Transport Research Laboratory
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CLIENT PROJECT REPORT CPR1714

Development of technical requirements / performance specifications for a) tracks and b) exterior and accessories of agricultural and forestry vehicles

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Prepared for: European Commission, DG Enterprise & Industry

Project Ref: ENTR/09/030 (Lot 1)

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Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Referee
v1	01/11/13	Initial draft for EC client review	BR	ME
v2	29/11/13	Re-draft incorporating EC comments	BR	ME
v3	17/12/13	Final version	BR	ME

Contents

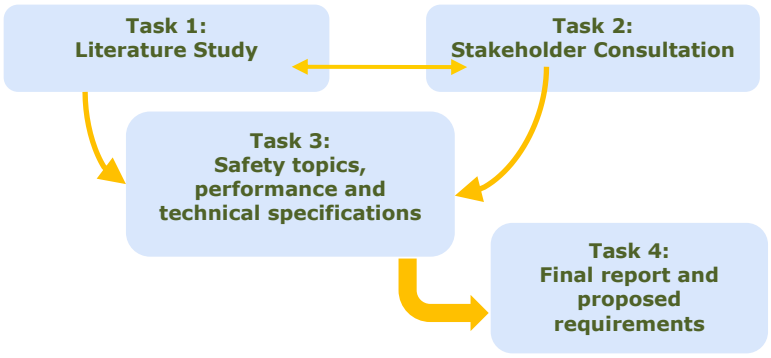
Executive Summary

The new "Regulation" (or "Co-decision Act") (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles was published in the EU Official Journal. Throughout 2013, the Commission have been working with stakeholders towards a full set of draft Delegated Acts to provide the technical requirements/performance specifications for the agricultural and forestry vehicles within the scope of Regulation 167/2013. These Acts will cover a wide range of safety and environmental topics.

TRL has been supporting the Commission through a project to develop the technical requirements/performance specifications for a defined set of functional and occupational safety topics. Those topics outside of the scope of this study (completed in June 2013) were, generally speaking, felt likely to use requirements or specifications based on well-established existing Directives, UN Regulations, etc. However, for two topics (vehicle exterior and accessories, and tracks installed on agricultural/forestry tractors), that were not in the scope of the original TRL study, such well-established criteria were not immediately obvious.

The scope of the study was to determine the provisions on technical requirements / performance specifications for safety subjects of agricultural and forestry vehicles related to a) tracks and b) exterior and accessories, in order to complete the draft delegated act "Regulation on Vehicle Functional Safety Requirements" (RVFSR).

TRL's methodology for the study comprised four main tasks to meet these objectives:



At an early stage of the project, a stakeholder questionnaire was drafted (Appendix A) and circulated widely by email to individuals involved with the Working Group on Agricultural tractors (WGAT), or who had otherwise been identified as likely to have some interest in the study. Existing standards or other relevant literature identified by stakeholders via their questionnaire responses, or by TRL through its own internet and database searches, were reviewed.

The "tracks" topic covers the steel or rubber tracks (also known as endless belts) fitted to crawler vehicles (category C). Specific areas of interest identified at the outset of the project include material strength, connections (for steel belts), installation, ground contact pressures and adaptability for off- or on-road conditions.

In European agriculture, steel tracked crawlers are low/medium power (typically 50-75 kW), of relatively low mass and low speed (~15 km/h max.), and can be C1 or C2 types

depending on their width. They are used in specialist applications such as orchards and vineyards on hills and very rarely, if ever, used on-road.

The situation is entirely different with rubber-tracked tractors. These are often very high power (200-400 kW), potentially quite high speed (30 – 40 km/h) and very high mass (20 – 25 tonnes technically permissible maximum laden mass). They are most frequently C1 types and are intended for power-demanding primary cultivation tasks on big farms. They are generally used in open field applications, particularly where soil compaction needs to be minimised, but much like equivalent T-category tractors they can also be used for road circulation.

In relation to the specific topics raised at the outset, the reviews have found that only the issue of ground pressure is widely felt to be relevant and amenable to provisions within the draft delegated act.

The main advantage of tracked agricultural vehicles over their wheeled counterparts is their reduced soil compaction off-road. While this has been the focus of considerable research, very little attention seems to have been paid by researchers to the performance of tracked vehicles on hard pavements, i.e. on-road. It is, of course, this performance, however, that is of interest to type-approval and other regulatory authorities. Accordingly, the review has identified several references detailing ground pressure requirements in individual Member States, as well as proposals for a draft (un-numbered) ISO standard (VDMA, 2006).

For rubber-tracked vehicles, the review suggests that the best approach would be to limit the mean ground contact pressure, calculated by a simple method according to the draft ISO standard. To further help minimise road damage and ensure peak loads do not exceed the upper limit set by Regulation (EU) 167/2013, limits should also be set for the load per roller and the load per metre of track in contact with the ground.

For steel-tracked vehicles, fitted with pads for on-road use, the existing Italian requirements, and calculation method for mean ground pressure, are appropriate. Such vehicles should be limited to no more than 15 km/h.

The "exterior and accessories" topic relates to the exterior bodywork and surfaces of agricultural/forestry vehicles and any attached accessories that are not covered by separate type approval requirements and are not detachable implements/machines covered by the Machinery Directive. Of particular interest at the outset were: reflectors and other visibility issues relating to the vehicles and their attached accessories; installation and functionality of accessories; operator safety; and particularities for off- or on-road use.

In general terms, the review indicates that other draft delegated act annexes already deal adequately with issues such as reflectors, conspicuity markings and mirrors. The sole exception to this general observation was the suggestion that this annex could usefully address the issues of exterior projections and minimising risks to Vulnerable Road Users (e.g. pedestrians, pedal cyclists and motor cyclists).

UNECE Regulation 26 has relevant provisions for M1 vehicles (passenger cars) which are not in their entirety suitable for agricultural and forestry vehicle type approval, but which can, we suggest, be readily adapted, very much along lines proposed by CEMA, and further enhanced by making specific reference to rough surfaces.

1 Introduction

Following the CARS21 report recommendation to improve the whole vehicle type-approval regulatory framework, for the purposes of better regulation and simplification, the European Commission has proposed to simplify EU law on agricultural and forestry vehicles (tractors, trailers and towed equipment). The proposal also foresees increased safety and improved environmental performance for these vehicles.

The proposal should significantly simplify the type-approval legislation by replacing 24 base Directives (and around 25 related amending Directives) in the field of agricultural and forestry vehicle technical requirements with one Council and Parliament Regulation on the approval and market surveillance of agricultural and forestry vehicles ("Regulation") and five implementing measures under it.

As a result, the new "Regulation" (or "Co-decision Act") (EU) No 167/2013 of the European Parliament and of the Council of 5 February 2013 on the approval and market surveillance of agricultural and forestry vehicles was published in the EU Official Journal.

Throughout 2013, the Commission have been working with stakeholders towards a full set of draft Delegated Acts to provide the technical requirements / performance specifications for the agricultural and forestry vehicles within the scope of Regulation 167/2013. These Acts will cover a wide range of safety and environmental topics.

TRL has been supporting the Commission through a project to develop the technical requirements/performance specifications for a defined set of functional and occupational safety topics. Those topics outside of the scope of this study (completed in June 2013) were, generally speaking, felt likely to use requirements or specifications based on well-established existing Directives, UN Regulations, etc. However, for two topics (vehicle exterior and accessories, and tracks installed on agricultural/forestry tractors), that were not in the scope of the original TRL study, such well-established criteria were not immediately obvious.

As with the earlier study, this current project combined published literature, stakeholder information and views, and engineering expertise to recommend the most suitable performance specifications and technical requirements for the various forms of agricultural and forestry vehicles covered by the new Regulation.

1.1 Project scope and objective

The scope of the study was to determine the provisions on technical requirements / performance specifications for safety subjects of agricultural and forestry vehicles related to a) tracks and b) exterior and accessories, in order to complete the draft delegated act "Regulation on Vehicle Functional Safety Requirements" (RVFSR).

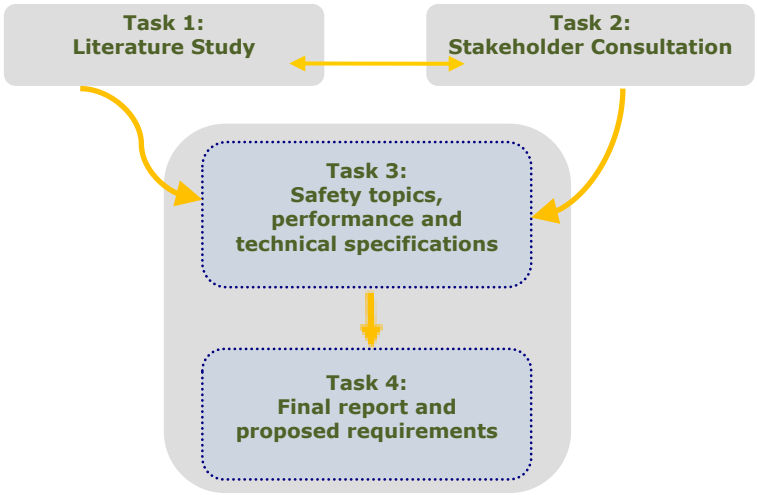
In general, these provisions were to be determined in terms of the functional safety of the vehicle, mainly related to the a) mechanical function of tracks when installed on the tractor and b) the vehicle's exterior forming and accessories installed on the vehicle.

The overall objective of this study was:

- To provide a complete document of safety technical requirements / performance specifications and related tests that will allow for the approval of agricultural and forestry vehicles or the component approval of the above two subjects with respect to the safety subjects concerned.

1.2 Project methodology

TRL's methodology for the earlier study (Robinson, Scarlett & Seidl, 2013) comprised four main tasks:



Published material and internet literature was reviewed (Task 1) to establish existing legislative requirements for agricultural and forestry vehicles under each safety topic. The review also identified existing test requirements from international regulations and standards, e.g. from UNECE and ISO.

Stakeholders were asked to contribute to the study by completing a questionnaire (Task 2). They were identified by various means, including via the Working Group on Agricultural Tractors (WGAT), its informal group on agricultural vehicle health and safety and previous relevant projects. The questionnaire was distributed by email, in spread-sheet format, to over 80 individuals and organisations across Europe.

Additional stakeholder input was sought and utilised throughout the project, even in the very latter stages of drafting the final report.

In Task 3, the results from the literature review and stakeholder consultation were combined with expert engineering judgement to provide, for each safety topic:

- A summary of its relevance and risk profile during mobility (functional safety), and how that relevance is affected according to vehicle type and maximum speed;
- A summary of the existing requirements, specification and/or test procedures identified and specific identification of those best suited to each vehicle type;
- A discussion of opportunities for harmonisation with other vehicle types;
- Draft technical requirements and, where required by the evidence resulting from Tasks 1 and 2 and by the co-decision text, more detailed performance specifications and approval test procedures.

The basic approach in this new study was to repeat but compress these stages, in order to deal with the two new topics and deliver the results by the required deadline (necessarily set to fit with the overall delegated act drafting process).

2 Literature Study & Stakeholder Consultation

To save time and make optimum use of the knowledge and expertise available from stakeholders, Tasks 1 and 2 were run in parallel and are thus considered together in this report. Both tasks were essentially aiming to achieve the same objectives, namely to identify what specifications and requirements, potentially relevant to one or other of the two topics under consideration, already exist, and to establish what particular safety risks the draft delegated act provisions should aim to mitigate.

At an early stage of the project, a stakeholder questionnaire was drafted (Appendix A) and circulated widely by email to individuals involved with the Working Group on Agricultural tractors (WGAT), or who had otherwise been identified as likely to have some interest in the study. Existing standards or other relevant literature identified by stakeholders via their questionnaire responses, or by TRL through its own internet and database searches, were reviewed.

In all, about 100 individuals and organisations were sent the questionnaire, and about 15 responses were received, from a variety of manufacturers, governmental representatives, regulatory authorities and others. While this is somewhat lower than the 35% response rate achieved during the previous study (Robinson, Scarlett & Seidl, 2013), this is thought likely to reflect the much more limited and specialist scope and strict deadline of this new study. The following sections describe the results of the literature reviews and stakeholder responses for each of the two safety topics in turn.

2.1 Tracks

This topic covers the steel or rubber tracks (also known as endless belts) fitted to crawler vehicles (category C). Specific areas of interest identified at the outset of the project include material strength, connections (for steel belts), installation, ground contact pressures and adaptability for off- or on-road conditions.

CEMA (2008) provides a good summary of the two forms of vehicle and their respective applications. In European agriculture, steel tracked crawlers are low / medium power (typically 50-75 kW), of relatively low mass and low speed (~15 km/h max.), and can be C1 or C2 types depending on their width. They are used in specialist applications such as orchards and vineyards on hills and very rarely, if ever, used on-road.

The situation is entirely different with rubber-tracked tractors. These are often very high power (200-400 kW), potentially quite high speed (30 – 40 km/h, but with none currently on the market able to travel at > 40 km/h) and very high mass (20 – 25 tonnes technically permissible maximum laden mass). They are most frequently C1 types and are intended for power-demanding primary cultivation tasks on big farms and are believed to be becoming increasingly numerous, particularly on very large arable farms (> 800 ha). They are generally used in open field applications, particularly where soil compaction needs to be minimised, but much like equivalent T-category tractors they can also be used for road circulation.

There are two basic designs of rubber-tracked crawler: (i) with skid-steering via differential speed between the left & right tracks, and (ii) articulated steering (e.g. Case Quadtrac) where four independent triangular track units are fitted to the axle ends of a basic articulated wheel tractor. However, whilst aftermarket track kits are available to convert wheeled tractors into tracked vehicles, the Quadtrac is built in this (tracked) form and cannot be converted to a wheeled vehicle.

In relation to the specific topics raised at the outset, the reviews have found that only the issue of ground pressure is widely felt to be relevant and amenable to provisions within the draft delegated act (see below). On the other topics, the evidence gathered suggests the following:

Material Strength. Steel and rubber tracks are made to withstand very high tensile loading and severe abrasion in service over an extended period (2000 – 3000 hrs). Track design and material choice to ensure adequate in-service durability is the driving factor and ensures existing designs are sufficiently strong and thus do not pose any significant safety risks, e.g. from belt failure.

Connections (if applicable). Connections are only found in steel tracks and are believed to be substantially over-engineered for the same reasons as stated for the material strength issue. Their low maximum speed further reduces any issues. This is considered to be a very mature technology which hasn't shown any problems in service.

Rubber tracks are formed of steel cables embedded in a multi-ply rubber carcase. No specific connections exist. As with steel belts, durability requirements appear to ensure tracks don't break up in service.

Installation. Removal & replacement of new tracks during service is recognised as a specialist task to be performed by trained dealer personnel. The reviews have not identified any evidence to suggest safety risks are created through untrained farm personnel attempting to install tracks themselves.

Adaptability for Off-Road and On-Road Use. In the case of steel-tracked crawlers, this area concerns the ease of installation / removal of road pads, but the reviews indicate that such pads, once fitted, tend not to be removed. The low forward speed effectively provides its own restriction against significant on-road use.

In the rubber-tracked instance, no adaptation is necessary. However issues that arise include (i) much higher on-road speed (existing models up to 40 km/h, with implications for steering control & braking), (ii) the existence of minimal suspension/compliance between the vehicle and the road surface and (iii) tread-bar induced bystander noise (during road travel) and related surface damage, particularly when turning with skid-steered vehicles. This is much less of an issue with articulated designs.

Accident studies such as those used to inform the prioritisation of safety topics in the earlier TRL study for the Commission (Robinson, Scarlett & Seidl, 2013)[1] provide no evidence of significant or common accident occurrence with tracked vehicles, suggesting they are of quite "low" priority. The results of a survey of tracked vehicle users (ETUI, 2013) identified some issues relevant to other delegated act ("Regulation on Vehicle Construction Requirements" - RVCR) annexes, such as operation and maintenance, operating space and access to driving position, protection against mechanical hazards, safety belts, visibility and driver's exposure to noise, but did not identify any concerns with the tracks themselves, further supporting a "low" prioritisation.

[1] Each safety topic assessed in that study was assigned a prioritisation of "low", "medium" or "high" according to the propensity for that topic to be associated with injury causation, as evidenced by accident studies.

2.1.1 Ground pressure

The main advantage of tracked agricultural vehicles over their wheeled counterparts is their reduced soil compaction off-road. While this has been the focus of considerable research (see for example Wong, 2008), very little attention seems to have been paid by researchers to the performance of tracked vehicles on hard pavements, i.e. on-road. It is, of course, this performance, however, that is of interest to type-approval and other regulatory authorities. Accordingly, the review has identified several references detailing ground pressure requirements in individual Member States, as well as a draft ISO standard, all described in the following paragraphs.

National legislation has existed in some Member States for many years, usually aimed at steel-tracked crawlers, which in actual fact very rarely travel on the road because of the associated inconvenience - it's quicker and easier to put them on a low-loading trailer.

Italy. National Regulation for the Road Circulation (Codice della Strada) has a specific article (N° 283) dealing with "ROAD PADS FOR TRACK-LAYING AGRICULTURAL TRACTORS". It is applicable only for crawlers with steel tracks, because there is no need for pads on rubber tracks. An Italian Government stakeholder provided the following English translation/ summary of the relevant Road Regulation.

- Pads are devices to adapt track-laying machines to the road circulation. They have to be fitted on every part of tracks with "grip spines", in order to preserve the road surface. Pads can be made of steel, rubber elements or both. The contact area of the pad is the contact area with a flat and rigid surface. It is normally measured on the pad drawing, excluding loop surfaces.
- Each pad must be stamped the manufacturer's logo and the maximum permissible load expressed in kg and calculated multiplying for 6.5 the contact area (expressed in square centimetres). Pads have also to comply with the relevant national standard approved by the Ministry of Transport.
- The contact pressure of the pad is calculated dividing the mass of the machine, including its mounted equipment, with a value resulting from the contact area of each pad multiplied for the number of tracks rollers. Driving or driven wheels of the track are considered as rollers.
- For the road circulation the contact pressure, calculated according to the previous prescriptions, shall not exceed 6.5 daN/cm2 (0.65 MPa).

UK. The Road Vehicles (Construction & Use) Regulations 1986, Part II Section 28 specifies the following requirements for tracks:

- Every part of every track of a track-laying vehicle which comes into contact with the road shall be flat and have a width of not less than 12.5 mm.
- The area of the track which is in contact with the road shall not at any time be less than 225 cm^2 in respect of every 1000 kg of the total weight which is transferred to the road by the tracks. [*equivalent to a mean ground pressure limit of 0.436 MPa*].
- The tracks of a vehicle shall not have any defect which might damage the road or cause danger to any person on or in the vehicle or using the road, and shall be properly adjusted and maintained in good and efficient working order.

Germany. A German industry stakeholder provided the following English summary of the German national requirements, as set out in articles 34 b and 36 of StVZO.

- Maximum load under each track roller: max. 2 t.
- In addition in the case of suspended roller tracks and vehicles above 8 t is the max. load under a 60 mm vertically lifted track roller: two times of the permissible value (i. e. 4 t); the maximum ground pressure is 1,5 N/mm² (1.5 MPa) under the conditions mentioned below.
- In addition in the case of unsuspended roller tracks and tracks consisting on the outer side fully of rubber: Max. ground pressure 0,8 N/mm² (0.8 MPa), where the contact area is limited to those areas which have effectively contact to the ground.
- The maximum mass of tracked vehicles, either self-propelled or towed, is 32 t the latter includes the vertical static load at the coupling point.
- The max. load per unit length between the first and the last track roller is limited to 9 t/m.
- The maximum operating speed (on German roads) is:
    i. limited to 8 km/h generally,
    ii. limited to 16 km/h if the track rollers are fitted with rubber wheels of a height of 40 mm or the tracks have rubber pads,
    iii. limited to 30 km/h if the track rollers are unsuspended and the tracks consist outside solely of rubber,
    iv. not limited if the tracks have rubber pads or consist outside solely of rubber and the track rollers are fitted with rubber wheels of a height of 40 mm or have a separate suspension.

Furthermore, a Danish government stakeholder suggested that "*Denmark has very strict rules at the moment. Only up to 1,500 kg for each supporting wheel under the belt, and a maximum laden mass of 16,000 kg for the vehicle. Denmark intends to relax the legislation by introducing a rule laying down a maximum contact pressure of 0.8 MPa based on real measurement or detailed calculation taking all aspects into consideration including the E-module of the rubber and the negative profile percentage. Denmark also intends to increase the maximum laden mass from 16,000 kg to 32,000 kg. Steel belts (without rubber) are not permitted on the roads.*"

The German industry stakeholder also provided some outline details of a draft ISO standard (VDMA, 2006) that an expert group of crawler vehicle manufacturers had worked on in 2006. Although these proposals have not progressed since that time, it is believed that the concepts developed are still representative of the "state of the art". With the aim of adapting the German StVZO requirements to the state of the art and internationalising them, the work focused exclusively on requirements pertaining to the approval of crawler undercarriages for use on conventionally paved hard road surfaces such as asphalt or concrete. As well as drafting a set of definitions, the working group also came up with some draft requirements, as follows:

- Crawler undercarriages must be non-damaging to roads.
- The mean ground pressure must not exceed 0.8 N/mm^2.

- The dimensions and type of track belts and undercarriages must correspond to the operating conditions, especially the load and maximum vehicle speed, which is determined by type of vehicle. The manufacturer of the crawler undercarriage must mark the undercarriage in permanently legible manner with the maximum permissible speed determined by design and the maximum load-bearing capacity of the crawler undercarriage.
- The track belt manufacturer must mark the track belt with at least the following information:
    - manufacturer's name,
    - maximum load-bearing capacity,
    - maximum permissible speed,
    - date of manufacture.
- The minimum tread depth / wear limit must be permanently marked on the track belt.
- In any given vehicle, it is permissible to use track belts having different patterns.
- In vehicles in which track belts are driven by friction, the operator shall have a continuous indication of track tension during road travel, or there shall be a visual and/or audible signal that is activated when the minimum belt tension is reached.

The Working Group further proposed two methods to calculate the mean ground pressure, one by reference to CAD design data of the track belt and the other by practical determination through imprinting the tread pattern onto Styrofoam panels. Either method, it was proposed, could be used to calculate the total effective area of the track in contact with the road at any given time. This is then divided into the vehicle's maximum weight to arrive at an average (mean) ground pressure.

There is also a proposed test procedure to determine whether crawler undercarriages are non-damaging to roads, involving the vehicle being driven through a prescribed test circuit at a minimum speed of 10 km/h, followed by a visual inspection of the road surface to ensure the absence of compression or scraping-induced damage.

In response to the questionnaire, CEMA (the main European trade body for agricultural vehicle manufacturers) have proposed that a ground pressure limit of 0.8 MPa be applied to all tracked vehicle types, defined in terms of the maximum permissible load on a track train and the total surface area of the lugs or shoes in contact with the ground (i.e. all those between the front and rearmost rollers).

A detailed discussion of the merits of the above regulatory/standardisation approaches, along with an assessment of which specific provisions should be included in the draft RVFSR delegated act annex on tracks, is included in the following Chapter of this report.

2.2 Exteriors and accessories

This topic relates to the exterior bodywork and surfaces of agricultural/forestry vehicles and any attached accessories that are not covered by separate type approval requirements (dealt with in other annexes to the delegated acts, such as tyres, lights, mirrors) and are not detachable implements/machines, which are covered by the Machinery Directive. Of particular interest at the outset were: reflectors and other visibility issues relating to the vehicles and their attached accessories; installation and functionality of accessories; operator safety; and particularities for off- or on-road use.

As can be seen from the questionnaire (Appendix 1), stakeholders were also asked whether this topic should address other issues, e.g. sharp edges, covers, other means of improving conspicuity or how accessories are fitted or connected to the vehicle.

In general terms, the review indicates that other draft RVFSR and RVCR (the delegated act addressing vehicle construction requirements) annexes already deal adequately with issues such as reflectors, conspicuity markings and mirrors. Some stakeholders suggested some further enhancements/refinements to the draft text for these annexes, which were passed on as contributions to the wider delegated act drafting process, but that were outside of the specific scope of this current study and are thus not considered further in this report.

The sole exception to this general observation was the suggestion from CEMA and other stakeholders that this annex could usefully address the issues of exterior projections and minimising risks to Vulnerable Road Users (e.g. pedestrians, pedal cyclists and motor cyclists). The review further identified UNECE Regulation No. 26 (*Uniform provisions concerning the approval of vehicles with regard to their external projections*) and the Machinery Directive (2006/42/EC) as potential sources of text for draft provisions.

While accident studies such as those used in Robinson, Scarlett & Seidl (2013) do indicate that pedestrian collisions are quite common, particularly in farm yards or out in the field, and very often have very serious or fatal consequences, their route cause is usually either poor visibility for the tractor driver or some form of uncontrolled movement of the vehicle, rather than any issues with external projections along the side of the vehicle. Motor cyclists, too, are often involved in collisions with tractors on rural roads, again often with very serious or fatal consequences, but these tend to be "head on" impacts or impacts into the back of a tractor, rather than glancing impacts with a tractor side. That said, vulnerable road users clearly do interact with agricultural vehicles and so provisions to minimise risks from glancing impacts are likely to be beneficial, at least in some circumstances, although overall a prioritisation of "low" seems appropriate.

UNECE Regulation No. 26 applies to external projections of category M1 vehicles (passenger cars). It does not apply to exterior rear-view mirrors or to the ball of towing devices. Its stated purpose is to reduce the risk or seriousness of bodily injury to a person hit by the bodywork or brushing against it in the event of a collision. This is valid both when the vehicle is stationary and in motion.

The Regulation contains some "General" (section 5) and "Particular" specifications (section 6). The "general" specifications exempt "those parts of the external surface which, with the vehicle in the laden condition, with all doors, windows and access lids etc., in the closed position, are either:

- At a height of more than 2 metres, or
- Below the floor line, or
- So located that, in their static condition as well as when in operation, they cannot be contacted by a sphere 100 mm in diameter."

The "general" specifications then require (in summary) that external surfaces not exempted by the above conditions:

- shall not have "pointed or sharp parts or any projections of such shape, dimensions, direction or hardness as to be likely to increase the risk or seriousness of bodily injury"

- shall not "exhibit, directed outwards, any part likely to catch on pedestrians, cyclists or motor cyclists"
- shall not have a radius of curvature less than 2.5 mm (unless they protrude less than 5mm, but more than 1.5mm, in which case their outward facing angles shall be blunted, or they are made of a material with a hardness not exceeding 60 shore A).

The "particular" specifications cover more detailed accessories/fittings, including:

- Ornaments
- Headlights
- Windscreen wipers
- Bumpers
- Handles, hinges and fuel tank filler caps
- Wheels, wheel nuts, hub caps and wheel discs
- Sheet metal edges & body panels
- Lateral air or rain deflectors
- Jacking brackets and exhaust pipes
- Air intake and outlet flaps
- Windows
- Registration plate brackets
- Luggage racks, and
- Aerials

In response to the questionnaire, CEMA have suggested that a slightly adapted version of the "general" specifications would be suitable for agricultural and forestry vehicles, without any of the "particular" specifications of the UNECE regulation being necessary.

The Machinery Directive (2006/42/EC) applies to, amongst other things, machinery, interchangeable equipment and safety components. Under the present legislative arrangements it exempts "agricultural and forestry tractors for the risks covered by Directive 2003/37/EC, with the exclusion of machinery mounted on these vehicles".

In Annex I (*essential health and safety requirements relating to the design and construction of machinery*), section 1.3.4 covers risks due to surfaces, edges or angles and requires that "insofar as their purpose allows, accessible parts of the machinery must have no sharp edges, no sharp angles and no rough surfaces likely to cause injury". Although clearly these provisions are far less detailed than those of UNECE Regulation 26, unlike that Regulation, they do specifically mention the subject of "rough surfaces".

A detailed discussion of the merits of the above regulatory approaches, along with an assessment of which specific provisions should be included in the draft RVFSR delegated act annex on tracks, is included in the following Chapter of this report.

3 Proposed technical requirements and performance specifications

In this Chapter, the results from the literature review and stakeholder consultation are combined with expert engineering judgement to provide, for each safety topic:

- A summary of its relevance and risk profile during mobility (functional safety), and how that relevance is affected according to vehicle type and maximum speed;
- A summary of the existing requirements, specification and/or test procedures identified and identification of those best suited to each vehicle type;
- A discussion of opportunities for the safety specifications to be harmonised with other vehicle types;
- A summary of the proposed technical requirements for the Delegated Acts and, where required by the evidence resulting from Tasks 1 and 2 and by the co-decision text, more detailed performance specifications and approval test procedures.

Exactly as with the previous TRL study that contributed to the drafting of the RVFSR and RVCR delegated acts (Robinson, Scarlett & Seidl, 2013), the approach to the drafting of the technical requirements here has essentially been to apply an approval hierarchy to each safety topic and vehicle type, with the resultant proposals depending on the topic's prioritisation and on the obligations resulting from the co-decision text, by applying the decision process of the table below that accounts for the outcome of Tasks 1 and 2 within it, its suitability for approval testing and the availability of appropriate test procedures. Each step of the hierarchical decision process was informed by the literature review and stakeholder contributions, and based firmly on suitably qualified engineering expertise. The decision process is summarised in Table 1:

Table 1. Task 3 Decision Hierarchy

Question	Answer	Decision
Step 1 – Is the safety topic an important contributor to accidents and can its risks be reduced via detailed testing and/or performance specifications at type approval?	Yes	Go to Step 2
	No	Draft easily verifiable technical requirements only.
Step 2 – Does a suitable test procedure exist?	Yes	Go to Step 3
	No	Draft detailed performance specifications based on readily measurable or identifiable criteria only.
Step 3 – Can robust limit values or test performance criteria be defined for the most suitable test procedure?	Yes	Draft detailed performance specifications based on the most suitable test procedure.
	No	Draft detailed performance specifications based on readily measurable or identifiable criteria only, and recommend steps to establish suitable limit values using the most suitable test procedure.

Wherever possible, specifications have been based on existing test procedures and robust limit values already applied to other vehicle types, or based on other, good quality stakeholder or published evidence.

Appendix B provides the draft delegated act annex text arising from this study.

3.1 Tracks

The literature review and stakeholder consultation tasks established that the most significant issue regarding crawler tractors, potentially addressable via detailed provisions within the RVFSR delegated act, is that of contact pressure on the ground. There are also potential concerns with "high speed" crawlers, i.e. those capable of over 40 km/h (Cb category). While there are no such vehicles currently available on the European market, the possibility that situation may change needs to be considered. Both of these topics are discussed in more detail in the following sections, for both rubber-tracked and, separately, for steel-tracked vehicles.

3.1.1 Rubber tracks

Of the two basic types of crawler (steel and rubber-tracked), it is the rubber-tracked varieties that seem to present the greatest difficulties with regard to the measurement or calculation of their ground pressure.

One of the major advantages of rubber tracked tractors is their low ground pressure when operating on (deformable) soil surfaces. In such conditions the entire base area of the track-soil contact patch is able to support a proportion of the vehicle's mass. The track (rubber) tread bars simply serve to provide traction. A quite different situation arises during on-road mobility. Whilst a major advantage of these vehicles over steel-tracked counterparts is their ability to travel at speed (30 – 40 km/h is feasible with current models) on the road, such use incurs a number of undesirable characteristics:-

- Unlike modern wheeled tractors or even a pneumatic tractor tyre, rubber tracks and their running gear do not embody significant compliance/ suspension, other than to permit limited vertical oscillation between the left & right tracks to accommodate ground profiles;
- Bystander noise and tread bar vibration due to road surface contact can be significant at higher forward speeds;
- The entire vehicle mass is now supported on the tread bar surface area within the track-ground contact patch. In reality, due to the flexible nature of the track, the vehicle mass is not likely to be distributed evenly along the track contact area, but rather vertical loadings are likely to be concentrated directly under each track drive/tensioning/idler roller. This will be further exacerbated by the prevailing bias of vehicle mass distribution front-to-rear along each track. When heavy mounted implements are in transport *(as would be the case on-road)*, the vehicle's mass distribution will move rearwards, placing most of the vertical load on the rear drive roller. Conversely, when travelling unladen or with front ballast weights, but with no implement attached *(as would be the case at the time of type-approval testing)* peak vertical loadings are likely to be biased towards the front ends of the tracks.

This situation raises two questions for this particular investigation:-

i) By what methodology should tracked tractor ground contact pressure be calculated / measured during Type-Approval?

ii) What should the contact pressure limit value be?

Considering the latter question first, the value of 0.8 MPa has been suggested and indeed appears in Article 17 of EU Regulation 167/2013: interestingly this is equally-applicable to both agricultural tractor tracks and tyres but it must be emphasised that Article 17 specifies this as the maximum pressure allowable, implying that any measurement/calculation of the mean pressure should have some safety margin to ensure peak loads are unlikely to exceed this maximum limit.

Other Member States have specified similar requirements in national legislation, although usually these apply to all tracked vehicles, they were probably developed with steel-tracked crawlers in mind and the precise limit values differ *(see* Table 2*).* It is worthy of note that a number of national requirements also take the loadings present on individual track rollers into consideration in some way or another.

Table 2. European Requirements for On-Road Use of Track-laying Tractors *(excluding max. vehicle mass)*

Member State / Body	(Rubber) Track requirement(s) for Road Use
EU *(proposed)*	Hard surface contact pressure ≤ 0.8 MPa
CEMA	As per proposed EU requirement
Germany	Contact pressure ≤ 0.8 MPa **plus** track roller load ≤ 2 tonnes **plus** *(if suspended)* track roller load ≤ 4 tonnes when raised by 60 mm
Denmark	Track roller load ≤ 1.5 tonnes
Italy	Contact pressure ≤ 0.65 MPa, but calculation procedure considers no. of track rollers supporting the vehicle
UK	Contact pressure ≤ 0.436 MPa

Regarding the methodology by which tracked tractor ground contact pressure could be calculated / measured, there are probably four options:-

i) **Calculation of Mean Contact Pressure as per the draft ISO procedure:-** Pressure distribution across/along the track-ground contact area is considered to be uniform. The contact area is taken to be the total tread bar surface area within this region. Contact pressure is derived by dividing vehicle max. permissible weight *(in Newtons)* by the total tread bar surface area in contact with the ground *(in mm^2)*.

ii) **Modified ISO calculation procedure:-** As per (i), but with some consideration of the number and/or features of the *(vehicle load-supporting)* track rollers.

iii) **Direct measurement of Peak Contact Pressure:-** Specialist instrumentation *(force transducer arrays)* exist whereby localised vehicle tyre / track – ground surface contact pressure may be recorded as the vehicle is driven over the equipment. Such equipment is not cheap, but the results obtained are a true measurement of Peak Contact Pressure.

iv) **Complex calculation method:**- Denmark have indicated their intention to allow for ground pressure to be calculated, as an alternative to direct measurement, using a more complex formula that considers properties of the rubber (i.e. how much it flexes under the rollers and thus how much of the load is transferred to the road along each part of the contact length). At the time of writing this report, full details of the proposed Danish calculation methodology were not available, though information that was provided indicates that the method, while still quite simplistic, does allow an estimate to be made of the peak ground pressure across the rib contact length, rather than just the mean pressure. It could potentially be useful for a future revision of the delegated act requirements, if the method can be suitably validated. A worked example of the Danish method applied to one existing vehicle has been provided, and is discussed below.

Research such as Rowlands (1972) and other studies cited by Wong (2008) show that, even when operating on soft soil, substantially higher ground contact pressures exist under the track rollers than the calculated 'mean' contact pressure. This, and the provisions of certain National legislation, makes it difficult to advocate the use of Method (i) alone without further adaptation, along the lines of Method (ii) at least.

Table 2 presents mean ground contact pressure values (calculated in accordance with the draft ISO procedure) for the main rubber-tracked tractors currently on sale in the EU. The ranges of calculated mean pressures shown relate to the different track patterns available for each vehicle type. It will be noted that, by this calculation method:-

- All the vehicles are well under the 0.8 MPa ground pressure limit value;
- The skid-steered machines (Challenger & John Deere) generate comparable / slightly higher values than the articulated-steer Case-IH Quadtrac, and the latter also benefits from a greater number of load-carrying track rollers which are likely to create more uniform pressure distribution along the track – ground contact area *(see Figures 1 & 2)*.

Table 3. Rubber-Tracked Tractors:- Typical Mean Ground Contact Pressures *(ISO calculation procedure)*

Tractor	Engine Power (kW)	Max. Permissible Mass (kg)	Track Rollers *(pairs)*	Mean Ground Contact Pressure (MPa)
Challenger MT700 John Deere 8RT	225 – 300	~20,000	5 / side 10 total	0.2 – 0.35
Challenger MT800 John Deere 9RT	345 – 430	~25,000	6 / side 12 total	0.2 – 0.38
Case-IH Quadtrac	290 - 490	~26,000	5 / track 10 / side 20 total	Front = 0.20 - 0.28 Rear = 0.14 - 0.20 Overall = 0.17 - 0.24

This situation raises two further questions:-

i) Is the 0.8 MPa limit value excessive?

ii) Is the proposed draft ISO ground pressure calculation procedure too simplistic?

It would appear that, if the ISO calculation procedure is employed, a mean load limit of around 0.4 – 0.5 MPa might well be suitable (in that existing designs would meet the requirement). Such a limit value for the mean pressure would also leave a comfortable 0.3 - 0.4 MPa safety margin providing some leeway for peak loads (which will inevitably be higher than the mean calculated pressure) to remain within the 0.8 MPa upper limit required by Regulation 167/2013. The draft Danish calculation methodology applied to the Challenger MT800 vehicle produces a calculated peak pressure of 0.64 MPa, which is itself about 0.2 - 0.3 MPa higher than the mean value calculated according to the draft ISO procedure and reported in the table above.

Informal observation of road pavement damage by rubber-tracked tractors suggests it is considerably greater than that caused by wheeled tractors; note, however, that relatively few wheeled tractors are as heavy as the tracked vehicles under consideration.

Actual vehicle operating masses are also worthy of consideration. Large, high-powered rubber-tracked crawlers tend to be used with trailed implements, which impose much lower additional loads on the rear of the tractor (than carried implements). This is believed to be the usual practice with articulated tractors. However, as illustrated by Figure 3, it is common to use 'smaller' *(200-300 kW)* tracked tractors with mounted implements, which can significantly add to the total vehicle mass. Vehicle pitching is common during road travel, further exacerbating peak track-ground contact pressures.

Figure 1. Case IH Quadtrac ***(5 track roller pairs per track unit. 20 roller pairs per vehicle)***

Figure 2. AGCO Challenger MT700 series ***(5 track roller pairs per track unit. 10 roller pairs per vehicle)***

Figure 3. AGCO Challenger MT700 series plus 6 metre power-harrow drill combination and front-mounted 2000 litre seed hopper. In transport *(top)* and in-work *(below)* *(Tractor mass ~ 15,000 kg, rear implement ~ 5,500 kg, front hopper ~ 2,500 kg: Total ~ 23,000 kg, Vehicle max. permissible mass ~19,000 kg)*

Spreading the load across as many rollers as possible is likely to be an effective way to further ensure peak loads are not dramatically higher than the mean pressures calculated using the simple (ISO) method (which effectively considers only the distance between the front and rear rollers and does not take the number of intervening rollers into account). Table 3 indicates that existing designs vary between per-roller loads of about 2.08 tonnes (for the 25t machines on 12 rollers) and 1.30 tonnes (for the articulated 26t vehicle on 20 rollers).

In terms of a possible limit value for the delegated act, therefore, the current Danish limit of 1.5 tonnes would exclude all but the articulated Quadtrac model, whereas the German limit of 2 tonnes would only exclude the larger Challenger and John Deere models (unless they meet the requirements for the 4 tonne roller load limit to apply).

For simplicity, and to avoid excluding existing designs (for which there is no evidence that road damage is a significant problem), we suggest a roller load limit of 2.25 tonnes. This is low enough to ensure that existing 10/12 roller designs cannot go to 8/10 roller versions without also reducing their maximum permissible mass (they would have roller loads of 2.5 tonnes at their existing max. permissible masses), but high enough not to exclude any of those existing designs.

A further consideration is to ensure that the load is also distributed over a reasonable length of road/track. For a given number of rollers the wider they are spaced, in general, the better for minimising road damage. Existing national legislation such as in Germany addresses this via a maximum load per metre of track in contact with the road (currently 9 tonnes per metre). CEMA have proposed a limit of 75 kg per cm (about 7.4 t/m).

Measurements of existing rubber-tracked vehicle designs obtained for this study indicate that per metre maximum permissible loads are in the range 3.0 – 4.5 tonnes per metre of track in contact with the road, so a lower limit than either CEMA propose or is in force in Germany should be feasible.

To summarise the study's findings surrounding the issue of ground contact pressure:-

- All current vehicles can easily meet the 0.8 MPa limit value if the simplistic draft ISO calculation procedure of mean ground contact pressure is employed, though a lower limit value of 0.4 MPa would also, for example, be achievable by current designs and allow a good safety margin between the calculated *mean* pressure and the *maximum* pressure allowed by Regulation (EU) 167/2013 (0.8 MPa);
- A more accurate and realistic contact pressure measurement technique would be more complex and expensive and would require a period of development/ verification;
- Increasing the number of load-supporting track rollers should lead to a more uniform distribution of ground pressure along the track contact patch, and further help to ensure that the 0.8 MPa limit is not breached. A useful enhancement, therefore, to the simplistic ground pressure calculation approach is to set a limit on the per-roller maximum permissible load. A figure of 2.25 tonnes is suggested;
- Another enhancement, to ensure the loads transmitted via the rollers are spaced effectively is to limit the tonnes per metre of track in contact with the road. A value of 4.5 tonnes per metre is suggested.

- Appropriate administrative provision will need to be included in the Type-Approval process to effectively 'approve' the use of specific rubber track makes, widths, tread patterns, etc, for use on a given machine, seeing as all the tracks are produced by Third Parties and that more than one track make/variant is available for each machine.

The draft ISO procedure also specifies a physical test of the vehicle, driven around a tightening radius course at no less than 10 km/h, with pass/fail criteria based on visible damage to the road surface. The procedure does not, however, go into any detail as to the exact specification of road surface, and should a vehicle fail such a test it is likely to be a complex and expensive procedure to re-instate it for future tests. For these reasons, we do not consider a physical test of road surface damage to be appropriate for type approval purposes at this time.

As mentioned previously, it is also important to consider the issue of maximum speed for rubber-tracked vehicles. At present, no rubber-tracked crawlers are designed to travel in excess of 40 km/h. Regulation (EU) 167/2013 requires that type approval requirements be laid down for Cb vehicles, i.e crawlers capable of speeds exceeding 40 km/h. We believe there is almost certainly good reason to propose that such vehicles should not be treated in exactly the same way as existing (Ca) models, due to:-

- Relatively poor directional control (especially skid-steered machines);
- Absence of effective suspension;
- Increased track heat build-up, higher wear and reduced track life and greater risk of failure if used at higher speeds. The draft ISO procedure already specifies that belts driven by friction should have a continuous indication of track tension or a low-tension warning device, so clearly the risk of track detachment is real (even if accident studies do not seem to indicate it as being commonplace);
- Increased bystander noise levels at higher travel speeds;
- Possibly greater road pavement damage (especially surface scraping damage from skid-steered machines);
- Greater risk of accident / injury to other road users (on basic kinetic energy, momentum and stopping distance grounds if nothing else).

These issues are important but to-date the other draft Delegated Act annexes (often based on existing Directives or Standards) have usually, we suggest, been developed with wheeled vehicles in mind. It is by no means clear that a rubber-tracked crawler would have similar road behaviour following track failure/loss as that of a large wheeled tractor following a puncture, for example. In the absence of good evidence to indicate that high speed tracked vehicles would have equivalent safety to their wheeled counterparts (even if they do satisfy all the type approval requirements applicable to them), we suggest the sensible approach might be to impose a 50 km/h maximum speed limit on rubber-tracked crawler vehicles and require Cb vehicles to use articulated steering and have track rollers separately suspended. We understand, however, that Regulation 167/2013 does not provide a mandate for the maximum design speed of fast vehicles to be restricted at Type Approval, though individual Member States would still be free to set their own "in-use" limits. Type Approval legislation could, however, be updated at a later stage, as an upgrade to technical progress.

For the time being, we suggest that to further compensate for the potentially higher (dynamic) loadings imposed on road surfaces by faster (Cb) vehicles, an additional safety factor between the calculated mean pressure and the 0.8 MPa overall limit is used, and that to achieve this, the calculated mean ground pressure for Cb vehicles be limited to 0.2 MPa. To further protect road surfaces from damage, only articulated steering systems should be permitted for Cb vehicles (defined as where the axle changes angle relative to the median longitudinal plane of the vehicle).

3.1.2 Steel tracks

For steel-tracked crawlers, operating at low speeds and fitted with pads for on-road use, the existing Italian national requirements are the only current source of detailed technical requirements. They assume an even distribution of weight across all the rollers, but no load transferred to any pads not directly under a roller.

This seems to be a sensible and appropriate approach to limiting the road damage potentially caused by such vehicles. Precise data from existing vehicle designs has not been obtained for this study or made available by stakeholders, but the existing Italian limit of 0.65 MPa seems reasonable, and provides a safety margin for peak loads to still fall within the overall 0.8 MPa limit imposed by Regulation (EU) 167/2013.

The safety concerns discussed above for high speed rubber-tracked crawlers apply also to steel-tracked varieties, and in many ways to even greater extent. Evidence gathered by this study indicates that existing models have maximum speeds of no more than 15 km/h, and German national requirements impose a limit of 16 km/h. These low maximum speeds help to ensure such vehicles are rarely, if ever, used on the road (because it is so much easier and quicker to carry them on a low-loader trailer). We suggest, therefore, that steel-tracked vehicles should not be permitted (for type approval purposes) to have a maximum design speed above 15 km/h.

3.2 Exteriors and accessories

The literature review and stakeholder consultation exercise suggest that this annex of the RVFSR delegated act focus on the subject of exterior projections and minimising risks to vulnerable road users from glancing impacts with the sides of agricultural vehicles. UNECE Regulation 26 has relevant provisions for M1 vehicles (passenger cars) which are not in their entirety suitable for agricultural and forestry vehicle type approval, but which can, we suggest, be readily adapted.

CEMA's adaptation involves the following main variations from UNECE Regulation 26:

i. Exclude all the "particular specifications"

ii. Include only the side of the vehicle (i.e. exclude the front and rear)

iii. Redefine the main target area as being between 1 m and 2 m from the ground (Regulation 26 has it as between the 'floor line' and 2 m from the ground)

iv. Below 1 m, the points considered are restricted only to those forming the extreme outer edge in each vertical plane perpendicular to the length axis

v. Exclude the metallic tracks of vehicles in category C

vi. Allowing a hardness value to be declared by the component manufacturer (Regulation 26 specifies an in-situ hardness measurement)

CEMA further propose to make special provisions for "exposed ground or crop engaging tools and material distribution devices on vehicles of category R & S [trailers and towed equipment] that have sharp edges or teeth when folded in road transport mode". These provisions essentially exempt such vehicles from the requirements if they are already covered under the Machinery Directive and require compliance only "insofar as the function of the part allows it" for any other part of category R & S vehicles.

These proposals seem to be broadly reasonable, given the obvious differences between tractors and passenger cars and the relatively low priority and rareness of glancing collisions between them and vulnerable road users.

The only exception to this is the 1 m replacement for the 'floor line' boundary in Regulation 26. This seems rather high, certainly much higher than a car's floor line, but also higher than the ground clearance of many agricultural vehicles. This could potentially allow protruding parts (unless they are at the extreme outer edge in each vertical plane) to be fitted at a height that would bring them into the 'danger zone' for pedestrians, cyclists and motor cyclists. Adult VRUs may well be quite reasonably protected by such provisions, because their arms are likely to be more than 1 m from the ground (and legs tend not to move very far sideways when walking or cycling in the same way as arms do, e.g. when indicating to turn). Children's arms, however, could, we suggest, become entangled with protruding parts not at the extreme outer edge of a vehicle at heights lower than 1 m. To ensure more comprehensive protection, for a wider age range of vulnerable road users, we therefore suggest a value of 0.75 m might be more appropriate, but otherwise agree with CEMA's proposals.

The only other enhancement to these proposals we suggest, inspired by the reference to rough surfaces in the Machinery Directive, is to clarify that such surfaces are also potentially injurious to VRUs. Rather than simply referring to "any pointed or sharp parts or any projections…", as Regulation 26 and the CEMA adaptation proposals use, we suggest amending this to "any pointed or sharp parts, rough surfaces or any projections…".

4 Conclusions

1. Published literature (Task 1) and stakeholder contributions (Task 2) were reviewed, to establish existing legislative requirements for agricultural and forestry vehicles under each safety topic. The review also identified existing test requirements and draft standards, e.g. from UNECE and ISO.

2. This topic of "tracks" covers the steel or rubber tracks (also known as endless belts) fitted to crawler vehicles (category C). Specific areas of interest identified at the outset of the project include material strength, connections (for steel belts), installation, ground contact pressures and adaptability for off- or on-road conditions.

3. In relation to the specific topics raised at the outset for tracks, the reviews have found that only the issue of ground pressure is widely felt to be relevant and amenable to track-specific provisions within the draft delegated act. Further provisions may be needed, however, to mitigate a wider range of potential safety risks likely to arise with higher speed (> 40 km/h) tracked vehicles, if any such vehicles are introduced to the market (there are none currently on the market).

4. The review has identified several references detailing ground pressure requirements in individual Member States (Italy, UK, Germany and Denmark), as well as a draft ISO standard.

5. A limit value of 0.4 MPa for the mean ground contact pressure of Category Ca rubber-tracked vehicles, as calculated using the simple approach suggested in a draft ISO standard, would be achievable by current designs and allow a good safety margin between the calculated *mean* pressure and the *maximum* pressure allowed by Regulation (EU) 167/2013 (0.8 MPa).

6. A lower limit value of 0.2 MPa for the mean ground contact pressure of Category Cb rubber-tracked vehicles would further compensate for the higher (dynamic) loads that would be imposed on road surfaces by such faster vehicles.

7. A useful enhancement to the simplistic ground pressure calculation approach is to set a limit on the per-roller maximum permissible load. A figure of 2.25 tonnes is suggested;

8. A further enhancement, to ensure the loads transmitted via the rollers are spaced effectively, is to limit the load per metre of track in contact with the road. A value of 4.5 tonnes per metre is suggested.

9. Appropriate administrative provision will need to be included in the Type-Approval process to effectively 'approve' the use of specific rubber track makes, widths, tread patterns, etc, for use on a given machine.

10. For steel-tracked crawlers, fitted with pads for on-road use, the existing Italian national requirements seem to be a sensible and appropriate approach to limiting the road damage potentially caused by such vehicles. The existing Italian mean ground pressure limit of 0.65 MPa seems reasonable, and provides a safety margin for peak loads to still fall within the overall 0.8 MPa limit imposed by Regulation (EU) 167/2013.

11. There are a range of potential safety concerns with high speed crawlers, defined here as rubber-tracked vehicles > 40 km/h and steel-tracked > 15 km/h. No such vehicles are currently available in the EU, but restricting their future type approval seems a prudent move, until their safety case can be adequately demonstrated as being equivalent to wheeled vehicles. Articulated steering, suspended track rollers and a 50 km/h maximum design speed for rubber-tracked vehicles are suggested, along with a 15 km/h maximum design speed for steel-tracked vehicles.

12. The "exterior and accessories" topic relates to the exterior bodywork and surfaces of agricultural/forestry vehicles and any attached accessories that are not covered by separate type approval requirements and are not detachable implements/ machines covered by the Machinery Directive. Of particular interest at the outset were: reflectors and other visibility issues relating to the vehicles and their attached accessories; installation and functionality of accessories; operator safety; and particularities for off- or on-road use.

13. In general terms, the review indicates that other draft delegated act annexes already deal adequately with issues such as reflectors, conspicuity markings and mirrors.

14. The sole exception to this general observation was the suggestion that this annex could usefully address the issues of exterior projections and minimising risks to Vulnerable Road Users (e.g. pedestrians, pedal cyclists and motor cyclists).

15. UNECE Regulation 26 has relevant provisions for M1 vehicles (passenger cars) which are not in their entirety suitable for agricultural and forestry vehicle type approval, but which can, we suggest, be readily adapted, and enhanced by making reference to rough surfaces.

5 References

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Acknowledgements

The authors would like to thank the many individuals and organisations who have contributed their time, expertise and experience to this study. We would particularly like to thank all those who responded to the email questionnaire or otherwise contributed to the stakeholder consultation part of this work.

Appendix A Stakeholder Questionnaire

TRL has been appointed by the European Commission to help develop the technical requirements for various functional and occupational safety topics relevant to the future type approval of agricultural and forestry vehicles under the Regulation (EU) 167/2013 on the approval and market surveillance of agricultural and forestry vehicles. The study is focusing particularly on the topics of tracks (for crawlers) and vehicle exteriors/accessories. This questionnaire seeks your expert/stakeholder views on these topics.

Please complete all the questions in section 1 and as many of the questions in sections 2 and 3 as you can, depending on your particular expertise or experience.

1 Your details

1.1 What is your name and position in your organisation?

1.2 What is your organisation?

1.3 What is your email address?

2 Tracks

This topic covers the steel or rubber tracks (also known as endless belts) fitted to crawler vehicles (category C). Specific areas of interest include **material strength, connections** (for steel belts)**, installation, ground contact pressures** and **adaptability for off- or on-road conditions**.

2.1 **Please list any standards, national requirements or other published specifications that you feel might be useful,** as a basis for future type-approval requirements with regard to any or all of the above-mentioned topics, including the ones known from other vehicle types, e.g. off-road trucks, construction or quarrying vehicles.

a) Are those you've listed already suitable for agricultural/forestry vehicles or can they be readily adapted?

b) Please specify whether such requirements are suitable for vehicle, system, component or separate technical unit type-approval under the Regulation (EU) 167/2013.

2.2 What are the particular safety risks with tracked agricultural/forestry vehicles?

a) How commonplace are injuries arising from these risks?

b) Are these risks different for rubber and steel tracks?

c) Are these risks different for each vehicle type, e.g. C1, C2, C3 etc?

d) Do high speed crawlers (category b, >40 km/h) pose significant additional risks?

3 Vehicle exteriors/accessories

This topic relates to the exterior bodywork and surfaces of agricultural/forestry vehicles and any attached accessories that are not covered by separate type approval requirements, such as tyres, lights, mirrors, and are not detachable implements/machines, which are covered by the Machinery Directive. Of particular interest are: **reflectors** and other **visibility issues** relating to the vehicles and their attached accessories; **installation and functionality of accessories**; **operator safety;** and **any particularities for off- or on-road use**.

3.1 In terms of bodywork for safe use of a vehicle and mounted items that are not machines or covered by other type approval requirements, **what, apart from reflectors, should this topic address (e.g. sharp edges, covers, other means of improving conspicuity or how they are fitted or connected to the vehicle)?**

3.2 **For the topics you've listed in 3.1, please list any standards, national requirements or other published specifications that you feel might be useful**, as a basis for future type-approval requirements, including for other vehicle types, e.g. off-road trucks, construction or quarrying vehicles.

a) Are they already suitable for agricultural/forestry vehicles or can they be readily adapted?

b) Please specify whether such requirements are suitable for vehicle, system, component or separate technical unit type-approval under the Regulation (EU) 167/2013.

3.3 For reflectors, Directive 76/757/EEC contains detailed requirements (for various other types of non-agricultural motor vehicle). **Are these also suitable for agricultural/forestry vehicles? If not, can they be readily adapted?**

a) Are you aware of any other standards/requirements that might provide suitable alternative provisions for reflectors? Please list them.

3.4 What are the particular safety risks associated with agricultural/ forestry vehicle bodywork and accessories, including reflectors?

a) How commonplace are injuries arising from these risks?

b) Are these risks different for each vehicle type, e.g. T/C1, T/C2, T/C3, R, S etc?

c) Do high speed vehicles (category b, >40 km/h) pose significant additional risks?

Appendix B Draft Annexes to RVFSR

ANNEX XIV

Requirements on vehicle exterior and accessories

1. GENERAL

1.1. The provisions of this Annex do not apply to exterior rear-view mirrors.

1.2. The provisions of this Annex do not apply to the metallic tracks of vehicles of category C.

1.3. The purpose of these provisions is to reduce the risk or seriousness of bodily injury to a person hit by the exterior of the vehicle or brushing against it in the event of a collision. This is valid both when the vehicle is stationary and in motion.

2. DEFINITIONS

2.1. 'external surface' means the outside of the vehicle including tyres, doors, bumpers, bonnet, access means, tanks.

2.2. 'radius of curvature' means the radius of the arc of a circle which comes closest to the rounded form of the component under consideration.

2.3. 'laden vehicle' means the vehicle laden to the maximum permitted technical mass.

2.4. 'extreme outer edge' of the vehicle means, in relation to the sides of the vehicle, the plane parallel to the median longitudinal plane of the vehicle coinciding with its outer lateral edge, and, in relation to the front and rear ends, the perpendicular transverse plane of the vehicle coinciding with its outer front and rear edges, account not being taken of the projection:

2.4.1. of tyres near their point of contact with the ground, and connections for tyre pressure gauges;

2.4.2. of any anti-skid devices which may be mounted on the wheels;

2.4.3. of rear-view mirrors;

2.4.4. of side direction indicator lamps, end outline marker lamps, front and rear position (side) lamps and parking lamps.

3. GENERAL SPECIFICATIONS

3.1. The provisions of this Annex shall apply to those parts of the external surface which, with the vehicle in the laden condition, with all doors, windows and access lids etc., in the closed position, are either:

3.1.1. at the sides and at a height of less than 0.75 m, the parts forming the extreme outer edge in each vertical plane perpendicular to the length axis of the vehicle;

or

3.1.2 at the sides and at a height between 0.75 and 2 m, all parts, except those that cannot be contacted by a sphere with a diameter of 100 mm, when approaching horizontally in each vertical plane perpendicular to the length axis of the vehicle.

Vehicles equipped with hydro-pneumatic, hydraulic or pneumatic suspension or a device for automatic levelling according to load shall be tested with the vehicle in the most adverse normal running condition specified by the manufacturer.

3.2. The external surface of the vehicle shall not exhibit, directed outwards, any pointed or sharp parts, rough surfaces, or any projections of such shape, dimensions, direction or hardness as to be likely to increase the risk or seriousness of bodily injury to a person hit by the external surface or brushing against it in the event of a collision.

3.3. The external surfaces on each side of the vehicle shall not exhibit, directed outwards, any parts likely to catch on pedestrians, cyclists or motor cyclists.

3.4. No protruding part of the external surface shall have a radius of curvature less than 2.5 mm. This requirement shall not apply to parts of the external surface which protrude less than 5 mm, but the outward facing angles of such parts shall be blunted, save where such parts protrude less than 1.5 mm.

3.5. Protruding parts of the external surface, made of a material of hardness not exceeding 60 shore A, may have a radius of curvature less than 2.5 mm. The hardness measurement by the Shore A procedure can be replaced by a hardness value declaration from the manufacturer of the component.

3.6. Exposed ground or crop engaging tools and material distribution devices on vehicles of category R & S that have sharp edges or teeth when folded in road transport mode and that are already covered under Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, are exempted from complying with points 3.1 to 3.5. For exposed areas of any other part of vehicles of category R & S, the points 3.1 to 3.5 shall apply.

ANNEX XXXIII

Requirements (for vehicles) on tracks

1. GENERAL

1.1. The provisions of this Annex apply to the following vehicles of category C:

1.1.1. Vehicles equipped with metallic tracks, fitted with rubber pads on the track shoes, and with a maximum design speed of not less than 6 km/h and not exceeding 15 km/h.

1.1.2. Vehicles equipped with rubber tracks, and with a maximum design speed of not less than 6 km/h.

1.2 Vehicles with a maximum design speed exceeding 15 km/h shall be equipped with rubber tracks.

1.3. Crawler undercarriages must be non-damaging to roads. Vehicles with crawler undercarriages are non-damaging to roads if

1.3.1. the limits set out in points 3.1 – 3.3 are not exceeded; and

1.3.2. the contact surface of the crawler undercarriage with the road pavement is composed of an elastomeric material (such as rubber, etc.).

1.4. Vehicles in Category Cb (> 40 km/h) must additionally be fitted with an articulated steering system.

2. DEFINITIONS

2.1. Crawler undercarriage means a system comprising at least two track rollers, which are spaced a specified distance apart in one plane (in-line) and a continuous metallic or rubber track belt runs around them.

2.2. Track rollers: means the system that transmits the weight of the vehicle and crawler undercarriage to the ground via the track belt, transmits torque from the vehicle's drive system to the track belt and may produce a change of direction of the moving belt.

2.3. Track belt means a continuous flexible belt, which can absorb longitudinal tractive forces.

2.4. Track length: The distance between the centres of the extreme track rollers under which the pads or track belt are contacting the ground.

2.5. Track width: The distance between two parallel planes bounding the outside of the raised tread pattern (lugs) or pads.

2.6. Articulated steering means where the steered axle changes angle relative to the median longitudinal plane of the vehicle.

3. GENERAL SPECIFICATIONS

3.1. Mean Ground Contact Pressure

3.1.1. Metallic tracks

3.1.1.1. Vehicles meeting the requirements of 1.1.1. shall have a Mean Ground Contact Pressure, P, not exceeding 0.65 MPa, calculated according to the following formula:

$$P \text{ (in MPa)} = \frac{\text{Maximum permissible mass of vehicle (in kg) x 9.81}}{N_R \times A_P}$$

Where N_R is the total number of track rollers directly transferring load onto the road surface (via the tracks and pads) and A_P is the outer surface area of each pad (i.e. in contact with the road), in mm^2. A_P is defined by measuring the footprint of one pad perpendicular under the centre of a not extreme track roller, by lowering a

laden vehicle onto a suitable piece of cardboard or other permanently deformable material and measuring the area of the depression so caused.

3.1.1.2. For vehicles with a combination of wheeled axles and tracks, the load acting through the wheeled axles with the vehicle in the laden condition shall be measured using suitable weigh pads and subtracted from the overall maximum permissible mass to calculate P. Alternatively, the manufacturer's declared maximum combined load for the track trains may be substituted for the maximum permissible vehicle mass.

3.1.2. Rubber tracks

3.1.2.1. Category Ca vehicles meeting the requirements of 1.1.2. shall have a Mean Ground Contact Pressure, P, not exceeding 0.4 MPa, calculated according to the following formula:

$$P \text{ (in MPa)} = \frac{\text{Maximum permissible mass of vehicle (in kg) x 9.81}}{A_L}$$

Where A_L is the total surface area of rubber lugs in contact with the road, between the centres of the extreme track rollers under which the track belt is contacting the ground. The supplier of the rubber belt shall provide the percentage of lug area[1] versus the total surface of the belt (defined as the track length multiplied by the track width), or the total lug area in contact with the road can be measured by lowering a laden vehicle onto a suitable piece of cardboard or other permanently deformable material and measuring the total area of the depressions so caused.

Category Cb vehicles shall have a Mean Ground Contact Pressure, P, not exceeding 0.2 MPa, calculated in the same way.

3.1.2.2. For vehicles with a combination of wheeled axles and tracks, the load acting through the wheeled axles with the vehicle in the laden condition shall be measured using suitable weigh pads and subtracted from the overall maximum permissible mass to calculate P. Alternatively, the manufacturer's declared maximum combined axle load for the track trains may be substituted for the maximum permissible vehicle mass.

3.2. The maximum load per track roller shall not exceed 2,250 kg, calculated by dividing the maximum permissible mass in kg (allowing for any mass acting on any wheeled axles in the same way as 3.1.1.2 or 3.1.2.2) by the total number of track rollers directly transferring load onto the road surface.

3.3. The maximum load per unit length of track surface in contact with the road shall not exceed 4,500 kg per metre, calculated by dividing the maximum permissible mass in kg (allowing for any mass acting on any wheeled axles in the same way as 3.1.1.2 or 3.1.2.2) by the total length in metres of tracks in contact with the road at any given moment in time (i.e. between the centres of the extreme track rollers).

3.4 On the inside of the track belts, there must be elements to ensure that the track belt is guided over the rollers. On the outside, there the track pattern must be appropriate for the specific intended use in the agricultural or forestry sector.

3.5 Torque can be transmitted by friction (directly) or by positive engagement of the track rollers with the track.

3.6. In vehicles in which track belts are driven by friction, the operator shall have a continuous indication of track tension during road travel, or there shall be a visual and/or audible signal that is activated when the minimum belt tension is reached.

[1] % of lug area, also known as "land and sea"