

Performance Improvement for Vehicles On Track

D1.1 Technical Revision of Inputs Developed in Previous Project

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Glossary

Abbreviation / acronym	Description
(C)FRP	(Carbon) Fibre Reinforced Plastic
CSM	Common Safety Method
DTS	Damage Tolerance Strategy
EMC	Electromagnetic compatibility
FST	Fire, Smoke and Toxicity
FSW	Friction Stir Welding
LCC	Life Cycle Cost
NDT	Non Destructive Tests
NVH	Noise, Vibration and harshness
OC	Open Call
REFRESCO	Towards a REgulatory FReamework for the usE of Structural new materials in railway passenger and freight CarbOdyshells
S/N	Stress vs. no. of cycles
SHM	Structural Health Monitoring
TD	Technological Demonstrator
TRL	Technical Readiness Level
VHST	Very High Speed Train
WP	Work Package

1 Executive summary

This deliverable is a summary of the previous funded projects related with carbodies and lightweight design: REFRESCO and Work Package 3 of Roll2Rail.

It will be presented the main technical conclusions obtained in the projects maintaining the same structures of each ones for setting a baseline for all the partners involved in the TD1.3 of Shift2Rail.

REFRESCO is devoted to set the framework for the implementation of new materials in the railway sector providing recommendation to afford the certification processes for rolling stock.

The WP3 of Roll2Rail is focused on setting the basement for the preliminary stages of the next generation of carbodies shells.

2 Introduction

The main objective of WP1 of PIVOT is to define the material, joints and manufacturing process to be used during the build-up of demonstrator.

Due to these issues has been conceptually treated in previous projects like REFRESCO and Roll2Rail, it is important to create a common baseline of knowledge regarding the past experience with the topic for all the partners involved in PIVOT.

It will be summarised information about materials, structural requirements maintenance or joints.

3 REFRESCO Project

REFRESCO or Towards a REgulatory FRamework for the use of Structural new materials in railway passenger and freight Carbodyshells was European funded Project in European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 605632.

REFRESCO was a thirty-month project coordinated by UNIFE, the association of the European rail industry. It has a budget of approximately €4.7 million. It began on September 1st 2013, and run until February 2016.

The overall objective of REFRESCO was to set the framework for the implementation of new materials in the railway sector through the evolution of certification processes for rolling stock. REFRESCO generated recommendations and provide the information needed to adapt the regulatory framework of railway carbody structures to the introduction of new materials.

These are the issues that were identified as critical for the future development of lightweight primary structure.

- Fire and smoke performance/Noise and Vibration performance/Electromagnetic Compatibility issues (WP3);
- Structural resistance and fatigue analysis (WP4);
- Crashworthiness (WP5);
- Joint and Manufacturing (WP6);
- Prognostic and Health Management (WP7);
- Reparability and Maintainability (WP8).

3.1 Materials and benchmarking

In the WP2 ("Materials Benchmarking and Gap Analysis") were benchmarked material solutions available in railway and other sectors. It also looked at rail certification processes and standards to find out if any gap that might affect future composite applications in the railway sector.

This exercise was carried out to understand what materials are used in rail and for which applications. It turns out that the rail industry makes extensive use of metals and a minor use of composites compared to other sectors, especially for structural parts. A survey was made to learn about which structural materials are used in other sectors such as aeronautic, automotive, wind farming and others. A database of these materials has been compiled including their main uses and properties.

Based on this database a decision tool was created. It consists of a matrix where material properties and uses can be filtered by the manufacturer to find the best combination available. The choice was made to keep the studied materials range as wide as possible in order to avoid hastily discarding materials with good potential.

Carbon fibre (a combination of high strength and stiffness) with structural resins is the most promising combination to achieve the objective of weight reduction. The uses of new carbon fibre

reinforced plastics (CFRP) in the automotive sector are reducing the price of the raw material making affordable for the railway market. This combination can be used under the shape of monolithic or sandwich (foam or honeycomb) material.

Regarding the certification process the Common Safety Method (CSM) was used to identify the relevant standards. It is a risk based approach with a harmonisation of assessment methodologies which contributes to improving mutual recognition. This safety based method can be coupled with the identification of the functional requirements to estimate the impact on the railway system when composite materials for rolling stock carriages are introduced.

The CSM gives a harmonised framework for the risk assessment process through the prescription of Hazard Identification, Risk Analysis and Risk Evaluation. The regulation gives a broad framework for the use of risk assessment methodologies to assess changes to the railway system. It allows the proposer, without prescribing any order of priority, to use interchangeably among three risk acceptance principles already in place such as acknowledged codes of practice and reference systems, or explicit risk estimation for the acceptance of the risks related to the change.

3.2 Fire, NVH and EMC

Today no major structural parts of the new carriage shell are made from composites, so there are currently only a few composite materials certified according to EN45545.

With the growing demand for lightweight structures it is expected that composites with good mechanical and FST properties will enter the market.

As carbon fibres have good fire protection properties, it is mainly the resin that has to be improved regarding fire. Usually epoxy resins are used for structural parts but they lack good fire protection properties. Suitable resins have been identified, such as Cyanate Ester, special epoxy and Polybenzoxazine, but this topic will be treated by the OpenCall (OC) Mat4Rail of the PIVOT Project.

Regarding NVH which concerns the passengers' comfort, a review of literature and numerical modelling revealed the advantages and drawbacks of composites. The acoustic disadvantages due to a lower mass and a higher stiffness in comparison to metallic structures can be faced by a higher damping with sandwich cores, a better design of joints and a choice among many parameters to design an optimal solution.

Negative impacts have been identified on the return current and on thermo-mechanical effects of arcing. A possible way to mitigate these effects is, for example, favouring hybrid (metal/composite) structures if a good conductivity is necessary. The EMC approach recommended multi-material carriage structure mainly for roof (current return) and underframe (radiation).

3.3 Structural Strength

The main objective of work package dedicated to structural analysis was to understand the structural requirements concerning issues, such as fatigue, arising from the replacement of metal with high performance composite materials in rail carriage shells. The goal was achieved by studying the existing standards such as EN 12663 to see which parts are applicable and which

ones need an update, and by developing a logic procedure for the material characterization and analysis. The process was applied in two different examples, but there were no real tests for validating it. The test that was carried helped to obtain material characteristics.

The work was carried out in three different steps:

- First, material characterization and modelling procedures for the new structural materials were defined. This work was decisive for the simulation of the different load scenarios using finite elements in order to predict correctly the behaviour of the structure. Different tests were carried out and the minimum number of specimens was defined. . The safety factors according to the loading control, uncertainties and the maturity of the program were defined.
- The second step focused on the calculation and testing of the responses of structures manufactured using new materials under static loadings. The different existing criteria were analysed and the most suitable was chosen. The applicability of the procedure was validated. Besides, the effect of different phenomena such as cut fibres, delamination or environment was addressed. Finally, new procedures for testing such structures have been designed. The testing pyramid has been selected as the most adequate testing process.
- The third step focused on the calculation and testing of structures manufactured with new materials under different fatigue loadings. The applicability of the methodology was validated by applying it on existing structures. The effects of different phenomena such as cut fibres, delamination or environment in the case of fatigue were investigated. A study of manufacturing defects as well as ballast projection effects was carried out. Finally, new procedures for testing such structures were designed. As in the case of the fatigue analysis, the testing pyramid was found to be the most suitable testing process.

Regarding the standard, it is necessary to modify the EN 12663 to allow the consideration of composite for static and fatigue tests and calculations. In addition additional safety factors should be considered taking into account the experience of other industries. A standard or recommendation sheet for testing would be advisable for assessing the numerical simulation for railway applications.

3.4 Crash

The design rules of a crashworthy rail vehicle in Europe are defined in EN 15227. A survey conducted among different industries such as railway, aeronautics, automotive and marine proved that crashworthiness in railway vehicles follows a specific validation process based on a combination of tests of sub-systems and numerical simulations at train system level. This means that numerical simulation is a key procedure towards certification of a rail vehicle for crashworthiness. Consequently, the successful introduction of composite materials in rail vehicle manufacture means ensuring that numerical simulation software can reliably and accurately model such materials. Using carbon fibre composite sample tests performed within the REFRESCO project, numerical simulations were performed to correlate and characterize the material, demonstrating that software is suitable for modelling crash scenarios. It is important to note that it was not available real test to correlate the numerical simulation developed.

Composite materials behave very differently from ductile materials like steel or aluminium; brittle and orthotropic, composite materials exhibit various failure modes depending on the loading modes and directions. This inherent complexity and lack of ductility raised the question of the strength of the body-shell structure when a collision occurs. For evaluating the difference of behaviour between a composite and a metallic structure at the scale of a rail vehicle, crash simulations were conducted on a passenger train lead car and a freight locomotive. The choice of the collision scenario for the study was extracted from the EN 15227 which describes a collision with a large deformable obstacle, a typical collision partner at level crossings in Europe.

Reference crash simulations were performed on current metallic designs to observe their behaviour against the obstacle and confirm compliance to EN 15227 safety criteria; both body-shell designs showed controlled plastic and ductile deformations of the front structure. Then, the front cabin structure was redesigned to introduce composite materials; initial results exhibited some cracking instead of ductile deformations exhibited by metallic structures. By reinforcing the composite structure or extending the surrounding metallic interfaces, passing the collision scenario test is possible, but with the consequence of transferring the energy previously absorbed by the surrogate structure to the non-structural crashworthy devices and to the deformable obstacle. The key recommendations as compared to the currently applicable EN 15227 are: limited or no damage allowed on the main body-shell structure, more demanding validation tests of absorbing systems, and additional sub-systems tests for critical areas. Other strategies are to absorb the energy of the impact with specific devices maintaining the integrity of the carbody made in composite, with or without and added metallic front driver cab, avoiding extra consideration in the model of the hybrid structure.

In line with EN 12663, the EN 15227 should be modified for considering composites. A standard or recommendation sheet for testing would be advisable for assessing the numerical simulation for railway applications.

3.5 Joints

It was investigated manufacturing and joining of new structural materials based on the state of the art in other sectors. It aims at developing quality criteria and respective validation methods for the manufacture and joining of structural elements out of composite and sandwich materials or hybrid structures.

The manufacturing processes that are most likely to be used for manufacturing of structural components were identified and their attributes and process parameters including the influence on quality, performance and cost were studied. In order to understand the influencing parameters, the use of parameter trees was proposed for the choice of a process.

Based on the output from the work on materials manufacturing and processes, the effects of the variation of different parameters was investigated. The work focused on the technical consequences of the variation of parameters and correlated this to performance classes, which have been proposed.

This WP also investigated the joining processes for composite, sandwich and hybrid structures. Examples from different industries were summarised. To visualize the complexity of the joining

techniques, parameter trees were also created for bonding, welding and mechanical fastening. The status of regulations was considered and proposals for further improvements were made.

Destructive and non-destructive test measures which are necessary to set and control acceptance criteria were investigated. The tests were clustered according to the most relevant joining principles.

Also in connection with the test procedures, gaps in the regulatory framework were observed and recommendations or limits for the use of the available standards were given. An approach for a future regulatory framework in relation to joining methodologies was derived, i.e., standard or recommendation on a homologation concept for composite materials (manufacturing) is needed. EN 15085 (Welding in Railway Vehicle Construction) or DIN 6701 could be used as a template for this purpose

3.6 Prognostic and health monitoring

It is gathered the experiences of other industries (in particular aeronautic and spatial sectors) regarding the introduction of structural composite materials, and to apply the lessons learned for designing future generation train carbody shells, respecting to the existing maintenance control periodicity.

All methods related to Non Destructive Tests (NDT) and Structural Health Monitoring (SHM) of the full life cycle were described, taking into account the state of the art and the specificities of metallic carbody shells for all railways segments (VHST, metros, tramways, regional, etc.). In many cases, only access to the exterior face of the carbody is possible and the NDT must be adapted in consequence (problem for the sandwich composite).

A complete analysis of the damage scenarios that occur when rolling stock is running was also made, and collected in a defects catalogue. Also, a methodological guideline on Damage Tolerance Strategy (DTS) and on Health Monitoring was also proposed.

DTS is commonly used in aeronautics and defines among other things what kind of defects the aircraft structure should be able to sustain. Adapting the DT strategy used in other industries to the railway sector requires selecting relevant NDT and PHM methods; those most adapted for rolling stock were recommended. A recommendation at European level to state damage scenarios for railway structural applications, together with a database of damages is considered needed.

Critical areas due to the design architecture and optimization were identified and were found to be similar to those of metallic structures (windows, doors, connection with running gear...). Health monitoring during the life cycle could therefore bring a significant advantage and help reduce the life cycle cost (LCC) for operators in charge of maintenance (in addition to reparability and no corrosion). For metros and tramways, SHM may be less relevant.

Acquisition cost was not found to be the most relevant criteria when objectively comparing the competitiveness of structural composites vs. metallic materials (aluminium, steel) used today for reference solutions.

A special emphasis was placed on the “Building Block” concept considering a deterministic approach based on the detectability limit of the damages to avoid any growth of damages due to fatigue. Structural composites avoid this phenomena compared to metallic, once of course taken into account as design criteria for sizing.

The last part was focused on “Recommendations on Health Monitoring & Non Destructive Test”. For Non Destructive Tests: Relevant tools and known methods are perfectly usable and useful. For Structure Health Management: as this technology is not very mature yet, it should be limited to sensitive areas and qualification and testing stage. At short term it is recommended a robust sizing process and relevant tolerance damage strategy. However, the Structure Health Management technology will contribute to reinforce at mid-term LCC performance for operators and seems to be very useful for implementing in the demonstrator to gain experience and knowledge of composite behaviour and joints.

3.7 Reparability and Maintainability

Two main topics are studied: the preventive maintenance with an adapted plan from the current metallic carbodyshell practice with the associated controls (visual or NDT), and the corrective maintenance (repairing).

The repair technologies and maturity of railway industry on representative structures is evaluated according to the state of art in rolling stock design and manufacturing, and also repair criteria and a maintenance strategy are proposed, suitable for the safe operation of multi-material carbody structure of rolling stock.

The repair techniques are likely to be very similar to the ones applied in the aeronautic sector. The repair techniques mainly consist in removing the damaged material and replacing it by a new one in most of the cases. The repair technique to be used depends mainly on the severity of the damage so it is key point the correct uses of NDT in such a context.

After the repair it is needed to inspect again and check the quality of the repair afterwards.

In addition, nine specimen of different structure were manufactured, damaged and tested.

For monolithic laminates, after being repaired, strength shown in the compression tests is 96% and 83% of the original (nor damaged nor repaired).

For sandwich laminates after being repaired, the core shear ultimate strength shown in the flexure C393 ASTM test

- For foam core: 78.67 % compared to non-damaged samples,
- For honeycomb core: 81.08 % compared to non-damaged samples
- In all cases, the tests showed that repairs cause a decrease of the material’s key properties. This result is not in line with the experience of the Aeronautic sector where the reductions of properties of the materials due to repair process are not significant.

4 Roll2Rail Project

Roll2Rail aims to impact the performance at railways system level by introducing breakthrough technologies as a radical change that should revolutionise the train concept for the future. The innovations to be achieved in the various work packages will Roll2Rail will focus on technological innovations in different subsystems of the vehicles which, each and all together contribute to achieve the desired impact at vehicle level and whole railway system level on capacity, reliability, efficiency, comfort and LCC. The project expects innovations in 8 different areas such as traction and power electronics, train communications, car bodyshell, running gear technologies, brakes, train interiors, noise and vibration and energy performance.

According to the previous REFRESCO project, the topic of the Roll2Rail Project was not to set the state of the art on the composites applications and the possible contribution to the railway structures. It was mainly carried out to prepare the PIVOT project (Shift2Rail), with the definition of the technical specifications and the design methodologies for the future composite carbodyshell, and some complementary elements like for joining technologies.

4.1 Technical Specification

Two generic carbodies (one for high speed and other for urban application) were defined to create the technical specification including: geometry, working conditions, passenger and interior space, simplified interfaces (running gear, equipment, etc.), loads and boundary conditions, noise, vibration and thermal requirements, EMC, fire and maintenance restrictions.

These documents are the baseline for the technical specification of the demonstrators of TD1.3.

4.2 Joints

The main joining technologies evaluation is presented in Table 1, taking into account different design parameters, being one of the more critical the assembly and disassembly of the joint. All technologies seem structurally feasible, being only necessary to adapt the current constructive techniques designed to welding to the other technologies like bonding.

Joining properties	Welding	Mechanicals assemblies (bolting, riveting, screwing)	Bonding
Joining of different materials	Identical metals but difficult for certain materials (Al or Ti).	Different materials (metal/metal, plastic metal/, plastic/wood...).	All materials
Shapes and sizes of the parts	Large and small surfaces (by different types of welding joint).	Parts of all shapes but with a dimensioning and an adequate design of the parts to be assembled.	Parts of all shapes and all dimensions, but the joint must only work in shearing.
Impossibilities	Certain metals or alloys cannot be welded (cast iron, copper, bronze, zinc).	Difficulty with small parts and materials not being able to be machined bored. Risk without flat and parallel	No impossibility.

		surfaces.	
Assembly, disassembly, repair	Permanent assembly. Reparable for MIG, not for laser, and with conventional process for FSW	Assembly easily. dismountable and repaired	Permanent assembly.
Stress distribution	Irregular	Concentrated stresses towards holes, screw, rivets and bolts.	Excellent distribution of shear stresses on all surface, but bad in the case of the cleavage or of peeling.
Mechanical strength	Can be very high.	Can be very high.	High in shearing. Weak in cleavage or peeling.
Fatigue and vibration strength	Good but must be studied.	The assemblies can lose tightening when they are subjected to the vibrations.	Very good fatigue strength
Heat strength	Very high strength (the same with assembled metals).	Very high strength (the same with assembled metals).	Limited (maximum temperature of 120°C for the epoxy adhesives and of 300°C for the thermostable adhesives).
Water resistance, and corrosion	Excellent. Very little risk of corrosion.	Good. Possibility of corrosion with different metals	Risk of corrosion for the assemblies with tension.
Labour and Implementation	Must be qualified	Little qualified	Must be qualified. Careful in the preparation.
Manufacturing process controls	Non-destructive tests (NDT): visual inspection, radiography, tightness test (with X-rays in particular), ultrasounds, etc.	Visual inspection (presence of the screws, bolts, rivets), checking of the tightening of the screws and bolts.	Different methods: - following test-tubes: - traction; - NDT: visual inspection, tightness test, radiography (with X-rays in particular), ultrasounds, etc.
Process constraints	MIG: Heat introduction, deformation, shrinkage (thermomechanical treated materials). Loss in mechanical properties, especially Al-alloy.	Screwing/bolting: Weight, holes in the structure, cost, accessibility, added weight. Riveting: holes in the structure, expensive automated installation, weakness of the holes (FRP), to pass to a higher diameter of rivet for a damaged rivet, added weight	Depending on temperature and humidity, Low fire resistance, Weathering, Process time (additional surface treatment and preparation is necessary), time of curing process...
	Laser: high quality of body edges and tight tolerances are necessary, High surface finish of parts...		
	FSW: Exit keyhole left when		

	tool is withdrawn, Large down forces, higher tolerance accuracy of joints...		
Standard	Standard process, joint geometries, certification and qualification workers...	Standards exist	Only German Standard
Design calculation	Can be calculated with existing guidelines	Can be calculated with existing guidelines	Can be calculated with condition hypothesis and bonding strength qualification
Aging	No impact	No impact	Ageing of adhesive joints is not well known, lack of experience for long term behaviour of structural adhesives
Environmental	For classic welding : safety risk due to the weld pool, toxic fumes, arc or the spatter of molten material	Drilling boreholes in FRPs cause strong wear of the drill bits	Needs dedicated area for manufacturing, maintenance and storage

Table 1: Comparative table between technologies

In line with bonding German standard, it is necessary to continue developing a European standard for bonding (with specification and validation method).

Depending on the application is very important to choose the correct technique. For refitting a technique should be used for which disassembly is possible. Therefore, bolting and screwing would be the best selection. To some extent also riveting and even bonding (secondary structures and elastic adhesives, e.g. windows and glazing, panelling etc.) could be the choice.

If no disassembly is needed, a permanent joining technology should be used. Among the possibilities available, the first choice is welding for metallic structures. If it is not possible, riveting or bonding or the combination of both might be used. In the latter case each of the combined technologies should have a clear function. As an example, the combination of riveting and bolting is briefly considered: In this case rivets can be used to carry the creep loads and to function as crack stopper in an adhesive joint, while the adhesive joint can be used to carry the fatigue loads. In aircraft industry a combination of riveting and bonding is widely used. In car industry joining of primary structural parts is made by spot-welding and bonding. In this case the bonding enables the folding of the metal during crash to absorb maximum energy, but it is important to note the difference in the force level compared to railway.

Each joining technology considered is mature, partly to a high TRL in certain application fields, but does not reach this TRL in other application fields. This is a typical situation appears due to the fact of different technological and requirements and homologation criteria or simply the lack of certain data which are only needed because of some very specific requirements. These gaps have to be closed in order to transfer a technology to a new field, for this purpose this topic is covered in the OpenCall (OC) Mat4Rail of the PIVOT Project.

4.3 Design Methodologies

With the different feasibility and structural studies the objective related with weight reduction seems possible, but it need to be objectified in a complete design proposal and should be checked the compliance with EMC and fire requirements. Regarding weight, the studies carried out showed potential saving between 10% and 30% in subassemblies and whole carbodyes but the influence of the fatigue on the composite part has to be investigated to complement the above mentioned analysis. Fatigue assessment has not been carried out due to the lack of S/N curves (stress vs. no. of cycles) of the material.

So it is identified the necessity to characterize properly and according to the railway environment the new materials and joining methods (fatigue, crash behaviour, aging, manufacturing process...).

The optimization methodology has been shown as a powerful tool for the design phase to have a general overview of the impact of the interfaces locations, best orientations of the fibres (with the choice of the corresponding material: orthotropic as composite or isotropic as metallic elements) or the proper location of reinforcements.

With the experience of Roll2Rail, it is necessary the developing of a global approach in the design phases including material, manufacturing, joints, maintenance etc. To do this it is necessary to have in mind all the subassemblies and interfaces as soon as possible.

4.4 Standardization issues

Taking into account the different steps done until now and in line with the characterization necessity, it is clear that the principal obstacle to face in subsequent developments is the one related with framework standard and the certification process. According to a meeting with the advisory group, the members should develop a common methodology (alternative to current framework standard) to validate the future hybrid structures which will constitute the next generation of the carbodyes.

5 Conclusions

Taking into account the lightweight strategy, previous studies showed the feasibility to use composite material in the primary structure of railways carboodies.

Regarding material the most promising is carbon fibre structure in monolithic structure due to the problem of sandwich with inspections. In addition, It is needed the development of structural resin fire compliant, now under development inside the OC. Together with the material is under development the design of joints for multi-material adapted to the railway environment.

In order to have a homologated product it is necessary to develop demonstrators and gain experience with composites in the railway environment. After that it is necessary to add the experience achieved to the state of the art and generate a new generation of standards in later stages fully compatible with the use of new materials.

6 References

All public documents generated in REFRESKO and Roll2Rail available in the corresponding webpages:

- <http://www.refresco-project.eu/deliverables/>
- <http://www.roll2rail.eu/>

7 Antitrust Statement

While some activities among competitors are both legal and beneficial to the industry, group activities of competitors are inherently suspect under the antitrust/ competition laws of the countries in which our companies do business.

Agreements between or among competitors need not be formal to raise questions under antitrust laws. They may include any kind of understanding, formal or informal, secretive or public, under which each of the participants can reasonably expect that another will follow a particular course of action or conduct. Each of the participants in this initiative is responsible for seeing that topics which may give an appearance of an agreement that would violate the antitrust laws are not discussed. It is the responsibility of each participant in the first instance to avoid raising improper subjects for discussion, notably such as those identified below.

It is the sole purpose of any meeting of this initiative to provide a forum for expression of various points of view on topics

- (i) that are strictly related to the purpose or the execution of the initiative,
- (ii) that need to be discussed among the participants of the initiative,
- (iii) that are duly mentioned in the agenda of this meeting and
- (iv) that are extensively described in the minutes of the meeting.

Participants are strongly encouraged to adhere to the agenda. Under no circumstances shall this meeting be used as a means for competing companies to reach any understanding, expressed or implied, which restricts or tends to restrict competition, or in any way impairs or tends to impair the ability of members to exercise independent business judgment regarding matters affecting competition.

As a general rule, participants may not exchange any information about any business secret of their respective companies. In particular, participants must avoid any agreement or exchange of information on topics on the following non-exhaustive list:

1. Prices, including calculation methodologies, surcharges, fees, rebates, conditions, freight rates, marketing terms, and pricing policies in general;
2. any kind of market allocation, such as the allocation of territories, routes, product markets, customers, suppliers, and tenders;
3. production planning; marketing or investment plans; capacities; levels of production or sales; customer base; customer relationships; margins; costs in general; product development; specific R&D projects;
4. standards setting (when its purpose is to limit the availability and selection of products, limit competition, restrict entry into an industry, inhibit innovation or inhibit the ability of competitors to compete);
5. codes of ethics administered in a way that could inhibit or restrict competition;
6. group boycotts;
7. validity of patents;
8. ongoing litigations.