final report

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Feasibility of manure collection automation

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Executive summary

Automated manure collection from feed-lots is a viable proposition using mostly existing technology with some enhancement for the unique circumstances of this industry.

The study undertaken was as a joint venture at the invitation of MLA, in response to problems encountered by every feed-lot operator certainly in Australia, but also internationally. The problems are:

- How to collect and dispose of manure from pens in a more efficient manner and with less disruption to the lot. The current methods are not ideal because they are expensive in machines and labour, damage the feed-lot surface and disrupt the operation of the pens.

- In many cases feed-lot pens are cleaned only from one to 4 times per year, leading to an almost overwhelming quantity of manure that has to be dealt with at once, as well as issues that are costing the industry money in terms of lost animal weight gain and health issues such as lameness.

- This study examined typical feed lot operations in both wet and dry conditions, and the quantities of manure produced per animal. It then looked at existing technologies used for manure collection (mainly confined to dairy operations) and determined how best to apply known technologies, with modification, to the current problem.

The original project scope asked for full autonomous operation (no human driver) for the proposed solution. Whilst this does not form the main thrust of the project at this stage, we fell that existing autonomous vehicle guidance technology is advanced enough to be applied at a later stage. The feeling being that the development of the mechanical solution, for manure collection, is the most pressing problem to be solved by this relatively small scale study. This in itself will provide benefit enough in the short term, to give sufficient confidence to proceed with the full scope, in a later project.

The benefits to the industry if this project recommendation is adopted will be:

1. Efficiency of cleaning pens without damage to pen surfaces in handling manure from slurry to hard cake, in almost any weather conditions.
2. A solution that can operate with animals still in the pen.
3. Reduced labour and machinery costs because a single machine can potentially replace a variety of currently used earth moving machines.
4. Benefits to animal productivity, comfort and health issues such as lameness by keeping the quantity of manure in the pen down.
5. Possible utilisation potential of collected manure as a source of bio-gas, because it will be collected before loss of volatiles.

This machinery, if developed, could be used in other farm manure collection scenarios. For example dairy and pig farms. Anywhere where a large number of animals create a quantity of manure in pens of approximately 30m x 30m or larger.

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1 Background

1.1 Feed-lot Manure Control

1.1.1 Is this Happening at present?

In short, the issue of manure control is an 'elephant in the room' so to speak. It is acknowledged as being necessary but expensive. Up to now, no one has come up with a better solution than collection periodically with earth moving machinery such as box scrapers, excavators, front end loaders and dump trucks.

Weather plays a role in the current frequency of manure collection. In wet weather it is more detrimental to the pen surface to use machinery in the pens, machinery sinks into the softened underlying pen surface. As a consequence, collection it is left until the overall water content decreases. This can have a negative effect on animal productivity and health issues such as lameness and only increases the scale of the problem to be dealt with.

Another barrier to an effective solution, is the actual dollar cost of manure collection. Contractors are the usual solution in big feed-lots because of the capital cost of up to 2 excavators, 2 front end loaders and five dump-trucks. In the smaller lots everyone has a tractor and so a box scraper is used to mound the manure. In some cases it may be left for up to 4 months to degrade and dry down before being removed. We had one operator tell us that they had contractors on site continuously cleaning pens with wet manure and the cost was up to A$10k per day.

Current methods of control are not efficient and can result in a degradation of the pen surfaces. This is because the machinery used is not able to control the depth of cut within tolerances required. As a consequence more capital should be used to re-establish the pen surface. In reality this rarely happens, in some cases pen resurfacing was reported to have not occurred in 20 years. The results were clear to see. Drop-offs from the aprons of 300mm were not uncommon and the manure collected clearly contained a lot of material from the pen surface. This has to be screened out before being reapplied as fertiliser on fields.

This project sought to look at and quantify the issues faced prior to attempt to put real numbers on any potential solution. The initial approach from MLA and talks with Scott Automation had considered a large version of the scraper used to clean alleys in dairy sheds. The potential solution after this project draws on current technology utilised in the dairy industry with modifications.

2 Project objectives

2.1 To determine the feasibility of Automated feed-lot manure control

2.1.1 Research technology that has been applied for material handling collection in agriculture and broader industries.

2.1.2 Report the scope of required outcomes for a feedlot manure scraper after industry consultation and research.

3 Methodology

3.1 What is the industry attitude to Manure Control

3.1.1 Available Technology for manure control.

It is always preferable to look for existing solutions to any problem. There is no point 'reinventing the wheel'. Research indicated that self-guidance would not be a problem as there are many instances of autonomous machines operating in the agriculture, mining and construction industries. There are unique problems to be solved, but we feel that the existing technology is sufficiently advanced to be applied here, but that it is in itself a complex and separate project within MLA and should be divorced from the scope of this project because of the complexity of manure collection.

We focused our initial research on what was used currently for manure control in any field of animal farming, with specific applications in the dairy industry. We found a number of promising technologies used in the dairy industry but nothing specifically aimed at manure with less than 50% moisture content. All current technologies were aimed at slurry collection off concrete floors on a daily basis.

3.1.2 What does the data show.

We visited feed-lots within Australia, with MLA staff assistance, to a determine the scale of the problem and what methods are being employed currently.

MLA supplied data from various published sources which we have extrapolated to quantify the amounts of manure that any potential solution may have to deal with. As it happens this data was more accurate than the anecdotal evidence from feed-lot operators which over-estimated the quantities involved.

We looked at technologies we could adapt to achieve manure collection in any environment from slurry to hard cake and built a micro-scale machine to test these theories.

We examined the current mind-set of feed-lot operators to see how they felt about the problem of manure collection and how they would like to see it dealt with. This in itself was interesting because although they were frustrated by the issue and the effect it had on their productivity they appeared almost resigned to the status-quo. One of the factors to be overcome with any potential solution is the willingness of the feed-lot operator to change the way they deal with the problem. For example an increase in frequency of collection (wet or dry) and the need to repair and maintain the pen surfaces (that in some cases are so degraded that the cost of repair will be substantial).

4 Results

4.1 There is a solution

4.1.1 Constraints

We feel able to say that a mechanical manure control machine can be developed, with existing technology forming the basis of the solution. Development of the final solution should proceed with concentration on the means of breaking and collection the hard cake manure material that will be most common in the drier periods of the year. Milestone Report 2 indicated that the average cow produces 3.8kg of dry manure per day *(see extract from Milestone 2 Report below).* 1.4 tons / cow / annum.

> *"Let us consider an individual animal of average weight 600kg. The amount of fresh manure produced per year is approx. 13 tons. But the amount of matter removed from the pen is (according to literature) on average 1.4 tons / animal / year, with a moisture content of roughly 30% and a decomposition of also roughly 30%.*
> *If the average 2750m² (50 x 55m) pen holds 500 animals then that pen has 700 tons / annum to be removed.*
> *The above figure is at odds with some of the observed data from NSW after a particularly wet winter in 2016, but is consistent with observations from QLD where conditions were a lot drier overall.* "

We therefore believe that cleaning pens weekly is reasonable and in fact desirable. This is based upon our manure collecting solution being capable of holding 10 tons of manure in a single load before the need for emptying. A far more rigorous study would be needed to determine that actual quantity of manure deposited per week by 500 cows but we believe from the data that if a cow deposits 3.8kg/day, that this amount will decrease by natural means slightly over the week on the ground and that if there were 500 cows in 1 week would create 10 tons of manure.

Increased frequency of cleaning will encounter some resistance from operators to start with, until the second phase of autonomous guidance is implemented. To start with there will be little or no decrease in labour requirements, because an operator will drive the machine around the pen. But once this is autonomous the machine will drive around without human intervention and only return to base for refuelling and cleaning.

We also believe that unless feed-lot operators adopt the principle of cleaning and maintaining feed pens more frequently than current practice, the introduction of new technology will fail. Therefore it is imperative to get operators to alter their current perception of the issue of manure collection.

4.1.2 Direction.

We believe that there is an technology currently utilised in the dairy industry fulfils 75% of the requirements for manure collection, but that it will require modification to deal with the variety of manure present in feedlot operations. For example, as stated, most current technology is designed to operate on manure slurry. Therefore the modifications will deal with the problem of the various physical forms of feedlot manure. This is where the project risk is concentrated. Without full scale trial it is difficult to fully access the power requirements and design criteria. But since it is an add-on to the existing machine the risks are limited and additional research and experience will indicate the starting point.

There are a number of machines, not just in manure collection, but construction, that use vacuum or belt to convey material from collection to hopper.

Honey Loader

Nuhan Alley Vacuum

Mensch manure vacuum

Veolia Vacuum Excavator

Why wouldn't we use existing tractor pulled appliances? The answer is that these cannot manoeuvre efficiently in the environment intended. A self-propelled and compact machine is required. Also animal safety is a concern. If a machine is manouvering within a pen with animals present, the whole machine must be sensed, so that animals cannot be harmed by it. A single body is a lot easier to guard than 2 separate items which would approach 12m in length.

It was after more searching that we found what we consider to be an ideal vehicle for conversion for this purpose. The criteria being:

1) Power (In excess of 100 hp).
2) Load carrying capacity (10 tons or greater).
3) Compact foot print.
4) 4 wheel steering with 4WD.
5) Hydrostatic drive with additional capacity possible.
6) Driver's cab suitable for modification for Autonomous control.
7) Manure unloading devices controlled from the cab.
8) Retractable scraper
9) Good speed control from working to transporting to the dump site.

Further investigation is required to determine if the vehicle is adaptable for feedlot conditions.

5 Discussion

5.1 Issues tackled

5.1.1 Industry Practice

The feedlot industry needs a solution that will operate in all conditions at any time of the year with minimum impact on their operation of the feed-pens. There is no current best practice, with every operator irrespective of size, preferring their own method. For example visiting different operations in different states of Australia netted 3 different approaches to manure control. The assumption would have been, that the smaller operators were less inclined to spend money on feed pen maintenance. In fact the reverse was true. The smaller operators had quarries on-site for pen surface material and in one case resurfaced pens, alleys and roadways annually or as the need arose. Whereas one of the largest operations visited had not resurfaced pen surfaces for 20 years.

The smaller operators generally used a site tractor and box scraper, whereas the larger players hired contractors who used heavy earth moving machinery to achieve the goal.

5.1.2 Practical implications.

There is no clear data to suggest frequent automated pen cleaning will benefit the industry by a given dollar amount. But it is clear that decreased weight gain, and possible increased incidence of lameness is costing the industry considerable sums in lost production. Whilst it cannot currently be proved that weekly feed pen cleaning, pen surface maintenance drain cleaning and road maintenance will save a specific dollar amount, it can be reasonably suggested that it could help to improve animal comfort and by inference productivity.

In the short term an operator will have to drive the manure collection vehicle around the pens and to the dump site. But as stated, existing technology can eliminate the driver in favour of GPS & laser guidance. But the amount of machinery used and its impact on the feed lot operation should be seen to be less than current practice. Even machinery running & maintenance can be considered a fixed known cost, because the machines will be running for specific time periods, dependant on the number of pens. We can imagine that companies would lease the machines and pay a fixed amount based on use time.

5.1.3 How was the proposed solution arrived at?

First by looking at all available research and information on the internet, and by talking with feedlot operators. We were surprised at the lack of innovation in the area. There is plenty of effort applied to dairy sheds and barns but nothing for feed-lots. Dairy sheds have numerous devices for manure control:

a) The sluice method where a large volume of water is released to cascade down the alleys and wash the manure before it down into pits for processing.
b) Cable pulled scrapers that slowly traverse from one end of an alley to the other, 'bulldozing' manure before it.
c) Tractor driven bucket scrapers and self propelled vacuum scrapers.

There are even dewatering presses that remove water from slurry to enable windrowing of the manure solids. None of this has been applied to feed-lots.

The assumption is that in the close confines of a concrete floored dairy shed or barn, manure is a real problem. It doesn't soak away, or degrade down or evaporate as quickly as if it were in an open dirt floor environment. Therefore it has to be dealt with on a daily basis. Also in the dairy environment cleanliness of the animal is more important because you are collecting the milk which can't be contaminated with faecal matter.

Feed-lots are generally located in areas that are dry and can hold many 10's of thousands of animals. The water content of the manure quickly drains away or evaporates and the odour is not an issue if grain processing and pen drainage is adequate . Therefore leaving the manure in place is not viewed as a bad thing. After time it naturally decreases in volume and consequentially cost to remove. Manure piles are often viewed as places where cattle like to congregate and lie. If the weather is favourable there is not a problem. However if the weather in an area is unseasonal, such as occurred in the Riverena in 2016, then there is most definitely a problem.

Secondly thinking about the various methods of 'collection' of material over a wide swath.

6 Conclusions/recommendations

6.1 Phase 2 – Full Machine Prototype

6.1.1 What Next?

We recommend that MLA finance 2 additional projects to run consecutively. The second based on the success of the first project.

We recommend that the 2 projects be progressed:

1. the development of a manure collection vehicle.
2. the development of autonomous guidance of the vehicle in project 1.

7 Key messages

7.1 Change

7.1.1 Automation is not easy.

There are some culture changes that the feed-lot industry would have to adopt if automated manure collection was to be adopted or indeed if it were to be successful at all. This is common to all industries that turn away from the human element of control and move toward machine control. 'People' are the most amazing automated control devices around. They simply lack consistency, they make mistakes, they make judgements based on irrational decisions, they get tired and bored. Machines on the other hand are the polar opposite but have one great disadvantage that makes them challenging to implement. That is they only do as they are programmed and cannot make adjustments easily for the unexpected or the unusual. As such the 'environment' they operate within must be controlled.

As such a rutted and variable pen surface, with variable obstacles is not ideal for automation. Gates that require opening with tricky latches or difficult terrain with objects left lying about cannot be tolerated. Machinery cannot be left out in the open in amongst the weeds and expected to operate flawlessly. These things can be accommodated but at greatly increased cost and complexity and we suggest would be unsuited to this environment of tractors and manure.

Therefore in order to make automation work in the intended environment, certain changes must be adopted by the human inhabitants.

1) Consistent pen surface as close to ideal as possible must be maintained.
2) Alterations to layout and access may have to be considered.
3) Alleyways, roads and dump site must be maintained in ideal condition
4) Gates and people machine animal interaction will have to be considered and rules governing interaction implemented
5) Machines must be maintained by skilled personnel. Washed frequently and maintenance tasks followed to the letter.

These changes are often viewed as additional unnecessary costs. People have to accept that in fact they are costs they are bearing currently but are often hidden.

For example if a tractor were washed and kept under cover when not in use and maintained regularly it may not break-down with attendant losses in productivity. The costs could be known and evenly spread, instead of appear unexpectedly. Budgeted rather than ignored.

7.1.2 Automation is just an additional cost.

This is the view often taken because it does not appear always to remove the element that most people expect. For example “if I automate I will be able to decrease the labour requirements”. Partly true. In some cases that labour unit is saved from the boring repetitive job to be redeployed to achieve a task(s) currently not being done. Automation is not the end of human effort, it is theoretically, the end of boring jobs done, with varying degrees of thoroughness, by people who don’t really want to do those jobs.

Agriculture is experiencing a scarcity of good labour in all areas. Automation is seeking to address this problem by eliminating the repetitive and replacing it with skill. For example one skilled mechanic can maintain many machines if that maintenance is planned and scheduled.