Road and Landing Spacing Under the Consideration of Surface Dimension of Road and Landings

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ABSTRACT

Methodologies are developed for optimal road and landing spacing when considering roads and landing with surface dimensions. Example shows that the width of road and the size of landing do affect the solutions to optimal road and landing spacing.

Keyword: *Road width, landing length and depth, road spacing and landing spacing.*

INTRODUCTION

When considering roads and landings as features with surface dimension, the mathematical formulas for the optimized road spacing and landing spacing should be appropriately changed to reflect the magnitude of the surface dimension of the road and landing (note that the conventional road and landing spacing planning process does not take the surface dimension into account [1,3,4,5]). In the following cases the formulas of road and landing spacing are derived for two different road and landing layout patterns.

Case A.

When considering a road as an entity with surface dimension, the timber is skidded to the edge of roadside, not on to the road (see Figure 1).

The maximum skidding distance is one half of the road spacing (**S**) minus one half of the road width (**W**) [2]. Therefore the Average Skidding Distance (ASD) is:

$$ASD = \frac{(S - W)}{4}$$

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The area served by one unit length of road is (**S-W**).

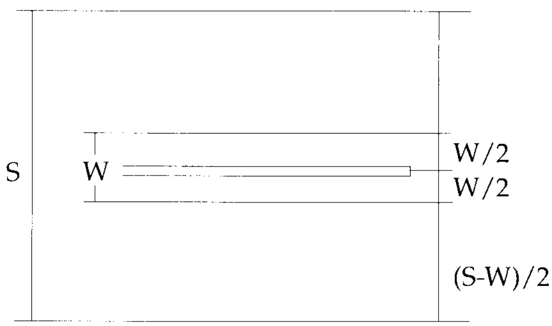

Figure 1. The road layout pattern for direct skidding when considering a road as a surface feature with a width of **W**.

The optimal road spacing is:

$$S = 100 \cdot \sqrt{\frac{2 \cdot R}{f \cdot c \cdot V}} + W$$

f is the sinuosity factor, **c** is the skidding cost per unit of volume, per unit of distance ($\$/m/m^3$), **R** is the road cost per unit of distance ($/m), **V** is the volume of wood per unit of area (m^3/ha) and **W** is the road width.

Case B.

Considering roads and landings as surface features, the road has a width of **W** and the landing has a length of **A** and depth of **B** (see Figure 2). Since the road serves the areas on both sides, we assume that a landing exists of the same size somewhere along the road on the other side. The skidding operation is done from stump site to the nearest point of the landing.

The cost of unit product will be:

$$cost = 2 \cdot c \cdot f \cdot ASD + \frac{10000 \cdot (R \cdot L + 2 \cdot land)}{V(S \cdot L - W \cdot L - 2 \cdot A \cdot B)}$$

A is the length of landing (m), **B** is the depth of landing (m), **cost** is the total cost per unit of volume wood, which includes the cost of skidding, road and landing construction ($\$/m^3$), and **land** is the cost of a landing in dollars. Average skidding distance (**ASD**) is given in APPENDIX.

To minimize **cost**, the derivatives of **cost** against **S** and **L** are obtained and set to zeros (see APPENDIX).

The numerical solutions to the two derivative equations, which were proved to produce the minimum **cost**, were obtained through nested binary searches. A program in PASCAL is available upon request of the authors. Table 1 shows the resulting optimal road spacing and landing spacing with various widths of road, and various sizes of landing. For the calculation of Table 1, volume of timber per hectare (**V**) is 120 m^3, road construction and preparation cost (**R**) equals to US\$6.56/m, **f** is 1, the cost

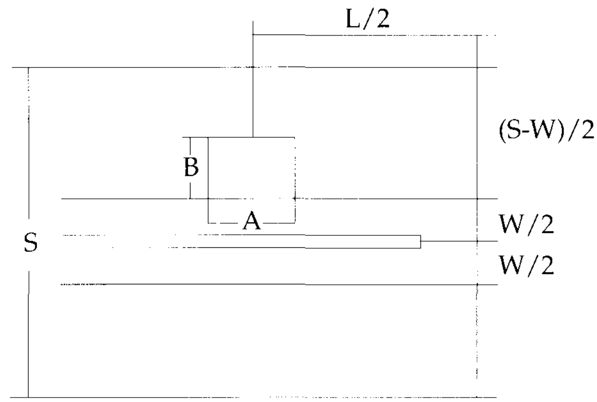

Figure 2. The road and landing layout pattern when roads and landings are considered as rectangles.

Table 1. Road spacing (**S**) and landing spacing (**L**) considering road and landing surface dimensions.

Case	Landing Length (A)	Landing Depth (B)	Road Width (W)	Road Spacing (S)	Landing Spacing (L)	Average Skidding Distance (ASD)
			(m)			
1	25	6	6	674.5	195.6	178.1
2	25	6	9	677.5	195.6	178.1
3	25	6	12	680.5	195.6	178.1
4	25	9	6	675.6	196.3	177.3
5	25	9	9	678.5	196.3	177.3
6	25	9	12	681.5	196.3	177.3
7	25	12	6	676.6	196.9	176.6
8	25	12	9	679.6	196.9	176.6
9	25	12	12	682.7	196.9	176.6
10	30	6	6	674.7	196.3	178.3
11	30	6	9	677.7	196.3	178.3
12	30	6	12	680.8	196.0	178.3
13	30	9	6	675.9	196.9	177.6
14	30	9	9	678.9	196.9	177.6
15	30	9	12	682.0	196.9	177.6
16	30	12	6	677.2	197.8	177.0
17	30	12	9	680.1	197.8	177.0
18	30	12	12	683.2	197.8	177.0
19	35	6	6	675.1	196.7	178.5
20	35	6	9	678.0	196.7	178.5
21	35	6	12	681.0	196.7	178.5
22	35	9	6	676.3	197.8	177.9
23	35	9	9	679.2	197.8	177.9
24	35	9	12	682.4	197.8	177.9
25	35	12	6	677.7	198.9	177.3
26	35	12	9	680.6	198.9	177.3
27	35	12	12	683.6	198.9	177.3

of skidding (**c**) equals US$0.003, landing construction and preparation cost (**land**) equals US$100. **R** and **land** include the cost/profit of removing the trees on the road and landing. The costs associated with road or landing construction and preparation may realistically be functions of their dimensions and not constants as used illustratively in Table 1.

DISCUSSION

Case B has assumed that the landing is completely external to the road. If this is not the case, the layout pattern of road and landings will be different from Figure 2. Therefore the formulas for road and landing spacing should not be applied.

ASD and **cost** may not be sensitive to the changes of width of road or the size of landing. When the densities of roads and landings getting larger or/and the surface areas of road and landing getting bigger, the magnitude of improvement in the accuracy of road spacing will increase. The improvements when considering roads and landings as surface features can be important. When studying the costs of harvesting operations, roads and landings could well be considered as rectangles, rather than lines and points.

REFERENCES:

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APPENDIX: NEXT PAGE

To simplify **ASD**, let

$$g(x,y)= x^3 \ln\left[\tan\left(\frac{\arctan\frac{x}{y}}{2}\right)\right]+y^3\ln\left[\tan\left(\frac{\arctan\frac{y}{x}}{2}\right)\right]$$

$$-2xy\sqrt{x^2+y^2}$$

then,

$$ASD=\frac{2g(A,B)-g(L,S-W-B)-g(L,B)}{12(SL-WL-2AB)}$$

The derivative of **cost** against road spacing (**S**):

$$\frac{\partial Cost}{\partial S} = c\cdot f\cdot\left\langle (S\cdot L-W\cdot L-2A\cdot B)\cdot\left\{\frac{2L\cdot\left[2(S-W-B)^2+L^2\right]}{\sqrt{(S-W-B)^2+L^2}}\right.\right.$$

$$+\frac{L^4}{2\sin\left[\frac{\arctan\left(\frac{L}{S-W-B}\right)}{2}\right]\cos\left[\frac{\arctan\left(\frac{L}{S-W-B}\right)}{2}\right]\left[(S-W-B)^2+L^2\right]}$$

$$\left.-3(S-W-B)^2\ln\left[\tan\left(\frac{\arctan\left(\frac{S-W-B}{L}\right)}{2}\right)\right]-\frac{(S-W-B)^3\cdot L}{2\sin\left[\frac{\arctan\left(\frac{S-W-B}{L}\right)}{2}\right]\cos\left[\frac{\arctan\left(\frac{S-W-B}{L}\right)}{2}\right]\left[L^2+(S-W-B)^2\right]}\right\}$$

$$-L\cdot\left\{2L(S-W-B)\sqrt{L^2+(S-W-B)^2}-L^3\ln\left[\tan\left(\frac{\arctan\left(\frac{L}{S-W-B}\right)}{2}\right)\right]-(S-W-B)^3\ln\left[\tan\left(\frac{\arctan\left(\frac{S-W-B}{L}\right)}{2}\right)\right]\right\}$$

$$-4\cdot A\cdot B\sqrt{\left(A^2+B^2\right)}+2A^3\ln\left[\tan\left(\frac{\arctan\left(\frac{A}{B}\right)}{2}\right)\right]+2B^3\ln\left[\tan\left(\frac{\arctan\left(\frac{B}{A}\right)}{2}\right)\right]$$

$$\left.+2B\cdot L\sqrt{\left(B^2+L^2\right)}-L^3\ln\left[\tan\left(\frac{\arctan\left(\frac{L}{B}\right)}{2}\right)\right]-B^3\ln\left[\tan\left(\frac{\arctan\left(\frac{B}{L}\right)}{2}\right)\right]\right\}\Bigg\rangle/6(S\cdot L-W\cdot L-2A\cdot B)^2$$

$$-\frac{10000L(R\cdot L+2land)}{(S\cdot L-W\cdot L-2A\cdot B)^2\cdot V}=0$$

The derivative of **cost** against landing spacing (**L**):

$$\frac{\partial Cost}{\partial L} = c \cdot f \cdot \Big\langle (S \cdot L - W \cdot L - 2A \cdot B) \Big\{ 2 \cdot (S-W-B) \cdot \sqrt{(S-W-B)^2} + L^2 + 2L^2 \frac{(S-W-B)}{\sqrt{(S-W-B)^2 + L^2}}$$

$$-3L^2 \ln\left[\tan\left(\frac{\arctan\left(\frac{L}{S-W-B}\right)}{2}\right)\right] - \frac{L^3(S-W-B)}{2\sin\left[\arctan\frac{\left(\frac{L}{S-W-B}\right)}{2}\right]\cos\left[\arctan\frac{\left(\frac{L}{S-W-B}\right)}{2}\right]\left[(S-W-B)^2 + L^2\right]}$$

$$+2B\sqrt{\left(B^2 + L^2\right)} + \frac{2B \cdot L^2}{\sqrt{B^2 + L^2}} + \frac{(S-W-B)^4}{2\sin\left[\arctan\frac{\left(\frac{S-W-B}{L}\right)}{2}\right]\cos\left[\arctan\frac{\left(\frac{S-W-B}{L}\right)}{2}\right]\left[(S-W-B)^2 + L^2\right]}$$

$$-3L^2 \ln\left[\tan\left(\frac{\arctan\left(\frac{L}{B}\right)}{2}\right)\right] - \frac{L^3 \cdot B}{2\sin\left[\frac{\arctan\left(\frac{L}{B}\right)}{2}\right]\cos\left[\frac{\arctan\left(\frac{L}{B}\right)}{2}\right]\left[L^2 + B^2\right]} + \frac{B^4}{2\sin\left[\frac{\arctan\left(\frac{B}{L}\right)}{2}\right]\cos\left[\frac{\arctan\left(\frac{B}{L}\right)}{2}\right]\sqrt{B^2 + L^2}} \Big\}$$

$$-\Big\{ 2L \cdot (S-W-B)\sqrt{L^2 + (S-W-B)^2} - L^3 \ln\left[\tan\left(\frac{\arctan\left(\frac{L}{S-W-B}\right)}{2}\right)\right] - (S-W-B)^3 \ln\left[\tan\left(\frac{\arctan\left(\frac{S-W-B}{L}\right)}{2}\right)\right]$$

$$-4A \cdot B\sqrt{\left(A^2 + B^2\right)} + 2A^3 \ln\left[\tan\left(\frac{\arctan\left(\frac{A}{B}\right)}{2}\right)\right] + 2B^3 \ln\left[\tan\left(\frac{\arctan\left(\frac{B}{A}\right)}{2}\right)\right] - L^3 \ln\left[\tan\left(\frac{\arctan\left(\frac{L}{B}\right)}{2}\right)\right]$$

$$+2B \cdot L\sqrt{\left(B^2 + L^2\right)} - B^3 \ln\left[\tan\left(\frac{\arctan\left(\frac{B}{L}\right)}{2}\right)\right]\Big\} \cdot (S-W) \Big\rangle / 6(SL - WL - 2AB)^2 - \frac{2 \cdot 10000(land \cdot W - R \cdot W - land \cdot S)}{(S \cdot L - W \cdot L - 2A \cdot B)^2 \cdot V}$$

$$= 0$$