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THE ECONOMIC TRANSPORT UNIT SIZE IN ROUNDWOOD TOWING ON LAKE ISO-SAIMAA (IN EASTERN FINLAND)

TALOUDELLINEN KULJETUSYKSIKKÖ ISONSAIMAAN NIPPULAUTTAHINAUKSESSA

Yrjö Roitto

SUOMEN METSÄTIETEELLINEN SEURA

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THE ECONOMIC TRANSPORT UNIT SIZE IN ROUNDWOOD TOWING ON LAKE ISO-SAIMAA (IN EASTERN FINLAND)

YRJÖ ROITTO

RESUME:

LE VOLUME ECONOMIQUE DU REMORQUAGE DE BOIS RONDS SUR LE LAC ISO-SAIMAA, EN FINLANDE ORIENTALE

TIIVISTELMÄ:

TALOUDELLINEN KULJETUSYKSIKKÖ ISON-SAIMAAN NIPPULAUTTAHINAUKSESSA

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FOREWORD

This work was initiated by Mr. Martti Niskala, the Director General of the National Board of Public Roads and Waterways. I am indebted to him for stressing the importance of this topic.

The Foundation for the Investigations of Natural Resources in Finland considered that a study on the economic transport unit size in roundwood towing on Lake Iso-Saimaa would be useful and awarded me a grant for this purpose, for which I am deeply grateful.

The basic material for this paper has been the statistical information on the member companies of the Saimaa Shipowners' Association (Saila). The statistics of the Inland Waterway Transport Department of Enso-Gutzeit Osakeyhtiö have played the main role. A good checking point for all floaters' operations has been Laitaatsilta in Savonlinna, where Savon Uittoyhdistys (the Floating Association of Savo) records the data by enterprises. I am grateful to all the organizations concerned for their kind cooperations.

One point may be worth stressing: although in the past it was not always easy to get information for a work such as this, the cost elements needed for study have been available, though not from a single source. The price of a tug cannot be a secret, for whoever buys one wants to know its price beforehand. Oil dealers have to give the selling price of their products. The salaries are negotiated between the parties concerned and have been in print for many years. Overhead costs are unknown but they have no importance in a paper of this type which intends to show the differences between the economies of transport unit sizes but not those between firm sizes, managerial skill, etc.

During my work I have received valuable assistance from many persons. The grant mentioned above was awarded to Mr. Antti Kanerva, B. Sc. (Eng.) and myself. Mr. Kanerva calculated the velocity regressions and read through the manuscript.

The greatest help came from Mr. Toimi Mikkonen, whose experience of roundwood towing, and the statistics connected with it, covers several decades.

This type of work, based to a great extent on practical experience, cannot be carried out without the entire cooperation of the tug captains. I have been fortunate to work with captains willing to improve their work and try out new ways.

While thanking all these persons I want to mention especially, besides Mikkonen, the former Harbour Master Usko Savolainen and Captain Erkki Reinikainen. Mr. Reinikainen undertook much extra work in recording velocities, measuring raft lengths by radar, compiling data, etc.

I am also very grateful to the Society of Forestry in Finland, which agreed to print this paper in Acta Forestalia Fennica. The English text was checked by the English Centre in Helsinki and Mr. Tim Peck, M. F., to whom I must record a special debt of gratitude.

SI units are used in this paper and the recommendations and general principles concerning quantities, units and symbols are followed (See, for instance Ref. No. ISO 1000—1973 (E) and Ref. No. ISO 31/0—1974 (E)).

Finally, I hope this work will be of some practical value to route planners and builders and to route users who tow roundwood.

Berne, May 1976

Yrjö Roitto

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1. INTRODUCTION; PURPOSE AND METHOD

The transport unit in roundwood towing on Lake Iso-Saimaa comprises a tug and a raft of bundled wood with a towline between them. Where long-distance transport in the mid-1970s is concerned, the power of tugs varies, with some exceptions, between 150 and 440 kW. The average raft size is around 15 000 m^3, containing about 1100 bundles with an average bundle size of 14 m^3. The bundles are bound with chains and wires or with wires only. The biggest raft ever towed on Lake Iso-Saimaa had almost 75 000 m^3 of wood. The smallest rafts may contain only a few bundles, but then they are not normally considered as rafts for long-distance towing. The normal width of the raft has, since 1967/68, been 10 bundles, or about 30 m. The length of the average raft is about 100—110 bundles, equivalent to 600 m. The diameter of the towline is usually 20—22 mm and its full length between the tug and the raft is 350—450 m. The full length of the towline is always used when the routes and weather conditions allow. The full length is determined so that under the normal towing conditions the propulsion from the tug's propeller equals zero at the front of the raft. In the mid-1970s the transport unit on Iso-Saimaa usually has an assistant ship of 90—100 kW. It is mainly used for pushing the raft sideways to prevent it from touching ground, road ferries, piers, etc.

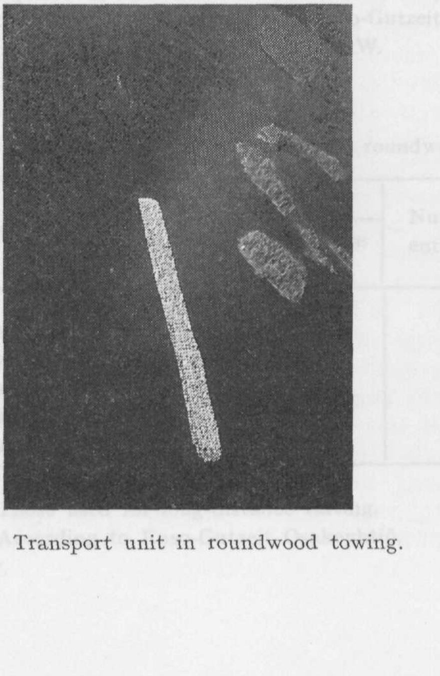

Fig. 1. Transport unit in roundwood towing.

There are several factors influencing the economic size of the transport unit in roundwood towing. These are changing with the enterprises and along with general developments. In this paper these factors or factor groups are seen from the point of view of the enterprise. The main question is to determine the most economic combination of tug and raft size. If the conditions are, or can be, standardized then the determination of this combination is easier than under differing conditions. However, one has to foresee in which direction developments are going.

In towing rafts of bundled wood, the velocity is relatively slow and can hardly be more than 5 km/h. A velocity superior to this causes the bundles to dive. For Saimaa rafting, cigar-shaped rafts cannot be built because constructing them is expensive and the routes are often too twisty for them. Increasing towing velocity in bundle rafting above a certain point increases costs so much that it is sound planning to start from the minimum velocity which is safe for the routes or for part of them. The degree of reliability in weather forecasting also enters the picture. It may be decided *in casu* whether it is wise to determine the safe minimum velocity on the basis of a comparatively small stormy part of the entire route or to use bigger tugs and/or smaller rafts on the stormy part of the route.

When the safe minimum velocity is determined, the next question is the size of the raft and the power of the tug. Smaller rafts with smaller tugs may reach the same velocity as bigger rafts with bigger tugs. Economically the relation is usually the following: the bigger the rafts, and hence the tugs, the smaller the costs per unit towed. There are two basic reasons for this:

- The form of the velocity function, dependent on raft size, in roundwood towing.
- The cost of tugs as a function of power.

The rafts cannot be indefinitely increased in size. In addition, there are factors influencing towing, although they are not called transport factors. The size of the enterprise (its factories, forest properties, etc.) influences the size of the raft, and so does the number of points from which the wood is brought in bundled form, the timing of deliveries, etc. The buoyancy of wood also plays a role.

In Finland, as in many other countries, the state promotes transport by building and improving routes. It is often a question of balancing the private economic and the national economic interests when the economic transport unit size is being determined. Especially on those waterways which consist of many artificial channels and lock canals, the larger the locks, channels, etc., the bigger the private economic benefit. This, of course, is said under the assumption that the enterprises using the waterways do not pay in full for the building and operation costs of the waterways. This is usually the case. From the builder's point of view, the bigger the construction work, the higher the costs. National economics does not only involve building and operating waterways; goals of general development have also been involved in public decisions. From the pure point of transport economics it is sound policy to require that each form of transport pays its costs, both private and national.

This paper is intended to help the planner and builder of waterways to decide how large constructions such as channels, widenings of waterways, etc. should be for the route user and roundwood tower. This is done by determining what would be the private economic transport unit size in roundwood towing on Lake Iso-Saimaa (in Eastern Finland), if the waterways were not to provide any restraints. The decision as to whether the size of the unit satisfies public development goals and fits the expenditures of national economy may be made only when the costs of necessary waterway improvements are known and the non-monetary effects (intangibles) recognized. Thus, this paper sheds light only on one aspect of the problem.

Since many factors influence the question under consideration, the ways of dealing with it in this paper vary. There is no uniform method employed; it is discussed in detail or is implicitly shown chapter by chapter. A short description of the features of development is intended to give an idea of why the question of raft size became so acute after the mid-1960s. A review of past developments also helps one to set the framework within which the problem has to be considered.

2. MAIN FEATURES OF DEVELOPMENT UP TO THE MID-1970S

Fig. 2 shows the main features in the development of raft size over a period of 50 years. According to the series showing the development of Enso-Gutzeit Osakeyhtiö's Saimaa rafting, it took almost 45 years to increase the raft size by about 100 per cent (1921–65) while it increased by the same percentage in the following 4 years (1965–69). Further increases have taken place between 1969 and 1975.

No major changes occurred in transport amounts and performances between 1960 and 1974 and no clear trend can be found on the basis of the figures presented. This implies that on Lake Iso-Saimaa, unless radical transport-policy changes occur, the quantities towed will, in the long run, be 4–5 mill. m³ per year and transport performance 800–1000 mill. m³km per year.

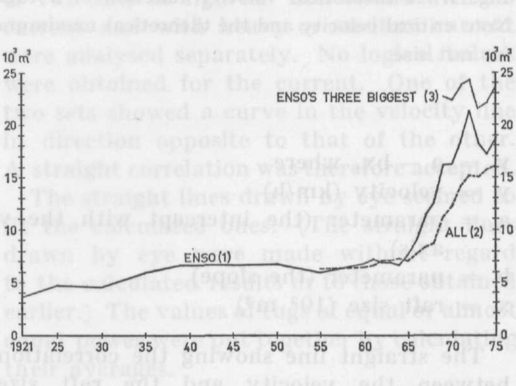

Fig. 2. Raft size of Enso-Gutzeit Osakeyhtiö in the Saimaa water system in 1921–74, that of all enterprises at Laitaatsilta Sound (Savonlinna) in 1955–75 and that of tugs of Enso-Gutzeit Osakeyhtiö with a power of 370–440 kW.

The number of enterprises engaged in roundwood towing has decreased by about 55 per cent during the period 1960–74. This does not necessarily mean the disappearance of firms whose wood was being towed. It mainly implies that the degree of rationalization and cooperation has increased, especially since the middle of the 1960s. Three big firms on Lake Iso-Saimaa formed a common organization for forestry activities, including roundwood towing, and ceased to be separate operators in 1968. Many firms, small and medium-sized, have discontinued their own towing and made contracts with bigger firms.

The number of tugs used in long-distance towing has decreased by 60–65 per cent during the period 1960–74. This is due to the above-mentioned discontinuation of independent operators and to a simultaneous increase of 80–90 per cent in the average power of tugs.

The average size of the bundle has changed very little.

Table 1. Main characteristics of roundwood towing on Lake Iso-Saimaa in 1960–74.

Year	Transport quantity 10^3 m³	 performance 10^6 m³km	Number of enterprises	Number of tugs[1])	Tug power, kW	Average size of bundle[2]), m³
1960	3,77	729	12	40	130	14,4
1965	4,36	864	13	42	140	13,8
1968	4,19	777	11	26	150	15,0
1969	4,88	928	9	23	180	15,1
1974	4,20	831	6	15	240	14,1

[1]) Those used for long-distance rafting.

[2]) According to Enso-Gutzeit Osakeyhtiö.

3. THE VELOCITY OF TRANSPORT UNIT

3.1 Velocity as a function of raft size and tug power

Data on towing velocities have been collected from logbooks since 1960. Before 1966, the variation in raft size was very small. Special experiments were organized for practical purposes and for this study. Raft sizes varied widely. Permanent test stretches were measured on nautical charts so that they were easily seen from the tugs; velocities on them were measured. The stretches were selected so that they also differed with respect to current.

At the time this paper was written (1975) no tugs of over 440 kW existed on Lake Iso-Saimaa. Values for bigger tugs were obtained not only on the basis of data calculated from the tugs of 440 kW and less, but also through experiments with two tugs of 440 kW or with tugs having a total of 660 kW.

The results from the logbooks and experiments agreed basically with studies and writings made earlier (especially Eklund 1952), and indicated that the correlation between the towing velocity and the raft size was linear and not sloping steeply. The velocity function may be expressed as follows:

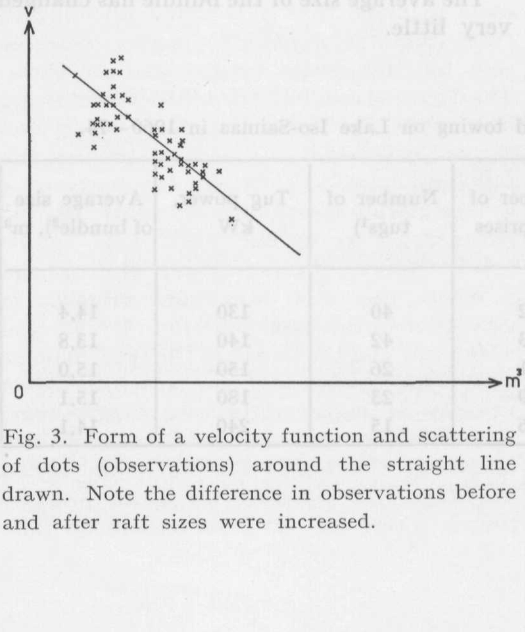

Fig. 3. Form of a velocity function and scattering of dots (observations) around the straight line drawn. Note the difference in observations before and after raft sizes were increased.

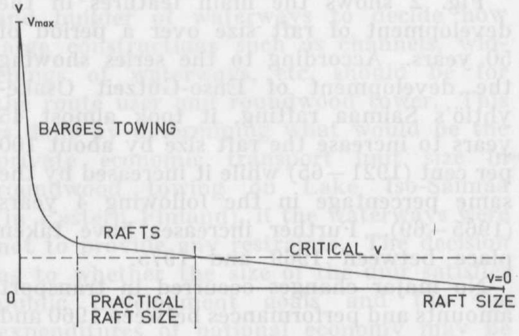

Fig. 4. A theoretical velocity function of a tug. Note critical velocity and the theoretical maximum for raft size.

$y = a - bx$, where
$y =$ velocity (km/h)
$a =$ parameter (the intercept with the y axis)
$b =$ parameter (the slope)
$x =$ raft size (10^3 m³)

The straight line showing the correlation between the velocity and the raft size cannot be used for all values of x. With $x = 0$, the velocity cannot be indicated by the parameter a, since a is supposed to imply the towing velocity with the 'smallest practicable raft'. Theoretically, $x = 0$ implies the velocity of the tugs without a raft which is much higher than the towing velocity with any size of raft. If the raft is excessively large its towing velocity is zero or almost zero.

Considering the limit where the 'effectively most rapid' towing velocity changes to that where the bundles dive helps one to understand the velocity functions of tugs of different power. Logically, the critical maximum velocity should be about the same regardless of the power of the tug. If this is true, then the velocity functions, when extrapolated to intercept with the y axis, may have their intercepts very close to each other. Consequently, the more powerful the tug, the smaller the slope of

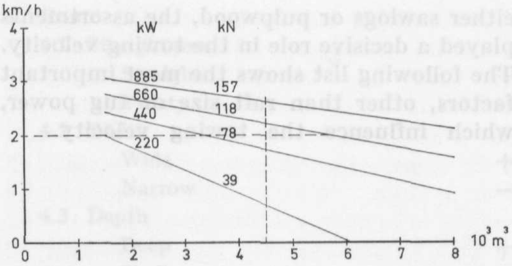

Fig. 5. Some velocity functions by raft size and tug power.

its velocity function according to the size of the raft (Fig. 5).

Regressions were calculated on the basis of two sets of figures. Conditions with no current and with heavy or medium current were analysed separately. No logical values were obtained for the current. One of the two sets showed a curve in the velocity line in direction opposite to that of the other. A straight correlation was therefore accepted.

The straight lines drawn by eye seemed to fit the calculated ones. (The straight lines drawn by eye were made without regard to the calculated results or to those obtained earlier.) The values of tugs of equal or almost equal power were put together by calculating their averages.

The velocity functions from which the values for Table 2 were derived and some of which are presented in Fig. 5, are as follows:

$y_{220} = 2{,}60 - 0{,}042\ x$
$y_{330} = 2{,}70 - 0{,}031\ x$
$y_{440} = 2{,}80 - 0{,}024\ x$
$y_{550} = 2{,}90 - 0{,}020\ x$
$y_{660} = 3{,}00 - 0{,}017\ x$
$y_{775} = 3{,}12 - 0{,}015\ x$
$y_{885} = 3{,}25 - 0{,}014\ x$

The subscripts below y refer to the power (kW) of the tugs concerned. Otherwise the symbols are as expressed earlier (p. 8).

The functions may not hold true — as already explained — for small values of x, but they *might* for big ones. Although the last mentioned case is not needed for practical purposes, for curiosity's sake the x values with y = O were calculated. They were as follows:

TUG POWER, kW	y = 0, 10³ m³ APPROXIMATELY
220	60
440	115
660	175
885	230

3. 2 The influence of other factors

The most decisive factors *influencing* the towing velocity are the raft size and the power of the tug when the raft construction remains the same. For this paper, only the raft size and the power of the tug were analysed quantitatively. The other factors were, however, recognized. One can list them and deduce the direction in which their influence is felt.

Table 2. Velocities, km/h, by tug power and raft size.

Tug power,	Raft size, 10³ m³						
kW	15	20	25	30	35	40	45
220	1,97	1,76	1,55	1,31	1,09	0,87	0,66
330	2,24	2,08	1,92	1,77	1,62	1,47	1,33
440	2,44	2,32	2,20	2,08	1,96	1,84	1,72
550	2,60	2,50	2,40	2,30	2,20	2,10	2,00
660	2,74	2,67	2,57	2,49	2,41	2,33	2,23
765	2,89	2,82	2,74	2,68	2,59	2,54	2,44
885	3,04	2,93	2,90	2,83	2,76	2,69	2,62

This paper concentrates on the average conditions on Lake Iso-Saimaa in the mid-1970s. The rafts usually include wood of several assortments, placed differently. In the 1940s and 1950s for example, when many rafts consisted only or mainly of either sawlogs or pulpwood, the assortments played a decisive role in the towing velocity. The following list shows the most important factors, other than raft size or tug power, which influence the towing velocity.

+ = increase
− = decrease

FACTOR AND CHANGE IN IT	INFLUENCE ON TOWING VELOCITY	REMARKS
1. Structure of raft		
Much water between bundles	−	See e.g. Helle 1927 and 1933 and Eklund 1952
Little water	+	
1.1 Wood		
1.1.1 Species	+ and −	Often linked with specific gravity, form factors and straightness of logs
1.1.2 Quality		
Good	+	
Poor	−	
1.1.3 Length of logs		
Unequal	−	Connected with point 1
Equal	+	
Long	(+)	Connected with points 1 and 1.1
Short	(−)	
1.1.4 Debranching		
Well done	+	Connected with points 1 and 1.1.1
Poorly done	−	
1.1.5 Debarking		
Barked	+	
Unbarked	−	
1.1.6 Water content, i.e. Dryness		
Green	−	
Dry	+	
1.2 Bundles		
1.2.1 Size		Each unit has a constant resistance independent of volume
Big	+	
Small	−	
1.2.2 Quality of bundling		
Good	+	
Poor	−	
2. Tug characteristics other than power	− and +	Linked with dimensions of tug such as length, draft, wind surface, etc.
3. Length of towline		
Long	+	
Short	−	

4. Route		
4.1 Straightness		
Straight	+	
Twisty	−	
4.2 Width		
Wide	+	
Narrow	−	
4.3 Depth		
Deep	+	
Shallow	−	
4.4 Current		
Upstream	+	
Downstream	−	
5. Weather		
5.1 Wind Speed		
High	−	
Low	± 0	
5.2 Direction		
Against	+	
Following	(−)	
5.3 Fog, rain, etc.	− or ± 0	Depends a great deal on tug equipment and its use
6. Professional skill of captains		
Good	+	
Poor	−	
7. Control		
Intensive	+	
Extensive	−	
8. Social conditions, personnel relations, etc.		
Good	+	
Poor	−	

3. 3 The critical towing velocity

If the raft size is constant, the critical velocity of the raft below which towing would not be advisable depends on the characteristics of the waterways and on weather, including the degree of reliability of forecasting the changes. The power of the tug would then be selected afterwards. The main question is how rapidly a tug should be able to cross an open lake with a raft in order to be able to reach shelter in time, if necessary.

The critical towing velocity was, in this paper, defined as follows: *The critical towing velocity is that needed to reach a sheltered place within the time interval for which weather forecasts are given with 80 per cent accuracy.* For conditions in the mid-1970s, this time interval is 18 h (Mäkelä 1975). However, it is assumed that reliable weather forecasts will be available by the end of the 1980s (Niitamo 1970, p. 284; Mäkelä 1975 a). This may, in the future, influence decisions concerning critical velocity. The critical velocity varies in different regions of Lake Iso-Saimaa. One critical region is Pyhäselkä in the northeastern part of the lake, where the towing route is 20 km on open lake. Since it is not logical to apply the requirements of one part of the lake, and especially that situated in the north, to the whole lake, different standards should be applied to Pyhäselkä.

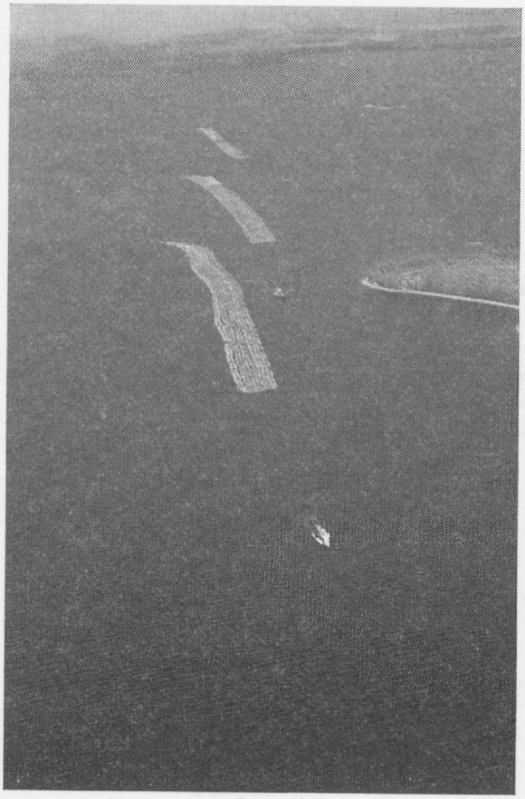

Fig. 6. Concentration of traffic in roundwood towing is often due to weather-bound stoppages. Three units which most likely had previously to stop at the same sheltered place.

Determining the critical towing velocity is a more delicate question than the critical raft size. Even relatively small decreases in velocity have sizable effects on the raft size (Fig. 5). In supplying wood for factories it is unimportant whether the velocity is 2 or 3 km/h. No strict time tables can be applied in roundwood towing anyway. Owing to bad weather, a trip may last three or four times as much as usual.

In addition, the timing of bundling, the operations of the floating associations, the collection of wood into big rafts from numerous bundling and other places, etc. are often more decisive factors affecting the *total* flow of wood to the factories by towing than the towing velocity itself.

The opinions of the four most experienced tug captains interviewed on *the critical towing velocity* varied from 1,9 to 2,0 km/h. *Here 2,0 km/h was chosen to be the critical towing velocity, which should not be undercut except in emergencies, when routes are twisty, for test purposes, etc.*

4. RAFT SIZE

4.1 Raft dimensions in different combinations

The normal raft on Lake Iso-Saimaa in the mid-1970s is usually 10 bundles wide. Therefore, under average conditions, the cubic volume of the raft can be determined by the number of bundles in the row. There are differences, of course, depending on the assortments of wood in the raft. Pulpwood is the most common type of wood in the 1970s. Most wood rafted on Lake Iso-Saimaa is bundled on trucks, so the conditions are more or less standardized since strict regulations exist on the dimensions of trucks, the weights of their loads, etc.

Fig. 7. Structure of a bundle raft. The raft has almost passed Laitaatsilta Sound.

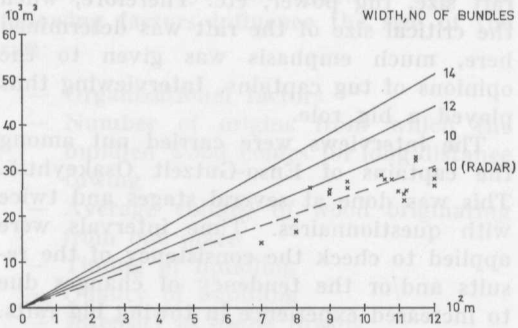

Fig. 8. Raft size in relation to length and width. Three theoretical examples and one using radar measurements.

The width of one bundle is about 3 m. The length of the bundle varies. The most common pulpwood length is 3 m. There is water between the bundles. Since rafts more than 10 bundles in width have also been towed, and since one of the purposes of this paper is to determine the most economic size for a raft, rafts wider than 10 bundles are also discussed.

It may be worth mentioning that before 1967 a raft 8 bundles wide was standard on Iso-Saimaa. Then, the minimum width of the row consisted of two bundles with a wooden boom between them. In the mid-1970s (and mainly since 1968), a row with one bundle is a common module and the bundles are linked to each other lengthwise by a cable usually 12 mm in diameter. Fig. 8 gives an example of the dimensions of rafts in different combinations.

4.2 The critical size

The feasibility of towing large bundle rafts through a narrow, twisty sound cannot easily be learnt from books or from theories taught at school. Long, varied experience produces good tug captains. The conditions vary from year to year, and it is not only the captains' own experience which counts.

Others' experiences, good or bad, are remembered perhaps for decades and are correlated mentally with prevailing conditions as regards weather, water level, current, raft size, tug power, etc. Therefore, when the critical size of the raft was determined here, much emphasis was given to the opinions of tug captains. Interviewing thus played a big role.

The interviews were carried out among the captains of Enso-Gutzeit Osakeyhtiö. This was done at several stages and twice with questionnaires. Time intervals were applied to check the consistency of the results and/or the tendency of changes due to increased experience in towing big rafts. The method of interviewing somewhat resembled that of the so-called Delfi techniques (Lastikka 1971). Much value was put on the opinion of those captains whose experience with big rafts was extensive and who were considered to be most qualified.

To define what is meant by the critical size of the raft requires assumptions on what, in the future, might be the minimum dimensions of a channel or sound on the main towing routes. Here, the dimensions of Puumala Sound were taken as the first criterion. This sound is centrally and strategically situated for roundwood towing in the whole Saimaa water system; it has a current, it is S-shaped and has road ferry traffic. All water traffic of importance moving along the main routes has to pass through this sound. Furthermore it is known by all tug captains. (Interviews are supposed to produce more reliable results when something real is referred to, instead of a theoretical sound or narrow stretch.)

Thus, for the purposes of this paper the critical size of the raft was first defined as follows: *The critical size of the raft is the maximum size which can safely be towed through Puumala Sound (southern Saimaa) with the help of an assistant ship of adequate power.*

The characteristics of Puumala Sound are as follows: minimum width 280 m, turning radius upstream 1830 m and downstream 315 m, average depth about 9 m (Lietsalmi . . .), average waterflow passing the sound 300 m³/s.

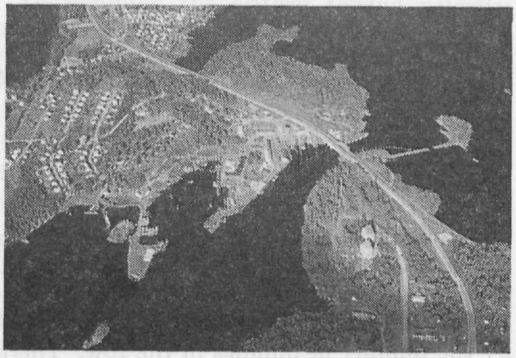

Fig. 9. In the mid-1970s, the practical critical raft size is often determined by sounds and channels like the one in this picture: Laitaatsilta. The biggest rafts which passed through this sound totalled 30 000—33 000 m³ in 1971—74.

The narrow and twisty sections also show how much flexibility a raft should have for safe towing. This is not only a question of the size of the raft, but how it is constructed, and also the relation between the width of the raft and its length. Besides the narrow places, open stretches and the position of sheltered places (natural or man-made) determine the critical size and the width/length ratio of the raft.

When the width/length ratio fulfils the flexibility requirements of the raft, weather enters as a critical factor. The length of the raft must be such that under windy

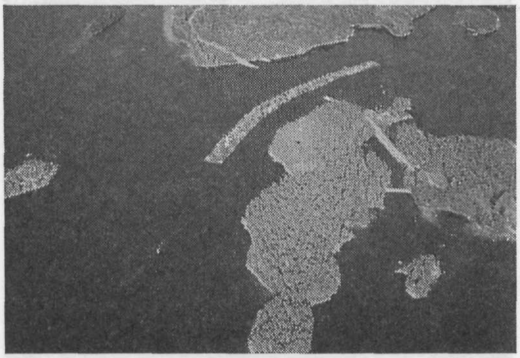

Fig. 10. A tug with a raft passing Vekaransalmi. — A very high degree of flexibility for the raft is required when a turn is made to the right after the small island on the left of the picture.

or stormy conditions it can be sheltered completely. In theory as well as in practice it is possible to cut the raft, but often such sudden changes in weather take place that there is no time for this operation.

There are also two reasons why one tends to build rafts as wide as the flexibility required by the route allows. The bundles, on the sides of the raft are most exposed to storms (waves). The shorter the raft, the fewer side bundles.

Secondly, the breakage of bundles increases towards the end of the raft. The following figures were obtained by analysing the breakage percentages during a whole navigational season and using the data of Enso-Gutzeit Osakeyhtiö:

EQUAL SECTION OF RAFT LENGTH FROM THE FRONT	BREAKAGE, PER CENT
1	13,9
2	16,9
3	28,6
4	40,6
RAFT	100,0

The results of the group interviews showed that the average critical size of the raft which could be towed safely through Puumala Sound was between 30 000 and 35 000 m^3, if an assistant ship was used. The biggest raft towed through this sound was, up to 1974, about 36 000 m^3.

The four captains with the most experience in towing big rafts with the most powerful tugs existing on Lake Iso-Saimaa by the mid-1970s were, however, interviewed again at the end of the 1974 navigational season. They were then of the opinion that the biggest raft which could be towed safely, with adequate power and with the help of an assistant ship, through Puumala Sound and which would only be safe in the spring and summer time, might have the following dimensions: *14 bundles, i.e. about 45 m wide and not longer than 1200 m. A raft with the above dimensions has a wood content of about 45 000 m^3* (Fig. 8). *For reasons other than purely navigational and disregarding towing techniques, this size was considered only as a theoretical critical size for which towing velocity and costs were calculated.*

4.3 The influence of other factors

The size of the raft is widely influenced by many factors other than available tug power, waterways and weather. E.g. the following factors influence the size of the raft:

- Organizational factors
- Number of origins from which the bundled wood comes for long-distance towing
- Average volume of wood originating from one place
- Timing of bundling
- Quality of bundling
- Intensity of feeder towing
- Buoyancy of wood
- Transportation distance
- Time requirements of factories
- Psychological factors.

Many of the above aspects may be interlinked. The organizational factors are of several types. A decisive role is played by the size of the enterprise or towing organization. If it is smaller than average, its annual wood procurement is also likely to be small. If the procurement is, in addition, spread widely over an area, the transport units of such enterprises are inevitably smaller than those of bigger ones. If the number of places from which the bundled wood originates for long-distance towing consists of only a few more or less permanent ones, the rafts tend to be bigger than in the opposite case.

On Lake Iso-Saimaa there are two distinct locations where wood is collected from large areas before it is handed over for long-distance towing. These are Joensuu in the northeast and Varkaus in the northwest of Lake Iso-Saimaa. In 1975, the average raft sizes of Enso-Gutzeit Osakeyhtiö from these places were about 15 000 m^3 (Joensuu) and about 19 000 m^3 (Varkaus). The average size of the raft originating from all truck bundling places was only about 3000 m^3 and was taken in 2–3 (2,6) rafts from one place during the navigational season. These places amounted to 41 in 1975. (North of Joensuu there are 25 bundling piers and north of Varkaus 38.) In addition to these so-called summer or permanent bundling places (or bundling piers), wood is bundled on ice and on the shore. The number of wood units originating from these (including the permanent places also used in winter) exceeds those mentioned above. The average units from them may, if the winter is mild, be less than 500 m³.

The timing of bundling plays a decisive role. It is closely connected with organizational questions, e.g. whether one tractor supplies a certain bundling place with wood for a long period of time or whether the bundling operations are highly concentrated in place and time.

Bundling has a great bearing on feeder towing when the buoyancy of wood, for several reasons, begins to deteriorate. If, in addition to a slow rhythm of bundling and the poor buoyancy of the wood, the quality of the bundling work is poor, then the feeder transport from bundling places must not be delayed, and this results in small rafts.

Usually small rafts are towed for smaller distances. When factories take wood by raft towing, they should either have adequate storage space or alternatively be able to take wood efficiently by barge or land transport as well. No timetables can be set for raft towing since storms cannot be forecast weeks ahead and operations may be brought to a standstill for days or weeks because of bad weather.

The following calculation from 1964—68 (Enso-Gutzeit Osakeyhtiö) shows the *average* change in weather-bound stoppages of tugs with respect to time:

TIME INTERVAL	STOPPAGES, PER CENT OF TOTAL NAVIGATIONAL TIME
—31.05.	4,8
01. 06.—30. 06.	6,7
01. 07.—31. 07.	8,8
01. 08.—31. 08.	11,9
01. 09.—15. 09.	18,7
16. 09.—30. 09.	24,1
01. 10.—15. 10.	31,0
16. 10.—31. 10.	32,0
01. 11.—15. 11.	33,7
16. 11.—	36,3

Still, there have been cases where wood towed in rafts has been required so urgently by factories that this has caused raft sizes to be reduced. In a case like this one could also speak of inadequate organization or communications.

There are psychological reasons also which may influence the size of the raft. The factories were 'not prepared' to take rafts bigger than they were used to and this has caused 'disturbances'. It is hard to believe, however, that it is more difficult to take in wood from one raft of 50 000 m³ in one hour than from 5 rafts of 10 000 m³ each in about 1 hour, especially if the rafts arrive at their destination at night.

Road ferry users have complained about the passing through of big rafts, although the total passing time of one raft of 50 000 m³ is much less than that of the combined passing time of 5 rafts each of which has 10 000 m³ of wood.

There is at least one psychological factor which is relevant. The tug captains (and mates) are paid according to the power of the tugs, not to the degree of difficulty in their work, skills required, performances produced, etc. Towing bigger rafts with constant power requires more attention than for smaller rafts. The captains are not themselves monetarily responsible for destroyed bundles or rafts. Within the accepted limits, the captains have freedom to choose what size of raft they take. It is understandable that, with the salary being the same regardless of the size of the raft, the tendency may be towards choosing smaller rafts.

5. TUGS

5.1 Characteristics and annual capacities

The tugs used on Lake Iso-Saimaa should fulfil the following requirements: extensive operations without bunkering, minimum draft combined with maximum power, good accommodation (with minimum noise level) and relatively high speed without a raft.

Mr. Matti Kaipiainen (from Enso-Gutzeit Osakeyhtiö, the Laitaatsilta Shipyard) has planned two sets of tugs, one for roundwood towing in general and one for Lake Iso-Saimaa (Kaipiainen 1970). The characteristics of the last mentioned set are shown in Table 3.

In Iso-Saimaa, the ice-free period lasts approximately 210 days, equal to about 5000 h. For many reasons, the navigational season of the tugs for roundwood towing is less than 5000 h. Although navigational seasons of almost 4500 h per tug have been recorded on Iso-Saimaa (the average towing distance being 200—230 km) a navigational season of 4000 h was considered an appropriate average for this paper.

There is enough empirical evidence that the annual performances (outputs) of the tugs of about 220 kW are between 55 and 60 mill. m³km on Iso-Saimaa when calculated to correspond to a navigational season of 4000 h. Under the same conditions, the recorded values for the tugs of 440 kW are 100—130 mill. m³km. By extrapolating these values, the capacities for the bigger tugs were obtained. Extrapolation could not be made in a straight way since in the case of 550 kW per tug the critical size of the raft was reached and hence a velocity of more than 2,0 km/h had to be employed. The levelling off in the raft size is not compensated for by an increase in velocity, owing to the gentle slope of the velocity functions. Since there is some evidence that more powerful tugs have less weather-bound stoppages than less powerful ones, this was taken into account in extrapolating.

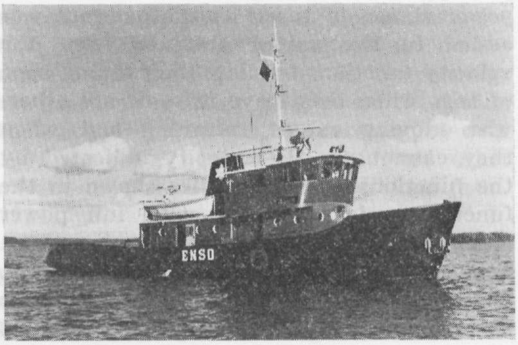

Fig. 11. The tug *Enso*, 440 kW, built in 1971. Photo by Erkki Reinikainen.

There is also another way of determining the annual capacities of tugs with different power. The functions show the average towing velocities by different tug power and raft size. The velocities without a raft are usually higher for more powerful tugs. On the other hand, the bigger rafts have been said to require more time per raft for

Table 3. Characteristics of the tugs concerned.

Power, kW	Corresponding force in towing, kN	Length of hull, m	Maximum draft, m	Displacement, m³
220	39	18,3	2,08	90
440	079	22,7	2,59	173
660	118	25,1	2,86	234
885	157	26,6	3,03	279

starting the tow and for delivery at the destination. By assuming different values for tugs of different power because of the reasons mentioned above, the average time per trip of 230 km was calculated by the power classes of tugs. Thirty per cent was added to the values obtained from the velocity functions to show the running time of tugs when they have rafts or are otherwise moving except returning and when they cannot use the velocity indicated by the functions. The velocities shown in the functions refer to those with full power employed normally in towing and without any slowdowns because of other traffic, adding bundles to the raft or reducing the size of raft, etc. After this correction, it was found which figure of the value thus obtained made 70—74 per cent (equal to total running time of tugs of different power classes). By so doing the figure obtained was for an average trip and included all stops. 4000 h divided by that figure gave the number of trips or the number of rafts towed during one navigational season. By multiplying this by the size of the raft concerned, the total quantity towed during the navigational season was obtained. By multiplying this quantity by the average distance of 230 km the capacity in transport performance was the product. These fitted the extrapolated values rather well. The results are shown in Table 4.

5. 2 Costs

5.2.1 Price of tugs

One would assume that the price of tugs of different power classes would be easily available. This was not the case unless by ease one means the freedom to choose between many possible prices.

The bigger shipyards were not interested in giving information. The smaller shipyards, from which price data were obtained, did not have much experience in building tugs in general or at least not those with a power of more than 440 kW. The chiefs of two shipyards, one medium-sized and one small, gave sets of prices. One set included the aggregate prices of tugs, the other excluded the main engine. In addition a set of index numbers, with the price of a 235 kW tug as its basis, was obtained from a consulting marine engineering bureau. The deplacement values by KAIPIAINEN (Table 3) were also used for checking purposes. In addition, at the end of 1974, the real selling prices were available from the same shipyard for a tug of 240 kW and 440 kW. The first was for delivery in mid-1975, the second for 1976. Thus the actual price level for tugs could also be checked.

The price of a tug, like that of a car or an aircraft, depends greatly on how it is equipped (radar(s), gyro compass, automatic pilot, radios, etc.). The most important single cost item is the main engine: it amounts to 10—15 per cent of the total cost of the tug. Its price varies according to make and type.

Table 4. Capacities, 10^6 m^{3}km, by tug power and raft size (navigational season 4000 h and towing velocity not below 2,0 km/h).

Tug power, kW	Raft size, 10^3 m^3						
	15	20	25	30	35	40	45
220	58	—	—	—	—	—	—
330	67	83	—	—	—	—	—
440	74	93	110	126	—	—	—
550	79	102	121	139	155	168	179
660	84	108	131	153	170	187	202
765	90	115	141	165	185	207	224
885	94	123	150	175	200	221	242

The price of low running engines tends to rise progressively towards higher power classes, while the price behaviour of fast running engines is the opposite. In the mid-1970s, engines with revolutions lower than 16—17/s were favoured for long-distance roundwood towing on Lake Iso-Saimaa.

All the price sets referred to above differed widely from each other. The set given by the engineering bureau showed progressive values towards higher power classes. It was not accepted here as such, since it differed from the other two price sets and did not coincide with the displacement series. It is not easy to believe that a tug of 885 kW costs twice as much as one of 440 kW. The former does not need crew accommodation twice as big as that of the latter. Both need only one galley, one mess room, one sauna, etc. For these reasons, its price should logically be less than double the price of a tug of 440 kW. Therefore, for the purpose of this paper a compromise set of prices was constructed.

It does not matter if the price of a tug is not exact. The main concern is that the price series is intended to show the *right magnitude* of the price and, in particular the *right* price *relationship* between the different power classes of tugs. The price of each tug is in any case individual, depending on the shipyard where it is built, the time of ordering (depression or boom), level of equipment, etc. Worth noticing at a time when prices moved steeply upwards (1970—1975) is that the tug prices here are intended to show those for delivery in 1974/75.

In this paper, 20 per cent of the tug price was assumed to indicate the annual interest on investment and the annual depreciation. If half of it is supposed to reflect interest, then half is left for depreciation. This would then imply a time span of 10 years. In the case of the Saimaa tug, this may imply a rather short time and hence, high annual capital cost. The price of the assistant ship has been omitted here (Table 5).

5.2.2 Labour

Labour is included in all cost items of towing, the price of tug, fuel, ship repair, etc. All prices usually increase when salaries and wages go up. What is meant by labour costs here are the salaries[1]) of the persons working on board.

The salaries are negotiated annually and agreed upon between the employer's association and the three federations or unions representing the ship personnel. The earnings are based on monthly salaries which, during the navigational season, are exceeded by over 100 per cent, due to overtime and other additions (for instance, Rannikko- ja . . . 1974).

The salaries are in direct relation to the power of the vessels. The basic monthly salary of the captain of a tug of circa 440 kW is about 8 per cent higher than that of the captain of a tug of 220 kW. The overtime done by the captains is compensated for by the so-called navigation fee and the difference in it between the power classes referred to is 12—13 per cent. Roughly, an addition of 100 per cent onto the tug power causes an addition of 10 per cent onto the salary of the key persons such as captains, mates and engineers. The salary for the deckhands and the cook is independent of the power of the vessel and, thus, the total increase in labour costs per vessel may be less than 10 per cent. Often it is more than 10 per cent since more persons are used in big than in small ships.

It has been discussed whether the power of the tug is a good basis for a salary scale since an increase in the power of the tug often facilitates the work both manually (less raft repair) and mentally (less work under risky conditions). In the future some structural changes may take place, but presumably they will not be radical. If the dependence on power were made directly proportional instead of using the dependence referred to, it would make no sense.

For checking purposes, the labour costs of tugs of different power classes was determined in many ways. The empirical data were used by converting them to correspond to navigational seasons of 4000 h. Theoretical labour costs were calculated on the

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[1]) Since the price of labour is mainly paid on a monthly basis, here the term salary is used all along.

basis of the salary agreements in force in 1974.

The number of persons forming a crew plays an important role, too. In the mid-1970s, a tug of 220 kW had a crew[1]) of 5 persons. A tug of 440 kW used a crew of 6 persons. The probable crew for a tug of 660 kW is 6–7 and for 880 kW 7–8.[2]) Since in determining the labour costs by tug power an extrapolation of the empirical values from tugs 220–440 kW was used, this implicitly reflects an increase of one crew member per 200 kW (approx.).

Unlike the practice of the mid-1970s, the salaries of all the crew for the whole year are included in the labour costs here (in a way allocated to the navigational season of 4000 h). That part of the salaries which could be allocated to specific work done for purposes other than tug repairs etc. might be excluded. There were two reasons why this was not done. Extended social benefits shorten the time when, outside the navigational season, the crew is free for other work. Second, the possibility was taken into account that no other work was available. Furthermore, it is logical to allocate the costs to the work for which labour is employed. Labour cost is supposed to include 30–35 per cent of social costs paid by the employers. This share is actually higher, about 44 per cent in 1975, but some of the reasons explained above justify the use of 30–35 per cent. The labour cost was supposed to reflect the 1974/75 price level. The annual labour costs obtained here for tugs of different power classes are shown in Table 5.

5.2.3 Fuel

Lubricating oil, roughly 10 per cent of the total fuel cost, is also included in this cost item. Fuel cost is composed of the consumption of the main engine, the aggregate, the assistant ship and the boiler for central heating (if any).

When the engine power and the time for using it are known, the consumption of fuel for tugs of different power may be calculated. The consumption for the main engine, often referred to, is about 210 g/kW/h (usually in the form of 167 g/H.P./h). Here consumption statistics were also used. They showed discrepancies from year to year, probably due to poor recording. From the averaged series, one important result was found: the statistical values were about 10 per cent below those obtained theoretically. This may show that, more often than assumed, the tugs have to use less than full power.

The price level of fuel and oil was calculated according to the 1975 price level. This already took into account the drastic change in fuel price over a short interval. Table 5 shows the fuel cost by different tug power classes.

5.2.4 Repair and other costs

Tugs need annual repair and upkeep. In Finland this work is normally done during the winter. Other costs, just a small fraction of the total, may include acquiring new equipment (not replacement), supplying tugs with soap, washing powder, paper, etc.

Repair costs may vary widely from year to year. The variation is due to basic repairs needed perhaps once or twice during the time a tug is used or to accidents such as collisions, sinking, engine explosion, or the like. Often it is statistically difficult to see what part of the annual repairs and upkeep is 'normal' and what is due to accidents. However, the repair costs caused by accidents also belong, as averaged, to the annual repair costs.

The repair costs have been determined to be 1,5–2,0 per cent of the price of a vessel, at least in the case of coasters (Norges . . .). EKLUND'S (1956, p. 59) series on the annual repair costs of the tugs of 7–180 kW show a rather slight dependence on the power, and hence the price, of the tug. EKLUND'S series also fit in well with the statistical data available for this paper. A source concerning self-propelled barges and pushers was used for checking purposes (MARCHAL 1970, p. 844) as were data on bigger ships (Ett fartygs . . ., p. 20).

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[1]) Here all ship personnel is included in the term crew.

[2]) The tug 'Harold A. Jones' of the Vancouver Tug Boat Co (Ltd) has 2730 kW and a crew of 8 (Vancouver . . .).

Since operation with a new fleet was one of the bases of this paper, the 'normal' annual capital costs by tug power classes were needed. The total costs here do not include overheads or fixed costs of an organizational nature. They are usually business secrets and even if they were not, they would play no role as far as this paper is concerned. Under otherwise constant conditions the power of the tugs does not influence the overheads of the organizations, at least not to such a degree that this question would be relevant here. The results of repair and other costs can be seen in Table 5.

6. SUMMARY OF COSTS: THE ECONOMIC TRANSPORT UNIT SIZE

Table 5. Costs, 10^3 FM/a, by cost group and tug power.

Group of cost	Tug power, kW 220	330	440	550	660	765	885
Capital	200	300	400	500	600	700	800
Labour	180	200	223	250	270	295	320
Fuel	74	112	149	190	225	260	300
Repairs and others	39	47	54	61	68	75	82
Total	493	659	826	1001	1163	1330	1502

Table 5 summarizes the costs (Chapters 5.2.1–5.2.4) by tug power.

When the annual capacities of tugs are known by power (Chapter 5.1) the unit costs of towing can be calculated by dividing the total costs by the annual capacities. Table 6 shows the results.

Table 6 and Figure 12 show that the minimum cost combination is where the size of the raft is 45 000 m³, and the power of the tug 550 kW (the towing velocity not below 2,0 km/h).

A raft size of 45 000 m³ is the critical theoretical maximum which was determined on the basis of captains' interviews using Puumala Sound as the route criterion. The calculations were based on the critical velocity of 2,0 km/h, which must not be undercut. Higher costs per unit are obtained when one moves towards tugs more powerful than 550 kW, keeping the raft size constant. This is because *a velocity increase in bundle raft towing does not pay as seen from Figure 13.*

If, in the mid-1970s the average raft size of 20 000–25 000 m³ is considered as an overall optimum, then tug power classes of 230–440 kW are considered to be within the power limits of the economic transport unit size. If one wants to be more precise, then a unit with a tug of 330 kW and a raft of 22 600 m³ is the optimum. However, often more velocity is needed or else rafts bigger than 20 000–25 000 m³ are easily available. In this case a tug of 440 kW with a raft of about 25 000 m³ or slightly less produces almost the optimum.

When considering the above results, one should also take into account the following aspect. The calculations in this paper were based mainly on the empirical material available from Iso-Saimaa towing, and it is not so long ago that the last steam tug disappeared. Therefore, probably too high

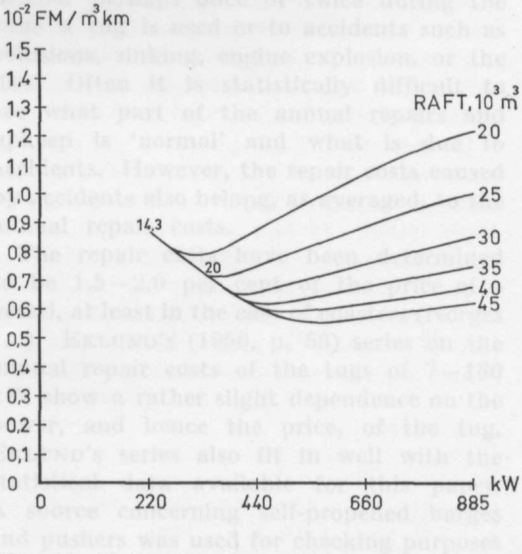

Fig. 12. Unit costs of roundwood towing by tug power and raft size, velocity not below 2,0 km/h.

Table 6. Unit costs of towing, 10^{-2} FM/m³km, by tug power and raft size (velocity not below 2,0 km/h).

Tug power, kW	Raft size, 10³ m³						
	15	20	25	30	35	40	45
220	0,85	—	—	—	—	—	—
330	0,98	0,79					
440	1,12	0,88	0,75	0,66	—	—	—
550	1,27	0,98	0,83	0,72	0,65	0,60	0,56
660	1,38	1,08	0,89	0,76	0,68	0,62	0,58
765	1,48	1,16	0,94	0,81	0,72	0,64	0,59
885	1,60	1,22	1,00	0,86	0,75	0,68	0,62

a degree of effective power is taken out per kW from diesel engines, causing, in the long run, unnecessary and expensive repair costs or an early change of engine. In practice when selecting the tug power, it may be advisable to use certain safety additions.

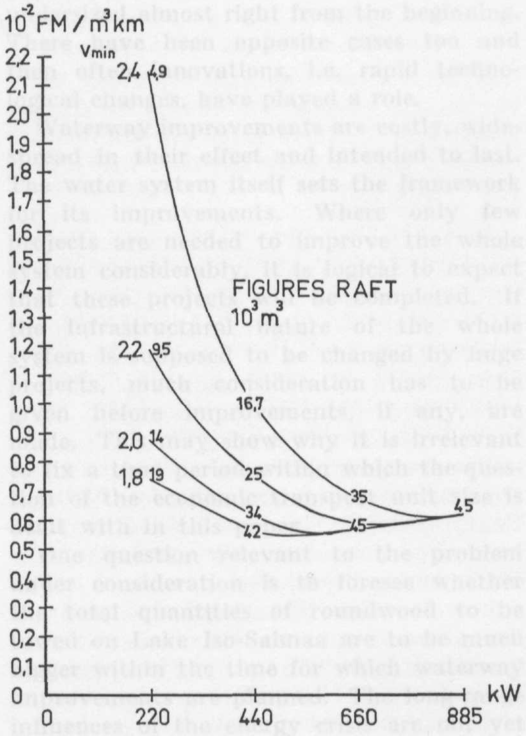

Fig. 13. Unit costs of roundwood towing by tug power and raft size, velocity being 1,8, 2,0, 2,2 and 2,4 km/h.

A raft of 45 000 m³ would, on average, be 1050 m long when 14 bundles wide and 1230 m long when 12 bundles wide. The former is preferred. For smaller rafts the lengths, when 12 bundles wide, would be as follows:

LENGTH, m	RAFT SIZE, 10³ m³
1090	40
950	35
820	30
680	25

In the long run, a certain price development has become common. The labour cost, especially for heavy and/or uncomfortable work has increased at a faster rate than prices in general. With time, the prices for certain commodities have stayed almost constant or have risen only at a very slow rate in relation to general prices. During the 1960s, fuel, for instance, belonged to that group of commodities where the nominal prices rose so little that the real prices went down. For some time, the real prices of machinery and equipment have also been fairly constant, perhaps due to increased international competition and the economies of scale.

Just before the mid-1970s, unusual price changes took place. They were drastic despite severe inflation. Among others, oil went up in price three times in about two years. There is, at the beginning of 1976, uncertainty as to what further developments will be. The earlier price changes have mainly concerned raw materials and, through this, the prices of engines and other equipment made out of metal.

The conclusions concerning the economic transport unit size were based mainly on 1974/75 price levels. A calculation for the future may be based on an assumed price development. The following assumptions may be made on the changes in labour cost in relation to other prices:

1. An increase of 100 per cent.
2. An increase of 200 per cent.

There are reasons for this supposition. It is most likely that in the long run labour costs in particular will increase most, especially since raw material and fuel prices underwent drastic changes not long ago (1975 as a base). Also from the point of view of analysing the sensitivity of the calculations, and especially from the point of view of the unit costs, there is no point in changing cost items which are fully or almost fully proportional to tug power (capital cost and fuel) or which are insignificant (repairs and other costs).

From the point of view of this paper, i.e. finding the economic solution regarding the size of the transport unit, the effect is nil. The calculated optimum stays where it was on the basis of the situation in the mid-1970s. The only change worth mentioning is that increases in labour costs bring less powerful tugs further away from the calculated or decided optimal power. Since a relative increase in labour costs is a rather real assumption and since a labour shortage is already a fact, this may have a bearing on future plans.

7. DISCUSSION

Forecasting is not an easy task. Forecasting in the field of transportation is no exception: on the contrary. One would like to know the future transport quantities and distances, the development of the different means of transport, their cost relations, size of transport units, velocities, etc. Transport creates other activities. Similarly, other activities create transport. In a way, the question is the same as that of a dependent and independent variable. Economic activities are linked with many factors, including innovations which are difficult to foresee.

The route planner and builder is in a difficult position even when forecasts exist. Usually the rate of future developments has been underestimated and, as a result, a highway, canal or airport has proved to be undersized almost right from the beginning. There have been opposite cases too and then often innovations, i.e. rapid technological changes, have played a role.

Waterway improvements are costly, widespread in their effect and intended to last. The water system itself sets the framework for its improvements. Where only few projects are needed to improve the whole system considerably, it is logical to expect that these projects will be completed. If the infrastructural nature of the whole system is supposed to be changed by huge projects, much consideration has to be given before improvements, if any, are made. This may show why it is irrelevant to fix a time period within which the question of the economic transport unit size is dealt with in this paper.

One question relevant to the problem under consideration is to foresee whether the total quantities of roundwood to be towed on Lake Iso-Saimaa are to be much bigger within the time for which waterway improvements are planned. The long range influences of the energy crisis are not yet completely known. What is known is that no *sudden* changes can take place in forest growth in Finland. Road construction, at least in eastern Finland, is supposed to progress more than waterway construction. The USSR will probably export less roundwood, well suited for floating, in the future. More intensified silviculture is expected to produce wood with less density than before; this means that the buoyancy of wood will decrease. Consequently, a part of the wood which would have been towed in rafts in the mid-1970s will, in the future, be moved by land or barge transport if the last mentioned form is developed in Finland. The belief that no major changes will take place in the raft towing quantities of roundwood in eastern Finland in the long run helps to determine the economic transport unit size in roundwood towing on Lake Iso-Saimaa. Whether this is the best assumption is not easy to say since some national economic, social and environmental factors may push more traffic from roads onto railroads and waterways than believed in 1975.

If it is assumed that no drastic changes in the transport performances of roundwood towing on Lake Iso-Saimaa are expected, the following question arises: what should be done to move towards more economic operations which, in turn, require more powerful tugs and bigger rafts. Large enterprises should acquire more powerful tugs, and the enterprises whose annual roundwood towing is less than 130 mill.m^3-km should not operate alone since they are not large enough to benefit from the economies of scale. Consequently, a further prerequisite towards more economic operations would be increased cooperation. It would mean perhaps only 2—3 enterprises towing roundwood rafts on long distances on Lake Iso-Saimaa instead of 6 in 1975 (for instance ROITTO 1973).

Building a new fleet for roundwood towing on Lake Iso-Saimaa would cost around 20 mill. FM in 1974/75 delivery prices, regardless of the power of tugs between approximately 220 and 880 kW per vessel. Fewer expensive tugs are needed than cheaper ones. When compared with the smallest power class dealt with in this

Table 7. Alternative costs (in 1974/75 prices) of roundwood towing on Lake Iso-Saimaa by tug power with respective force, number of tugs, raft size and velocity.

Tug power, kW	The corresponding force, kN[1]	Capacity 10^6 m^{3}km/ navigational season	Number of tugs required[2]	Size of raft, 10^3 m^3	Velocity, km/h	Costs per tug, 10^3 FM/a	Total costs,[3] 10^6 FM/a	Marginal costs, 10^6 FM/a
220	39	55	23	14,2	2,00	493	11,4	—
330	59	90	14+1	22,5	2,00	659	9,5	−1,9
440	79	135	9+1	33,5	2,00	826	7,9	−1,6
550	98	180	7+1	45,0	2,00	1001	7,5	−0,4
660	118	200	6+1	45,0	2,23	1163	7,7	+0,3
775	137	220	6	45,0	2,44	1330	8,0	+0,3
885	157	240	5+1	45,0	2,62	1502	8,3	+0,3

[1] Not according to the bollard pull but by practical force used in towing, about 80 per cent of bollard pull.

[2] The number after the sign + refers to a tug belonging to a lower power class.

[3] Without overheads.

Note: The total transport performance per navigational season is supposed to be about 1250 10^6 m^{3}km; in addition, some extra capacity is included in the number of tugs.

paper, some 4 mill. FM could be saved annually if an average size of raft of 45 000 m³ could be reached. Since this is difficult, if not unrealistic, and could cause extra costs elsewhere than in long-distance towing of roundwood, the average size of a little less than 35 000 m³ should be considered a reasonable long-term goal, especially when the annual savings for towing enterprises would only decrease from the above mentioned 4 mill. FM by less than half a mill. FM (Table 7).

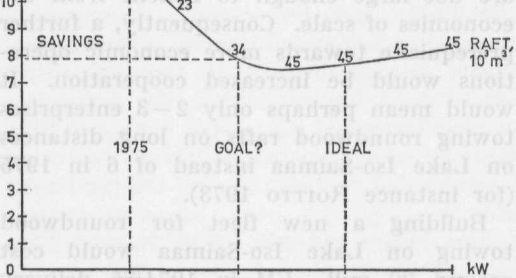

Fig. 14. Alternative total costs of Iso-Saimaa roundwood towing without overheads by tug power combined with respective raft size and velocity not below 2,0 km/h.

It would then not be necessary to plan raft-towing routes wider than those allowing free space of about 50 m, especially when a channel, sound or the like is straight and relatively short. If it is not straight, allowance should be made for the degree of twistiness, other traffic, etc. These questions have not been discussed here.

The results of this paper show how far-reaching the planning of the National Board of Public Roads and Waterways has been. The standards applied up to the mid-1970s have allowed the roundwood towers almost to triple the size of their rafts in less than 10 years. The waterways, at least those from 1960 to 1964 (the completion of Vuokala and Haponlahti and the widening of Laitaatsilta Sound) have not yet been a big handicap for developing raft towing. The worst bottleneck which does not let rafts 10 bundles wide pass, can be avoided. This bottleneck is the Kutvele Channel in

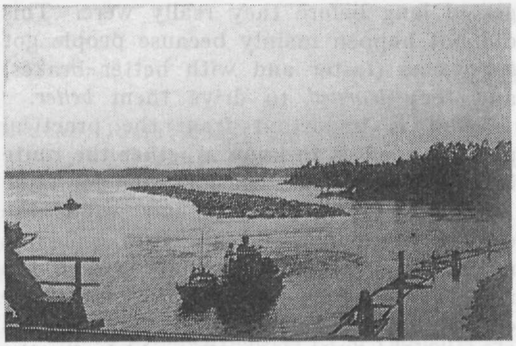

Fig. 15. A transport unit of roundwood towing approaching a future bottleneck, Laitaatsilta. Note two assistant ships, one approaching the raft from the side.

South Saimaa, which, however, should be rebuilt by summer 1977. Laitaatsilta Sound as well as Haponlahti Channel will soon have a maximum limit for rafts 9 bundles wide. Decreasing the adopted width of 10 bundles in the size of the raft to 9 would mean a degression in rafting.

It is the planner's and builder's task to determine the costs involved in waterway-improvement investments if the width of channels or the like is suitable for taking rafts 11, 12, 13 or 14 bundles wide. One logical width for rafts is 12 bundles since Varkaus lock passes parts of rafts 3 bundles wide and Joensuu 4 bundles wide; the smallest common product of the modules 3 and 4 equals 12. It is also the planner's and builder's work to foresee whether it is more economic to build one width of a channel etc. in one or several stages. Special single and fixed costs are always involved only in one stage and it may be wise at least to acquire land for possible further widenings at the initial stage. On the other hand, if land acquisition is ignored, there are practical experiments which show that in time construction methods tend to improve to such an extent that building in several stages might prove to be more economic than in one stage.

After Kutvele, Laitaatsilta is the next important route improvement project on Lake Iso-Saimaa. It is questionable whether it is worth while widening again, since, to get the maximum benefit from it, Haponlahti Channel should also be widened. Haponlahti has already (by 1974) been too narrow for rafts 10 bundles wide in dry summers. Widening Laitaatsilta should be connected with widening Haponlahti. The width of the possible new building of Muhasaari (Roitto 1969) should be the same as in Laitaatsilta. The possible rebuilding of Kivisalmi Channel to make it suitable for raft towing should be done according to the same raft size requirements as Tikankaivanto and Vuokala.

Lastly, one point of interest connected with route building should be mentioned:

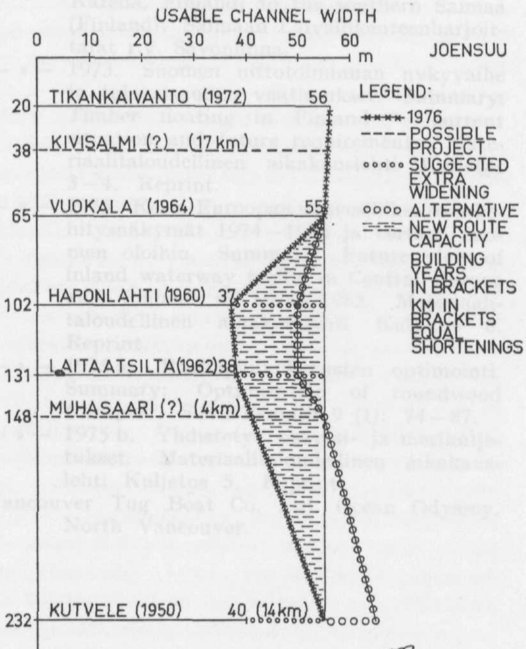

Fig. 16. Scheme of critical channels and sounds on the route between Joensuu (north end of Iso-Saimaa) and Imatra (one of the south ends of the lake). The 1976 situation and some suggestions.[1]

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[1] The measures of the usable channel width vary according to the source used. The measures used in Fig. 16 of this paper are those given by the National Board of Public Roads and Waterways by telex on 4th and 9th December, 1975.

why Vuokala Sound, rebuilt in 1964, is still relevant to future plans since it was said, some 10 years ago, to be difficult even for rafts 8 bundles wide. The following explanation may help one to understand the situation: it was a new route 10 years ago and experiences gained by then were few. Psychologically, what is new is very often considered to be bad (for ex. Roitto 1958). Raft construction has since changed, tug power increased and the system of assistant ships adopted. The level of knowledge has increased. According to the forecasts, the bridges of San Francisco's Big Bay should have been completely congested long before they really were. This did not happen mainly because people got *better* cars (faster and with better brakes) and they *learned* to drive them *better*.

What is important from the practical point of view is to know whether the route improvements under consideration for Lake Iso-Saimaa are feasible and what the dimensions should be. The best economic results as a whole are achieved when the route builder does not invest in extra route capacity and when the route user acquires tugs and constructs rafts which fit the waterway system so that the optima can be reached.

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Résumé:

LE VOLUME ECONOMIQUE DU REMORQUAGE DE BOIS RONDS SUR LE LAC ISO-SAIMAA, EN FINLANDE ORIENTALE

Au cours de la période de 1921 à 1965, le volume des radeaux de bois ronds remorqués sur le Lac Iso-Saimaa s'est accru de 100 pour cent. Selon les mêmes données statistiques, il a augmenté à nouveau de 100 pour cent entre 1965 et 1969. Depuis lors il a continué d'augmenter.

Ceci étant, l'Administration Publique des Ponts et Chaussées a exprimé le voeu que les entreprises utilisant les voies de flottage pour remorquer du bois rond établissent des prévisions quant au développement ultérieur de la dimension des radeaux. La présente étude vise à fournir un tel pronostic.

En ce qui concerne le remorquage de bois ronds sur le Lac Iso-Saimaa, les limites de vitesse ne sont pas grandes. La vitesse critique de remorquage en dessous de laquelle on ne devrait pas opérer normalement est d'environ 2,0 km/h. D'autre part, augmenter la vitesse pour le remorquage de bois ronds n'est pas économique. Pour une augmentation relativement modeste de la vitesse, une puissance supplémentaire importante est nécessaire. La vitesse pratique de remorquage varie entre 2,0 et 2,5 km/h.

La dimension du radeau est essentiellement déterminée par les voies de flottage et les conditions atmosphériques, ainsi que par la précision des prévisions météorologiques. Cependant, il y a encore bien d'autres facteurs qui influencent la dimension pratique du radeau, tels ceux qui dépendent des organisations, de la flottabilité du bois, des considérations psychologiques, etc. Quand, après avoir tenu compte de tous ces éléments, la dimension du radeau a été déterminée, la puissance du remorqueur entre en jeu. Plus le radeau est grand, plus le remorqueur doit être puissant.

Pour le remorquage de bois ronds, les fonctions de la vitesse ne sont pas très importantes. Les coûts de remorquage augmentent moins que la puissance du remorqueur. Par conséquent, plus le radeau est grand plus les coûts par unité diminuent, pour autant que la vitesse critique de 2,0 km/h soit maintenue.

Comme il existe de nombreuses raisons de ne pas considérer comme réaliste un radeau maximum — contenant 45 000 m^3 de bois — c'est un volume de 35 000 m^3 qui a été pris en considération dans la perspective d'un développement à long terme. Remorquer des radeaux de cette grandeur à une vitesse pas inférieure à 2,0 km/h exige un remorqueur de 550 kW. La formule optimale des années 1970 serait soit un radeau de 22 600 m^3 avec un remorqueur de 330 kW, soit un radeau de 30 000 m^3 avec un remorqueur de 440 kW. Cela donne l'ordre de grandeur dans lequel se situe l'unité économique. Pour des 'raisons de sécurité', on devrait toujours augmenter dans une certaine mesure la puissance calculée du remorqueur.

De toute façon, si le volume de 35 000 m^3 doit être également pris en considération dans les prévisions des planificateurs et des constructeurs de voies navigables comme un but réaliste à long terme, les chenaux et l'élargissement des détroits devraient être préparés de manière à permettre le passage de radeaux d'une largeur de 36 à 40 m et d'une longueur approximative de 1000 m.[1]) Toutefois si la voie navigable n'est ni longue ni sinueuse, normalement une largeur de 50 m est suffisante pour la grandeur du radeau mentionnée ci-dessus.

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[1]) En eaux libres, le câble de traction entre le remorqueur et le radeau a une longueur d'environ 400 m, qui est réduite dans les passages étroits.

Tiivistelmä:

TALOUDELLINEN KULJETUSYKSIKKÖ ISON-SAIMAAN NIPPULAUTTAHINAUKSESSA

Nippulauttahinauksessa hinaaja ja lautta ovat kuljetusyksikkö. Lautan rakenteen, puulajin ym. tekijöiden ollessa vakio lautan koko ja nopeus ovat negatiivisesti korreloituneet. Korrelaatio on lineaarinen ja kulmakerroin pieni vaihdellen välillä 0,014 . . . 0,042 hinaajan teholuokissa 220 . . . 885 kW. Edellä mainitut teholuokat vastaavat hinauksessa voimaa 39 . . . 157 kN. Lautan nopeus on positiivisesti korreloitunut hinaajan tehoon ja vetovoimaan.

Tärkeimmät aluskohtaiset kustannukset ovat pääoma, palkat ja polttoaine. Näistä polttoaine on suoraan verrannollinen aluksen tehoon, pääoma lähes suoraan ja palkat vähiten.

Nopeusfunktioiden muodosta ja palkkakustannusten suhteesta aluksen tehoon johtuu, että mitä suurempi kuljetusyksikkö, sitä pienemmät *hinauskustannukset* yksikköä kohti.

Vesistön ominaisuudet asettavat rajan lautan maksimikoolle ja miniminopeudelle. Viimeksi mainittuun vaikuttaa myös sääennusteiden luotettavuustaso. Edellisten tekijöiden lisäksi on organisatorisia, psykologisia ja muita hinauksesta riippumattomia tekijöitä, jotka estävät lautan teoreettisen maksimin hyväksi käytön.

Edullisin kuljetusyksikkö on se, joka tuottaa pienimmät yksikkökustannukset annetuissa puitteissa. Annettuja tekijöitä ovat tällöin miniminopeus, jota ei normaaliolosuhteissa aliteta sekä keskimääräinen lauttakoko, joka pyritään määräämään lähinnä *käytännöllisen* maksimin mukaan.

Kriittisenä nopeutena eli miniminopeutena on tässä työssä pidetty 2,0 km/h ja kriittisenä lauttakokona eli maksimina 45 000 m^3. Ko. lauttakoko on kuitenkin siinä määrin teoreettinen, että se on otettu huomioon vain laskennallisena maksimina. Jos käytännöllisenä lautan optimikokona 1970-luvun puolivälissä halutaan pitää 20 000 . . . 25 000 m^3, silloin vastaavasti hinaajatehot 300 . . . 440 kW muodostavat em. lauttojen kanssa taloudellisen kuljetusyksikön, tarkasti sanoen 330 kW hinaaja ja 22 600 m^3 lautta. Usein tarvitaan enemmän nopeutta kuin kriittiseksi otettu 2,0 km/h ja usein myös suurempi lautta kuin 22 600 m^3 on helposti saatavissa. Tällöin n. 25 000 m^3 lautta ja n. 440 kW tai vähän heikompi hinaaja on lähes yhtä taloudellinen edellisen vaihtoehdon kanssa.

Taloudellinen kuljetusyksikkö on suuresti tavoitteenasettelusta riippuva. *Jos lauttakooksi valitaan 45 000 m^3, 550 kW hinaaja tuottaa minimiyksikkökustannuksen. On varsin kyseenalaista, voidaanko lautan keskikoko 45 000 m^3 saavuttaa ja onko se edes edullista väylänrakennus ja monet muut seikat huomioon ottaen.*

Pitkäjänteisenä tavoitteena voitaneen pitää lauttakokoa 35 000 m^3. Tällöin hinaajan vastaavan tehon tulisi olla 550 kW (optimi) tai yli. — Kauan kestäneen höyrylaivakauden vaikutuksesta dieselmoottoreilla saatetaan vieläkin käyttää liian suurta kuormitusta. Tämän vuoksi edellä sanottuihin (lähinnä empiirisiin) tuloksiin lienee lisättävä riskivaraa niissä käytännön ratkaisuissa, joissa valitaan hinaajan teho. — 12 nippuriviä käsittävänä 35 000 m^3 lautan leveys olisi 36 . . . 40 m ja pituus keskimäärin vähän alle 1000 m. Näillä perusteilla tulevaisuuden väylätyöt voitaneen mitoittaa.

Résumé

LE VOLUME [illegible]
SAIMAA, EN FINLA[illegible]

Au cours [illegible] des radeaux [illegible] de [illegible] les Saimaa [illegible] les mêmes [illegible] nouveau [illegible]

Depuis [illegible]

Ceci établi [illegible] et Chaussée [illegible] utilisant [illegible] bois ronds [illegible] qui a été pris en considération dans [illegible] développement [illegible] radeaux [illegible] pronostic [illegible]

En ce qui [illegible] de 330 kW. La [illegible] sur le Lac [illegible] sont pas grandes [illegible] en dessous [illegible] normalement [illegible] dans lequel se situe [illegible] part, augmenter [illegible] bois ronds [illegible] mentation relativement modeste de la vitesse, mais [illegible] puissance [illegible] La vitesse [illegible] et 2,5 km/h [illegible]

La distance [illegible] navigables comme [illegible] déterminé [illegible] atmosphériques [illegible] prévisions [illegible] encore [illegible] dimension [illegible] eaux [illegible] dépendent [illegible] bois, des [illegible] après avoir [illegible] dimension du radeau a été déterminée, la puissance du remorqueur entre en jeu. Plus le radeau est grand, plus le remorqueur doit être puissant.

Pour le remorquage de bois ronds, les fonctions

---

[1] En eaux libres, le câble de traction entre le remorqueur et le radeau a une longueur d'environ 400 m, qui est réduite dans les passages étroits.

ROITTO, YRJÖ O.D.C. 378.34

1976. The economic transport unit size in roundwood towing on Lake Iso-Saimaa (in Eastern Finland). ACTA FORESTALIA FENNICA 153, 31 p. Helsinki.

The above mentioned subject was dealt with from the point of view of towing enterprises. Then the unit costs of transport are the most decisive factor. Both the size of the raft as well as the power of the tug influence strongly the unit costs. As a long-term goal a raft of about 35 000 m^3 and a tug of 550 kW or more is considered to be advisable. The width of channels and sounds then allow a free passage for rafts being 36—40 m wide.

Author's address: SF-57510 Savonlinna 51, Finland.

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