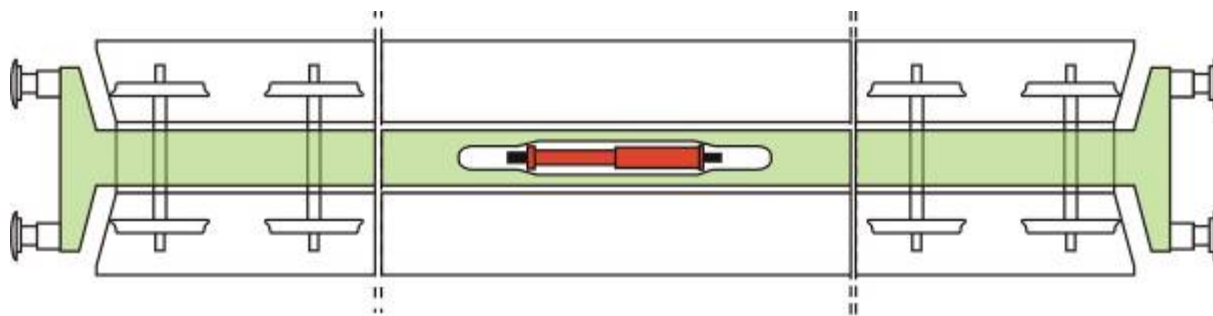
UIC 526-3 – 130 and 150 mm stroke hydraulic and hydrodynamic buffers  
UIC 529 – Long stroke buffers

Buffers with 105 mm stroke are the most commonly used. They are furthermore divided into three subgroups depending on their energy absorbing capacity in accordance with the following:

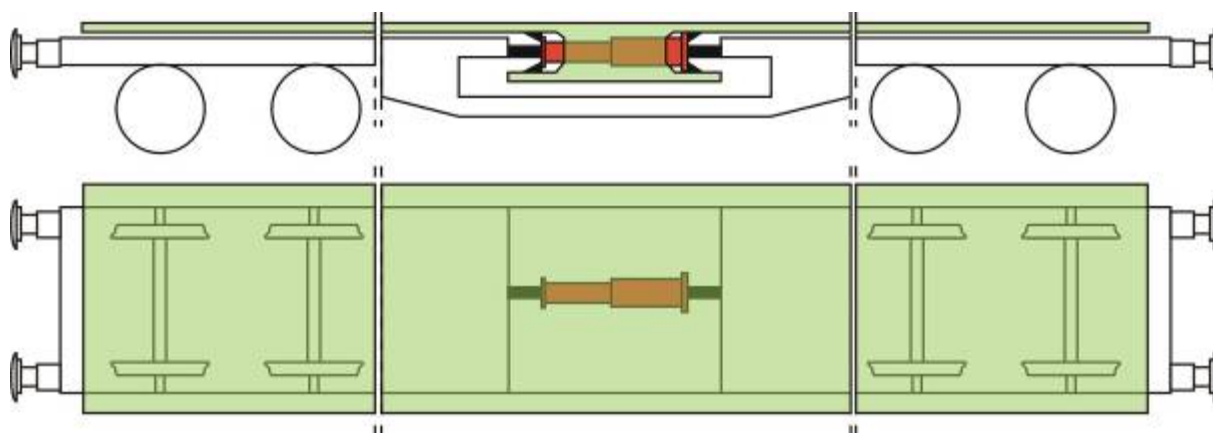
Buffer group	Energy absorption
A	$\geq 30$ kJ
B	$\geq 50$ kJ
C	$\geq 70$ kJ

Buffers with 140 or 150 mm stroke compose there own subgroup, L.

Two distinctly different designs for long stroke buffers are regulated by the leaflet UIC 529; buffer arrangements with a longitudinal sliding girder and arrangements with a sliding loading platform. The two designs are illustrated in the figures below.



*Long stroke buffer arrangement with longitudinal sliding girder.*



*Long stroke buffer arrangement with sliding loading platform.*



## 5 FIELD STUDIES CARRIED OUT IN THE PROJECT

Within the project a number of field studies have been performed during 2005 and 2006. In this chapter a brief description of these tests are given.

### 5.1 Test Transports of paper reels in normal wagons

The first and also the largest of the test transports was with paper reels in freight wagons from Piteå in the north of Sweden to Vienna in Austria. Two additional tests were carried out as a follow up and complementary tests of this transport, one between Piteå and Eslöv and one between Fors and Trelleborg.

Some paper producers experience damages on the wrapping of the reels due to shaving during rail transportation. The aim with the test transport from Piteå to Vienna was to evaluate different cargo securing equipment and wagons to minimize the shaving and movement of reels. Most of the reels were stowed standing, but some were also stowed laying. Five different types of wagons were used and the reels were secured by different methods. Most of the reels were from *Kappa Kraftliner*, but some reels from *Stora Enso Fors AB* and *SCA in Sundsvall* were also included in the tests.

### 5.2 Transports of paper reels in swap bodies

Commissioned by CargoNet AB, MariTerm performed an inspection of swap bodies in the terminal for intermodal transports in Malmö. In the swap body, standing paper reels from Norway were carried and the inspection clearly showed shaving damages between the reels also during intermodal transportation.

### 5.3 Shunting tests

The shunting tests were carried out in Malmö in early autumn 2005 and in the tests two freight wagons with copper and paper load respectively as well as three different types of wagons for intermodal transports were shunted at different speeds and directions. The copper used in the tests were supplied by *Elektrokoppar AB*, the paper reels by *Kappa Kraftliner* and the pallet with paper sheets by *Stora Enso Fors AB*, and the cargo was secured by different means.

The main purpose of the tests was to measure accelerations experienced during different shunting speeds at various places in the wagon and to compare the ability for different cargo securing arrangements to protect the goods from damages when subjected to shunting.

Two different sets of equipment were used to record the shocks. One set, the Mobitron Cargolog, provided high accuracy figures of maximum accelerations and duration of the impact forces. The other set, Vernier Pro accelerometers, possibly at slightly less accuracy than the first one, provided several values for the accelerations during each shock, enabling the plotting of a timeline history graph.

## 5.4 Tests with plastic packaging material

Five tests were performed with plastic packaging materials, three shunting tests and two inclination tests. The plastic packaging tested were stretch wrapping from *Trioplast AB* wrapped by *Cyclop AB* and shrinks and stretch hoods from *Lachenmeier A/S*. The cargo on the tested pallets was cardboard boxes with A4 paper sheets supplied by *Stora Enso Nymölla AB*.

The required amount plastic packaging material to be able to withstand railway shunting operation and enable a safe transport of sparsely stowed free standing pallets, was determined through shunting tests. As a complement the pallets with different wrapping material was tested by simple inclining tests. By comparing the result of the two different test methods, the required inclination angle to simulate shunting forces has been possible to establish.

Based on the outcome of the tests, a simple static inclination test procedure for verifying the required wrapping could thus be recommended to railway users and be used as basis for future guidelines.

## **6 TEST TRANSPORTS OF PAPER REELS**

The results of the test transports including the inspections of the reels during the transport are given in this chapter. The test transports were performed with standing and laying paper reels in freight wagons and standing reels in swap bodies.

### **6.1 Basic information on used equipment and registrations**

Below a description of the used wagons, reels, securing equipment, registrations as well as the UIC Loading Guidelines 2005 is given.

#### **6.1.1 Used wagons**

The following five wagon types were used:

**Hiqqrrs-vw 011 (K Industrier)**

Wagon number: 43742919200-2

Max load: 56.8 ton

*Note! The wagon has very good running characteristics*



The Hiqqrrs-vw<sup>011</sup> is a short-coupled two-axle freight wagon with a modulated design. The exchangeable superstructure makes the wagon very flexible and the wagon can very easily be adjusted to the customers need for different kinds of cargo. The wagon has an electrical automatic opening of the doors on both sides, which will improve the ergonomics for the personnel that handle the cargo. The wagon is fitted with TF25SA single axle running gear with hydraulic damping.

**Technical Data**

- Tare weight	33.200 kg
- Payload at axle load:	22,5 tonne 56,8 tonne
- Speed:	Tare 120 km/h, Laden 100 km/h
- Length over buffer	30.080 mm
- Length, load surface	2 x 13.400 mm
- Width, load surface	3.180 mm
- Internal height	3.200 mm
- Deck height (ARL)	1.078 mm
- Buffer height	1.050 mm
- Min. curve radius	60 m
- Electrical connection	400 V

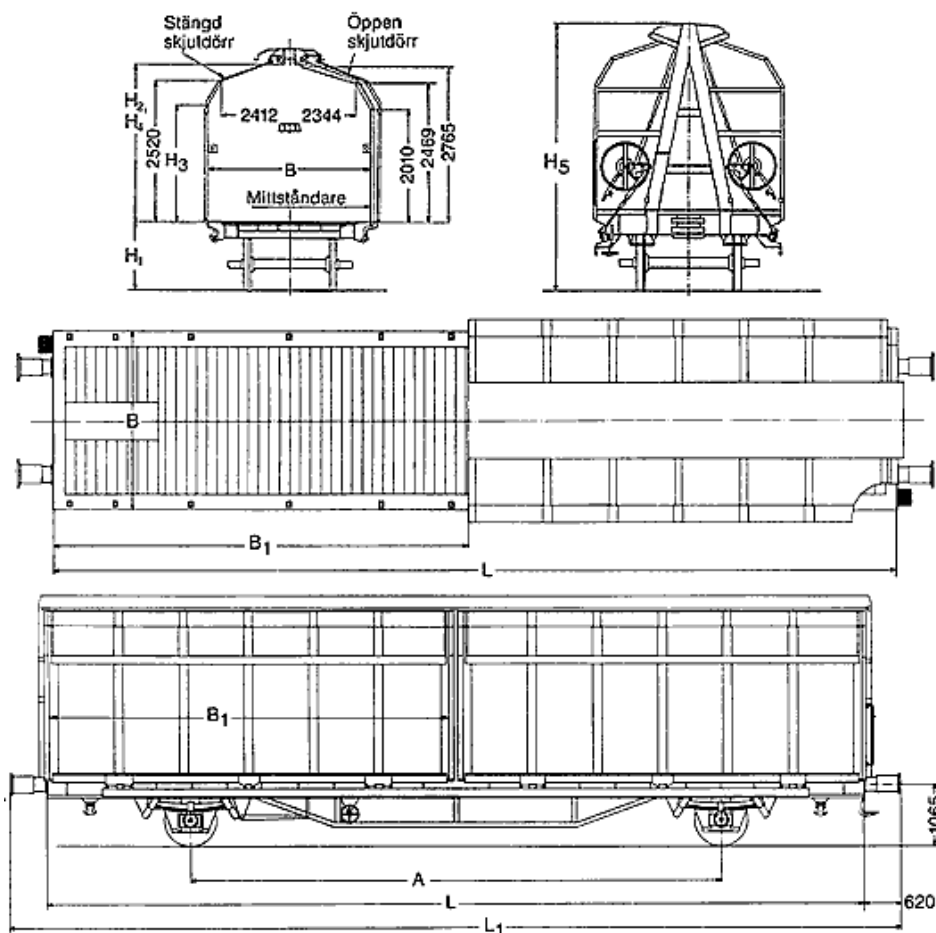


**Hbbins** (Green Cargo)

Wagon number: Piteå - Vienna 2469252-3; Piteå - Eslöv: 2174 2469-1475

Max load: 30 ton

*Note! The wagon's floor is treated with polyurethane for increased friction.*

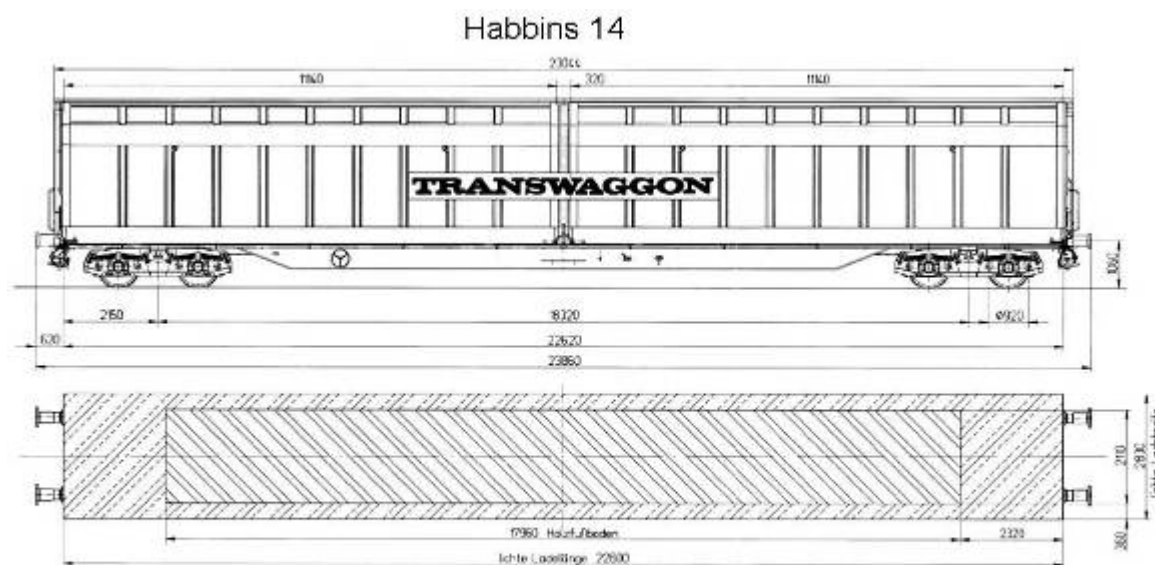


Littera and type	Unit	Hbbins 881
L	mm	14240
B	mm	2900
H3	mm	2100
L1	mm	15500
Loading area	m <sup>2</sup>	41,3
Volume	m <sup>3</sup>	87
B1	mm	7000
H2	mm	2800
H4	mm	2800
Loading volume (to roof)	m <sup>3</sup>	108
Tara	kg	15000
Floor height	mm	1200
H5	mm	4275
A	mm	9000

**Habbins 14** (Transwaggon)

Wagon number: 2770255-8

Max load: 64,2 ton

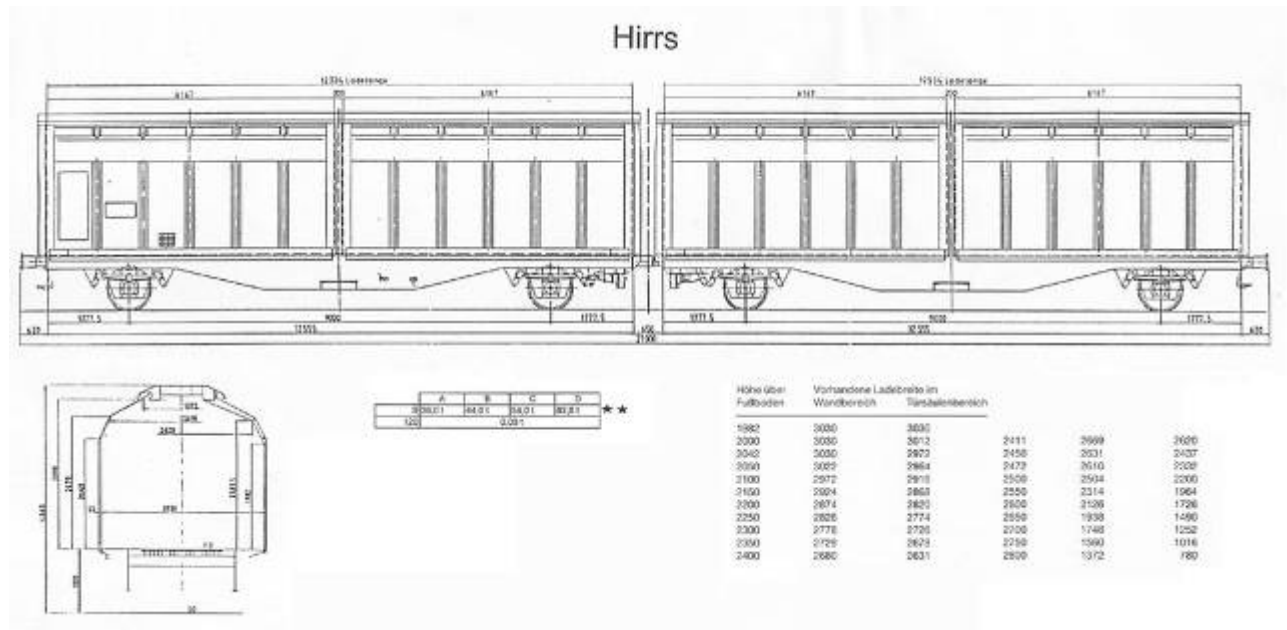


Loading length	22.600 mm	Number of doors	2
Loading width	2.830 mm	Door length	11.140 mm
Loading area	64 m <sup>2</sup>	Door height	2.860 mm
Loading volume	173 m <sup>3</sup>	Floor height	1.192 mm
Max. payload	64,2 t	Minimum curve radius:	60 m
Wagon weight	25,8 t		

**Hirrs** (Transwaggon)

Wagon number: 2922593-1

Max load: 64 ton

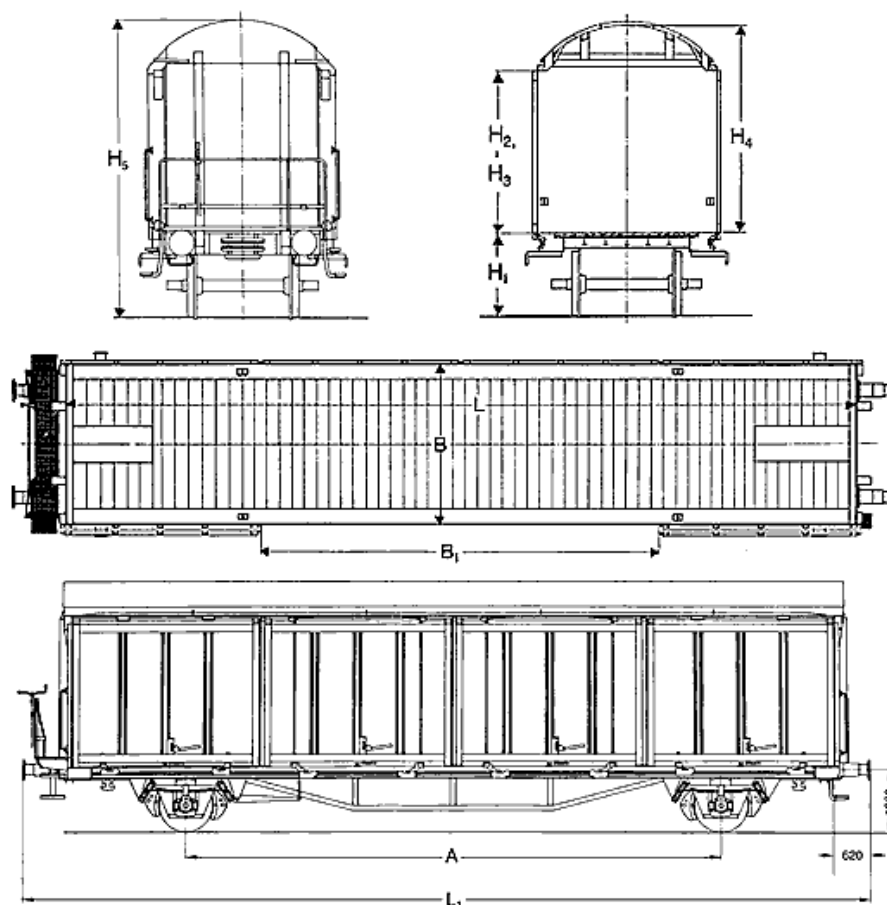


Loading length	2 x 12.534 mm	Number of doors	2 x 2
Loading width	3.030 mm	Door length	6.167 mm
Loading area	2 x 38 m2	Door height	2.800 mm
Loading volume	2 x 103 m3	Floor height	1.200 mm
Max. payload	64,0 t	Minimum curve radius:	75 m
Wagon weight	26,0 t		

**Hbins** (Green Cargo)

Wagon number: 2265041-6

Max load: 30 ton



Littera and type	Unit	Hbins 763
L	mm	12800
B	mm	2600
H3	mm	2330
L1	mm	14342
Loading area	m <sup>2</sup>	33.3
B1	mm	6310
H2	mm	2330
H4	mm	2990
Loading volume (to roof)	m <sup>3</sup>	94.3
Loading volume (side wall)	m <sup>3</sup>	77.7
Tara	kg	15000
Floor height	mm	1214
H5	mm	4264
A	mm	9000

**Sins (shell wagon) (Transwaggon)**

Wagon number: 4638074 – 1

Max load: 62 ton

*Note: Plywood flooring in the wagon*



A unique wagon construction combining advantages with the open wagon with those from the fully enclosed wagons. Fully accessible loading and discharging capability in combination with full weather protection. The cargo compartment is fully accessible by uncovering half of the outer shell construction of the wagon. This gives ability for loading both from sides and from top. This type of wagon has an internationally acceptable dimensioning profile and may thus be used for traffic in entire Europe.

Loading length	21.980 mm	Number of doors	2
Loading width	2.770 mm	Door length	10.740 mm
Loading area	61 m <sup>2</sup>	Door height	3.000 mm
Loading volume	166 m <sup>3</sup>	Floor height	1.200 mm
Max. payload	62,0 t	Minimum curve radius:	35 m
Wagon weight	28,0 t		

**6.1.2 Used reels**










The following types of reels were used in the tests:

<b>Piteå - Vienna</b>	Total number of reels	Total weight (ton)	Diameter (mm)	Width (mm)
Kappa	78	184,6	1250 and 1450	2000 - 2450
SCA	9	11,2	1250	852
Stora Enso Fors	18	29,2	1800	1006
<b>Piteå - Eslöv</b>	Total number of reels	Total weight (ton)	Diameter (mm)	Width (mm)
Kappa	10	23,7	1200 - 1450	2000 - 2450

<b>Fors - Trelleborg</b>	Total number of reels	Total weight (ton)	Diameter (mm)	Width (mm)
Stora Enso Fors	48	46,2	1750	615

### 6.1.3 Cargo securing and measuring equipment

The cargo securing equipment suppliers participating in the BREAKAGE-project supplied the required cargo securing and measuring equipment listed below.

Product	Supplier	Legend
Load Grip $3,2 \times 120 \times 1065$ mm (strips)	IW Ventures	
Load Grip $3,2 \times 1000 \times 2000$ mm (mats)	IW Ventures	
Marotech $8 \times 120 \times 1065$ mm (strips)	Kappa Kraftliner	
Lanocatch (strips)	Tetec Trading	
Finnish stripes	SCA	
Block of corrugated cardboard (strips)	Tetec Trading	
Cradle of corrugated cardboard	Tetec Trading	
10 kN webbing, low tension	Kappa Kraftliner	
40 kN webbing, high tension	Ancra ABT	
Cargolog (shock recorder) with GPS	Mobitron	✕

Which way the stripes of the different friction material were placed in the wagons, longitudinal or transverse is indicated on the sketches.

### 6.1.4 Stowage of the reels

Some reels were stowed in double layers. In these stacks **L** is used to mark the lower reel and **U** is used to mark the upper reel.

The reels were stowed closely or sparsely (see abbreviations in the following section). The loading and securing of the reels was in some of the wagons not in accordance with the UIC Loading Guidelines, see section 6.1.6. Sparsely stowage and unsecured reels were tested just for comparison.

### 6.1.5 Account of the results

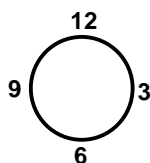
The results of the test transports will be presented as follows. The motion of the centre of the reel is indicated in cm together with the direction of the motion. The rotation is given as distance along the circumference in cm together with direction; clockwise (cw) and counter clockwise (ccw) respectively. If no value is given in the tables, the registration is missing.

The following abbreviations have been used to describe the loading and securing of the reels:

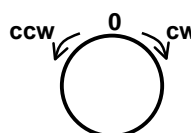
n	= nothing under
mt	= Marotech strip
lgm	= Load Grip mat
lgs	= Load Grip strip
lc	= Lanocatch
f	= Finish stripes
w	= block of corrugated cardboard
c	= closely stowed
s	= sparsely stowed <i>Note! This is not in accordance with the Loading Guidelines</i>
0	= no lashing
1	= Low tension 1-tons lashing
4	= High tension 4-tons lashing

The following abbreviations have been used to describe the recorded motions for the reels:

*Direction of linear movement*



*Direction of rotation*



The following colour codes have been used to empathise the level of motions among the reels:



*Light movements*

0-5 cm linear or circular movement



*Moderate movements*

6-15 cm linear or circular movement



*Heavy movements*

more than 16 cm linear or circular movement  
or contact with wagon structures



*Registration is missing*

### 6.1.6 UIC Loading Guidelines 2004

For reference the latest UIC Loading Guidelines for standing reels are given below.



## Loading guidelines 4.1.3

## Rolls of paper loaded upright ("eye-to-sky")

Single wagons and groups of wagons

Wagons in block trains and combined transport  
Wagons with long-stroke shock absorbers

## Type of goods

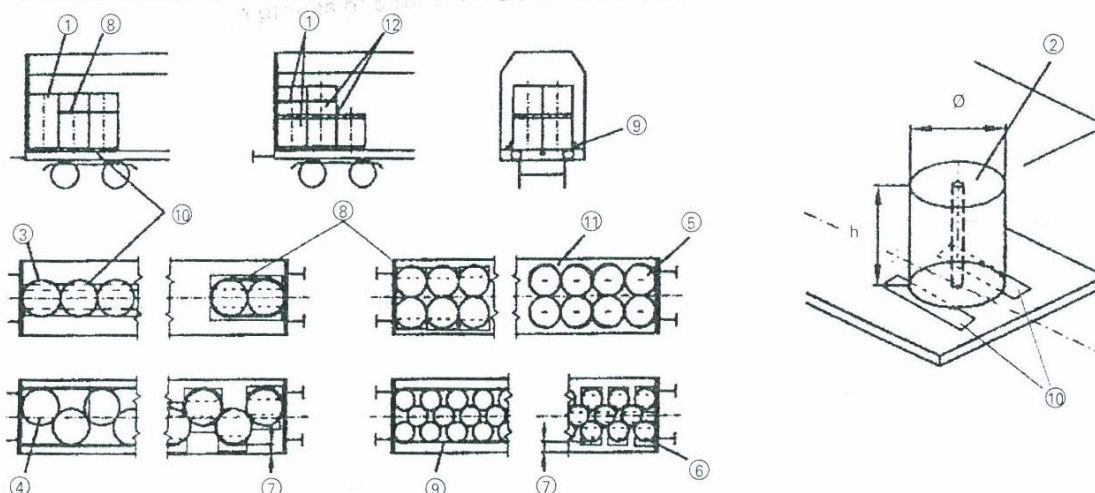
Rolls of paper

## Wagons

Wagons with sliding walls and fixed end walls (H..., Li..., Si...)

## Method of loading

- ① Rolls should be loaded "upright" in one or more tiers. They should if possible cover the whole loading surface. When loaded in several tiers, rolls should be placed exactly one on top of another.
- when loaded without intermediate spacing, the diameter of the rolls must be at least 5/10 of their height. Otherwise, roll diameter must be at least 7/10 of roll height.
- rolls should be arranged as follows in the wagon
  - in a single line one behind the other (roll axis placed along the wagon longitudinal centreline),
  - in two staggered lines (symmetrical about the wagon longitudinal centreline),
  - in two lines, with the rolls one behind another,
  - in three staggered lines (in groups of 5 rolls),
- upright and in contact with the end walls, with space left in the middle of the wagon
- if arranged according to ④ or ⑥, rolls should be formed into fixed groups crossways in the wagon or else the load should be at least 10 cm clear of the sliding walls.
- there should be no contact with the sloping part of the roof.



## Securing

- lengthways in the wagon
- ⑧ by the end walls, able to slide if appropriate. Rolls whose diameter is less than 7/10 of their height should be bound together and prevented from moving. Breaking strength of bindings: at least 1000 daN.
- crossways in the wagon
- ⑨
  - by guide-rails<sup>1)</sup> that are an integral part of the wagon or are fixed, for example, to existing battens or
  - by wooden guide-pieces approx. 5 cm high. Number of nails per side : 1 nail/2000 kg with at least 2 nails per guide-piece or
  - by cradles resting against the sliding walls (corrugated cardboard, several layers thick, wooden laths) to fill up the space across the wagon or
- ⑩ using friction-enhancing inserts, 2 parallel strips laid lengthways under each roll, with a  $\mu$  value of at least 0.7 and a minimum width of 15 cm. The friction coefficient, resistance to deformation and average resistance to dirt shall be guaranteed by the manufacturer or
- ⑪ sliding walls: if loaded as shown in ⑤, loading without friction-enhancing inserts is possible providing the lateral clearance to the sliding wall is  $\leq 10$  cm and the height of the paper rolls is no greater than the vertical part of the sliding wall.
- ⑫ If the rolls are stacked, friction inserts should be placed between each tier.

## Additional indications

Distribution of load: see sheet 0.1

1) For example, profiled tubes of height  $\geq 50$  mm; the upper edge facing the goods should be rounded off to avoid causing damage.



## Loading guidelines 4.1.4

## Rolls of paper and wood pulp loaded upright ("eye-to sky")

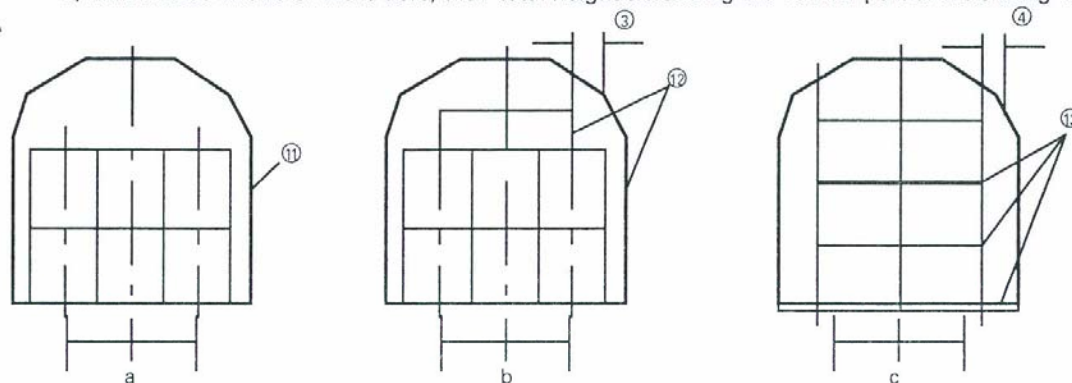
Single wagons and groups of wagons

Wagons in block trains and combined transport  
Wagons with long-stroke shock-absorbers

## Type of goods

Rolls of paper and wood pulp with a diameter of at least 5/10 of the height of the rolls or stacks

- a) rolls loaded in one or more tiers, the total height not exceeding the vertical part of the sliding walls,
- b) rolls loaded in several tiers, their total height not exceeding the vertical part of the sliding walls, with a further tier loaded centrally in the sloping roof area only if the underlying tiers are arranged in aligned rows,
- c) rolls loaded in one or more tiers, their total height exceeding the vertical part of the sliding walls.

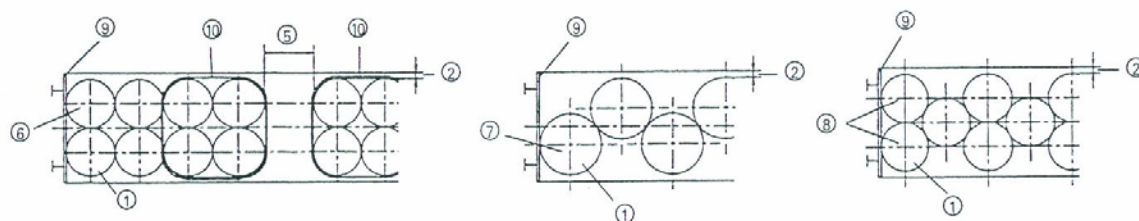


## Wagons

Bogie wagons and permanently-coupled wagon units with strengthened sliding walls and fixed end walls, marked with the code letters "ii" or conforming to loading guidelines 100.2

## Method of loading

- ① Rolls should be loaded in unbroken formation, packed tightly against one another, in one or two tiers, with the first rolls against the end walls and using as much of the floor area as possible.
- ② - lateral clearance to the sliding walls: 10 cm maximum
- ③ when loaded as in (b) the lateral clearance between the tier and the sliding wall in the sloping roof area must be greater than 10 cm
- ④ when loaded as in (c) the distance to the walls should be approx. the same on each side and greater than 10 cm in the sloping roof area
- ⑤ - lengthways, any loading gaps should be left in the middle of the wagon; when loading in several tiers, a loading gap may only be left in the upper tier
- rolls should be arranged as follows:
  - ⑥ • in rows packed tightly one behind another (and one next to another as appropriate) when the diameter of the rolls is no more than 1/2 the loading width, or
  - ⑦ • in 2 staggered rows when the diameter of the rolls is greater than 1/2 of the loading width, or
  - ⑧ • in several staggered rows when the diameter of the rolls is less than 1/2 of the loading width.



## Securing

- lengthways in the wagon
  - ⑨ by the end walls,
  - ⑩ when there is a gap of more than 50 cm in the centre of the wagon, any free-standing rolls must be bound to the adjacent rolls with self-adhesive fastenings (breaking strength 1,000 daN minimum) or secured against sliding
- crossways in the wagon
  - ⑪ goods as in a) by the sliding walls
  - ⑫ goods as in b) by the sliding walls, with the tier in the sloping roof area secured using friction-enhancing inserts/packages
  - ⑬ goods as in c) by enclosed lateral securing or lateral guide-pieces or friction inserts/packages; the upper tiers should be secured using friction inserts/packages.

## Additional indications

Distribution of load: see sheet 0.1

Friction coefficient of friction-enhancing inserts  $\mu = 0.70$ 

1.10.2004

## 6.2 Test transport of paper reels from Piteå to Vienna

In the test transport between Piteå and Vienna the following parameters were used to combine different tests:

- Five different wagons
- Three types of reels
- Standing and laying reels
- Closely or sparsely stowed reels
- Six types of friction material (including wagon floor coating as one type)
- Four of the materials supplied in stripes could be placed either transverse or lengthways in the wagon. The stripes were mostly placed lengthways under the reels in the upper part of figures below, and transverse under the reels in the lower part of the wagon in the figures.
- Two types of lashings, with high and low pre tension respectively

The intention was to test as many combinations as possible. At the same time it was desirable to test the same combinations in as many of the wagons as possible.

The reels from Stora Enso arrived to the Kappa mill in Piteå in a Hbbins-wagon. Unfortunately the diameter of the reels was too large to make it possible to handle the reels with the trucks at the Kappa mill. Due to this none of the Stora Enso reels were tested in any of the other wagons and no friction material was put underneath the reels. As the Stora Enso reels totally occupied the Hbbins-wagon, no other reels could be tested in this wagon.

The test transport started with loading in Piteå and inspections were carried out in Hallsberg and during unloading in Vienna. The following persons were attending the inspections on the different places:

Attendance		Loading in Piteå 2005-04-13	Inspection in Hallsberg 2005-04-14	Unloading in Vienna 2005-04-19
K-G Fältmark	Kappa Kraftliner	x		x
Stanley Öberg	Green Cargo	x		x
Kent Johansson	Green Cargo		x	
Kent Rabb	Stora Enso Fors	x		
Thore Söderqvist	SCA Transforest	x		x
Per Nordblom	Oden Energy	x		
Thomas Tegstam	Tetec Trading	x	x	
Lars Lundgren	Lastrådgivaren	x		x
Sven-Olof Olsson	Mobitron	x	x	x
Björn Widell	K Industrier			x
Rolf Nordström	TFK			x
Nicklas Axell	TFK		x	
Peter Andersson	MariTerm	x		
Sven Sökjer-Petersen	MariTerm		x	
Robert Bylander	MariTerm	x	x	x

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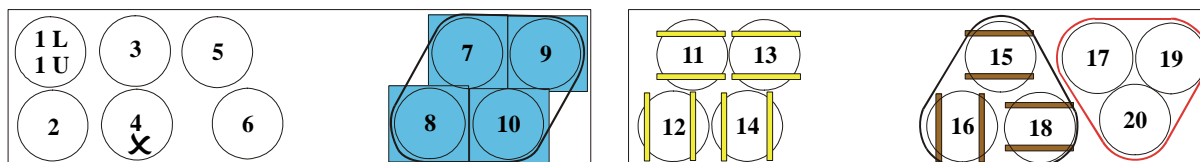
Arno Meske	Railion (DB)			✕
Roman Embacher	ÖBB			✕
Walter Panzer	ÖBB			✕
Urs Dannenauer	SBB			✕

During the stop in Hallsberg and at arrival in Vienna the reels were inspected and any movement and damage was documented. By the use of shock recording equipped with GPS the magnitude and direction of the accelerations the reels had been exposed to and where the accelerations occurred could be determined.

### 6.2.1 Loading in Piteå

Below a description of the loading and securing in the five different wagons is given.

#### Wagon: Hiqrrrs



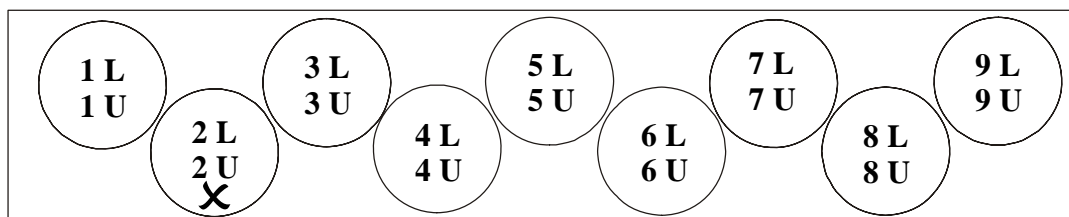
Reel	Stowage and securing	Type	Wrapping	Weight (kg)	Dia. (mm)	Width (mm)
1 – 2	Standing direct on wagon floor Stowed closely Double Stacked	SCA	Wrapped	1243	1250	852
3 – 4	Standing direct on wagon floor Stowed sparsely	Kappa	Unwrapped	2450	1250	2350
5	Standing direct on wagon floor	Kappa	Unwrapped	2450	1250	2350
6	Stowed closely	Kappa	Unwrapped	3450	1450	2450
7 – 10	Standing on Load Grip mats Tighten with one loose 1-tons web Stowed sparsely	Kappa	Unwrapped	3450	1450	2450
11 – 13	Standing on Marotech strips	Kappa	Unwrapped	3170	1450	2250
14	Tighten with one loose 1-tons web Stowed closely	Kappa	Unwrapped	3450	1450	2450
15, 18	Standing on Lanocatch strips	Kappa	Unwrapped	2400	1250	2300
16	Tighten with one low tension 1-tons web Stowed sparsely	Kappa	Unwrapped	3170	1450	2250
17, 20	Standing direct on wagon floor	Kappa	Unwrapped	2190	1250	2100
19	Tighten with one high tension 4-tons web Stowed closely	Kappa	Unwrapped	3170	1450	2250



Paper reels number 1 – 4 in the front of the Hiqrrrs wagon



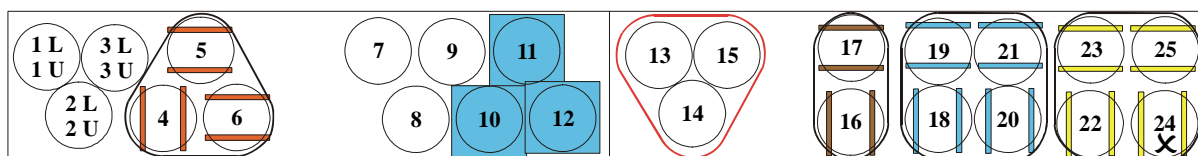
Overview of the paper reels number 11 – 20 in the second part of the wagon.

**Wagon: Hbbins**

Reel	Stowage and securing	Type	Wrapping	Weight (kg)	Dia. (mm)	Width (mm)
1 – 9	Standing direct on wagon floor Stowed closely	Stora Enso Fors	Wrapped	1611 - 1630	1800	1006



*Reels from Stora Enso Fors standing direct on the wagon floor.*

**Wagon: Habbins**

Reel	Stowage and securing	Type	Wrapping	Weight (kg)	Dia. (mm)	Width (mm)
1 – 3	Standing direct on wagon floor Stowed closely	SCA	Wrapped	1243	1250	852
4 – 6	Standing on block of corrugated cardboard stripes Tighten with one low tension 1-tons web Stowed sparsely	Kappa	Unwrapped	2400	1250	2300
7 – 9	Standing direct on wagon floor Stowed sparsely	Kappa	Unwrapped	2400	1250	2300
10 – 12	Standing on Load Grip mats Stowed sparsely	Kappa	Unwrapped	2400	1250	2300
13 – 15	Standing direct on wagon floor Tighten with one high tension 4-tons web Stowed closely	Kappa	Unwrapped	2090	1250	2000
16 – 17	Standing on Lanocatch strips Tighten with one low tension 1-tons web Stowed closely	Kappa	Unwrapped	2090	1250	2000
18 – 21	Standing on Load Grip strips Tighten with one low tension 1-tons web Stowed closely	Kappa	Unwrapped	2090	1250	2000
22 – 25	Standing on Marotech strips Tighten with one low tension 1-tons web Stowed sparsely	Kappa	Unwrapped	2090	1250	2000

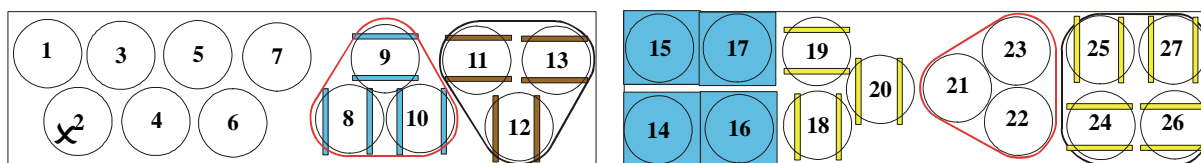


*Reel 1 - 12 stowed in Piteå.*



*Overview of the reels 13 - 25 in the second part of the wagon.*



**Wagon: Hirrs**

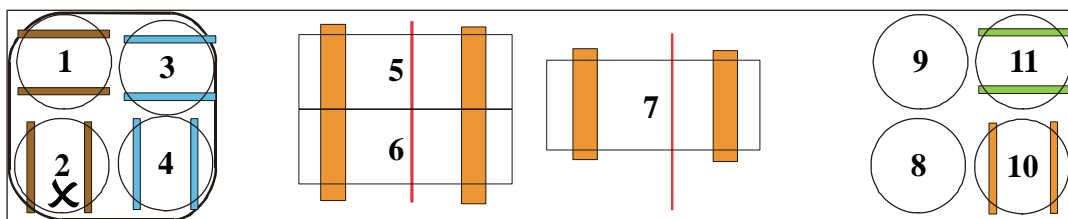
Reel	Stowage and securing	Type	Wrapping	Weight (kg)	Dia. (mm)	Width (mm)
1 – 7	Standing direct on wagon floor Stowed sparsely	Kappa	Unwrapped	2300	1250	2200
8 – 10	Standing on Load Grip strips Tighten with one high tension 4-tons web Stowed closely	Kappa	Unwrapped	2450	1250	2350
11 – 13	Standing on Lanocatch strips Tighten with one low tension 1-tons web Stowed sparsely	Kappa	Unwrapped	2450	1250	2350
14 – 17	Standing on Load Grip mats Stowed sparsely	Kappa	Unwrapped	1980	1250	1900
18, 20	Standing on Marotech strips	Kappa	Unwrapped	1980	1250	1900
19	Stowed sparsely	Kappa	Unwrapped	1840	1250	1760
21 – 23	Standing direct on wagon floor Tighten with one high tension 4-tons web Stowed closely	Kappa	Unwrapped	1840	1250	1760
24 – 27	Standing on Marotech strips Tighten with one low tension 1-tons web Stowed sparsely	Kappa	Unwrapped	1980	1250	1900



*Reels 1 – 7 stowed standing in the front of the wagon.*



*Reels standing on Load Grip mats in the second part of the wagon.*

**Wagon: Hbins**

Reel	Stowage and securing	Type	Wrapping	Weight (kg)	Dia. (mm)	Width (mm)
1 – 2	Standing on Lanocatch strips Tighten with one low tension 1-tons web Stowed sparsely	Kappa	Unwrapped	2140	1250	2050
3 – 4	Standing on Load Grip strips Tighten with one low tension 1-tons web Stowed closely	Kappa	Unwrapped	2400	1250	2300
5	Laying in cradle of corrugated cardboard Secured with 4-tons high tension top-over web lashing	Kappa	Unwrapped	2450	1250	2350
6	Laying in cradle of corrugated cardboard Secured with 4-tons high tension top-over web lashing	Kappa	Unwrapped	2140	1250	2050
7	Laying in cradle of corrugated cardboard Secured with 4-tons high tension top-over web lashing	Kappa	Unwrapped	3170	1450	2250
8 – 9	Standing direct on wagon floor Stowed sparsely	Kappa	Unwrapped	2140	1250	2050
10	Standing on block of corrugated cardboard stripes Stowed sparsely	Kappa	Unwrapped	2140	1250	2050
11	Standing on Finish stripes Stowed sparsely	Kappa	Unwrapped	2140	1250	2050



*Reels 8 - 11 and a glimpse of the lying reel 7.*



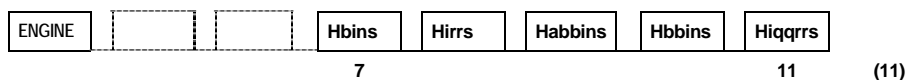
*Reels 5 - 7 lying in a cradle of corrugated cardboard.*



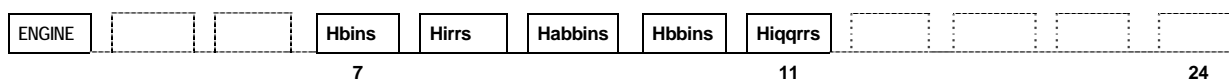
## 6.2.2 Location of the wagons in the trains during different parts of the transport

The magnitude of the accelerations in a wagon during transit is to some extent depending on where in the train the wagon is located. If a wagon is located at the very end of the train the accelerations are normally the largest. It is worth to note that the five wagons have been transported in one uncoupled group all the way from Piteå to Vienna.

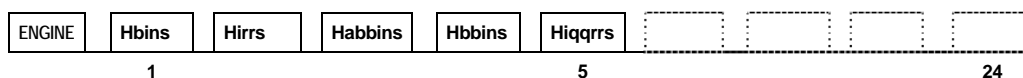
### Order of the wagons from *Piteå – Vännäs*, about 250 km



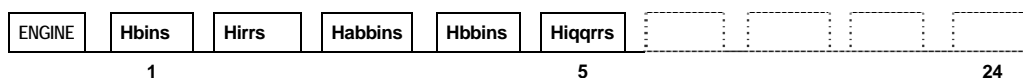
### Order of the wagons from *Vännäs – Hallsberg*, about 750 km



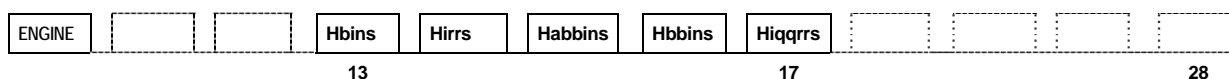
### Order of the wagons from *Hallsberg – Malmö*, about 470 km



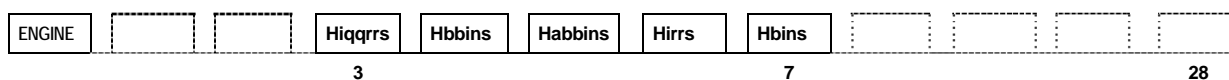
### Order of the wagons from *Malmö – Maschen*, about 520 km



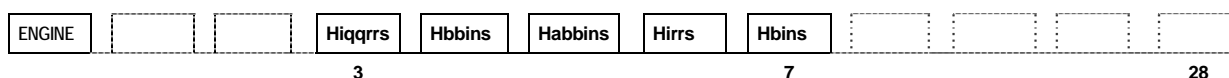
### Order of the wagons from *Maschen – Nürnberg*



### Order of the wagons from *Nürnberg – Vienna Centralbahnhof*



### Order of the wagons from *Vienna Centralbahnhof – Matzleinesdorf*



### 6.2.3 Recorded accelerations in the different wagons

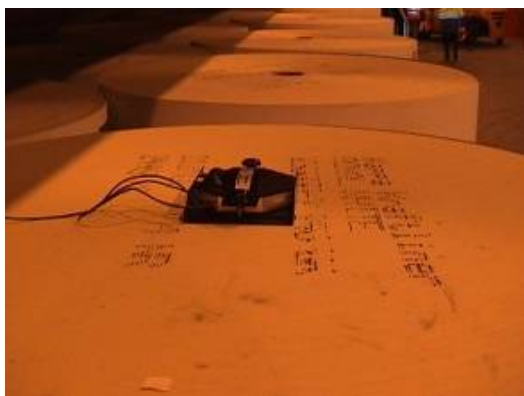
In each of the five wagons a Cargolog equipment was mounted. By this equipment the following data can be recorded as function of the time:

- Accelerations in three directions
- Tilting in one direction
- Position by GPS
- Moisture
- Temperature

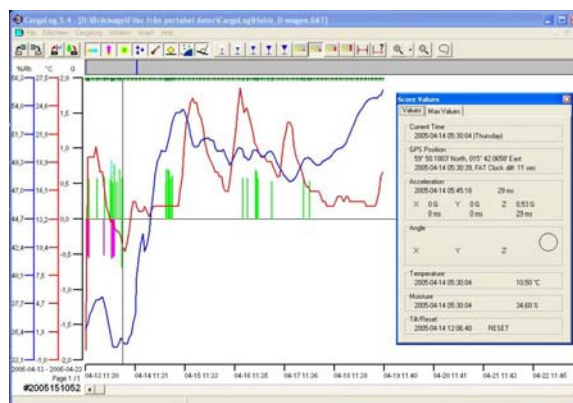
A trig value was set for accelerations in each direction and the magnitude and duration for accelerations were recorded whenever this trig value was exceeded.

The GPS position was recorded a few seconds after a trig value had been exceeded in any direction and at one hour intervals.

The Cargolog recorders were mounted on the core on top of the reels, see photo below.



*Cargolog sensor mounted on top of reel*



*Screenshot from the computer program that was used to interpret the registered shocks.*

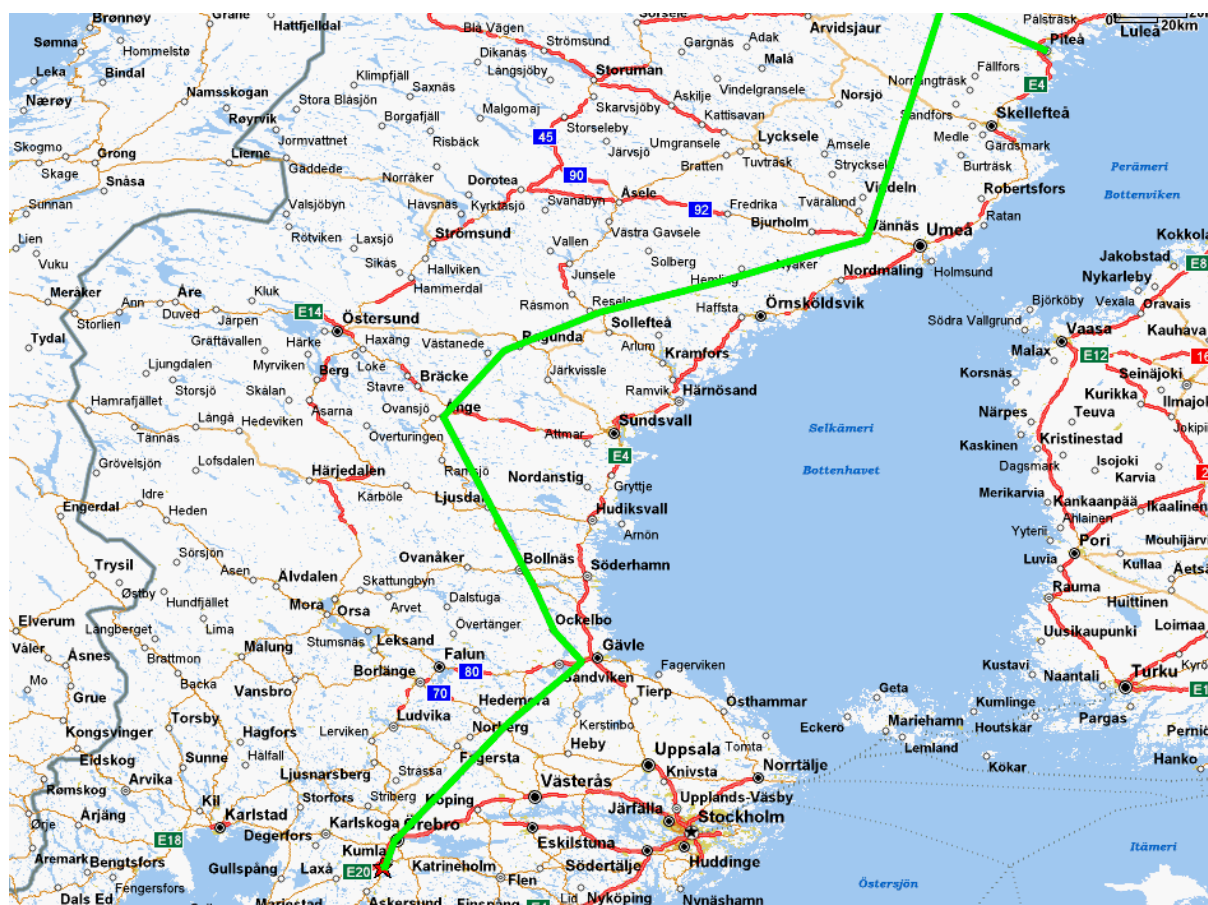
Minimum so called trig values can be set for each of the accelerations. Temperature, moisture and location can be registered at set intervals.

In the table below a summary of number of registrations as well as maximum acceleration in each direction is shown for the five wagons. The trig value was set at 0.5 g in vertical (Z) and transverse (Y) direction. In longitudinal (X) direction the trig value was set at 0.9 g. The values were filtered at 10 Hz vertically and transversally. In longitudinal direction the values were filtered at 20 Hz.

Wagon type	Number of accelerations within defined limits							
	<i>X</i>	<i>Y</i>				<i>Z</i>		
	<i>a</i> >=0.9	<i>a</i> >=0.5	<i>0.5</i> <= <i>a</i> < <i>0.6</i>	<i>a</i> >=0.6	<i>a</i> >=0.5	<i>0.5</i> <= <i>a</i> < <i>0.6</i>	<i>a</i> >=0.6	
Hlqqrrs	2	2	1	1	6	1	5	
Hbbins	9	20	10	10	108	31	77	
Habbins	0	19	16	3	40	12	28	
Hirrs	2	32	27	5	635	178	457	
Hbins	4	23	14	9	216	84	132	

Wagon type	Maximum acceleration		
	<i>X</i> <i>Longitudinal</i>	<i>Y</i> <i>Transverse</i>	<i>Z</i> <i>Vertical</i>
Hlqqrrs	1,5	0,9	0,8
Hbbins	1,4	0,8	1,1
Habbins	-	0,6	0,8
Hirrs	1	1,1	1,2
Hbins	1,1	1,2	1,1

In the maps below, the position of the wagons registered by the Cargolog between Piteå and Vienna is shown. In the maps it is possible to get an overview of the transport route as well as details where special triggering of the set values has occurred.



*Route from Piteå to Hallsberg*





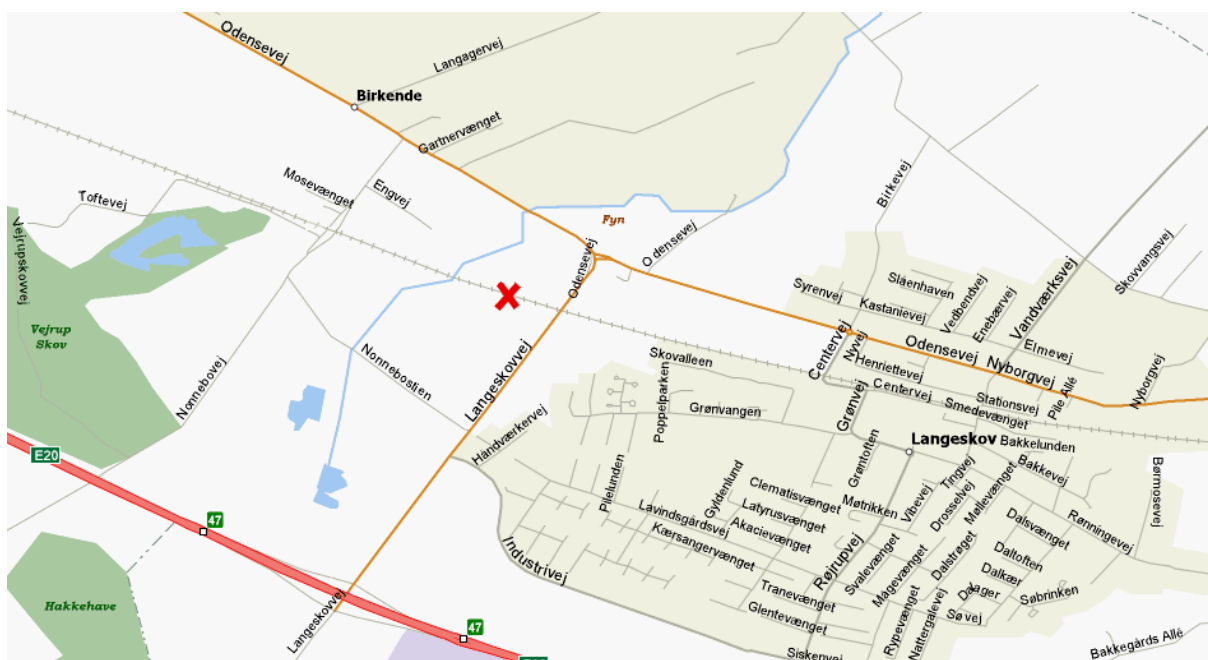
*Route from Hallsberg to Malmö*



*Route from Malmö to Hamburg*

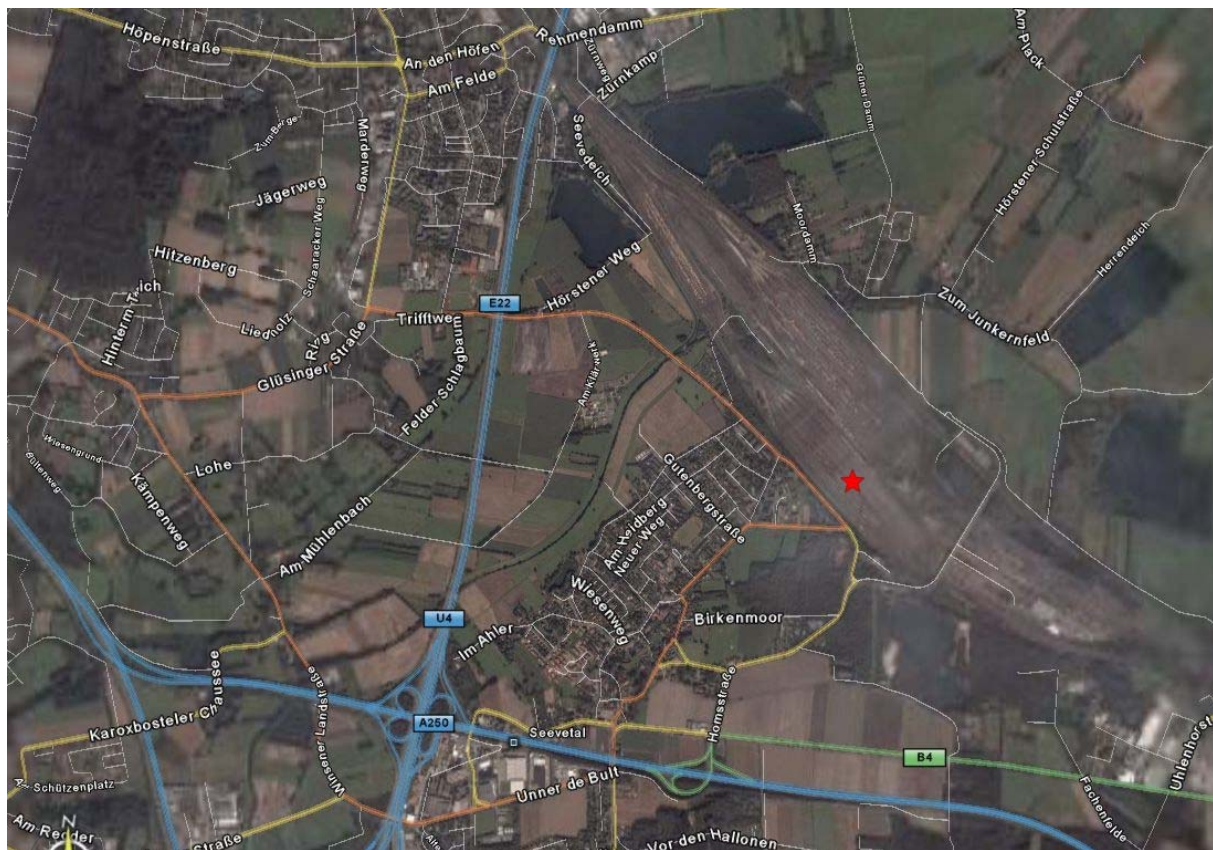


*Route from Hamburg to Vienna*

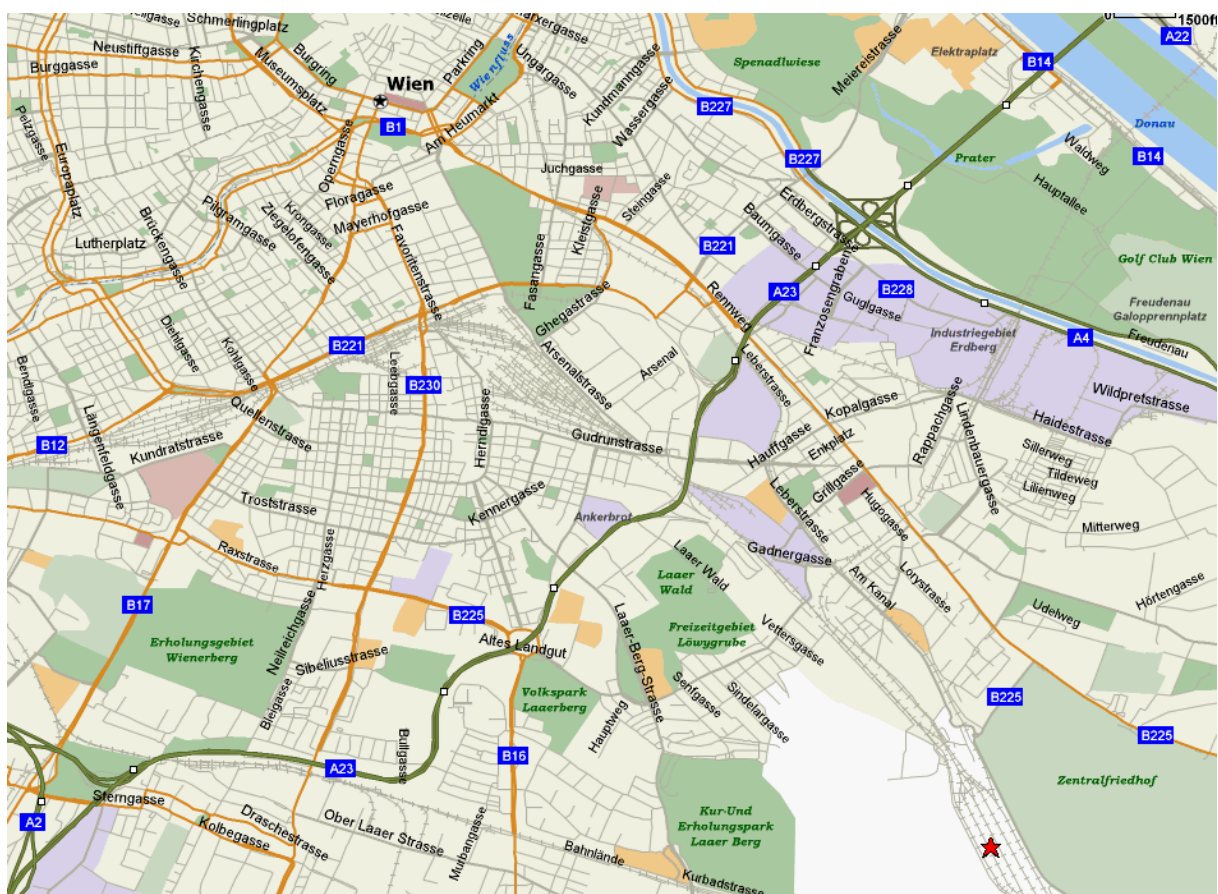


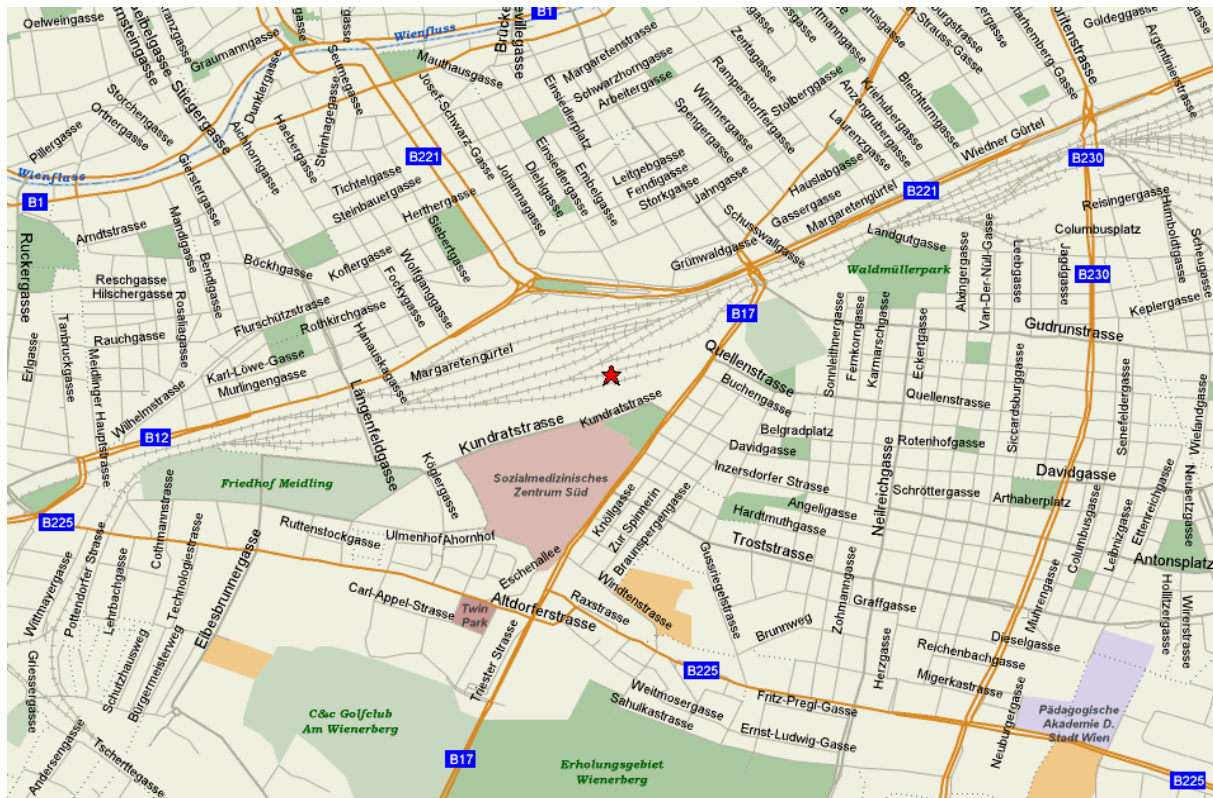
*Detail from position near Odense where a large vertical shock in the vertical direction were recorded in all wagons.*





Detail from Maschen near Hamburg where large longitudinal accelerations in the Hiqqrrs wagon was recorded.





*Detail from unloading site in Vienna.*

Below graphs and tables of the registrations in the different wagons are given. The following line colours are used in the graphs below to mark accelerations and velocity:

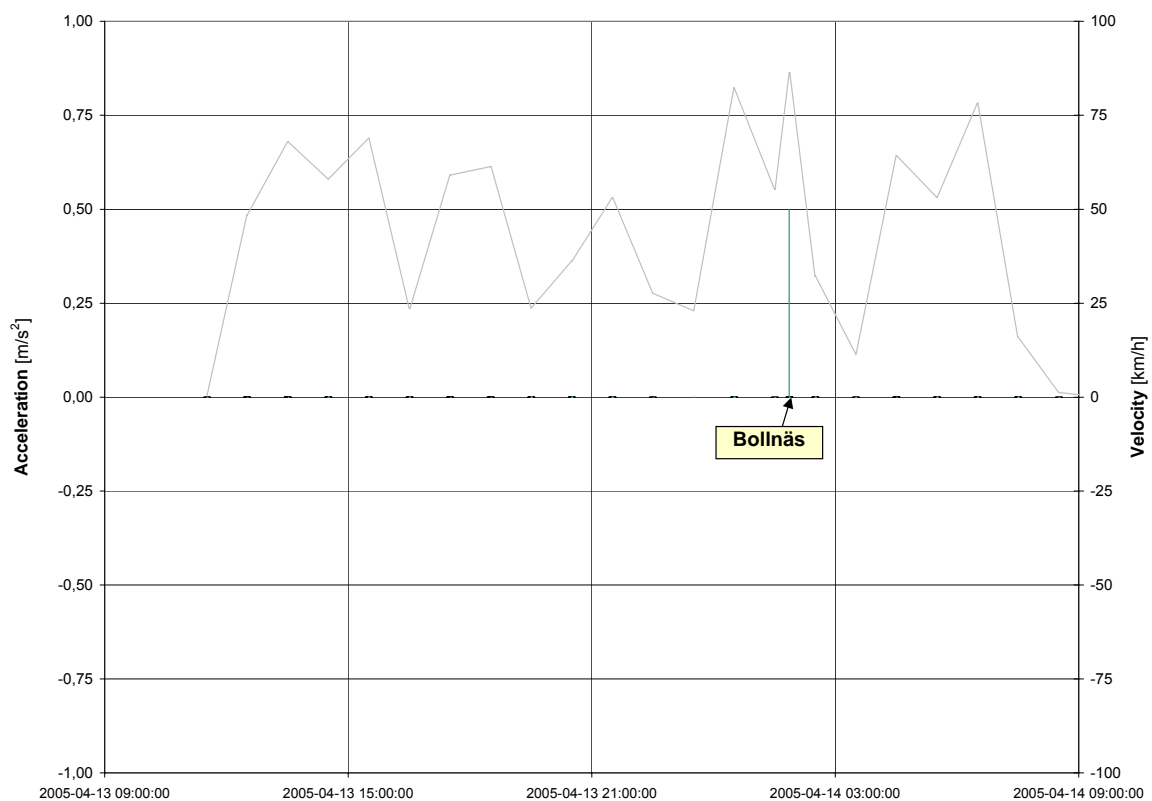
Longitudinal (X) acceleration	<span style="color: red;">—</span>
Transverse (Y) acceleration	<span style="color: blue;">—</span>
Vertical (Z) acceleration	<span style="color: green;">—</span>
Mean velocity between record positions	<span style="color: grey;">—</span>

The velocity was calculated as a mean velocity between each recorded position. For wagons with few recorded accelerations, the position of the wagon is recorded mostly ones every hour. For wagons with numerous of recorded accelerations the position is recorded more frequently. This is the reason why the speed differs between the wagons.

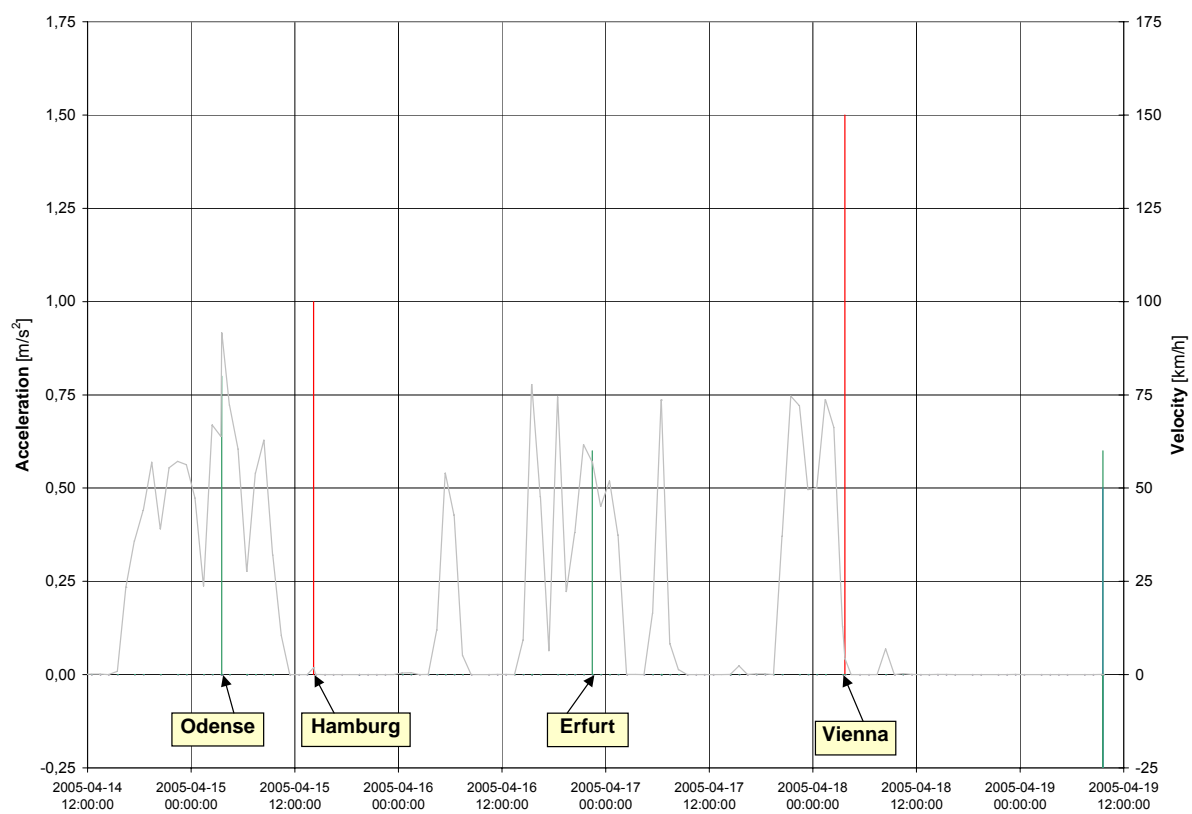
This method gives an idea of the velocity only and no exact value.

Wagon: Hiqqrrs

## Piteå to Hallsberg



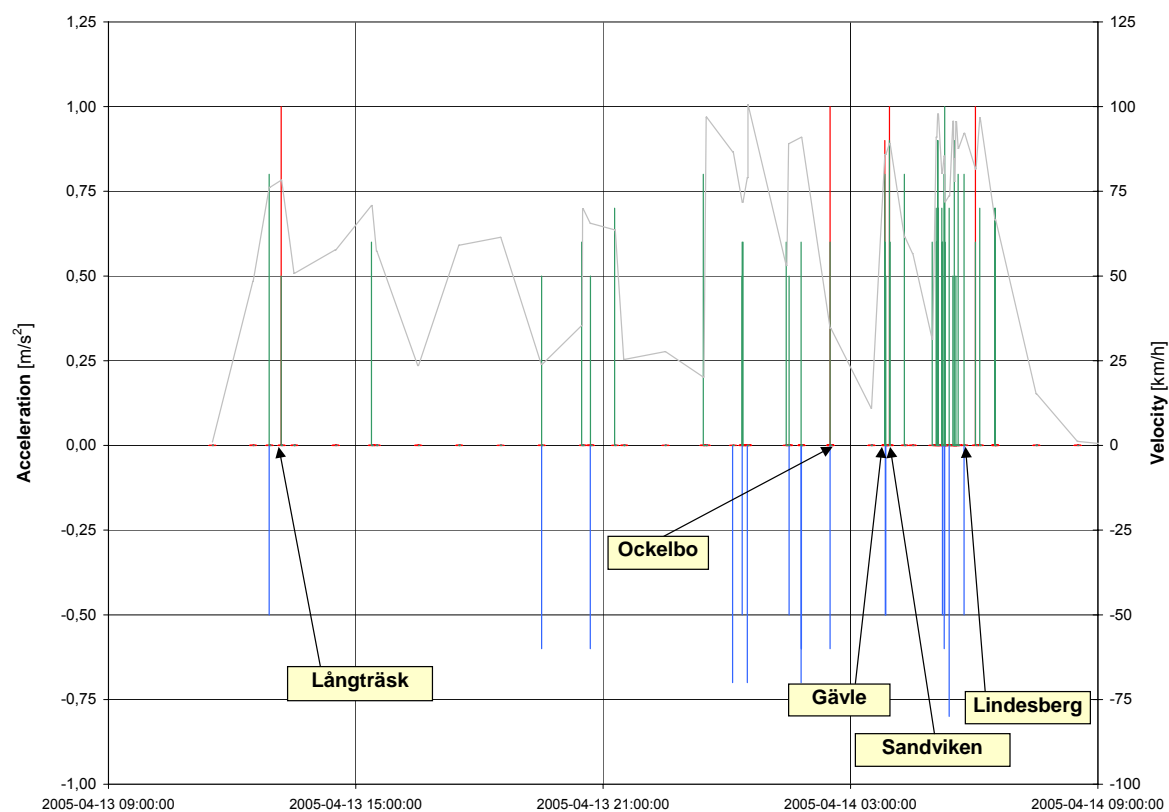
## Hallsberg to Vienna



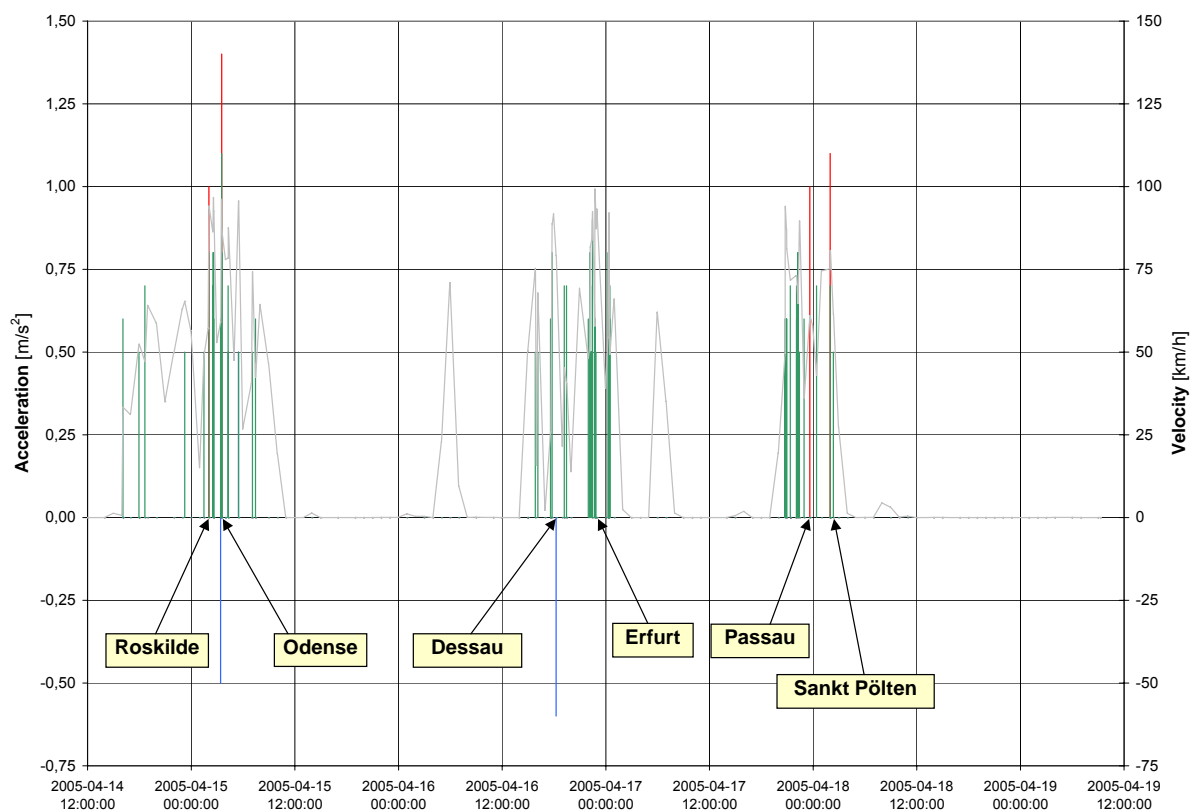


Wagon: Hbbins

### Piteå to Hallsberg

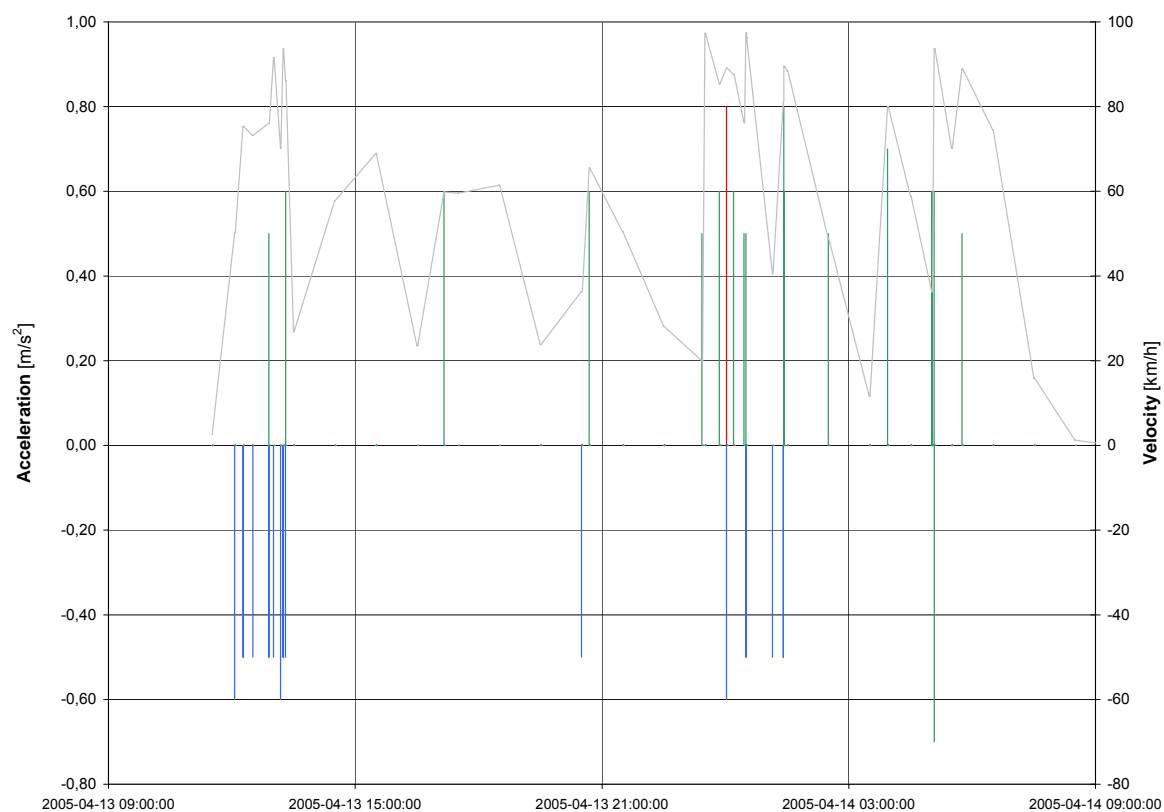


### Hallsberg to Vienna

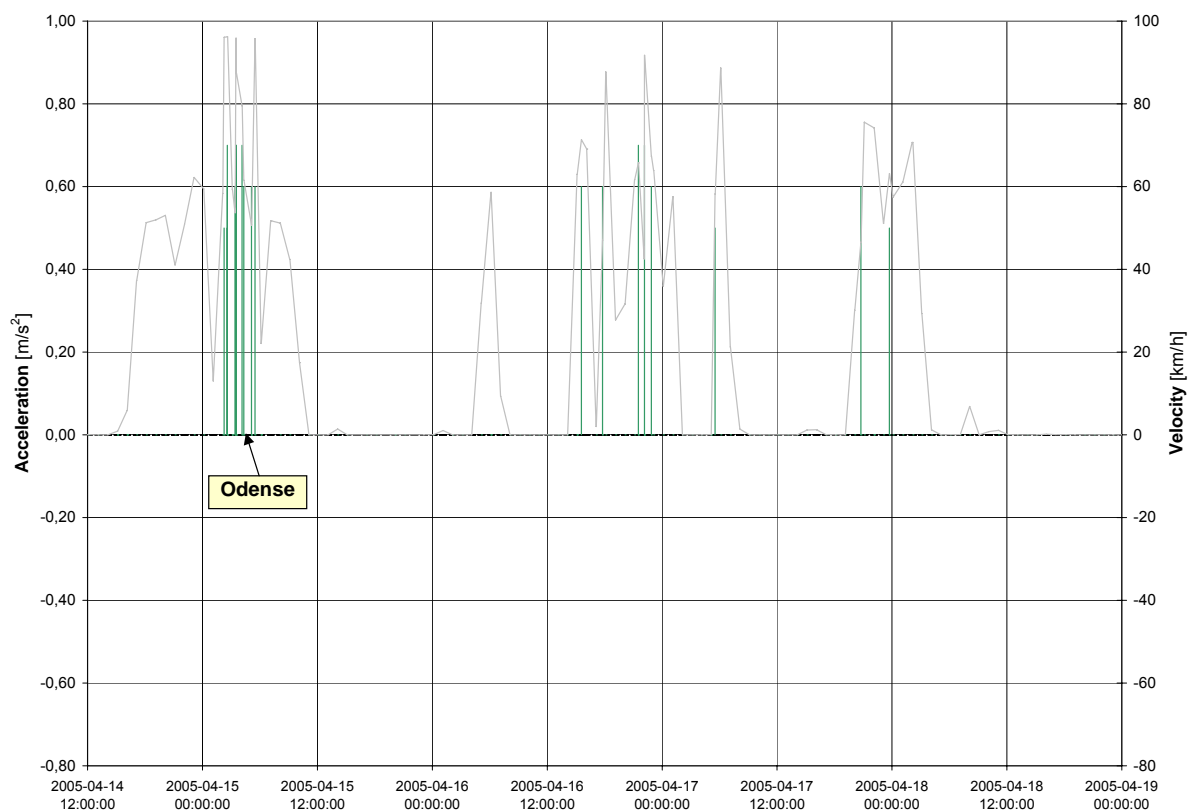


Wagon: Habbins

## Piteå to Hallsberg

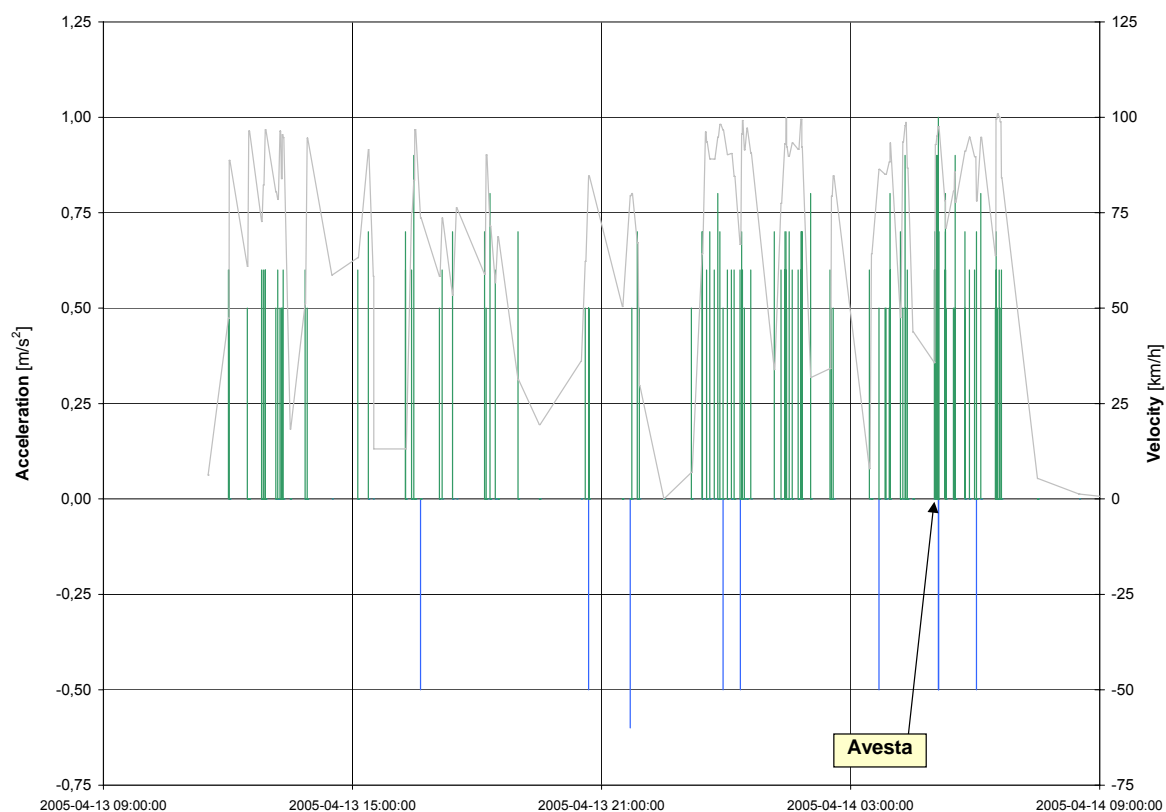


## Hallsberg to Vienna

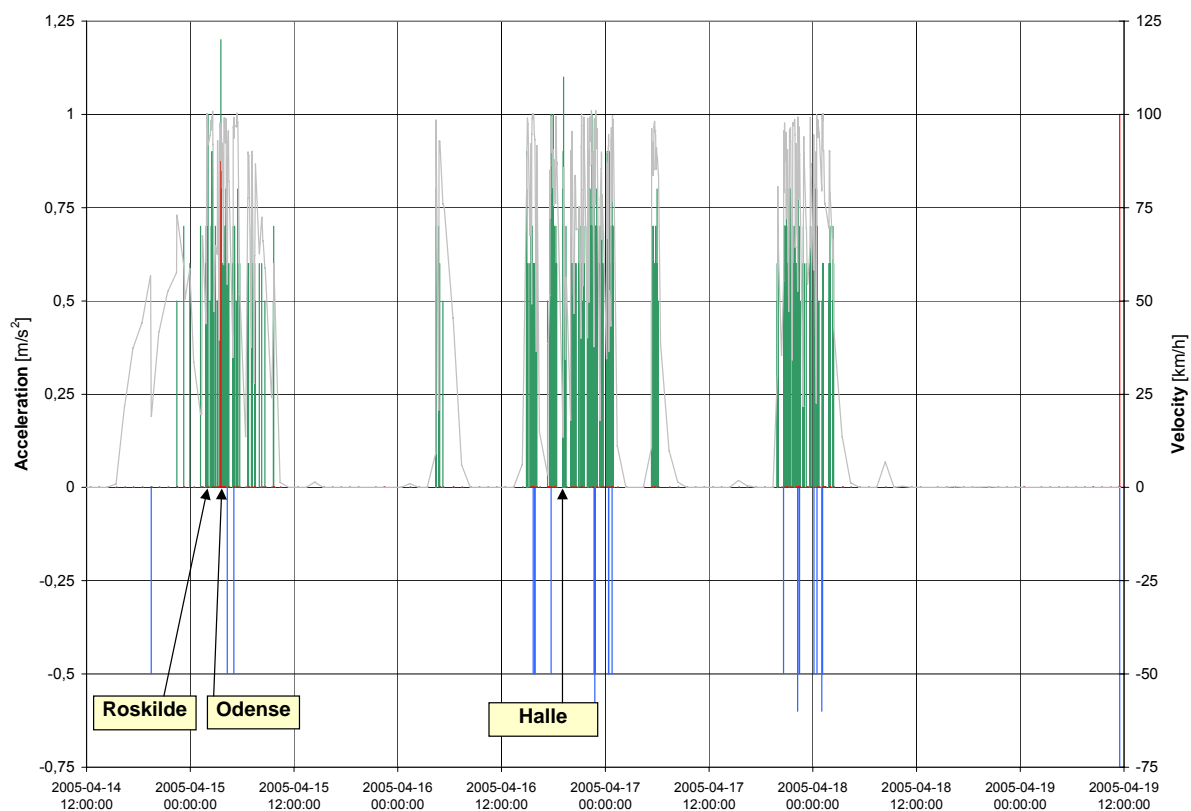


Wagon: Hirrs

### Piteå to Hallsberg



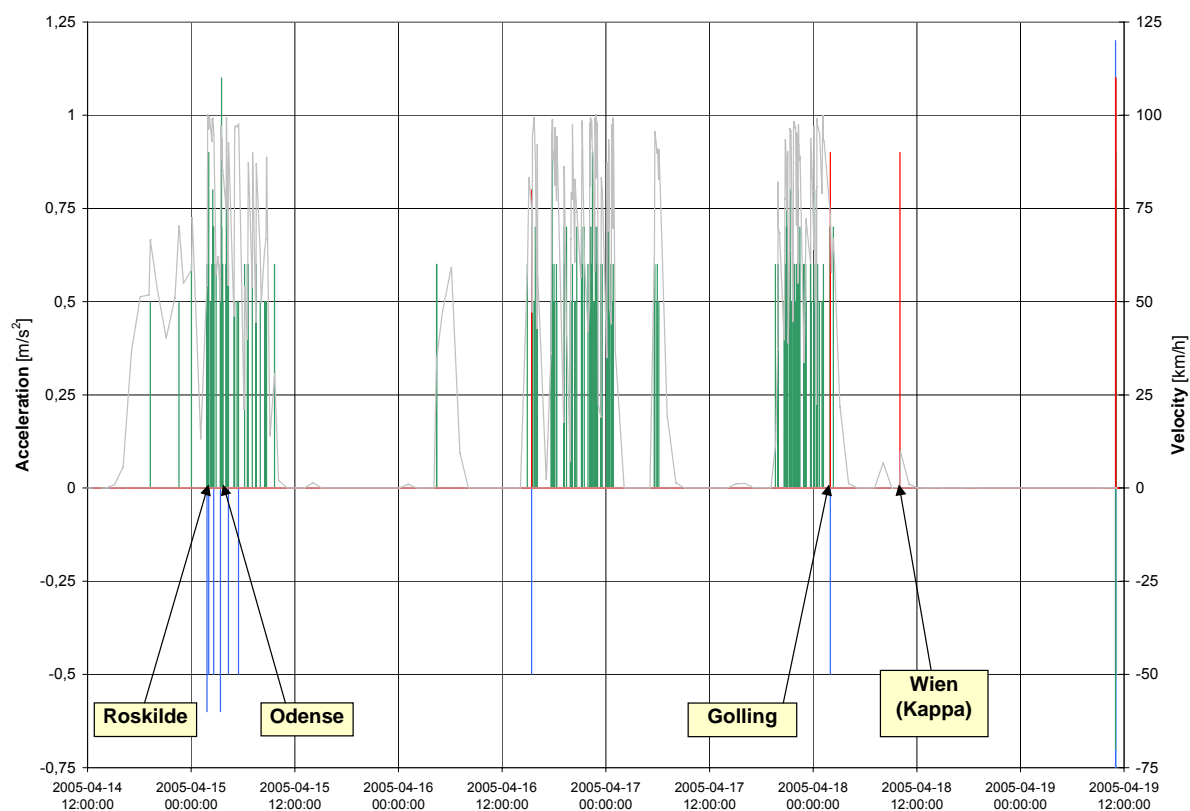
### Hallsberg to Vienna



**Wagon: Hbins**

Due to shortage of time, the Cargolog equipment was not properly install in the wagon and the equipment failed shortly after leaving Piteå. Therefore no recordings were made between Piteå and Hallsberg.

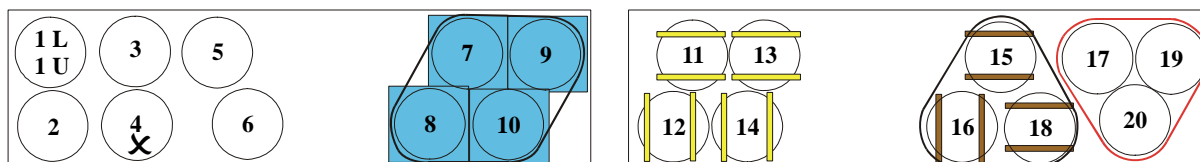
The problem was corrected at Hallsberg.

**Hallsberg to Vienna**

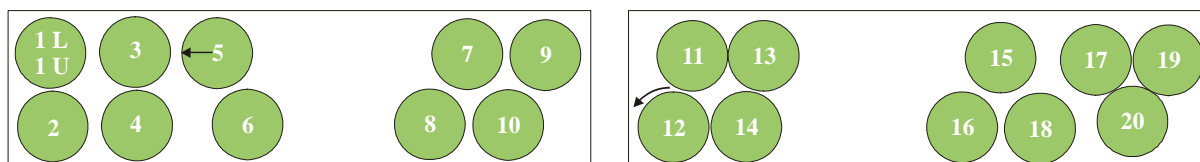
#### 6.2.4 Recorded movements in Hallsberg and Vienna

Below the recorded lateral movements and rotation of the reels in Hallsberg and Vienna in relation to the original position in Piteå in each wagon are shown. The lateral motion of the centre of the reel is indicated in cm together with the direction of the motion as well as the magnitude and direction of the rotation.

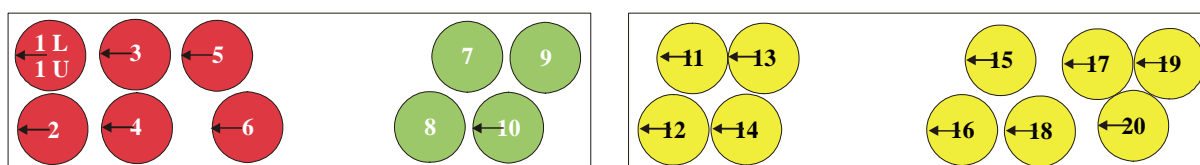
##### Wagon: Hiqqrrs



##### Movement Piteå to Hallsberg



##### Movement Piteå to Vienna



##### Comments

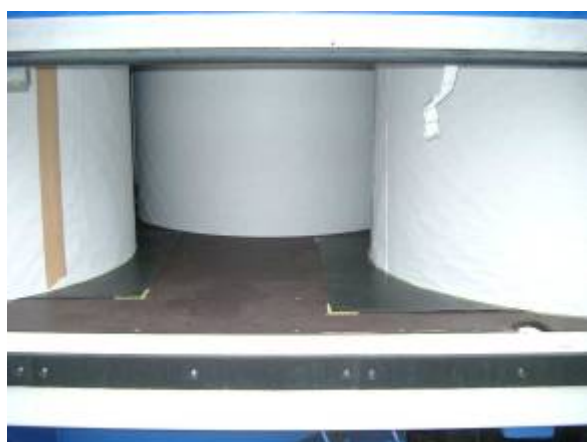
The Hiqqrrs-wagon, is a modern wagon build and owned by K Industrier in Malmö. The wagon is a test wagon, and it was put at the disposal of the project by the owner. The wagon is equipped with a modern bogie with a damping system for good running performances.

Notable for this wagon is that there were hardly any movements among the reels during normal transport, independently of the stowage pattern or securing method used for the different reels. Very few transverse and lateral accelerations were recorded.

No significant dislocations were found in Hallsberg.

In Maschen (Hamburg) and Vienna the wagon was subjected to two heavy shunting shocks in the same directions, which caused all reels except those on Load Grip mats to move in the longitudinal direction. The reason why the reels in the right half of the wagon moved less than the ones in the left can be that buffers are placed between the two parts of the wagon.

Reel	Id.	Securing	Hallsberg				Vienna			
			Linear movement		Rotation		Linear movement		Rotation	
			Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw	Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw
1 L	SCA	n - c - 0	0		0		11 (to end wall)	9	0	
1 U	SCA	n - c - 0	0		0		11 (to end wall)	9	0	
2	SCA	n - c - 0	0		0		5 (to end wall)	9	0	
3	216817-3	n - s - 0	0		0		24 (to reel)	9	0	
4	216817-4	n - s - 0	0		0		18 (to reel)	9	0	
5	216817-1	n - c - 0	2	9	0		29	9	0	
6	218396-11	n - c - 0	0		0		30	9	0	
7	218396-8	lgm - s - 1	0		0		0		0	
8	218396-9	lgm - s - 1	0		0		0		0	
9	218396-7	lgm - s - 1	0		0		2	9	0	
10	218396-10	lgm - s - 1	0		0		0		0	
11	218396-5	mt - c - 1	0		0		7	9	0	
12	218396-3	mt - c - 1	0		2	ccw	5	9	0	
13	218396-6	mt - c - 1	0		0		7	9	0	
14	218396-12	mt - c - 1	0		0		8	9	0	
15	216518-4	lc - s - 1	0		0		8	9	0	
16	218396-1	lc - s - 1	0		0		8	9	0	
18	216518-3	lc - s - 1	0		0		8	10	0	
17	216525-4	n - c - 4	0		0		9	9	0	
19	218396-4	n - c - 4	0		0		10	9	0	
20	216525-3	n - c - 4	0		0		8	9	0	



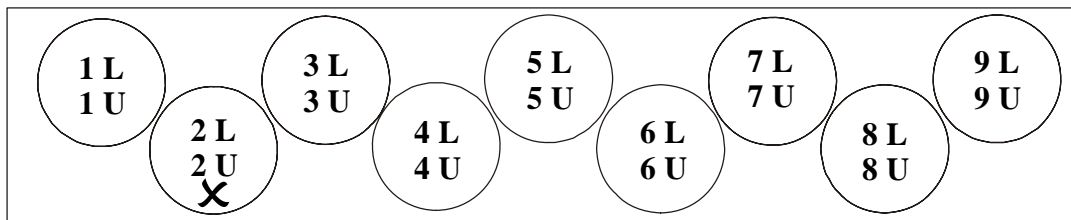
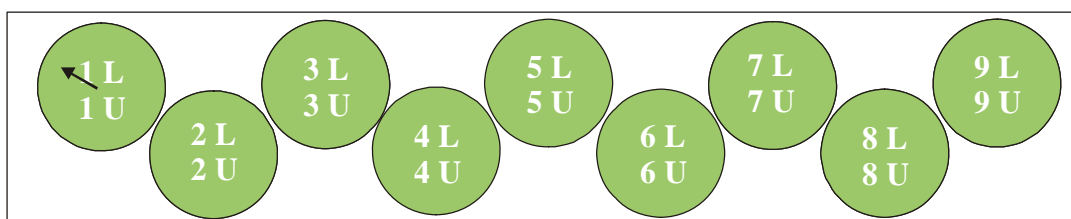
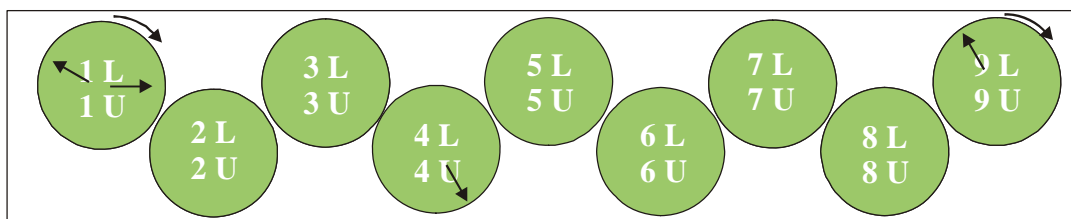
*The reels that were standing on Load Grip mats hardly moved. Here a photo from Hallsberg.*



*A photo from Vienna of reel no 6, the one that moved the most, 30 cm in longitudinal direction.*

**Wagon: Hbbins**

With friction-floor (sprayed polyurethane in stripes)

**Movement Piteå to Hallsberg****Movement Piteå to Vienna****Comments**

Only marginal movements were recorded in this wagon. This was the only wagon with Stora Enso reels. These reels were wrapped and had a bigger diameter than the other reels in the test. The wagon floor was coated with longitudinal stripes of friction increasing polyurethane foam.

The shock recording equipment on top of the one of the reels made very few registrations. The conclusion that can be drawn from this is that the Stora Enso reels with the wrapping material used had a good ability to absorb the vibrations when standing on this type of floor coating.

Reel	Id.	Hallsberg				Vienna			
		Linear movement		Rotation		Linear movement		Rotation	
		Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw	Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw
1 L	StoraEnso	2	10	0		4	10	2	CW
1 U	StoraEnso	0		0		2	3	0	
2 L	StoraEnso	0		0		0		0	
2 U	StoraEnso	0		0		0		0	
3 L	StoraEnso	0		0		0		0	
3 U	StoraEnso	0		0		0		0	
4 L	StoraEnso	0		0		1	5	0	
4 U	StoraEnso	0		0		3	5	0	
5 L	StoraEnso	0		0		0		0	
5 U	StoraEnso	0		0		0		0	
6 L	StoraEnso	0		0		0		0	
6 U	StoraEnso	0		0		0		0	
7 L	StoraEnso	0		0		0		0	
7 U	StoraEnso	0		0		0		0	
8 L	StoraEnso	0		0		0		0	
8 U	StoraEnso	0		0		0		0	
9 L	StoraEnso	0		0		1	11	1	CW
9 U	StoraEnso	0		0		0		0	

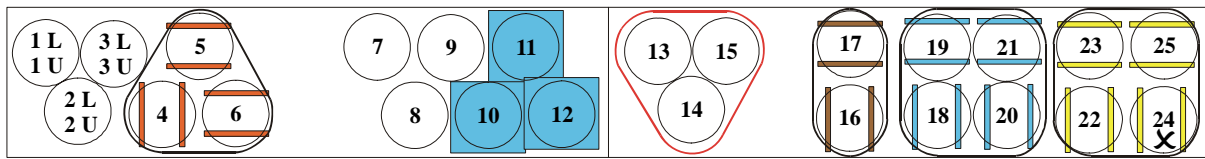
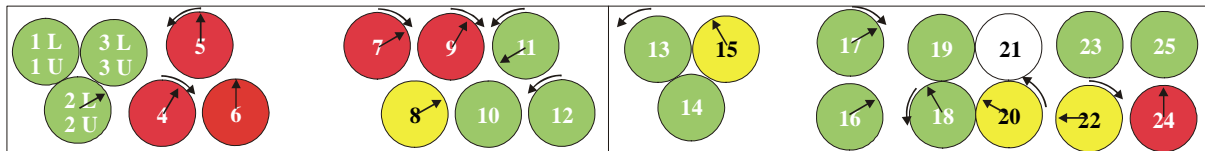
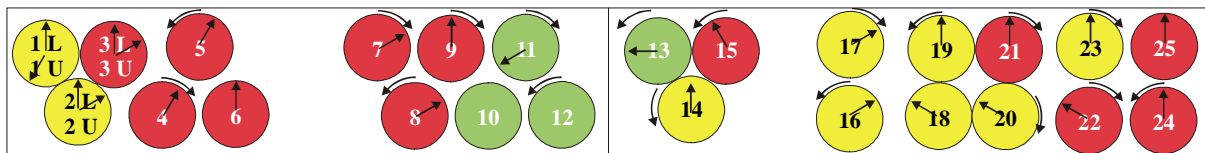


*Inspection of the Stora Enso Fors reels in Vienna.*



*A photo from Vienna of reel no 1 L with a very small rotation of 2 cm clockwise and a longitudinal movement of 4 cm.*



**Wagon: Habbins****Movement Piteå to Hallsberg****Movement Piteå to Vienna****Comments**

There were few big vertical accelerations and no big longitudinal shocks recorded for this wagon. Even so, most reels in this wagon moved significantly. Only the reels on the Load Grip mats were kept in their original position throughout the entire transport.

Generally, the reels stowed towards the wagon ends, except the closely stowed and wrapped SCA reels, moved more than reels standing in the mid section of the wagon.

The greatest dislocations were found among the reels that were standing on blocks of corrugated cardboard strips.

Reel	Id.	Securing	Hallsberg				Vienna			
			Linear movement		Rotation		Linear movement		Rotation	
			Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw	Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw
1 L	SCA	n - c - 0	0		0		4	7	0	
1 U	SCA	n - c - 0	0		0		2	12	0	
2 L	SCA	n - c - 0	2	2	0		5	2	0	
2 U	SCA	n - c - 0	0		0		2	12	0	
3 L	SCA	n - c - 0	0		0		17 (to door)	12	0	
3 U	SCA	n - c - 0	0		0		2	12	0	
4	218406-4	w - s - 1	20	1	10	cw	22	1	15	cw
5	218406-5	w - s - 1	13	12	7	ccw	15	1	5	ccw
6	218406-9	w - s - 1	15	12	0		14	12	0	
7	218406-6	n - s - 0	25	2	20	cw	28	2	23	cw
8	218406-7	n - s - 0	8	2			15	2	3	ccw
9	218406-8	n - s - 0	17	1	32	cw	17	12	30	cw
10	218406-2	lgm - s - 0	0		0		0		0	
11	218406-3	lgm - s - 0	1	8	2	ccw	1	8	1	cw
12	218406-1	lgm - s - 0	0		1	ccw	0		4	ccw

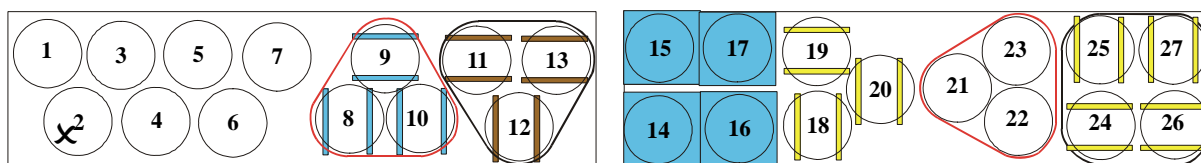
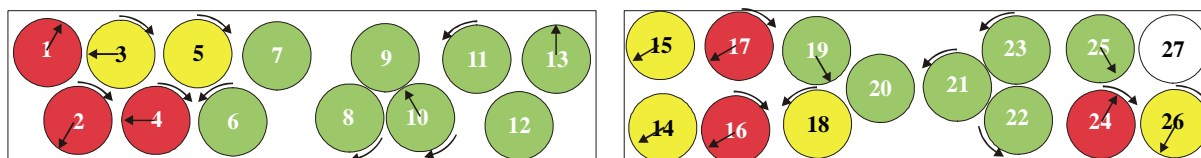
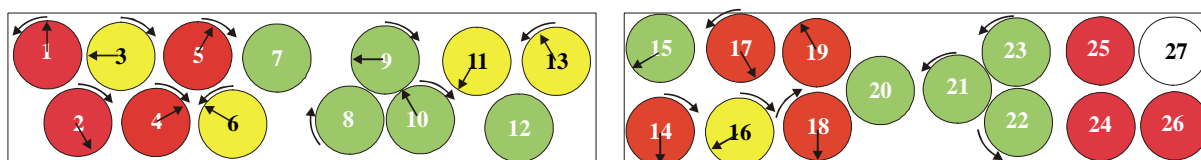


*Reels no 4 – 6 standing on blocks of corrugated cardboard strips here photographed in Hallsberg and Vienna, showed significantly movements in both rotational and longitudinal directions.*

Reel	Id.	Securing	Hallsberg				Vienna			
			Linear movement		Rotation		Linear movement		Rotation	
			Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw	Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw
13	218501-1	n - c - 4	0		1	CCW	3	9	7	CCW
14	218501-2	n - c - 4	0				7	12	3	CCW
15	218501-7	n - c - 4	5	11	0		16	11	7	CCW
16	218501-8	lc - c - 1	2	2			5	2	35	CCW
17	218501-9	lc - c - 1	2	2	1	CW	10	2	3	CW
18	218501-10	lgs - c - 1	3	11	2	CCW	7	10	0	
19	218501-11	lgs - c - 1	0				5	12	3	CCW
20	218501-13	lgs - c - 1	5	10	2	CCW	12	10	1	CW
21	218501-14	lgs - c - 1					17	12	20	CW
22	218501-12	mt - s - 1	5	9	35	CW	15	2	70	CW
23	218501-17	mt - s - 1	0				7	12	30	CW
24	218501-16	mt - s - 1	25	12	0		25	12	30	CCW
25	218501-15	mt - s - 1	0		0		(to door)	12		



*Photos from Hallsberg and Vienna of the reel no 24 that moved the most in the Habbins wagon.  
Please note the round turn lashing lying on the floor.*

**Wagon: Hirrs****Movement Piteå to Hallsberg****Movement Piteå to Vienna****Comments**

A very large number of vertical accelerations were recorded for this wagon. Already in Hallsberg, significant movements among the unsecured reels were noted. The reels position in the wagon clearly influences how much they move. The greatest movements among the unsecured and sparsely stowed reels are found towards the ends of the wagon.

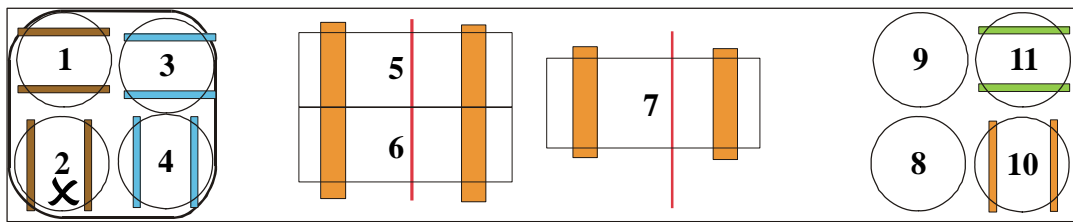
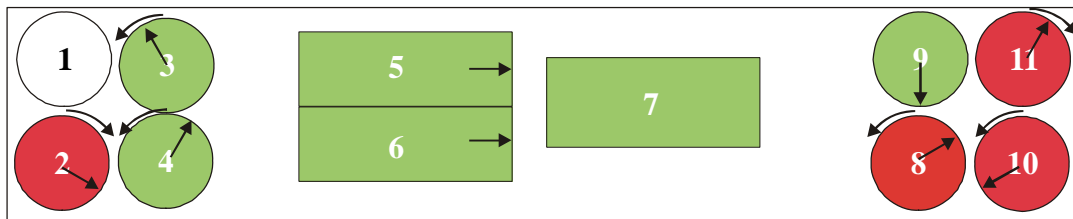
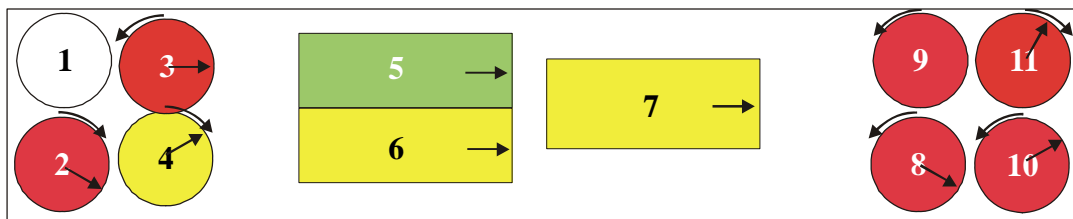
In this wagon, the sparsely stowed reels standing on Load Grip mats have moved significantly.

The reels that have been closely stowed and secured by 4 tons webbing have moved the least.

Reel	Id.	Securing	Hallsberg				Vienna			
			Linear movement		Rotation		Linear movement		Rotation	
			Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw	Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw
1	216511-4	n – s – 0	25	1			18	12	7	CCW
2	216511-7	n – s – 0	10	7	40	CW	29	7	7	CW
3	216511-3	n – s – 0	2	9	5	CW	4	9	6	CW
4	216511-2	n – s – 0	3	2	25	CW	8	2	45	CW
5	216511-1	n – s – 0	0		11	CW	2	1	16	CW
6	216511-6	n – s – 0	0		1	CCW	2	10	6	CCW
7	216511-5	n – s – 0	0		0		0		0	
8	216526-1	lgs – c – 4	0		1	CW	0		4	CW
9	216526-6	lgs – c – 4	1	3			2	3	1	CW
10	216526-2	lgs – c – 4	2	11	2	CW	2	11	3	CW
11	216526-4	lc – s – 1	0		1	CCW	8	7	0	
12	216526-3	lc – s – 1	0		0		0			
13	216526-5	lc – s – 1	1	12	0		5	11	11	CCW
14	218502-6	lgm – s – 0	5	8			2	6	Half revolution	
15	218502-7	lgm – s – 0	5	8			2	8		
16	218502-5	lgm – s – 0	5	8	20	CW	2	8	10	CW
17	218502-10	lgm – s – 0	3	8	15	CW	19	5	12	CCW
18	218502-4	mt – s – 0	0		13	CCW	25	6	4	CW
19	218393-9	mt – s – 0	4	5			15	11		
20	218502-8	mt – s – 0	0				0	0	0	
21	218393-7	n – c – 4	0		1	CCW			1	CCW
22	218393-6	n – c – 4	0		1	CCW			1	CCW
23	218393-8	n – c – 4	0		2	CCW			1	CCW
24	218502-1	mt – s – 1	3	1	15		40 (to door)	6		
25	218502-2	mt – s – 1	4	5			22	6		
26	218502-9	mt – s – 1	6	7	5		21 (to door)	6		
27	218502-3	mt – s – 1								



*Photos taken in Vienna of reels no 24 – 27 respective 1 – 4 in the Hirrs wagon. Significant shavings damages were observed between the reels.*

**Wagon: Hbins****Movement Piteå to Hallsberg****Movement Piteå to Vienna****Comments**

A very large number of vertical accelerations were recorded for this wagon. All reels except those laying in cradles and secured with top over lashings have moved significantly.

The reels on the finish strips and the blocks of corrugated cardboard have moved the most, even more than the reels that were standing directly on the wagon floor.

Significant shavings were observed between reels 3 and 4 already in Hallsberg.

Reel	Id.	Securing	Hallsberg				Vienna			
			Linear movement		Rotation		Linear movement		Rotation	
			Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw	Length (cm)	Direction (1-12)	Length (cm) (circumference)	cw / ccw
1	216512-7	lc – s – 1								
2	216512-4	lc – s – 1	To door	4	7	CW	To door	4	10	CW
3	218394-6	lgs – c – 1	2	11	3	CCW	16	3	22	CCW
4	218394-5	lgs – c – 1	5	1	2	CCW	9	2	8	CW
5	216817-2	Cradle	2	3	-		2	3	-	
6	216512-1	Cradle	2	3	-		8 (cradle)	3	-	
7	218396-2	Cradle	0	0	-		5 (+cradle 3 cm)	3	-	
8	216512-3	n – s – 0	8	2	40	CCW	13	4	30	CCW
9	216512-2	n – s – 0	1	6			To door	12	Half revolution	
10	216512-6	w – s – 0	To door	8	40		To door	2	Half revolution	
11	216512-5	f – s – 0	To door	1	30		To door	1	Half revolution	



*Shaving damages were observed between reel 3 and 4 in Hallsberg.*



*An inspection of the laying reels in Vienna.*



*Significantly linear movements between Hallsberg and Vienna were observed on reel 6 and 7.*

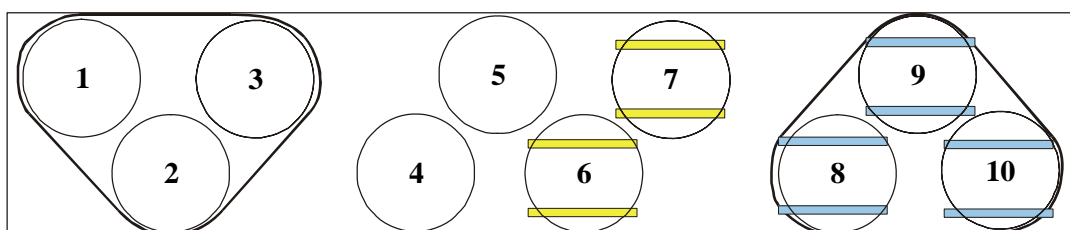
### 6.3 Test transport of paper reels from Piteå - Eslöv

Encourage by the good results in the Hbbins wagon with Stora Enso reels, a complementary test transport between Piteå and Eslöv was arranged in May 2005.

The marking of reel position in the wagon prior to the transport was done by *K-G Fälmark, Kappa Kraftliner in Piteå*. The inspection in Eslöv was conducted by *Sven Sökjer-Petersen and Peter Andersson, MariTerm AB*.

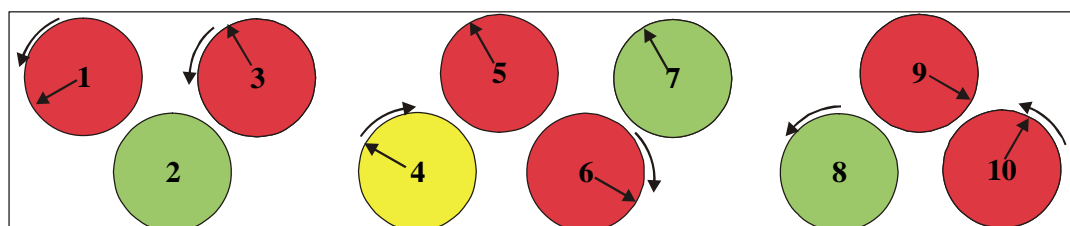
#### 6.3.1 Loading

Ten Kappa reels was sparsely stowed in the Hbbins wagon and secured in different ways.



Reel	Stowage and securing	Type	Wrapping	Dia. (mm)	Width (mm)
1	Standing direct on wagon floor	Kappa	No wrapping	1450	2000
2, 3	Stowed sparsely Secured with one loose 1-tons web	Kappa			2200
4	Standing direct on wagon floor	Kappa	No wrapping	1450	2450
5	Stowed sparsely	Kappa			2200
6, 7	Standing Marotech strips Stowed sparsely	Kappa	Wrapped	1200	2000
8	Standing on Load Grip mats	Kappa	Wrapped	1200	2200
9	Tighten with one loose 1-tons web	Kappa	No wrapping	1250	2450
10	Stowed sparsely	Kappa	Wrapped	1200	2450

#### 6.3.2 Recorded movements in Eslöv





Reel	Id.	Securing	Piteå to Eslöv			
			Linear movement		Rotation	
			Length (cm)	Direction (1-12)	Length (cm) (circumference)	CW / CCW
1	221056-10	n-s-1	10	8	25	CCW
2	221979-02	n-s-1	0		0	
3	221980-07	n-s-1	20 (against door)	11	5	CCW
4	210959-02	n-s-0	2	10	5	CW
5	211979-01	n-s-0	5 (against door)	11	0	
6	216542-04	mt-s-0	25	4	60	CW
7	216542-03	mt-s-0	72	11	0	
8	221648-02	lgm-s-1	0		2	CCW
9	221072-02	lgm-s-1	16	4	0	
10	221651-07	lgm-s-1	18	1	8	CCW



*A significant rotation of reel 1 was observed.*



*A linear movement of reel 6 of 25 cm. The rotation was 60 cm along the circumference.*

## 6.4 Test transport of paper reels from Fors – Trelleborg

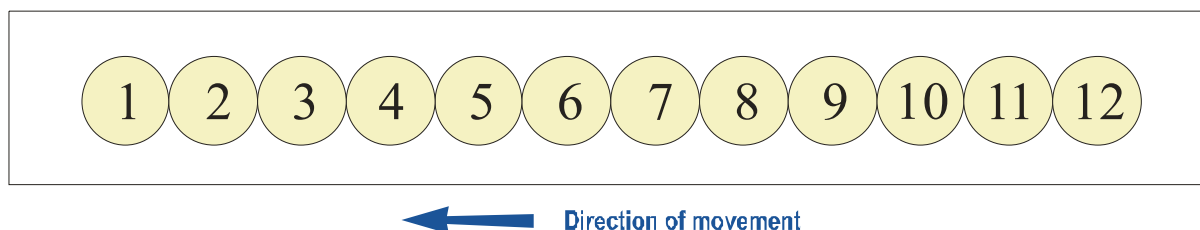
This test transport was done as a follow up of the Piteå - Vienna test transport and was aiming to give a more detailed analyse of factors influencing the amount to which reels move due to vibrations during railway transports.

In the previous test transport from Piteå to Vienna, a Hbbins wagon with stripes of friction enhancing material embedded in the flooring, was loaded with paper reels from Stora Enso Fors. In this test, a Sins wagon was used.

When arriving in Trelleborg all reels had moved longitudinally in the same direction.

### 6.4.1 Loading in Fors

The figure below illustrates the load pattern for the reels.



The load consisted of 48 paper reels, stacked four high in 12 stacks. The test reels were supplied by Stora Enso Fors and were all wrapped. The wagon was a Sins-type wagon (463 8 074-1) with plywood flooring, which upon inspection in Trelleborg was found to be dry and clean. The wagon was equipped with DB type 665 link suspension bogies.

Stack of reels	Stowage and securing	Type	Weight (kg)	Dia. (mm)	Width (mm)
1 - 12	Standing directly on wagon floor Stowed closely Each stack four reels high	Stora Enso Fors	3840 per stack	1750	2460 (615 per reel)



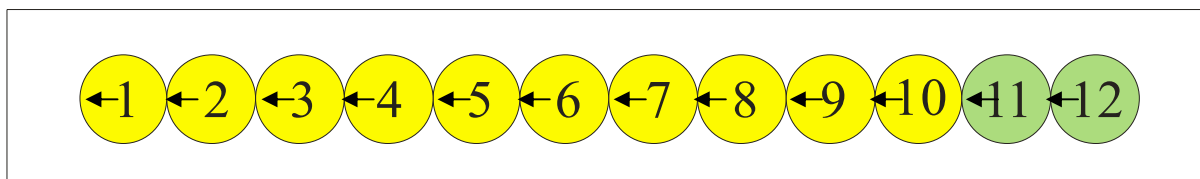
*Marking of reels*



*Stack 12, 11, 10*

### 6.4.2 Recorded movements in Trelleborg

When inspected in Trelleborg, all reels had moved approximately 10 cm in the same direction, lengthwise in the wagon (direction 9). No particular rotation had occurred for any reel and no considerable movement crosswise in the wagons was found.



It is evident that the reels had been moved during at least one impact from shunting.

The movement for each stack of reels is given in the table below.

Stack of reel	Securing	Fors to Trelleborg			
		Linear movement		Rotation	
		Length (cm)	Direction (1-12)	Length (cm) <small>(circumference)</small>	CW / CCW
1	n-c-0	13	9	0	-
2	n-c-0	12	9	0	-
3	n-c-0	10	9	0	-
4	n-c-0	10	9	0	-
5	n-c-0	11	9	0	-
6	n-c-0	10	9	0	-
7	n-c-0	13,5	9	0	-
8	n-c-0	11	9	0	-
9	n-c-0	11,5	9	0	-
10	n-c-0	10	9	0	-
11	n-c-0	5,5	9	0	-
12	n-c-0	4,5	9	0	-



*The movement of stack number 3.*



*The movement of stack number 5.*

In previous transports of similar Stora Enso reels from Fors to Trelleborg, dislocations of reels in the top layers have been recorded. The photo below illustrates such a case.



*Dislocations of reels in a previous transport. (The photo is not taken of the reels in the test transport).*

## **6.5 Transport of standing paper reels in swap bodies**

MariTerm AB has, commissioned by CargoNet AB, carried out inspections of some swap bodies in the terminal for intermodal transports in Malmö. The swap bodies were stowed with five to four paper reels standing directly on the floor. The reels had the following dimensions and weights: width 2210 mm, diameter 1450 mm and weight approximately 3 tons per reel. The reels were unwrapped and of craft liner type.

Despite some top-over lashings, round-turn lashings and supporting edge protectors between the top-over lashings and the reels, significantly shavings were observed between several reels in the swap bodies. The inspections, however, showed that the paper reels in the swap bodies were not secured according to current rules for neither road transports nor intermodal transports on railway. The reels had been loaded at a paper mill in Norway.



*Extensive shaving damage*



*Shaving damages*

## 6.6 Summary and conclusions of the test transports

Below the results of the test transports are summarised.

### 6.6.1 Summary and conclusions of test transport I; Piteå - Vienna

A short summary of the accelerations in the different wagons as well as the movements of the reels in the different wagons is given together with conclusions of the results.



**Wagon: Hiqqrrs**

The Hiqqrrs-wagon, is a modern wagon build and owned by K Industrier in Malmö. The wagon is a test wagon, and it was put at the disposal of the project by the owner. The wagon is equipped with a modern Unitruck single axle running gear with a hydraulic damping system for good running performances, see photo below.



Notable for this wagon is that there were hardly any movements among the reels during normal transport, independently of the stowage pattern or securing method used for the different reels. Very little transverse and lateral accelerations were recorded.

No significant dislocations were found in Hallsberg.

In Maschen (Hamburg) and Vienna the wagon was subjected to two heavy shunting shocks in the same directions, which caused all reels except those on Load Grip mats to move in the longitudinal direction.

The five wagons were transported in one group all the way from Piteå to Vienna. This means that when shunting either the Hiqqrrs or the Hbins wagon was the one that had to take up the shunting shocks. From the accelerometers it seems as if it was the Hiqqrrs wagon that was the one that took the shocks in the occasions when heavy shunting occurred. The recorded shocks on the paper reels (not on the floor of the wagon) were of the magnitude 1,0 and 1,5 m/s<sup>2</sup> and the freestanding reels in the wagon moved about 300 mm due to those two shocks.

From the shunting tests performed later in Malmö it can be concluded that the speed has to be quite high to obtain such acceleration and motions of the actual type of reels, see further description in section 7.4. It can further be concluded that shunting in quite high speeds is rather a rule than an exception during “normal” rail operation, which directly point on one of the weak points with rail transports and the way the wagons are handled at the shunting yards.

**Wagon: Hbbins**

Only marginal movements were recorded in this wagon. This was the only wagon with Stora Enso reels. These reels were wrapped and had a bigger diameter than the other reels in the

test. The wagon floor was coated with longitudinal stripes of friction increasing polyurethane foam.

The shock recording equipment on top of one of the reels made very few registrations. The conclusion that can be drawn from this is that the Stora Enso reels with the wrapping material used, had a good ability to absorb the vibrations when standing on this type of floor coating.

In the complementary test carried out in May 2005 between Piteå and Eslöv with Kappa reels in a similar wagon, these outstanding results were not duplicated. Most reels in the latter test moved significantly although the reels were wrapped and they were standing on the same type of floor coating and, see further description below.

#### **Wagon: Habbins**

There were few recorded big vertical accelerations and no big longitudinal shocks recorded for this wagon. Even so, most reels in this wagon moved significantly. Only the reels on the Load Grip mats were kept in their original position throughout the whole transport.

Generally, the reels stowed towards the wagon ends, except the closely stowed and wrapped SCA reels, moved more than reels standing in the mid section of the wagon.

The greatest dislocations were found among the reels that were standing on blocks of corrugated cardboard strips.

#### **Wagon: Hirrs**

A very large number of vertical accelerations were recorded for this wagon. Already in Hallsberg, significant movements among the unsecured reels were noted. The reels position in the wagon clearly influences how much they move. The greatest movements among the unsecured and sparsely stowed reels are found towards the ends of the wagon.

In this wagon, the sparsely stowed reels standing on Load Grip mats surprisingly also moved significantly.

The reels that have been closely stowed and secured with 4 tons webbing moved the least.

Significant shaving damages were noted on the reels in this wagon, which directly point on another problem with rail transports, the vibrations.

#### **Wagon: Hbins**

A very large number of vertical accelerations were recorded for this wagon. All reels except those laying in cradles and secured with top over lashings moved significantly.

The reels on the finish strips and the blocks of corrugated cardboard moved the most.



**General conclusions of the Piteå – Vienna test transport**

The tests clearly shows that wagons with more sophisticated running gear arrangements give much less vibrations and much less cargo damages than wagons with traditional arrangements.

The tests clearly show that shunting is one of the largest problems for rail transports when it comes to transport quality. In the wagon with the most modern running gear the reels experienced were few accelerations and moved insignificantly until the wagon was subjected to heavy longitudinal shocks during shunting in Machen and Vienna.

Unfortunately all Stora Enso reels were transported in a separate wagon with special friction increasing coating on the floor, so it is not possible to draw any certain conclusions on how they performed in comparison to the other reel types. Generally though, the reels from Stora Enso and SCA, which were wrapped, moved less than the unwrapped reels from Kappa.

The greatest movements were found towards the ends of the wagons and reels standing in the mid section of the wagons generally moved less.

Reels standing on rubber mats and reels that were secured with 4 tons round turn lashings generally moved the least, although there are exceptions.

Reels standing on blocks of corrugated cardboard moved more than reels standing direct on the wagon floor.

In at least one of the five wagons significant shaving damages were noted on the reels, which directly point on the problem with vibrations during rail transports if traditional wheel arrangements are used.

**6.6.2 Summary and conclusions of test transport II; Piteå - Eslöv**

Most reels moved significantly in this wagon regardless of the securing method used. The outstanding results for the Stora Enso reels in a similar wagon in the test transport from Piteå to Vienna were not found here.

Reel number 3 and 5 moved towards the sloping top parts of the doors and the top edges were damaged. When this happens, there is a risk that the resulting upwards directed pressure might force the doors open.

None of the used securing methods can be said to be more effective than the others.

**6.6.3 Summary and conclusions of test transport III; Fors - Trelleborg**

All the stacks of reels had been dislocated approximately 10 cm in the same direction. This was most likely caused by one or several impacts during shunting. The reels had not moved around stochastically or rotated due to vibrations.

The lack of wandering motions among the reels can not just be explained by an unfavourable height to breadth ratio. The height to breadth ratio for the stacks in this test was considerably larger than for those from Stora Enso Fors, used in the test transport between Piteå and Vienna, and yet neither of the two sets of reels showed any movements due to vibrations.

Also, the height to breadth ratio for the stacks in this test was approximately the same as that for some of the reels from Kappa, which were studied in the test transport between Piteå and Eslöv. In that test, even though the wagon floor was coated with stripes of a friction enhancing compound, the Kappa reels had moved around and rotated in various directions. Several of them showed damages from shaving and contact with the structural parts of the wagon.

The reels from Stora Enso Fors, used both in this test transport and the transport from Piteå to Vienna had the same density, some  $600 \text{ kg/m}^3$ , which is fairly low. The reels from Kappa, which had moved a lot, had a density of about  $900 \text{ kg/m}^3$ . Some of the Kappa reels were wrapped and some were not. It is quite possible that low density reels are better at absorbing vibrations.

The Kappa reels were all loaded in one layer only, while the reels in the test transport from Fors to Trelleborg had a smaller breadth and were stacked in several layers. They were all wrapped and vibrations were possibly reduced by the damping effect achieved by the use of double layers of protective cardboard sheets in both ends of the reel.

The movement in longitudinal direction again point on the fact that the wagon must have been subjected to a shunting shock in a speed larger than 6 km/h and again pointing on the weak point for rail transports when it comes to transport quality for high value and damageable cargo.

#### **6.6.4 Summary and conclusions of inspection of paper reels in swap bodies**

Unfortunately also in the swap bodies, inspected during the project period, significant shaving damages were noted, this even though the transport was quite short from southern Norway to Malmö only.

This point on the need to have more sophisticated wheel and bogie arrangements also on intermodal wagons if cargo damages shall be avoided. There are many old wagons on the market, which are rebuilt and offered for intermodal transports. The rail customers must be made aware of this situation so that such wagons are forced out of operation if the reputation for rail transports shall be possible to improve.



## **7 MEASUREMENTS OF ACCELERATIONS DURING SHUNTING**

The results of the measurements of accelerations during shunting are given in this chapter. In the tests two freight wagons with copper and paper load respectively and three different types of wagons for intermodal transports were shunted at different speeds and directions.

### **7.1 Basic information on used equipment and registrations**

Below a description of the aim with the tests, measuring equipment, test method as well as the UIC Loading Guidelines for impact tests is given.

#### **7.1.1 The aim of the shunting tests**

The aim of the impact tests were:

- to measure accelerations experienced during different shunting speeds both at various places on the wagon floor, as well as on top of cargo placed at different positions in the wagon and secured with different means.
- to compare, verify and validate test data collected during the test transport of paper reels from Piteå to Vienna (see chapter 6)
- to compare accelerations experienced in wagons for intermodal transports equipped with different means of absorbing shocks.
- to draw conclusions regarding proper shunting speeds for railway wagons.
- to compare the ability for different cargo securing arrangements to protect the goods from damages when subjected to shunting.

#### **7.1.2 Used wagons and materials**

The wagons used in the copper wire and paper reel shunting tests were of Habins-respectively Habbins-type, see the descriptions in section 6.1.1 and below. The impact wagon (8474 9853 0421) used in both tests was a bogie wagon with Category A 105 mm stroke buffers, loaded with gravel to a total mass of 80 ton. The wagons for intermodal transports were equipped with regular buffers, with regular buffers and a sliding top and with a long stroke buffer arrangement.

The copper wagon was loaded with 12 wooden pallets with copper wire rod in coils, each pallet weighing approximately between 4 and 5 tons and having a diameter of 1,6 m. The copper used in the tests were supplied by *Elektrokoppar AB*.

The paper wagon was loaded with 11 reels of paper from *Kappa Kraftliner* and one shrink filmed pallet with paper sheets from *Stora Enso Fors AB*. The reels had the following approximate dimensions and weights: width 2100 - 2450 mm, diameter 1250 – 1450 mm and weight 2190 - 3450 kg.

The swap bodies used on the intermodal wagons were loaded with two stows of concrete elements on the wagon with regular buffers and the one with long stroke buffers, and with four stows on the wagon that was equipped with regular buffers and a sliding top.

### Habins wagon



## Habi(n)s

A modern and very flexible bogie wagon with large load capacity. The large sliding doors made from aluminium gives a wide opening which enables rational loading and discharging. This type of wagon has an international profile and is thus able to traffic the entire European network. The wagon is available in designs with load limits C and D.

Loading length	21.978 mm	Number of doors	3
Loading width	2.770 mm	Door length	7.110 mm
Loading area	61 m <sup>2</sup>	Door height	2.800 mm
Loading volume	163 m <sup>3</sup>	Floor height	1.200 mm
Max. payload	6: 52,0 ton 6/6: 62,0 ton	Minimum curve radius	35 m
Wagon weight	ca 28,0 t		

### 7.1.3 Measuring equipment

Two different sets of equipment were used to record the shocks, the Vernier Pro accelerometers and the Mobitron Cargolog.

### Vernier Pro accelerometers

Two 3-axis accelerometer sensors were connected to an interface that was able to read the accelerations for four channels.

The recorded values were analysed in a special PC / Windows program.

Two sensors were placed in different positions both on the cargo and directly on the wagon and swap bodie floors during all tests.



Accelerations were recorded for all 3 axis for the sensor mounted on top of the cargo but only in longitudinal direction for the sensor placed on the wagon floor.

The position of the sensors for the Vernier Pro equipment have been marked with black numbered triangles in the figures illustrating the load pattern in the different wagons.

1

In the impact diagrams below, the following colour code and notations have been used:

Legend	Notation	Description
	x <sub>1</sub>	Longitudinal acceleration for sensor on cargo
	y <sub>1</sub>	Transverse acceleration for sensor on cargo
	z <sub>1</sub>	Vertical acceleration for sensor on cargo
	x <sub>2</sub>	Longitudinal acceleration for sensor on wagon floor

### Mobitron Cargolog

The Cargolog unit from Mobitron AB can measure and register accelerations along 3 axis. Although all accelerations and vibrations are registered, only shocks that exceed preset values, in terms of amplitude and duration, are recorded. The recorded values can be analysed in a special PC / Windows program.



Several units were placed in different positions both on the cargo and directly on the wagon and swap bodie floors during the tests.

Only accelerations exceeding the preset trig value of  $\pm 0.5 \text{ g}$  ( $4.9 \text{ m/s}^2$ ) in any direction during at least 100 ms lengthwise or 50 ms vertically or crosswise, were recorded. The accelerations given in this report from this set of equipment are mean values over the duration of the shock.

The position of the sensor for the Mobitron Cargolog equipment have been marked with black numbered octagons in the figures illustrating the load pattern in the different wagon.

1

#### 7.1.4 Test method

The wagon loaded with copper was tested fully in accordance with the test method described in the UIC Loading Guidelines as described below in the next section. For the other wagons, exceptions were made regarding shunting speed and the number of impacts, but the guidelines were otherwise followed.

The wagon loaded with paper was tested in one direction only, although eventually at higher impact speeds than prescribed.

The wagons for intermodal transport would according to the methods described below only have needed to be subjected to two impacts in the same direction at speeds of 3-4 km/h. Despite this, impacts were produced at higher speeds in order to test the capability of the different type of wagons to reduce the shocks for the cargo carried.

#### 7.1.5 UIC Guidelines for impact tests

The following guidelines for impact tests can be found in *RIV Appendix II, Loading Guidelines, Section 1, Principles, Table 4*.

##### Impact test for loading methods and loose fastenings

###### 1 Purpose

The purpose of these tests is to check whether the loading methods used and loose fastenings stand up to the longitudinal stresses exerted during railway operating

###### 2 Test conditions

###### 2.1 Impact wagon

The wagon shall be

- a high-sided open bogie wagon,
- fitted with Category A sided buffers in accordance with **UIC Leaflet 526-1**,
- loaded to a total mass of 80 t, preferably with bulk goods,
- kept stationary on flat straight track in the unbraked position by means of stop blocks positioned at a distance of approximately one metre.

###### 2.2 Wagon loaded according to the method requiring testing

The wagon must be:

- loaded as far as possible to maximum capacity (part load: insufficient), in order to limit investment in means of fastening,
- fitted in principle with Categories A and B side buffers, in accordance with **UIC Leaflets 526-1** or **528-2**.

The results of tests carried out with wagons with buffers in accordance with **UIC Leaflets 526-1**, Category C, or **UIC Leaflets 526-3** may not be transposed to wagons fitted with conventional buffers (**UIC Leaflets 526-1**, Categories A and B, and **UIC Leaflets 526-2**).

The floor of the wagon shall be



- clean,
- free from any load debris, fastenings, snow or ice.

The state of the floor (eg. wet or dry) must be stated in the report.

### 2.3 Position of the impact wagon

For testing purposes, the impact wagon may also impact the wagon loaded according to the method which is being tested.

### 2.4 Impact programme

#### 2.4.1 full wagons fly or gravity shunted

2 impacts in the same direction,

- 1<sup>st</sup> impact at 5-7 km/h
- 2<sup>nd</sup> impact at 8-9 km/h

followed, without any adjustment of the load fastenings, by

- counter-shock at 8-9 km/h

The need to carry out a counter-shock must be assessed on the basis of the results of the two previous impacts with account taken, where appropriate, of the features of the goods carried and loading type.

#### 2.4.2 full wagons not fly or gravity shunted (block trains)

2 impacts in the same direction, both at 3-4 km/h

### 2.5 Measurement of impact speeds

- section measured preferably to be marked with primer caps,
- end of the section situated approximately 18 m from the buffers on the impact wagon,
- measurement by means of a chronometer and conversion using the time/impact speed concordance table and the tolerance ranges given under Point 5,
- in order to avoid involuntary impact, i.e., at speeds outside the range of values given under Point 2.4, placing of a stop block to act as an emergency brake between the section measured and the impact wagon. Removal if the tolerance range is respected.

It is also possible to apply more sophisticated measurement techniques.

## 3 Analysis of results

After the impact programme has been carried out in accordance with Point 2.4

- operating safety must be preserved
- the fastenings, wagon gear and load must be free of damage

In the case of loads likely to move about freely in the lengthwise direction across the wagon, the analysis will focus on the distance covered by the load during the second impact.

The result of the test must be recorded in accordance with Point 7 of Specimen 1.

## 7.2 Freight wagons

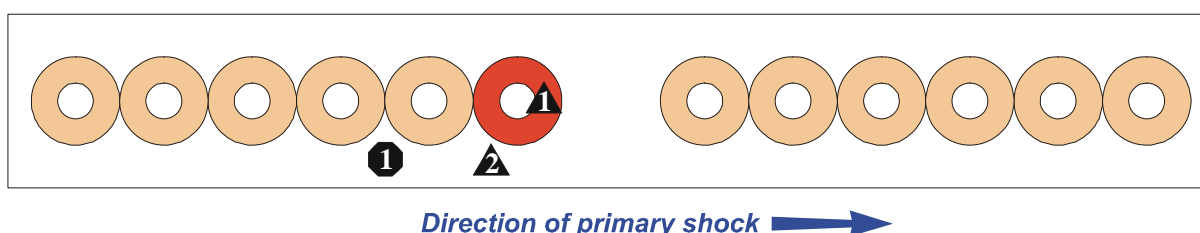
Two different freight wagons loaded with copper coils respectively paper reels were shunted at different speeds and directions. The accelerations were measured by shock recording equipment and the results are given in this section.

### 7.2.1 Copper wagon

This Habins-type wagon (2782157-9) was loaded by 12 wooden pallets with copper wire rod in coils, each pallet weighing approximately between 4 and 5 tons and having a diameter of 1.6 meters. The load pattern for the copper pallets and the positions of the shock recording equipment are shown in the sketch below.

The wagon was equipped with normal buffers.

None of the pallets were secured to the wagon. The plywood floor of the wagon was dry but not particularly clean.



The wagon was subjected to 3 shocks. The first 2 shocks were produced by letting the wagon hit a counter weight wagon. The third shock was produced by letting the counter weight wagon run into the test wagon in the opposite direction to the two initial shocks. This wagon was tested fully in accordance with the test method prescribed in the UIC Loading Guidelines.



*The dislocation of the cargo during the tests was measured for the copper coil with the board on the top (the copper coil coloured in red in the sketch above).*



*The Vernier Pro accelerometer in the front and the one Mobitron Cargolog in the back of the photo.*

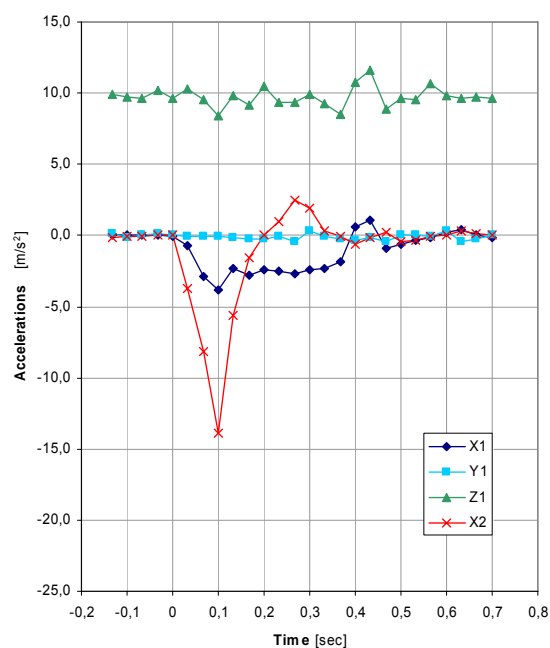
### Recorded shocks during the tests

The shock recording equipment registered the following accelerations and durations:

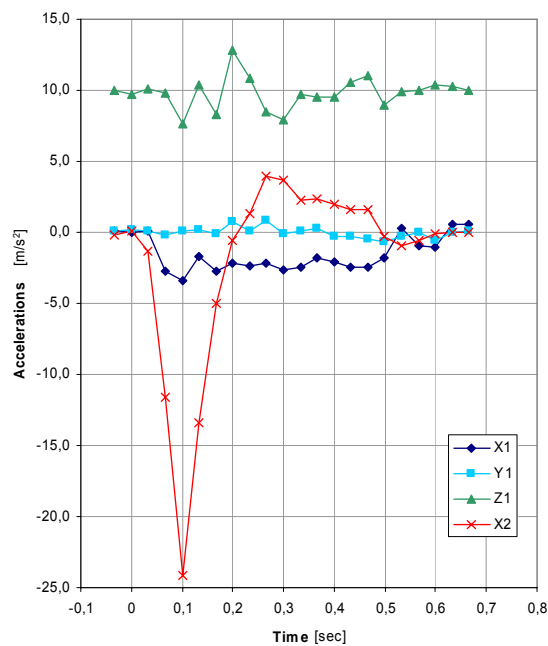
Shock	Speed [km/h]	Maximum longitudinal shock [m/s <sup>2</sup> ]			Duration [ms]
		Vernier 1	Vernier 2	Cargo log 1	Cargo log 1
1	5.6	- 3,9	- 13,9	- 11.1	79
2	8.2	- 3,4	- 24,1	- 17.7	101
3*	8.9	3,5	22,6	17.9	97

\* Counter shock

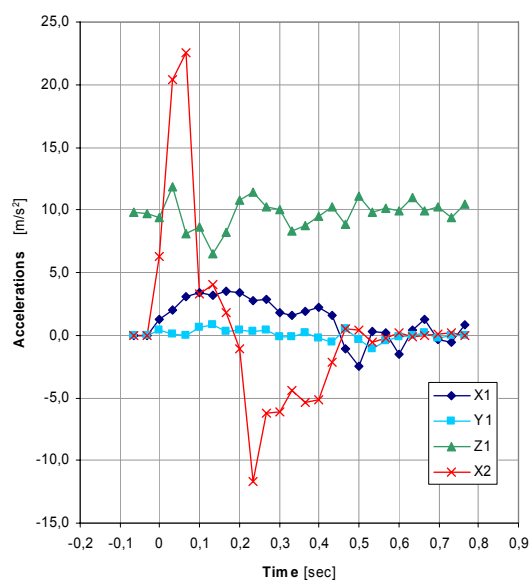
### Accelerations recorded by the Vernier equipment



*Accelerations recorded by the Vernier equipment during shock 1.*



*Accelerations recorded by the Vernier equipment during shock 2.*



*Accelerations recorded by the Vernier Equipment during shock 3 (counter shock).*

### Recorded movements of the cargo during the tests

The dislocation of the cargo during the tests was measured for the copper coil coloured in red in the sketch above.

Shock	Speed [km/h]	Measured dislocation of the copper reel [mm]	
		Distance moved during shock	Accumulated moved distance
1	5.6	120 mm forward	120 mm
2	8.2	390 mm forward	510 mm
3*	8.9	365 mm backward	145 mm

\* Counter shock

During the second impact, the coil on the far right in the sketch above moved against the end wall and the coil was deformed. This was due to the insufficient free space between the copper coils and the wagons fixed structure.



*The deformed coil on the far right after the second impact.*



*The movement of the coils.*

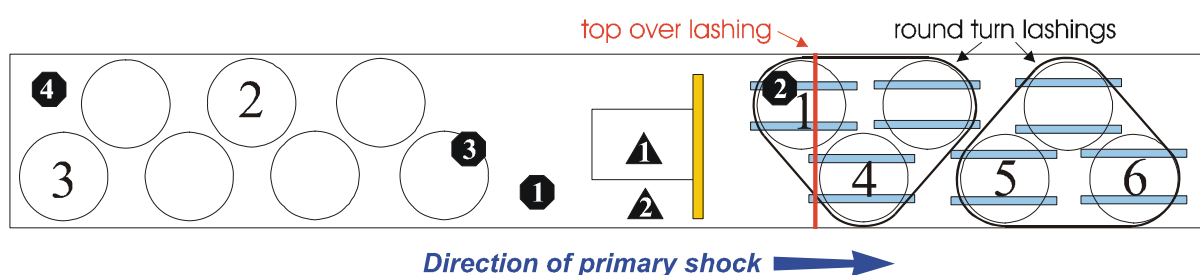
### 7.2.2 Paper wagon

This Habbins-type wagon (2770608-8) was loaded with 11 reels of paper from Kappa and one shrink filmed pallet with paper sheets from Stora Enso Fors. The reels were stowed sparsely which is not in compliance with the Loading Guidelines. The load pattern is illustrated below.

The plywood floor of the wagon was dry but not particularly clean.

The wagon was equipped with normal buffers.

The reels on the right were standing on rubber strips, type Load Grip, marked with light blue stripes in the sketch below. A wooden batten was nailed to the floor in front of the pallet with paper sheets, blocking its movement in the direction of the primary shock.





*Some of the persons attending in the shunting tests in front of paper reels.*



*The reels in the front of the wagon with round turn and top over lashings.*

It is notable that heavy shaving damages were observed prior to the impact tests, on the reels that were not standing on rubber strips.



*The heavy shaving damages on the reels that were not standing on rubber strips. The damages were observed prior to the impact tests.*

This test wagon was subjected to 5 shocks at different speed, all in the same direction.

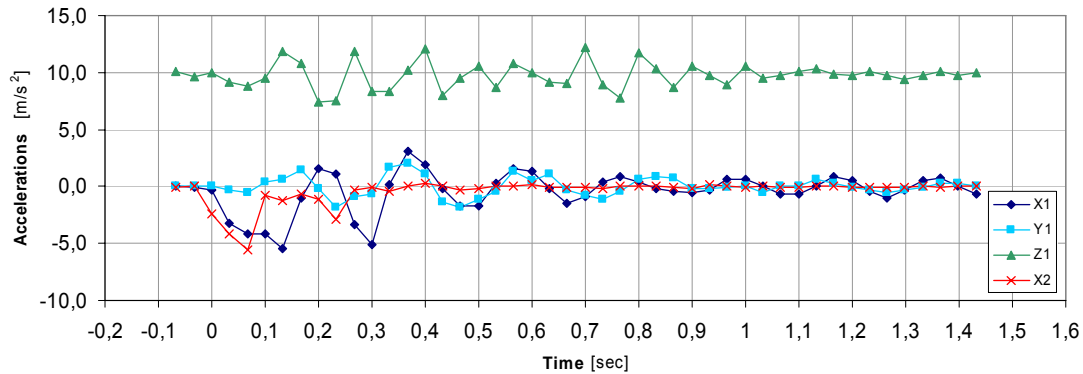
### Recorded shocks during the tests

The positions of the shock recording equipment are marked in the sketch above and the equipment registered the following accelerations and durations:

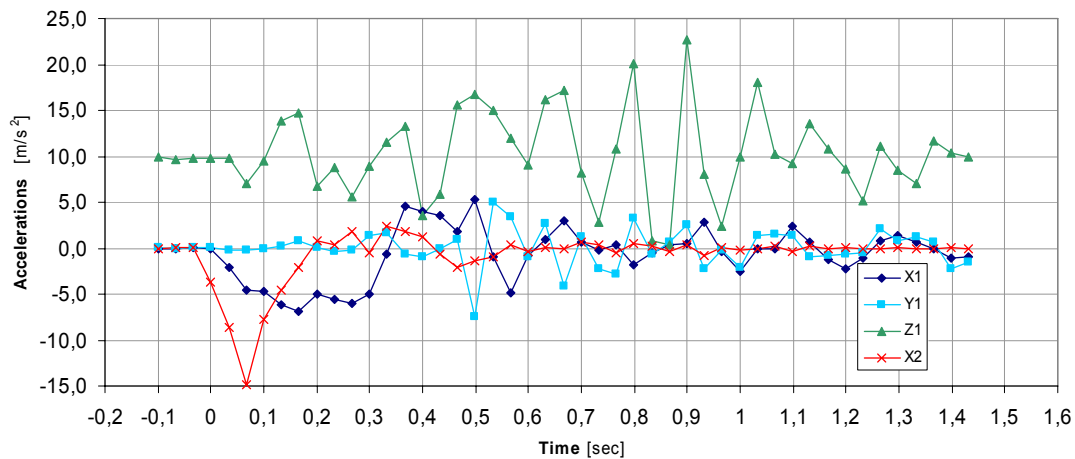
Shock	Speed [km/h]	Maximum longitudinal shock [m/s <sup>2</sup> ] and duration [t=ms]					
		Vernier 1	Vernier 2	Cargolog 1	Cargolog 2	Cargolog 3	Cargolog 4
1	4.1	- 5,4	- 5,6	-	- 6.9 (t=39)	-	-
2	6.9	- 6,8	- 14,8	- 13,0 (t=98)	11.5 (t=164)	- 5.6 (t=37)	- 13.2 (t=93)
3	7.2	- 15,8	- 17,0	- 14,5 (t=104)	12.6 (t=211)	-	- 14.9 (t=105)
4	7.3	- 18,4	- 19,9	- 15,4 (t=101)	14.3 (t=203)	- 4.6 (t=5)	- 16.9 (t=104)
5	10.7	- 23,4	- 27,8	- 21,5 (t=114)	12.3 (t=184)	- 6.0 (t=24)	- 22.1 (t=115)

None of the sensors used, recorded accelerations that exceeded the limit of  $39 \text{ m/s}^2$  ( $4.0 \text{ g}$ ) stipulated by UIC, although the last shock was produced at a speed well above the  $9 \text{ km/h}$  prescribed for impact tests by the UIC Loading Guidelines.

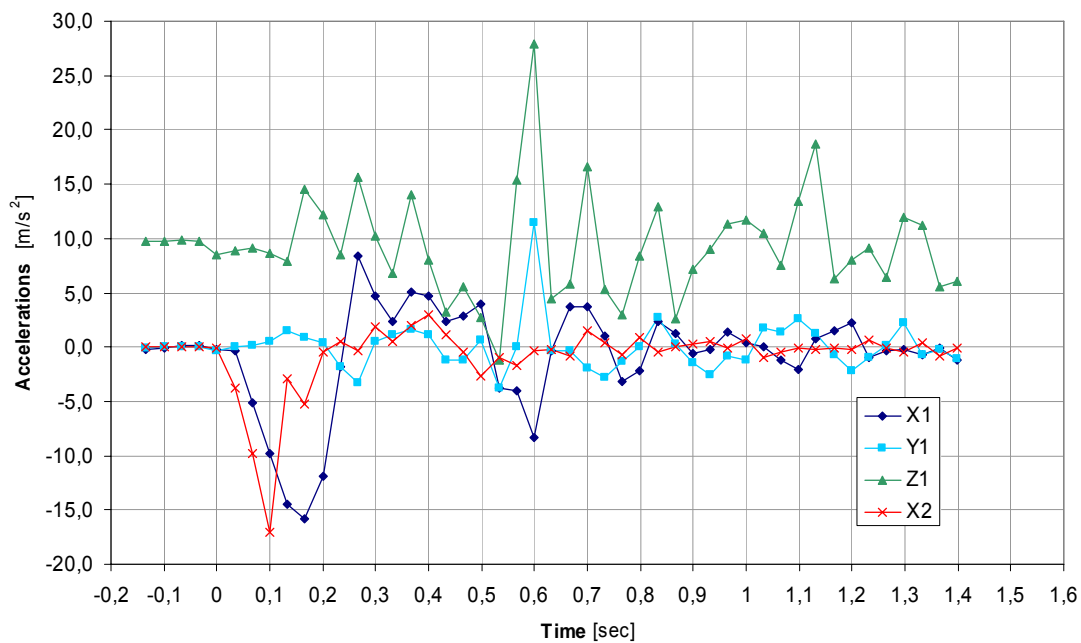
### Accelerations recorded by the Vernier equipment



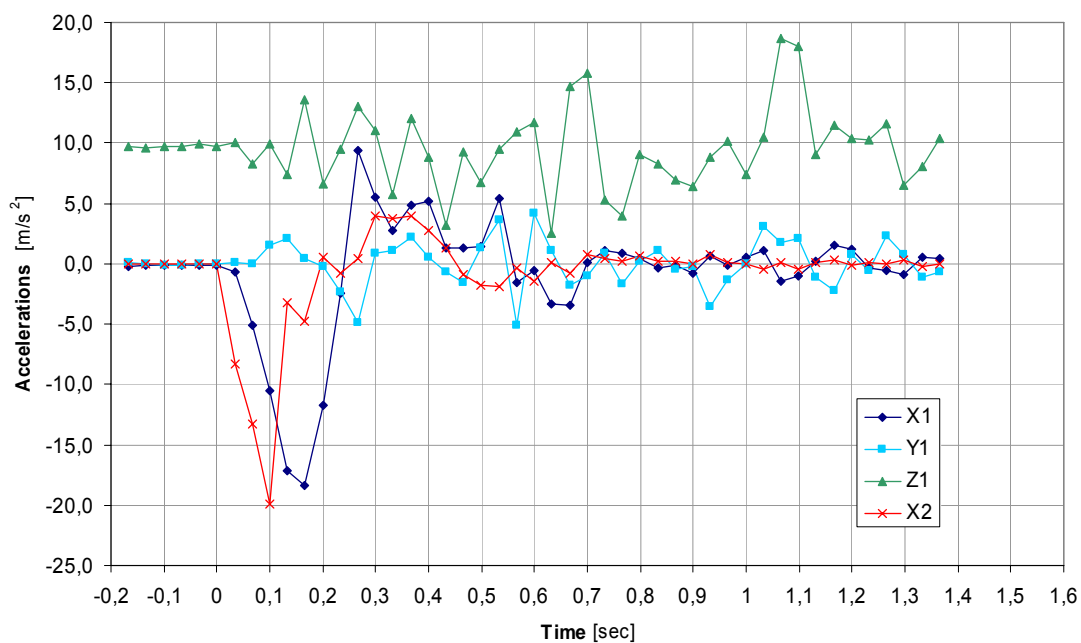
*Accelerations recorded by the Vernier equipment during shock 1.*



*Accelerations recorded by the Vernier equipment during shock 2.*

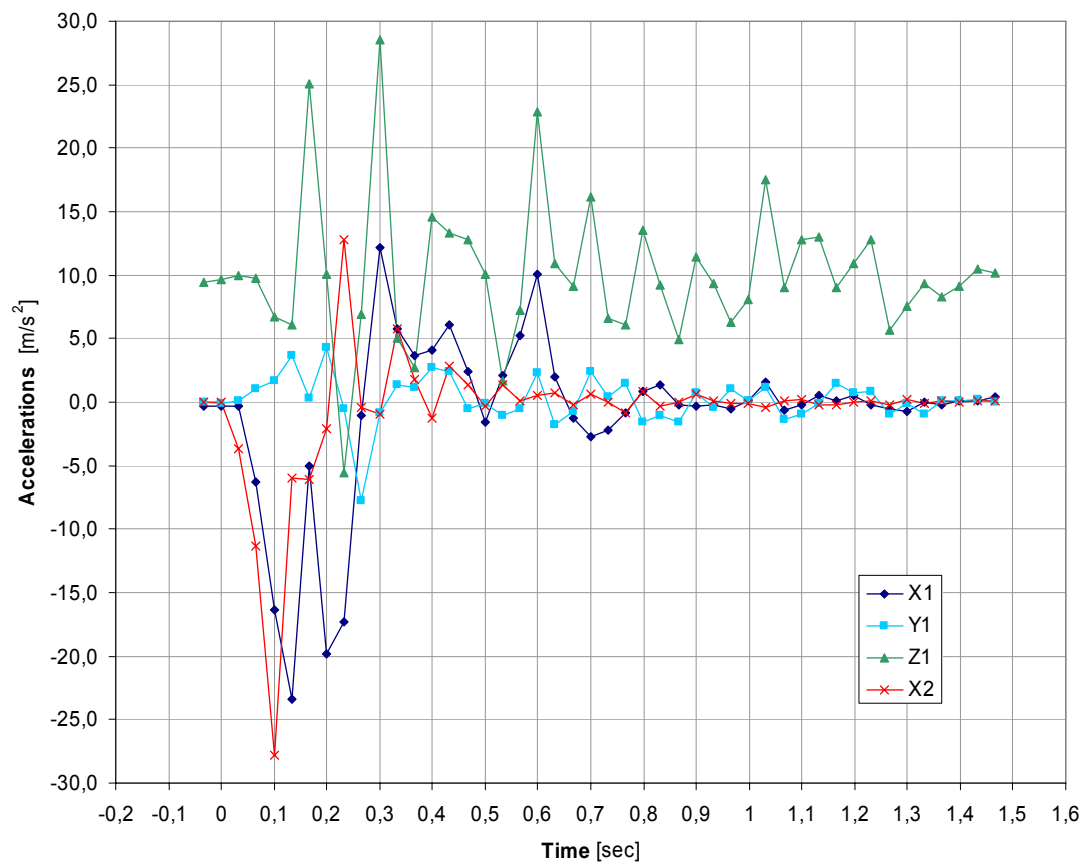


*Accelerations recorded by the Vernier equipment during shock 3.*



*Accelerations recorded by the Vernier equipment during shock 4.*





*Accelerations recorded by the Vernier equipment during shock 5.*

### Recorded movements of the cargo during the tests

The dislocation of the cargo during the tests was measured for the pallet and 6 out of the 13 reels, see the sketch above.

Shock	Speed [km/h]	Measured dislocation of the paper reels, accumulated distance [mm]						
		Pallet	Reel 1	Reel 2	Reel 3	Reel 4	Reel 5	Reel 6
1	4.1	-	-	10	10	0	10	0
2	6.9	90	20	200	200	20	130	120
3	7.2	Against blocking device	25	430	430	25	285	260
4	7.3	-35	55	730	720	100	495	675
5	10.7	-	300	-	1330	410	750	Against end wall

Shock	Speed [km/h]	Distance moved during single shock [mm]						
		Pallet	Reel 1	Reel 2	Reel 3	Reel 4	Reel 5	Reel 6
1	4.1	-	-	10	10	0	10	0
2	6.9	-	20	190	190	20	120	120
3	7.2	-	5	230	230	5	155	140
4	7.3	-	30	300	300	75	210	415
5	10.7	-	245	-	600	310	255	-

According to the results above when comparing the movements for reel number 5 and 6 to those of reel number 2 and 3, the rubber strips reduced the motions of the reels up to impact speeds of approximately 7 km/h. This speed corresponds to an acceleration of approximately 1.5 g in this wagon.



*The movement of reel number 2 after shock 2.*



*The movement of reel number 3 after shock 2.*



*The movement of reel number 5 standing on rubber strips after shock 2.*



*The movement of reel number 6 standing on rubber strips after shock 2.*



*The movement of reel number 3 after shock 5.*



*The movement of reel number 5 standing on rubber strips after shock 5.*

Reel number 4 was indirectly secured by the top over lashing placed over the reel number 1, since these two reels were held together by a round turn lashing.

If wagons loaded like this one are subjected to shocks produced at the speeds normally used for intermodal transports and block trains, i.e. 3-4 km/h, one would only find slight movements among the reels.

On the other hand, if following shunting procedures for hump and fly shunting, the reels would move significantly and probably be damaged. The end reels would, at least if repeatedly shunted, move up against the end walls.

As a comparison, in the test transport between Piteå and Vienna, free standing paper reels of similar type was subjected to two shocks of 15 and 10 m/s<sup>2</sup> respectively in the same direction. These measurements were made by sensors placed on top of the reels. The reels were loaded in the Hiqqrrs wagon, and at arrival in Vienna the recorded movement of these reels was approximately 300 mm. By the above recorded movement as a function of shunting speed it can be concluded that the shunting speed of the wagons during the test transport must have been close to 7.5 km/h.

The shrink filmed pallet was heavily deformed and this method of palletizing cargo can not be said to be a proper choice for cargo that is only bottom block without any support of the cargo on the pallet. Further tests have been performed with stretch and shrink wrapped and hooded pallets which were allowed to slide during shunting, see chapter 8.



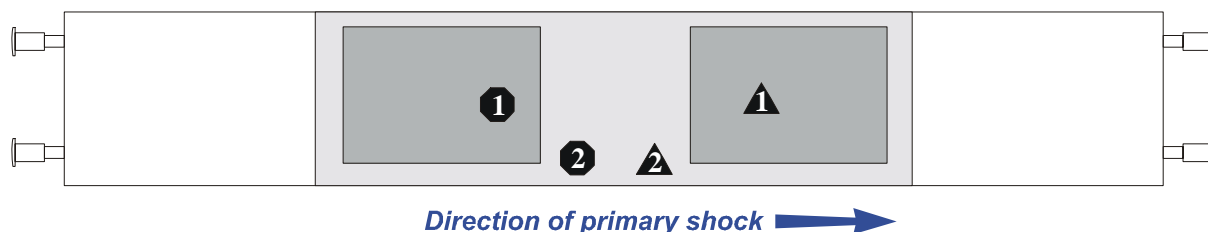
*The shrink filmed pallet with only bottom block was heavily deformed during the shunting tests.*

### 7.3 Wagons for intermodal cargo transport units

Three wagons for intermodal transports were loaded with one swap body each and wagons with regular buffers, with regular buffers and a sliding top and with long stroke buffers were tested.

#### 7.3.1 Wagon with regular buffers

The 20-foot swap body on top of the wagon was loaded with two stows of concrete elements, see the sketch below. The wagon was equipped with regular buffers.





*Concrete elements in the swap body.*



*Top over lashings on the two stows.*

The wagon was subjected to 3 shocks at different speeds, all in the same direction.

No motions of the cargo were noted after the first shock.

The supporting battens underneath the cargo rolled 90 degrees during the second shock and the cargo moved 160 mm.

During the third shock the cargo moved substantially and the forward stow moved towards the end wall.



*20-foot swap body with one drop side down.*



*Spring lashing on the rear stow.*

### Recorded shocks during the tests

The positions of the shock recording equipment are marked in the sketch above.

Shock	Speed [km/h]	Maximum longitudinal shock [m/s <sup>2</sup> ] and duration [t=ms]			
		Vernier 1	Vernier 2	Cargo log 1	Cargo log 2
1	4.3	- 11.6	- 8.8	- 10.9 (t=143)	- 9.0 (t=31)
2	7.2	- 20.9	- 42.7	- 13.4 (t=238)	- 22.0 (t=107)
3	9.1	- 29.0	- 47.6	- 28.4 (t=252)	- 24.7 (t=114)

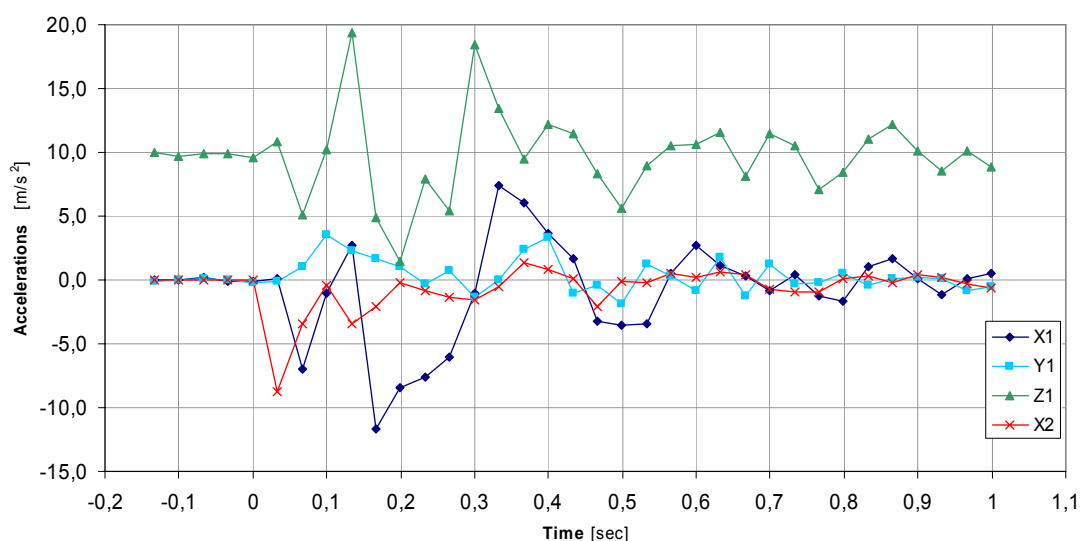
These were the only impact tests where greater accelerations than the stipulated  $39 \text{ m/s}^2$  (4.0 g) were indicated by any instrument. In this case that acceleration was only exceeded during approximately 1/30 of a second (33 ms).

The readings for both the *Vernier 2* and the *Cargo Log 2* sensors placed directly on the wagon floor indicates a massive increase in accelerations when increasing the impact speed from 4.3 to 7.2 km/h, while they only indicate a slight increase between shock 2 and 3. One explanation for this would be that the buffers becomes fully compressed and hits bottom when this wagon with its particular load is shunted at speeds somewhere between 4.3 and 7.2 km/h. There is however too little test data to prove that for certain.

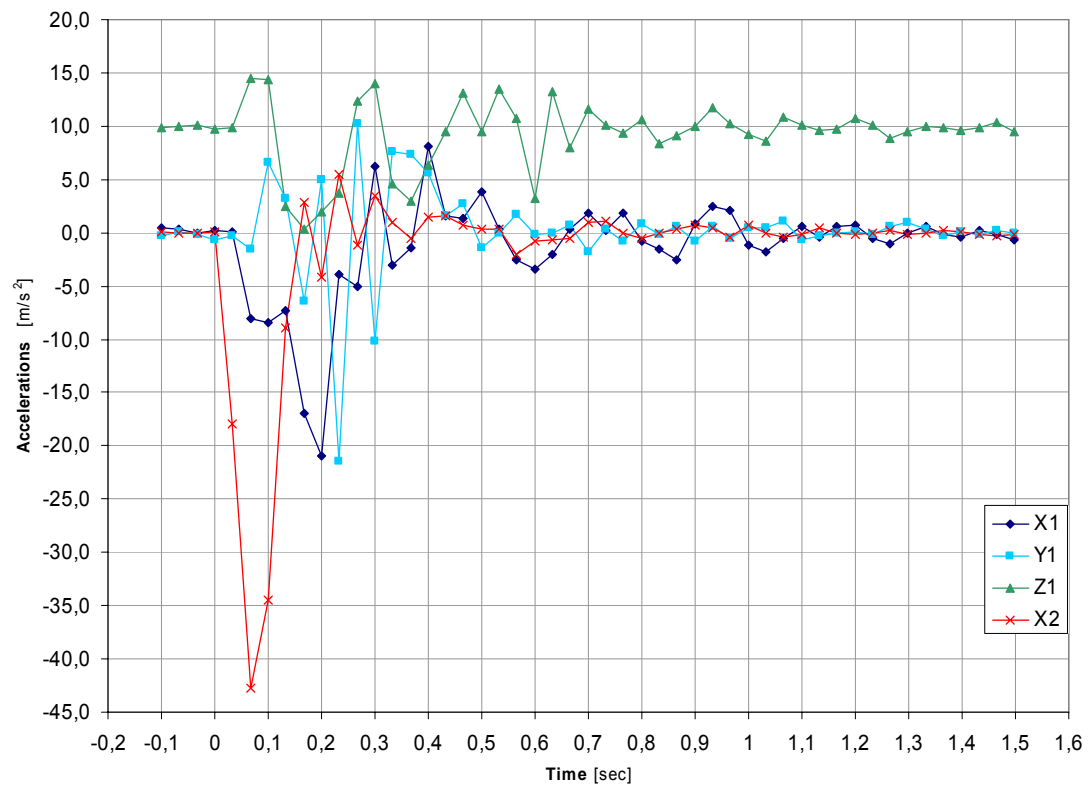
If accelerations lengthwise in the wagon at the wagon floor are calculated for impact speeds 4 and 8 km/h respectively by interpolation from the recorded accelerations at other speeds, the following figures are obtained:

Equipment	Expected maximum acceleration [ $\text{m/s}^2$ ]	
	4 km/h impact speed	8 km/h impact speed
Vernier Pro	7.2	44.8
Mobitron Cargolog	7.8	28.0

### Accelerations recorded by the Vernier equipment

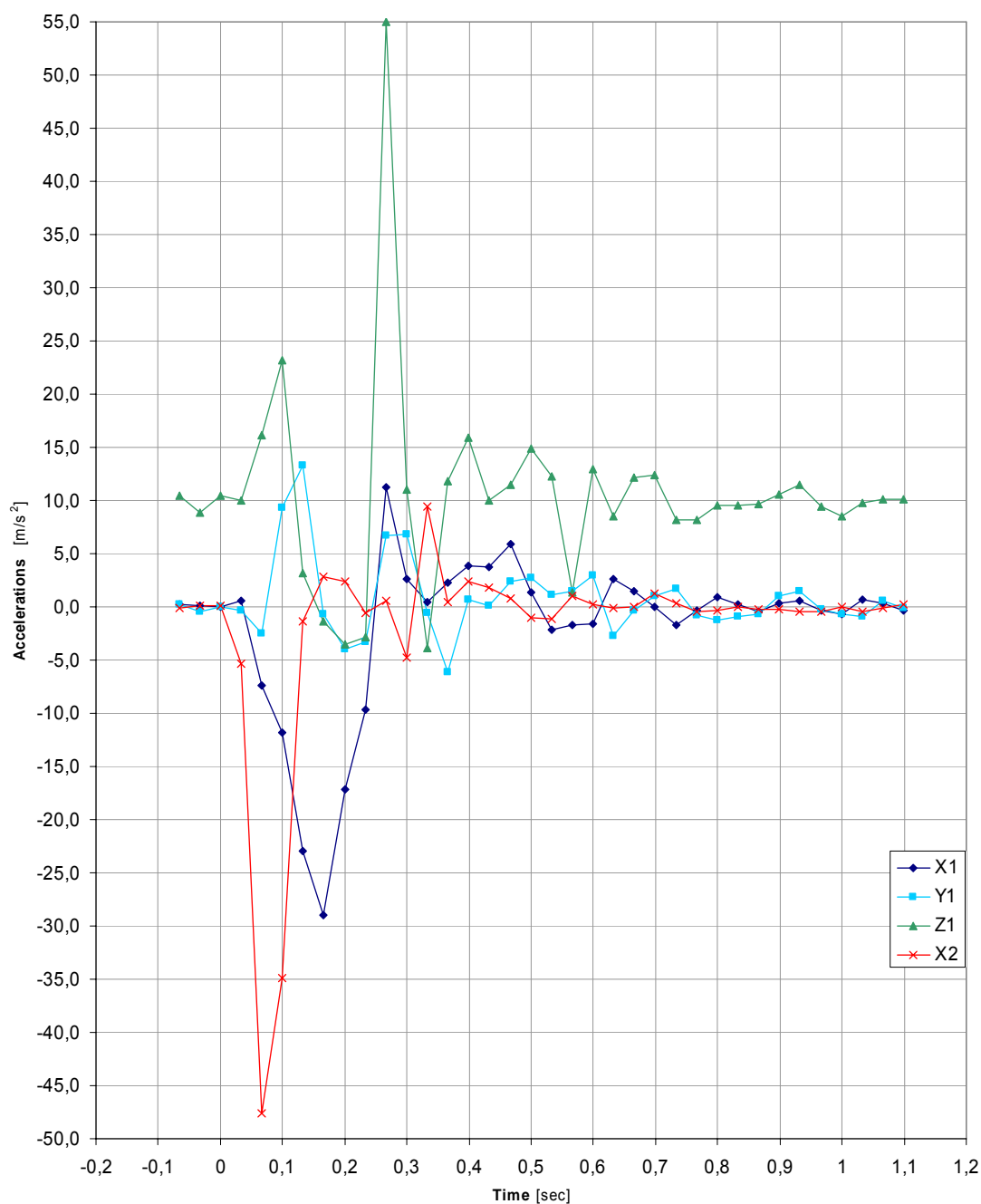


*Accelerations recorded by the Vernier equipment during shock 1.*



*Accelerations recorded by the Vernier equipment during shock 2.*



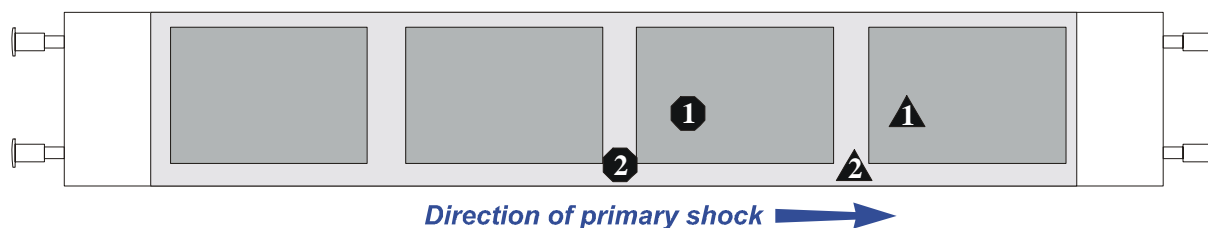


*Accelerations recorded by the Vernier equipment during shock 3.*

### 7.3.2 Wagon with sliding top

The swap body on top of the wagon was loaded with four stows of concrete elements according to below sketch.

The wagon was equipped with regular buffers and a sliding top.



*The wagon for intermodal transports with sliding top used in the shunting tests.*

The wagon was subjected to 3 shocks at different speeds, all in the same direction. No motions of the cargo were noted after either of the shocks.

The sliding top on the wagon slid a total distance of 270 mm during the second shock and 360 mm during the third shock.

### Recorded shocks during the tests

The positions of the shock recording equipment are marked in the sketch above.

Shock	Speed [km/h]	Maximum longitudinal shock [m/s <sup>2</sup> ] and duration [t=ms]			
		Vernier 1	Vernier 2	Cargo log 1	Cargo log 2
1	4.6	- 5.7	- 6.3 / + 2.1	-	- 5.2 (t=31)
2	7.2	- 7.9	- 6.8 / + 1.9	- 6.5 (t=83)	- 5.7 (t=131)
3	8.8	- 8.5	- 6.1 / + 3.1	- 8.2 (t=218)	- 6.5 (t=271)

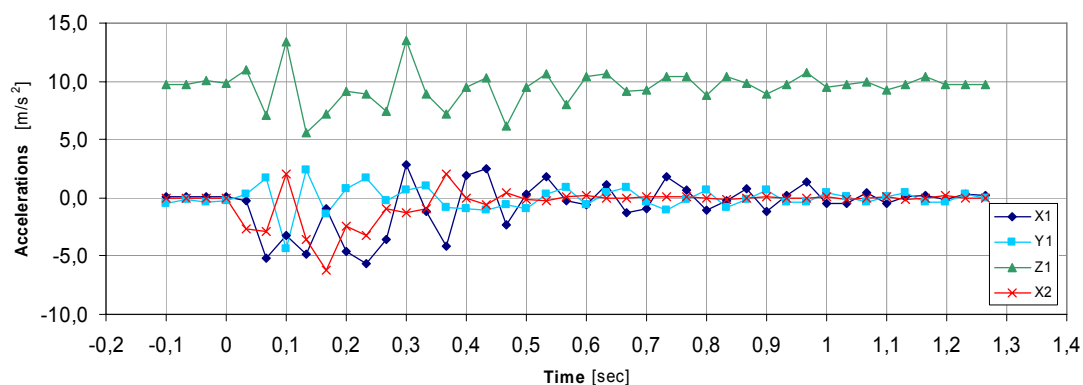
For this wagon, the readings for the *Vernier 2* sensor shows that the first acceleration peak is followed by an acceleration in the opposite direction within the first 1/10 of a second for all three tests.

The swap body was in these tests subjected to much lesser accelerations than the one carried out by the standard wagon for intermodal transport with normal buffers.

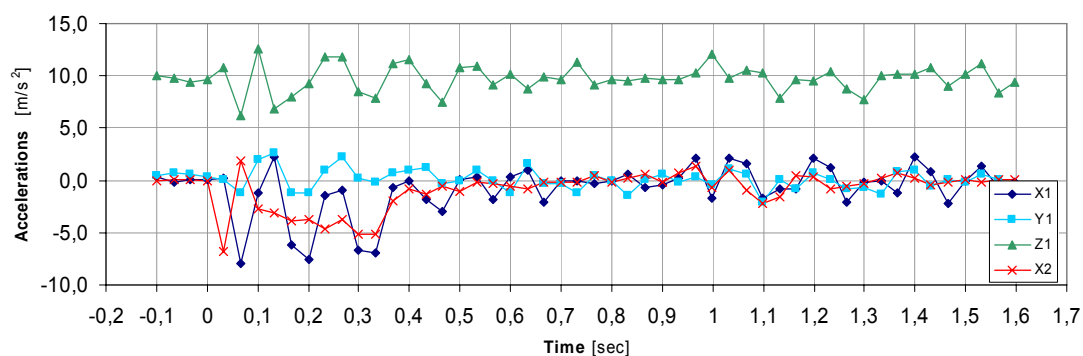
If accelerations lengthwise in the wagon at the wagon floor are calculated for impact speeds 4 and 8 km/h respectively by interpolation from the recorded accelerations at other speeds, the following figures are obtained:

Equipment	Expected maximum acceleration [ $\text{m/s}^2$ ]	
	4 km/h impact speed	8 km/h impact speed
Vernier Pro	6.1	6.4
Mobitron Cargolog	5.2	6.2

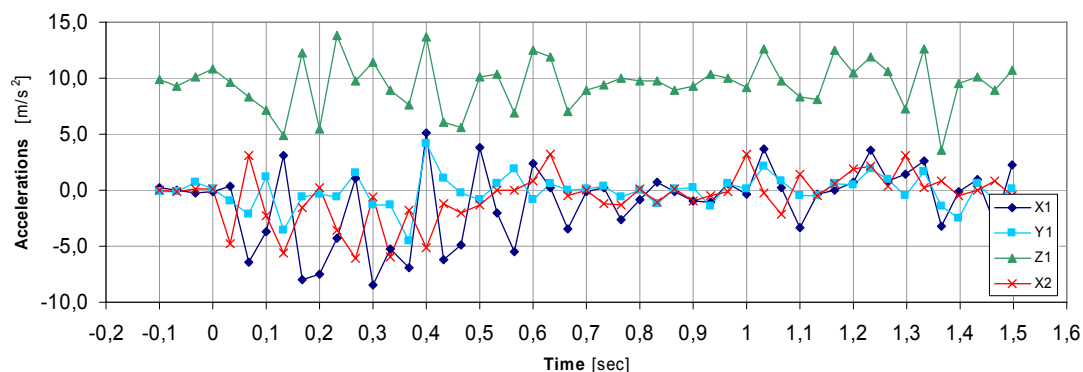
### Accelerations recorded by the Vernier equipment



*Wagon for intermodal transport with sliding top during shock 1.*



*Wagon for intermodal transports with sliding top during shock 2.*

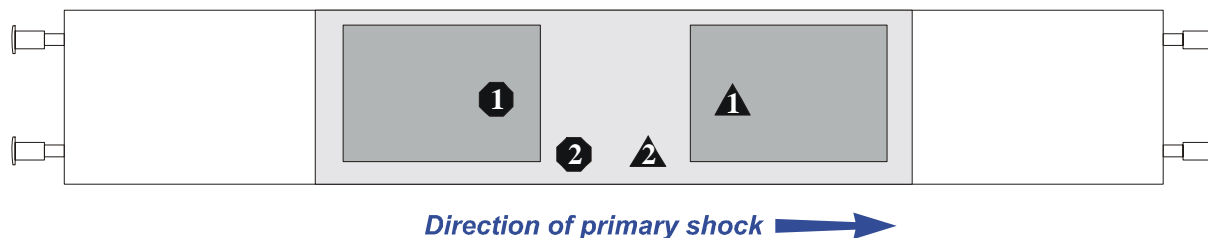


*Wagon for intermodal transports with sliding top during shock 3.*

### 7.3.3 Wagon with long stroke buffers

The 20-foot swap body on top of the wagon was loaded with two stows of concrete elements according to the sketch below.

The wagon was equipped with long stroke buffers.



*Installation of the shock recording equipment.*



*The two stows of concrete elements on the swap body on the wagon with long stroke buffers.*



*The Vernier Pro accelerometer and Mobitron Cargolog placed directly on the floor in the middle of the wagon.*



*The wagon for intermodal transports with long stroke buffers used in the shunting tests.*

The wagon was subjected to 4 shocks at different speeds, all in the same direction. The last shock was produced at a speed of not less than 11.9 km/h.

During the first three shocks the cargo did not move any noticeable distance.

During the fourth shock both stows with concrete elements moved. The stow on the left in the sketch above moved approximately 150 mm. The stow on the right moved 120 mm and the spring lashing snapped.

It shall be noted that the speed in which the wagon was shunted at the fourth time is greater than the prescribed speeds for shunting tests even for normal wagons and much greater than that prescribed for intermodal wagons.

### Recorded compression of the buffers

During the shunting tests the compression of the buffers on the test wagon was visually observed and noted according to the following:

Shock	Speed [km/h]	Buffer compression [mm]
1	3.4	70
2	6.1	220
3	9.3	300
4	11.9	Completely compressed

### Recorded shocks during the tests

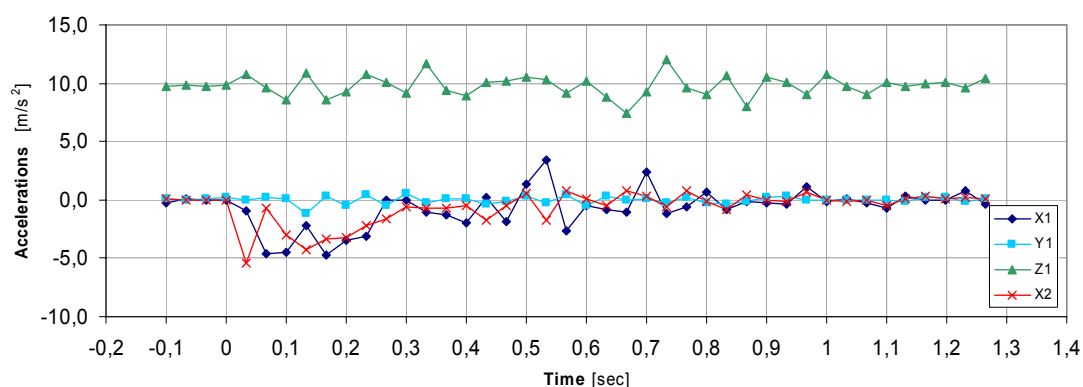
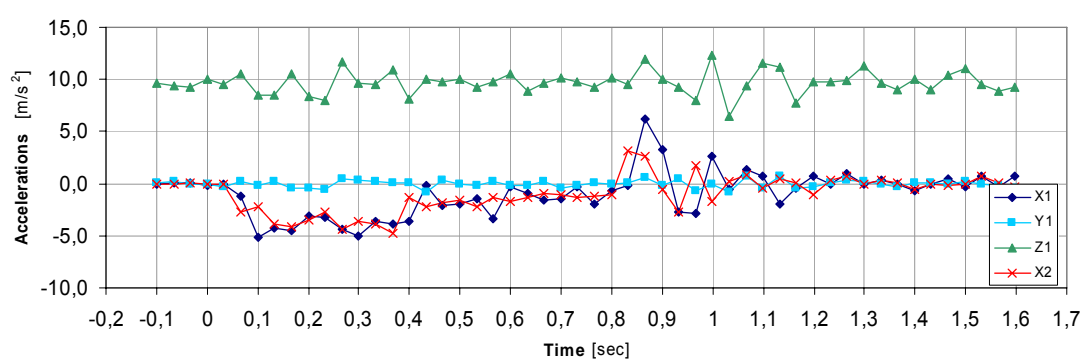
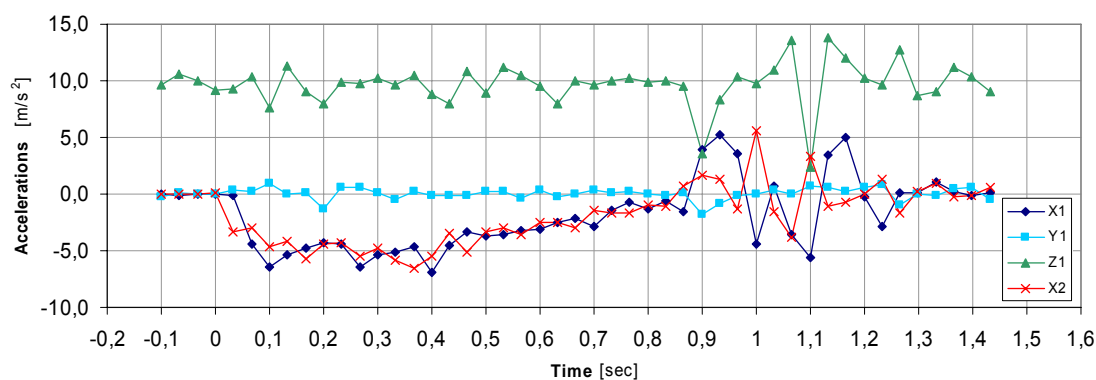
The positions of the shock recording equipment are marked in the sketch above.

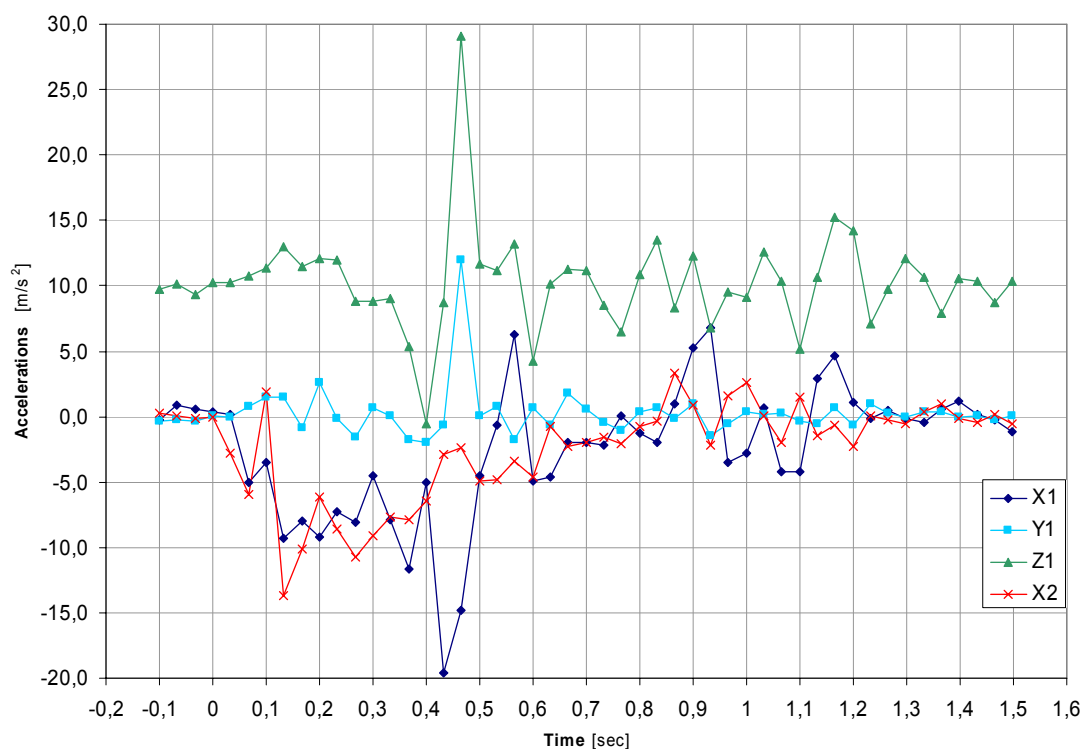
Shock	Speed [km/h]	Maximum longitudinal shock [ $\text{m/s}^2$ ] and duration [t=ms]			
		Vernier 1	Vernier 2	Cargo log 1	Cargo log 2
1	3.4	- 4,6	- 5,4	- 5.3 (t=40)	-
2	6.1	- 5,2	- 4,8	- 5.5 (t=53)	- 5.0 (t=206)
3	9.3	- 6,9	- 6,6	- 8.0 (t=366)	- 6.9 (t=418)
4	11.9	- 19,6	- 13,6	- 20.8 (t=145)	- 12.0 (t=377)

A tendency can be noted, regarding the accelerations registered in the longitudinal direction by the *Vernier 2* sensors placed directly on the floor of the swap body, similar to the tendency for the corresponding sensor in the wagon with sliding top. The retardation, indicated with a red line in the diagrams below, is first increasing, then halted during the first 100 ms after impact and then increasing again.

If accelerations lengthwise in the wagon at the wagon floor are calculated for impact speeds 4 and 8 km/h respectively by interpolation from the recorded accelerations at other speeds, the following figures are obtained:

Equipment	Expected maximum acceleration [ $\text{m/s}^2$ ]	
	4 km/h impact speed	8 km/h impact speed
Vernier Pro	5.3	5.9
Mobitron Cargolog	< 4.9	6.2

**Accelerations recorded by the Vernier equipment***Wagon for intermodal transport with long stroke buffers during shock 1.**Wagon for intermodal transports with long stroke buffers during shock 2.**Wagon for intermodal transports with long stroke buffers during shock 3.*



*Wagon for intermodal transports with long stroke buffers during shock 4.*



*The stow on the right in the photo above moved significantly during the fourth shock and the spring lashing snapped.*



*The movement of the stow to the left in the sketch above after shock 4.*





*The movement of the stow to the right in the sketch above after shock 4.*

## 7.4 Summery and conclusions of the shunting tests

According to RIV Appendix II the stresses that may arise during rail operation lengthwise in the wagon and that shall be taken into account are 4.0 g ( $39 \text{ m/s}^2$ ) for wagons subjected to hump and fly shunting and 1.0 g ( $9.8 \text{ m/s}^2$ ) for wagons in block trains or those used for intermodal transports.

The test data received from the tests carried out within the BREAKAGE-project indicates that, if performing impacts within the stipulated speed ranges for each type of shunting method, the prescribed stresses above will not be obtained.

In the wagon for intermodal transports with normal buffers, accelerations exceeding  $39 \text{ m/s}^2$  (4.0 g) were observed, at one occasion during a very short time frame of approximately 30 ms. This acceleration was produced at the impact speed of 9.1 km/h and was only registered by one of the four sensors used in that particular test. Had the tests been performed in complete compliance with the Loading Guidelines the impact speed should not have exceeded 4 km/h.

On the other hand, the tests show that cargo secured with reasonable and commonly used methods are at risk of being damage when shunted at normative speeds.

### Travelling distances due to shunting impacts

Cargo that are not secured in any way and are allowed to slide during impacts, such as the copper coils and some of the paper reels, travelled great distances from their original position during shunting. Travelling distances up to 600 mm per impact were recorded repeatedly. In the shunting tests for paper pallets described in chapter 8 below in this report travelling distances above 1 m per impact were recorded. If the cargo comes in contact with end or side walls and slanted roofing during movements due to shunting impacts, it would probably be damaged or deformed, as was the case for the copper coils. This is due to the insufficient free space between the copper coils and the wagons fixed structure.

**Forces on wrapping of bottom blocked pallets**

The shrink filmed and bottom blocked pallet was heavily deformed during the shunting already in slow speeds even though the pallet was wrapped according to the UIC Loading Guidelines with 150 µm shrink film. It is thus concluded that pallets that are bottom blocked requires quite heavier wrapping to be able to withstand shunting shocks. It does also clearly shows that the goods on the pallets should fill out the pallets entirely. If not there is a very large risk that the cargo on tightly stowed and blocked pallets is sliding off the pallet during shunting.

**Shaving damages recorded of cargo during transport to test site**

Heavy shaving damages were noted on some of the free standing reels in the wagon, which had occurred during the transport from Piteå to Malmö. Rubber strips placed under some of the paper reels seemed to effectively have prevented them from moving around due to vibrations during the transport.

**Shunting speeds of wagons during test transport Piteå - Vienna**

In the test transport between Piteå and Vienna, free standing paper reels of similar type as used in the shunting tests were subjected to two shocks of 15 and 10 m/s<sup>2</sup> in the same direction. These measurements were made by sensors placed on top of one of the free standing reels without friction material below the reel. The reels were loaded in the Hiqqrrs wagon, and at arrival in Vienna the recorded movement of these reels was approximately 300 mm. By the recorded accelerations and movements as function of shunting speed done in the shunting tests it can be concluded that the shunting speed of the wagons during the test transport Piteå – Vienna must have been close to 7.5 km/h.

**Acceleration in intermodal transports and in wagons with sophisticated buffer systems**

Regarding the wagons for intermodal transports loaded with swap bodies, the sliding top construction and the long stroke buffer arrangement reduced shocks considerably compared to the wagon with regular buffers, at least for impacts at greater speeds. This is clearly indicated by both sets of equipment for measurement of accelerations. When these wagons were subjected up to the impact speeds that they are supposed to be handled at, moderate accelerations were recorded and the cargo did not move notably. It may and have from time to time happened that wagons for intermodal transports are shunted at greater speeds than they are supposed to, but with the more sophisticatedly equipped wagons, the cargo are given great chances for surviving also such impacts.

In the tables below, expected maximum accelerations on the floor of a swap body are given for impact speeds of 4 and 8 km/h when transported in different types of wagons for intermodal transports. The values below have been indicated by the accelerations recorded by the two different sets of equipment.

**Vernier Pro Accelerometers**

Wagon type	Expected maximum acceleration [ $\text{m/s}^2$ ]	
	<i>4 km/h impact speed</i>	<i>8 km/h impact speed</i>
Normal buffers	7.2	44.8
Sliding top	6.1	6.4
Long stroke buffers	5.3	5.9

**Mobitron Cargolog**

Wagon type	Expected maximum acceleration [ $\text{m/s}^2$ ]	
	<i>4 km/h impact speed</i>	<i>8 km/h impact speed</i>
Normal buffers	7.8	28.0
Sliding top	5.2	6.2
Long stroke buffers	< 4.9	6.2

At shunting speeds of 4 km/h, which is the maximum prescribed by Loading Guidelines, the acceleration lengthwise in the wagons is limited to around  $5 \text{ m/s}^2$  (0.5 g). This is also the dimensioning stress backwards in most regulations used in road transports. For wagon equipped with more sophisticated buffer systems the shunting speed could be up to 8 km/h and still the longitudinal acceleration could be limited to acceptable levels.

## 8 TESTS WITH DIFFERENT TYPES OF PLASTIC PACKAGING

Three shunting tests and two inclination tests with three different plastic packaging techniques were carried out in the project. In this chapter a description and the results of the tests are given.

### 8.1 Introduction

Below a description of the purpose of the tests, used pallets as well as plastic packaging techniques is given.

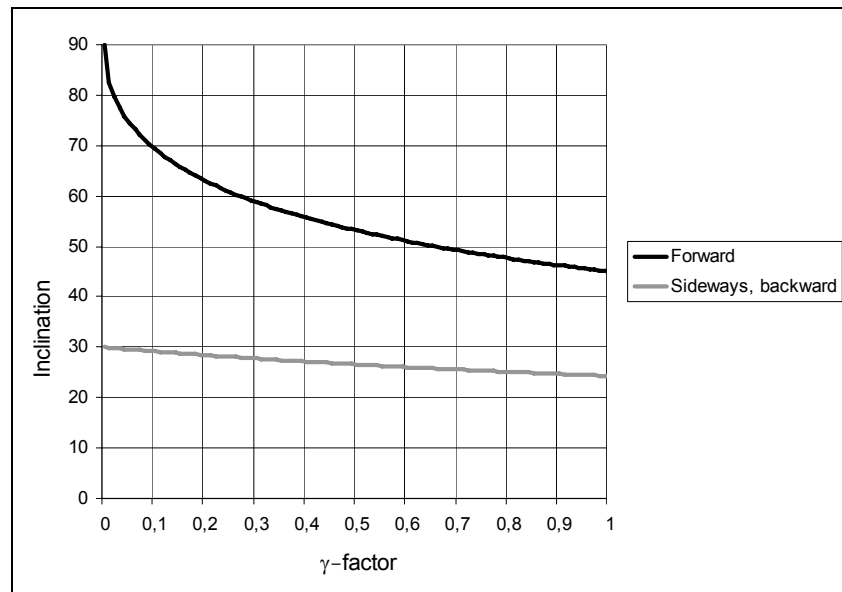
#### 8.1.1 Purpose of the tests

The purpose of the tests was to determine the amount and strength of plastic packaging material needed to produce a rigid pallet, suitable for rail transport including shunting operations. Based on the outcome of these tests, a test procedure for verifying the required strength of different wrapping methods and materials could be recommended to UIC.

The background for this is the lack of good instructions in the Loading Guidelines. The one instruction for palletised load units found there only indicates a required thickness of the film, although a number of other factors are likely to influence the pallet stability. The required thickness, 150 µm, is thicker than normally used for these types of wrappings and the tests performed aimed to verify the relevance of this requirement. The tests also aimed to develop an easier test procedure for the railway users to replace the shunting tests with inclination tests since the shunting tests are complicated and very time consuming.

According to the Loading Guidelines for Impact Tests free standing cargo has to be subjected to two impacts at different speeds in the same direction followed by a counter-shock in the opposite direction. Instead of this demanding procedure a simple inclination test to determine if the cargo securing arrangement is sufficiently made could be done.

For road and sea transport this kind of inclination tests are used and prescribed in the *Swedish Road Regulations TSVFS 1978:10*, the *Swedish Maritime Administration's Regulations SJÖFS 2003:14*, the *European Best Practice Guidelines on Cargo Securing for Road Transport* and the *IMO Model Course 3.18*. According to those regulations the cargo is tested on a vehicle platform or similar that is tilted to a certain angle according to the diagram below taken from the EU Best Practice Guidelines and valid for road transport. If the cargo is kept in position during the inclination with only limited motions, the securing arrangement withstands the prescribed accelerations, see photos below.



The  $\gamma$ -factor is the lowest value of the coefficient of friction ( $\mu$ ) and the ratio of breadth (B) and height (H) and number of rows (n),  $\frac{B}{n \cdot H}$ , at accelerations sideways. At accelerations forward or backward  $\gamma$ -factor is the lowest value of the coefficient of friction ( $\mu$ ) and the ratio of length (L) and height (H),  $\frac{L}{H}$ .



*The efficiency of the securing arrangement of a heat exchanger is tested for accelerations forward and sideways.*

### 8.1.2 Test procedure

In the tests within the BREAKAGE project, a number of pallets with different types of plastic packaging techniques and different amount of plastic material were shunt tested. The pallets that just barely survive the shunting tests were afterwards tested in inclination tests to get the static inclination angel that corresponds to the forces obtained during shunting.

**8.1.3      Used pallets and plastic packaging techniques**

Nine pallets with cardboard boxes with A4 paper sheets used in the tests were supplied by Stora Enso Nymölla AB. The standard EURO pallets were all loaded with 48 cardboard boxes and the boxes were stacked in four layers, each consisting of 12 boxes. The weight of the cargo on each pallet was approximately 600 kg and the pallets had the following approximate dimensions:

- Length: 120 cm
- Width: 80 cm
- Height: 110 cm

The plastic packages that were tested were stretch wrapping, shrink hood and stretch hood. The stretch film was wrapped around the pallet with the same film thickness but with different number of laps, from 10 to 25 laps. On the pallets that were covered with shrink hoods, the film thickness varied between 100 and 180 µm, and the stretch hooded pallets all had the same thickness of the film but different number of layers was covering the top and the bottom of the pallets.

**8.1.4      UIC Guidelines for impact tests and for formation of palletised load units**

The shuntings were carried out according to the guidelines for impact tests that can be found in *RIV Appendix II, Loading Guidelines, Section 1, Principles, Table 4*, see section 7.1.5 above.

The following guidelines for use palletised load units can be found in *RIV Appendix II, Loading Guidelines, Volume 2, Chapter 11, section 1*.

## Formation of palletised load units

### Type of goods

Cases, sacks, building materials, stone, slabs, paper, cardboard, casks, drums, fruit and vegetables in boxes or crates, etc.

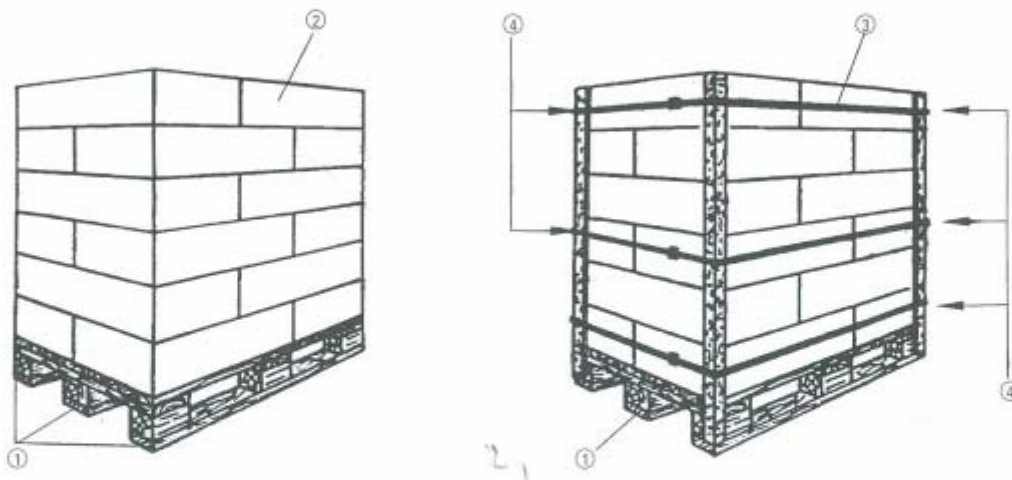
### Loaded on

Flat pallets made of wood, plastic, pressboard, etc.

- ① – with feet / bearers designed and fastened to ensure they will not tip up or break off

### Method of loading

- ② Goods should be arranged on the pallet in stable and compact manner, with sides flush with the pallet edges (avoid offset or projecting goods)
- in interlocking layers (e.g. crates)
  - stacked in criss-cross formation (e.g. sacks)



### Securing

Cohesion of load unit increased by

- ③ – using steel strip, textile or synthetic bands (breaking strength 7 kN minimum) to encircle the load vertically and/or horizontally
- ④ – horizontal encircling bands for easily displaced goods with edge protection bound to the load, one to be placed
- round the lower tier
  - one around the middle and
  - 1 one towards the top of the load unit
- the application of shrunk or stretched plastic sheeting of sufficient thickness (min 150 µm) is permitted (should also cover the pallet feet)
- use of
- inserts made from friction-enhancing material between individual layers or
  - special adhesives or
  - corner pieces.

## 8.2 Inclination test 1

This inclination test was carried out in Helsingborg 2005-10-31 and the following persons were attending:

Bo Eriksson  
Carl-Erik Silow  
Erik Andersson

Cyklop AB  
IKEA Svenska AB  
IKEA Svenska AB

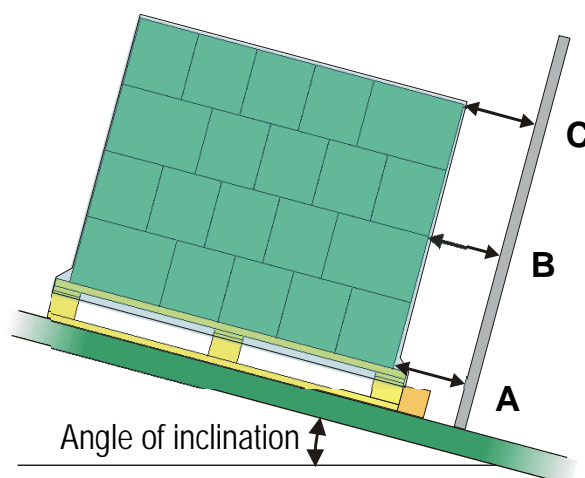


Christer Nilsson	Green Cargo AB
Stanley Öberg	Green Cargo AB
Roger Leandersson	Green Cargo AB
Thomas Kullgraf	Green Cargo AB
Georg Tegstam	Tetec Trading AB
Dan Christiansen	Trioplast AS
Hans Karlsson	Trioplast AB
Kurt Larsen	Trioplast AS
Lars Ulrik Krarup	Trioplast AS
Peter Carstensen	Trioplast AS
Anders Jönsson	Stora Enso Nymölla AB
Lena Ramquist	Eka Chemicals AB
Nils-Åke Hellman	Autonordic AB
Peter Andersson	MariTerm AB
Peter Madsen	Lachenmeier AS
Ronny Romare	Börje Jönssons Åkeri
Sven Sökjer-Petersen	MariTerm AB
Thore Söderqvist	SCA Transforest AB
Ulf Söderlund	SCA Ortviken
Tommy Paramo	Transport och Hantering
Rolf Nordström	TransportForsk AB

### 8.2.1 Test method

The pallets were placed on a vehicle platform that was inclined until the plastic film around the pallets started to yield and the palletized cargo were on the brink of collapsing. The inclination was halted at intervals of about 5 degrees and the dislocation of the cargo was measured at three different heights as illustrated in the figure below.

The pallets were bottom blocked by means of a wooden batten nailed to the platform floor, so that the pallets were unable to slide along the platform. As illustrated in the figure below, the wooden batten did not reach above the wooden pallet, and did not influence the movement of the boxes on the wooden pallet.





### 8.2.2 Test pallets

In these tests nine pallets loaded with cardboard boxes and three different packaging techniques to bind the boxes on the pallets together with plastic film were used:

- stretch wrapping
- shrink hood
- stretch hood

Each technique was used on three pallets and the plastic film consumption was varied between the pallets in each group.



*Stretch wrapping*



*Shrink hood*



*Stretch hood*

Cyclop AB performed the wrapping of the plastic film from Trioplast AB for the three stretch wrapped pallets and Lachenmeier A/S in Denmark applied the shrink and stretch hoods for the remaining six pallets.

The pallets from Denmark with shrink and stretch hoods showed some handling damages in the plastic film see photos below. This influenced their performance during the tests and the misleading results are for that reason excluded from the report. Hence, these pallets were tested again, see section 8.5.



*Shrink hood pallet 1 and 3.  
The plastic film has been torn apart when handled by a fork lift.*



*Stretch hood pallet 2. The plastic film  
has been ripped through by the sharp  
corners of the wooden pallet.*

### 8.2.3 Results

Below the measurements of the dislocation of the cardboard boxes with wrapped stretch film are listed for different angles of inclination. Apart from the measured distances from the closest point of the pallet to the barrier at different heights A, B and C, the calculated movement from the original position is given for all pallets.

Where the comment “Collapsed” is given in the tables below, the boxes showed a major movement or were sliding against the wooden pallet. In some cases the boxes were moving at such speeds that measurement of the distances where not possible to carry out.

## Stretch wrapped pallets

### Pallet 1

Film weight: 400 g      Pre-tension: 150 %  
 Film thickness: 20  $\mu\text{m}$       Type of film: Blown Coex  
 Number of laps: 34

Inclination [degrees]	Distance to barrier [mm]			Accumulated movement [mm]			Comment
	A	B	C	A	B	C	
0	219	207	203	0	0	0	
10	219	207	203	0	0	0	
15	219	206	202	0	1	1	
20	218	204	198	1	3	5	
25	218	193	180	1	14	23	
27	216	185	165	3	22	38	
30	210	168	135	9	39	68	
34	-	-	-	-	-	-	<b>Collapsed</b>



*Pallet 1 prior to testing.*



*Pallet 1 at 27 degrees inclination.*

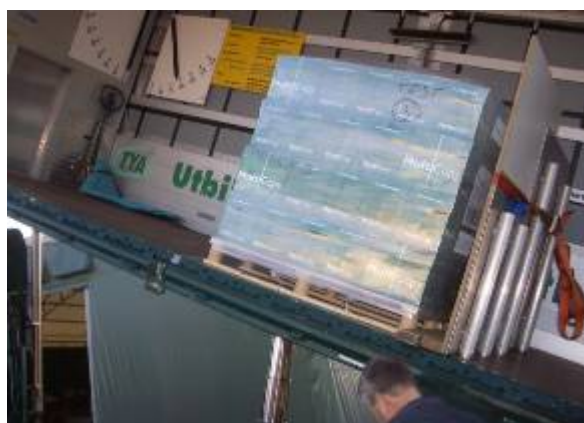


*Pallet 1 at 34 degrees inclination*

**Pallet 2**

Film weight: 450 g      Pre-tension: 150 %  
Film thickness: 20 µm      Type of film: Blown Coex  
Number of laps: 30

Inclination [degrees]	Distance to barrier [mm]			Accumulated movement [mm]			Comment
	A	B	C	A	B	C	
0	217	205	201	0	0	0	
10	217	205	201	0	0	0	
15	217	203	200	0	2	1	
20	217	200	196	0	5	5	
25	216	190	176	1	15	25	
27	215	181	160	2	24	41	
30	208	165	131	9	40	70	
33,5	-	-	-	-	-	-	<b>Collapsed</b>



*Pallet 2 at 27 degrees inclination.*



*Pallet 2 after the inclination test.*



**Pallet 3**

Film weight:	585 g	Pre-tension:	150 %
Film thickness:	23 $\mu\text{m}$	Type of film:	Blown Coex
Number of laps:	34		

Inclination [degrees]	Distance to barrier [mm]			Accumulated movement [mm]			Comment
	A	B	C	A	B	C	
0	202	190	190	0	0	0	
10	202	190	190	0	0	0	
15	201	190	190	1	0	0	
22	201	188	188	1	2	2	
25	201	187	187	1	3	3	
27	200	185	182	2	5	8	
30	199	180	173	3	10	17	
35	190	160	145	12	30	45	<b>Close to tipping</b>



*Pallet 3 at 27 degrees inclination.*



*Pallet 3 at 30 degrees inclination.*

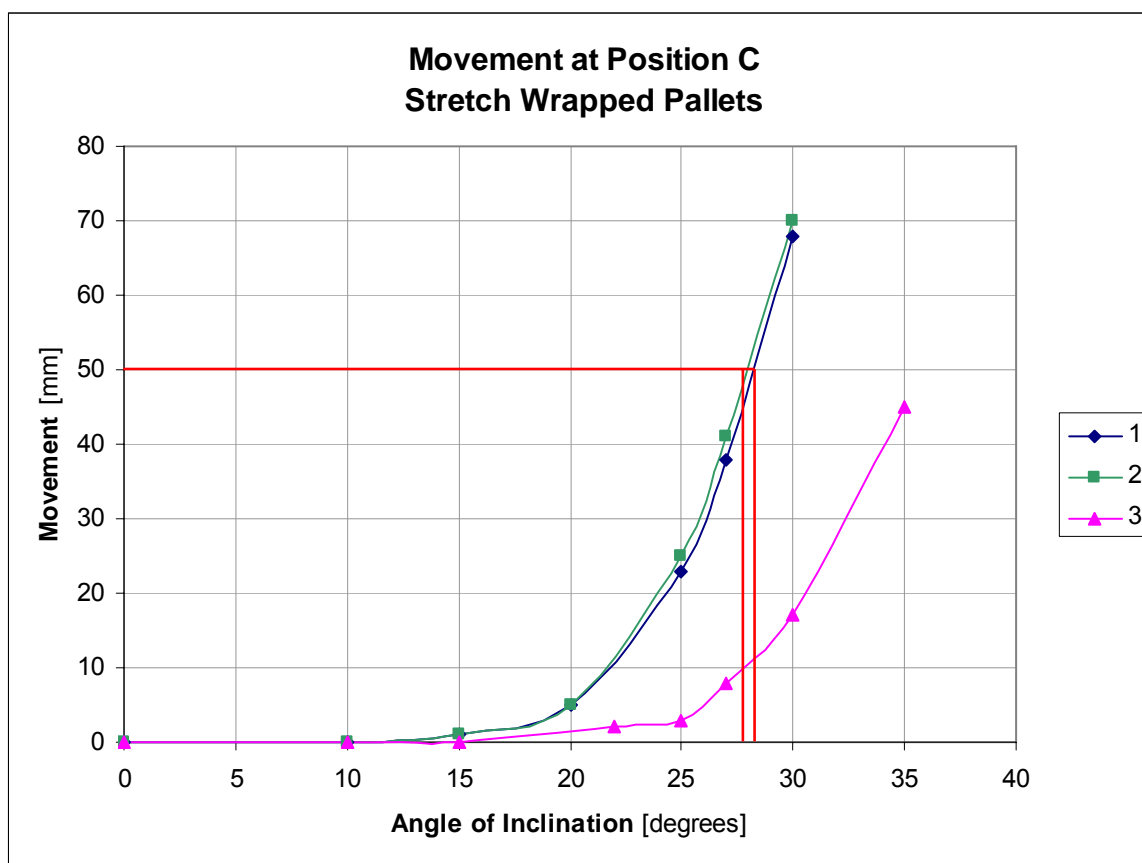


*Pallet 3 at 35 degrees inclination*



*Pallet 3 after the inclination test.*

### Comparison of movement between the stretch wrapped pallets



Pallet 1 and 2 survived the inclination to about 28 degrees and the boxes in the top layer had at this point moved approximately 50 mm from their original position. At the inclination of 30 degrees they were still stable but had been quite deformed.

Pallet 3 was only slightly deformed at the inclination of 27 degrees and at the inclination of 35 degrees, the top boxes had only moved 45 mm but the whole pallet was on the brink of tipping over.

### 8.3 Pallet shunting tests 1

The first shunting tests with stretch wrapped pallets were performed in Malmö 2005-11-15 and the following persons, among others, were attending the tests:

Ann-Sofie Edhag  
Tomas Tegstam  
Arno Meske  
R. Roman Embacher  
Björn Matsson  
Lennart Svenberg  
Christer Nilsson  
Tommy Hilding  
Håkan Sjöström  
Kent Tegelberg  
Peder Nilsson

Trioplast AB  
Tetec Trading AB  
Railon Deutschland  
ÖBB Traktion GmbH  
Holmen Papper AB  
Holmen Papper AB  
Green Cargo AB  
Green Cargo AB  
Green Cargo AB  
Green Cargo AB  
Green Cargo AB



Stanley Öberg  
Helena Nilsson  
Inge Högström  
Per-Anders Lindström  
K-G Fältmark  
Lars Lundgren  
Fredrik Lundgren  
Sven Sökjer-Petersen  
Tore Söderqvist  
Ulf Söderlund  
Urs Dannanhauer

Green Cargo AB  
Transwaggon  
Transwaggon  
Transwaggon  
Kappa Kraftliner  
Lastrådgivarna AB  
Lastrådgivarna AB  
MariTerm AB  
SCA  
SCA  
SBB Cargo

### 8.3.1 Test method

As prescribed by the Loading Guidelines for Impact Tests above, the wagons were to be subjected to two impacts in the same direction but at different speeds and one counter shock in the opposite direction. Apart from the number of impacts, the tests were performed in complete compliance with the guidelines.

### 8.3.2 Used wagon

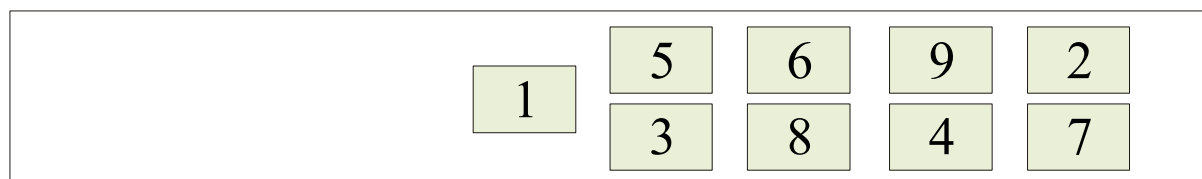
The wagon was a Hbis-type wagon (2253053-5) with rough wooden flooring, which upon inspection at the test site was found to be dry and satisfactory clean. The impact wagon (8474 9853 042-1) was a bogie wagon with Category A 105 mm stroke buffers, loaded with gravel to a total mass of 80 ton.

### 8.3.3 Used pallets

The same nine standard EURO pallets loaded with cardboard boxes were shunted. The pallets were now rewrapped by Cyclop AB with different amounts of plastic stretch film, Blown Coex, from Trioplast, but all with the same film thickness: 20 µm. The total weight of the plastic film used for each pallet was varied, ranging from 213 grams for pallet number 1 to 463 grams for pallet number 9. The film quality was FBLN and the film on all the pallets was 190 % pre-tensioned. Data for the plastic wrapping of each pallet is given in the table below.

Pallet	Film weight [g]	Number of laps
1	213	10
2	231	11
3	247	13
4	303	17
5	310	19
6	328	20
7	392	20
8	463	25
9	463	25

The figure below illustrates the loading pattern for the 9 pallets. The pallets were loaded sparsely over the wagon floor and all pallets were free to slide during the impact test. Their position was marked on the floor prior to the impact test with crayons.



*Pallet 1 in the foreground before the test.*



*Pallet 8, 4 and 7 before the test.*



*Pallet 7 in the foreground before the test.*

### 8.3.4 Results

The wagon was only subjected to one shock in low speed, since it was concluded that the cargo on most of the pallets would not have survived a second shock at a higher impact speed. The one impact was produced at a speed of 5.3 km/h.

The following movements of the cargo relative to the pallets and of the pallets themselves were noted.

Pallet	Movement of wooden pallet against the floor [mm]	Movement of bottom layer against pallet [mm]
1	10	120
2	0	130
3	5	125
4 *	110	40
5	0	140
6	0	95
7	90	60
8	0	130
9	100	25

*\* This wooden pallet broke during the test and splinters from the overlaying boards were protruding upwards, into the cargo and hindered its movement against the pallet. See photo below.*



*Pallet 4 with splinters from the wooden pallet protruding upwards into the cardboard boxes after the shock.*

Most of the pallets did not slide at all or very little against the wagon floor while the cargo moved quite a long distance against the wooden pallet. This indicates that the plastic wrapping were not strong enough to transfer the mass forces from the cargo to the pallet. Instead the stretch film yielded.

For all pallets, the cargo slid primary at the bottom against the wooden pallet and not so much between the layers. Only the pallets with the very least film had a tilted shape after the impact, while boxes on the others had moved almost as a solid block, see the photos below.



*Pallet 8, 4 and 7 after the shunting test.*



*Pallet 3 and 8 after the shunting test.*



*Pallet 4 after the shunting test.*



*Pallet 3 after the shunting test.*

Three of the pallets, number 4, 7 and 9, performed better than the rest. On these pallets the plastic film held the cargo and the wooden pallet together well enough to transmit the mass forces to the pallet and they all slid a distance of approximately 100 mm against the wagon floor.

Surprisingly, this was not the case for pallet no 8 which was wrapped with the same amount of plastic as pallet number 9. It may have been wrapped in an inappropriate way or the film may have been damaged during handling, but no imperforations was noted prior to the impact. The pallet may also have been more firmly constrained by the uneven flooring than the rest of the pallets.

In case of pallet number 4 a wooden board was broken and held some of the cargo back. Therefore the shrink film around this pallet was not subjected to as high loads as for the rest of the pallets.

None of the pallets performed well enough to be able to withstand a higher impact speed of somewhere between 8 and 9 km/h, and the tests were thus stopped after only one impact.

## 8.4 Pallet shunting tests 2

These tests were carried out in Malmö 2006-01-10 and the following persons were attending the tests:

Ann-Sofie Edhag	Trioplast AB
Håkan Karlsson	Trioplast AB
Christer Nilsson	Green Cargo
Stanley Öberg	Green Cargo
Peter Andersson	MariTerm AB
Sven Sökjer-Petersen	MariTerm AB

### 8.4.1 Test method

The wagon was to be subjected to two impacts in the same direction but at different speeds and one counter shock in the opposite direction, as prescribed by the Loading Guidelines for Impact Tests.

Since the test wagon did not reach required speed at the second impact test, this impact was repeated once. Therefore the wagon was shunted four times in total.

Apart from the additional impact, the tests were performed in complete compliance with the guidelines.

### 8.4.2 Test wagon

The wagon was a Hbins-type (Hbins 22657759) wagon with rough wooden plank flooring, which upon inspection at the test site was found to be satisfactory dry but rather unclean. The impact wagon (8474 9853 0421) was a bogie wagon with Category A 105 mm stroke buffers, loaded with gravel to a total mass of 80 ton.

### 8.4.3 Test pallets

Nine pallets were tested of which six (number 1 – 6) were rewrapped by Trioplast AB with different amounts of plastic stretch film. Before the six new pallets were transported to Malmö, they were tested by Trioplast and they all survived an inclination of 27 degrees. Data for the plastic wrapping of these pallets are given in the table below.

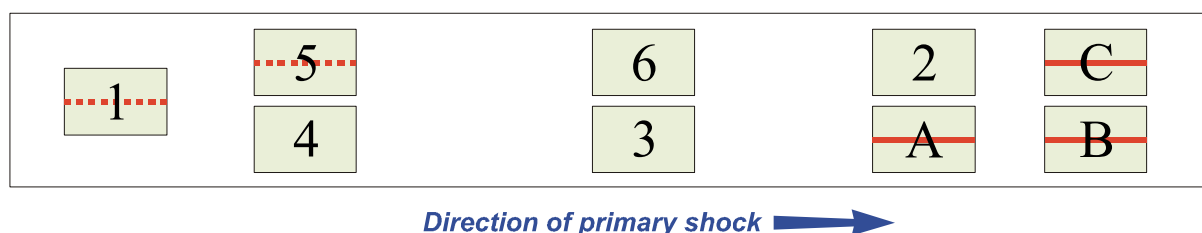
Pallet	Film weight [g]	Type of film
1	833	Pre-tensioned, 20 $\mu\text{m}$
2	780	Pre-tensioned, 20 $\mu\text{m}$
3	700	Pre-tensioned, 20 $\mu\text{m}$
4	500	Blown Coex, 23 $\mu\text{m}$
5	300	Blown Coex, 23 $\mu\text{m}$
6	450 <sup>1)</sup>	Blown Coex, 23 $\mu\text{m}$

<sup>1)</sup> Later after the tests measured to 577 g.

Prior to the tests, it was noted that the film on pallet number 1, 4 and 5 had all some minor damages, caused by the corners of the wooden pallet.

The remaining three pallets (A, B and C) had not been rewrapped for this test and the plastic film on these pallets was all in very poor condition. The boxes on these pallets were therefore secured to the pallet with a lashing.

The figure below illustrates the loading pattern for the nine pallets. The pallets were loaded sparsely over the wagon floor and all pallets were free to slide during the impact test. Their position was marked on the floor prior to the impact tests with crayons.



The red lines in the figure above indicate reinforcements by lashings. The pallets with dotted lines collapsed during testing and were secured at different stages of the testing.

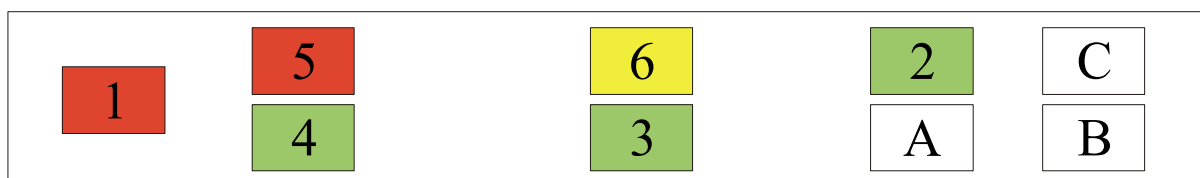
#### 8.4.4 Results

The wagon was shunted four times at different speeds and directions. The last shock was produced by letting the impact wagon run into the test wagon, thus generating a counter shock as prescribed by the Loading Guidelines.

The following speeds were recorded for the impact tests:

Shock no	Impact speed [km/h]	Prescribed speed [km/h]
1	4.5	5 – 7
2	6.7	5 – 7
3	7.8	8 – 9
4 (Counter shock)	10.2	8 – 9

In the figure below the pallets that fully survived all impact tests are marked in green. Pallet number 6 that only showed slight movements of the boxes inside the plastic wrapping is marked in yellow. The pallets that collapsed and needed lashing are marked in red.



Direction of primary shock →

The following movements of the cargo relative to the pallets and of the pallets themselves were noted after each of the four impacts:

Pallet	Shock 1		Shock 2		Shock 3		Shock 4	
	I *	II *	I	II	I	II	I	II
1	20	30	0	195	55	-75	-300	-285
2	130	0	200	0	340	0	-740	0
3	110	0	200	0	280	0	-600	0
4	160	0	215	0	305	0	-535	0
5	0	125	20	-30	250	-5	-350	-90
6	80	0	145	5	245	15	-520	-20
A	80	0 **	150	0	240	0	-530	0
B	95	0	165	0	280	0	-520	0
C	115	0	175	0	220	0	-500	0

- \* In the table above movements for each shock is given in two separate columns:
- I The column marked **I** gives the movement in **mm** of the **wooden pallet against the floor** during each shock.
  - II The column marked **II** gives the movement in **mm** of the **bottom layer against the pallet** during each shock.

\*\* The cardboard boxes on the pallets A, B and C were secured to the wooden pallet by the means of a web lashing, as seen in the photos below. The cells in the column for the movement of the cargo against the pallet (II) are therefore shaded for these pallets.

Pallet number 5 was secured after the first impact and pallet number 1 after the second. The cells where the movement of the cargo against the pallet is noted are therefore shaded for the subsequent tests.





*Pallet A after shock 2.*



*Pallet 1 after shock 4.*



*Pallet 4 and 5 after shock 4.*

Pallet number 2, 3 and 4 showed no dislocations of the cargo against the wooden pallet after any of the impacts. They all slid considerable distances over the wagon floor.

The cargo on pallet number 6 moved very little and this pallet can be considered to have passed the test just barely. Since the rough flooring on this wagon provided the toughest conditions likely to be experienced during railway transport, the amount and quality of the plastic film around this pallet can be said to set the limit for what requirements that shall be imposed on palletising methods. This pallet shall therefore be used to establish a proper test procedure by other means of testing, an inclination test. (See section 8.6)

Pallet number 5 was wrapped with the least amount of plastic film, and it was also the first one to collapse, already at the first, low speed impact. It can also be noted that damages to the film around the corners of the wooden pallet were noted prior to the test.

Even though pallet number 1 was wrapped with the most amount of plastic film of all the pallets in the test, it collapsed during the second impact. The pallet was very reluctant to move against the wagon floor even after the cardboard boxes had been tied to the wooden pallet and it was probably experiencing a higher friction force than the rest of the pallets. Considering the roughness of the wagon floor and the wooden pallet it may even be considered to be on

the verge of mechanical locking. Also, slight damages to the film around the corners of the wooden pallet were noted prior to the test and this in combination with it's reluctance to move, may be the explanation for why the plastic yielded.



*Pallet 5 after shock 1.*



*Pallet 3 after shock 1.*



*Pallet 3 after shock 4.*



*Pallet 3 and 6 after shock 4.*

## 8.5 Pallet shunting tests 3

In these shunting tests, carried out in Malmö 2006-02-23, one freight wagon with eight shrink and stretch hood pallets were shunted at different speeds and directions. The following persons were attending the tests:

Christer Nilsson	Green Cargo
Stanley Öberg	Greed Cargo
Peter Andersson	MariTerm AB
Sven Sökjer-Petersen	MariTerm AB
Petra Hugoson	MariTerm AB
Peter Madsen	Lachenmeier A/S
Lars Erik Krarup	Trioplast A/S

Georg Tegstam  
Thomas Tegstam

Tetec Trading AB  
Tetec Trading AB

### 8.5.1 Test method

The wagon was subjected to two impacts at different speeds but in the same direction and one counter shock in the opposite direction, as prescribed by the Loading Guidelines for Impact Tests above.

### 8.5.2 Test wagon

The wagon was a Hbillns-type (2472341-9) with wooden flooring and 105 A buffers. The floor of the wagon was dry and clean. The impact wagon (8474 9853 0421) was a bogie wagon with Category A 105 mm stroke buffers, loaded with gravel to a total mass of 80 ton.

### 8.5.3 Test pallets

The load consisted of 8 wooden pallets with cardboard boxes. These pallets were covered; half of them with shrink hoods of 4 different thicknesses and the other half with stretch hoods of different number of extra plastic layers on the top respectively on the bottom of the pallets, see the table below.

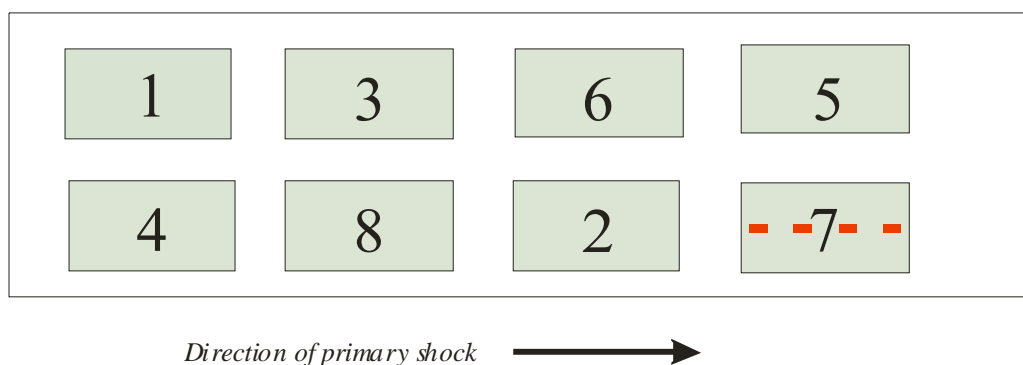
Pallet	Type of wrapping	Thickness of the film [ $\mu\text{m}$ ]	Weight of the film [g]	Number of extra layers
1	Shrinkhood	100	870 <sup>1)</sup>	-
2	Shrinkhood	120	1044 <sup>2)</sup>	-
3	Shrinkhood	150	1305	-
4	Shrinkhood	180	1566	-
5	Stretchhood	70	555	3 layers at the bottom
6	Stretchhood	70	650	6 layers at the bottom
7	Stretchhood	70	715	3 layers at the bottom 3 layers at the top
8	Stretchhood	70	865 <sup>3)</sup>	6 layers at the bottom 6 layers at the top

<sup>1)</sup> Later after the tests measured to 697 g.

<sup>2)</sup> Later after the tests measured to 850 g.

<sup>3)</sup> Later after the tests measured to 882 g.

None of the pallets were secured to the wagon. The figure below illustrates the load pattern for the eight pallets. The pallets were stowed sparsely over the wagon floor and all pallets were free to slide during the impact tests. Their position was marked on the floor prior to the impact test with crayons.



The pallet with dotted red line collapsed during testing and was secured after the first impact.

There was a lengthwise rip half way up on pallet number 8 and a foot was missing on the wooden pallet number 6.



*Pallet 5 and 7 in the foreground before shunting.*



*Pallet 7 in the foreground before shunting.*

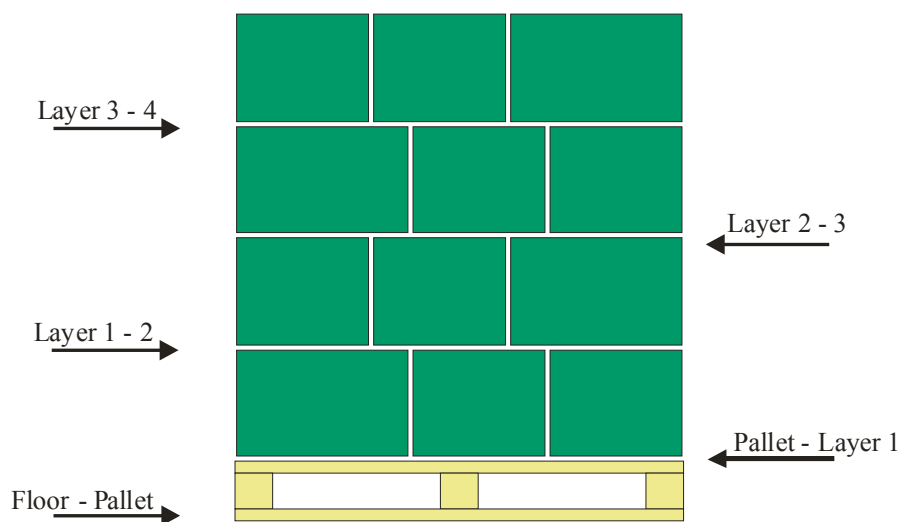
The wagon was subjected to 3 shocks. The first two shocks were produced by letting the wagon hit a counter weight wagon. The third shock was produced by letting the counter weight wagon run into the test wagon in the opposite direction to the two initial shocks.

The following speeds were recorded for the impact tests:

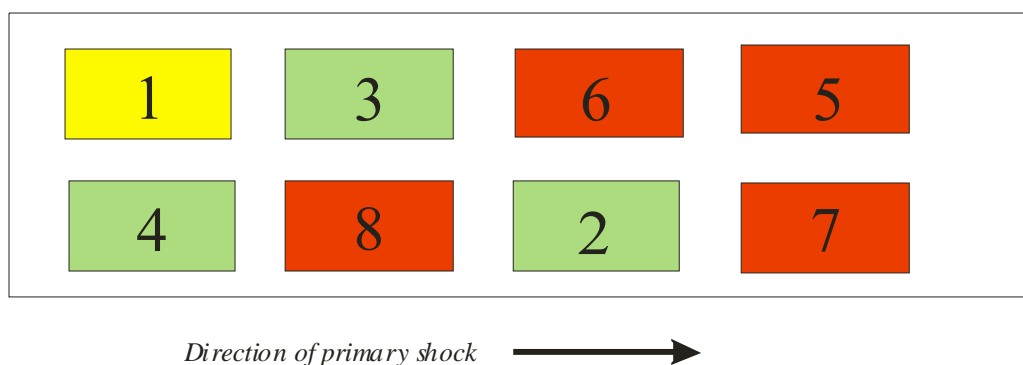
Shock no	Impact speed [km/h]	Prescribed speed [km/h]
1	5.5	5 – 7
2	9.7	8 – 9
3 (Counter shock)	8.7	8 – 9

#### 8.5.4 Results

The dislocation of the pallets was inspected after each shock and the lengthwise movement and direction was recorded. The movement was measured between the wagon floor and pallet, the pallet and the first layer and between the other layers, according to the figure below.



In the figure below the pallets that fully survived all impact tests are marked in green. Pallet number 1 that only showed slight movements of the boxes inside the plastic wrapping is marked in yellow. The pallets that showed significant movement of the cargo or totally collapsed are marked in red.



In the tables below the movements are recorded in millimetres and with a “-“ for a movement backward in the wagon in relation to the direction of the primary shock. The tables show the movement after each shock and, at the end of the tables, the accumulated moved distance after all three shocks.

## Shrink hood pallets

### Pallet 1

Film weight: 870 g  
 Measured weight: 697 g  
 Film thickness: 100 µm

Shock	Speed [km/h]	Measured dislocation of pallet 1 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	50	80	0	0	0
2	9.7	880	10	0	0	0
3*	8.7	- 830	- 80	0	0	0
Accumulated [mm]		100	10	0	0	0

### Pallet 2

Film weight: 1044 g  
 Measured weight: 850 g  
 Film thickness: 120 µm

Shock	Speed [km/h]	Measured dislocation of pallet 2 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	130	0	0	0	0
2	9.7	970	0	0	0	0
3*	8.7	- 1050	0	0	0	0
Accumulated [mm]		50	0	0	0	0

### Pallet 3

Film weight: 1305 g  
 Film thickness: 150 µm

Shock	Speed [km/h]	Measured dislocation of pallet 3 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	100	20	0	0	0
2	9.7	910	10	0	0	0
3*	8.7	- 1100	- 30	0	0	0
Accumulated [mm]		- 90	0	0	0	0

### Pallet 4

Film weight: 1566 g  
 Film thickness: 180 µm

Shock	Speed [km/h]	Measured dislocation of pallet 4 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	130	0	0	0	0
2	9.7	690	40	0	0	0
3*	8.7	- 650	- 80	0	0	0
Accumulated [mm]		170	- 40	0	0	0

**Stretch hood pallets:****Pallet 5**

Film weight: 555 g  
 Film thickness: 70 µm  
 Number of extra layers: 3 at the bottom

Shock	Speed [km/h]	Measured dislocation of pallet 5 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	0	50	35	30	0
2	9.7	590	90	25	10	20
3*	8.7	- 140	- 260	- 140	- 60	- 30
Accumulated [mm]		450	- 120	- 80	- 20	- 10

**Pallet 6**

Film weight: 650 g  
 Film thickness: 70 µm  
 Number of extra layers: 6 at the bottom

Shock	Speed [km/h]	Measured dislocation of pallet 6 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	0	0	50	20	0
2	9.7	540	40	20	0	0
3*	8.7	- 320	- 40	- 110	- 20	0
Accumulated [mm]		220	0	- 40	0	0

**Pallet 7**

Film weight: 715 g  
 Film thickness: 70 µm  
 Number of extra layers: 3 at the bottom; 3 on the top

Shock	Speed [km/h]	Measured dislocation of pallet 7 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	0	40	50**	0	0
2	9.7	-	0	0	0	0
3*	8.7	-	0	0	0	0
Accumulated [mm]		- 40	0	0	0	0



**Pallet 8**

Film weight: 865 g  
 Measured weight: 882 g  
 Film thickness: 70 µm  
 Number of extra layers: 6 at the bottom; 6 on the top

Shock	Speed [km/h]	Measured dislocation of pallet 8 [mm]				
		Floor – Pallet	Pallet – Layer 1	Layer 1 – 2	Layer 2 – 3	Layer 3 – 4
1	5.5	0	40	0	0	0
2	9.7	280	0**	0	0	0
3*	8.7	- 10	0	0	0	0
Accumulated [mm]		270	0	0	0	0

\* Counter shock

\*\* The pallet collapsed and the cells in the columns for movements of the boxes against the wooden pallet and against each other are therefore shaded.

During the first shock pallet 7 collapsed and to prevent the boxes to be all over the wagon floor the cardboards were secured to the wooden pallet by the means of a web lashing, see the photos below.



*Pallet 7 to the left before shunting.*



*Pallet 7 after shock 1.*



*Pallet 7 after the first shock.*



*Pallet 7 secured to the wooden pallet by lashing.*

During the second shock the cardboard boxes on the wooden pallet number 8 fell off. When the counter weight wagon ran into the test wagon, in the opposite direction of the two initial shocks, the boxes went back upon the wooden pallet again. See below photos.



*The collapse of pallet 8 after shock 2.*



*The collapse of pallet 8 and the jump back of the cargo on the pallet during the counter shock.*

Pallet number 2, 3 and 4 hardly showed any dislocations of the cargo, neither against the wooden pallet nor against each other, after any of the impacts. However, they all slid considerable distances over the wagon floor.

The cargo on pallet number 1 showed marginal movements and this pallet can be considered to have passed the test just barely. This pallet will therefore be used in the inclination test, see section 8.6.

The pallets 5 – 8 were covered with different numbers of stretch hoods and independent of the number of hoods significantly movements among the cardboard boxes were noted. Even though pallet number 7 was covered with 3 hood layers both on the top and at the bottom, it collapsed already during the first impact.

Pallet number 8 that was covered with the largest numbers of hood layers, 6 layers both on the top and at the bottom of the pallet, collapsed at the second impact. It can be noted that a lengthwise rip half way up the pallet was found prior to the tests and that this rip may be the explanation for why the stretch hoods yielded totally.



*Pallet 2 in the middle of the photo after the first shock.*



*Pallet 8 after shock 1.*



*A close-up of pallet 8 in the foreground to the left and pallet 6 in the background to the right after shock 1.*



*Pallet 8 after the second shock.*





*Pallet 1 after shock 2.*



*Pallet 1 after the counter shock.*

## 8.6 Inclination test 2

The last tests with plastic film were performed as inclination tests in Helsingborg 2006-02-28 and attending were:

Peter Andersson	MariTerm AB
Sven Sökjer-Petersen	MariTerm AB
Petra Hugoson	MariTerm AB
Ronny Romare	Börje Jönssons Åkeri

### 8.6.1 Test method

Exactly like the inclination tests described in section 8.2 three pallets were inclined on a vehicle platform until the plastic film around the pallets started to yield and the palletized cargo were on the brink of collapsing. The inclination was halted at intervals and the dislocation of the cargo was measured at three different heights. The pallets were bottom blocked by means of a wooden batten nailed to the platform floor, so that they were unable to slide along the platform.

In a second set of tests, the coefficients of friction between the cardboard boxes and the pallet, as well as between the boxes themselves, were determined through inclination tests.

### 8.6.2 Test pallets

In these tests two of the pallets with shrink hoods that were on the brink of collapsing in the shunting tests described in section 8.5 and one stretch wrapped pallet from the shunting tests described in section 8.4 were tested on the vehicle platform. The shrink hoods were supplied by Lachenmeier A/S and were 100 respectively 120 µm thick and weighed according to the manufacturer 870 g respectively 1044 g. After the tests the plastic packages were taken off and measured to 697 g respectively 850 g. The stretch film was of thickness 23 µm with a weight of 450 g wrapped by Trioplast AB. This plastic package was after the tests measured to 577 g.

### 8.6.3 Results

Below the measurements of the dislocations of the cardboard boxes is listed for different angles of inclination. Apart from the measured distance from the closest point of the pallet to the barrier at different heights A, B and C, the calculated movement from the original position is given for all pallets.

Where the comment “Collapsed” is given in the tables below, the boxes were showed a major movement or sliding against the wooden pallet. In some cases the boxes were moving at such speeds that measurement of the distances was not possible to carry out.

### Shrink hood pallets

#### Pallet 1

Film weight: 870 g  
 Measured weight: 697 g  
 Film thickness: 100 µm

Inclination [degrees]	Distance to barrier [mm]			Accumulated movement [mm]			Comment
	A	B	C	A	B	C	
0	210	210	215	0	0	0	
15	210	210	215	0	0	0	
20	210	210	210	0	0	5	
25	205	200	195	5	10	20	
30	175	165	165	35	45	50	
32	-	-	-	-	-	-	<b>Collapsed</b>



*Pallet 1 before testing.*



*Pallet 1 before testing.*



*Pallet 1 before testing.*



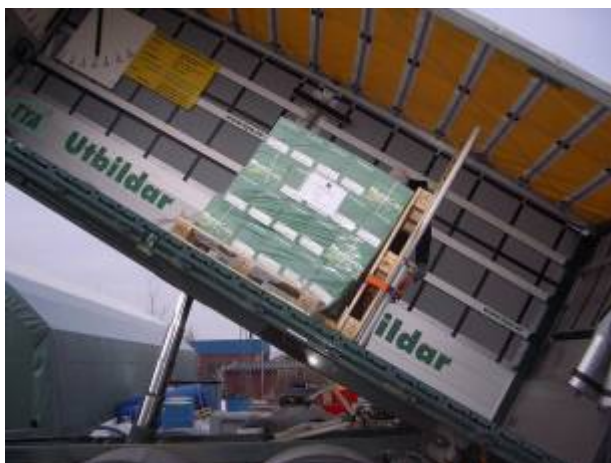
*Pallet 1 at an inclination of 20 degrees.*



*Pallet 1 at 25 degrees inclination.*



*Pallet 1 at 30 degrees inclination.*



*The collapse of pallet 1 at 32 degrees inclination.*

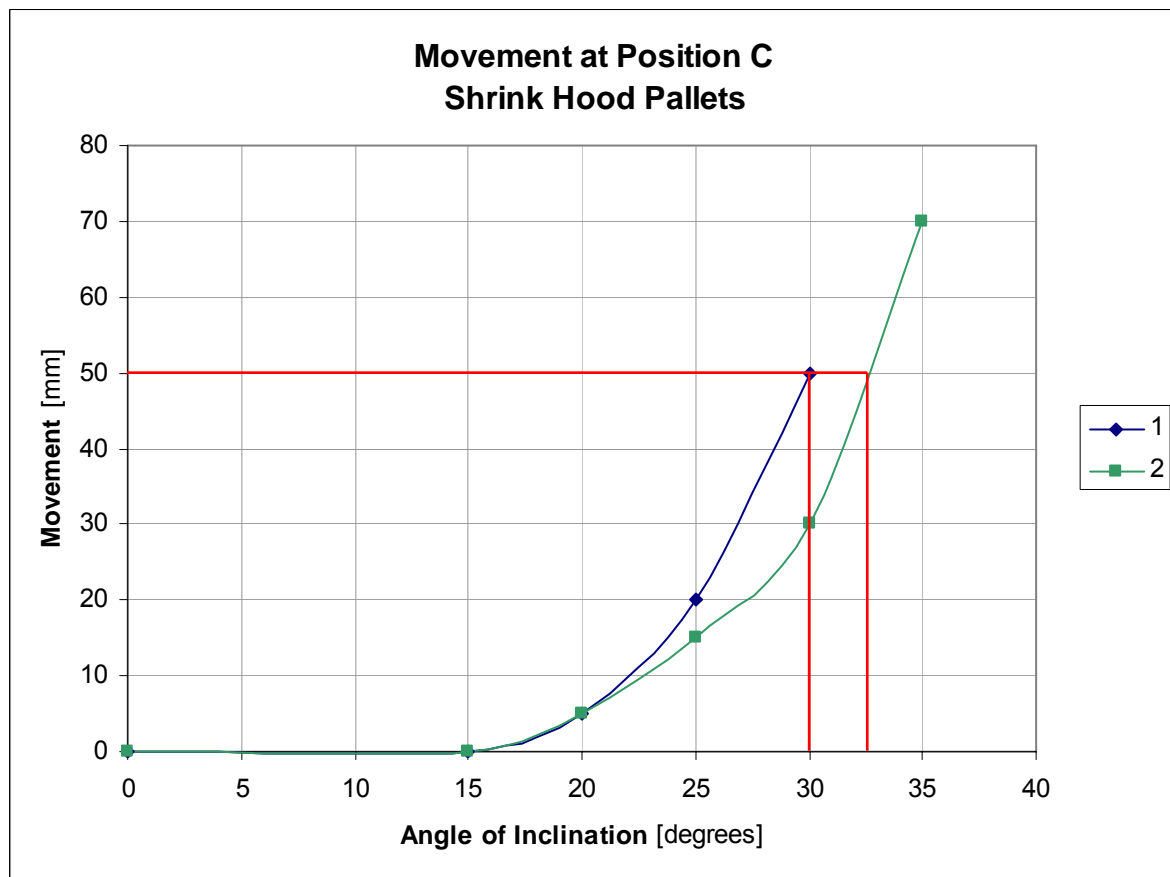
## Pallet 2

Film weight: 1044 g  
 Measured weight: 850 g  
 Film thickness: 120  $\mu$

Inclination [degrees]	Distance to barrier [mm]			Accumulated movement [mm]			Comment
	A	B	C	A	B	C	
0	210	210	210	-	-	-	
15	210	210	205	0	0	0	
20	210	210	205	0	0	5	
25	205	200	195	5	10	15	
30	195	185	180	15	25	30	
35	165	145	140	45	65	70	Near the brink of collapsing



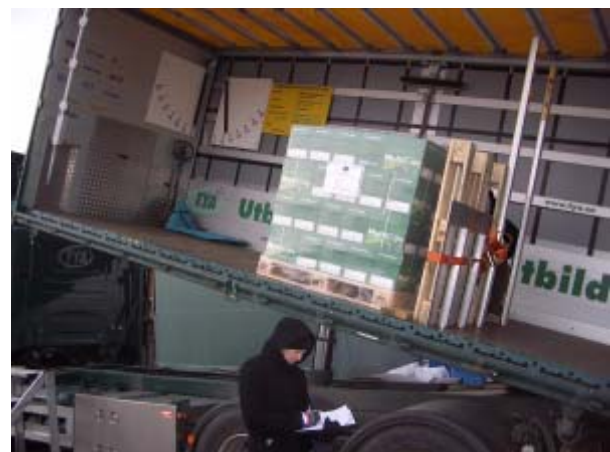
## Comparison of movement between the shrink hooded pallets



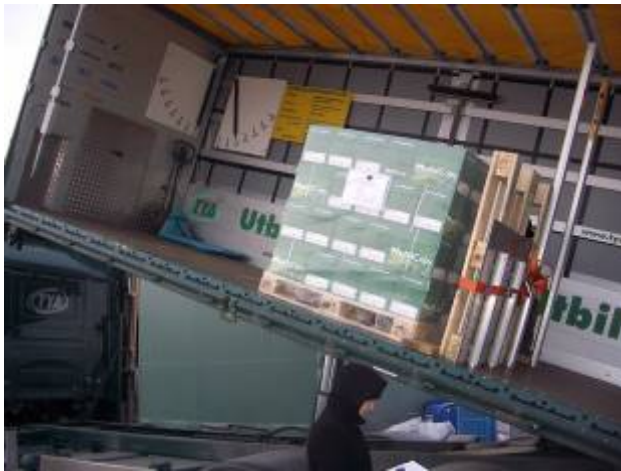
Pallet 1 with the least plastic material withstood an inclination of approximately 30 degrees with limited movements in the cargo of about 50 mm at the top of the cargo. Pallet 2 reached about 32 degrees when the cardboard boxes in the top layer had moved approximately 50 mm from their original position. A motion of about 50 mm in the top of this somewhat non rigid type of cargo is reasonable as a limit value.



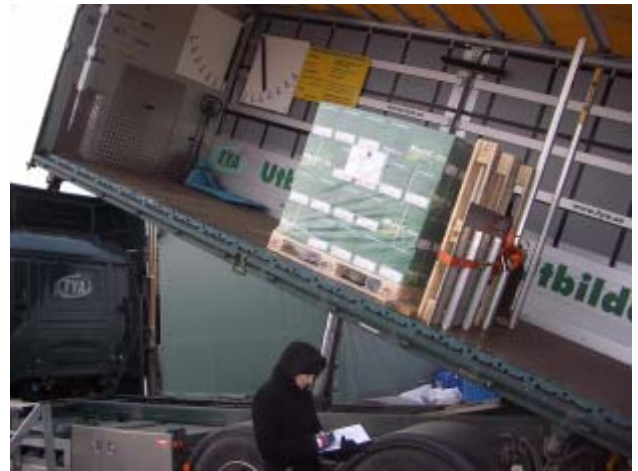
*Pallet 2 before inclination.*



*Pallet 2 at 15 degrees inclination.*



*Pallet 2 at 20 degrees inclination.*



*Pallet 2 at 25 degrees inclination.*



*Pallet 2 at 30 degrees inclination.*



*Pallet 2 at 36 degrees inclination.*



*36 degrees inclination and near the brink of collapsing of pallet 2.*

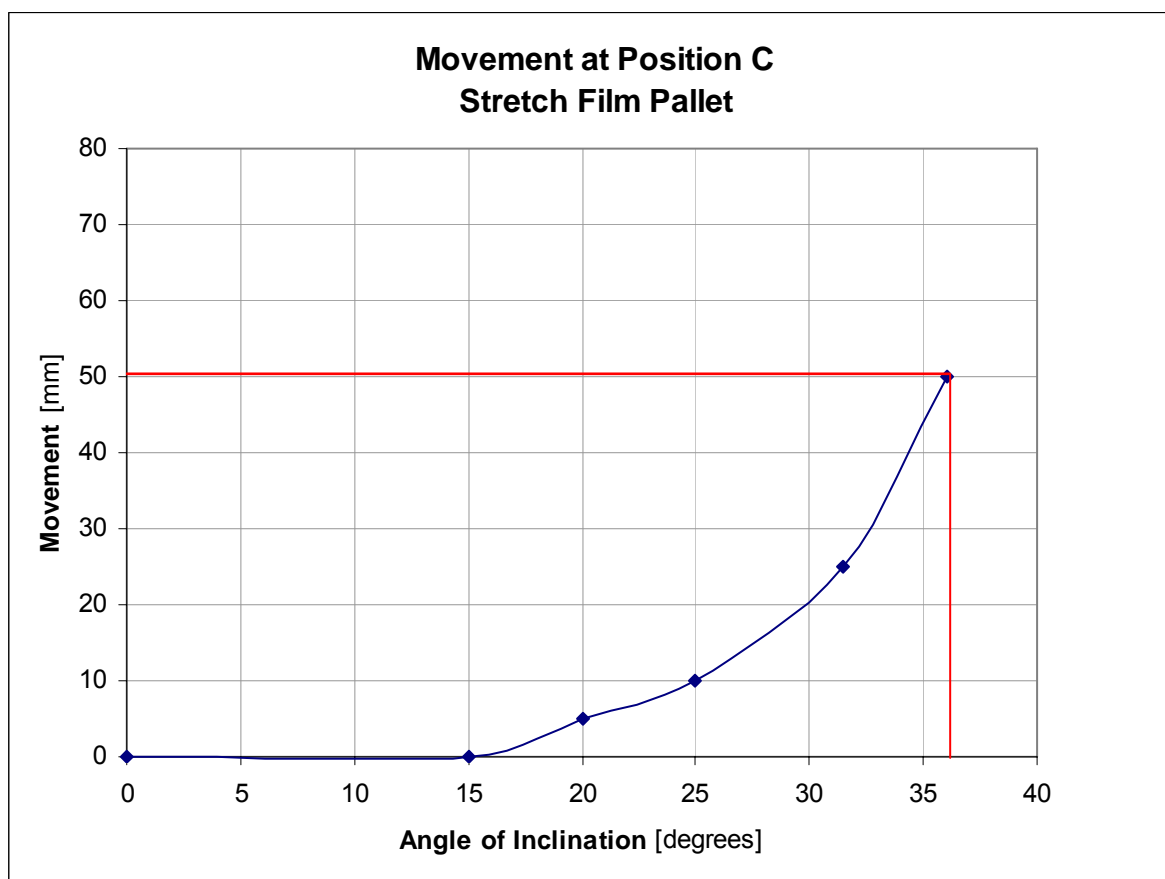
## Stretch film pallet

### Pallet 6

Film weight: 450 g  
Measured weight: 577 g  
Film thickness: 23  $\mu\text{m}$ , Blown Coex

Inclination [degrees]	Distance to barrier [mm]			Accumulated movement [mm]			Comment
	A	B	C	A	B	C	
0	230	230	210	0	0	0	
15	230	230	210	0	0	0	
20	230	225	205	0	5	5	
25	230	225	200	0	5	10	
31,5	220	210	185	10	20	25	
36	210	185	160	20	45	50	<b>Collapsed</b>

### Movement of the wrapped stretch film pallet



This pallet wrapped with 577 g stretch film started tilting at 36 degrees and the boxes in the top layer had at this point moved approximately 50 mm from their original position. As seen in the photos below, the pallet was only slightly deformed, but the whole pallet was at this

position on the brink of tipping over. This is in compliance with the result from the initial inclination test where pallet number 3 wrapped with 585 g stretch film showed about the same strength.



*Pallet 6 at an inclination of 20 degrees.*



*Pallet 6 still at inclination 20 degrees.*



*Inclination of 36 degrees of pallet 6.  
The pallet is near the brink of tipping.*

#### 8.6.4 Friction tests

In order to determine the coefficient of friction between the cardboard boxes and the wooden pallet, a box was removed from one of the previously tested pallets, so that the box was completely free to move against the wooden pallet. The platform was inclined until the box started to slide and the angle was measured.

In order to determine the friction between the cardboard boxes, one cardboard box was placed on top of another cardboard box and the platform inclined until the box started to slide.

Material contact	Angle of inclination	Coefficient of friction
Cardboard boxes against pallet	25.5	0.48
Cardboard box against cardboard box, test 1	22.0	0.40





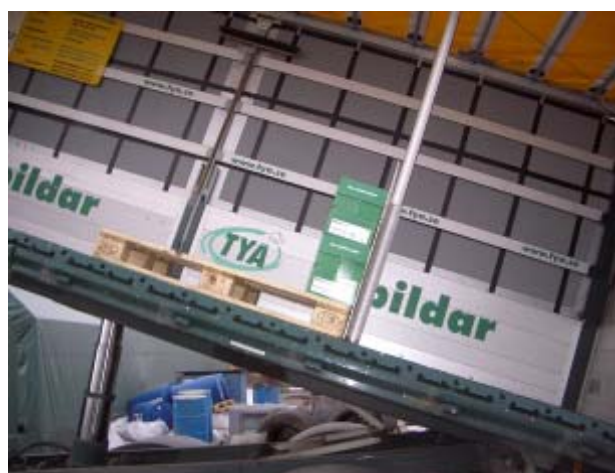
*The cardboard box on the wooden pallet for determination of the coefficient of friction.*



*Inclination until the box started to slide along the platform.*



*Determination of the friction between two cardboard boxes.*



*The box on the top started to slide at an inclination of 22 degrees.*

## 8.7 Summery and conclusions of the pallet tests

The aim with the shunting and inclination tests was to compare the methods and the amount of plastic material to make a recommendation regarding limit values for inclination angles to be used when testing suitability for railway transport.

The results of the first inclination test were somewhat disappointing. The stretch and shrink hood pallets were damaged prior to the tests and thus the results were misleading and not showed in this report.

Also the second test, the first shunting test with the pallets, was disappointing. Although the stretch wrapped pallets were free standing and allowed to slide on the wagon floor, the film around all nine pallets yielded already at an impact speed of 5.3 km/h, allowing the cargo on the pallets to move considerable. Due to their weak performance, the pallets could never be tested at the by UIC prescribed impact speed of at least 8 km/h, and the tests had to be terminated.

The first shunting test was remade with six pallets with a different and stronger film configuration. In this second shunting test three of the six stretch wrapped pallets showed no dislocations of the cargo at all after the tests. The plastic film around two pallets yielded during testing out of which one was deemed to be just on the limit. This test was thus a great success as a limit for required amount of plastic packaging material needed to withstand a shunting test was obtained.

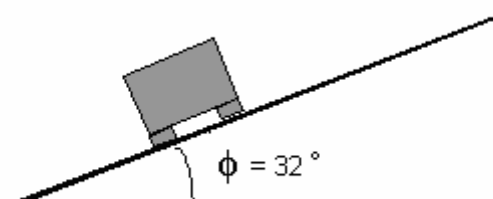
The amount and quality of the plastic film around pallet 6, the reference pallet (23 µm film thickness and measured to 577 g plastic material in total) can be said to set the limit for what requirements that shall be imposed on palletising methods. This pallet was therefore tested in the second inclination test.

In the third and last shunting test eight pallets with plastic packages, shrink and stretch hood pallets were shunted just like prescribed in the Loading Guidelines. The cargo on the four stretch hood pallets all moved significantly and two of them even collapsed. Three out of four shrink hood pallets wonderfully passed the tests. Pallet number 1, covered with a 100 µm thick shrink hood, only showed marginal movements of the cargo and this pallet can be considered to have passed the test just barely. This pallet, together with the pallet number 2 covered with 120 µm thick shrink hood and the stretch wrapped pallet number 6 from the second shunting test were inclined in the last test.

The three pallets described above showed a limited movement on the top of the cargo of about 50 mm at the following inclinations:

Pallet	Inclination [degrees]	Packaging technique	Amount of plastic material according to the manufacturer [g]	Measured amount of plastic material [g]
1	30	Shrink hood 100 µm	870	697
2	32	Shrink hood 120 µm	1044	850
6	36	Stretch film 23 µm	450	577
<b>Mean</b>	32			

The conclusion of these tests is that if a plastic packaging of palletised cargo survives an inclination of 32 degrees it will also survive the shunting test prescribed by the Loading Guidelines. This requirement seems to be more relevant than the existing prescribed 150 µm film thickness without any specifications of other parameters such as strength, stretch, etc.



The inclination of 32 degrees is valid for free standing pallets on a rough wood floor. If the floor instead consists of smooth plyfa flooring the required inclination will decrease and if the pallets on the other hand are bottom blocked without support for the cargo on the pallet, the

angle will increase considerably. If the pallets are closely stowed the demand of packaging is of minor importance. There is no reason way this test method could be used also for other types of packaging techniques for freestanding cargo for rail transport.

As can be seen from the table above the stretch film technique required less plastic material to obtain the required strength than the shrink hood technique. None of the stretch hooded pallets withstood the shunting test, although up to 882 g plastic material was used. However, it is important to check that the cargo on pallets wrapped with stretch film can stand the pressure from the stretch film without being deformed.





## 9 COST ESTIMATE FOR IMPROVED TRANSPORT QUALITY

The additional costs associated with fitting new wagons with sophisticated equipment for improved running and shunting characteristics have been evaluated. The costs are compared to those for a wagon equipped with standard Y25 bogies and Category A, 105 mm stroke buffers, see description in Chapter 4.

The calculations are based on an order of some 250 wagons. Only the direct investments have been considered in this calculation. The weight of different concepts influences the cargo carrying capacity of the wagon, but on the other hand, wagons with more sophisticated running gear may in the future allow greater axle loads, lower track fees and higher train speeds. Since it is not possible to predict these aspects, they have been disregarded in these calculations.

The following costs for equipment are used in the calculations:

<b>Running gear</b>	<b>Cost</b>
<i>Y25 bogie</i>	<i>95.000 SEK</i>
<i>TF25 bogie</i>	<i>215.000 SEK</i>
<i>In a near future anticipated resilient running gear</i>	<i>125.000 SEK</i>
<b>Buffers</b>	<b>Cost</b>
<i>Category A, 105 mm stroke buffer, 4 pieces</i>	<i>15.000 SEK</i>
<i>Long stroke buffer arrangement</i>	<i>90.000 SEK</i>

The additional costs, including 5% interests over 25 years with equal annual instalments, have been calculated for two different wagon configurations:

<b>Wagon configuration</b>	<b>Additional cost</b>
<i>Wagon with TF25 bogie and long stroke buffers</i>	<i>547.000 SEK</i>
<i>Wagon with future running gear and long stroke buffers*</i>	<i>219.000 SEK</i>

(\* There are indications that modern types of running gear will be available in the marked in a near future at reasonably low prices.)

The total expected load to be carried by one wagon throughout its lifetime has been calculated based on a middle long transport according to the following figures:

<i>Life expectance</i>	<i>25 years</i>
<i>Roundtrips per year</i>	<i>50 trips</i>
<i>Average load per trip</i>	<i>50 tons</i>
<b><i>Total load carried during lifetime</i></b>	<b><i>62.500 tons</i></b>

The additional cost for each wagon configuration is then calculated per ton carried during the full lifetime of a wagon:

**Wagon configuration****Additional cost***Wagon with TF25 bogie and long stroke buffers**8.75 SEK/ton**Wagon with future running gear and long stroke buffers**3.50 SEK/ton*

The additional costs per ton may then be compared with different cargo values per ton for different rolling stock categories.

**Cargo type****Wagon configuration**

		<i>Wagon with TF25 bogie and long stroke buffers</i>	<i>Wagon with future running gear and long stroke buffers</i>
<i>Low value</i>	<i>10.000 SEK/ton</i>	<i>0.088 %</i>	<i>0.035 %</i>
<i>Middle value</i>	<i>50.000 SEK/ton</i>	<i>0.018 %</i>	<i>0.007 %</i>
<i>High value</i>	<i>200.000 SEK/ton</i>	<i>0.004 %</i>	<i>0.002 %</i>

From the statistics available, it is not possible to draw any general conclusions about the costs caused by breakage during transit, per ton goods or as a percentage of the cargo value, for all types of cargo transported on railway.

Furthermore, there is no guarantee that the more expensive wagons will eliminate all damages to the cargo during transit.

In one example in the statistics evaluated in Chapter 3.2.1, the costs for damages associated with improper stowage and securing of paper products from one single mill, was concluded to be 0.029 % of the cargo value. This indicates that the suggested investments will only be motivated for middle and high value cargo, but they may very well be necessary in order just to attract those types of cargo.

It is however concluded that if the railway shall be seen as an alternative to transportation by modern air suspended vehicles when it comes to transport quality technical improvements must be considered also on railway wagons.







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