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

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

“Some men...you just can’t reach”

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

Carl Wilhelm Friedrich Launhardt
1832-1918

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

Early Network Developments

§ 7a.

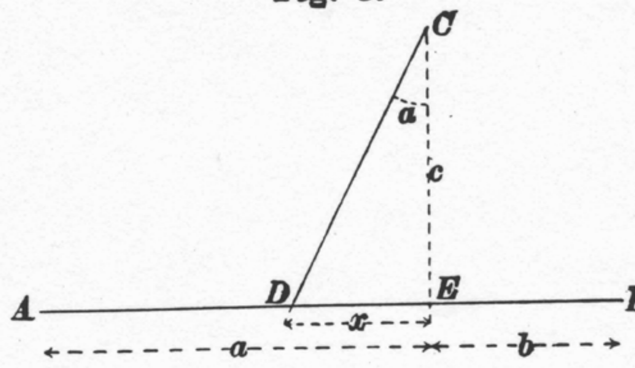
The Principle of Junctions.

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

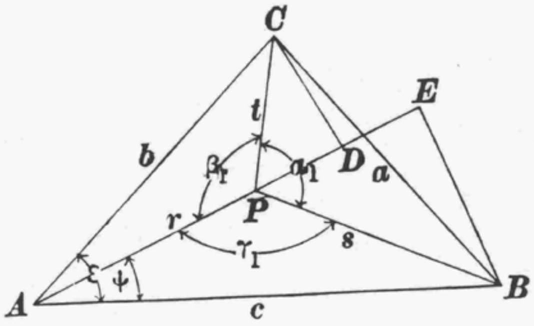
§ 8.

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.

Fig. 9.



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.

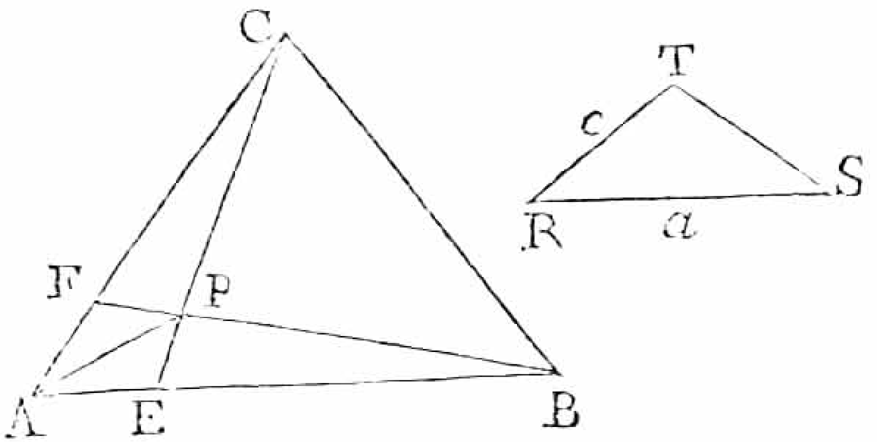
LONDON:

Printed for John Nourse, in the Strand, Bookseller to His MAJESTY.

MDCCLXXVI.

PROB. 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

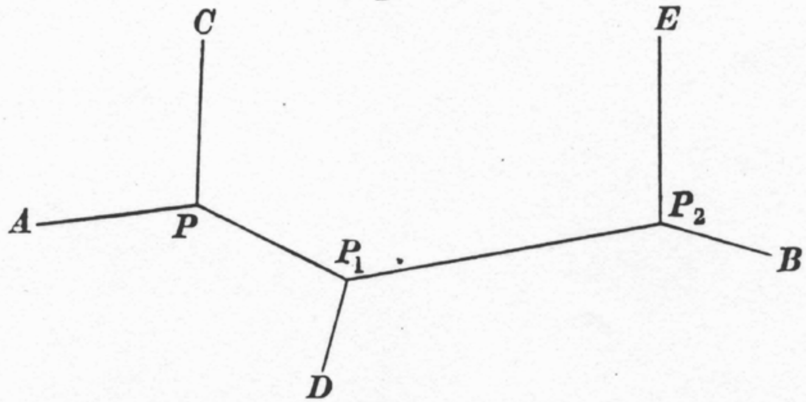
§ 9.

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

Concepts Transplanted to America

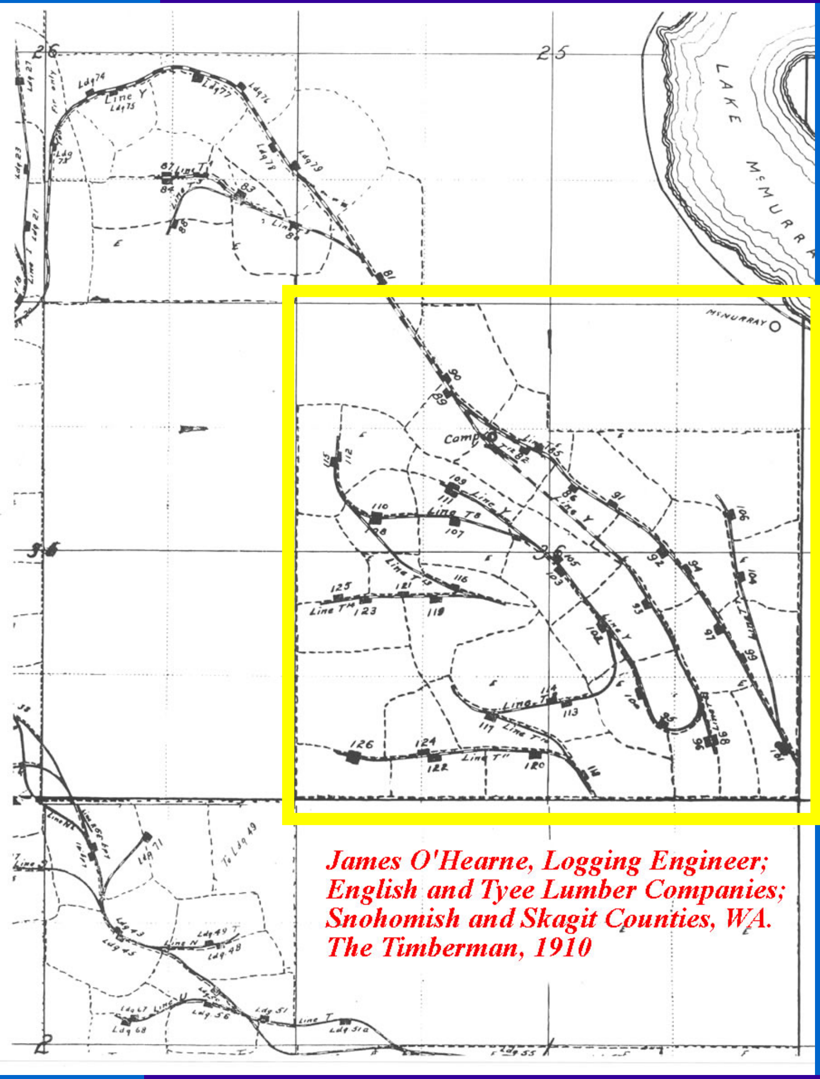
"Cheap but efficient road building and railroad building, I am afraid, is a matter with which even few engineers are well acquainted; it is a subject in which the forester is intensely interested"

"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….."

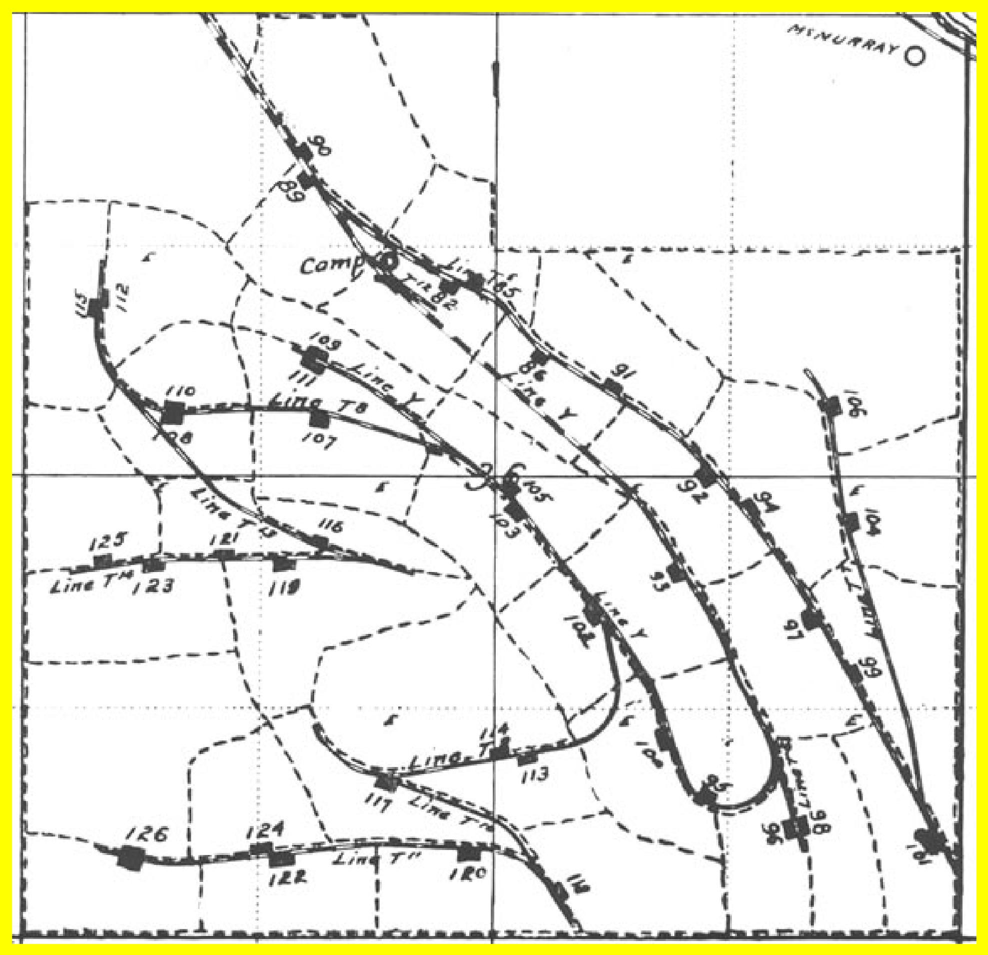
"Whether the transportation is by rail or water, or by sled or wagon, the locating of roads is one of the most important functions of the logger. Be it that temporary roads or permanent summer roads are to be used, a well planned system of main roads and branches must be located"

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 Tyee 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: Distance between railroad spurs [1]	Tractor skidding: Combined cost	Horse skidding: Distance between railroad spurs [1]	Horse skidding: Combined cost
	M ft. b. m.	*Feet*	*Dollars*	*Feet*	*Dollars*
0 to 15 per cent slope:					
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

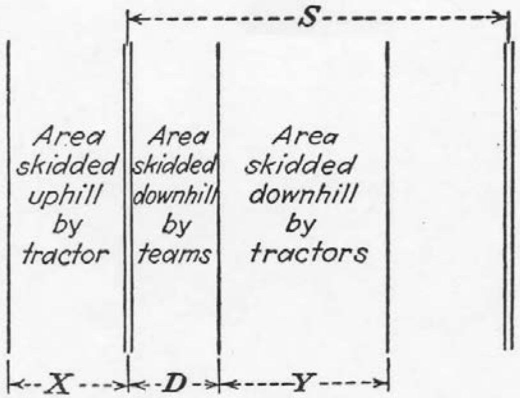
Taking Inventory

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

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 = {Maximum downhill team skidding distance / Minimum downhill tractor skidding distance}
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:	*Feet*	*Feet*	*Dollars*
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

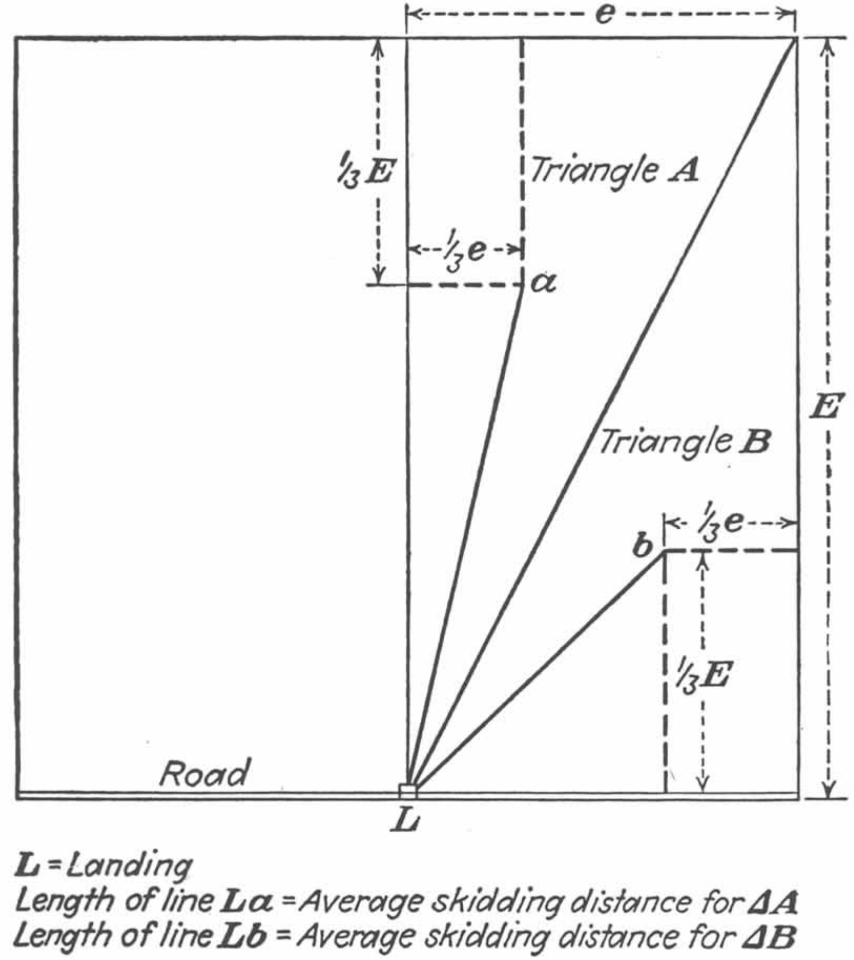


Fig. 6.

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

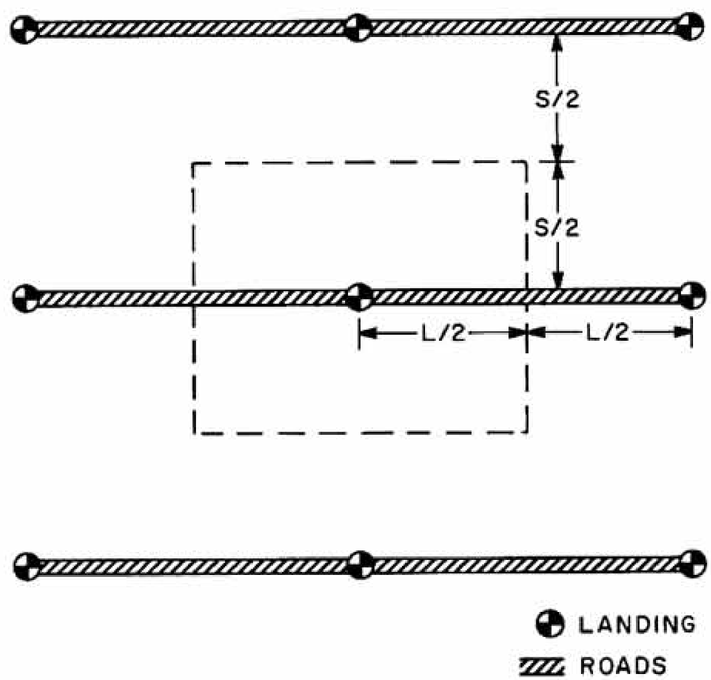


FIGURE 1. Geometry of rectangular area, two-way yarding. L = landing spacing and S = road spacing.

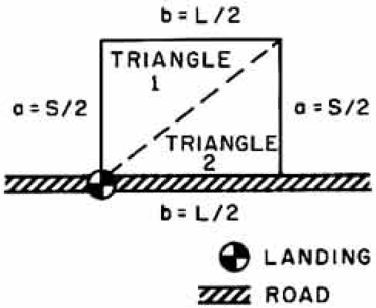
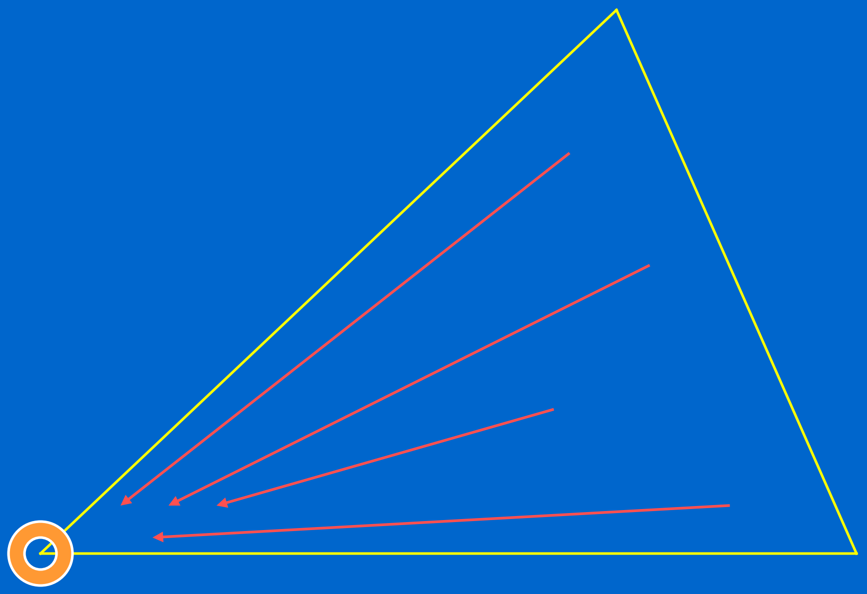


FIGURE 2. Upper right-hand quadrant of rectangular harvest setting. L = landing spacing and S = road spacing.

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

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

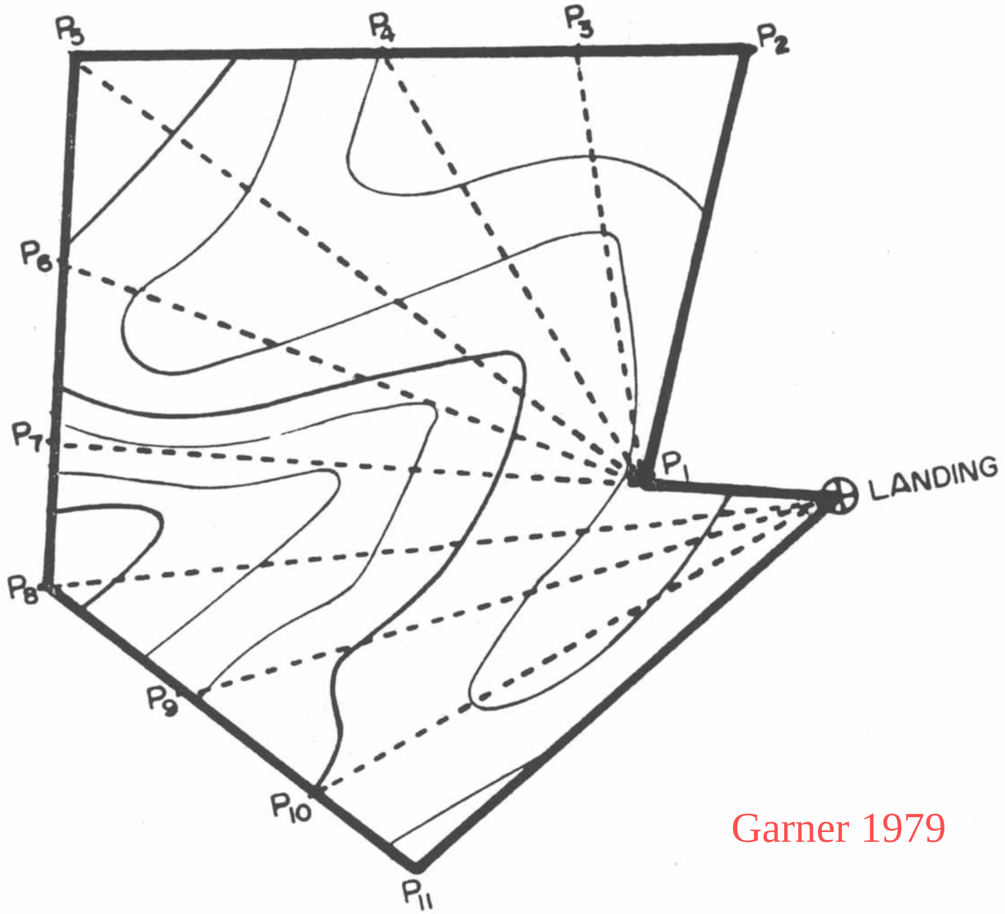


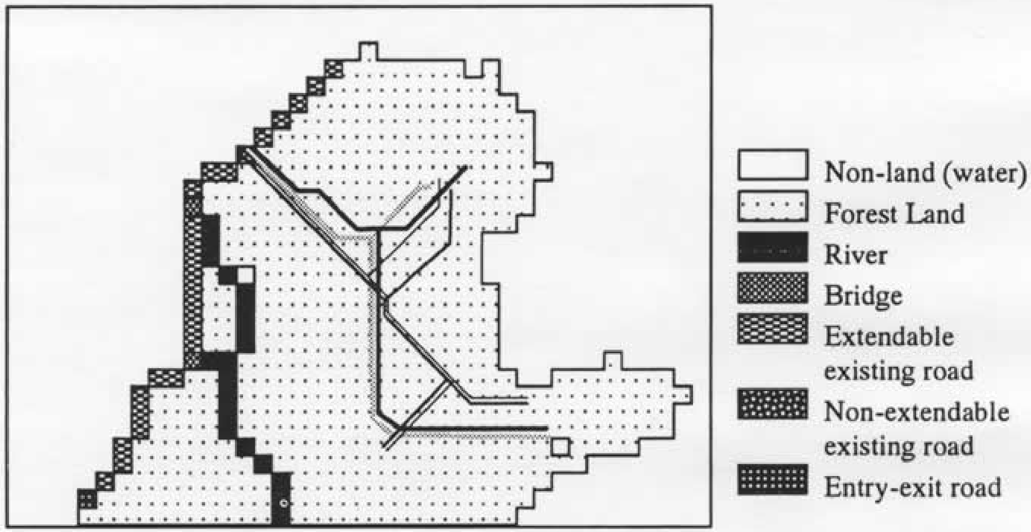
Figure 1. Irregularly shaped cut-block with contour lines.

Garner 1979

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	282 375	§4.3.3
road-a4	150	900	9.4	270	3 628	128 592	282 222	§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.