ROUTE PLANNING REDUCES THE COSTS OF ANIMAL TRANSPORTATION: ANIMAL WELFARE VERSUS ECONOMICS

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SUMMARY

Animals are more stressed on long transport routes with stops at many farms. The positions of farms and abattoirs are the basic properties that set the limits for route planning. Mobile abattoirs can reduce the cost of transportation and increase the welfare for the animals. The trade-offs between welfare and profit can be reduced by effective route planning. We have, by computer simulations, investigated how trade-offs differs between areas in Sweden and in general landscapes. The general results are applicable to any area and hence for animal transportation in general.

Keywords: animal transport, route optimization, 1/f noise, DFT, cost, animal welfare

INTRODUCTION

Long animal transports are both stressing for the animals and expensive. During transport, animal stress can be caused or increased by: weather conditions, handling, road conditions, meeting unfamiliar animals and long transport distances (Atkinson 2000). Longer transports could cause a higher percent of PSE (pale soft exudative), DFD (dark firm dry) and bruising defects on meat (Atkinson 2000).

We have studied how transport distance and the number of stops vary with respect to landscape structure and transport strategies. The basic structure of a landscape, distribution and number of farms and abattoirs, determines the limits for route optimization. We have tested different transport strategies in Sweden and specific areas in Sweden: Skåne, Östergötland and Västergötland. We also used neutral (virtual) landscapes with different landscape structures. By using virtual landscapes we can get a large data-set, analyze structures that are perhaps not available in our sample of the real world and get more general results.

Animal transport routes can be optimized with respect to animal welfare, economics or a combination of both. We have analyzed how the trade-offs between these changes with more effective route planning. We have made an algorithm that generates transports on a scale from very random to almost like the route planning algorithm of Clarke and Wright. Route planning for animal transports has been done in some areas in Sweden; for example in Uppsala (Ljungberg et al. 2006) and Västergötland (Algers et al. 2006). With our model of both optimized route planning and route planning that might resemble what is done today; we can compare the effects of effective route planning on a larger data set.

The number of abattoirs determines how good the routes can become in Sweden given that the farms are where they are. We have studied the effect of the small abattoirs and how transport distances could be shortened with mobile abattoirs.

We will see that the landscapes in Sweden have different basic properties for route planning, and what the gain is of effective route planning. We will also se how small-scale and mobile abattoirs influence the transport costs in Sweden.

THEORY AND METHOD

We have focused on models of cattle transport. We have used the coordinates for 22657 farms with cattle in Sweden. To analyze the differences in different regions we have chosen three areas of size 100x100 km, in Skåne, Östergötland and Västergötland, with 2517, 1021 and 2026 farms respectively. To analyze how transports in these landscapes differ we have placed 1–16 animals from a uniform distribution on each farm and simulated transports with different transport strategies. Sweden has 28 large and 40 small abattoirs, and we have assumed that animals are transported to the nearest of these abattoirs.

Transport strategies

The different transport strategies we use are: (i) Clarke and Wright is a heuristic which is commonly used in route planning and (ii) a modified version that more resembles a good choice than actual planning. Both algorithms starts with every farm on its own route and makes sure no route has more than 16 animals or is longer than 500km. Clarke and Wright iteratively connect the farms that will increase profit the most (minimize truck distance). The other method works in a more random way and resembles good choices made by transport operators. It takes a farm at random, connects the farm to up to two other farms, takes a new farm at random and works through all farms in this way. The "up to two" is partly because no farm can be connected to more than two farms and partly because a farm can keep the connection to the abattoir. When connecting the farms we use a 2-dimensional probability distribution to decide which sites (farms and the abattoir) the farm will be connected. The probability for connecting two possible sites is: $p=\exp(-d^b/k^b)$ where d is the distance between the sites. The parameter b determines kurtosis (peakedness) of the distribution; a low b gives a high kurtosis and farms that are very close are more probably connected than those further apart. The parameters k and b determines standard deviation and determines how far away farms could be connected. Large k and b gives very random transports; on the contrary low k and b means that only very close farms will be connected and these routes are more similar to Clarke and Wright. We have used standard deviations 10, 25 and 50 km and kurtosis 10/3 and 1.5. Uniform distribution has kurtosis 4/3 and an exponential distribution has kurtosis 10/3.

Virtual landscapes

We compare the transports in Sweden with transports in virtual landscapes. A landscape with aggregated farms may have different properties than one with more uniformly distributed farms. To generate landscapes with different levels of aggregation we use spectral methods. We generate a fractal 2-dimensional 1/f-noise, with discrete Fourier transformation (DFT) (Halley et al.2004, Keitt 2000). We start with a Gaussian white noise landscape, i.e. a 100x100 matrix L with random placed values drawn from a Gaussian distribution. We transform L with DFT and scale the amplitudes with $|f|^{-\gamma/2}$. This gives a spectral density function proportional to $|f|^{-\gamma}$. The inverse transform of the scaled matrix is the aggregated landscape.

The parameter γ measures aggregation. A high γ means that we have a landscape where waves with low frequencies dominate, which is the same as an aggregated or red landscape. For γ=3.5 we get very aggregated farms and γ=0 gives uniformly distributed farms. We have used γ 0, 0.5, 1, 1.5, 2, 2.5, 3 and 3.5 in the analysis on virtual landscapes.

The DFT gives a landscape of continuous values, but farms are discrete. Because we can have no negative farms we scale the landscape by subtracting the lowest value. Then we normalize the landscape so that it sums to wanted number of farms. After that we determine what limit fraction shall be rounded up to get a landscape with the wanted number of farms. We then distribute the farms uniformly in the squares. We test with 500, 1000, 1500, 2000 and 2500 farms.

To find γ for the landscapes in Sweden we fit a line to a log-log plot of amplitude versus frequencies of the spectral density function. The slope of this line depends on parameter γ and on the density in the landscape. We have by simulation estimated a numeric function between γ, density and the slope of this line; with that we estimate γ. We have estimated γ for Skåne, Västergötland and Östergötland to 1.5, 1.2 and 1.0 respectively.

The abattoirs are placed randomly in the simulated landscapes. Skåne, Östergötland and Västergötland have 2, 4 and 8 abattoirs respectively. So in the virtual landscapes we test with 1–8 abattoirs. We consider the abattoirs as periodic. When we model mobile abattoirs in Sweden we iteratively consider the farms with more than 100 km to nearest abattoir, and add a mobile abattoir in the area where the total distance gain is the most.

RESULTS, DISCUSSION AND CONCLUSIONS

For animal health we look at how far the animals are transported and how many stops there are on their routes. For the costs we measure how far the truck is transported. Because we want to compare different landscapes with varying number of farms and animals we divide the cost with number of animals, so it is cost per animal.

To evaluate the direct effect of route planning we compare the generated routes with the scenario that every farm gets its own route. This is not a realistic scenario, but by comparing these scenarios we can evaluate the effect of the transport strategies. We define relative animal transport distances by mean transport distance for animals divided by the same for the scenario where they get their own route. In the same manner relative costs are costs divided by costs for the scenario where every farm got its own route.

Skåne has the best properties for animal transportation; animals are transported almost twice as far in Östergötland (fig 1).

In all landscapes, virtual and real, we can see that Clarke and Wright give the best transports both for animals and economics. When evaluating relative welfare against relative costs, figure 1, we can see that Clarke and Wright decreases costs the most (about 40%) without increasing transport distance for the animals very much (<5%). The mean number of stops for the animals is 1.78 (varying between 1.59 and 1.92) for Clarke and Wright compared to 1.72–1.73 for the 'good choice' heuristics (varying between 1.53 and 1.88). Clarke and Wright gives 6–30% lower costs and 2–24% shorter transport distances for the animals than the other heuristics; the lower values are for the smartest heuristic of the 'good choice'. For the study in Uppsala optimization could save 18% (Ljungberg et al. 2006). The study in Västergötland found potential savings 14%–23%.

An ANOVA on the transports in the virtual landscapes shows that the most important, about 90% of M.S., for total transport distances and costs are the number of abattoirs, #A, i.e. for transport distances (#A 92% and heuristic 8%) for costs (#A 87% and heuristic 12%). For the relative costs and welfare the heuristic is most important (about 90%), i.e. relative transport distances (heuristic 92%, γ 4% and #A 3%) and for relative costs (heuristic 91%, #A 4% and γ 4%). The number of farms and the interactions always explain less than 1%.

In figure 2, we can se the differences in costs and welfare in Sweden when removing the small abattoirs or adding mobile ones. With effective route planning the animals are transported about 13 km shorter with small abattoirs and yet 2 km shorter with mobile abattoirs. More interesting than the effects on the mean is the effect for the 2.5% of the cattle that are transported longest distances. With the small abattoirs this is decreased from 140 to 90 km and with the mobile ones it is decreased to 70 km (this is for Clarke and Wright heuristic).

The conclusions are that an effective route planning decrease both costs and mean transport distance for animals, but slightly increase the number of stops. Landscapes in Sweden have different basic properties and therefore different limits for route planning. The small-scale abattoirs in Sweden are important for costs and animal welfare and especially for those animals transported the longest. Mobile abattoirs could improve the welfare even more.

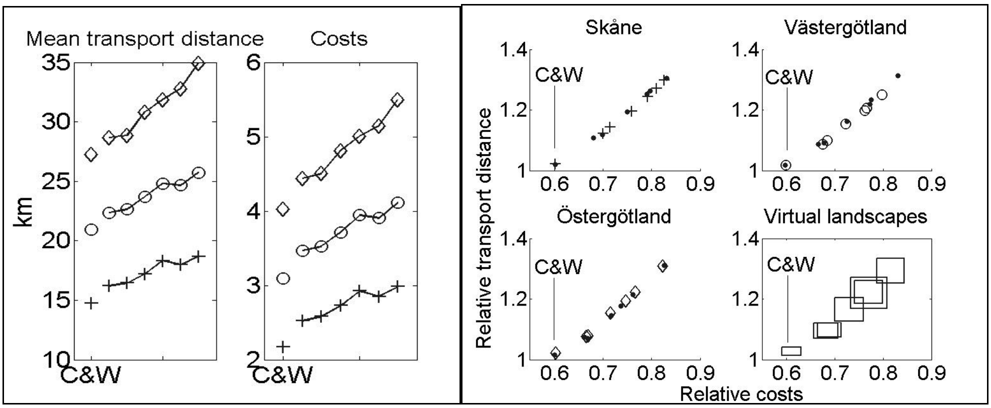

Figure 1. Plus signs is transport in Skåne, circles Västergötland, diamonds Östergötland and dots virtual landscapes. Clarke and Wright is indicated in the figures (C&W). The other markers are for the 'good choice' heuristic. Left: Mean over 20 replicats and redistributed animals for every replicate. The standard deviations are less than 0.6 km for the transport distances and less than 0.07 km for the costs. Right: Relative costs and mean transport distance in real and virtual landscapes. Mean over 10 replicats for virtual landscapes. Squares show 95% av the transport means per heuristic

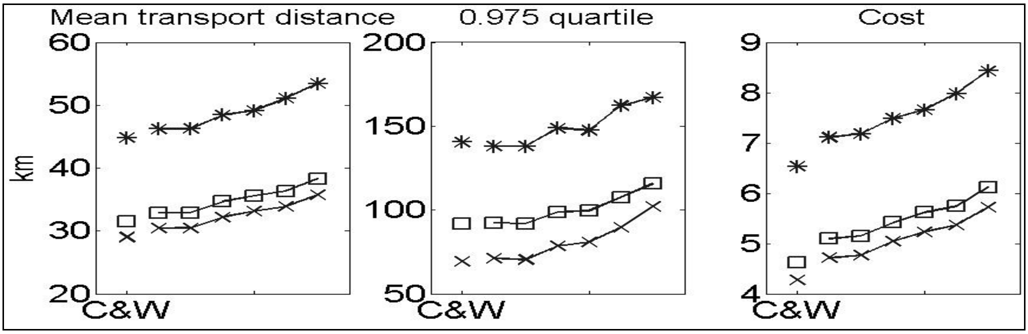

Figure 2. Transports in Sweden mean over 20 replicates. The standard deviations are smaller than 0.3 km, 1.1km and 0.03km. Stars are only large abattoirs, squares are small and large abattoirs and the crosses are large, small and mobile abattoirs

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