Forest Research *Technical Development*

TD JR177

Small to medium scale self-loading timber trailers: a guide to safe use

Including:

An operating checklist for small to medium scale tractor-timber trailers (Appendix 7)

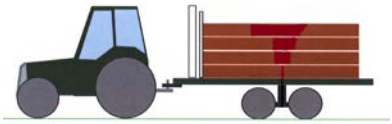
The Research Agency of the Forestry Commission

Contents

Appendices

This report is formatted so that key information is highlighted thus:

	**Information**		**Consider**		**Warning**



Summary

Timber trailers - whether large, medium, small or 'mini' - are a potentially valuable part of the harvesting 'toolbox' but efficiency and safety ultimately relies on effectively dealing with risks through informed choice of tools, machinery and working method.

This report has highlighted the issues that should be considered when choosing tractor-timber trailer combinations and a method of working, and has pointed to some underlying rules of physics. It has also provided a checklist of issues, both to consider and to follow during operations.

There is no simple 'must have' list that can cater for all machines and situations. The key factors required for a safe system of working when using timber trailers with tractors (or other prime movers) are training, risk assessment and using machinery and combinations of machinery matched to the conditions. This is in some ways analogous to felling by chainsaw, where the operator is not enclosed in a cab.

Correct choice of tractor for conditions is crucial because it can significantly affect the efficiency of the timber trailer and safety of the operator.

However, although all these factors are important, the correct choice of method of working is essential. A good choice of method is particularly important because it can enable small timber trailers to be used with suitably matched tractors, which may not necessarily have operator cab protection.

The report concludes with a table to aid the matching of tractor-trailers to working site conditions, and there is an appendix checklist for machine selection and operation.

Introduction

Background

Timber trailers are in widespread use for extracting roundwood, especially in small and medium scale forestry operations. Unlike purpose built forwarders, timber trailers are a separate unit from the prime mover and are designed to be hitched to a suitably sized 'tractor'.

Choice of timber trailer should be made within the normal health and safety hierarchy of control measures, a key step within that – where an issue is identified - being to consider substitution of a safer design or specification of equipment.

Timber trailers and associated loaders are a fundamental category of mini / small and medium scale harvesting machinery (**Table 1**). Trailers are manufactured in UK and Europe to fairly standard designs across the size range, which can be summarised as:

Table 1. General machine size categories

Description[1.]	Load capacity
Large	12 tonnes and over
Large-Medium	9 - 12 tonnes
Small-Medium	6 - 9 tonnes
Small	3 - 6 tonnes
Mini	2½ tonnes and under

Loader operation is potentially hazardous for the operator. In purpose built forwarders operators are fully protected by the cab. Similarly, larger timber trailers will be towed by a larger tractor, which in the UK will be equipped with a cab. Tractors used in forestry should be equipped with safety glazing and / or window bars / grills (amongst others), although exact requirements will be based on an assessment of risk involved for intended use. Agricultural tractors may need to be adapted to meet these standards.

However, smaller timber trailers are likely to be towed by tractors or other prime movers without cabs, or with limited safety frames. Trailers can be configured with loader controls on the trailer close to the kingpost, or with hydraulic hoses allowing positioning on the rear of the prime mover or in its vicinity, or with remote control. In these cases **the operator is likely to be operating the loader, potentially unprotected, *within its reach*.**

Furthermore, small and mini timber trailers can readily be physically attached to prime movers – such as mini tractors (or even ATCs) - which may not have the weight, stability or tow hitch capability for safe use of the trailer.

These issues are explored further in the 'Key Issues' section below:

Key issues

Timber trailers are a separate unit from the prime mover and are designed to be hitched to a suitably sized 'tractor'. Larger forestry tractor cabs should be suitably protected, including Falling Object Protection (FOPS) and correctly fitted safety / polycarbonate glazing and / or window grills to defend against objects penetrating the cab. In such cases the loader controls can, and where possible should, be mounted on the rear of the tractor such that they are operated by the driver from the seated position (in the case of swivel seats) or by kneeling on the seat. In either case the operator will be within the cab and protected by the cab roof, pillars and glazing. Protective measures should to permit good visibility and easy access to the controls.

However, smaller timber trailers are likely to be towed by tractors or other prime movers without cabs, or with limited ROPs / FOPs frames.

Therefore, an important safety issue in respect of self-loading timber trailers is the potential for the operator to be struck by the suspended load, or the loader, whilst working the controls from outwith a cab. Ideally the controls would be mounted within reach of an operator protecting cab but this is clearly not a widespread possibility for smaller timber trailers that will not be drawn by conventional tractors with cabs. Therefore, **operator protection** will be provided by one or more of:

- The geometry of the loader, and any swivel stops etc. fitted to limit the movement of the loader so that the operator cannot be struck by it when standing in the operating position (at or away from the headboard end)
- Operating method including an operator-regulated ('voluntary') limitation on the length of timber loaded so that the operator cannot be struck by the timber should the grapple spin the load (thereby nullifying the benefit of any restriction to the movement of the loader itself, as above)
- Positioning controls at a safe distance from the loader and load, which will be dependent on the length of hydraulic hose from the loader to the controls and options for positioning them, if remote control is not an option.

In some cases, especially with small prime movers, it is possible that the 'nose weight', that is the weight of the drawbar on the tow hitch, may well be exceed the manufacturer's rated limit when the trailer is being towed. Conversely, a trailer with too much weight to the rear may lift the drawbar and therefore the rear wheels, leading to instability.

Given the scope and range of individual machinery options on the market there has been a lack of detailed guidance on use of self-loading trailers. Whilst CE marking is sometimes considered to be primary evidence of a basic safe design and fabrication it is important to understand that this "Declaration of Conformity" only indicates that the equipment is safe to sell and market. It does not necessarily indicate that it is fit for use in a specific manner, combination, condition or task. Therefore, despite CE marking, there still needs to be very clear evidence of how it will be used safely in specific task/site conditions for grant applications to be supported.

PUWER regulations require 'that where there is a risk of mobile work equipment overturning, or operators being struck by objects it is minimised' – typically by the fitting of ROPS, FOPS and OPS structures. Overturning or "struck by" incidents are possible in the case of trailers in a variety of circumstances.
In respect of "struck by" risk, the combination of loader movement and grapple swivel may mean that an operator could be struck by a suspended log, at least when

positioned to operate the loader controls located near the headboard, on a stand nearby or even mounted at the rear of a prime mover.

In some cases it is possible that a higher headboard would provide sufficient protection, or the control stand could be positioned far enough away to be out of the suspended-load risk zone. Whilst these issues should be addressed through risk assessment, there is nevertheless a gap in guidance highlighting issues to consider and the importance of operating methods to militate against residual hazards.

Although manufacturers information can be used as a guide in specific cases, there is currently no clear guidance, including evidence from operational tests, to **match trailers to the correct scale of prime mover in general**.

Technical Development produced the report *'Small and mini harvesting and extraction machinery: a guide to their selection for safety'*, (2016, TDJR131). The aim was to support Forestry Commission staff with guidance on selection of small-scale timber extraction trailers. The report has been used in support of the FC Scotland Harvesting and Processing grant scheme within the Scottish Rural Development Programme, and elsewhere. The guide explains design and specification factors to be considered when choosing machinery for small and medium scale harvesting operations. It promotes the **risk assessment approach** to ensure that individual equipment is suited for the particular role and circumstances of intended use.

In some cases equipment is clearly suitable for a wide range of duties because it is designed and manufactured with full safety features, an example being the purpose built forwarder.

However, in the case of *smaller-scale* equipment, not equipped or used with fully protective cabs, *judgements* need to be made on the suitability of *operator protection* in relation to the *design* and *operating method*. Aspects of particular machines, or their use in combination, may compromise their ability to form part of a safe system of work, especially in relation to roll over, falling object and operator protection.

This report aims to clarify the design features required of self-loading timber trailers and the associated safe working arrangements, including load specification and distribution for both trailers and tractor prime movers. Consideration is given to the nature of 'risk zones' resulting from the geometry and pan of loaders, and resulting safety issues for positioning the loader controls. Measures to mitigate risk in different loader operating positions are discussed and a checklist of considerations for safe selection and operation of tractor-timber trailer combinations is given.

The resulting advice supports our safe use guidance on *Small and mini harvesting and extraction machinery.* It provides information for assessment of trailers and highlights safe working practice that will minimise residual risks to the operator.

Objectives

To produce guidance on the:

1. Safe selection and operation of small to medium scale self-loading timber trailers
2. Main types of tractor, including ergonomics, operator protection, stability, trailer weight, traction / terrain-ability, tow hitch and overall suitability for use with the main types of small to medium self-loading trailers
3. Main types of loader, including loader configuration, control stance, potential for cab mounting of controls and to recommend action to minimise risk.
4. Matching of trailers to suitable tractor prime movers and
5. Use of tractor - trailer combinations in dynamic forestry conditions, including the key operator protection and weight / load distribution issues resulting from engineering design.

Method

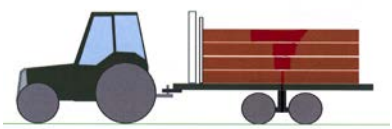
The work method comprised an initial review of the range of types of smaller self-loading timber trailers available on the market and an assessment of the likely main issues arising from design and operational use. This was followed by a concentrated site visit tour to review specific examples of the performance of equipment in the field. A very important aspect of the visits was to capture the experience and views of owners and operators using the equipment in a variety of forestry scenarios.

The fundamental geometry and physics of timber trailers were considered in relation to trailer stability, loader movement, tractor specification and operator protection so that the issues concerning safe use, especially of loaders were understood. The importance of correct selection of the prime mover ('tractor') was a key issue so recognition of tractor and trailer combination limitations was highlighted. Finally, existing industry best practice guidance was applied and augmented to produce a consolidated user guide.

This report has been compiled to include evidence from both accepted industry sources and the underlying behaviour of machinery where governed by the laws of physics (much of which is within Appendices). This is applied to trailers, loaders and prime movers, the main characteristics of which are first described, the progression being:

- the characteristics of trailers, including
- influences of weight,
- the characteristics of loaders, including
- operator protection
- the characteristics of tractors, including
- operator protection
- small scale tractors as a specific class and in summary
- a consolidated guide to safe selection and operation of small scale timber trailer - tractor combinations.

Although the issues affecting small scale machinery differ in some respects from ‘medium’ scale equipment, the principles are essentially the same as with larger tractor-trailer combinations and hence this guide draws upon experience and guidance that is applicable across these categories.



Trailer characteristics

Construction

In general, timber trailers comprise a steel box section or tubular frame bunk on a 'spine' ('central beam'), or parallel frame chassis, and a headboard. Bolsters, and sometimes headboards, may be movable to suit produce length.

The standard design of timber trailers uses four wheels in a bogie arrangement, which may be movable along the chassis, and soft-terrain pneumatic tyres. Trailers may be fitted with a movable frame extension at the rear to increase the length of the bunk by as much as c. 90 cm. Such 'bunk extensions' may be hydraulically operated on larger trailers.

Wheels are positioned towards the centre of balance so that the trailer tends to sit level when unhitched. Their position on some trailers can be adjusted slightly, and even hydraulically. Except for the smallest models, trailers can be supplied with drive to the two or four wheels powered mechanically from the tractor PTO or - more usually - by the tractor hydraulic pump system. Wheels may be powered by hydraulic motors located at the wheel. Four-wheel units, especially the smaller ones, often utilise a single driven axle mounted above the wheels whereby drive is transmitted to front and rearmost wheels via a friction hub, 'roller drive' or 'drive wheel' bearing down on the tyres from above.

All but the smallest trailers (i.e. those over c. 2 tonnes) are usually equipped with hydraulic running / parking brakes acting on two, or all four wheels. Larger trailers may have pneumatic brakes and even 'ABS' if designed for faster road use.

All but the smallest trailers, which might be loaded by hand, are equipped with a loader (see 'Loader characteristics' section).

Twin stabiliser legs are often fitted to support the loader during operation, especially with smaller trailers, and are usually activated by twin hydraulic rams. These legs may be either pivoted to 'Flap Down' in a sideways arc or telescope from an 'A' structure, which occupies less space to the side.

The main features of a tractor-towed timber trailer designed to forward felled round-wood timber from within woodland blocks to roadside landing are:

- 'Ladder' or 'Spine / Central beam' type main frame of tubular steel, box section or girder construction
- Drawbar with hitch facility at the forward end
- Steerable drawbar options are available for tighter turns and greater manoeuvrability on some larger models, whereby twin hydraulic rams, mounted within the trailer front chassis, push the drawbar to either side from a pivot point to give a form of 'frame steering' capability
- Load bay or 'bunk' behind the drawbar comprising the remainder of the main frame rearwards
- Two or more pairs of, usually partly-movable, steel bolsters on the bunk section, each clamped to the main frame / spine. The upright parts of the bolsters keep the load on the bed and may slot into holders enabling a degree of free movement in the event of knocks. Bolsters may have extension 'pins' slotted into the top, which may be fixed or loose and removable
- Headboard of steel frame with 'mesh' or bar infill fixed to the main frame / spine forming the forward end of the load bay. Unlike some forwarders, the headboard is

generally fixed rather than slightly movable to modify the bunk length. Similarly, timber trailer headboards tend not to have extensions (a 'flap' that can be raised to extend the height)

- Axle and wheel assembly fixed to the underside of the main frame, usually bogie construction with two wheels each side mounted on a 'rocking' cross member. The bogie may be clamped to the frame so as to be partly movable rearwards / forwards along the frame when loosened. One or both wheels each side may be driven by hydraulic motors directly or by a chain within the rocking cross member, or by a centrally mounted driven 'pressure' basket or 'roller' exerting downward pressure on the tyres to give four wheel drive
- Loader mounted on the chassis / drawbar to the front of the headboard, or in some cases mounted on the tractor three point linkage or roof
- Stabiliser 'legs' fitted to the trailer frame at front (or integral with frame mounted loader) loader, usually hydraulically - not manually - operated.

Weight

The mass or weight of an object is one of its most important attributes.

The weight of a tractor or trailer has a profound effect on its **towing and stability characteristics**, because *weight*[1] results in *force*[2].

Tractor weight must be sufficient to safely manage the trailer weight, which is discussed later in this report.

Weight issues have a key influence on timber trailers, and tractors, owing to:

- Momentum
- Moments
- Weight distribution
- Centre of gravity
- Nose weight.

These influences are summarised below and are considered in detail in **Appendix 2** 'The importance of tractor and trailer weight':

Momentum and Moments

A *moving* weight exerts a greater force owing to its momentum[3]. A moving object has *kinetic energy* because a force was invested to make it move.

Momentum (*movement*) **amplifies the force** exerted by weight **in direct proportion** to the increase in velocity so, for example, if *velocity* of a grab full of timber doubles then the force that it exerts (*kinetic energy)* will double.

A weight moving around a *pivot* exerts a force as a *turning force* or moment. This is the principle used in *levers*, whereby a larger weight close to a pivot can be moved by a smaller weight (or force) at a greater distance from the pivot.

[1] Scientifically, *weight* (and *force)* are expressed in Newton (N), which is the force required to give a mass [which is independent of gravity] an acceleration of 1 m/s/s (Physics classroom). However, for practical purposes, mass and weight are commonly equated and expressed in kilograms (Kg, where 1 Kg = 10N).
[2] *Force* is 'any interaction that, when unopposed, will change the motion of an object' and includes gravitational, electrical, magnetic and contact forces (Wikipedia).
[3] Momentum has both a magnitude and a direction and is 'the tendency of the object to keep moving in the same direction' (bbc.co.uk bitesize, 2017)

Movement occurs when a force is *unopposed*, or opposed by a smaller force. When a trailer is stationary the forces resulting from the various moments are opposed by equal and opposite ones and hence there is *no* movement. Nevertheless, the forces still exist within the structure of the trailer. However, when the trailer is moving over the ground the forces that oppose the turning forces of moments will also move, for example by 'bouncing' upwards, downwards and side to side.

Moments **increase** the turning **force** exerted by weight **in direct proportion** to reduction in the distance to the pivot.

Moments will cause an **opposite effect** on any structure beyond the pivot e.g. tending to lift or the compress the hitch

The forces of moment and momentum generated in a moving trailer can be **rapid and powerful**. They may be brief and act over short distances but can nonetheless be critical.

Movement of a load in an arc will also generate centrifugal force (a similar concept to momentum) that will tend to push an object outward when turning, and which increases *proportionally* with the radius of the arc but as a *square* of the speed[4].

Therefore, the magnitude of the weight of the *structure* or the *load, and the way that it* is distributed on a timber trailer may have a profound effect on its handling characteristics owing to the forces thereby created in use.

Weight distribution and centre of gravity

The structure of the trailer and the position of the load on it affect the way that the weight distribution is exerted as a *force* on the ground (through the wheels) and the hitch. The hitch conducts the force to the tractor, and ultimately to the ground through the tractor wheels.

In basic terms, weight is transmitted to two supports in inverse proportion to their respective proximity. Thus if one support is 1/3rd of the distance to the weight, then it will bear 2/3^{rds} of the weight.

The weight-bearing supports of a trailer are the hitch and wheels.

The weight distribution of the trailer itself will be changed by the position of any constituent movable parts, such as:

- Headboard position, along the frame
- Bogie position, along the frame
- Bunk extension, along the frame

[4] http://phun.physics.virginia.edu/topics/centrifugal.html

- Bolsters movable between positions, along the bunk
- Loader main boom, dipper and extension position, in any direction.

These variables can move the weight *forward* or *rearward*, so they have a *proportionate* effect on the weight borne-by, and the forces acting-on, the *hitch* and *wheels* that are the 'supports'. The loader can also move weight laterally and vertically.

The same principle applies to the way weight is distributed owing to the position of fixed parts of the trailer construction, such as the:

- position of the loader kingpost, and the
- length of the frame from headboard to hitch (the *drawbar length*),

both of which affect the proportion of weight distribution forward to the hitch and rearwards to the wheels.

The **position** of the *load* and *movable structures* on the trailer will affect the *forces* exerted onto the wheels and hitch.

The centre of gravity is a key factor governing the stability of objects because a high centre of gravity is a predisposition to instability. Toppling or roll-over will occur if the imaginary vertical line through the centre of gravity falls outside points on which the object is supported.

Swaying occurring when driving over rough ground may temporarily move the centre of gravity outwith the stable position, and *momentum* may increase the toppling force.

Take care to **operate well within the stable position** of the centre of gravity of the combined machine and load, especially on steeper ground and *side slopes*, and drive especially *slowly* and in a wider arc in marginal conditions to reduce sway and centrifugal effects.

Nose weight

The nose weight[5] of the trailer is the force exerted by the drawbar of the trailer on the hitch mechanism of the towing vehicle (towball, eye, pin etc.) and is a consequence of the position of the *centre of gravity* in respect of the wheels and the combined trailer / load weight.

The wheels or bogie-wheels of timber trailers are often designed so that they can be moved a short distance forward or rearward along the frame. Movable bogies are an important way of ensuring that the nose weight is correct and that the trailer remains more or less level, irrespective of the load. If the load or wheels are positioned such

[5] Also known in the UK as the 'Nose Load' and the 'Vehicle Static Load'. Ryder, D. (2000). Guide to Safe and legal Towing. National Trailer Towing Association. [Similar to 'Tongue Weight' and Drawbar Pull used in USA]

that the centre of gravity is forward of the wheels, then some of the weight will be transferred onto the hitch. For example, if the load's centre of gravity is moved forward by ¼ of the distance from wheels to hitch then ¼ of the weight will be transferred to the hitch (**Figure 1**).

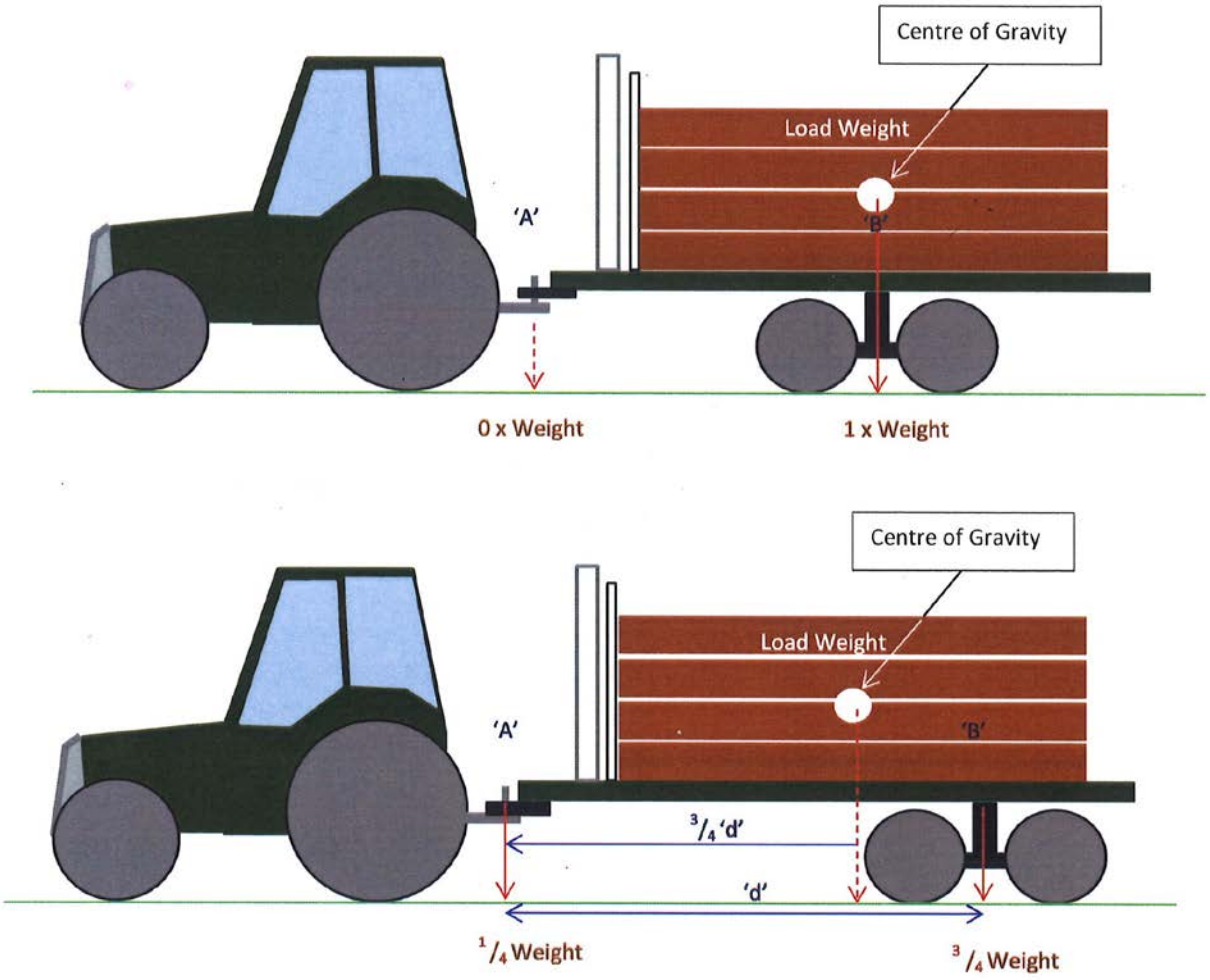


Figure 1. If load centre of gravity is moved forward, so will weight transfer to hitch

In practice, there are structural limits to the adjustment of bogie position to correct for the centre of gravity of loads, that can be further reduced by hydraulic drive and braking systems. Furthermore, adjustments can be cumbersome and unlikely to be carried out regularly with changes in product specification. Nevertheless, it is important that the position of the load-and-trailer *centre of gravity* is considered and adjustments are made to bogie positions, load size or load length if the effect on nose weight could be significant.

The nose weight of the trailer can be significantly **increased** if the centre of gravity of the **load is too far** in front of the wheels, and *vice versa.*

The **nose weight is important** because it influences key characteristics of the handling and performance of the towing vehicle and trailer combination or 'vehicle train'. In extreme cases it could contribute to lifting the front of the tractor, which can

cause rear overturn[6]. Towing vehicles will also have stated manufacturers hitch loadings that should not be exceeded.

Hitches will transfer any downward force of the trailer drawbar nose weight onto the rear of the towing vehicle. Most trailers (with over two wheels) are designed so that the frame / bed will rest level when unladen - whether hitched or unhitched - and exert only a limited force on the towing vehicle's hitch. Incorrect nose weights will reduce performance which, if excessive, can be serious, including - potentially - overturning.

Most road-going towing vehicle hitches, and trailer drawbars, are rated at between 50 kg and 100 kg when stationary[7]. However, tractors and other *purpose built* towing vehicles are designed to compensate for higher nose weights. For example, tractor hitches are positioned close to the substantial rear axle - especially pick-up / Euro hitches[8] - so that the *moment* created by relatively high nose weights (turning force or levering effect) is minimised. However, trailer nose weights outside the design limits can have unwanted effects:

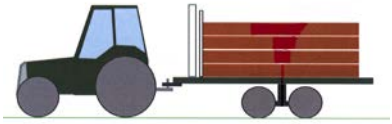
- **High nose weights** can reduce steering effectiveness (understeer), loss of traction in front wheel and four wheel drive vehicles and damaging stress to hitches, draw bars and mountings. They can be a consequence of loading so that the *centre of gravity is in front of the trailer wheels*

- **Low nose weights** can reduce rear wheel traction and steering effectiveness and can be a consequence of loading so that the *centre of gravity is behind the wheels*. They can also cause potentially very dangerous trailer 'weaving' or 'snaking' on road-going vehicles because they are driven at higher speeds.

Whilst the *weaving* effect of low nose weight is unlikely to be a problem for slow moving off road vehicles, a tractor-trailer unit moving **uphill** or over **uneven ground** may experience 'nose lift', whereby the trailer drawbar exerts a 'negative', (upward) force on the hitch. This can exacerbate traction, steering and hitch-stress problems, especially if compounded by *momentum*.

Remember that nose weight and 'nose lift' **can cause problems** with the steering, traction and stability of the tractor-trailer unit, and will be **worse in dynamic situations** where *momentum* and *centrifugal force* increases the forces involved.

[6] Murphy, D. (2016). https://extension.psu.edu/tractor-stability-and-instability Pennsylvania State University
[7] Certain trailers may be designed to permit loading of more weight to the rear of the rear wheels, such as horse trailers that allow for the animals to rest their weight rearwards.
[8] Pick-up / Euro hitches are short and positioned close to the axle. Clevis / drawbar hitches can extend further back, in which case will turning force will be increased and nose weight capability reduced



Loader characteristics[9]

Construction

All but the smallest trailers, which might be loaded by hand, are equipped with a loader. Although 'wire crane' loaders are available for small trailers, hydraulic loader systems are otherwise ubiquitous.

The most common of the loader types is the 'Knuckleboom', whereby the booms pivot around 'axle / pin' joints and are raised and lowered by hydraulic rams fixed directly to them. There are also loader designs based on a 'Parallelogram' arrangement at the main boom, which use the 'lever' principle to enhance power (and reduce hydraulic demand) to raise the outer boom[10]. The main loader mounting options are:

- Roof mounting
- Three point linkage
- Trailer mounting.

Further consideration is given in **Appendix 3** 'Loader construction characteristics'.

Examination and inspection of loaders

Loaders can be subject to the provisions of the *Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)*, which sets out best practice for planning and inspection. Guidance on how LOLER applies in forestry situations is available from the Health & Safety Executive which is summarised and considered here in respect of timber trailers.[11]

Most requirements for the safe use of timber loaders are covered by general **good practice** backed by well-known legislative requirements.

In particular:

- ✓ Operations should be properly planned by a competent person, which includes
- ✓ Using machinery and a method of working suited to the job and conditions
- ✓ Operators should have the appropriate training, instructions and supervision
- ✓ Loaders (and any attachments) must be strong enough i.e. used within their Safe Working Loads)[12]
- ✓ Safe Working Loads at boom reach distances are clearly marked (which would also apply to any shackles or slings etc., albeit a timber grab will normally be used for lifting

[9] Largely drawn from: Jones, D.H. (1995). Hydraulic Loaders for Agricultural Tractors Forestry Commission Forest Research, Technical Development Branch TN25/95

[10] Jones, D.H. (1995). Hydraulic Loaders for Agricultural Tractors Forestry Commission Forest Research, Technical Development Branch TN25/95

[11] http://www.hse.gov.uk/treework/safety-topics/lifting-equipment-forestry.htm

[12] HSE: *'This should not be a problem for forestry machines working within their normal design purpose i.e. handling trees and timber'*. However, consider other uses e.g. lifting grab tanks

instead)

- ✓ **'Work is organised so that** loads are **not carried** or suspended over **people'**, and any risk of loads 'drifting' / falling / slipping (from the grab) is covered[13]
- ✓ The loader is stable in use - use outrigger legs if required, and use correct method e.g. avoid heavy loading on side slopes
- ✓ Loaders are inspected for wear and damage that could affect safety weekly or every 50 hours if less[14]- this can be done by a competent operator during normal daily and weekly maintenance[15]

AND ADDITIONALLY:

- ✓ Loaders that are operated from outside a [suitable] cab structure (and within the reach 'danger zone') must be subject to '**Thorough Examination**' arrangements[16].

The 'Thorough Examination' is a **defined statutory requirement**, although loaders operated from within a purpose built forwarder or tractor etc. having 'appropriate protective structures' are exempt providing that they do not lift loads over people (including the operator within the cab).

Loaders operated from outwith a protective structure (ROPS, plus FOPS and suitable OPS) need to have a 'Thorough Inspection' regime within each 12 months[17]. The 'CE' Certificate of Conformity supplied with new equipment qualifies as the initial 'Thorough Examination' (if dated within 12 months).

Thorough Examinations must be a '*detailed and specialised examination by a competent person*', independent of line management, and any defects must be rectified. In this respect, a trained service engineer - for example - should qualify as a competent person providing that he or she is not responsible for the routine maintenance of the loader. Reports and the Certificate of Conformity should be retained.

Timber trailer loaders operated within reach from outside a cab - having suitable ROPS, FOPS and OPs - must have a written '**Thorough Examination**' report by a 'competent person' dated within 12 months, and should be included in daily operator checks.

A suitable and sufficient Risk Assessment for operating a forestry loader from outside a suitable cab is likely to require the equipment "to be inspected at suitable intervals between thorough examinations"[18] (set by a competent person). Therefore,

[13] LOLER 1998. Regulation 6.1 "… ensure that lifting equipment is positioned or installed in such a way as to reduce to as low as is reasonably practicable the risk - a) of the equipment or load striking a person; or b) from a load i) drifting; ii) falling freely; or iii) being released unintentionally; and is otherwise safe.
[14] HSE. (2019). Lifting equipment in forestry. www.hse.gov.uk/treework/safety-topics/lifting-equipment-forestry.htm
[15] HSE. (2014). Safe use of lifting equipment, LOLER 1998 Approved Code of Practice. Regulation 8. Organisation of lifting operations. Para. 289. Pre-use checks "such checks should be carried out before the lifting equipment is used during each working day".
[16] HSE. (2019). Lifting equipment in forestry. www.hse.gov.uk/treework/safety-topics/lifting-equipment-forestry.htm
[17] Or an alternative interval specified '*in an examination scheme prepared by a competent person*'. Thorough Examinations should also be made after any significant damage or repair.
[18] Thorough examination of lifting equipment. A simple guide for employers. (2008). INDG422. HSE.

Loaders should also be inspected regularly between the thorough examinations[19], including visual and functional checks. This can be included in the daily and weekly **operator's checks**.

Slewing arc

The loader (booms and grapple) can be slewed around the Kingpost through an arc from about ¾ of a complete circle (270 degrees), up to a full circle. Capabilities of 360 to 380 degrees (more than a full circle) are now common. The slewing arc may be limited by the gearing in the slewing mechanism. Movement 'stops' can be welded to the kingpost but this is not common nor necessarily practicable owing to the slewing power needed.

Where the arc is restricted, the excluded part is situated to the front of the loader and tractor, leaving the bunk and side areas accessible. However, the arc is also effectively a risk zone within which the driver or machine structures can be hit. The main boom may - or may not - be capable of hitting the tractor cab structure, or being positioned close to a point above the driver's seat or loader operating position. The main boom can be raised to a steep angle (although not vertical) but nevertheless it will still sweep an arc around the Kingpost. These factors are especially important in respect of the loader operator's control position, that is whether *within* or *outside* the cab.

The position of the loader controls is very important for ergonomics and the **assessment of risk**.

However, in addition to the arc encompassed by the loader itself, a grab full of timber billets or logs will extend the arc both outwards and, more importantly, inwards.

Therefore, the load itself will **extend the risk zone both over the Kingpost and potentially into and over the driver's seat and loader operating position** (**Figure 2**).

[19] … according to a regime specified by the manufacturer or other competent person. From INDG422

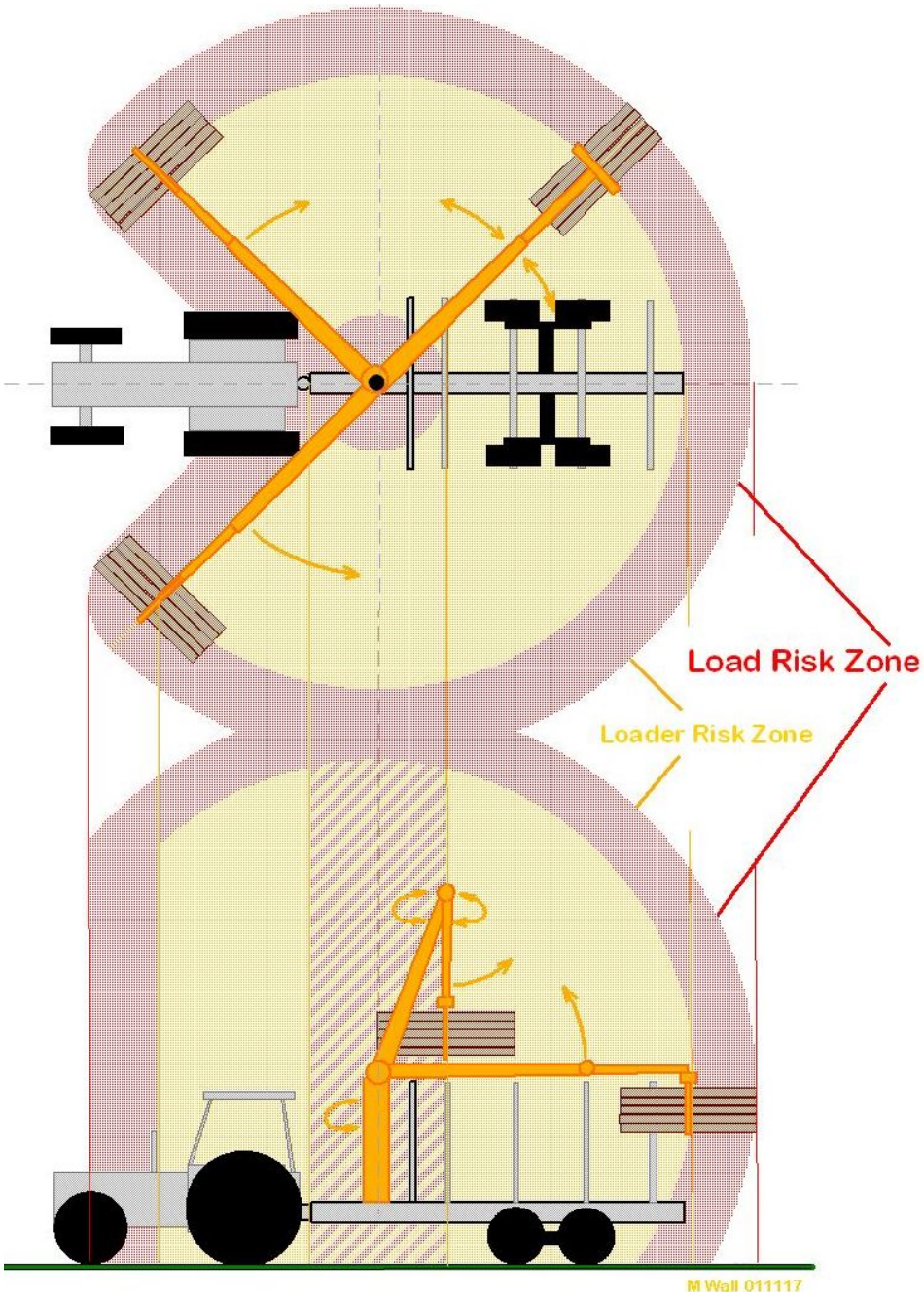


Figure 2. Generalised representation of loader and load risk zone

The arc that can swept by the loader, and loader with a load in the grapple, creates a **risk zone**, within which the operator's position and potential for being struck **must be assessed**.

Loader operator protection

Loaders for larger machinery (other than timber lorries) are almost universally operated in close proximity but *from within a cab*, which implies a developed degree of operator protection.

Loaders for smaller machinery, and particularly for small-scale and 'mini' timber trailers, are likely to be operated in close proximity but *without a cab*, or with only a rudimentary cab structure for operator protection.

The position from which the machine **operator controls the loader** is of fundamental importance for the management of health and safety, for which risks **must be assessed**.

However, the procedure for the management of health and safety is to assess risk *in specific circumstances,* and there are several factors involved that can have both positive and negative implications.

There is **no** simple universal rule that cabs are *always sufficient* or *always necessary* and, by implication, **that cab-less situations are *always unacceptable***.

The environment within which the loader operator works *when loading* has an important and direct impact on comfort and physical stress (ergonomics) on the one hand, and risk (likelihood) / hazard (severity) of injury whilst working (safety) on the other.

Operating a loader from outside a cab is in some ways analogous to operators working within the risk zone of other machinery, which may be an issue in roadside processing, for which the FISA Safety Guide states[20]:

> "During this process two or more machines may be operating within each other's designated risk zones" and "All operators must be protected by **machine guarding** or by **work position** from hazards such as being injured by chain-shot, hit by timber or crushed by machinery".

The work position is a prime consideration in choosing the **work method** for an operation.

The options for loader operator position are:

1. Seated (or kneeling-facing rearwards) within the tractor cab - with the potential for differing operating space and levels of operator protection and ergonomics
2. Seated or kneeling (facing rearwards) on the tractor seat without a cab

[20] FISA Safety Guide 605 (2013). Mechanical roadside processing. Forest Industry Safety Accord

3. Standing on a small platform on the trailer forward of the headboard and kingpost (albeit this is unusual in UK)
4. Standing at the rear of the tractor to operate the controls located there
5. Standing remotely from the loader outwith its reach - theoretically possible with electrical remote control but not currently used in practice
6. Standing remotely from the loader within its reach - possible with controls (such as manual levers) mounted on the valve block, which is 'tied' to the loader by the hydraulic hoses. This appears to offer no working or safety advantage so is not considered further.

These options are considered further below:

Operation from tractor seat (1 & 2)

Forest machinery cab structures are expected to provide a degree of protection for the operator from risks in their intended operating circumstances. The three protective structure classifications as defined in British and International Standards are[21]:

> Roll Over Protective Structures (ROPs): "system of structural members whose primary purpose is to reduce the possibility of a seat-belted operator being crushed should the machine roll over".
>
> Falling Object Protective Structures (FOPs): "system of structural members arranged in such a way as to provide operators with reasonable protection from falling objects (e.g. trees, rocks)".
>
> Operator Protective Structures (OPs): "system of structural members arranged in such a way as to minimize the possibility of operator injury from penetrating objects (such as whipping saplings, branches and broken winch lines)".

The BS / ISO Standards for ROPS and FOPs for "Machinery for forestry" are separate from those for "Tractors for agriculture and forestry". Although the OPs "Machinery for forestry" standard does not directly apply to tractors as such, it does apply to forestry machines used in analogous situations including forwarders and skidders[22] and is therefore of value in assessing operator protection for forestry tractors.

The key issues for loader operating position from within a tractor cab are described together with the level of operator risk and protection in **Table 2** for prime mover / tractor *seated* control. The key issues for *operating with and without cabs* are highlighted thus ⚠, and discussed below.

[21] Definitions from: BS ISO 8084:2003+A1:2015. Machinery for forestry - Operator protective structures (OPS) - Laboratory tests and performance requirements
[22] BS ISO 6814:2009. Machinery for forestry - Mobile and self-propelled machinery - Terms, definitions and classification

Table 2. Operator position factors - tractor seated loading

Issue	Degree				
	Standard cab		Small cab		No cab ('open cabs')
	Loading operation				
Sound awareness[23]	Moderate		Basic		Limited
Seat swivel (0° to 180°+)	Developed	Moderate	Often not practical		Often not practical
Seat reverse (0° or 180°)	Not necessary		Limited		Basic
FOPs	⚠ Developed		Moderate / Limited		By method
OPs - loader / billet	⚠ Developed	Moderate	Moderate / Limited		By method
Intruding-object strike			Basic / By method		
Lower risk	Level of Provision - Key				*Higher risk*
Developed Not necessary	Moderate		Limited	Basic	By method / Not Practical

⚠ Falling object protection (FOPs)

Standard tractor cabs with forestry FOPs provide a *Developed* degree of protection owing to the roof and cab framework, although unmodified agricultural tractors may not meet an accepted FOPs standard.

Small tractor cabs are likely to provide a *Moderate or Restricted* degree of protection because they will have a more limited 'space envelope' around the operator. They may also have a less robust construction, although this is inevitably a generalisation.

'Open cabs' - cab-less tractors provide no additional protection for the operator over and above the safety helmet that must be worn in risk situations.

Protection from **falling objects** whilst driving 'cab-less' tractors in the forest therefore relies on the '**method**' of use, which should be the result of an assessment of risk and consequent mitigating measures.

For example:

- ✓ Maintain overhead vigilance and wear helmet
- ✓ Drive with due care for the circumstances, especially:
- ✓ Avoid driving under suspect trees
- ✓ Avoid brushing against trees / large branches *(good silvicultural practice anyway)*
- ✓ Avoid driving in the risk zone from operating loaders.

⚠ Operator protection (OPs) - loader / billets and intruding objects strike

Standard tractor cabs - the operator is generally well protected within the cab, although there is a residual risk of a grab of billets or a log striking the cab, breaking safety glazing and even entering the cab. Trained and qualified operators will be aware of the risk and will prevent this by correctly deploying the loader,

[23] Ireland, D. (2006). Compact Tractors in Forestry. Internal Project Information Note 14/05. Forestry Commission, Technical Development Branch: "*Consideration should be given to whether there is a requirement for maintaining awareness of ambient noise for safety reasons e.g. movements in crops warning of danger. This could affect the type or specification of noise protection selected. The noise level of any ancillary equipment must also be assessed.*"

especially when swinging grapples of timber towards the bunk from a forward position, and when 'butting up' logs against the headboard.

Small tractor cabs - the protection provided by the cab depends on the location and specification of the cab frame, glazing and bars or mesh screens. Cabs with open-unglazed and unbarred / meshed window spaces will be effectively unprotected except for the cab frame itself and by the work method / operator ability.

'Open cabs' - protection relies on operator training, ability and attention. The work method might also be modified to lower the risk.

Although larger cabs are more secure, a cab may not provide complete protection from a strike to the machine or operator by the loader, billets or logs so **careful attention to the work method is <u>always</u> necessary**.

For example:

- ✓ Limiting billet / log length
- ✓ Confining the loader to an arc to the rear of the operator (at the tractor seat)
- ✓ Not swivelling a loaded grab adjacent to the operator (at the tractor seat)
- ✓ Placing the load against the headboard without 'butting up'.

Operation from standing position (3 - 5)

The key issues for loader operating position are described together with the level of operator risk and protection in **Table 3** for *standing* control. The key issues for standing operating positions are highlighted thus - ⚠, and discussed below.

Table 3. Loader operator position factors - standing

Risk	Degree				
	By kingpost / headboard		By tractor rear		Outside reach
FOPs					
-billet drop ⚠	By method Proximity to grapple		By method Proximity to grapple		Developed Out of boom arc
-tree strike	Moderate Proximity to trees		Moderate Proximity to trees		Moderate Proximity to trees
OPs					
-sound awareness	Developed	Moderate	Restricted	Basic	Developed
-boom strike ⚠	Developed Out of boom arc	Moderate Inside boom arc	Developed Out of boom arc	Limited Inside boom arc	Developed Out of boom arc
-grapple strike ⚠	Developed Out of boom arc	Moderate Inside boom arc	Developed Out of boom arc	Limited Inside boom arc	Developed Out of boom arc
-billet strike ⚠	Limited Under Headb'd	Basic Above Headb'd	Moderate Out of boom arc	Basic Inside boom arc	Developed Out of boom arc
Lower risk	Level of Provision - **Key**				*Higher risk*
Developed	Moderate		Limited	Basic	By method

The risk factors are similar for each Risk, so they are considered together for each operator standing position below:

From tractor rear (3)

Operating the loader at or near the rear of the tractor involves the operator standing to one or other side of the drawbar, which has several **advantages and disadvantages**

- ✓ Out of loader boom swept arc (*restricted-arc loaders only*)
- ✓ Protection from headboard when placing load / 'butting up'
- ✓ Not directly 'under' grapple load from side / rear (*especially shorter products*)
- ✓ Away from grapple load from side / rear
- ✓ Some protection by tractor from grapple load from front-side
- ✓ Avoids climbing in & out of cab (of value in very limited situations).

- ✗ Restricted vison to rear and far side of the trailer
- ✗ Restricted to basic operator sound awareness (owing to noise levels)
- ✗ Within loader boom swept arc (except restricted-arc loaders)
- ✗ May be 'under' grapple load from front-side
- ✗ Proximity to grapple load (from front-side, *longer products and 'front bay'*)
- ✗ No vision to front of tractor (issue only if able / need to reach over cab)
- ✗ *Residual risk of fall from platform when operating.*

The main (slight) advantage of operating the loader from a position on the ground, behind the tractor, compared to by the Kingpost, is slightly improved protection from the head board to the rear and tractor cab to the front-side. Providing that the operation is *configured to ensure that the load does not pass over the operators head*, the main disadvantage is lack of protection when loading from the front quarter, which can be avoided completely.

Methods used in loader operation from the ground at the tractor rear should avoid bringing any part of the loader or load over or close to the operator e.g. by **not loading from the front-side** quadrant.

By kingpost / headboard (4)

This is the closest position to the loader and the operator will be within the potential arc of the loader, and therefore potentially within the swept arc of the loader and within reach of the grab (and its load of timber), unless it is restricted to c. 270°. Even if restricted, there is the potential, however slight, for timber to slip from the grapple and fall outwith the loader swept arc.

Operation from a stand on the trailer behind the headboard (e.g. with a 'pedestal' control block) has both potential advantages and disadvantages.

- ✓ Good visibility and close to 'line of sight' operation
- ✓ Developed to moderate operator sound awareness
- ✓ Out of loader boom swept arc (*restricted-arc loaders only*)

- ✓ Not directly 'under' grapple load from side / rear (*especially shorter products*)
- ✓ Away from grapple load from side / rear (*shorter products, except headboard 'butting up'*)
- ✓ Avoids climbing in & out of cab (*of value in very limited situations*).

- ✗ Little or no protection from headboard, especially when 'butting up'
- ✗ Within loader boom swept arc (*except restricted-arc loaders*)
- ✗ May be 'under' grapple load from front-side
- ✗ Proximity to grapple load (*from front-side & longer products and 'front bay'*)
- ✗ Climbing on-off risk of slips / trips
- ✗ Restricted vision to front of tractor (*issue only if able / need to reach over cab*)
- ✗ Residual risk of fall from platform when operating.

The main advantage of operating the loader from a position behind the headboard and near the kingpost is good visibility of the loader position and movement. Providing that the operation is *configured to ensure that the load does not pass over the operators head*, the main disadvantages are lack of protection when:

- 'butting up', which can be mitigated by careful placing of the load, and
- loading from the front quarter, which can be avoided completely.

Methods used in 'Kingpost' loader operation should avoid bringing any part of the loader or load over or close to the operator e.g. by **careful placing of the load** on the bunk and **not loading from the front-side** quadrant.

Loaders should **not be operated** from controls 'dropped over' the headboard itself, which puts the operator in very close proximity to timber being 'butted up'.

Outside reach (5)

The safest position for any operator is clearly always going to be when outside the reach of the loader *and of any produce within the grab*. This is impracticable for *manual* hydraulic controls owing to the length of hydraulic hose that would be needed and the inherent working difficulties.

However, *electrically* operated controls, requiring only 'light' electrical cables, or even radio remote controls, could be used and are available for some loaders - although they will be expensive[24]. This would give protection against strike by the loader boom or grapple and timber gripped within it. Depending on distances, there might still be a theoretical risk of loose timber flying from the grapple outwith the loader's arc, or of debris being dislodged from trees (or trees falling) onto the operator in some situations.

However, there may still be inherent difficulties in operating the loader remotely, such as space within confined crops, operator movement time-penalty (and extra fatigue-

[24] For example, £3k to £5k for a 3 tonne trailer (S Cabrol, Pers Comm, 2016)

induced risk from frequent climbing in and out of driving seat), operator's vision and operator's *non-line-of-sight* coordination.

'Remote' loader operation could give a **high degree of operator protection**, although not necessarily always complete or practicable.

Loader operator position summary

- The loader operator control position is a key factor to consider for **working method** in any given circumstances and in **risk assessment**
- For operation with large or small cabs or without cabs, each case must be **considered on its merits** (or otherwise) in its given circumstances
- Even larger cabs may not give complete protection, so **method is crucial**
- Remotely operating the loader from outside it's sweep, if practicable, can be **'low' risk**
- Methods used in 'Kingpost' and 'tractor rear' loader operation should avoid bringing any part of the loader or load over or close to the operator e.g. by **avoiding the front-side quadrant**.

Tractor characteristics[25]

Timber trailers are designed to be towed off road by a separate *tractor* power unit.

Tractors are essentially powered vehicles designed to give a high tractive effort (torque) at low speeds for carrying, moving, powering or towing equipment and loads[26]. Tractors are usually, but not necessarily always, used primarily off road.

There are numerous potential variations in design and function, owing to the wide range of uses. For example tractors may be wheeled or tracked and may be steered by pivoting wheels on the axle (rigid frame), by pivoting two halves around a centre joint (frame steering) or by slowing or stopping traction on one side (skid steering). The front axle of most rigid frame machines usually also articulates vertically to aid movement over obstacles. These variations, amongst others, result in **significantly different handling characteristics**.

This guide primarily covers the twin axle, rigid frame type of tractor, steered by pivoting the front wheels, which is by far the most common design for agriculture and forestry, and commonly referred to as the 'agricultural' tractor. Although frame steering is also used, for example on some small tractors, it is much less common *and is less suitable for towing timber trailers*[27].

Driving and operating forestry equipment can be **very different** to farm machinery.

Tractor requirements and use

Requirements for tractors for use in agriculture or forestry, and trailers intended to be used with them, are specified by the 'Tractor etc. (EC Type-Approval) Regulations 2005' and amendments. These Regulations implement the Directive 2003/37/EC[28], which specifies a list of Directives covering detailed design aspects that must be complied with[29]. These include a requirement to affix a mark or number identifying the EC type-approval and issue of a 'certificate of conformity' to the Directive. These Regulations do not cover specialised purpose-built forestry machines such as forwarders and skidders.

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[25] Jones, D.H. (1995). The adaptation of agricultural tractors for forestry. Forestry Commission Technical Development Branch TN 24/95
Jones, D.H. (1997). Using farm tractors and machinery in woodlands. Forestry Commission Technical Development Branch TN 20/96

[26] The Tractor etc (EC Type Approval) Regulations 2005 defines a tractor as *"any motorised, wheeled or tracked agricultural or forestry tractor having at least two axles and a maximum design speed of not less than 6 kilometres per hour, whose main function is tractive power, and is designed to perform the pulling, pushing, carrying and actuating of interchangeable equipment associated with agricultural or forestry work, or to tow agricultural or forestry trailers, although it may be adapted either to carry a load in connection with that work or be equipped with passenger seats or both"*

[27] Jones, D.H. (1995). Timber trailers for agricultural tractors. Forestry Commission, Forest Research, Technical Development Branch Technical Note 28/95. "…the double articulation makes the combination difficult to manoeuvre. Weight transfer from the trailer can adversely affect the tractor when turning."

[28] Directive 2003/37/EC on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units and repealing Directive 74/150/EC

[29] Annex II Chapter B. List of requirements for the purposes of vehicle EC type-approval

The Regulations and Directive have a similar effect to the Machinery Directive [2006/42/EC] and it's implementing Regulations[30], but from which agricultural and forestry tractors are excluded.

There are also basic requirements that all tractors must fulfil, and features necessary for safe and effective performance in the forest according to both specific[31] and general[32] legislative conditions.

A guide to the requirements for equipping and using 'agricultural'-type tractors in forestry are summarised in HSE and FISA the safety guides, including 'Tractor units in tree work'[33], which is an essential reference for all forestry tractor operators. Guidance includes important provisions for driving technique as summarised in **Appendix 4** and include (here blue is the situation, **black bold** as the action):

- ⚠ **Stop** if any person comes within the risk zone, unless the person is included in an approved safe working system
- ⚠ If a machine starts to slide when travelling downhill, steer straight downhill and gradually increase the engine speed to regain traction. **Do not** *depress the clutch!*
- ⚠ Descend straight down a slope if possible, rather than diagonally across it
- ⚠ **Avoid turning** *a frame steered /* **articulated** forwarder **uphill**[34] [35] on side slopes[36] - this increases rollover risk very much! *It is, however, safer than turning downhill for a rigid tractor pulling a trailer*[37]
- ⚠ **Avoid turning** a *rigid frame* **tractor downhill** on side slopes[38] - *this is especially hazardous*
- ⚠ **Avoid** steep side slopes, soft ground, driving over felled trees & other major obstacles
- ⚠ If side slopes are unavoidable, **reduce the load height**[39] (*for skilled operators, it may also be possible to extend the trailer boom on the upper side to maintain stability*)
- ⚠ **Be aware** of the risk of rearwards overturn, including driving up steep slopes, when drive wheels are stuck fast in mud or a heavy load cannot move. **Ensure** sufficient front counterbalance for rear-mounted weights and always hitch trailers to the correct point. *Rear overturn can be fatal and happen very fast!*[40] [41]
- ⚠ **Do not** attempt to jump clear from "a safety cab/frame" if a machine overturns *This should be covered by the method and site Risk Assessment*
- ⚠ **Use the parking brake** when **stopped** / loading, where appropriate
- ⚠ **Do not** suspend grab tanks when refuelling

[30] The Supply of Machinery (Safety) Regulations 2008, as amended 2011
[31] Such as The Agricultural (Tractor Cabs) Regulations 1974 and amendments
[32] Particularly the Provision and Use of Work Equipment Regulations 1998 and the Health and Safety at Work Act 1974
[33] Tractor units in tree work. Forestry Industry Safety Accord (FISA) Guide 501 (reprinted 2013)
[34] Extraction by forwarder. FISA Safety Guide 503. (2013)
[35] Hietala, P. (1991). Puutavaran Metsakuljetus. "When … the logging road… turns .. uphill, the hinge pivot is on the downhill side … the kinetic energy of the load's weight is in the same direction with the hinge pivot, thus maximising the risk of overturning". In 'Forwarder Extraction course, FOTC. Forestry Commission (2001).
[36] E.g. FISA Safety Guide 503 Extraction by forwarder (2013). Para 10 "Avoid turning uphill on side slopes"
[37] Forsyth, R. (2017). Pers Comm
[38] Using tractors safely, a step-by-step guide. HSE (2013)
[39] Reduction of load height is an additional option not included in FISA 501
[40] Using tractors safely. HSE INDG 185. (2013).
[41] Murphy, D. (2016). https://extension.psu.edu/tractor-stability-and-instability Pennsylvania State University

⚠ **Do not** work under suspended or 'propped' parts and do not rely on the machine's hydraulic system

⚠ **Do not** use your hand to check for hydraulic leaks (use paper / cardboard) - high pressure fluid can enter the blood stream!

⚠ **Do not** operate a double acting ram that has a broken pipe.

Modifications to tractors must be carried out by competent personnel and any structural changes should be **approved by the manufacturer**.

Tractor design

It is crucially important to use a tractor that is suitable (safe and effective) for the job i.e. the terrain conditions (ground/soil conditions, roughness/obstacles and slope) and the activity (such as towing a trailer and powering a loader). Important tractor design considerations are summarised in **Table 4**, excluding operator protection, which is considered later.

Table 4. General performance considerations

Factor	Pros (if more of)	Cons
Engine Power *~ 20-120 hp (15-85 kW)* *(mid-range 60-80 hp)*	✓ More tractive effort, more hydraulic / PTO power, less engine stress, more versatility	✗Greater cost & fuel consumption Potentially greater implications of driver errors ✗May overload attachments ✗Wasted unless used for equipment or drawbar pull
Even weight distribution *Agric. usually ~60% to rear - add 45 kg front weights / 10 hp*[42]	✓ Front proportion aids steering	
4WD	✓More traction (usually important) ✓Heavier front axle helps redress rear weight bias	✗Greater cost
Forestry tyres *Cross ply, reinforced rim bead & sidewall*	✓Less subject to puncture by stumps / debris ✓Chains improve traction ✓Wider improves flotation & stability ✓Narrower can improve traction ✓Lower pressure improves flotation generally use lowest recommended	✗Radials not recommended (TN24/95) ✗Smaller diameter, more easily bogged ✗Chains increase wear & ground damage, must remove for road use ✗Wider reduce traction & passage gap ✗Lower pressure may reduce stability
Height *Ground clearance* *Agric. ~ 35-40 cm, purpose built forestry 50 cm*	✓More terrain-ability with greater ground clearance ✓Greater terrain-ability, stump clearance etc.	✗Less stability with greater height and centre of gravity ✗Less clearance to overhead branch etc. obstructions
Hydraulic services	✓Cater for forestry attachments - loaders etc. ✓Some makes more suited / adaptable TN24/95	✗Modifications may be required for forestry attachments
Power steering	✓Aids manoeuvring	✗Cost

[42] Folkem, M.P. (1996). Logging winches for farm tractors. Forest Engineering Research Institute of Canada, TN-90

Cab[43]	✓Covers ROPS & potentially FOPS, & OPS (with upgrade) ✓Improved ergonomics & operating environment (usually)	✗May be impracticable / un-ergonomic on v. small / 'Mini' tractors, where ROPS may be limited to a roll bar[44]
Swivel or Reversible seat	✓Better ergonomics for operating loader etc. to rear (avoids awkward kneeling on seat)	✗Increased cost, *if available at all* ✗Time to reverse (e.g. some small tractors)
Length & width	✓More stability with greater wheelbase length and width	✗Less terrain-ability - more grounding ✗Less manoeuvrability - larger turning circle if longer, greater passage-gap if wider ✗Greater transport implications ✗Poorer 'fording angle' if machine extends over front or rear axle
Frame Steering *Compared to wheel pivot steering*	✓More manoeuvrability, grip & climbing ability with frame steering	✗Weaker structure (potentially) ✗Less suitable for towing trailers (TN24/95)
Guarding	✓Reduces downtime and protects: Sump / belly guard (~10 mm steel plate) - rocks, stumps, brash, debris ✓Front / radiator & side / engine grill or mesh - branches, brash ✓Wheel rims & tyre valves-brash (punctures), stumps, rocks ✓Branch deflectors / cab frame-branches & trees ✓Exhaust guarding-brash and obstructions ✓Cab / operating position bars, mesh, safety glazing-penetrating objects	✗Increases cost & weight ✗May limit ease of access to parts ✗May collect debris (belly plate) ✗May obstruct operator access, windows and visibility
Hitch *Pick-up (PU), swinging drawbar (SD)*	✓PU - versatile & convenient ✓SD - strong, v. secure	✗PU - May limit ground clearance ✗SD - Inconvenient frequent manual use and may limit ground clearance
PTO / 3 point linkage / hydraulic feed	✓Standard equipment with agricultural tractors and 1 or more is essential for most mounted equipment. Range of options and sophistication	✗Increased cost if non-standard (some, but not all, small scale tractors)
Attachments	✓May be essential or helpful for job (e.g. lighting) ✓Improves versatility	✗Structural modifications may be required (*with manufacturer's approval*) ✗Affects driving characteristics if heavy ✗May affect weight / balance and require ballasting of tyres or front / rear weights ✗Cost

The tractor selected should be matched to the **conditions** of its use, which are summarised in Table 4 above.

It is crucially important that the tractor characteristics and capabilities are **matched** to those of the trailer and *vice versa.*

Key issues for matching combinations are highlighted in **Appendix 5**.

[43] Compliant with the Agriculture (Tractor cabs) Regulations 1974
[44] HSE (2000). The Provision and use or work equipment Regulations 1998 (PUWER). Local Authority Circular 90/3

Tractor operator protection

A Risk Assessment is required by legislation[45] to determine the nature and degree of risk from hazards at work and any necessary control measures. As a first consideration, hazards should be removed, for example by changing the work method. Where this is not effective, engineering controls such as machine guarding should be provided. Personal Protective Equipment (PPE) must be provided where a residual risk remains.

Forestry tractor operators may be at risk of the machine *overturning* or objects *falling* onto or *penetrating* the operator's position. Requirements for tractor cabs are established by legislation[46] and engineering standards are provided by British and International standards[47].

Tractor cabs can provide the operator with a degree of engineering **protection** against rolling over and falling and penetrating objects.

Tractors without cabs may be used where a **thorough and sufficient Risk Assessment** shows that a particular risk is absent (e.g. site conditions), or is otherwise controlled (e.g. by work method).

PPE is a *backup*, **not a substitute** for other more fundamental controls.

A Roll Over Protective Structure (ROPS) is a bar or frame - that may be incorporated into a cab structure - providing a safe zone to prevent the operator from being crushed.[48] A ROPS structure is a requirement "if the machine can roll over in use"[49].

Therefore, in **most** forestry situations a ROPS structure is effectively a **minimum requirement** for tractors so that even those without cabs **must** have provision such as a roll bar. ROPS bars may be designed to be folded down for transport but must always be in place when there is a risk to the operator, which in practice means *for most operations*.

A ROPS structure (i.e. cab or frame) must be provided if the tractor can roll over in use, so **will be required in most forestry situations**[50].

Exceptions will be rare and would need to be justified by method and Risk Assessment.

[45] Health and Safety at Work Act 1974 (HASWA) & The Management of Health and Safety at Work Regulations 1999
[46] Agricultural (Tractor Cabs) Regulations 1974 and amendments: tractor cabs must pass specified tests
[48] Ireland, D. (2006). Compact Tractors in Forestry. Forest Research, Technical Development, Internal Project Information Note 14/05
[49] Tractor units in tree work, para. 5. FISA Safety Guide 501. (2013).

[50] Tractor units in tree work, para. 5. FISA Safety Guide 501. (2013).

Seat restraints are required "**where there is a risk** of the operator being injured during rollover"[51].

This should be covered by the method and site Risk Assessment.

A Falling Object Protective Structure (FOPS) is a safeguard against objects such as dead branches or trees, or in agriculture bales, falling onto the operator. Cab structures usually incorporate FOPS. However, some tractors do not have FOPS, or may also have a glass or plastic escape hatch / sunroof. The Risk Assessment should confirm that protection is adequate for the operation concerned.

A FOPS structure (e.g. incorporated into a cab) must be provided if the tractor is used "where trees, cut timber or other objects can fall onto the operating position"[52].

This should be covered by the method and site Risk Assessment.

Operator Protective Structures (OPS) are additional protection to the zone around the operating position (seat) from identified specific hazards. In forestry these commonly comprise penetrating and whipping branches and, depending on machine type and use, loader grabs and timber billets, chain-shot from harvesters and flying / broken winch rope and tackle from skidders and cable cranes. Protection may be provided by window bars / mesh, safety glazing (the most effective being polycarbonate), steel panels etc.

There is no British and International *standard* that is specific to agricultural and forestry tractor OPS, but there *is* one covering forestry machines in general[53].

Guidance is that "An operator protective structure needs to be fitted[54]" and can take various forms.

"The Risk Assessment will determine the level of [OPS] protection required[55]".

This should be covered by the correct method and machinery chosen for the site conditions.

Operator protection when driving

The key issues for operator protection when using the loader have been described previously. This section considers the level of operator risk and protection when driving (**Table 5**). The key issues for operating with and without cabs are highlighted thus ⚠, and discussed below.

[51] Tractor units in tree work, para. 5. FISA Safety Guide 501. (2013).

[52] Tractor units in tree work, para. 6. FISA Safety Guide 501. (2013).

[53] ISO 8084:2003 Machinery for forestry - Operator protective structures (OPS)

[54] Tractor units in tree work, para. 7. FISA Safety Guide 501. (2013).

[55] Tractor units in tree work, para. 7. FISA Safety Guide 501. (2013).

Table 5. Operator position factors - tractor driving

Issue	Degree				
	Standard cab		Small cab		No cab ('open cabs')
Driving operation					
Normal entry/exit	Slight restriction		Slight restriction		Slight restriction
Emergency exit	Slight restriction		Moderate restriction		Slight restriction
Vision of loader	Slight restriction		Moderate / Restricted		Not restricted
Seat swivel	Developed	Moderate	Not practical		Not practical
Sound awareness[56]	Moderate		Basic		Restricted
Ventilation	Slight restriction		Open - Not restricted		Not restricted
			Enclosed - Restricted		
Heating	Not Restricted		Open - Not practical		Not practical
			Closed - Not restricted		
Demisting	Not Restricted		Open - Slightly or Not restricted		Not restricted
			Closed - Restricted		
ROPs ⚠	Cage - Developed		Cage - Moderate		Bar - Basic
			Semi cage - Restricted		
FOPs ⚠	Developed		Moderate / Restricted		By method
OPs	Developed		Open-unglazed - By method		By method
-chain-shot ⚠					
	Restricted		Closed - Restricted		
-flying objects ⚠ strike	Developed	Moderate	Restricted		By method
			By method		
-boom / billet / ⚠ intruding objects strike	Developed	Moderate	Moderate / Restricted		By method
			Basic / By method		
Lower risk Level of Provision - **Key** *Higher risk*					
Developed / Not Restricted	Slight restriction	Moderate	Restricted	Basic	By method / Not Practical

Issues highlighted ⚠ are discussed further in **Appendix 6** 'Tractor operator protection'.

To summarise the key points:

There is no single simple rule that ensures a safe system of work because **each element** must be assessed in the context of the whole circumstances through an effective **Risk Assessment**.

[56] Ireland, D. (2006). Compact Tractors in Forestry. Internal Project Information Note 14/05. Forestry Commission, Technical Development Branch: "*Consideration should be given to whether there is a requirement for maintaining awareness of ambient noise for safety reasons e.g. movements in crops warning of danger. This could affect the type or specification of noise protection selected. The noise level of any ancillary equipment must also be assessed.*"

The degree of operator **protection** in a larger tractor cab may be greater than that in a small tractor, which in turn may be greater than that in an 'open-cab' cab-less situation.

Cab characteristics have a **strong influence** on the degree of roll over protection, which nevertheless can be very variable.

Even when fitted, polycarbonate glazing **may not** provide **complete protection** from chain-shot in every circumstance.

Rudimentary or small cabs may be **comparable to** 'open cab' / cab-less tractors with roll bars, which may even be preferable in some circumstances.

A cab may not provide complete protection in all circumstances so careful attention to the **work method** is always **important**.

Cab-less 'open cab' driving should be subject to the same standards of operator **risk assessment** as other forestry activities such as **felling**.

- ✓ Maintain overhead vigilance and wear helmet
- ✓ Drive with due care for the circumstances, especially:
- ✓ Avoid driving under suspect trees
- ✓ Avoid brushing against trees / large branches (good silvicultural practice anyway)
- ✓ Avoid driving in the risk zone from operating loaders.

The work method and any operator cab protection can **both contribute** to a safe system and one or the other by itself may, or may not, be sufficient.

The work method, such as machinery used and operator position, must **effectively mitigate risks** within the working system, which is *always* important and is the primary safeguard in the 'open cab' cab-less situation.

Small scale tractors[57]

Small scale tractors and timber trailer combinations (**Plate 1**) have become increasingly popular where light, narrow machinery with good manoeuvrability is an advantage. Examples include particularly sensitive sites, those with restricted access (**Plate 2**) and where frequent transport between sites is a factor. Small tractors are less suited to longer extraction distances owing to load capacity and slower speed.

[57] Ireland, D. (2006). Compact Tractors in Forestry. Forestry Commission Forest Research, Technical Development Branch Internal Project Information Note 14/05 and Ireland, D. & Roux, S. (2007). Alpine tractors in forestry. Forestry Commission Forest Research, Technical Development TN45 (unpublished)

Plate 1. Small-scale 'Compact / alpine' tractor and purpose-built forwarding trailer[58]

Plate 2. Narrow dimensions allow access on narrow tracks with minimal disturbance to trackside vegetation

Engine size is generally under 50 hp, although larger engines up to 90 hp or more are available. Engine power around 20 to 25 hp is common.

Various terms and definitions have arisen that can be applied to 'small scale' tractors so it is useful to make some basic distinctions:

- **Small** - general term and FC machinery classification for 3 to 6 tonne machine weight or load capacity[59].
- **Mini** - term used by FC to describe a machine weight or load capacity of under 2.50 tonnes. An unladen weight of under 2.5 tonnes is a distinct category recognised as an 'endorsement' by City and Guilds for forestry base machines[60]. However, the International Standards Organisation class an unladen weight of under 600 kg as 'small'.[61]
- **Compact, Alpine**[62] - refers to comparatively small overall dimensions plus design to operate on steep terrain and confined conditions, robustly dimensioned axles & components for improved durability. Introduced to UK from 1980s.

The term 'Small scale' is used in this report to describe machinery **under 3 tonnes weight** or load capacity (at and below the FC 'Small' category), *which includes 'Mini' and 'Compact' / 'Alpine' tractors.*

The relatively small size of small scale tractors may accentuate particular issues in use, such as:

- ⚠ General handling and correct loading
- ⚠ Operator ergonomics and position when using attachments such as kneeling on seat to use loader controls

[58] From: Ireland, D. (2006). Compact Tractors in Forestry. Forestry Commission Forest Research, Technical Development Branch Internal Project Information Note 14/05

[59] Saunders C.J. (2015). Small and mini harvesting and extraction machinery: A guide to their selection for safety. Forestry Commission Forest Research, Technical Development Report TDJR131

[60] City & Guilds, NPTC Level 2 Award in Forest Machine Operations – Base Machine (QCF), 600/9102/2

[61] ISO 26322-2:2010(en) Tractors for agriculture and forestry - Safety - Part 2: Narrow-track and small tractors. Also defines 'narrow tracked' tractors as having a smallest fixed or adjustable track width of not more than 1,150 mm

[62] Also 'Vineyard' tractors e.g. Italy

- ⚠ Towing capacity in terms of manufacturers' specification, tractive effort, traction, braking, hitch rating and nose weight
- ⚠ Stability and handling when comparatively heavy attachments are used
- ⚠ Stability, owing to narrow width
- ⚠ Stability, owing to overall lighter weight e.g. a lesser force (acting above the centre of gravity) can topple the machine
- ⚠ Roll over protection, owing to smaller or no cab[63]
- ⚠ Frame steering issues such as reduced stability on side slopes (*and, as with articulated / frame steered larger machines, avoid turning uphill on side slopes*).

General characteristics of small scale tractors that may be suitable for small scale forestry operations are summarised in **Appendix 7**, which excludes 'domestic' or 'garden' type equipment. Key points are highlighted in the following sections.

Weight

- ⚠ Observe manufacturer's limits for both tractor and trailer (see VIN Plate). CE 'Certificate of Conformity' states load **towing capacity** of tractor required (for braked / un-braked trailers).
- ⚠ Front weights may be needed to **counterbalance** rear attachment or hitch loading.
- ⚠ Ensure sufficient tractor power, but if excessive can be difficult to **control safely** and can induce wheel slip that increases wear and fuel use.

Steering

- ⚠ Front wheel steering - ensure correct **weight** on **tractor wheels**. Use front weights or wheel ballast if necessary, and ensure correct drawbar **nose weight** on hitch (*refer to manufacturer's specifications*).
- ⚠ Frame steering is not recommended for **towing**.
- ⚠ Steering drawbars using tractor hydraulics are fitted to some (larger) trailers to aid **manoeuvring** within the crop, reduce tyre 'scrubbing' and the tendency for a powered trailer to 'push' the tractor on turns.
- ⚠ For trailers with a steering drawbar, ensure correct **load distribution**, so that the *nose weight* is not excessive because induced actuation of the drawbar could tip the trailer e.g. when driving downhill.

Hitches

- ⚠ Light vehicle hitches: usually a rigid ball-hitch on chassis / shell, couples to a swivelling socket with retractable locking tongue on the trailer drawbar - allows multi-directional movement. Used with security braking cable on braked road trailers (required over 750 kg gross weight). **Not usually used off road**, except for smallest trailers.

[63] The Provision and Use of Work Equipment Regulations 1998 states that for some small or very old tractors a roll bar will be the only practicable ROPS structure available

- Smaller tractor hitch: usually a rigid clevis hitch on chassis, the *clevis* (bracket) couples to a trailer *eye* (ring) through which the *clevis pin* passes and is locked in place by a *linch pin*, *'R' clip* or similar. **Commonly used off road**.
- Ensure that the trailer has a swivelling drawbar, allowing for **lateral movement** at the tractor / trailer coupling, and in case of overturning on steep / uneven terrain.
- Ensure that the ring and clevis / pin are **matched**, with sufficient but not excessive free play.
- **Nose weight** is less critical for tractor traction with driven trailers.

Towing trailers

- Adhere to CE 'Certificate of Conformity' stated safe braked / un-braked towing capacity.
- Ensure the trailer nose weight (on tractor hitch) is within tractor **specification** because it affects steering and stability, especially if excessive.
- Load position / centre of gravity and bogie position significantly affects **nose weight**.
- Ensure tractor-trailer+load combination puts correct **nose weight** on tractor hitch for traction, especially up-slope.
- Slight adjustment of wheel / bogie position fore-aft can have a very big **effect**.
- Larger Wheel diameter - faster speed per revolution, greater **ground clearance** but higher centre of gravity
- Smaller Wheel diameter - increased **torque** (if driven).
- Bogie wheel spacing is important. **Wider** gives smoother ride over obstacles but higher turning stresses. **Closer** can exacerbate lateral swaying.
- Bogie drive increases traction and machine load / terrain **capability**.
- Wider tyres have more **flotation** but less traction.
- Driven wheels have a cleated tread design (e.g. 'V') for off-road traction, which **wear faster** on-road.
- Flexible sidewall of radials more liable to **damage** than cross plies.
- Higher ply ratings preferred - **10 to 14** for most forestry conditions.
- Load distribution fore-aft can have a very big **effect**.
- Ensure correct tyre pressure for task - harder is faster on road, softer better off road flotation.
- Only use wheel-chains where necessary for improved **traction** on driven wheels (especially rear bogie wheels) or for trailer **braking** (especially on front non-drive bogie wheels). Aggressive 'ring' type chains have greatest affect but can damage ground / roads and increase tyre wear.
- Ensure ground clearance is **sufficient** to avoid being 'hung up' on stumps, but if excessive will unduly raise centre of gravity.

Matching tractor-trailers to site

A basic summary of the main factors to consider when choosing tractor-trailer combinations for a site or range of sites is given in **Table 6**. The summary is given as trends, and the exact position of boundaries will vary. The key site factors here are:

- Slope
- Tree / Produce Size
- Extraction distance
- Ground roughness
- Ground condition
- Manoeuvring *within* sites
- Moving *between* sites
- Access *to* sites
- Ergonomics
- Method
- Economics.

Tractor-trailer combinations are unsuited to the more extreme site conditions, where purpose built and larger forwarders, skidders, winches and other options may be more suited as discussed in Technical Development Report 150 and its associated six site type guides from firm level to steep and soft.[64]

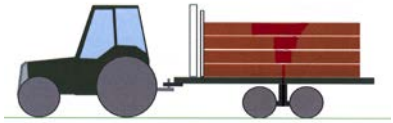
[64] Ireland, D. (2015). Small and Medium Harvesting and Extraction Machinery: A guide to site suitability. Forestry Commission Forest Research, Technical Development Report 150, and TD Technical Notes 150.1 to 150.5

Table 6. Matching tractor-trailers to site - influence of main factors

Factor	Machine class			
	Small-Medium (6 - 9 tonnes)	Small (3 - 6 tonnes)	Mini (< 2½ tonnes)	
Slope				
Gentler slopes	✓ Not restricted			
Steeper slopes	Powered bogie trailers		⚠ Unpowered trailers	
Tree / produce size				
Smaller tree / produce size	✓ Not restricted, *but production is lower and costs higher with smaller material*			
Larger tree / produce size	✓ Larger & stronger bunks & loaders	<Transition>	⚠ Smaller bunks & loaders	⚠ Too small
Extraction distance				
Shorter extraction distances	✓ Not restricted, *but output will be lower with smaller bunks as travel element is proportionately greater*			
Longer extraction distances	✓ Highest output	<Transition>	⚠ Output decreases & costs rise	⚠ High cost
Ground roughness				
Smoother ground	✓ Not restricted			
Rougher ground	✓ Best clearance	Some travel / ergonomic impediment	⚠ Travel / ergonomics impediment	⚠ Too restricted
Ground condition				
Firmer ground	✓ Not restricted			
Softer Ground	⚠ Too soft	⚠ Ground damage	Limited ground damage	✓ Low impact
Manoeuvring <u>within</u> sites				
More open stocking	✓ Not restricted			
Closer stocking	⚠ Too restricted	⚠ Crop damage	<Transition>	✓ Not restricted, *but outputs lower* ⚠ Too restricted
Moving <u>between</u> sites				
Infrequent moves	✓ Not restricted			
Frequent moves	⚠ Costs rise	<Transition>	✓ Lower costs, *can ow with 4WD plus trailer*	

TD JR177

Access to sites				
Easy access	✓ Not restricted			
Restricted access	⚠ Too restricted	🚦 Difficult	<Transition>	✓ More suited, *may be the only option*
Ergonomics				
Higher ergonomic levels	✓ Less fatigue & impact from site	<Transition>	🚦 More fatigue & method limitations, *rudimentary or no cab*	
Lower ergonomic levels	Some fatigue & impact from site	🚦 More fatigue & method limitations, *rudimentary or no cab*	⚠ Too restricted	
Method				
Site more suited to machine	✓ Largely unrestricted for best method	May be some restrictions *e.g. after Risk Assessment*		
Site less suited to machine	Some restrictions e.g. after Risk Assessment	🚦 Greater restrictions *e.g. after Risk Assessment*	⚠ Too restricted	
Economics - *cost: tonne ratio (combines factors)*				
Greater tonnage	✓ Lower cost	<Transition>	🚦 Rising costs	⚠ High cost
Lesser tonnage	⚠ High cost	<Transition>	✓ More suited, *may be environmental aims*	
	Small-Medium (6 - 9 tonnes)	Small (3 - 6 tonnes)	Mini (< 2½ tonnes)	



Safe operation

The key factors required for a safe system of working when using timber trailers with tractors (or other prime movers) are:

- ✓ Training and proof of competence relevant to the type of work equipment
- ✓ Using a trailer suited to crop / produce and terrain / ground conditions
- ✓ Using a tractor suited to the terrain / ground conditions
- ✓ Matching the tractor and trailer according to their capabilities and limitations
- ✓ Identifying and assessing the risks involved in using the machinery in the crop and terrain / ground conditions and
- ✓ **Using a method of working that avoids or mitigates the risks**.

Although all these factors are important, it is especially important to recognise that correct choice of method of working is essential.

Poor method will be **inefficient** or even **unsafe** irrespective of good training and equipment choice.

This report has highlighted the issues that should be considered when choosing tractor-timber trailer combinations and a method of working, and has pointed to some underlying rules of physics. It has also provided a checklist of factors to understand, consider and assess when planning or undertaking operations.

Timber trailers - whether large, medium, small or 'mini' - are a potentially valuable part of the harvesting 'toolbox' but efficiency and safety ultimately relies on effectively dealing with risks through informed choice of tools, machinery and working method.

Operating checklist for small to medium scale tractor-timber trailers

A summary checklist of issues, both to consider and to follow during operations can be found at the end of this document at **Appendix 7**.

Acknowledgements

The author is grateful for the experience and knowledge shared by contractors and agents, particularly those who made time available during the tour undertaken in spring 2016. Much of this report has been drawn from previous reports written by colleagues in Technical Development and from sources of published and unpublished guidance for which references are given. Appreciation is also given to Forestry Commission Scotland for commissioning this report and contributing to related ones in the series.

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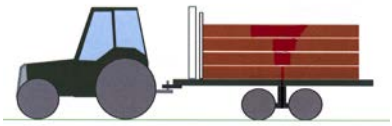
Forestry Commission 1919
Work Study 1957
2019 Technical Development
Forestry Commission 100
over 60 years of work study in British forestry

Technical Development helps develop, evaluate and promote safe and efficient equipment and methods of work, maintains output information, advises on forest operations and provides related specialist services.



The list of products/manufacturers in this report is not comprehensive; other manufacturers may be able to provide products with equivalent characteristics. Reference to a particular manufacturer or product does not imply endorsement or recommendation of that manufacturer or product by Forest Research or Technical Development.

Appendix 1

The importance of tractor and trailer weight

Momentum and Moments

A *moving* weight exerts a greater force owing to its momentum[65]. A moving object has *kinetic energy* because a force was invested to make it move.

Thus, for example, a 300 Kg grab full of timber billets moving at 1 metre per second (1 m/s) has greater *energy* in the form of *momentum* than one moving at a tenth of that speed.

This can be calculated using the equation: **Momentum = mass x velocity**
i.e. 300 Kg x 1 m/s = 300 Kg m/s *compared to* 300 Kg x 0.1 m/s = 30 Kg m/s

A weight moving around a *pivot* exerts a force as a *turning force* or moment. This is the principle used in *levers*, whereby a larger weight close to a pivot can be moved by a smaller weight (or force) at a greater distance from the pivot.

Thus, for example, a tonne of timber (1,000 Kg or 10,000 N) positioned on a bunk 3 m from a pivot such as a wheel, will exert three times the *turning force* (moment) than the same weight 1 m from the wheel.

This can be calculated using the equation **Force x distance = moment**
i.e. 10,000 N x 3 m = 30,000 Nm whereas 10,000 N x 1 m = 10,000 Nm

Moments will also have an *opposite effect* if there is the structure extends beyond the pivot, as in a 'see-saw'. Thus, a weight causing a *downwards* moment will *raise* the other side (**Figure A1**). Furthermore, if the distance on the other side is *shorter*, then the resulting upwards force will be proportionately *greater*.

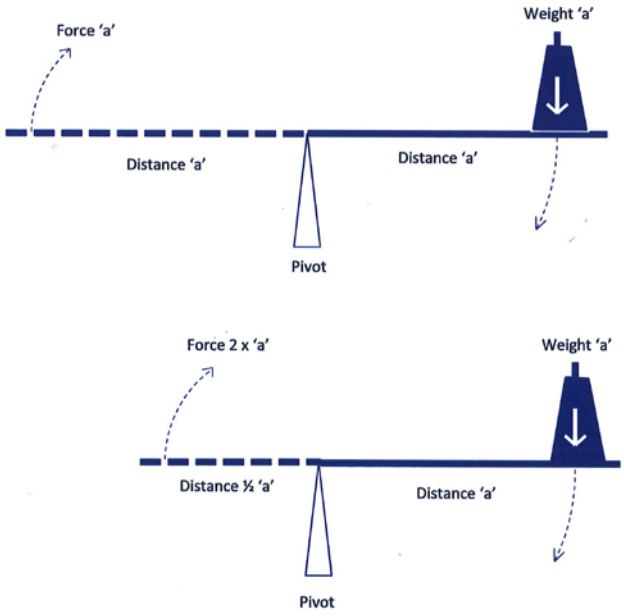


Figure A1. Raising effect of a downward moment
Top: equal if distance is equal Bottom: Double, if distance is half

[65] Momentum has both a magnitude and a direction and is 'the tendency of the object to keep moving in the same direction' (bbc.co.uk bitesize, 2017)

The influence that *moments* have on the turning forces exerted by weights on a timber trailer are illustrated in **Figure A2**, and explained in the box below.

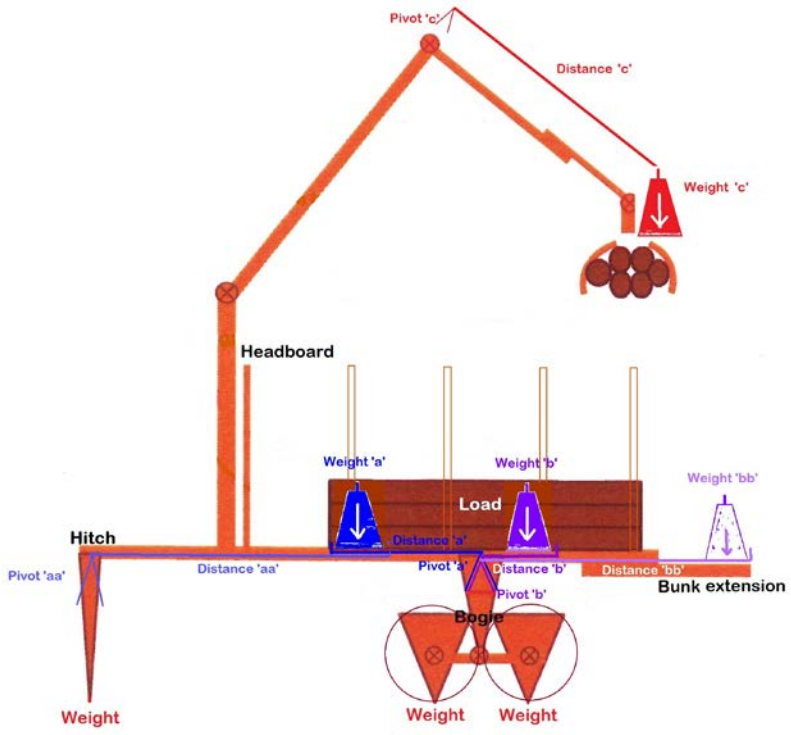


Figure A2. Stylised moments *(weight and distance to pivot)*

Commentary

Weight 'a' is the proportion of the timber Load that lies to the front of the bogie. This exerts a downward / anticlockwise moment (*turning force*) around the bogie which forms Pivot 'a'. The magnitude of the moment is **Weight 'a'** X **Distance 'a'**.
This anticlockwise force will tend to lift the structure to the rear of the bogie.

However, the trailer Hitch also acts as a Pivot ('aa'), so Weight 'a' also creates a downwards / clockwise moment around the hitch. The magnitude of the moment is **Weight 'a'** X **Distance 'aa'**.
This clockwise force will tend to lift the tractor hitch.

Note that Distance 'aa' is *greater* than Distance 'a', so the force exerted by the moment around the Hitch is *greater* than the force that *the same weight* exerts around the Bogie.
Therefore Weight 'a' will tend to lift the tractor more than the rear of the trailer.

Similarly, weight 'bb' - located on the bunk extension positioned *away* from the Bogie (Pivot) - exerts a far greater turning force (*to lift the tractor hitch*) than the same weight 'b' located *close* to the Bogie.

Also, Weight 'c' will exert a greater moment around the knuckle joint Pivot 'c' if the loader main boom is extended, because Distance 'c' will increase. Therefore the amount of force needed to counteract the turning force resulting from the load in order to keep the load suspended will be greater with the boom extension extended.

Movement occurs when a force is *unopposed*, or opposed by a smaller force.

It is important to recognise the effect that both *movement* and *pivoting* can have on the behaviour of a timber trailer, tractor and loader.

Weight distribution and centre of gravity

The structure of the trailer and the position of the load on it affect the way that the weight distribution is exerted as a *force* on the ground (through the wheels) and the hitch. The hitch conducts the force to the tractor, and ultimately to the ground through the tractor wheels.

In basic terms, weight is transmitted to two supports in inverse proportion to their respective proximity. Thus if one support is 1/3rd of the distance to the weight, then it will bear 2/3rds of the weight (**Figure A3**):

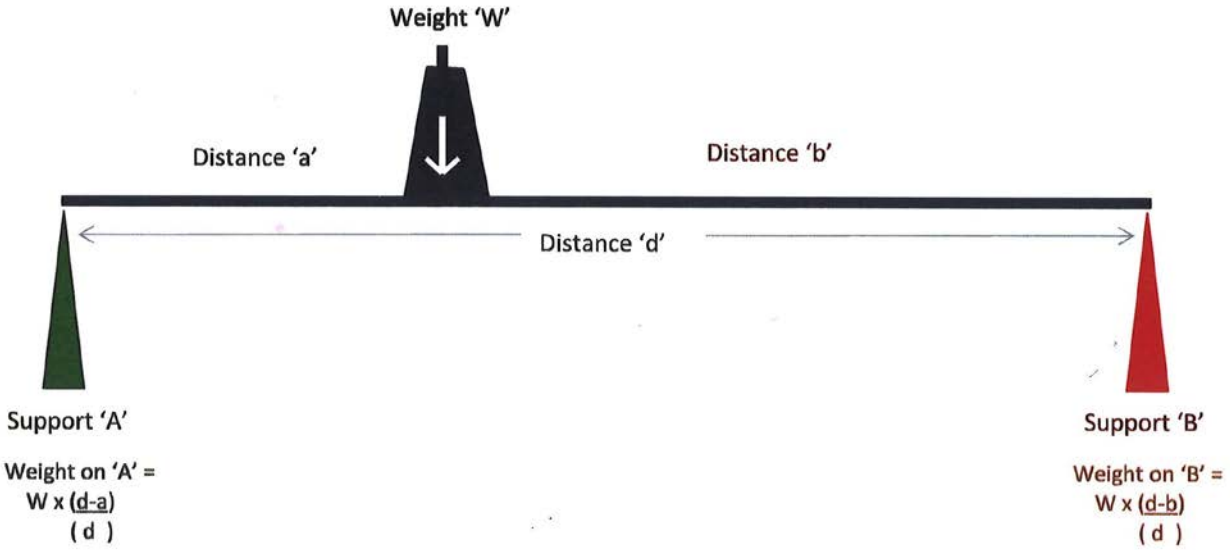


Figure A3. Simple weight distribution between two supports

The weight-bearing supports of a trailer are the hitch and wheels, and the load borne by each will depend on the distance to the weight[66].

The weight distribution of the trailer itself will be changed by the position of any constituent fixed or movable parts affecting the proportion of weight distribution forward to the hitch and rearwards to the wheels (**Figure A4**).

[66] Or, more specifically, to its centre of gravity

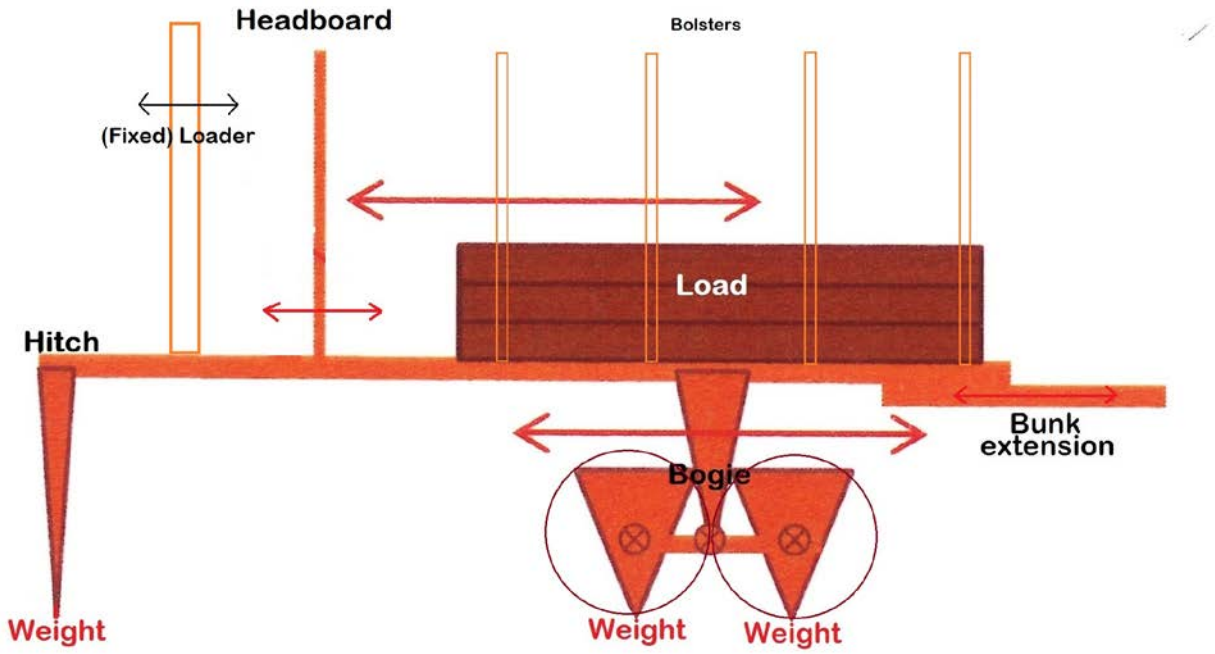


Figure A4. Stylised basic trailer physics, with load force shown

The centre of gravity can be defined as "*an imaginary point in a body of matter where, for convenience in certain calculations, the total weight of the body may be thought to be concentrated*"[67]. Although this can be straightforward in a symmetrical body of consistent density, it is less obvious in asymmetrical objects and those with variations in density. On occasion, the centre of gravity can also be *outside* the mass itself, for example that of a chair being under the seat.

The centre of gravity is a key factor governing the stability of objects because a high centre of gravity is a predisposition to instability. Toppling or roll-over will occur if the imaginary vertical line through the centre of gravity falls outside points on which the object is supported (**Figure A5**).

[67] Encyclopaedia Britannica

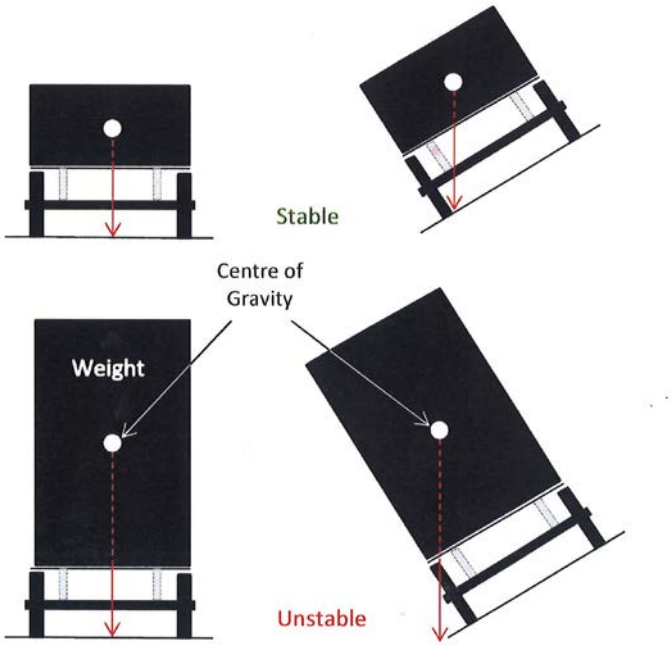
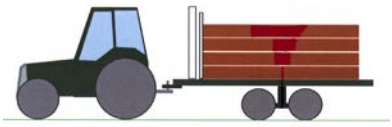


Figure A5. Relative positions of Centre of Gravity affecting stability

Swaying occurring when driving over rough ground may temporarily move the centre of gravity outwith the stable position, and *momentum* may increase the toppling force.



Appendix 2

Loader construction characteristics

Hydraulic loaders are usually connected into the tractor ancillary hydraulic system and powered by the tractor, although some loaders have a separate hydraulic tank and pump. Some loaders are available with a separate power unit (e.g. four stroke petrol unit) to power a completely free standing hydraulic system.

The main **loader mounting** options are:

- Roof mounting - on a specialist frame, allows good visibility, 'line of sight' operation, 'reach' to the front and better weight distribution over the rear axle. However, the centre of gravity is raised and the loader can be obstructed by overhead branches. A 'grab bar' must be fitted to the front of the tractor, if the loader is used without a trailer to 'park' the grab when the tractor is moving.
- Three point linkage - on a standard or modified linkage, allowing use with or without the trailer and relatively easy removal. Operator visibility is impeded by the kingpost, the PTO may be obscured, weight distribution is adversely affected and slewing may be restricted. The unit can move about under load so stabiliser legs are required at the loader base, and a grab bar is required if used independently
- Trailer mounting - fixed to the trailer chassis / drawbar just forward of the headboard. Improves tractor stability over the other options and visibility is better than with three point linkage mounting. Support legs are usually fitted, especially to the smaller trailers. Careful loader positioning within crops is required, as the operator is some distance from the kingpost, but less reach is needed to span the trailer bed. Removable three point linkage-type loaders are also available, for trailer mounting on an adaptor base plate.

In basic terms a **loader comprises** (**Figure A6**):

- Power source and mechanism - almost universally an *hydraulic* system, whereby a pump circulates hydraulic oil by pipework to the operating rams or cylinders. The hydraulic system is usually 'plugged' into the tractor's ancillary hydraulic take-off, but potentially comprises a separate system with a pump powered by the tractor PTO. 'Wire loaders' are an exception, for (very) small scale use, whereby the booms are moved with a manual, or electric motor, powered cable / pulley arrangement.
- Controls - there are two main types of loader hydraulic controls. The basic 'Manual hydraulic' system, often used with tractor towed timber trailers, comprises several (usually 5 or 6) 'push pull' levers 'in line', which operate individual rams. The levers are mounted directly onto the hydraulic valve block from which the hydraulic pipes lead to the loader rams. The valve block / control unit with hoses leading off it can be mounted at the rear of the tractor behind the operator's tractor seat, requiring the seat to be swivelled round,

reversed or 'knelt on' to avoid twisting the torso for operation. The control unit can also be mounted on the trailer near the headboard and some trailers are available with an operator's 'standing platform' equipped with control unit stand and operators backrest for this purpose. More specialised forestry tractor (and forwarder) systems, use servo assistance for ease and fine control of the more powerful loaders. The lever functions are combined into two 'joysticks' with hydraulic-servo assistance, or electric-servo assistance (Electro Hydraulic Control or 'EHC') so that the controls can be located separately from the valve block and hoses which do not need to be led into the tractor cab. The electrically operating joysticks may be mounted on either arms of the operator's seat. Several manufacturers offer EHC controls as an option, albeit more expensive. An intermediate arrangement based on linking the separate lever functions into two mechanical levers is also available[68]. The valve block / mechanical-lever controls may be placed within the cab or otherwise within reach of the operator's seat, or potentially mounted for the operator to be positioned on the trailer behind the headboard (and theoretically at least from anywhere within reach of the hydraulic hoses).

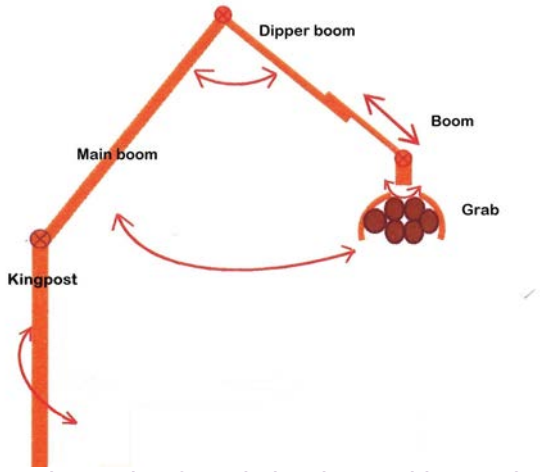


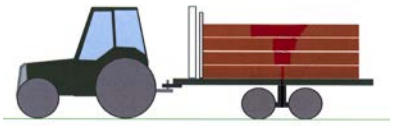
Figure A6. Schematic of Basic loader position and movement

- Kingpost - The loader base fixed to the trailer drawbar, tractor roof or three point linkage. The kingpost will be short if fitted to the roof and longer, to headboard height, if on the trailer drawbar. The various loader parts are fitted to or above the kingpost.
- Slewing mechanism - to move the loader booms above the kingpost from side to side. The 'slewing arc' is important because it may (or may not) restrict the movement of the loader behind the headboard in a limited arc away from the operator. The slew mechanism usually comprises one or two (giving greater power) sets of opposing hydraulic rams operating one or two rack and pinion arrangements, or gears
- Stabiliser legs - 'free standing' type loaders such as those mounted on the tractor three point linkage, and often removable units mounted onto a trailer

[68] Jones, D.H. (1995). Hydraulic Loaders for Agricultural Tractors Forestry Commission Forest Research, Technical Development Branch TN25/95

drawbar, will require a pair of stabiliser legs ('Jack legs') as described in the Trailer characteristics section

- Main boom - the lower part of the boom mounted onto the kingpost / slew mechanism by means of a shaft (axle / pin) so that it can be moved upwards or downwards by a double acting hydraulic ram
- Dipper boom ('outer boom') - fitted to the outer end of the main boom by means of an articulated ('knuckle') joint that enables it to be raised or lowered by a double acting hydraulic ram
- Telescopic / extension boom - some loaders have the facility for the outer boom to be extended along its axis (in one or more sections) using an hydraulic ram-operated sliding mechanism
- Grapple - the load grab fitted to, and suspended from, the outermost end of the boom by means of an hydraulically operated 'rotator' that enables the grab to be swivelled from side to side. Some grapples can be rotated continuously through 360 degrees, whereas others are limited to a c. 300^{o}. The jaws of the grapple are open and closed by a double acting hydraulic ram mounted at the apex. There are several types of grab mechanism[69].



[69] [69] Jones, D.H. (1995) TN25/95 Hydraulic Loaders for Agricultural Tractors

Appendix 3

Tractor requirements and use

Guidance from 'Tractor units in tree work'[70] on the requirements for equipping and using 'agricultural'-type tractors in forestry is an essential reference for all forestry tractor operators and is summarised below. The summary also includes guidance from other sources as stated:

Pre start
Ensure that the machine is fully equipped, inspected, maintained and operated by competent persons according to the manufacturer's handbook instructions (which should be available)
Carry out pre-start checks in accordance with manufacturer's instructions
Ensure any dangerous parts are guarded e.g. Power Take Off (PTO), and guards are secured
Ensure that the cab has suitable ROPS, FOPS and OPS for the job, as identified by Risk Assessment
A suitable and accessible fire extinguisher should be fitted
Ensure that a suitable First Aid kit is fitted and accessible
Ensure that you have ready access to an emergency spill kit for fuel / oil
Ensure a travelling and maximum machine height sign is within the cab, plus noise warning sign if over 85 dB
Ensure there is an emergency stop accessible from the cab seat (clearly marked with method of use) and that there are clear markings of controls and manufacturer's risk zone (e.g. at least twice the maximum reach of any boom, and danger zone if frame steered)
Ensure that adequate lighting is fitted if working in poor light conditions.
Cab / operator's position
Climb in / out using steps (where fitted) and facing inwards with three points of contact (hand, hand, foot etc.)
Use seat restraints where there is a risk of operator injury owing to rollover
Do not carry loose objects in the cab that could cause injury in a roll over
Do not drive when your vision is obscured and use working lights where necessary
Do not allow anyone to ride on the tractor unless on a specific seat
Driving
Only drive within the capabilities of yourself and the machine and be aware of limitations in poor weather and on difficult terrain
Ensure that independent brake pedals are locked together when independent braking is not required, and when on roads. *Use with care in soft, wet & sloping conditions:* TN24/95
Ensure any trailer boom and grab are in correct position when driving off, or the unit is being transported
⚠ **Stop** if any person comes within the risk zone, unless the person is included in an

[70] Tractor units in tree work. Forestry Industry Safety Accord (FISA) Guide 501 (reprinted 2013)

approved safe working system

If a machine starts to slide when travelling downhill, steer straight downhill and gradually increase the engine speed to regain traction. **Do not** *depress the clutch!*

Descend straight down a slope if possible, rather than diagonally across it

⚠ **Avoid turning** a frame steered / **articulated** forwarder **uphill** [71] [72] on side slopes - this increases rollover risk very much! *It is, however, safer for a tractor pulling a trailer*

⚠ **Avoid turning** a rigid frame **tractor** **downhill** on side slopes [73] - this increases rollover risk very much! is especially hazardous

If side slopes are unavoidable, reduce the load height[74] (*for skilled operators, it may also be possible to extend the trailer boom on the upper side to maintain stability*)

⚠ **Be aware** of the risk of rearwards overturn, including driving up steep slopes, when drive wheels are stuck fast in mud or a heavy load cannot move. **Ensure** sufficient front counterbalance for rear-mounted weights and always hitch trailers to the correct point. *Rear overturn can be fatal and happen very fast!*[75] [76]

⚠ **Do not** attempt to jump clear from an enclosed safety cab if a machine overturns - sit tight!

Use the parking brake when stopped / loading and during operations, where appropriate

Parking & maintenance

Park straight up / down a slope and chock wheels or wedge against stumps etc. if steeper

When parking - and before maintenance - lower machine parts safely, stop engine, release hydraulic pressure, set controls to neutral (except brake) and remove ignition key

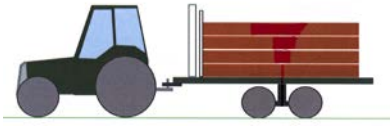
Ensure that the tractor unit, and any mounted or trailed equipment, is in a secure position before attaching or detaching - **beware of being crushed**!

⚠ **Do not** suspend grab tanks when refuelling

⚠ **Do not** work under suspended or 'propped' parts and do not rely on the machine's hydraulic system

⚠ **Do not** use your hand to check for hydraulic leaks (use paper / cardboard) - high pressure fluid can enter the blood stream!

⚠ **Do not** operate a double acting ram that has a broken pipe.



[71] Extraction by forwarder. FISA Safety Guide 503. (2013)
[72] Hietala, P. (1991). Puutavaran Metsakuljetus. "When … the loging road… turns .. uphill, the hinge pivot is on the downhill side … the kinetic energy of the load's weight is in the same direction with the hinge pivot, thus maximising the risk of overturning". In 'Forwarder Extraction course, FOTC. Forestry Commission (2001).
[73] Using tractors safely. HSE INDG 185. (2013). "Avoid turning down a slope - this is especially hazardous"
[74] Reduction of load height is an additional option not included in FISA 501
[75] Using tractors safely. HSE INDG 185. (2013).
[76] Murphy, D. (2016). https://extension.psu.edu/tractor-stability-and-instability Pennsylvania State University

Appendix 4

Matching tractor to timber trailer

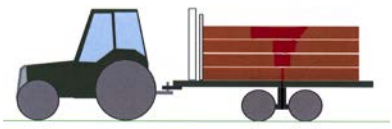
Feature	Characteristic[77]	
	Tractor	Trailer
Towing capacity	Guide to tractor power / trailer combination[78]	
	Up to 35 - 40 hp	Up to 3 tonne load capacity
	50 - 60 hp	4 - 5 tonne load capacity
	70 - 100 hp	6 - 8 tonne load capacity
	Some 20 hp to 30- hp more power may be required for a driven trailer *1hp = 0.75 kW*	
	Ensure sufficient power, but excessive power can be difficult to control safety Excessive power can induce wheel slip that increases wear and fuel use	
Weight 	Observe manufacturer's limits for both tractor and trailer (see VIN Plate) CE 'Certificate of Conformity' states load towing capacity of tractor required (for braked / un-braked trailers) Front weights may be necessary to counterbalance rear loading	
	Example of Vehicle Identification Number plate - weight section *(details may vary)*	
	Gross Vehicle Weight (Maximum Authorised Mass) of fully loaded vehicle	2,950 kg
	Gross Train Weight of towing vehicle and trailer allowed i.e. maximum trailer weight is '2' - '1' *	6,450 kg
	Maximum axle load (front)	1 1,200 kg
	Maximum axle load (rear)	2 1,750 kg
	**Line may be omitted if vehicle is unable to tow or is a trailer*	
Steering	Front wheel steering - ensure correct weight over wheels e.g. with front weights	 Ensure correct drawbar nose weight
	Frame steering	 Not recommended for towing
	Requires tractor hydraulics	Steering drawbar (larger trailers) - aids manoeuvring within crop, reduces tyre 'scrubbing' and tendency for a powered trailer to 'push' the tractor on turns  Ensure correct loading so that nose weight is not excessive as actuation could tip trailer e.g. downhill
Coupling	In the European Union, towbars must be a type approved to European Union directive 94/20/EC to be fitted to vehicles first registered on or after 1 August 1998	

[77] Includes information from Mr Stephen Cabrol, RIKO UK Ltd and Jones, D.H. (1996). Timber trailers for agricultural tractors. Forestry Commission Forest Research, Technical Development TN28/98

[78] Jones, D.H. (1996). Timber trailers for agricultural tractors. Forestry Commission Forest Research, Technical Development TN28/98

	Light vehicle hitch: fixed ball on chassis	Fixed socket on drawbar, with retractable locking tongue - allow multi-directional movement but not usual for rough terrain. Used with security braking cable
	Smaller tractor hitch: fixed *clevis* (bracket) takes *clevis pin* for trailer ring / eye	⚠ 'Ring / eye' on drawbar - ensure swivel type, important for steep / uneven terrain for tractor / trailer lateral movement & in case of overturn Ensure ring and clevis / pin are matched (sufficient but not excessive free play)
	Larger / standard tractor 'Pick up' hitch: hook mechanism lifted by hydraulics through trailer eye and locked shut against top plate	
Width	Should be similar for manoeuvrability & maximum lateral stability Wider wheelbase will be more stable	
Trailer brakes	Un-braked trailer legal maximum 750 kg gross weight (for road use) ⚠ Adhere to CE 'Certificate of Conformity' stated safe braked / unbraked towing capacity	
		Available. Front / all wheel hydraulic type with cab lever control. Larger trailers [~>5 tonne] may be linked to footbrake
Trailer nose weight (on tractor hitch)	⚠ Ensure within tractor specification as affects steering and stability, especially if excessive	Ensure within trailer specification e.g. usually 10% gross trailer weight for road trailers
	⚠ Load position / centre of gravity and bogie position significantly affects nose weight	
	⚠ Ensure tractor-trailer+load combination puts correct nose weight on tractor hitch for traction, especially up-slope 🚦 Nose weight is less critical for tractor traction with driven trailers	
		⚠ Slight adjustment of wheel / bogie position fore-aft can have a very big effect
		⚠ Load distribution fore-aft can have a very big effect
Wheel diameter	🚦 Larger - faster speed per revolution, greater ground clearance but higher centre of gravity Smaller - increased torque (if driven)	
Bogies	🚦 Wheel spacing is an important design attribute. Wider gives smoother ride over obstacles but higher turning stresses. Closer can exacerbate lateral swaying	
	Not applicable	Usual equipment. Geometry aids movement over obstacles by reducing

		vertical rise of trailer frame. Designed with c. 35° bogie arm tilt[79] Reduces shock loading on tractor hitch
		Often movable fore-aft slightly to adjust nose-weight but brakes / hydraulics limit. May rarely be moved in practice
Bogie drive	Increases traction and machine load / terrain capability	
	Tractor hydraulic feed required Engaged / disengaged from cab	External - driven steel 'basket' or 'cage' wheel engaging between bogie wheels each side. Assists tractor but 4WD may slip. Raise for faster 0WD travel. Use matched tyre tread to limit wear (e.g. not 'cleat' tread)
		Internal - hydraulic motors on front two or all four bogie wheels
Tyres	Wider have more flotation and less traction Driven wheels have a cleated tread design (e.g. 'V') for off-road traction, which wear faster on-road Flexible sidewall of radials more liable to damage than cross plies Higher ply ratings preferred - 10 to 14 for most forestry conditions	
	Ensure correct pressure for task - harder is faster on road, softer better of road flotation	
Wheel chains	Use only where necessary for improved traction on driven wheels (especially rear bogie wheels) or trailer braking (especially on front non-drive bogie wheels). Aggressive 'ring' type have greatest affect. Can damage ground / roads, increase tyre wear.	
Band tracks		May enable flotation or traction in extreme conditions but increased tyre wear, weight and road damage so limited use. May not fit some bogies
Ground clearance	Ensure sufficient to avoid being 'hung up' on stumps, if excessive will unduly raise centre of gravity	



[79] Jones, D.H. (1996). Timber trailers for agricultural tractors. Forestry Commission Forest Research, Technical Development TN28/98

Appendix 5

Tractor operator protection

A Roll Over Protective Structure (ROPS) is a bar or frame - that may be incorporated into a cab structure - providing a safe zone to prevent the operator from being crushed[80]. Legislation[81] requires ROPS that, where there is a risk to a person riding on [a tractor] from its rolling over, a structure is provided which ensures that it 'does no more than fall on its side', and 'gives sufficient clearance to anyone being carried if it overturns further than that'. It also requires that if there is a 'risk of anyone being carried … being crushed … it has a suitable restraining system for him' i.e. a seat belt must be fitted.

A ROPS structure is effectively an absolute requirement for tractors and even those without cabs must have provision such as a roll bar. ROPS bars may be designed to be folded down for transport but must always be in place when there is a risk to the operator, which in practice means *for operations*.

There are two British and International *standards* that are specific to 'standard' agricultural and forestry tractor ROPS, that concern dynamic and static loading[82]. These are distinct from the standards for 'narrow track wheeled tractors[83], and forestry machines such as forwarders and harvesters[84].

A Falling Object Protective Structure (FOPS) is a safeguard against objects such as dead branches or trees, or in agriculture bales, falling onto the operator. Cab structures usually incorporate FOPS.

The British and International *standard* that is specific to agricultural and forestry tractor FOPS[85] covers "*requirements for a falling-object protective structure, in the event such a structure is installed on an agricultural or forestry tractor …. applicable to agricultural and forestry tractors having at least two axles for pneumatic tyred wheels or having tracks instead of wheels."* [86] This is distinct from the standard for forestry machines such as forwarders and harvesters.

[80] Ireland, D. (2006). Compact Tractors in Forestry. Forest Research, Technical Development, Internal Project Information Note 14/05
[81] Provision and Use of Work Equipment Regulations 1998 (PUWER)
[82] ISO 3463:2006 Tractors for agriculture and forestry - Roll-over protective structures (ROPS) - Dynamic test method and acceptance conditions
ISO 5700:2013 Tractors for agriculture and forestry - Roll-over protective structures - Static test method and acceptance conditions
[83] ISO 12003-1:2008, Agricultural and forestry tractors — Roll-over protective structures on narrow-track wheeled tractors — Part 1: Front-mounted ROPS; Part 2: Rear-mounted ROPS
[84] ISO 8082 Self-propelled machinery for forestry - Laboratory tests and performance requirements for roll-over protective structures
[85] ISO 27850:2013 Tractors for agriculture and forestry — Falling object protective structures — Test procedures and performance requirements
[86] ISO 8083:2006 Machinery for forestry - Falling-object structures (FOPS)

Operator Protective Structures (OPS) are additional protection to the zone around the operating position (seat) from identified specific hazards. Protection may be provided by window bars / mesh, safety glazing (the most effective being polycarbonate), steel panels etc.

There is no British and International *standard* that is specific to agricultural and forestry tractor OPS, but there *is* one covering forestry machines in general[87]. Although this applies to "forestry machines defined in ISO 6814", which includes skidders but not 'tractors', this OPS standard is useful for determining operator protection standards in forestry tractors where a need is identified.

The OPS standard for forestry machines does not cover "small, thrown objects such as chain teeth" (for which there is no current standard) and the standard states that it "will not provide complete operator protection under all conceivable circumstances, but [is] expected to minimize the possibility of operator injury in normal operational situations".

Operator protection when driving

The level of operator risk and protection when driving were described previously in the Report (**Table 5**).

The key issues for operating with and without cabs are expanded below:

⚠ Roll over protection (ROPs)

Standard tractor cabs provide a *Developed* degree of protection owing to their enclosed, 'cage' design, the space envelope around the driver and the design and fabrication of the interior fittings.

Small tractor cabs are likely to provide a *Moderate* degree of protection because they will have a more restricted 'space envelope' around the operator. In the event of a roll over, the operator's body / head is more likely to strike objects within the cab or the framework, despite wearing a lap belt. If cabs for small tractors have unglazed / 'open' parts and a lesser degree of 'padding' within the space, there may be an increased risk of limb strike or crushing, especially if a limb or even head is thrown outside the cab frame. The *actual* degree of protection provided by a small cab will depend very much on the cab itself and the circumstances of the roll over.

However, there could still be a *significant risk* of injury if the machine *continues* to roll or 'cartwheels', given that the operator is confined inside.

'Open cabs' - are required by regulation to have a basic level of protection. This will comprise bar frame, at the very least, or a cage that will stop a machine that

[87] ISO 8084:2003 Machinery for forestry - Operator protective structures (OPS)

falls on its side from laying flat upside down on the ground surface, so as not to crush the operator in the seat.

However, depending on the circumstances of the roll over, there could still be a *significant risk* of the operator's body or limbs striking objects or the operator being crushed under the machine. The risk would clearly be even greater in a 'cartwheel' situation. For this reason operators may prefer to step off the machine on the upper side and this may be a natural (and safer) option. For this reason:

⚠ Falling object protection (FOPs)

Standard tractor cabs with forestry FOPs provide a *Developed* degree of protection owing to the roof and cab framework, although unmodified agricultural tractors may not meet an accepted FOPs standard.

Small tractor cabs are likely to provide a *Moderate or Restricted* degree of protection because they will have a more limited 'space envelope' around the operator. They have a less robust construction, although this is inevitably a generalisation.

'Open cabs' - cab-less tractors provide no additional protection for the operator over and above the safety helmet that must be worn in risk situations. Protection from falling objects whilst driving in the forest therefore relies on the 'Method' of use, which is effectively the result of an assessment of risk and consequent mitigating measures. For example:

⚠ Operator protection (OPs) - chain-shot

There is a risk of saw chain links breaking during harvester felling and cross cutting, as described in the box below.

> If, as appears usual, only one link-set breaks, then the whole chain may simply drop off. However, it is also possible for a link or fragment of chain to be thrown off the bar at high speed, analogous to firing a 'bullet'. Chain-shot *appears* to be relatively rare but the hazard (consequence) of an operator being hit by chain-shot could be severe. Chain-shot can commence at a very high velocity and could travel a considerable distance, so a harvester saw should never be operated towards any person within 200 m[88].
>
> Chain-shot *could* pass straight through glazing or thinner steel plate, so a special type of 'polycarbonate' safety glazing is used as protection in some forestry machines. Harvesters will have this fitted to the windows most exposed to the felling head, in particular the front window.

[88] FISA Safety Guide 603 (2013). Mechanical harvesting. Forest Industry Safety Accord

Polycarbonate glazing should be mounted so that it cannot be 'pushed in' and so will also provide additional protection over and above normal safety glazing against intruding objects such as timber poles being processed or loaded, steel winch cables and tackle. Therefore, polycarbonate glazing is also fitted to some or all windows (such as the rear window facing the loader and bunk) of purpose built forwarders and some skidders (although the latter will usually be equipped with steel mesh or bars). Clearly, the degree of protection provided is governed by the position of windows fitted with polycarbonate. However, the thickness of polycarbonate glazing is also critical, depending on the velocity of the 'shot'.

When machines are working within each-others' risk zones, such as in roadside processing / cable crane systems, or when a forwarder is loading within a harvester's 200 m chain-shot exclusion zone, it is *possible* that the harvester bar will be pointed towards the *other* operator from any direction.

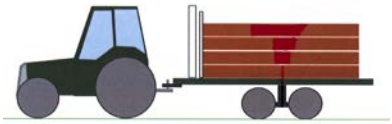
Standard tractor cabs - the degree of chain-shot protection provided depends on whether the cab is fitted with polycarbonate glazing, of what thickness and on which windows. Therefore the whole range of protection from 'Developed' to 'none' is possible. Forestry-ready or modified tractors may have polycarbonate glazing fitted to the front and rear (loader facing) windows for example, which will protect against intruding objects such as poles or branches (as would mesh screens or bars), but they may have only 'safety glazing' on side windows.

Small tractor cabs - although theoretically the full range of chain-shot protection *could* be provided, the tractor's equipment specification may not be as advanced as a larger, forestry-specification tractor. Clearly, cabs with open-unglazed window spaces will be effectively unprotected against chain-shot except by the work method, although screens or bars will give some protection against intruding objects.

'Open cabs' - chain-shot protection in respect of cab-less tractors relies on a safe method of operating, such as proximity to the harvester and its operator's direction of cutting.

⚠ Operator protection (OPs) - flying objects strike

Flying objects other than chain-shot could comprise (for example) ropes, pulleys, shackles and chokers when in the vicinity of a winch system, or debris from a nearby flail mulcher. The degree of operator protection against such flying objects is similar in principle to that against chain-shot, except that polycarbonate glazing may be replaced by one or a combination of: safety glazing, mesh screens or bars.



Appendix 6

General characteristics of small scale tractors

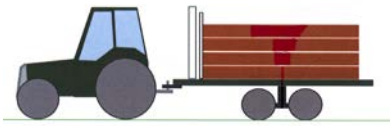
General characteristics of small scale tractors that may be suitable for small scale forestry operations, excluding 'domestic' or 'garden' type equipment is summarised in **Table A1**.

Table A1. Small scale tractor characteristics

Feature	Characteristic[89]
Power (hp)	Approx. 20 - 50 hp+
Matching power to task	Excess power may hinder handling precision (e.g. ATCs) 'Rule of thumb' is 25% greater than required for most common task Consider power to weight ratio [heavier weight to match greater power for traction and stability]
Engine	Usually 3 or 4 cylinder diesel
Weight	c. 900 - 1250 kg Tends not to vary with physical size Approx. 60% to front unladen aids balance with implement or trailer at rear
	Consider weight needed for traction and stability. Additional weight may be advised for lighter tractors in some conditions, and to balance attachments (which can be critical for stability and traction) Poor weight distribution can cause fore-aft and lateral instability. ⚠ Front weights may be needed to counterbalance rear attachment loading Consider load to weight ratio - a given load will have a greater effect on a lighter tractor than on a heavier one, and grapple loads will have a greater effect on stability
Towing capacity	Typically > 1 tonne
Hitch	Usually fixed bracket with pin for trailer ring (security on rough terrain) or ball hitch (road going type, smooth movement)
ROPS frames	No cab: Single bar type, often foldable Cab: Frame may incorporated ROPs
Cabs / 'half cabs'	If available may restricted operator movement and visibility owing to small physical size
Lap belts	With ROPS
Operator platform	Ideally unobstructed e.g. flat deck for ease of entry / exit
Controls position	Reversible seat + controls often available for rear facing operation
Drive	4 wheel drive usually preferable for traction and terrain ability

[89] Includes information from Mr Stephen Cabrol, RIKO UK Ltd

Differential lock	Available e.g. side-side lock, independently front & rear	
Tyres tread width - narrow vs wide	Narrower - improved traction but reduced flotation on soft ground	
Wheel weighting	Tyre water ballast: leave 25% air for flexing / cushioning	
	Wheel weights: 'Dough-nut'- bolted to rim studs (better)	
Articulation	Lateral: Independent lateral front and rear section movement by c 15^{o} allows axles top tilt to aid traction and movement over obstacles Directional / Frame steered (front and rear sections move left - right around a centre pivot): Unusual and not recommended for towing timber trailers	
Width	Wider wheelbase is more stable but less manoeuvrable	
Ground clearance	Consider optimum ~ 30 cm usually desirable in the wood but higher reduces stability	
Guarding	May require additional guarding for forest use	
PTO	Type: Usually Standard 540 rpm 6-spline or 1000 rpm 20 or 21 spline ($1^{3}/_{4}$" and $1^{3}/_{8}$" shafts)	
	Speed: 'Ground speed' or constant ratio to wheel rotation / gearbox for speed related tasks [or variable]	
3 - point linkages	Usually in basic specification, Category 1 (Toplink pins ¾" and Lift Arm pins $^{7}/_{8}$" diameter)[90], suited to 'standard' implements (if otherwise suited)	
Implements	Wide range of 'standard' types available, scaled down	
	Ensure tractor frame / component strength is suitable (check with manufacturers) Consider weight distribution on traction and stability	
Road going equipment	Offside mirror Speedometer and horn (if > 20 mph) Windscreen wipers (if need to view through) 2 red rear & white front lamps, brake lights & indicators	
Regulations	CE Marking, PUWER [91] (use for design purpose only), ROPs, FOPS & Ops[92] (depending on risk assessed), LOLER[93]	



[90] Tractors over ~55 hp may have 3 point linkages of Category 2 with top link 1" and lift arm 1 $^{1}/_{8}$" diameter pins
[91] Provision and use of work equipment regulations, 1998 and amendments or greater (Cat 3). The lowest category is Cat. '0' with all 5/8" pins for tractors <~ 20hp
[92] Roll over (ROPs), Falling object (FOPs) & Operator (OPs) protective structures
[93] Lifting operations and lifting equipment regulations 1998 and amendments

Appendix 7

An operating checklist for small to medium scale tractor-timber trailers[94]

Safe operation

Key factors:

- ✓ Training and proof of competence relevant to the type of work equipment
- ✓ Using a trailer suited to crop / produce and terrain / ground conditions
- ✓ Using a tractor suited to the terrain / ground conditions
- ✓ Matching the tractor and trailer according to their capabilities and limitations
- ✓ Identifying and assessing the risks involved in using the machinery in the crop and terrain / ground conditions and
- ✓ **Use a method of working that avoids or mitigates the risks**.

Poor method will be **inefficient** or even **unsafe** irrespective of good training and equipment choice.

Matching tractor-trailers to site

A basic summary of the main factors to consider when choosing tractor-trailer combinations for a site or range of sites is given in **Table A** (Table 6 in the full report). The summary is given as trends, and the exact position of boundaries will vary. The key site factors here are:

- Slope
- Tree / Produce Size
- Extraction distance
- Ground roughness
- Ground condition
- Manoeuvring *within* sites
- Moving *between* sites
- Access *to* sites
- Ergonomics
- Method
- Economics.

Tractor-trailer combinations are unsuited to the more extreme site conditions, where purpose built and larger forwarders, skidders, winches and other options may be more suited as discussed in Technical Development Report 150 and its associated six site type guides from firm level to steep and s

[94] This checklist includes guidance from forest industry sources as noted in the main Report text, including FISA Guides

A.7: A small to medium scale tractor-timber trailer operating checklist

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Table A. Matching tractor-trailers to site - influence of main factors

Factor	Machine class			
	Small-Medium (6 - 9 tonnes)	Small (3 - 6 tonnes)		Mini (< 2½ tonnes)
Slope				
Gentler slopes	✓ Not restricted			
Steeper slopes	Powered bogie trailers		⚠ Unpowered trailers	
Tree / produce size				
Smaller tree / produce size	✓ Not restricted, *but production is lower and costs higher with smaller material*			
Larger tree / produce size	✓ Larger & stronger bunks & loaders	<Transition>	⚠ Smaller bunks & loaders	⚠ Too small
Extraction distance				
Shorter extraction distances	✓ Not restricted, *but output will be lower with smaller bunks as travel element is proportionately greater*			
Longer extraction distances	✓ Highest output	<Transition>	⚠ Output decreases & costs rise	⚠ High cost
Ground roughness				
Smoother ground	✓ Not restricted			
Rougher ground	✓ Best clearance	Some travel / ergonomic impediment	⚠ Travel / ergonomics impediment	⚠ Too restricted
Ground condition				
Firmer ground	✓ Not restricted			
Softer Ground	⚠ Too soft	⚠ Ground damage	Limited ground damage	✓ Low impact
Manoeuvring <u>within</u> sites				
More open stocking	✓ Not restricted			
Closer stocking	⚠ Too restricted	⚠ Crop damage	<Transition>	✓ Not restricted, *but outputs lower* ⚠ Too restricted

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	Small-Medium (6 - 9 tonnes)	Small (3 - 6 tonnes)	Mini (< 2½ tonnes)
Moving <u>between</u> sites			
Infrequent moves	✓ Not restricted		
Frequent moves	⚠ Costs rise	<Transition>	✓ Lower costs, *can ow with 4WD plus trailer*
Access to sites			
Easy access	✓ Not restricted		
Restricted access	⚠ Too restricted	⚠ Difficult <Transition>	✓ More suited, *may be the only option*
Ergonomics			
Higher ergonomic levels	✓ Less fatigue & impact <u>from</u> site	<Transition>	⚠ More fatigue & method limitations, *rudimentary or no cab*
Lower ergonomic levels	Some fatigue & impact <u>from</u> site	⚠ More fatigue & method limitations, *rudimentary or no cab*	⚠ Too restricted
Method			
Site more suited to machine	✓ Largely unrestricted for best method		May be some restrictions *e.g. after Risk Assessment*
Site less suited to machine	Some restrictions e.g. after Risk Assessment		⚠ Greater restrictions *e.g. after Risk Assessment* ⚠ Too restricted
Economics - *cost: tonne ratio (combines factors)*			
Greater tonnage	✓ Lower cost	<Transition>	⚠ Rising costs ⚠ High cost
Lesser tonnage	⚠ High cost	<Transition>	✓ More suited, *may be environmental aims*

Trailer characteristics

The weight of a tractor or trailer has a profound effect on its **towing and stability characteristics**, because *weight* results in *force.*

The **position** of the *load* and *movable structures* on the trailer will affect the *forces* exerted onto the wheels and hitch.

Take care to **operate well within the stable position** of the centre of gravity of the combined machine and load, especially on steeper ground and *side slopes*, and drive especially *slowly* and in a wider arc in marginal conditions to reduce sway and centrifugal effects.

The nose weight of the trailer can be significantly **increased** if the centre of gravity of the **load is too far** in front of the wheels, and *vice versa.*

Remember that nose weight and 'nose lift' **can cause problems** with the steering, traction and stability of the tractor-trailer unit, and will be **worse in dynamic situations** where *momentum* and *centrifugal force* increases the forces involved.

Loader characteristics

Most requirements for the safe use of timber loaders are covered by general **good practice** backed by well-known legislative requirements.

In particular:

- ✓ Operations should be properly planned by a competent person, which includes
- ✓ Using machinery and a method of working suited to the job and conditions
- ✓ Operators should have the appropriate training, instructions and supervision
- ✓ Loaders (and any attachments) must be strong enough i.e. used within their Safe Working Loads)
- ✓ Safe Working Loads at boom reach distances are clearly marked (which would also apply to any shackles or slings etc., albeit a timber grab will normally be used for lifting instead)
- ✓ **'Work is organised so that**, where practicable, loads are **not carried** or suspended over **people'**, and any risk of loads 'drifting' / falling / slipping (from the grab) is covered
- ✓ The loader is stable in use - use outrigger legs if required, and use correct method e.g. avoid heavy loading on side slopes
- ✓ Loaders are inspected for wear and damage that could affect safety weekly or every 50 hours if less - this can be done by a competent operator during normal weekly maintenance

AND ADDITIONALLY:

✓ Loaders that are operated from outside a cab structure (and within the reach 'danger zone') are included in a '**Thorough Examination**' scheme.

Timber trailer loaders operated within reach from outside a cab - having suitable ROPS, FOPS and OPs - must have a written '**Thorough Examination**' report by a 'competent person', dated within 12 months and should be included in daily operator checks.

Loaders should also be inspected regularly in between the thorough examinations[95], including frequency, scope and visual and / or functional checks. This can be included in the **operator's daily and weekly checks**.

The position of the loader controls is very important for ergonomics and the **assessment of risk**.

The arc that can swept by the loader, and loader with a load in the grapple, creates a **risk zone**, within which the operator's position and potential for being struck **must be assessed**.

Operator protection in loader control position

The position from which the machine **operator controls the loader** is of fundamental importance for the management of health and safety, for which risks **must be assessed**.

There is **no** simple universal rule that cabs are *always sufficient* or *always necessary* and, by implication, **that cab-less situations are *always unacceptable***.

The work position is a prime consideration in choosing the **work method** for an operation.

Operation from tractor seat

Protection from **falling objects** whilst driving 'cab-less' tractors in the forest therefore relies on the '**method**' of use, which should be the result of an assessment of risk and consequent mitigating measures.

For example:

✓ Maintain overhead vigilance and wear helmet
✓ Drive with due care for the circumstances, especially:
✓ Avoid driving under suspect trees
✓ Avoid brushing against trees / large branches *(good silvicultural practice anyway)*

[95] … according to a regime specified by the manufacturer or other competent person. From INDG422

✓ Avoid driving in the risk zone from operating loaders.

Although larger cabs are more secure, a cab may not provide complete protection from a strike to the machine or operator by the loader, billets or logs so **careful attention to the work method is <u>always</u> necessary**.

For example:

- ✓ Limiting billet / log length
- ✓ Confining the loader to an arc to the rear of the operator (at the tractor seat)
- ✓ Not swivelling a loaded grab adjacent to the operator (at the tractor seat)
- ✓ Placing the load against the headboard without 'butting up'.

Operation from standing position

'Remote' loader operation could give a **high degree of operator protection**, although not necessarily always complete or practicable.

Operation from a stand on the trailer behind the headboard (e.g. with a 'pedestal' control block) has both potential advantages and disadvantages.

- ✓ Good visibility and close to 'line of sight' operation
- ✓ Developed to moderate operator sound awareness
- ✓ Out of loader boom swept arc (*restricted-arc loaders only*)
- ✓ Not directly 'under' grapple load <u>from side / rear</u> (*especially shorter products*)
- ✓ Away from grapple load <u>from side / rear</u> (*shorter products, except headboard 'butting up'*)
- ✓ Avoids climbing in & out of cab (*<u>of value in very limited situations</u>*).

- ✗ Little or no protection from headboard, especially when 'butting up'
- ✗ Within loader boom swept arc (*except restricted-arc loaders*)
- ✗ May be 'under' grapple load <u>from front-side</u>
- ✗ Proximity to grapple load (*<u>from front-side</u> & longer products and 'front bay'*)
- ✗ Climbing on-off risk of slips / trips
- ✗ Restricted vision to front of tractor (*issue only if able / need to reach over cab*)
- ✗ Residual risk of fall from platform when operating.

Methods used in 'Kingpost' loader operation should avoid bringing any part of the loader or load over or close to the operator e.g. by **careful placing of the load** on the bunk and **not loading from the front-side** quadrant.

Loaders should **not be operated** from controls 'dropped over' the headboard itself, which puts the operator in very close proximity to timber being 'butted up'.

Operating the loader at or near the rear of the tractor involves the operator standing to one or other side of the drawbar, which has several **advantages and disadvantages**

- ✓ Out of loader boom swept arc (*restricted-arc loaders only*)
- ✓ Protection from headboard when placing load / 'butting up'

- ✓ Not directly 'under' grapple load from side / rear (*especially shorter products*)
- ✓ Away from grapple load from side / rear
- ✓ Some protection by tractor from grapple load from front-side
- ✓ Avoids climbing in & out of cab (of value in very limited situations).

- ✗ Restricted vison to rear and far side of the trailer
- ✗ Restricted to basic operator sound awareness (owing to noise levels)
- ✗ Within loader boom swept arc (except restricted-arc loaders)
- ✗ May be 'under' grapple load from front-side
- ✗ Proximity to grapple load (from front-side, *longer products and 'front bay'*)
- ✗ No vision to front of tractor (issue only if able / need to reach over cab)
- ✗ *Residual risk of fall from platform when operating.*

Methods used in loader operation from the ground at the tractor rear should avoid bringing any part of the loader or load over or close to the operator e.g. by **not loading from the front-side** quadrant.

Loader operator position summary

- The loader operator control position is a key factor to consider for **working method** in any given circumstances and in **risk assessment**
- For operation with large or small cabs or without cabs, each case must be **considered on its merits** (or otherwise) in its given circumstances
- Even larger cabs may not give complete protection, so **method is crucial**
- Remotely operating the loader from outside it's sweep, if practicable, can be **'low' risk**
- Methods used in 'Kingpost' and 'tractor rear' loader operation should avoid bringing any part of the loader or load over or close to the operator e.g. by **avoiding the front-side quadrant**.

Tractor characteristics

Driving and operating forestry equipment can be very **different** to farm machinery.

Tractor requirements and use

Key points include:

- **Stop** if any person comes within the risk zone, unless the person is included in an approved safe working system
- If a machine starts to slide when travelling downhill, steer straight downhill and gradually increase the engine speed to regain traction. **Do not** *depress the clutch!*
- Descend straight down a slope if possible, rather than diagonally across it
- **Avoid turning** a *frame steered* / **articulated** forwarder **uphill** on side slopes - this increases rollover risk very much! *It is, however, safer for a tractor pulling a trailer*

⚠ **Avoid turning** a *rigid frame* **tractor** **downhill** on side slopes - this is especially hazardous

⚠ **Be aware** of the risk of rearwards overturn, including driving up steep slopes, when drive wheels are stuck fast in mud or a heavy load cannot move. **Ensure** sufficient front counterbalance for rear-mounted weights and always hitch trailers to the correct point. *Rear overturn can be fatal and happen very fast!*[96] [97]

⚠ **Avoid** steep side slopes, soft ground, driving over felled trees & other major obstacles

⚠ If side slopes are unavoidable, reduce the load height (*for skilled operators, it may also be possible to extend the trailer boom on the upper side to maintain stability*)

⚠ **Do not** attempt to jump clear from an enclosed safety cab if a machine overturns - *sit tight!*

⚠ Use the parking brake when **stopped** / loading and during operations, where appropriate

⚠ **Do not** suspend grab tanks when refuelling

⚠ **Do not** work under suspended or 'propped' parts and do not rely on the machine's hydraulic system

⚠ **Do not** use your hand to check for hydraulic leaks (use paper / cardboard) - high pressure fluid can enter the blood stream!

⚠ **Do not** operate a double acting ram that has a broken pipe.

Modifications to tractors must be carried out by competent personnel and any structural changes should be **approved by the manufacturer**.

The tractor selected should be matched to the **conditions** of its use, which are summarised in Table 4.

It is crucially important that the tractor characteristics and capabilities are **matched** to those of the trailer and *vice versa*.

Tractor operator protection

Tractor cabs can provide the operator with a degree of engineering **protection** against rolling over and falling and penetrating objects.

Tractors without cabs may be used where **Risk Assessment** shows that a particular risk is absent (e.g. site conditions), or is otherwise controlled (e.g. by work method).

PPE is a *backup*, **not a substitute** for other more fundamental controls.

Operator protection when driving

[96] Using tractors safely. HSE INDG 185. (2013).

[97] Murphy, D. (2016). https://extension.psu.edu/tractor-stability-and-instability Pennsylvania State University

A.7: A small to medium scale tractor-timber trailer operating checklist

There is no single simple rule that ensures a safe system of work because **each element** must be assessed in the context of the whole circumstances through an effective **Risk Assessment**.

The degree of operator **protection** in a larger tractor cab may be greater than that in a small tractor, which in turn may be greater than that in an 'open-cab' cab-less situation.

Cab characteristics have a **strong influence** on the degree of roll over protection, which nevertheless can be very variable.

Even when fitted, polycarbonate glazing **may not** provide **complete protection** from chain-shot in every circumstance.

Rudimentary or small cabs may be **comparable to** 'open cab' / cab-less tractors with roll bars, which may even be preferable in some circumstances.

A cab may not provide complete protection in all circumstances so careful attention to the **work method** is always **important**.

Cab-less 'open cab' driving should be subject to the same standards of operator **risk assessment** as other forestry activities such as **felling**.

- ✓ Maintain overhead vigilance and wear helmet
- ✓ Drive with due care for the circumstances, especially:
- ✓ Avoid driving under suspect trees
- ✓ Avoid brushing against trees / large branches (good silvicultural practice anyway)
- ✓ Avoid driving in the risk zone from operating loaders.

The work method and any operator cab protection can **both contribute** to a safe system and one or the other by itself may, or may not, be sufficient.

The work method, such as machinery used and operator position, must **effectively mitigate risks** within the working system, which is *always* important and is the primary safeguard in the 'open cab' cab-less situation.

Small scale tractors

The term 'Small scale' is used in this report to describe machinery **under 3 tonnes weight** or load capacity (at and below the FC 'Small' category), *which includes 'Mini' and 'Compact' or 'Alpine' tractors.*

Particular issues that may be accentuated include:

- ⚠ General handling and correct loading

- ⚠ Operator ergonomics and position when using attachments such as kneeling on seat to use loader controls
- ⚠ Towing capacity in terms of manufacturers' specification, tractive effort, traction, braking, hitch rating and nose weight
- ⚠ Stability and handling when comparatively heavy attachments are used
- ⚠ Stability, owing to narrow width
- ⚠ Stability, owing to overall lighter weight e.g. a lesser force (acting above the centre of gravity) can topple
- ⚠ Roll over protection, owing to smaller or no cab[98]
- ⚠ Frame steering issues such as reduced stability on side slopes (*and, as with articulated / frame steered larger machines, avoid turning uphill on side slopes*).

Weight

- ⚠ Front weights may be needed to **counterbalance** rear attachment or hitch loading.
- ⚠ Ensure sufficient tractor power, but if excessive can be difficult to **control safely** and can induce wheel slip that increases wear and fuel use.
- ⚠ Observe manufacturer's limits for both tractor and trailer (see VIN Plate). CE 'Certificate of Conformity' states load **towing capacity** of tractor required (for braked / un-braked trailers).

Steering

- ⚠ Front wheel steering - ensure correct **weight** on **tractor wheels**. Use front weights or wheel ballast if necessary, and ensure correct drawbar **nose weight** on hitch (*refer to manufacturer's specifications*).
- ⚠ Frame steering is not recommended for **towing**.
- ⚠ Steering drawbars using tractor hydraulics are fitted to some (larger) trailers to aid **manoeuvring** within the crop, reduce tyre 'scrubbing' and the tendency for a powered trailer to 'push' the tractor on turns.
- ⚠ For trailers with a steering drawbar, ensure correct **load distribution**, so that the *nose weight* is not excessive because induced actuation of the drawbar could tip the trailer e.g. when driving downhill.

Hitches

- ⚠ Light vehicle hitches: usually a rigid ball-hitch on chassis / shell, couples to a swivelling socket with retractable locking tongue on the trailer drawbar - allows multi-directional

[98] The Provision and Use of Work Equipment Regulations 1998 states that for some small or very old tractors a roll bar will be the only practicable ROPS structure available

movement. Used with security braking cable on braked road trailers (required over 750 kg gross weight). **Not usually used off road**, except for smallest trailers.

Smaller tractor hitch: usually a rigid clevis hitch on chassis, the *clevis* (bracket) couples to a trailer *eye* (ring) through which the *clevis pin* passes and is locked in place by a *linch pin*, *'R' clip* or similar. **Commonly used off road**.

Ensure that the trailer has a swivelling drawbar, allowing for **lateral movement** at the tractor / trailer coupling, and in case of overturning on steep / uneven terrain.

Ensure that the ring and clevis / pin are **matched**, with sufficient but not excessive free play.

Nose weight is less critical for tractor traction with driven trailers.

Towing trailers

Adhere to CE 'Certificate of Conformity' stated safe braked / un-braked towing capacity.

Ensure the trailer nose weight (on tractor hitch) is within tractor **specification** because it affects steering and stability, especially if excessive.

Load position / centre of gravity and bogie position significantly affects **nose weight**.

Ensure tractor-trailer+load combination puts correct **nose weight** on tractor hitch for traction, especially up-slope.

Slight adjustment of wheel / bogie position fore-aft can have a very big **effect**.

Larger Wheel diameter - faster speed per revolution, greater **ground clearance** but higher centre of gravity.

Smaller Wheel diameter - increased **torque** (if driven).

Bogie wheel spacing is important. **Wider** gives smoother ride over obstacles but higher turning stresses. **Closer** can exacerbate lateral swaying.

Bogie drive increases traction and machine load / terrain **capability**.

Wider tyres have more **flotation** but less traction.

Driven wheels have a cleated tread design (e.g. 'V') for off-road traction, which **wear faster** on-road.

Flexible sidewall of radials more liable to **damage** than cross plies.

Higher ply ratings preferred - **10 to 14** for most forestry conditions.

Load distribution fore-aft can have a very big **effect**.

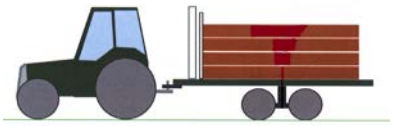
Ensure correct tyre pressure for task - harder is faster on road, softer better off road flotation.

Only use wheel-chains where necessary for improved **traction** on driven wheels (especially rear bogie wheels) or for trailer **braking** (especially on front non-drive bogie

wheels). Aggressive 'ring' type chains have greatest affect but can damage ground / roads and increase tyre wear.

Ensure ground clearance is **sufficient** to avoid being 'hung up' on stumps, but if excessive will unduly raise centre of gravity.

Poor method will be **inefficient** or even **unsafe** irrespective of good training and equipment choice.



Forest Research

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