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What we've got here is...failure to communicate.¹



¹ "The Captain" (Strother Martin) in *Cool Hand Luke*

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“Some men...you just can't reach”



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Transportation Networks in Forest Harvesting:

Early Development of the Theory

Research Communication in Network Theory -

Some observations and thoughts about its uneven history.

Early Development in Europe



- *The Theory of the Trace: Being a Discussion of the Principles of Location.* 2 v. in 1: pt. 1. *The Commercial Trace*, 1900.

Carl Wilhelm Friedrich Launhardt
1832-1918

Early Network Developments

§ 7a.

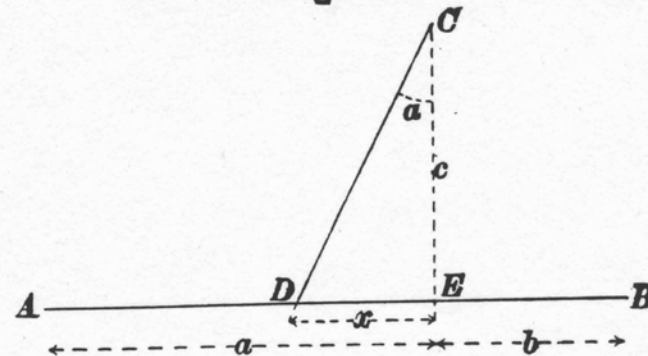
The Principle of Junctions.

The simplest problem in Commercial Location is the determination of the best line of connexion of a locality with an already existing route of traffic.

If C —**Fig. 8**—be such a locality and $A B$ the pre-existing route of traffic, the problem is to fix the point D in which the connecting-line or road, $C D$, shall most advantageously debouch in $A B$; or, in order words, to determine the angle α at which this connecting line should deviate from the perpendicular $C E$.

A development
mistakenly attributed
to Tord Palander (1936)
by Martin Beckmann (1999).

Fig. 8.



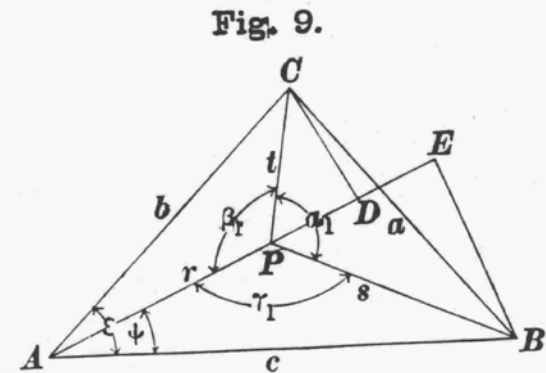
Early Network Developments

§ 8.

The Principle of Nodes.

If the line connecting two places A and B —**Fig. 9**—with which points a third place, C , is to be connected—is not as yet built it is preferable to make the route from A to B not rectilinear but as $A P B$, thereby joining the line C to P . The position of the node P is fixed from the consideration that the sum of the construction- and working-costs shall be a minimum.

A development frequently, and mistakenly, attributed to Albert Weber (1909) by many network researchers.



Very Early Network Developments

THE
DOCTRINE
AND
APPLICATION
OF
FLUXIONS.

CONTAINING
(Besides what is common on the Subject)

A Number of NEW IMPROVEMENTS
in the THEORY.

AND

The SOLUTION of a Variety of New, and very
Interesting, Problems in different Branches of
the MATHEMATICKS.

PART II.

By THOMAS SIMPSON, F. R. S.

THE SECOND EDITION.
Revised and carefully corrected.

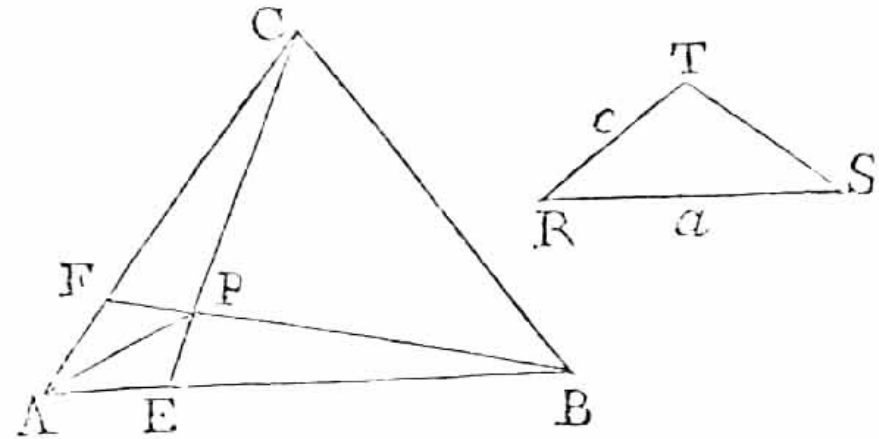
L O N D O N :

Printed for JOHN NOURSE, in the Strand,
BOOKSELLER TO HIS MAJESTY.

MDCCLXXXVI.

P R O B. VII.

431. Three Points A, B, C being given, to find the Position of a fourth Point P, so that, if Lines be drawn from thence to the three former, the Sum of the Products $a \times AP$, $b \times BP$, and $c \times CP$ (where a , b and c denote given Numbers) shall be a Minimum.



Originally published in 1750 Thomas Simpson's textbook poses and solves the 3-point optimal location problem using the differential calculus.

Early Network Developments

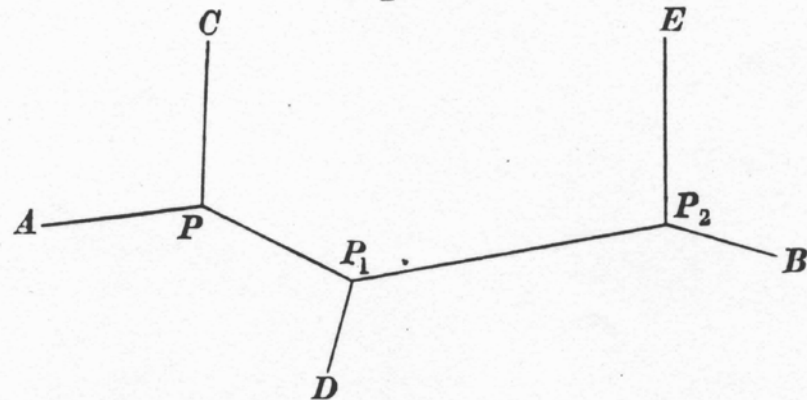
§ 9.

The Commercial Trace.

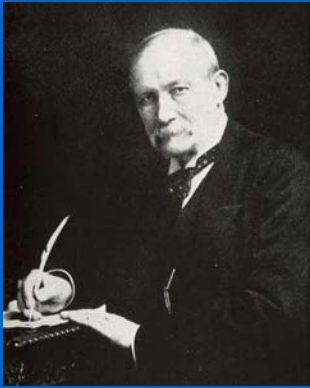
If a line of communication is to be laid down between two points A and B , whether it be a road, a canal, or a railway, by which a traffic of any given amount is to be distributed laterally to the localities laying on either side of it, then its Commercial Trace will form a chain of straight lines of varying directions from the nodes of which the connecting lines will proceed to the laterally out-lying localities.

The locations of the points P_i are determined by either mechanical analogue or geometric analysis of the equilibrium force structure.

Fig. 14.



The Formative Era, European Connections



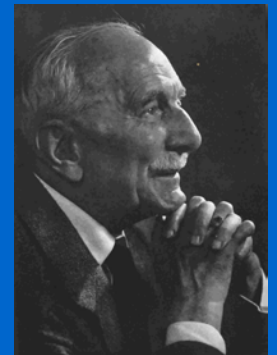
Sir Dietrich Brandis
1824 - 1907



Sir William Schlich
1840 - 1925



Bernhard Eduard Fernow
1851-1923



Carl Alwin Schenck
1868 - 1955

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Concepts Transplanted to America

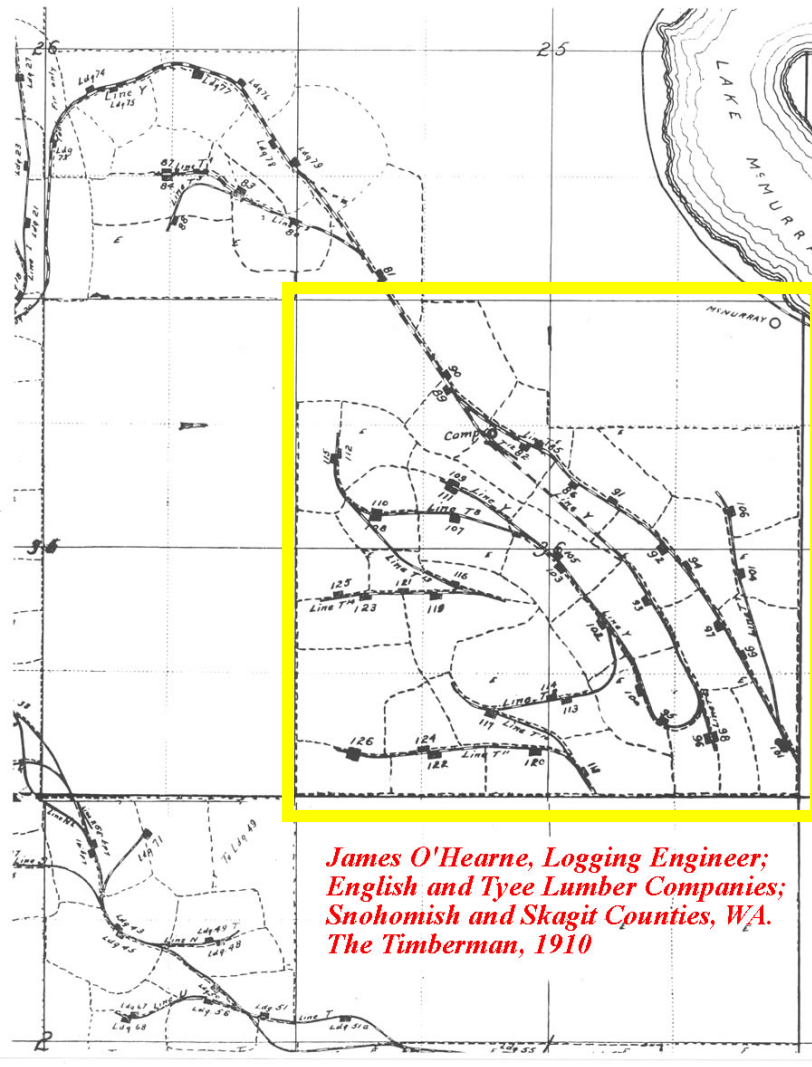
“Cheap but efficient road building and railroad building, I am afraid, is a matter with which even few engineers are well acquainted; it is a subject in which the forester is intensely interested”

“The first task of the forester, then, in beginning the management of a forest property is to provide cheap and efficient means of transportation for the removal of a bulky crop.....”

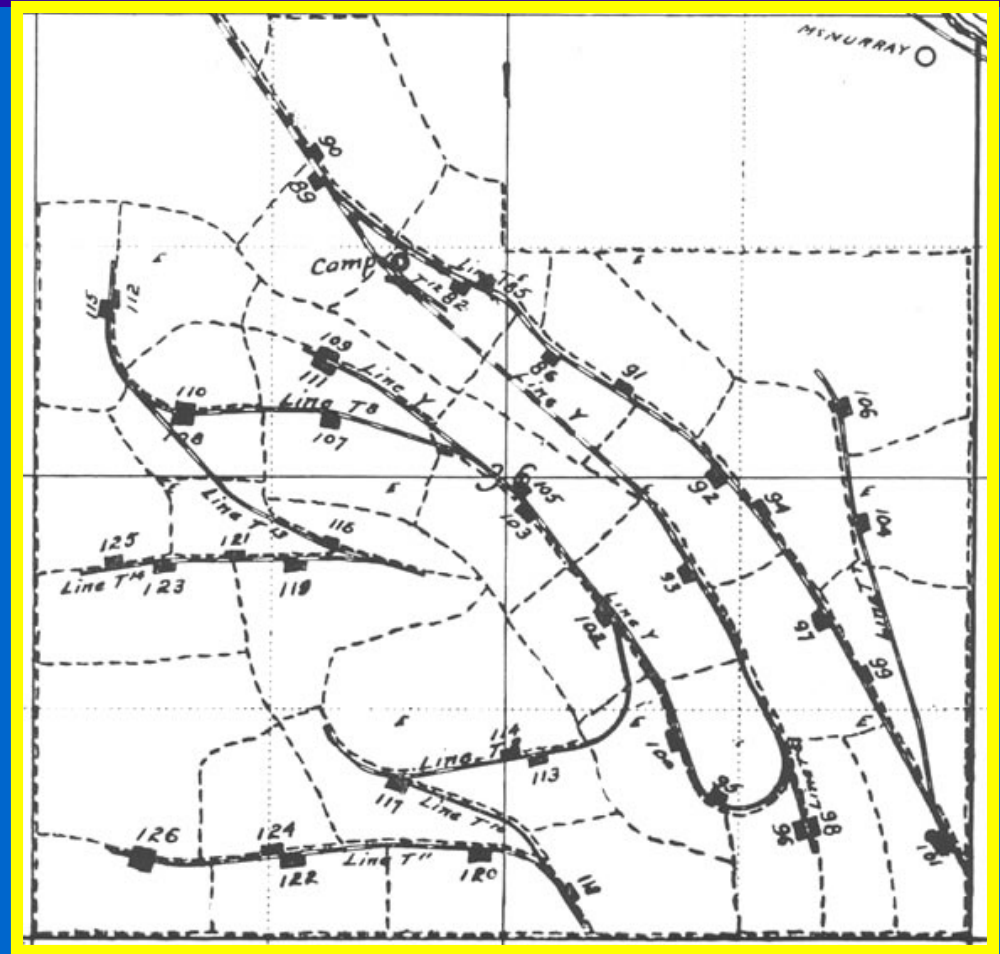
“Whether the transportation is by rail or water, or by sled or wagon, the locating of roads is one of the most important functions of the logger. Be it that temporary roads or permanent summer roads are to be used, a well planned system of main roads and branches must be located”

Fernow, B. (1901) “The forester, an engineer”, *Journal of the Western Society of Engineers*. Presented at the Chicago meeting at a time when Fernow was Dean of Cornell’s College of Forestry, 1898-1903.

Network Analysis Takes Root in America



*James O'Hearne, Logging Engineer;
English and Tye Lumber Companies;
Snohomish and Skagit Counties, WA.
The Timberman, 1910*



Note spur spacing and setting design.

Network Analysis Takes Root in America



James Walter Girard
1877 - 1952

“The amount of railroad which should be constructed, or the distance apart that the spurs should be constructed can be definitely determined, provided that there is a reliable estimate of the timber and the cost of railroad construction can be closely determined.”

“The skidding distance that gives a skidding cost which, when added to the cost of railroad construction results in the lowest total cost per thousand for both skidding and railroad construction, shows the distance apart that the railroad spurs should be.”

"Tractor and horse skidding in Inland Empire."
The Timberman XXIV(1):66,68,70. 1922.

Network Analysis Takes Root in America

TABLE 9.—*Most economical distances between railroad spurs and the most economical direct-skidding distances; and the combined cost per thousand of railroad construction and skidding*

Operating conditions	Stand per acre	Tractor skidding		Horse skidding	
		Distance between railroad spurs ¹	Com-bined cost	Distance between railroad spurs ¹	Com-bined cost
0 to 15 per cent slope:	M ft. b. m.	<i>Feet</i>	<i>Dollars</i>	<i>Feet</i>	<i>Dollars</i>
Summer work—					
3 to 5 log timber.....	{ 10	2,800	1.52	2,000	2.02
	{ 20	2,000	1.18	1,200	1.49
9 to 12 log timber.....	{ 10	2,400	2.09	1,600	2.56
	{ 20	1,800	1.71	1,200	1.94
Winter work—					
3 to 5 log timber.....	{ 10	3,400	1.50	2,200	1.88
	{ 20	2,400	1.22	1,400	1.46
9 to 12 log timber.....	{ 10	3,000	2.09	1,600	2.51
	{ 20	2,000	1.76	1,200	1.91
15 to 30 per cent slope:					
Summer work—					
3 to 5 log timber.....	{ 10	5,800	2.05	4,000	2.90
	{ 20	3,600	1.57	2,400	2.08
9 to 12 log timber.....	{ 10	5,000	2.93	3,000	3.98
	{ 20	3,000	2.35	2,000	2.92
Winter work—					
3 to 5 log timber.....	{ 10	6,000	1.97	5,200	2.43
	{ 20	3,800	1.50	2,800	1.80
9 to 12 log timber.....	{ 10	6,000	3.30	4,400	3.59
	{ 20	2,600	2.64	2,000	2.85

¹ Twice the maximum direct distance.

Bradner, Klobucher, Girard, and Fullaway.

1933.

“An analysis of log production in the ‘inland empire’ region”

Taking Inventory



Donald Maxwell Matthews
1886-1948

- *Cost Control in the Logging Industry, 1942.*

“A considerable amount of literature on the subject has been contributed by such foresters as Ashe, Bruce, Gerard (sic), Klobucher, Brandstrom, Brundage, Garver, and Rapraeger. [This book] ... is an extremely worthy addition to this list.”†

† Myron Krueger, Review in the *J. of For.* 40:349

Taking Inventory

CHAPTER V

THE ECONOMIC LOCATION OF ROADS AND LANDINGS 111

Economic Direct-skidding-distance Formula: Illustration, Case 1—Second Direct-skidding-distance Formula—Road-spacing Formula: Illustration, Case 2—Alternative Form of Road-spacing Formula—The Road-spacing Formula as a Criterion of the Economic Direct Skidding Distance—Supplementary Formula for the Economic Direct Skidding or Hauling Distance: Illustration, Case 3—Formulas for Road Spacing when Landings Are Used: Landings in the Centers of Square Settings: in the Centers of Rectangles—General Formula for All Rectangular Settings—Road-and-landing-spacing Table: Illustration of Use of, Cases 4 and 5—Determination of the Economical Spacing of Landings when the Spacing of Roads Cannot Be Controlled: Illustration, Case 6.

CHAPTER VI

DETERMINATION OF THE ECONOMIC SERVICE STANDARD FOR ROADS . . 158

The Economic Balance between Road-construction Cost and Hauling Cost—Determination of Road Standards: Exterior Main Hauling Road: Illustration, Case 7—Interior Main Logging Road: Illustration, Case 8—Procedure When There Is a Possibility of Building Portions of an Interior Main-line Road to Various Service Standards: Illustration, Case 9—Determination of the Standard for Secondary or Branch Logging Roads: Illustration, Case 10—The Effect of Changes in Volume and Hauling Distance upon the Branch Road Standard—Determination of the Various Standards for an Interior Main-line Road when Branch Roads Are Used: Illustration, Case 11—Determination of the Various Standards for an Interior Road If Timber Is Skidded to Landings on the Road: Illustration, Case 12—The Effect of Size of Load on Hauling Costs and on the Economical Service Standard for Roads—Advance Planning and Construction.

CHAPTER VII

SELECTION OF EQUIPMENT, ROAD STANDARD, AND ROAD SPACING . . . 201

Selection of Prehauling Equipment—Selection of Prehauling Equipment and Road Spacing: Illustration, Case 13—Selection of Prehauling Equipment and Road Standards and Road Spacing: Illustration, Case 14—Principles Governing the Use of Two Types of Skidding Machinery in Combination: Illustration, Case 15—The Spacing of Roads when They Are to Be Served by Two Types of Prehauling or Skidding Machines—Formula for the Spacing of Roads When They Are Served by Two Types of Machine: Illustration, Case 16—The Use of Two Types of Machines for Skidding to Landings—Selection of Hauling Equipment—Preparation of Comparative Truck Machine Rates—Illustration and Use of Comparative Truck Machine Rates—Case 17: Selecting the Type of Truck for Various External Hauling Distances—The Effect of Loading Efficiency on Truck Selection and Placement—The Effect of Travel Speed on Selection of Trucks

Types of Skidding Machinery in Combination: Illustration, Case 15—The Spacing of Roads when They Are to Be Served by Two Types of Prehauling or Skidding Machines—Formula for the Spacing of Roads When They Are Served by Two Types of Machine: Illustration, Case 16—The Use of Two Types of Machines for Skidding to Landings—Selection of Hauling Equipment—Preparation of Comparative Truck Machine Rates—Illustration and Use of Comparative Truck Machine Rates—Case 17: Selecting the Type of Truck for Various External Hauling Distances—The Effect of Loading Efficiency on Truck Selection and Placement—The Effect of Travel Speed on Selection of Trucks—The Effect of Size of Load on Selection of Trucks—Application of Comparative Truck Machine Rates to Specific Problems—Case 18: Determination of the Minimum Load and/or Speed Required of a Heavy Truck to Equal the Performance of a Light One—Case 19: Determination of the Amount That May Be Expended in Road Improvement to Maintain Higher Safe Truck Speeds—Case 20: Planning the Transportation System—Selection of Loading Equipment: Illustration, Case 21.

CHAPTER VIII

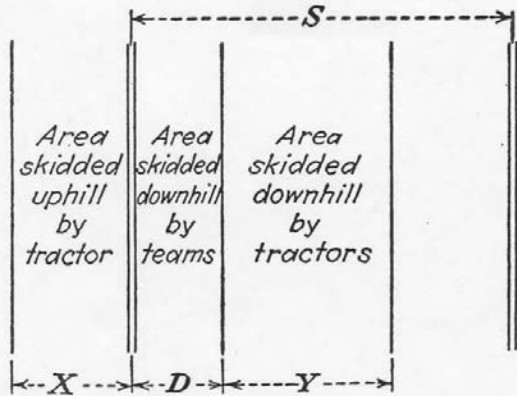
SELECTION OF EQUIPMENT AND ROAD SPACING ON SLOPES 262

Road-spacing Formula for One-way Direct Skidding—The Effect of One-way Skidding on Costs—Formulas for Road Spacing When Skidding Is from One Side of a Road to Landings—Road-and Landing-spacing Table for One-way Skidding—The Economical Spacing of Contour Roads for Two-way Skidding on Slopes—Road-spacing Formula for Uphill and Downhill Direct Skidding to Roads With the Same Machine—Application of the Formulas: Illustration, Case 22—The Economical Location of a Single-contour Road on a Slope: Illustration, Case 23—General Considerations with Regard to Skidding on Slopes—The Use of Two Machines in Combination for Skidding on Slopes: Illustration, Case 24—Combination Skidding on Slopes when Break-even Distances Do Not Exist: Illustration, Case 25—Road Spacing when Loaders Skid a Portion of the Timber: Formulas for Two Cases—Practical Application of the Formulas: Illustration, Case 26—The Economical Spacing of Roads and Landings on Slopes—Cable Skidding to Contour Roads—Actual vs. External Yarding or Skidding Variable Costs—Application of Data on Costs of Cable Skidding to the Problem of Road and Landing Location: Illustration, Case 27—Determination of the Economical External Yarding or Skidding Distance for a Cold-deck Setting: Formula: Application of the Formula: Illustration, Case 28—Changes in the Economical External Yarding Distance: With Changes in the Central Angle of the Setting: With Changes in Volume per Acre: With Changes in Size of Log—The Break-even Point in External Yarding Distance for Two Types of Machines: Illustration, Case 29—Variations in the Break-even External Yarding Distance—The Break-even External Yarding Distance for Rectangular Settings: Illustration, Case 30.

MAJOR TOPICS

- The economic location of roads and landings.
- Determination of the economic service standards for roads.
- Selection of equipment, road standard, and road spacing.
- Selection of equipment and road spacing on slopes.

Taking Inventory



S = Spacing of contour roads - 1360 feet
 X = Maximum uphill tractor skidding distance - 400 feet
 D = Break-even distance = 300 feet
 $D = \begin{cases} \text{Maximum downhill team skidding distance} \\ \text{Minimum downhill tractor skidding distance} \end{cases}$
 $Y + D$ = Maximum downhill tractor skidding distance = 960 feet

FIG. 20. Matthews 1942

TABLE 8.—Point and zone of equivalent cost as between tractor and horse skidding, under various operating conditions

Operating conditions	Point of equal cost ¹	Zone of equal cost	Cost per M ²
0 to 15 per cent slope:			
Summer work—			
3 to 5 log timber.....	210	350	0.56
9 to 12 log timber.....	270	450	1.07
Winter work—			
3 to 5 log timber.....	270	450	.64
9 to 12 log timber.....	330	550	1.16
15 to 30 per cent slope:			
Summer work—			
3 to 5 log timber.....	270	450	.49
9 to 12 log timber.....	330	550	1.08
Winter work—			
3 to 5 log timber.....	390	650	.52
9 to 12 log timber.....	480	800	1.38

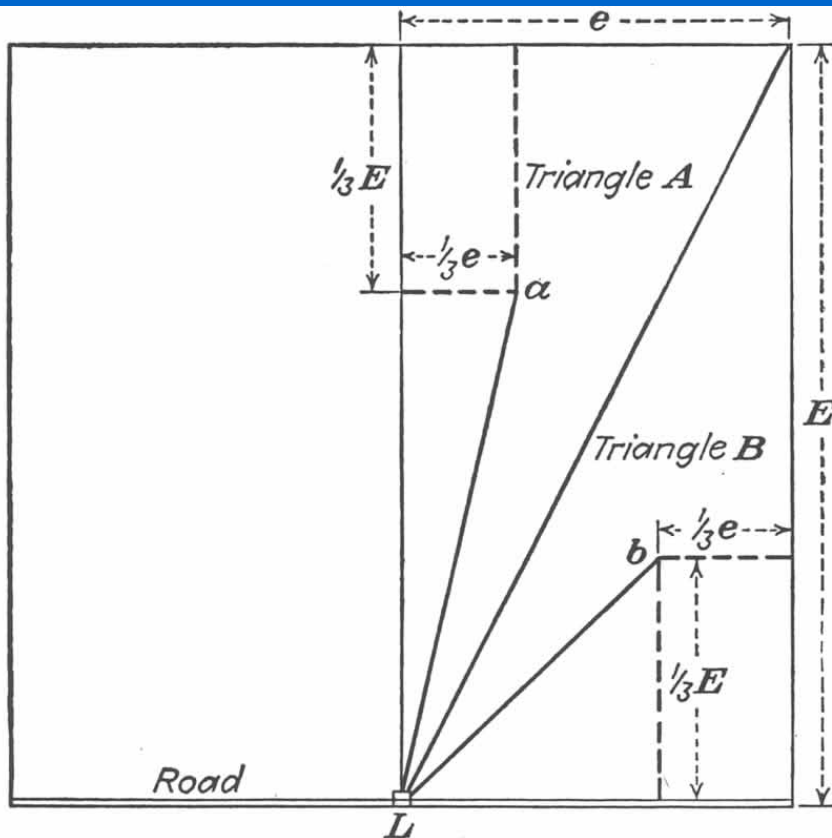
¹ Beyond distances given, tractor skidding is more economical; short of these distances horse skidding has the advantage.

² Cost at point of equivalence or average cost for zone. Bradner et al. 1933

Breakeven analysis of skidding systems

The lack of references within many early publications complicates correct attribution of original developments in the theory.

The Growing Scope of Research



L = Landing
Length of line $L\alpha$ = Average skidding distance for ΔA
Length of line Lb = Average skidding distance for ΔB

FIG. 6.

Matthews 1942

Matthews (1942) uses the weighted centroids of the triangles to calculate the average skidding distance.

Almqvist (Sundberg 1953) gives the correct formula.

Suddarth and Herrick (1964) rediscover the correct formula.

The Growing Scope of Research

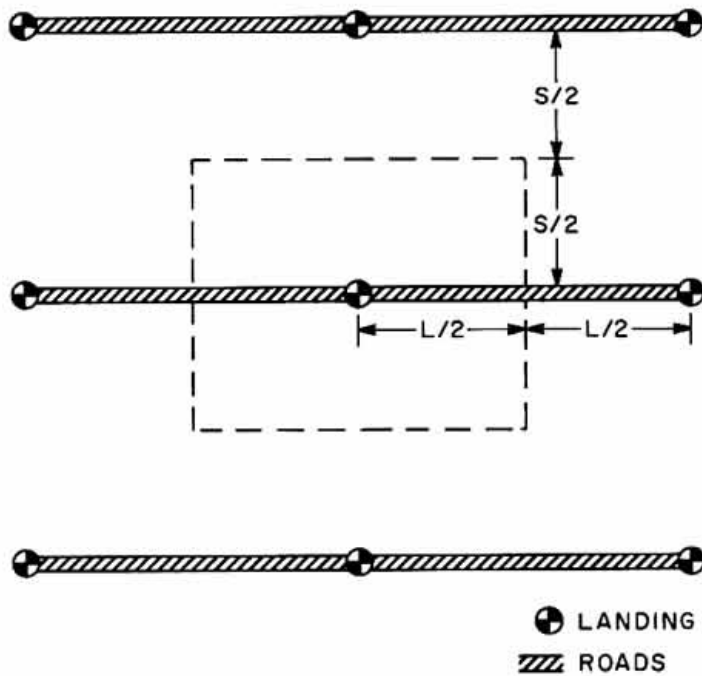


FIGURE 1. Geometry of rectangular area, two-way yarding.
 L = landing spacing and S = road spacing.

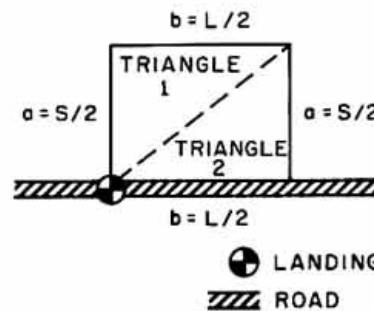
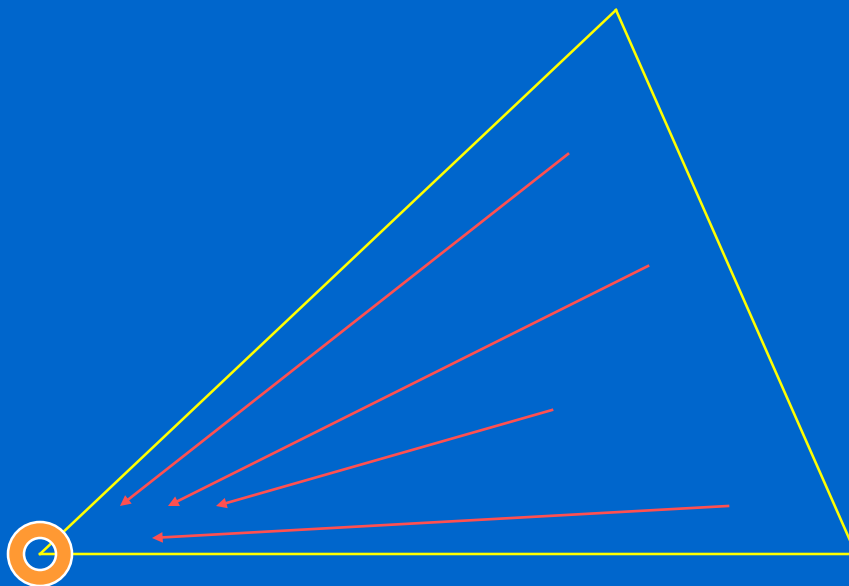


FIGURE 2. Upper right-hand quadrant of rectangular harvest setting. L = landing spacing and S = road spacing.

Peters (1978) when correcting Matthews' optimal landing and road spacing model for level, uniform terrain and stand conditions **cites Suddarth and Herrick** (1964).

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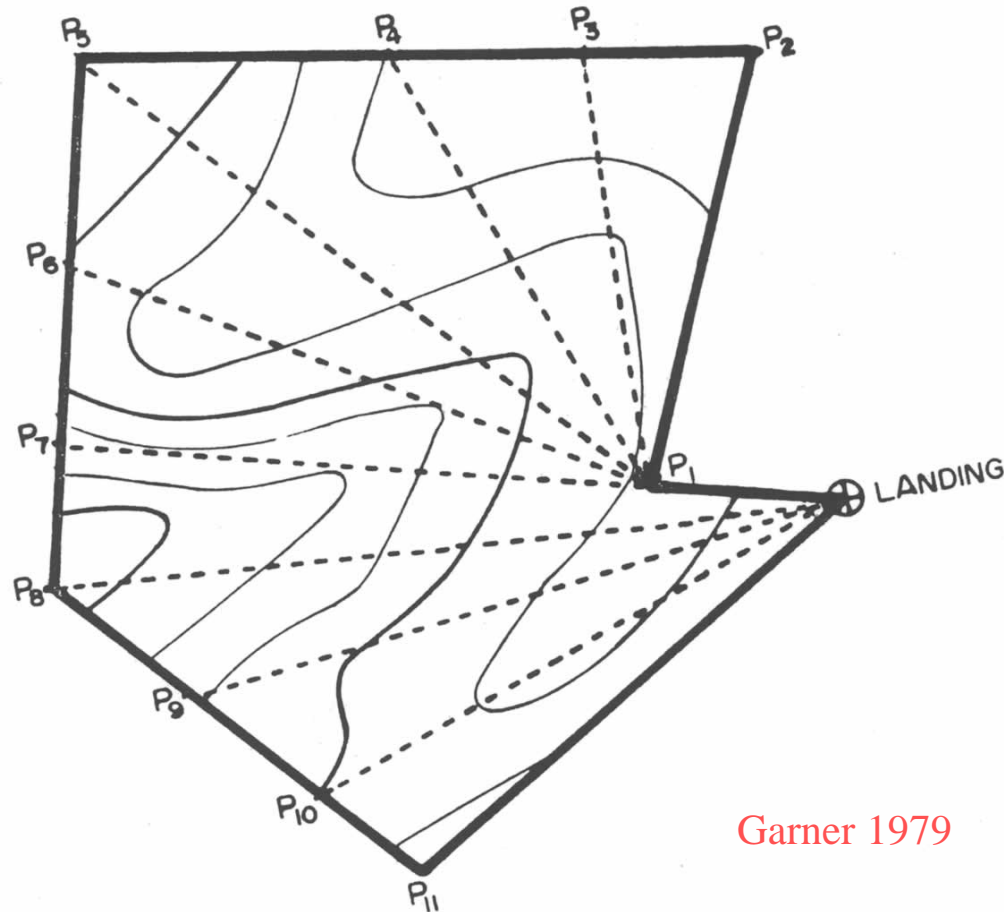
The Growing Scope of Research



Also in his 1978 paper Peters provides a formula for the average skidding distance to the vertex of any triangle.

Donnelly (1978) presents an efficacious procedure for the calculation of average skidding distances on settings of irregular shape on flat ground.

The Growing Scope of Research



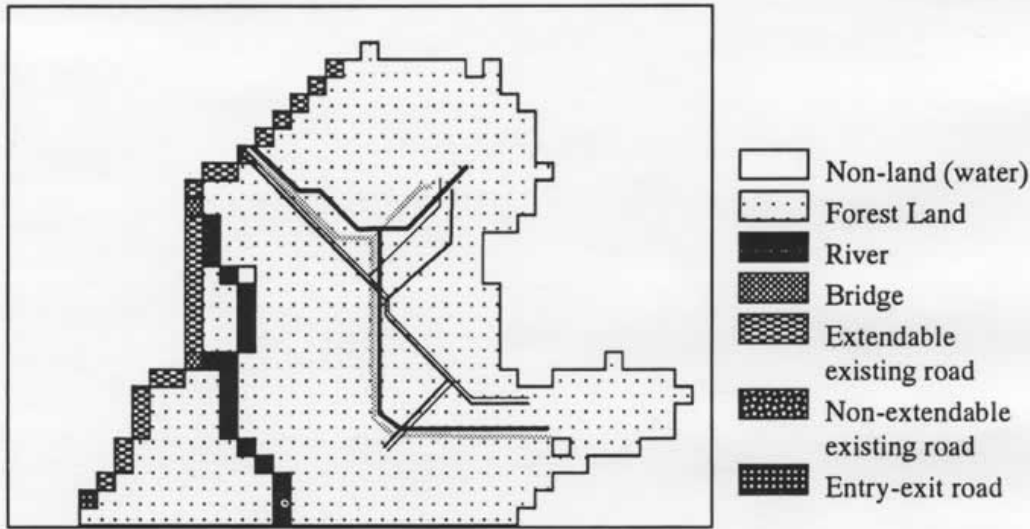
Garner 1979

Figure 1. Irregularly shaped cut-block with contour lines.

Garner (1979) extends Donnelly's procedure to sloping terrain by modifying Peters' triangle formula.

Greulich (1992) provides formulas for additional distance and slope parameters of a setting on sloping ground.

The Growing Scope of Research



Road network location index	ρ m	β m	d_r m/ha	D_s m	L_{er} m	C_{er} FIM	π FIM	References in the text
— road-a1	∞	∞	9.1	295	3 461	121 429	274 675	§4.3.1
— road-a2	150	∞	9.2	292	3 520	123 480	274 189	§4.3.2
..... road-a3	∞	900	8.9	286	3 387	120 143	<u>282 375</u>	§4.3.3
— road-a4	150	900	9.4	270	3 628	128 592	<u>282 222</u>	§4.3.4

Fig. 18. Locations of the forest road network as found by the network routing system with the starting nodes of alternative A.

Tan's monograph nicely summarizes much of the previous work done in the area of truck road location models including those based on heuristic optimization procedures (1992).

Some Final Thoughts

- Early publications (prior to about 1950) do not typically offer adequate attribution to previous work; e.g., Matthews' landmark text.

Some Final Thoughts

- Much research time has been expended in simply rediscovering previous results; e.g., Simpson→Launhardt→Weber and the “principle of the node”.

Some Final Thoughts

- There is little cross-fertilization between research fields; e.g., regional science, geological sciences, geographic studies, urban studies, electrical engineering.

Some Final Thoughts

- The “Imperfect lines of communication” faulted by Pinto (1977) continue to be a problem.