Group Enterprise Project

Optimal equipment for efficient delivery of feed to outdoor sows with minimal soil damage

Harper Adams University students' final report

Contents

Summary

Research into the environmental impact of outdoor pig herds highlighted five key areas which are a cause for concern; these include soil erosion and compaction nutrient leaching, nitrogen loading and the lack of legislation surrounding environmental protection.

The main issues of outdoor pig production include soil compaction and soil erosion, both of which can cause negative environmental impacts if not managed correctly. Due to outdoor pigs being temporary (usually three years) measures to reduce compaction and erosion must also be temporary and/or transferable to the next pig site. Outdoor pigs is part of a arable cropping rotation, so farming techniques during the arable cycle must enhance the soil structure to limit the impact of pigs. This report seeks to reduce this impact, as cross compliance regulations are likely to become more rigorous in the future, with more focus on sustainable agriculture, outdoor pig production must move forward.

One of the biggest issues regarding nutrient leaching, despite the immediate loss of valuable nutrients from the soil, is the consequential effect of its pollution into nearby watercourses mainly that of eutrophication and its effect on the aquatic life. The total annual volume of leaching can be influenced by soil type and structure, organic matter content, field topography, annual rainfall and the original nutrient content of the soil (Environment Agency, 2008).

Nitrogen loading was found to be an issue as a result of current feeding practises, reducing the total available space for the sows to defecate. It has been well documented that pigs do not eat where they defecate and as the current method of feeding revolves around broadcasting their food in a large band across the paddock, there is limited space for the sows to expresses their natural behaviour. This can result in areas of intense nitrogen loading where high levels of excreta are occurring in the paddocks, these are often referred to as nitrogen hot spots.

At present the UK government's legislation which covers outdoor pig farming is directed more towards animal welfare and animal husbandry than environmental protection. However there are regulations regarding stocking densities which state that a maximum level of 25 sows per hectare must not be exceeded. While site management such as soil protection and Nitrate Vulnerable Zones (NVZs) is only covered by the blanket legalisation stated by single farm payment scheme and cross compliance.

It was found that soil ingestion can have a major effect on the pig's digestive performance resulting in decreasing daily live weight gains. Soil can make up to 2.3% of the pig's daily food intake Herlin and Andersson, 1996) resulting in reduced feed usage which in turn increases costs. Furthermore the broadcasting of feed across the pen reduces the area that the pigs have to defecate creating a nutrient imbalance within the pen which can create problems if the field is returned back to arable land. The use of troughs and soil monitoring can eliminate these problems.

Outdoor pigs are susceptible to diseases and some are unavoidable like parasitic infections from soil parasites, others can by reduced by reducing feed spillages, wastage and access to feed. Birds are number one concern to outdoor pigs as they can spread diseases from farm to farm and pig to pig. A

move to a trough-based system is proven to reduce bird predation and other pests access to pig food thereby reducing disease transfer.

The social impact of trough feeding is perceived as bullying in the herd groups; however the BQP Eco pig project has disproved this and so long as the right trough space is maintained then bullying shouldn't be an issue.

Future legislation of outdoor pig farming will be likely to be focused around the environmental impact of the outdoor farming system. Currently there are multiple problems that are causing adverse effects to the environment; the industry does have the answers but they come with a cost.

The majority of outdoor housed pigs are currently broadcast fed using a machine made by Peter Allen Trading, which is commonly known as a "nut chucker". Dry sows are kept in large groups then singled out at farrowing. Whilst farrowing, sows are fed individually either by hand or with a pipe attached to the Peter Allen feeder. There are many problems associated with these feeding systems as the Peter Allen machine causes rutting and compaction, the feed increment on this machine is also relatively large compared to how much is fed to each pig and individual feeding by hand is very time consuming.

Recently there has become an interest into feeding pigs in troughs to reduce feed costs. This can be achieved by feeding smaller pelleted feed (6mm) directly into troughs. However, this presents the problem that the current machinery needs to be adapted to place the feed into the troughs or a new machine will need to be designed.

Various alternative feeding systems are included within the report with costings and available product suppliers. Payback periods are uncovered to give detailed information to the end user and allow for more accurate projections to be made. These new products included troughs, MPS Agri Apollo and the introduction of pipe and flexi-auger alternatives, currently being used in indoor pig production.

Introduction

At present, 40% of the breeding sows in England are kept outdoors in temporary paddocks, typically in radial style systems for dry sows and farrowing sows penned individually with their young. Dry sows are traditionally fed by broadcasting concentrated feed rolls (16mm in diameter) into paddocks. This method of feeding results in problems such as soil ingestion, increased feed requirements and overall production costs. However, this feeding method does promote natural behaviour of pigs, which is a growing concern for the end consumer and animal welfare critics.

With margins becoming increasing tight, it is vital that pig meat producers must strive to be more efficient in their production systems. This report details alternative feeding systems and possible solutions to increase the efficiency of the feed delivery to outdoor sows whilst minimising soil damage.

With pig feed accounting for almost 80% of overall production costs, minimising wastage and optimising utilisation is essential. Moving from 16mm rolls to 6mm pellets will have significant effects on the profit margin with a reduction in overall feed price per tonne.

Typically, outdoor pigs are fed using the Peter Allen "Nut Chucker". This product has given farmers an easy system for feeding sows, however, there are major problems arising from the use of this machine such as, high ground pressure causing deep ruts and soil compaction, raising concerns for producers as it leads to pollution through eutrophication, nitrogen leaching and can lead to deductions in support payments. The increment accuracy is also limited to approximately 1.8kg. Therefore, alternative solutions must be uncovered. The report will investigate alternatives and adaptions to this machine to achieve greater accuracy whilst reducing compaction and rutting.

The Problem

Compaction

Compaction reduces the volume of space in the soil for water and air, making it less productive and harder to work with (EA, 2012). There are measures which farmers can take to reduce compaction, but with outdoor pig production this can be difficult. Compacted layers increase the chance of surface run off into water courses/ roads and can breach cross compliance regulations. Outdoor pig farmers must ensure that all has been done to limit compaction in the field before they use it for pig production. Measures such as avoiding cultivation of wet soils and reducing the number of passes in a field can help limit compaction (EA, 2012). Tractors with feeders are usually towed around tracks in pig fields and, due to outdoor pigs being a temporary operation within an arable rotation usually, nothing too permanent can be used to combat compaction problems. Pigs are fed at least once daily so many trips on the tracks can cause huge compaction and soil erosion issues.

Soil Erosion

Soil erosion, usually from wind and rain can be a big problem with outdoor pig production due to pigs poaching and ripping up the soil. The fields soon become damaged with little structure, increasing the potential for runoff. This is particular a problem with lighter, sandy soils and also fields with any sort of gradient. Soil erosion removes the fertile top soil via run off, but can also cause other problems such as blocking field drains and cause water contamination (SEPA, Not dated). Buffer strips around watercourses and planting trees/ hedges can help reduce runoff (EA, 2012). Increasing organic matter content can reduce the risk as well as moving livestock regularly to avoid poaching of the soil.

Nose ringing of pigs is a method used to reduce the pig's ability to rut the paddocks with their noses (DEFRA, 2003). Rooting with their noses increases the damage caused to vegetation and plants roots (grass is usually present for outdoor pig production), affecting the structure of the soil. Reducing this damage by the use of nose rings will help keep some crop cover on the field to hold the soil together. Careful management and monitoring of stocking levels are important to limiting this problem. A guideline of 25 sows per hectare is recommended for suitable sites (DEFRA, 2003). Stocking levels should be altered depending on weather conditions. Planning of pig paddock layout can minimise the impact of soil erosion (DEFRA, 2006). Impacts from pigs can be long lasting, and in most cases outdoor pig sites return to arable rotations. A shallow top soil can be the result from excessive soil erosion, which can affect combinable crop yields and quality, and also affect rooting of plants and yield of straw, needed to bed the pigs on (DEFRA, 2006). Poaching and soil erosion are very much interlinked. Poaching is caused from pigs 'cutting up' the soil by tramping on it cutting up the crop cover (SEPA, not dated).

Environmental impact of UK outdoor pig production

It is estimated that 40% of the UK breeding pig herd is currently kept on outdoor production systems (BPEX, 2014). This is in response to consumer demands with an increasing trend of buyers wanting higher welfare pig meat, with pigs produced the 'natural' way. Outdoor production also benefits the farm in terms of producing a higher welfare product, providing the farmer with a premium price. It also has to be appealing in terms of the lower establishment costs compared to those of indoor systems.

Outdoor pig production has its benefits in terms of animal welfare and customer satisfaction, however the high level of nutrients deposited on free draining land, and the removal of vegetation by sow foraging activity result in significant risk of adverse environmental impact through leaching, runoff and gaseous emissions.

Nutrient Leaching

Nutrient leaching is a major factor affecting the quality of watercourses in the UK. Nutrient leaching from outdoor pig herds is one of the most important environmental issues to control. It is classified as the loss of nutrients and contaminates such as Nitrogen through the soil profile to the watercourse. The total annual volume of leaching can be influenced by soil type and structure, organic matter content, field topography, annual rainfall and the original nutrient content of the soil (Environment Agency, 2008). Outdoor pigs are commonly situated on light sandy soils, these soils have a low clay content in the top soil (<18%). Due to the low clay and organic content these soils have low aggregate stability. Is it common for these soils to rapidly disperse (slake) in the winter months causing internal slumping and a capping of the soil surface. Where these soils are free draining and well-structured they have a low run off potential. However when the draining is impeded by a high water table or a slowly permeable subsoil the risk of structural damage, run off and nitrate leaching is increased. (Environment Agency, 2008).

When nutrients enter the watercourse they can cause environmental concerns such as eutrophication. The eutrophication potential can be defined as the amount of nutrients (nitrate and phosphate from manure/slurry) leached to the aquatic environment. Nitrates and phosphates are essential for life but the increased concentrations within the aquatic environment can cause excessive growth of algae, on and within the water course reducing the total volume of oxygen within the water and damaging ecosystems (Oxford Dictionary, 2015).

However not all nutrients are lost through the soil, some are volatilised into the atmosphere as ammonia. A study into the nitrogen losses from outdoor pig farming, conducted by Williams *et al* (2000) found that Ammonia (NH_3) volatilization measurements indicated that losses from outdoor dry sows were in the region of 11 gNH_3-N sow/ day. The research also found that urine patches were identified as the major source of nitrous oxide (N_2O) emissions, with N_2O-N losses estimated at less than1% of the total N excreted.

Research by Eriksen and Kristensen (2001) investigated the distribution of nutrients in sow paddocks and the consequence of the nutrient loading for the following crop. Their results found that there is a significant correlation between the soil organic nitrogen and the distance from the feed sites. These findings support the general understanding that pigs are a clean animal and very rarely eat where they defecate. Therefore it can be assumed that if their food is broadcast in 10 metre bands across the full width of the paddock, as is common practice in outdoor herds, then there is a severe reduction in the space allowance available for the pigs to defecate, thus creating an area with high nutrient status.

Outdoor Pig Legislation

The UK's Government's legislation of outdoor pig production systems shows concerns of both animal welfare and the environmental impact. In terms of environmental protection the Welfare of Farmed Animals (England) Regulations 2000 (S.I. 2000 No. 1870), state that: the sites used for outdoor pig farming enterprises must be carefully chosen, with land that is prone to flooding, poorly drained or stony (especially flinty) soils and sites with heavy soils (especially in areas with high rainfall), are generally classed as unsuitable for outdoor systems, and that sites with free draining soil, in areas of low annual rainfall, with low incidences of frost most suitable (DEFRA, 2003).

It is also stated that field stocking densities must reflect the suitability of the site and its management. A guideline of 25 sows per hectare overall is reasonable for suitable sites. Stocking densities may be reduced for less ideal sites or in extreme circumstances during periods of adverse weather (DEFRA, 2003).

Ingestion of Soil

Soil ingestion occurs inadvertently when the pigs feed off the ground during the colder, wetter months. The ingestion of soil can result in the consumption of heavy metals, radionuclides, chemicals and pesticides. Furthermore soil ingestion can result in altered mineral levels, source of bacterial and parasitic infection and can decrease digestive function. These adverse products are often found in the top layers of soil which the pigs are feeding on as the land is often used as arable ground when the pigs are moved off. The volume of chemical concentration in the meat depends on the rate at which the chemical adheres to the soil. Studies have shown that soil ingestion can make up to 2.3% of the pig's daily food intake (Herlin and Andersson, 1996).

Nitrogen Hotspots

Poorly run outdoor pig units can pose a risk to the environment through creating an imbalance of nutrients in the soil such as nitrogen hotspots (Australian Pork, 2012). The nutrients that are found in the soil are brought to the unit through the feed that the pigs consume. Nutrients quickly build up in certain areas or pens or paddocks as pigs do not defecate close to where they feed therefore they often have to defecate in the same place numerous times creating a high level of nitrogen in that particular area (Australian Pork, 2012). One way to combat nitrogen hotspots is through the use of troughs which narrow the feeding area to a fixed point instead of broadcasting the feed across the pen. This provides the pigs with a greater area to defecate, and the use of troughs can be coupled with soil monitoring to make sure that nutrient levels are kept low so that they do not pose an ecological risk (Australian Pork, 2012). Other methods to reduce Nitrogen hotspots (as put forward by DARCOF e news, 2005) are that the huts, feed and water troughs should be moved around the pen periodically to distribute the nitrogen across a wider area.

The Effect of Birds

Due to rising feed costs over the past years it is essential to reduce wastage. The Pig Journal (2004) estimates that 10% of delivered feed is wasted which can be as much as 27 tonnes of wasted feed on a 250 sow unit. Birds can have a massive effect on feed wastage through excretion in feed bins and the eating of feed (The Pig Journal, 2004). Therefore feed bins must be checked regularly and covered when not in use. The same applies to feeding in the pig pens. If food is broadcast across the pen the chance of wastage is increased as it will be picked up and eaten by birds. Furthermore the greater area that the feed is spread across allows birds a longer period of time to search for food in the pen. If the pigs were fed in a trough there would be less wastage as the food is not scattered across the pen and lost in the soil. If the trough is designed correctly there should not be any space for birds to feed at the same time as the pigs, further reducing wastage (The Pig Journal, 2004).

Disease risk

Pigs are generally very susceptible to diseases and if housed outdoors they can come into contact with many more parasites compared with indoor systems. This is because they are naturally existing in the soil (Klingen, k. et al. not dated). However there are also many benefits to the outdoor system compared to the indoor pig system (Klingen, k. et al. not dated). The air quality is much better for the pigs outdoors as they experience lower concentrations of ammonia, hydrogen sulphide and harmful dust from straw. This is mainly due to better natural ventilation outdoors and they are not housed in the same environment as their own faeces (Klingen, k. et al. not dated). Also pigs that are housed outdoors generally have better feet as they are housed in a more natural environment, especially when compared to when they are housed on slatted board systems indoors (Klingen, k. et al. not dated).

Rearing pigs outdoors is typically the system with the least disease pressure. This is because of careful management and selection of the site (Klingen, k. et al. not dated). There is plenty of advice available for pig farmers to help them to maintain a clean herd of outdoor sows. From all of the advice available and research conducted it seems clear that site selection is critical when limiting disease risk. It is best to house pigs on free draining soils as this limits environmental impact but also reduces the amount of birds that feed on the site, reducing external disease pressure (Harvest Creative, 2012). It's also paramount that outdoor pig farmers use a rigorous and positive health plan to combat parasite infections. This is done with wormers, which is also common practice with beef, sheep and other outdoor housed animals (Iowa State University, 2001). This measure is more about prevention than cure, but it is simple and effective and helps the farmer to ensure the best health of their stock. This is the main reason that outdoor pig rearing is deemed the best for pig health and welfare. Also there is less disease transmission within the herd as pigs aren't housed so tightly (Iowa State University, 2001). Typical stocking density outdoors is 25 sows/ha, so they have plenty of room (DEFRA, 2011). Outdoor pig rearing is best for pig health and also is what the consumer wants, unfortunately output is reduced, but less intensive, high welfare produce, demands a higher market price (Harvest Creative, 2012).

Social impact of trough feeding

Pigs can be fed in troughs and they need a certain amount of space in a trough to feed in (DEFRA[b], 2011). A typical breeding sow will need from 28-30cm trough space to eat freely without the risk of bullying or risk of having too much space (DEFRA[b], 2011). If a pig has too much space it has more space to push other pigs out of the trough, but if it has too little space the smallest one typically won't be able to fit in to eat. There are numerous pros, and cons to trough feeding outdoor pigs, but with many of the benefits being environmental it's likely that farmers will have to seriously consider changing systems. Many farmers are against trough feeding outdoor pigs and much prefer the broadcast system, but this leads to poor soil structure and N-hotspots (Harvey, 2013). However research conducted by BQP's Eco pig

WEIGHT OF PIG (KG)	TROUGH SPACE (CMS)
5	10
10	13
15	15
35	20
60	23
90	28
120	30

Table 1: Table showing the weight of pigs and the trough space they need (source: DEFRA[b], 2011)

project has shown the benefits and shown that bullying is not a problem (Harvey, 2013). However it was also noted in BQP's project that once the pigs became accustomed to the system they would crowd around the end of the trough as feed was being distributed which could be a concern to the welfare of the pig. It wouldn't be strictly bullying but if injuries start to occur they would have a dramatic effect on the successfulness of the trough system (Harvey, 2013). It is well-known that outdoor pigs experience less bullying in the form of tail biting, belly nosing and aggressive biting as they are less confined (Klingen, not dated). It is paramount that this higher welfare status is kept, which is why farmers are sceptical of moving towards troughs. Also it is going to cost them money to change their system when they don't think they will see any dramatic improvements in pig welfare or production. However there are economic savings to be made by changing to a trough system (Harvey, 2013). Moving to a trough system won't be an overnight fix and in some instances may not work at all but its benefits for most should outweigh the issues and with careful planning and design minimal problems should occur (Harvey, 2013).

Future legislation

Currently outdoor pig farming is governed predominantly by general legislation about animal welfare and environmental and soil legislation. The future for pig farming legislation is likely to be very focused on the environmental impact of outdoor pig rearing because it's the part of the system that lets it down (Klingen, not dated). However because of the proactive nature of farmers many of the solutions to problems like N-hotspots and runoff have been developed (Natural England, not dated). At the moment the Environment Agency take special interest in outdoor pig farms. It is important that farmers remain vigilant in reducing their environmental impact so that outdoor rearing can continue effectively.

<u>Current problems with the outdoor broadcast feeding system (BPEX, 2014);</u>

- Poor grass cover in pens
- Lots of loose topsoil, which easily runs off and contaminates water courses
- Soil ingestion
- N-hotspots and leaching
- Feed losses through predation and soil losses
- Severe damage to tracks increasing runoff problems
- Bird predation and disease risk

The future is likely to consist of shorter field rotations so that grass cover can be more easily maintained where pigs are housed, unless other crops or longer term grass is used so that longer periods on the same land can continue (Natural England, not dated). The benefits to using a trough system would likely help farmers to reduce their environmental impact as well as make economic savings and reduce their carbon foot print at the same time (Clark, 2014). The key to moving forward is maintaining pig welfare and if farmers have to invest in a different feeding system to ensure the future of outdoor reared high welfare pork then they will.

Feed usage between Indoor and Outdoor Production

Approximately 40% of U.K. sows pig outdoors (RSPCA, 2015), a number which has declined as the industry has seen a push for production and margins over purchased feed have become increasingly tight, adding undesired pressure to an already heavily scrutinised sector of agriculture.

The main driver for outdoor-bred pig production remains within its low fixed cost structure by not requiring the need for permanent housing, thus, it does not suffer from heavy depreciation costs. However, as stated previously, the precision of outdoor production is loose with increased feed requirements and costs due to wastage. With, feed accounting for between 70-80% of pork production costs (Edwards, 2002), wasting feed is not an option. The current outdoor feeding systems can be seen in the section below, however the issues which arise from feeding in this manner are beginning to outweigh the benefits. Table 1 below shows outdoor vs indoor pig production systems feed costings. It is evident that indoor pig meat production requires lower inputs of feeding and thus, can reduce the total cost of £28.35/sow/year. Therefore, in order for outdoor production to remain sustainable, feed conversion ratios must be reduced and new designs away from the nut chucker must be uncovered to increase the viability of this method of farming.

Table 2 shows Outdoor vs Indoor production systems feed costings

	Outdoor	Indoor
Cost of feed (£/t) required for each system	226.82	212.31
Sow Consumption (kg)	1601	1476
Difference/system (kg)	125	
Cost/Sow (£)	363.14	313.37
Cost/1000 Sow herd (£)	363,140	313,369.56

(Source: Adapted from BPEX, 2014)

Lebret (2008) investigated the carcass composition and fat class between indoor and outdoor-bred pigs. The study showed that pigs bred and reared in outdoor production required more feed and had lower DLWGs than indoor production. In line with this, Stewart (2015) found that outdoor reared sows required up to 0.3kg/day more feed than indoor sows. Therefore, reducing feed wastage is critical to increase business profitability.

This raises the question of is there a future for outdoor pig production?

Existing Feeding Systems

Nut chucker

The main way in which UK outdoor housed sows are fed is by broadcasting large 16mm pellets of feed called cobs, over the area where the pigs are being kept. This is done with a machine that is similar to a fertiliser spreader, but trailed and discharges out of the side instead of the rear. These machines are built by Allen Trading, and known as a nut chucker. The image below shows one being used to feed pigs. This machine is very simple to maintain and use, requiring just one person to operate the machine, from the comfort of a tractor cab, with very few moving parts, and a simple system of a clicker that sounds in the cab allowing the operator to know how much feed has been dispensed. This machine is capable of spreading feed pellets up to 50m, over gates and fences, lightweight (when empty), capable of carrying up to 4 tonnes, easy to modify for other feeding systems, has a low power requirement, very few moving parts, low maintenance requirements/easily restored, and is also road legal (Allen Trading, not dated). All of these factors together has made the 'nut chucker' the well-known outdoor housed pig feeder it is now. The only main downside to using a nut chucker is that is expensive to buy (approximately £14,000) (Burling, T. 2014. Pers Comm. Mr T Burling is a member of the BPEX Environment and Buildings team).

Figure 1: A Peter Allen nut chucker in action (Author's Own).

The Peter Allen nut chucker can also be adapted by adding a hydro-arm (a part offered by the manufacturer) as shown below, to allow for the feed to be aimed at a trough, and fill the trough (Marriot, 2014). The main downside to simply adding this arm is that the nut chucker is still very inaccurate with the amount of feed it is discharging, as it is only accurate to 1.8kg.

General problems associated with the nut chucker

Problems associated with the nut chucker is that it requires to be taken around the same track around a field every day the pigs are to be fed. With most outdoor systems this means that the pigs need to be fed 365 times a year, from a track that is bare soil. This track after a while can become water logged, rutted and potholed, which then needs levelling, which can only be done in summer when the ground is hard. A solution to this would be to put a track in place but this cannot be done as the field will need to go back into arable operation as soon as the pigs are removed from the field. This problem is compounded by the feeder being heavy (weighing in excess of 4 tonnes when full) and a small contact area between the tyre and the ground, due to the use of super-single tyres on the feeder. To combat this larger diameter wider tyres should be used to reduce compaction (Diserens, 2009). This will also reduce the rolling resistance of the machine, meaning that even less power is required to tow the feeder (Botta *et. Al.,* 2012).

Figure 2: The hydro-arm system offered from Peter Allen trading (Plaisted, 2012)

Individual Feeding

Some sows are individually penned, especially during farrowing, and for approximately three weeks after farrowing. During this time the sow needs to be individually fed. This is currently done manually by filling individual hoppers with feed from bags. This system is much more expensive and more labour intensive than group feeding a large batch of pigs. Another way this is done is to use a nut chucker, but with the feed coming out a spout that is controlled manually, this system is again more labour intensive as it requires two people to operate the machine. The use of a nut chucker in this system is unfeasible as the pens are much smaller than pens used to house large groups of pigs, and the nut chucker broadcasts the nuts too far. This means that some feed would be wasted when feeding as it would not land in the pen, but if the nut chucker is adapted with the Peter Allen hydro arm it could be used to fill the individual troughs for the sows.

Trough feeding v Broadcast feeding

Using broadcasting feeding can cause the pigs to ingest some soil as well as the feed pellets, which can cause bacteria or any chemicals such as pesticides that have survived in the soil from the previous crop to be ingested. This can cause disease or poisoning of the livestock, or in some cases this can be passed on to the end consumer through its meat (Fries and Marrow, 1982). Broadcasting also requires the larger pellet sixe (16mm in diameter) which are more expensive than the smaller sized pellets on offer. This makes broadcast feeding more expensive than trough feeding in the long run.

Broadcast feeding also causes the feed conversion ratio (FCR) to be lower, as some of the feed is wasted as some pellets will be lost amongst the soil in the pen, as well as some pellets being shattered into too fine a particle size so that the pigs will not eat them. Broadcast feeding can also cause localised high nitrogen deposition on the field. This is especially important in NVZs, as the pigs will not defecate in the same area as they are eating at, and with the majority of the pen used for feeding then the pigs are then forced into defecating in a smaller area in a broadcast type system.

Using a trough does have some disadvantages though as a trough can increase competition for feed within a group. This can then lead to increase aggression and bullying within the group, which can then reduce the daily live weight gain (DLWG) of the pigs. To prevent this bars should be placed across the trough to prevent the pigs from pushing each other in the trough (Martin and Edwards, 1994). Troughs can also lead to localised compaction and poaching around the trough, and so they may need moving occasionally.

Possible Alternative Feeding Systems

This section will uncover possible alternative feeding solutions such as use of troughs, MPS Agri's Apollo and possible auger methods.

Troughs

Various indoor-feeding systems allow for the use of cheaper feeds such as 6mm pellets. This is achievable via emptying feed directly into troughs and wastage is therefore minimised. This however cannot be effectively operated in outdoor systems, as wastage would be significantly increased, if 6mm pelleted feed is dispensed through the nut chucker machine. Therefore, it is possible to introduce the use of troughs in outdoor systems, however, 6mm pellets are preferred as 3mm ones can often stick to pig's trotters (BPEX, 2015). The cost of moving from 15mm rolls down to 6mm pellets is estimated between £3-6/t (Wherton, C. 2015. Pers. Comm. Mr C. Wherton is the Pig specialist at GLW Feeds Ltd).

Figure 3 shows suggested feeding troughs for outdoor systems

Troughs which can be purchased from Mole Valley Farmers at a cost of £24.42 (Mole Valley Farmers, 2015) are capable of feeding 9 pigs and contain 305mm bracing to reduce the incidence of bullying at feeding (Hendersons, 2015). However, the weight of these individual troughs is estimated between 20-30kg. It has been noted by BPEX that fixation to the ground is required, or it is likely that the pigs would move them to a different site to where they are normally fed causing an increase in total labour requirement. John Harvey Engineering produce galvanised steel troughs that are heavier to reduce the likelihood of pigs moving troughs around the paddock. The cost of one 7.5m trough is £204.80 (Harvey, 2015) (See appendix 2) which would require considerably more capital than if purchased from Mole Valley Farmers.

To reduce bullying within the groups, mixing should be kept to a minimum (Turner *et al.,* 2006) and trough space provided should only be adequate for the number of pigs located in one pen to avoid confrontation (Stewart, 2015. Pers. Comm. Mr A. Stewart senior lecturer at Harper Adams University). Suggested troughs can be seen in figure 3 (above). For a 1000 sow unit, expected cost for troughs would be £2,650 (Mole Valley Farmers) or £8,200 (John Harvey Engineering). Table one below indicates the total payback period for the troughs.

Table 3 shows payback period for both sets of troughs based on reduced feed usage for 1000 sow units

Trough/Payback	Mole Valley Farmers	John Harvey
Total cost for 1000 sows	£2,650	£8,200
Reduced cost of feed per tonne on pellets	£4/t	£4/t
Reduced Feed Usage	125kg	125kg
Payback/sow/year (£)	(£0.004/kg x 125) = £0.50	(£0.004/kg x 125) = £0.50
Payback/1000 sows/year (£)	£0.50 x 1000 = £500	£0.50 x 1000 = £500
Payback period (years)	£2,650/£500= 5.3 years	£8,200/£500= 16.4 years

The introduction of Mole Valley troughs would pay back over 5.3 years compared to 16.4 years with the John Harvey option. However, the John Harvey troughs will reduce overall labour requirements, as they are structurally heavier, resulting in less chance of movement by the pigs at feeding.

The introduction of troughs requires a change in feeding/filling system. A new piece of mechanisation must therefore be designed/adapted to be able to fill into the troughs. A proposed design can be seen later in the report titled 11071400. The design demonstrates how the troughs would be filled and how environmental impact and soil compaction can be minimised.

A possible issue/benefit with trough feeding is that it condenses the area were soil compaction occurs. Depending on which aspect you look at, the condensation of compaction reduces the need for the whole field to be sub-soiled once the pigs have been removed off the site or the spread of lighter compaction may not require the need for subsoiling at all. Subsoiling will cost £57.40/ha (NAAC, 2014).

MPS Agri Apollo

MPS Agri have developed a new product, unique to outdoor pig production which aims specifically at reducing soil compaction through the reduced passing of heavy mechanisation and to reduce overall feed usage. It is named the 'Apollo' and can be seen in figure 2 (below).

Figure 4 shows MPS Agri's Apollo

The Apollo offers outdoor pig producers the opportunity to incorporate a more accurate and precise feeding method to their stock through use of Electronic Identification (EID) and online software systems, which allows farmers to monitor each animal individually. A key characteristic of this machine is that it reduces the incidence of bullying within groups as stock can choose when they want to be fed, therefore helping increase DLWGs and condition at critical times such as mating and farrowing. To calibrate the machine, the desired feed is simply weighed to give accurate readings. To keep production costs to a minimum, the EID management tag can be removed and reused in the next batch of stock entering the system. Each unit is capable of feeding up to 50 sows and the hopper has a maximum capacity of 1 tonne. Therefore, if 50 sows are fed 3kg/day the hopper is only to be re-filled once a week helping to reduce the environmental impact and soil compaction (MPS Agri, 2015).

The cost of one unit is £8,750 which includes EID, software and installation fees (Houston, A. 2015. Pers. Comm. Mr A. Houston is the owner at MPS Agri). To accommodate a 1000 sow herd, 40 units would be required which quickly escalates the total cost to £350,000. This is a staggering increase in comparison to trough usage, however it may offer more technological benefits to the farmer by offering individual sow analysis. Its major benefit is that it offers lower labour usage (thus reducing production costs) and improved soil structure as traffic passing is reduced significantly.

Pipeline Auger System

To completely eliminate traffic passing on tracks, a fully automated pipeline auger system could be installed. The Apollo would not be cost effective for individual sows at farrowing, therefore, a flexi auger pipeline system could provide a solution for feeding which again reduces the labour requirement and overall environmental impact. This system is commonly used in indoor production. This system offers increased feed precision as it allows for 100g increments to be set between 0.5-7kg (see figure 3). By feeding using this method, individual sows can be fed when farrowing alongside grouped dry sows. The cost of the dual feed dropdown dispenser is £30/unit and is capable of feeding 2 sows and includes drop chutes (Howard, A. 2015. Pers Comm. Mr A Howard is the Regional Accounts Manager at Collinson Agriculture) (See appendix 3). PVC piping is priced at £18/3m (60mm diameter) length and augers cost £6.36/m. A single phase electric motor is also required to power the auger and is priced at £679. One motor can only power one auger (Wicks, J. 2015. Pers Comm. Mr J. Wicks is the owner at BILDABIN) and can be supplied by BILDABIN UK. A feed silo is also required. Galvanised steel is recommended and can be purchased from QMAC Ltd. The price of a 27t silo fitted with a 60 degree cone (recommended for pig feed) is priced at £3,550 (McKeown, T. 2015. Pers Comm. Mr T. McKeown is the sales representative at QMAC Ltd.)

Figure 5 shows drop down dispensers

A pipe system with individual dropdown dispensers into troughs may prove to be a more cost effective method than the Apollo. E.g:

1000 sows

-500 dual feed dropdown dispensers = £30 x 500 = **£15,525**

- 2km pipe = £6/m = **£12,000**

- 2km of flexi-auger = £ 6.36/m x 2000m = **£12,720**

- 8 x Electric auger motor (based on 8 separate 60mm diameter lines) = **£679**

- 27t Tower Silo = **£3,450**

- Generator if required = Ingersoll 130KVA Diesel Generator (See appendix 4) = **£5,250**

- Troughs = **£ 2,650 / £8,200**

Total Costs Excluding Labour Set Up Costs (inc generator) = £57,027 / £65,227

Please see design 5 for layout of the pipe/fence feed system.

There are various existing feeding systems currently available on the market. However, new designs are required to ensure that environmental impact is minimised and cost of productions are reduced.

Designs

Design 1- Self-propelled feeder

Designs

The feed system is based around the Peter Allen broadcaster unit but with an adaptation of a spout on the end with mechanical control using hydraulic rams. This would mean that the existing metering system could be used. The spout will have a 2.5m reach from the machine to enable trough loading from over the perimeter fence with accuracy. Another adaptation made is to use a fibreglass tank on the feeder. This will help to reduce weight, therefore compaction and soil damage problems, and as filling is done from a larger hopper damage should not occur. The tank will also be between 4-6T capacity approx. 8m^3, for increased output. In addition, the tank will be of lower profile to existing ones to improve stability of machine.

The base of this design is around a tracked dumper, capable of carrying up to 10 tonnes and being on 700mm wide tracks helps to reduce ground pressure. This will enable better maintenance of tracks. It could be an adaptation of an existing machine, or be custom built. The track base is 2.64m wide and 2.9m tall so will be stable but still narrow enough to use existing tracks and gateways. The machine will have a fully enclosed cab so that the operator can remain in comfort all year round. See Appendix 1 for more detail on these machines.

Figure 8: tracked Dumper (Source: Google)

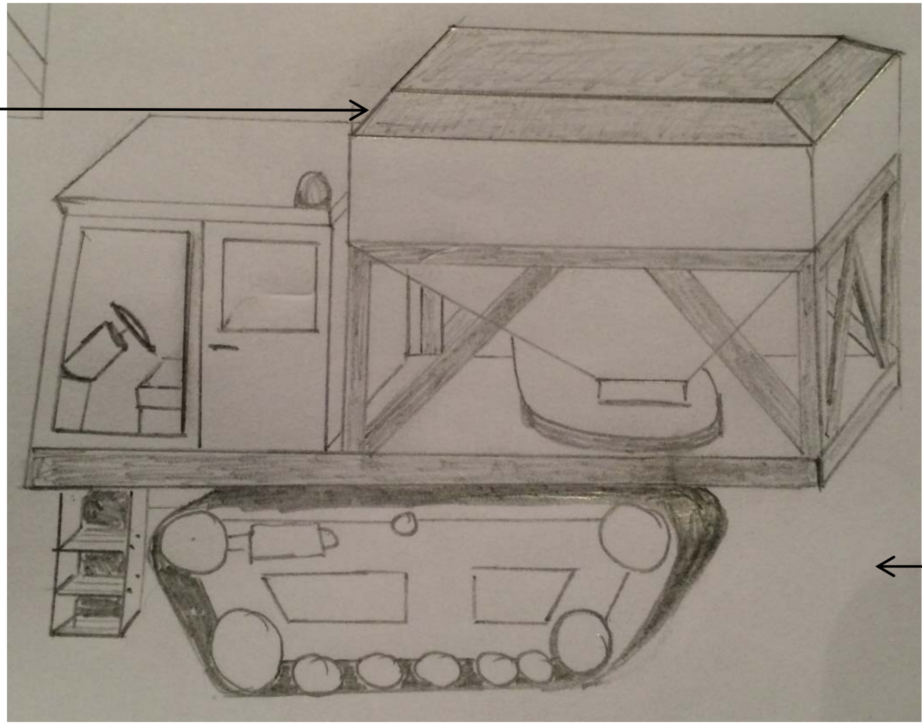
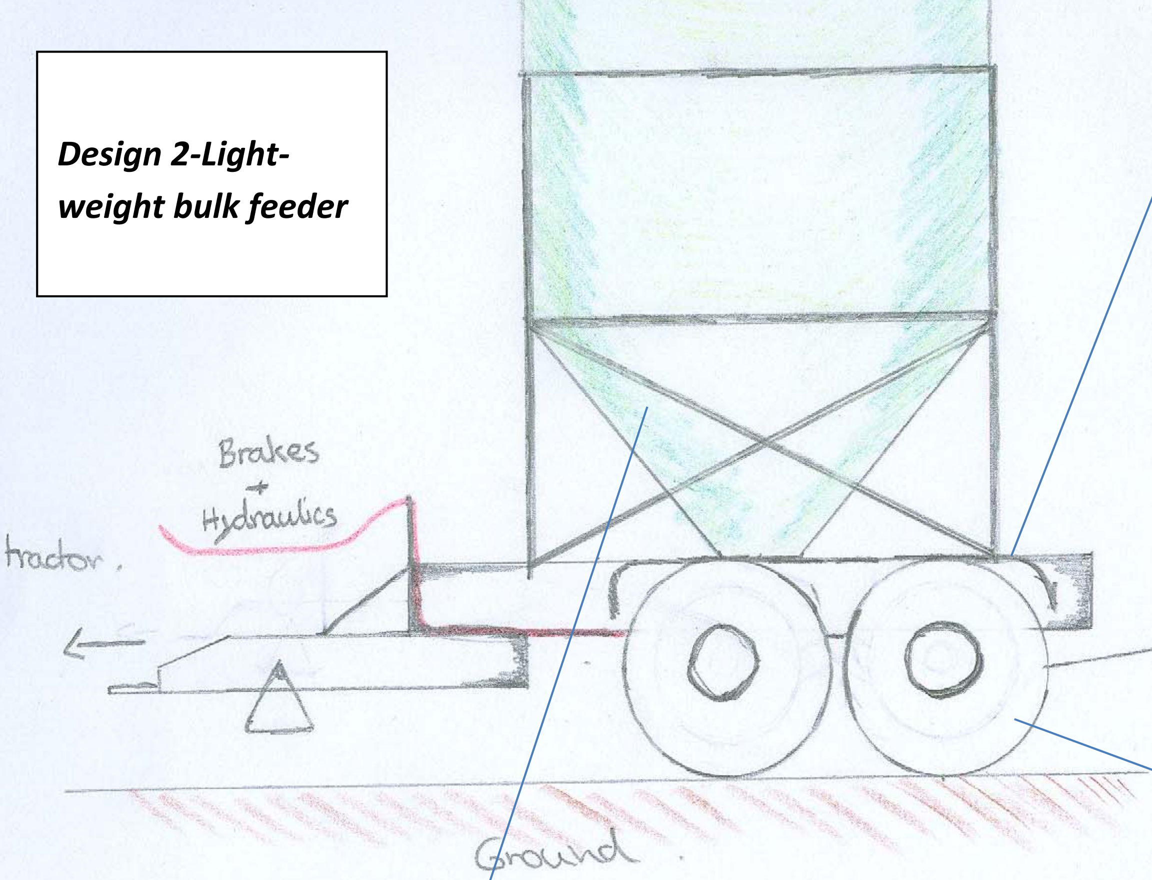


Figure 6: Self-propelled feeder concept (Source: Author's own)

Figure 7: Example of proposed arm design (Source: Author's own)

This machine will be on rubber tracks so will be able to travel on roadways without damaging them. It will however not be capable of excessive road work and will be mainly a field machine. Most farms are well set up with minimal distance from feed storage to pig paddocks so the lack of ability to drive on roads shouldn't be an issue. The cost of the build of this machine may be excessive compared to using a trailed machine if all parts need to be purchased from existing manufacturers. Buying second hand machines to modify may be a more cost effective option. The extra expense of this machine should be justified by an increased life span of the machine and also it helps to reduce environmental impact of the system.

Design 2-Light-weight bulk feeder



- Mud flaps to avoid soil throw from wheels onto machine in wet conditions.

Wheels and Tyres

- 500/60-22.5
- 500mm wide, 1117mm Diameter
- Flotation tread pattern
- Low inflation pressure
- Reduced pressure impact on soil
- Provide good traction, with a strong side lug

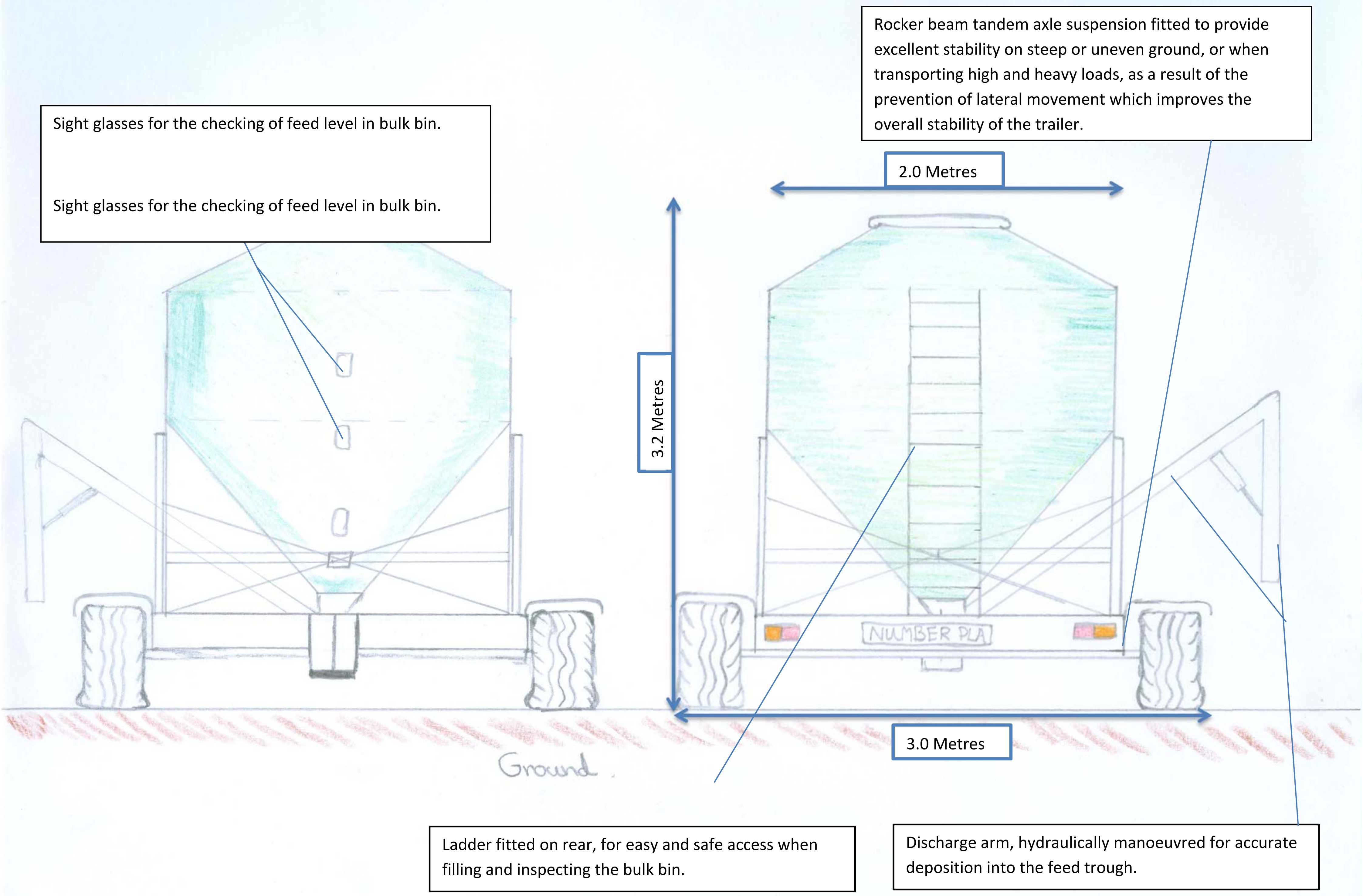
- Twin axles for even weight distribution across soil surface.
- Wide axles for improved stability.

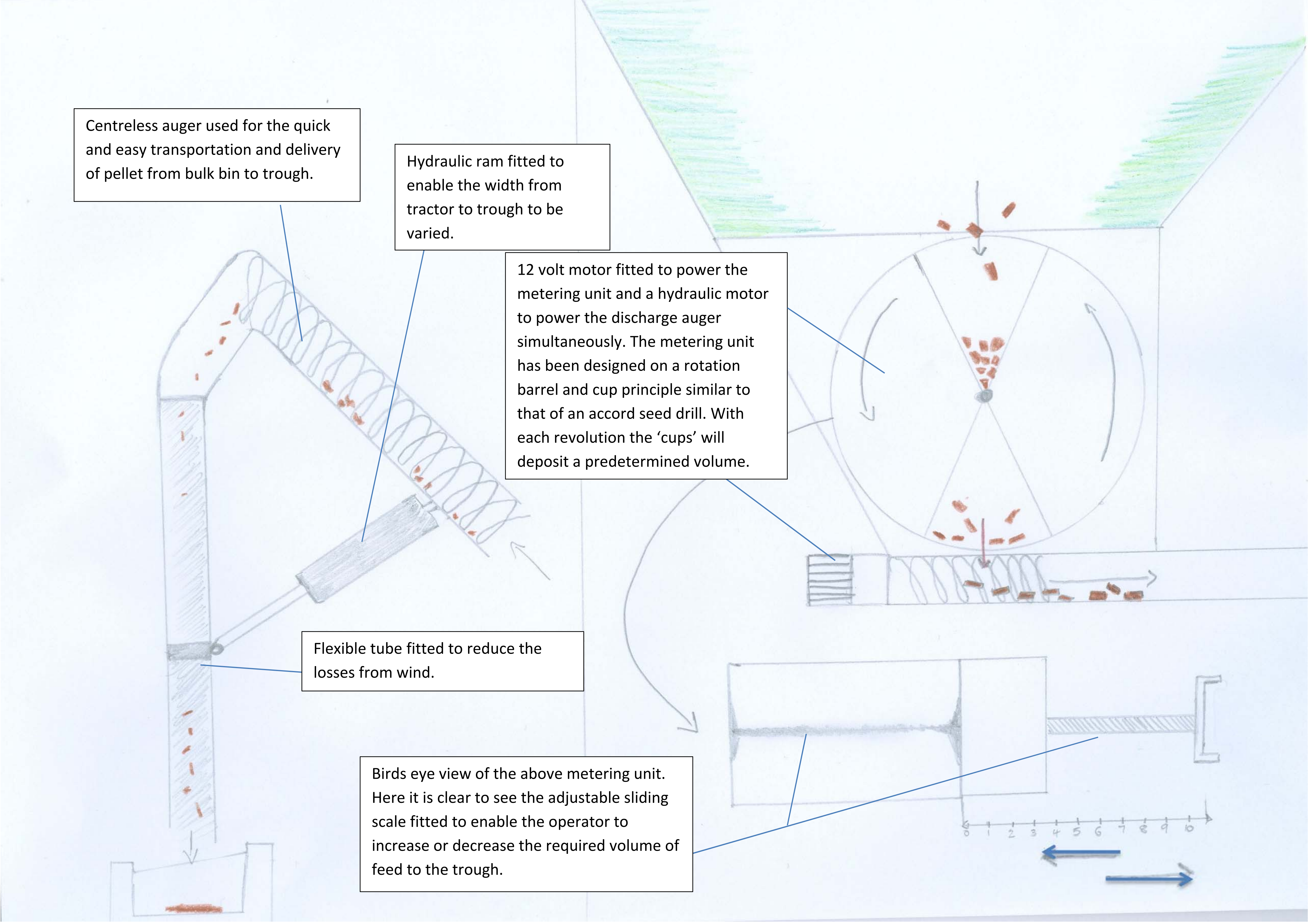
Bulk bin/ Silo

- Single piece cone & body.
- No seams, joints or bolted sections for meal to get stuck.
- Corrosion resistant for long life.
- UV stabilized Glass Reinforced Plastic (GRP) material to protect contents and silo.
- Semi-transparent GRP allowing contents level to be checked.
- Smooth interior for constant flow of feed.
- 45º Cone angle for reduced working height, whilst maintaining good internal flow.
- Superior thermal insulation values compared with steel resulting in lower risk of condensation.
- Inspection hatch on top aids the filling of silo.
- All steel work hot dipped galvanized.
- Capacity 4-6 tons.

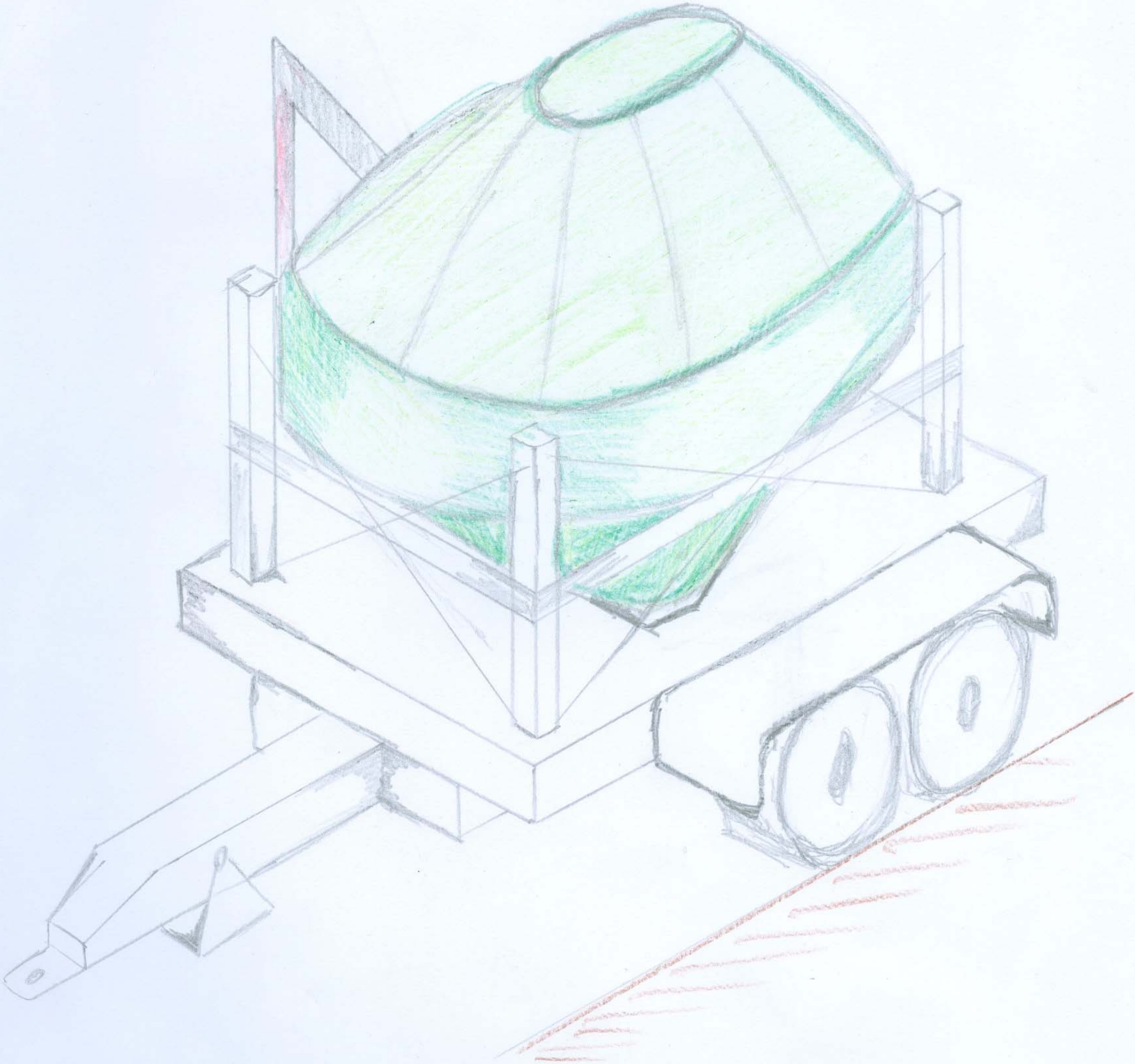
Machine Costings

- Trailer chassis complete with 10 stud commercial axles and break lines £4800 (Marshall Trailers)
- 4.8t bulk bin fitted with discharge arm and auger system £2636 (Collinson Agriculture)
- Set of 4 BKT 500/60-22.5 flotation tyres and rims, £670/unit £2680 (Abbey tyres)
- Total cost = £10,116


Sight glasses for the checking of feed level in bulk bin.
Sight glasses for the checking of feed level in bulk bin.
Rocker beam tandem axle suspension fitted to provide excellent stability on steep or uneven ground, or when transporting high and heavy loads, as a result of the prevention of lateral movement which improves the overall stability of the trailer.
2.0 Metres
3.2 Metres
NUMBER PLA
3.0 Metres
Ground
Ladder fitted on rear, for easy and safe access when filling and inspecting the bulk bin.
Discharge arm, hydraulically manoeuvred for accurate deposition into the feed trough.


Centreless auger used for the quick and easy transportation and delivery of pellet from bulk bin to trough.
Hydraulic ram fitted to enable the width from tractor to trough to be varied.
12 volt motor fitted to power the metering unit and a hydraulic motor to power the discharge auger simultaneously. The metering unit has been designed on a rotation barrel and cup principle similar to that of an accord seed drill. With each revolution the ‘cups’ will deposit a predetermined volume.
Flexible tube fitted to reduce the losses from wind.
Birds eye view of the above metering unit. Here it is clear to see the adjustable sliding scale fitted to enable the operator to increase or decrease the required volume of feed to the trough.

3D, Final Design



Design 3- Drone feeder

1 drone fills from hopper

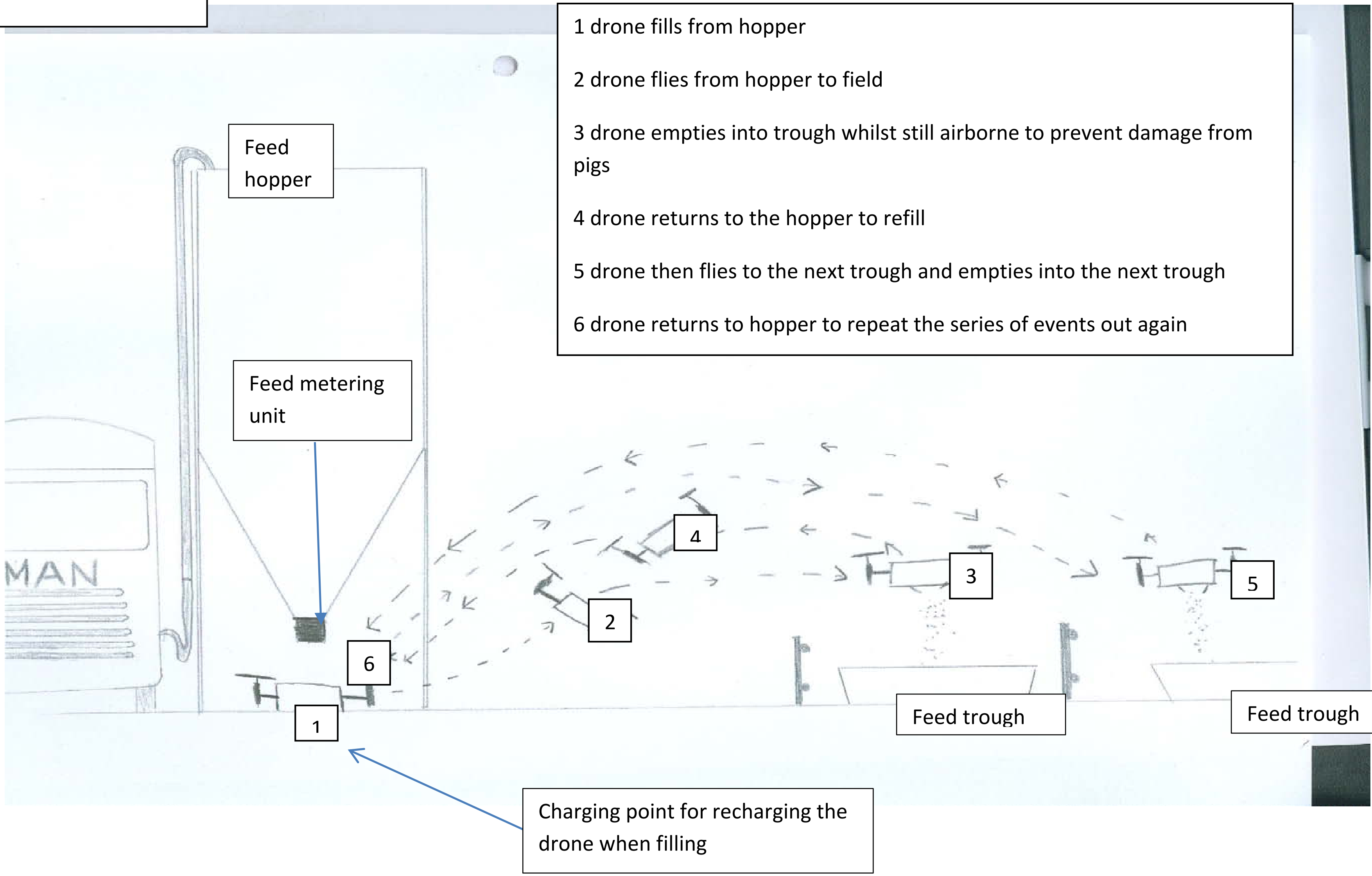
2 drone flies from hopper to field

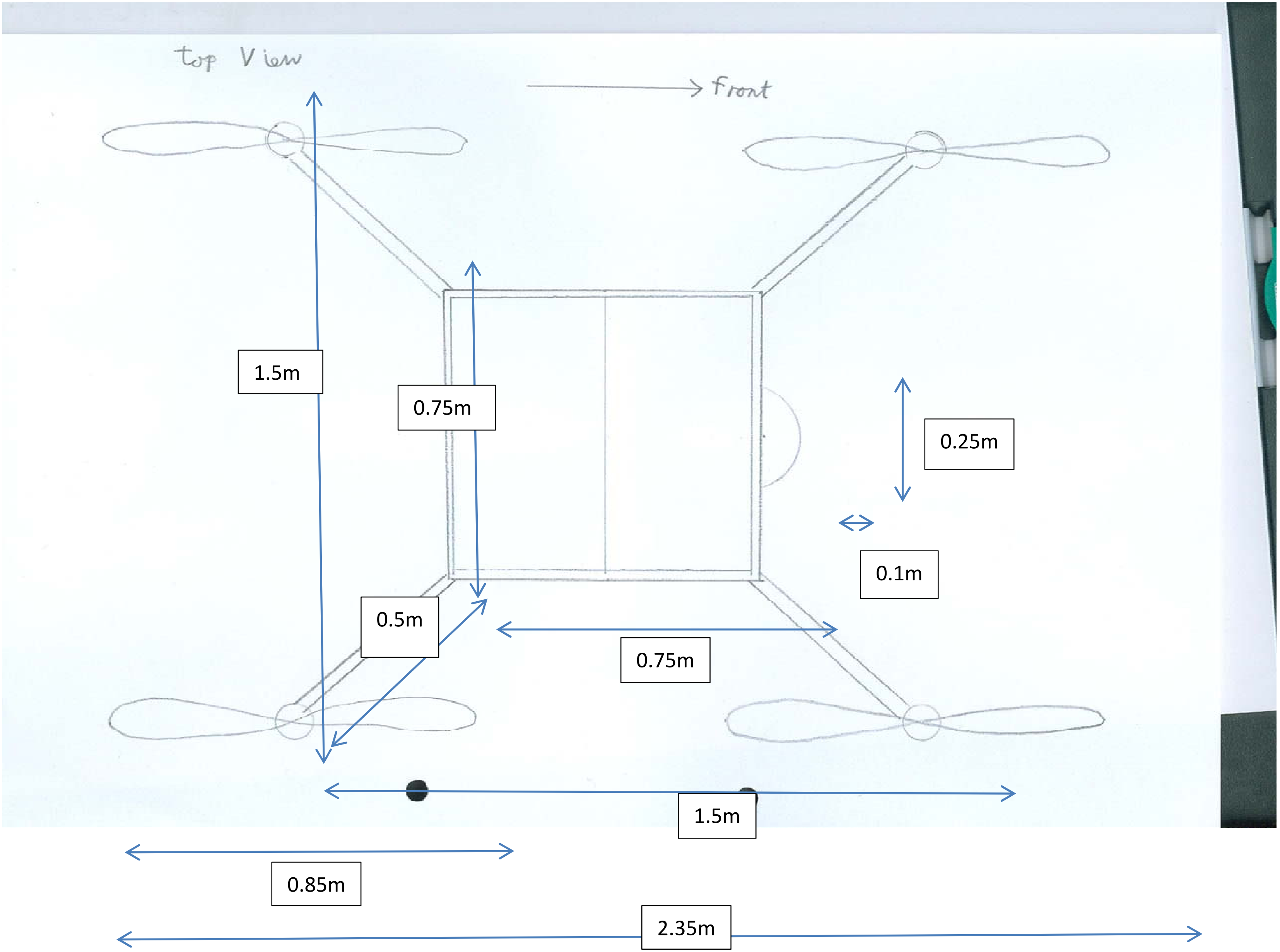
3 drone empties into trough whilst still airborne to prevent damage from pigs

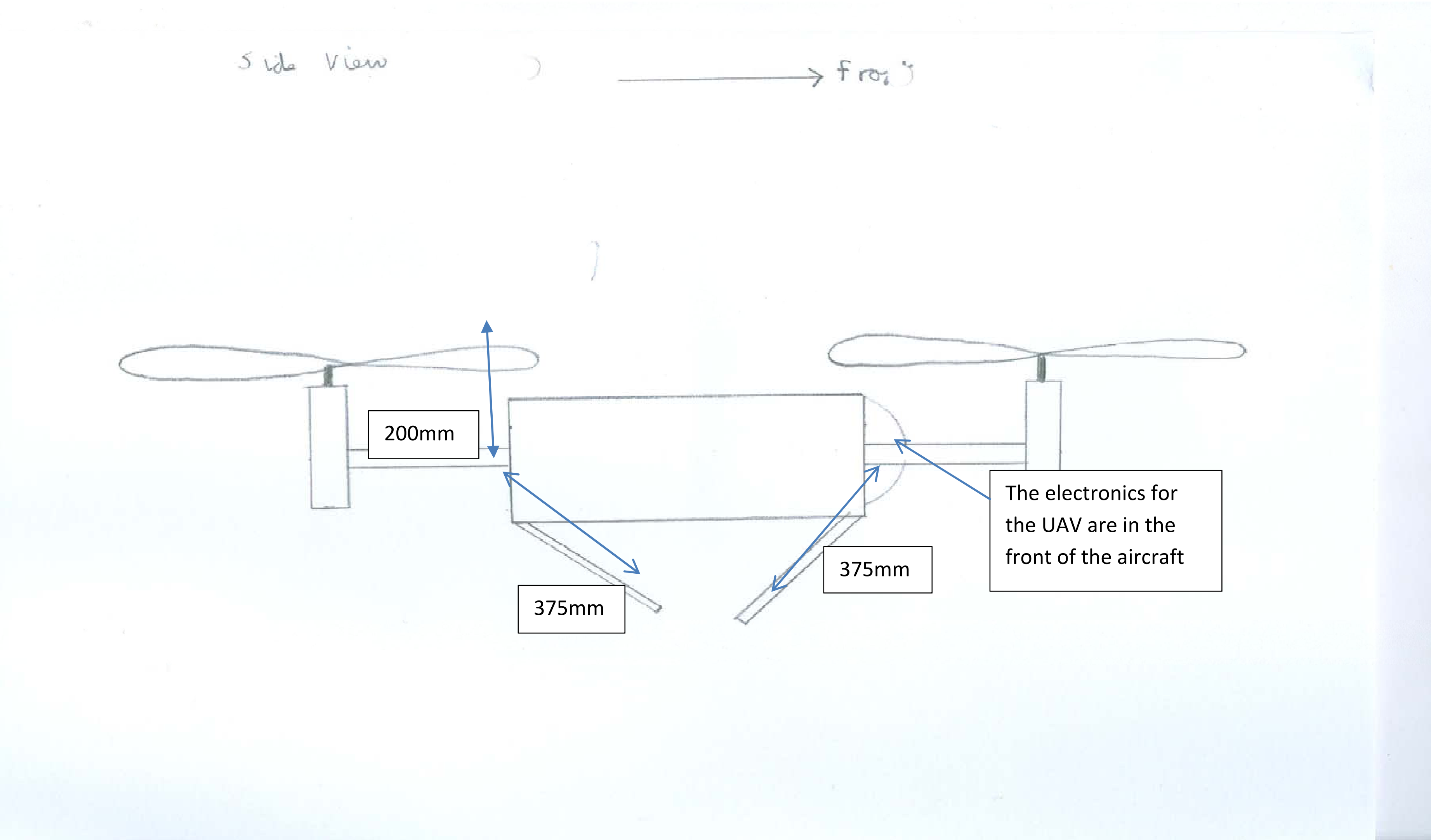
4 drone returns to the hopper to refill

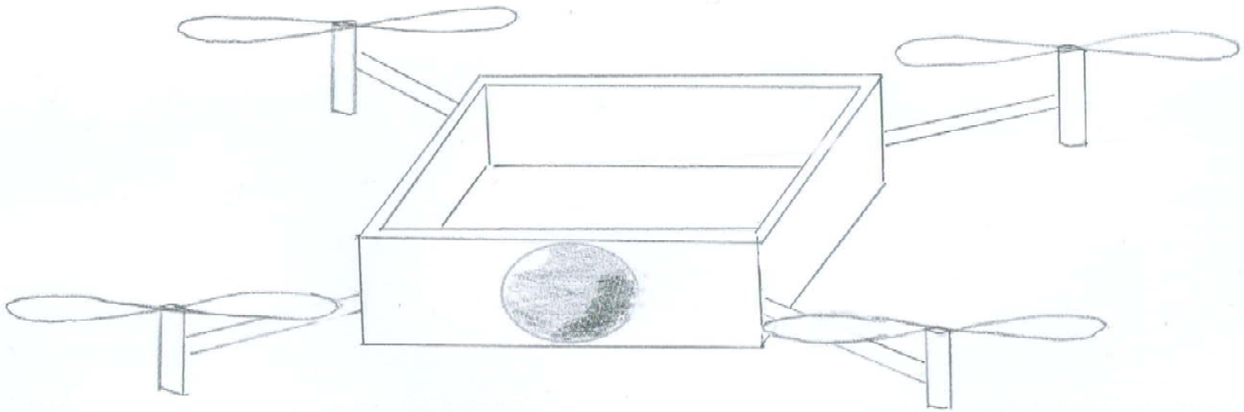
5 drone then flies to the next trough and empties into the next trough

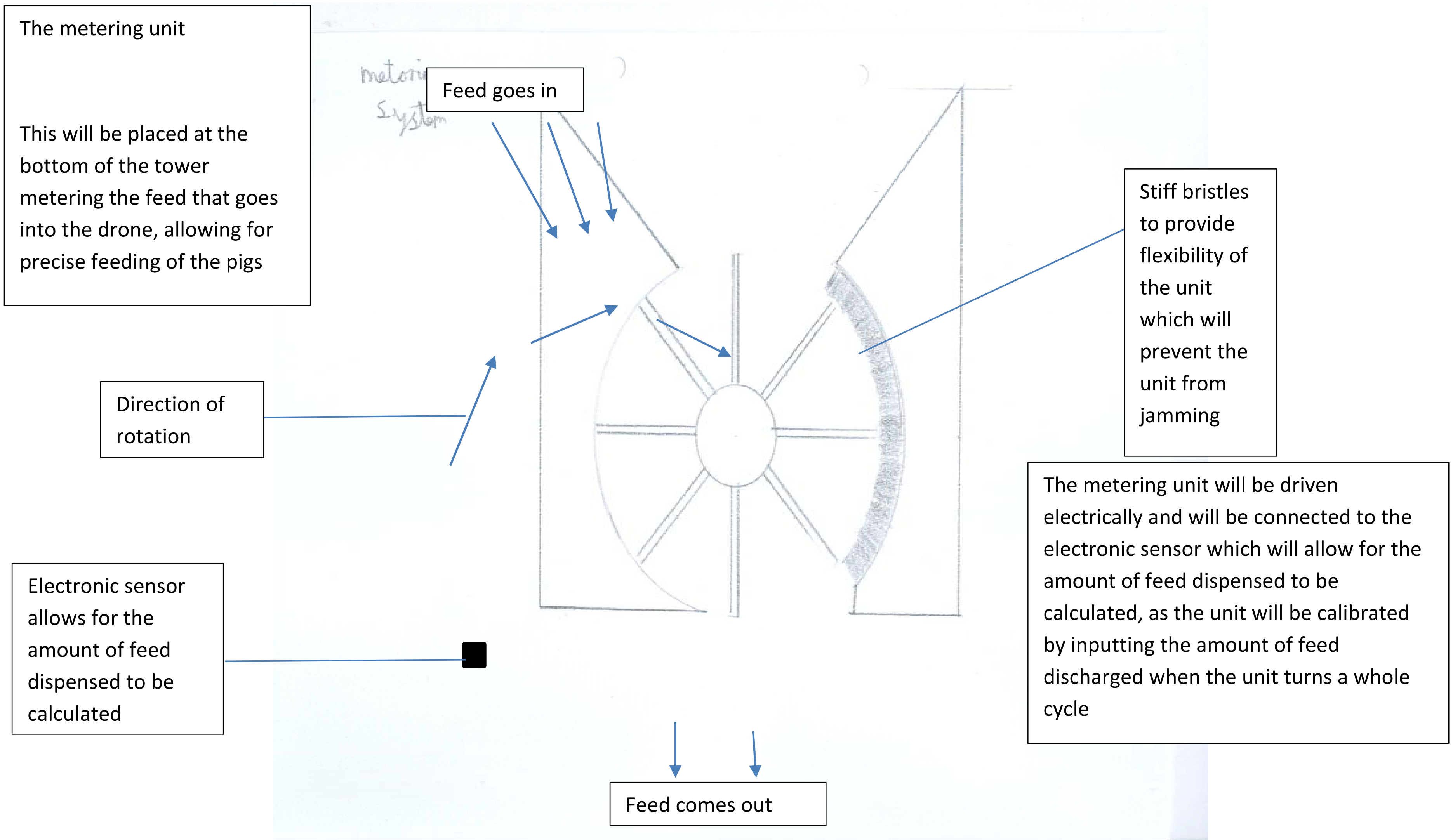
6 drone returns to hopper to repeat the series of events out again




top View
front
1.5m
0.75m
0.25m
0.1m
0.5m
0.75m
1.5m
0.85m
2.35m


Side View
200mm
375mm
375mm
The electronics for the UAV are in the front of the aircraft





The metering unit
This will be placed at the bottom of the tower metering the feed that goes into the drone, allowing for precise feeding of the pigs
Feed goes in
Direction of rotation
Electronic sensor allows for the amount of feed dispensed to be calculated
Stiff bristles to provide flexibility of the unit which will prevent the unit from jamming
The metering unit will be driven electrically and will be connected to the electronic sensor which will allow for the amount of feed dispensed to be calculated, as the unit will be calibrated by inputting the amount of feed discharged when the unit turns a whole cycle
Feed comes out

The use of a drone (UAV) for the feeding of outdoor pigs

The use of drones in agriculture is a relatively novel idea, with it still being prohibitively expensive and also very expensive to maintain drones. The use of drones also has some problems with regards to health and safety concerns, although the mandatory regulations required to get a drone into use in the UK, can now be met. Although the use of drones in agriculture is limited, they are currently been used for some jobs, such as checking for weeds in fields, field mapping and checking of livestock.

If a drone were to be used for feeding pigs it would have to be able to feed a whole pen, consisting of approximately 25 sows, requiring 3kg/pig/day, as well as being able to feed a different feed pellet type to individually penned sows. Therefore the payload must be a minimum of 75kg, which is below the maximum payload of the above drone which is 80kg. To cater for the change in pellets a second silo would be required, which doubles the metering and silo costs. To feed the individually penned sows the drone would have to make one trip per pig, this would be very time consuming, as the drone is designed to drop its whole load in one go. This would make feeding individually penned sows very time consuming for the drone.

Benefits

The main benefit of using a drone is that it can be used without any labour requirements, as once programmed, it will be able to fly around a pre-set path automatically. The drone will also prevent soil compaction and rutting of the farm tracks simply by never touching the soil. This is a big problem with current feeding systems as they rely on using tracks on the field that become very compacted, waterlogged and rutted. The latter are major problems, as they cause damage to the soil which needs to be rectified prior to handing the field back to landlord, if the field is rented, or prior to growing an arable crop, as this will have an effect on the yield of the arable crop.

Negatives

There are many negatives with regards to using a drone to feed livestock, which include the cost of the drone, upsetting the livestock, and extreme weather can ground the drone. This means that a back-up system is needed to feed the livestock on days when the drone is grounded. The battery life of the drone is also a major problem and that a licence to fly the drone may be required. The weather does create a serious problem with the use of a drone in the UK for feeding the livestock as it is expected that there are only 100 UAV flying days per year (Mark, 2014). Another major problem is that the maximum battery charge time for a drone is around 25 minutes. This means that the battery would have to be changed multiple times throughout the day, which will require labour input, and therefore the drone would not reduce the labour requirement of feeding the pigs (Scharr, 2015). Another possibility to overcome this would be to have the drone land on a charging point where it fills up at the same time. This would prevent the battery from having to be changed, but having the drone land on this in such a way that it could connect properly could pose a challenge.

For an outdoor pig farmer, like the majority of farmers, the use of a drone is prohibitively expensive with current drones costing "from £10,000 for the most basic up to £50,000", and with hire charges being around £1000 per day (Mark, 2014) for just the drone with no added extras, such as metering systems. The current drones offered for sale also have a relatively short lifespan, (approximately three years) which also adds to the daily running cost of the aircraft. These drones have also not yet been adapted for feeding livestock, as they can only currently carry sensors and cameras. This could be because of the change in the handling and balance of the aircraft when it unloads the feed when in mid-air.

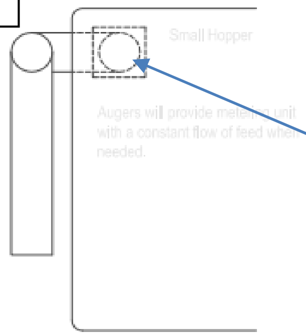
The use of a drone may also require that it has someone ready to take control of the aircraft to be present if it starts to encounter problems, endanger anyone or any livestock (NFU, 2015). The use of a drone has also had some more recent speculation from the government into its future with the House of Lords calling for an EU-wide register of drone operators and owners. With future legislation later in the year yet to be published for the use of UAVs and drones, there is great uncertainty into what legislation is going to be introduced into the use of a drone for feeding pigs (Dalby and Sethi, 2015).

Another major potential problem with using a drone to feed livestock is that livestock is often worried by low flying aircraft, which is a major problem in the use of a drone, as the drone would have to be very low when discharging its load. The fact that the aircraft will have to fly so low also presents problems again as in dry times this could cause soil to be blown off the surface of the ground creating a dust cloud, and with it flying so low, there is also potential for the drone to be damaged by the livestock.

Is the use of a drone a possibility in current feeding systems?

The use of a drone still has too many downsides to its use for feeding outdoor housed livestock, these problems are very major problems, including the average UAV flying days per year, the current and future legislation required to use a drone making a legal minefield, and the cost and lifetime of the drone. These downsides far outweigh the benefits of less labour requirements and prevention of soil damage through compaction and rutting. Therefore it is not recommended to use a drone for the feeding of livestock.

Design 4- Low ground pressure feeder

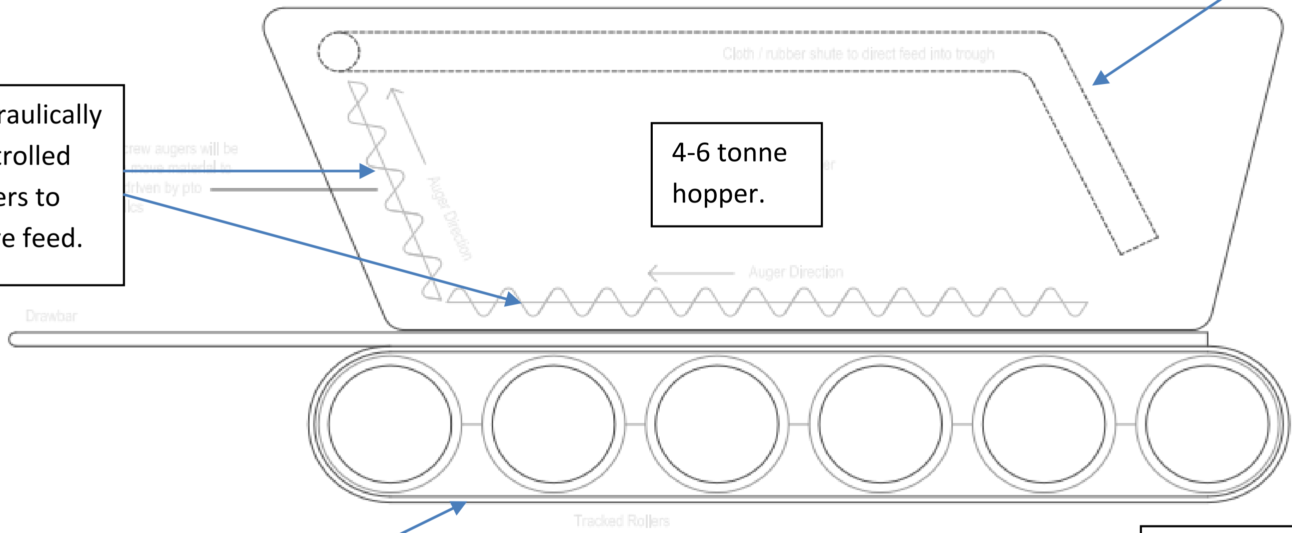


Augers will provide metering units with a constant flow of feed when needed. An "Accu-Feed" medium hopper feeder or similar product will be used to accurately meter the feed. The feed metering unit is operated electrically and can be adjusted from the cab making feeding more efficient.

Spout to enable feeding without entering the pen.

Hydraulically controlled augers to move feed.

4-6 tonne hopper.



Tracks 4.43m long and 600mm wide.

Machine Total length = 6.5m,
Machine Width =2.1m,
Machine Height = 2.5m.

Issues with Current Feeder Design

There are a number of issues that arise from using pig feeders that are currently on the market. For example many of the feeders are equipped with super single tyres which have a small surface area and lead to deep rutting and compaction of the tracks. Other issues are the feed metering system which has to be calibrated on the feeder and cannot be altered from the cab. This in turn increases the time it takes to feed the herd. Furthermore the feed metering systems are consistent in how much they feed but cannot be calibrated to feed single one kilo increments. This means that single sows or boars have to be fed separately and cannot be fed using the same machine.

Track Design Concept

In an attempt to combat the issues with current feeder design that have been discussed previously in this report a number of fundamental differences have been incorporated into the design as can be seen in the drawings.

The feeder sits on a pair of tracks which will be made of rubber much the same as the tracks fitted to Claas combines as can be seen in figure 7. This will allow the machine to be used on the road. The tracks will be driven through the use of a ground speed PTO which comes as standard on many new tractors. The driven tracks will be turned off for the most part, however if the tractor starts to become bogged down the trailer drive can be engaged. The addition of driven tracks should reduce slippage from the tractor making the machine more efficient reducing fuel costs (Palm Mach, 2014). Tracks have been chosen as opposed to tyres because of their ability to disperse weight due to a high surface area. The tracks will help reduce levels of compaction by up to 75 per cent. The tracks will also reduce the presence of ruts which will in turn decrease levels of nutrient leaching from the soil due to run off (Lynx-engineering, 2011).

Figure 9: Picture showing a Claas combine equipped with tracks (What's new in farming, 2015).

The feeder shown holds 6 tonne as oppose to the more common 4 tonne feeders (however the feeder can be supplied in a 4 tonne format). This reduces the number of times that the feeder has to stop to be refilled therefore creating a more efficient system. Furthermore reducing the number of trips to be refilled will in turn reduce levels of compaction and the presence of ruts because the ground will be driven over less.

The feeder is equipped with a spout containing a hydraulically driven auger which enables feed to be fed into troughs across the fence eliminating the need for the tractor and feeder to enter the pens. This will reduce the pigs' stress levels whilst reducing levels of ground damage, as a result of the addition of the spout feeding times will be reduced when compared to systems where the tractor and feeder has to enter the pen to feed the pigs.

A cloth or rubber shute is added to the end of the spout to reduce falling distances which should decrease dusting of the feed which reduces palatability. Furthermore the shute will enable the farmer to feed into troughs with a greater level of accuracy reducing wastage which will lower the farm's feed costs and reduce nitrogen hot spots and soil ingestion.

Hydraulically controlled augers inside the hopper will provide the metering unit with a constant flow of feed when needed. An "Accu-Feed medium hopper feeder" (Accu-feed, 2015) or a similar product will be used to accurately meter the feed. The feed meter is operated electronically and can be adjusted from the cab. The meter is capable of dispensing feed in 0.5 kilo increments if need be (Accu-Feed Engineering, 2015). As the feed rate can be adjusted from inside the cab of the tractor, time spent calibrating the feeder when a farms feed rates change such as in the winter will be eliminated. Accu-Feed is an American company that provides hyper accurate plastic dispensing systems for the plastic moulding industry. As the machines are currently used to dispense plastic pellets it should be suited to dispensing pig feed (Accu-Feed Engineering, 2015).

Figure 10: Picture of an Accu-Feed feeding unit (Accu-Feed Engineering, 2015).

Augers that are controlled by hydraulics have been chosen over other methods such as fans to prevent dusting of the feed (where the feed is pushed through the machine at such a rate that it breaks up) which will in turn lead to wastage as the dusted feed can easily be picked up by the wind and not be placed in the trough.

The design of the machine combats many of the issues that have been raised previously in the report such as reducing compaction, environmental impacts and decreasing feed wastage. However there are financial drawbacks for the addition of the tracks. The tracks will cost in the region of £7000 to £10,000 which is a large cost when compared to other machines on the market however the benefits that the tracks provide go some way to countering the cost (Farmers Weekly, 2014).

Design 5- Fence feeder system

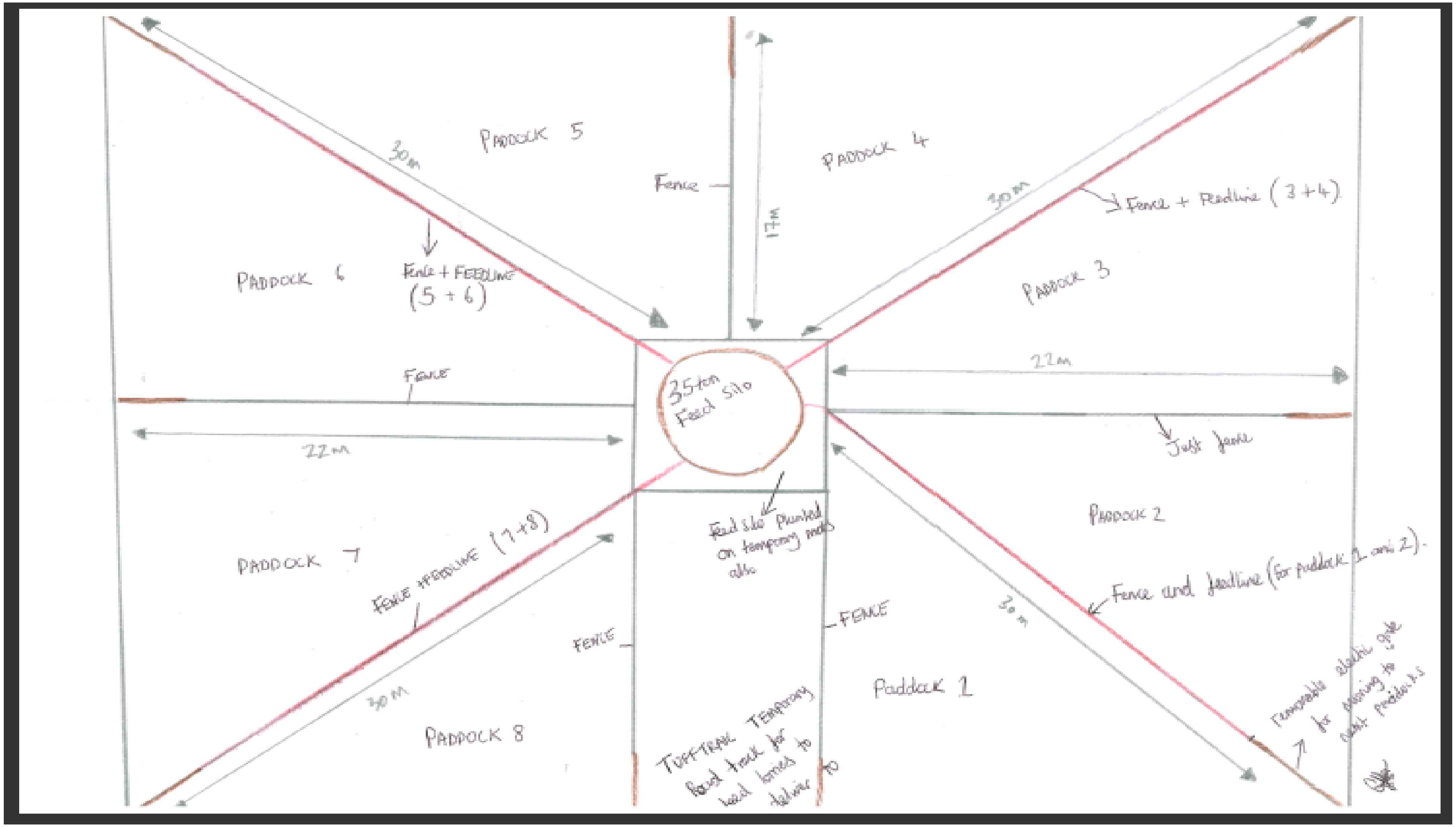


Figure 11: Birds eye view of fence feeder system (Source: Author's own)

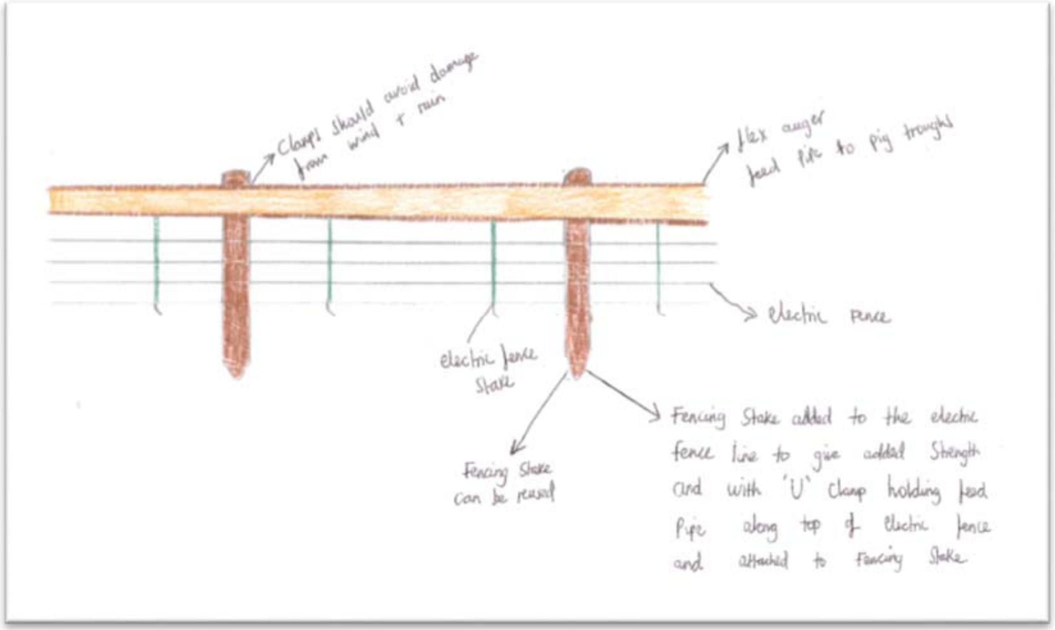


Figure 12: Fence feeder system (Source: Authors own)

This idea is based on a concept which uses little/no machinery in the field. A feed silo is placed in the middle of a field (or where suitable access from feed lorries) surrounded by the pig paddocks. This idea has come about by looking at how other livestock species such as poultry are fed. Some adaptations may need to be made to make it suitable for the outdoors.

Flexible auger feed pipes will be placed on top of the electric fence with the assistance of fencing stakes for extra strength. 'U' shaped clamps will grip the feed pipe around the fencing stake to hold it in position and to protect it from the weather conditions (especially wind). The flexible auger pipes are completely sealed so there is little wastage and is also very good for bio security. With the electric fence the pipe will also be protected from pig damage. The feed pipe will run down the middle of two paddocks so only one pipe is needed for every 2 paddocks saving costs. Troughs can be moved throughout the year to avoid too much poaching. A flexible piece of pipe will be added to the end of the feed line into the troughs and can change types of feed from each paddock, and this could be adapted to be done automatically. Pigs move from paddocks via electric wire gates on the end of the paddock. The feeders require power to drive the augers which would either require an electric source or a diesel powered generator to run. To divert the feed to each paddock, the feed specialist producers Collinson's have developed a 'Y' connector will feed either side of the paddock and drops the feed into the troughs below, with little wastage.

Figure 13: TuffTrack temporary matting (Source: TuffTrack)

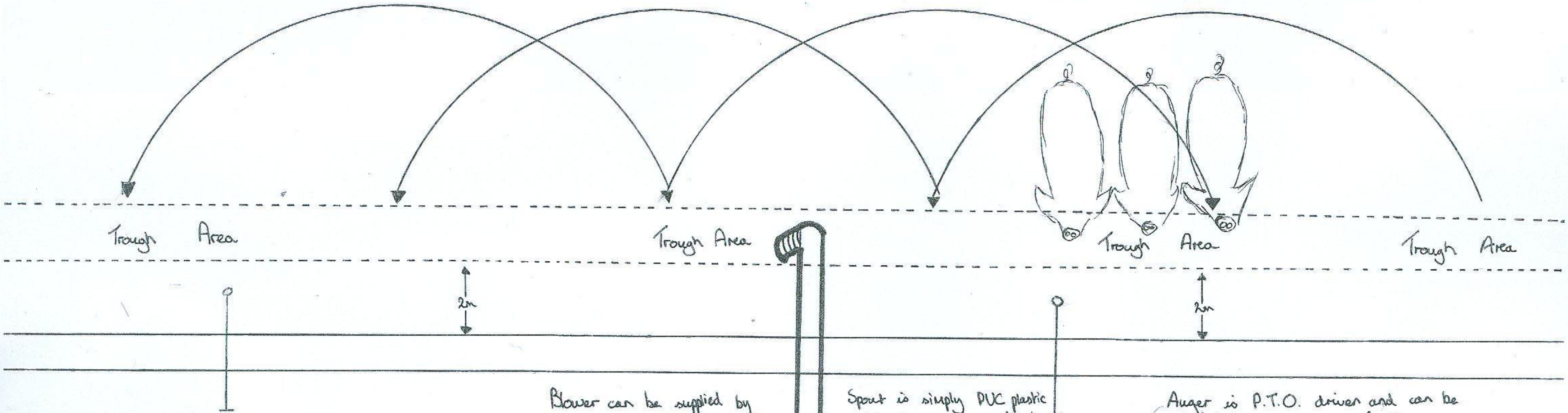
TuffTrack temporary road mats are then used to transport the feed lorry to the feed silo in the field. As seen in Figure 3, they are regularly used at large scale events so that vehicles and machinery can be transported over many terrains, dramatically reducing damage to the soils and compaction. Using this method would stop the need to pull large machinery through the paddocks during the winter months causing huge soil erosion, compaction and pollution issues.

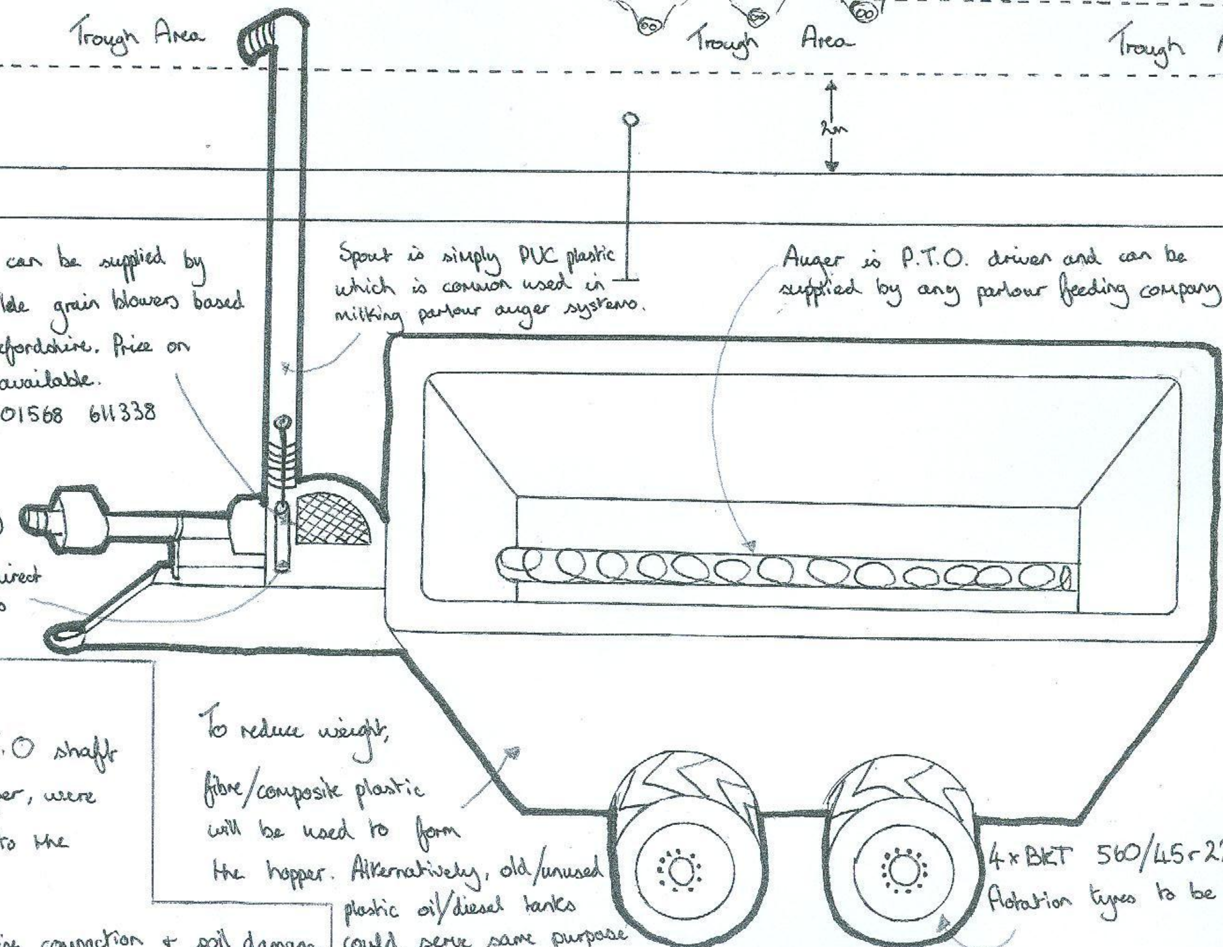
This system is very adaptable and could be altered depending on the access, size or conditions. It would be suggested that conventional bales of straw should be used to bed sows on in the arcs. This is because they can be taken by quad bike (or Mule), with or without a trailer to the arcs. This may be slower than using large straw bales, but a smaller implement can transport smaller bales to create less compaction, and when it is very wet there is the option to carry the bales by hand.

11071400

Troughs are to be moved when soil/ground conditions are becoming unsuitable.

Distance between electrified fence is set at 2metres to ensure that there is ample room to avoid bullying/pushing. This is important as it could cause the fence to collapse, and the animals may escape.





The Machine

This implement has been adapted and developed from the 'Peter Allen Nutchucker.' The axles + supporting frames/drawbar will be manufactured from steel whilst the hopper will be made from composite plastics to reduce the weight by up too 1000kg depending on hopper capacity.

Feed should be gravity fed from a bin when filling to reduce operational/production costs. An auger system powered from P.T.O shaft + tractor will auger the pelleted feed to the front of the hopper, were a blower (with hydraulically operating spout) will blow the feed into the troughs provided. Blower is powered off P.T.O.

Tyres to be used are 4 x BKT 560/45r 22:5 flotations to minimise compaction + soil damage.

Table 4: A Review of all the designs with appropriate costings over a 5 year period (source: Author's own, 2015)

Design Name	Approx. Cost	Cost per head on 1000 sow unit @ 5 year pay back	Pros	Cons
Design 1- Self-propelled Feeder	£45,000-£50,000	£9/head/yr	Lightweight Low Ground Pressure Uses composite materials Suitable metering system	Expensive Self-propelled not versatile Not road legal Poor visibility from cab
Design 2- Light Weight Bulk Bin	£10,1160 - £12,000	£2/head/year	Light weight Low Ground Pressure Simple, reliable and durable Suitable metering system Road legal	Bulk bin more liable to damage than steel construction. Possible scrubbing of tyres.
Design 3- Drone Feeder	£68,000-£70,000	£14/head/year	Compaction and rutting from feeding eliminated Labour input reduced	Legal minefield Blowing of soil during dry periods causing dust storm Battery life Size of drone required Limited flying days per year due to weather Cost of repairs and knowhow required for repairs
Design 4- Low Ground Pressure Feeder	£30,000-35,000	£7/head/year	Decreases levels of compaction Reduced rutting and slippage because of the driven tracks Reduced feed wastage because of accurate feed metering	High cost of the tracks Tractor must be equipped with a ground speed PTO Increased scrubbing from the tracks.
Design 5- Fence Feeder Systems	£57,000-£66,000	£13.20/head/year (excluding 125kg/feed/sow/year saved from wastage)	Increased accuracy Decreased disease risks (sealed pipes and trough feeding) Reduced wastage Reduced feed cost of moving from 15mm rolls to 6mm pellets from £3-6/t	High capital expenditure Labour intensive to set up Requires different lines and silos for dry and lactating sows
Design 6- Low Cost Bulk Feeder	£11,500-£13,500	£2.70/head/year	Low ground pressure hopper can be made from second hand materials i.e. adapted plastic diesel tanks	No precise metering system Does not eliminate environmental impact and still causes compaction

Evaluation of designs/ discussion

After a thorough evaluation of all of the above designs, it has been suggested that design 2 - the light-weight bulk bin and design 4 - the over fence feeding system, would be most appropriate to overcome the problems of existing feeding systems.

Design 2 - lightweight bulk bin

The key features of design 2 are the inclusion of a large lightweight bulk bin with a holding capacity of 4-6 tonnes. The hopper is made from Glass Reinforced Plastics (GRP) allowing for a strong and durable holding tank. The addition of large flotation tyres fitted on a wide wheel base (3m) improves stability, which is of paramount importance when feeding in the winter months over soft ground. These large low ground pressure wheels have also been selected with the aim of reducing soil degradation.

The metering system fitted to this feeder has been designed to provide a simple, reliable and robust unit, with a long working life, requiring minimal labour and servicing. The feed distribution unit allows for the accurate measurement of feed. The long discharge arm provides good reach and accuracy for feeding over the electric fences into the troughs whilst maintaining good visibility of the spout and the use of the hydraulic ram allows for the discharge arm to be folded away for road transport. The overall total dimension of the trailed feeder allows it to be legally towed down the road from field to field.

Finally due to its robust and light-weight construction, this trailed feeder has a low horsepower requirement, which makes this machine suitable for the implementation into existing outdoor pig farms. With a lower investment cost than the over fence feeding system it will likely be the preferred choice amongst farms as this feeder still provides the desired reduction in the environmental impact of the feeding process.

Design 4 – The over fence feeding system

The use of the pipe and auger system allows for soil compaction and rutting, caused by traffic passing on tracks, to be completely eliminated from outdoor pig production. This system is fully automated reducing the overall labour requirement, thus reducing pigmeat production costs. The principles of the design are based on bringing indoor pig production facilities outdoors, as indoor systems have reduced feed usage and wastage by up to 125kg/sow (BPEX, 2014).

How the system works?

Pelleted feed is augured along the paddock division on fences, where it falls into feed dispensers (filled to a specific weight) before being dropped into troughs.

The use of individual feed dispensers allows for precise feed increments to be delivered to grouped and single sows throughout the farm. These increments can be set from as low as 0.5kg up to 7kg and increased or decreased by 100g.

By feeding in this manner, grouped and individual sows can be fed and managed with different weights of feed being set in seconds. To calibrate each feeder, simply weigh the feed that has been dropped. Calibration is only required when a change in feed occurs.

Benefits and Drawbacks of the System

One of the main drawbacks in this system is that only one type of feed can be fed to the entire herd. This causes problems, as lactating and dry sows are unlikely to receive the same diet, as their nutrient requirements at these stages are very different. A possible solution to this would be to have a dedicated dry pipeline and a dedicated lactating sow pipeline. This however drives up set-up and equipment costs with the need for 2 x tower silos and 8 x electric motors (depending on how many lines are required).

With an estimated total cost of £57,000-66,000 (quotations for equipment obtained from available product suppliers), it is an expensive option. This high initial set-up cost does not include labour therefore costs will be increased further. The benefit however, is that with the reduced labour and one less salary estimated at £18,000, the system would payback over 3.6 years (set-up labour cost not included). The payback period is based on the elimination of a salary and does not included reduced feed wastage/usage.

As one site is only in operation for between 3-5 years, the easily portable design of the pipeline system is critical to its uptake. All parts used in the system can be stripped back and rebuilt at a new location, a key feature in its design. One section however, which is not portable, is the concrete required to stand up the tower silos.

The reduced feed wastage, ability to reduce feed costs from cobs to pellets and the minimised impact on the environment and soil structure indicates that this system, if well planned, could prove to revolutionise the way outdoor pigs are fed in the near future.

Conclusion

The outdoor pig rearing and breeding industry currently faces major problems all revolving around the environmental impact of existing feeding systems. It is well documented that the existing systems have numerous limitations such as; causing soil erosion, compaction, heavy rutting, surface run off, feed losses, nutrient leaching, poaching and nutrient hotspots. It is important that the industry responds to these problems to enable outdoor pig farming to succeed in the future and avoid large amounts of legislation and heavy fines. If farmers were to move towards a trough based system, many of the existing environmental problems that the industry faces could be reduced. It is recognised that it will come at an expense to the farmer, but will enable better soil management and crop cover of the pens to be maintained. The use of auto feeder systems or low ground pressure trailed feeders will mean that tracks can also be better maintained to further reduce these problems.

Trough systems will also reduce feed losses and health issues caused by soil ingestion. They will also help to improve the profitability of the outdoor pig industry by reducing feed waste and input costs. Input costs will be reduced via the change from 16mm rolls to 6mm. Overall this will improve efficiencies in outdoor pig production and help to reduce the carbon footprint.

The designs that we have chosen help to combat these problems, thereby ensuring that outdoor pig production moves forward. The low ground pressure feeder design is a lower cost option compared to the use of over-ground auger pipes, however the over ground system is a long term solution to the issues that have been raised in the current system. It is down to individual farmers to decide which is most appropriate in their system and how much they are willing to spend in relation to reducing their environmental impact.

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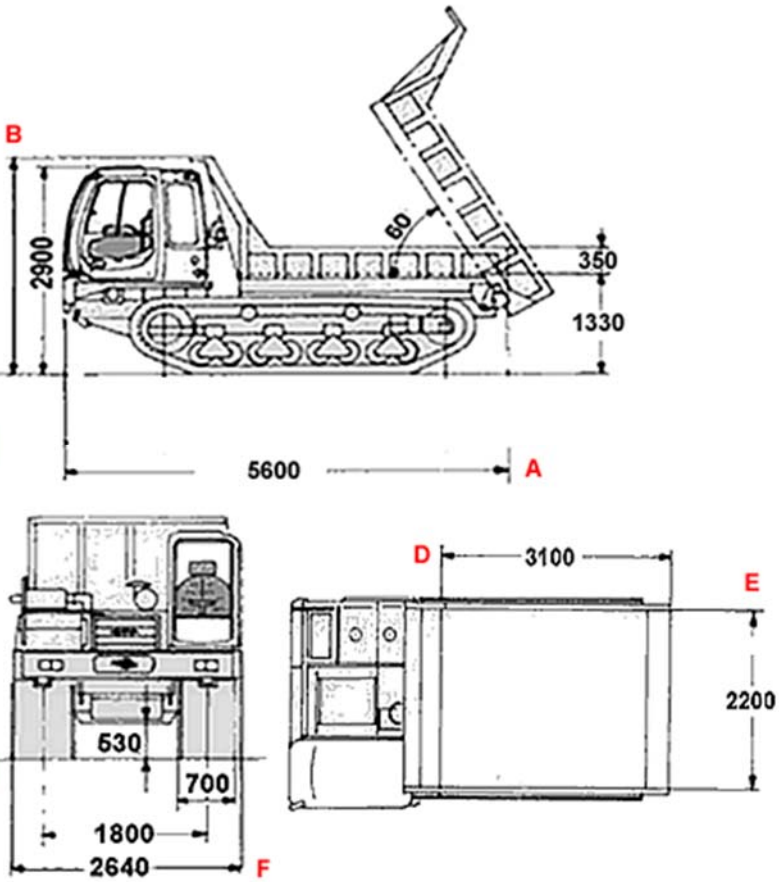
Appendix 1

TDH100: 10 TONNE PAYLOAD	
Full specifications	
Full Length (A) mm	5600
Full Width (F) mm	2640
Full Height (B) mm	2900
Machine weight (kg)	9200
Dump Body L (D) mm	3100
Dump Body W (E) mm	2200
Dump Body H mm	350
Ground Clearance (mm)	530
Track Width (mm)	700
Max. Payload (kg)	10000
Cabin	Yes
Engine Make	Hino
Engine Model	K13D-F
Fuel Type	Diesel
Fuel Tank cap (litres)	156
Braking	Service
Drive System	HST
Transmission	2 Speed
Performance	
Ground Pressure kg/cm2	0.17
Ground Pressure psi	2.4
Speed 1st Gear km/h	0 -7.6
Speed 2nd Gear km/h	0-11
Gradient Ability (deg)	57
Turning radius (m)	3.05



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http://www.trackeddumperhireuk.com/specs/tdh100.htm

Appendix 2

Quotations received from John Harvey Engineering

FARROW FEEDERS			
	SINGLE FARROW FEE	Part assembled	£ 155.90
BQP/WSG assembly inc, rest agree price for assembly			
OPTIONS			
	PLASTIC CHUTES	common	£ 17.70
	RAIN GUARD		£ 17.70
	BOLT ON GROUND PIN	uncommon	£ 5.30
	KNOCK IN GROUND PI	uncommon	£ 4.50
	FARROW FEEDER	2 SINGLE FARROW FEEDERS, 250Litre ANTI-BAC TANK, FLOAT VALVE, LEVEL INDICATOR, 2 LARGE BITE NIPPLES, 2 SINGLE FARROW FEEDERS	
	2 x SINGLE FARROW		£ 311.80
	250 LITRE TANK c/w		£ 209.50
	COMPLETE FARROW FEEDER	TOTAL COMBO PRICE (WITHOUT PLASTIC CHUTES)	£ 521.20

LONG FEED TROUGHS			
	7.5m ASSEMBLED	EAST ANGLIA DELIVERY	£ 204.80
	6m ASSEMBLED	EAST ANGLIA DELIVERY	£ 176.50
OPTIONS			
	KIT FORM DEDUCTION IN EAST ANGLIA		
	TROUGH JOINERS		£ 8.90
	REBAR GROUND HOOKS		£ 6.90
	WOODS		
	9" x 4" WOODS - comn	EACH, INCLUDING NUTS, BOLTS & WASHERS	£ 10.80
	FIT 9" x 4" WOODS (2	PER TROUGH	
	4" x 4" MIDDLE	EACH, INCLUDING NUTS, BOLTS & WASHERS	£ 5.00
	FIT 4" x 4" WOODS -	PER TROUGH	

Appendix 3

Collinson AGRICULTURE

Delivery Address:	**Niall, Harper Adams College, , , , ,**	**Quote Date:**	**20/03/2015**
Invoice Address:	**Niall, Harper Adams College, , , , ,**	**Valid Until:**	**19/04/2015**
Contact:	**Andy Howard - Mobile: 07736 560898 Office: 01995 607438**		

To supply parts for drops and drop tubing.

Rotaflex Conveyor Parts Quotation No: Party

Part Number	Description	Qty	Price	Total
1CR-MEX02	Rotaflex - Assembly & User Guide - Free of Charge	1	£0.00	£0.00
CRN-E170G	R75 - Type 101 Outlet Kit - 70 Outlet - w/o Cut Off Slide	1	£3.30	£3.30
CRN-E170F	R75 - Type 101 Outlet Kit - 70 Outlet - c/w Cut Off Slide	1	£6.51	£6.51
MQ4-W7025	Corevex - Drop Tube - White - Swelled Ends - 70/67 x 2.5m	1	£5.76	£5.76
BHR-07603	Rotaflex - Drop Tube - Flex/Conn Kit - 76 i/d x 0.33m	1	£15.48	£15.48
Total including chosen Delivery/Fitting Option				**£31.05**
Terms: Payment within 30 days of Invoice date				**VAT Extra**

Exclusions:
1. Any sum for the hire of suitable Access/Lifting Equipment, should this be deemed necessary by Collinson engineers. If you wish to source or hire your own Access and/or Lifting Equipment, then please refer to the "Access Equipment Specification" datasheet available on request.
2. Collinson engineers are not permitted to undertake any work that will involve contact with Asbestos or materials containing Asbestos. If any element of the work we are to undertake involves contact with Asbestos, the material must be removed prior to any installation work by Collinson engineers or the element of work involving Asbestos must be undertaken by the Duty Holder/Owner or a Contractor qualified to do so.
3. Fitting area to be free of animals & any other obstructions.
4. All electrical work (please note we can quote for this work separately, see below)
5. Making good walls, roofs etc.

Additional work: We can quote for the electrical wiring and connection to the mains by separate tender. Our ECA registered electrical engineers will ensure your system is installed and commissioned to the highest standards.Health & Safety: Risk Assessments & Safe Systems of Work will be conducted prior to installation work.

Collinson plc. Riverside Industrial Park, Tan Yard Road, Catterall, Preston, Lancashire PR3 0HP
Registered in England No. 3267051 | VAT Registration No. 677452988
To Order phone the Collinson Orderline Tel: + 44 (0) 1995 606 451 Fax: + 44 (0) 1995 605 503

Appendix 4

£5,250

€7,236

Generators

4000 Hrs Used

Diesel

Good Overall Condition

Static

165 kW

2,850 kg GVW

Ingersoll rand G130 kva,2003,approx 4,000 hrs Base fuel tank, 6cylin turbo John Deere engine, Leroy Somer alternator, runs and makes power £5,250

Get Insurance quote