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Int. J. Production Economics 40 (1995) 153–161

international journal of production economics

Estimation of investment costs in fish processing plants

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Accepted for publication April 1995

Abstract

Investment costs for fish processing plants are hereby presented along with a detailed analysis of different types of processes in relation to economies of scale.

The cost-capacity factor for fish industry is estimated as 0.84, except for fish meal plants where the cost-capacity factor is 0.61.

It is also discussed how technology, capacity and location in developed and developing countries can affect investment costs for fish processing plants, while cost-capacity factors remain unchanged.

The concept of minimum limit for industrial capacity is included. Investment costs for minimum size plants or plants below minimum size are even greater than what would correspond to the correlation line. This is due to the need to incorporate one or more oversized pieces of equipment.

Keywords: Investment costs; Cost-capacity factor; Fish; Food

1. Introduction

By the use of estimation methods proposed in the literature [1–5], it is possible to calculate, with a certain degree to accuracy, the required investment for a fish plant.

Estimating the cost of a plant can vary from a quick estimate to a carefully prepared, detailed calculation using a complete flow chart, with specifications, depending on how much is known about the product and how much time and effort is available to do the estimate.

Installed process equipment costs may be used as a basis for estimating the cost of complete plants.

Lang [6] was the first to state the empirical law that the relation between the cost of a plant and its primary equipment is a constant, as a result of analyzing the capital investment for the construction of a number of plants. The value of this constant, or the Lang factor, depends on the nature of the process, particularly the type of products manufacture. A marked difference is observed between the factors used for fish plants and chemical plants (where the latter are greater than the former). This difference is due to a larger auxiliary infrastructure

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SSDI 0925-5273(95)00043-7

in chemical plants, which is not often observed in food factories.

Besides, the cost of the primary equipment depends on the materials of construction. For food plants stainless steel is commonly used, and consequently the basic price should be multiplied by a correction factor (always higher than one and up to five).

Values on the Lang factor and detailed factor estimates for fish processing plants and food processing plants have been presented in previous papers [1].

The Lang factor method was limited to a single factor for calculating overall costs. The factor method, for detailed estimates, achieves improved accuracy by adopting separate factors for different cost items: several factors for the estimating of buildings, instrumentation and so forth, and of indirect expenses such as engineering, contractor's profit and contingency.

Total fixed investment costs can be estimated, with a 10–15% error margin, by carefully selecting the factors within a given range [2].

Similarly, the recognition that the cost of a plant (or an individual piece of equipment) is proportional to its capacity raised to a power, also provides a rapid costing technique with improved accuracy.

In fact, the literature on the subject usually does not contain detailed calculations but only descriptions of the main equipment and their costs, construction costs and data on total fixed investment, from which a global cost for the other items can be estimated.

On the other hand, many articles have been written about cost-capacity factors for chemical plants [3], but little information is available on food processing plants.

The purpose of this work is to present cost-capacity factors for fish processing plants, to support a faster estimating of investment costs for different plant sizes.

Furthermore, investment costs for fish processing plants in different locations, with different capacity and when technology varies, are analyzed.

2. Model application

In general, costs do not rise in strict proportion to size. Plant or equipment costs can be estimated when data are available for a similar project, although capacity is different from the project desired. For this reason, the relationship can be expressed in the form

$$I_1 = I(Q_1/Q)^x, \quad (1)$$

where I_1 is the calculated fixed investment for capacity Q_1, and I is the fixed investment for capacity Q (basic size).

The exponent x in Eq. (1) is known as the cost-capacity factor [4]. Its average value tends to be 0.6, and for this reason the relationship is also known as the six-tenths factor rule. But in recent articles, the average x value for 200 chemical processes [3] and engineering equipment was found to be 0.7 by Remer and Chai [5].

Some discrepancies can be found in the published factors. These may have been caused by variations in plant definition, scope and technology.

However, 0.7 is an average value and its range varies from below 0.2 to more than 1.0.

Fixed investment varies as the xth power of capacity in Eq. (1). Letting $x = 1$, a strictly linear relationship is obtained denying the law of economies of scale.

The model does not usually cover those situations where the estimated design Q_1 is greater or less than Q by a factor of 10.

Corrections for changes in investment over time can be made by using the appropriate cost index.

If the fixed investment is plotted against capacity on log–log paper, a straight line will be obtained with a slope equal to x. However, this does not always happen, and curves might be obtained which show the presence of two or more cost-capacity factors, each covering a certain range, and providing better results than an overall average factor.

Tables giving values of this factor, related to chemical plants and equipment, can be found in literature on the subject [3, 5, 7–12].

3. Results

3.1. Cost-capacity factors

Table 1 was obtained by applying Eq. (1) on the values of investment costs for fish processing

Table 1
Cost-capacity factors for fish processing plants

Type of plant	Basic		Size range (ton prod/ day)	Capacity Factor (x)	Country	Reference
	Size (Q) (ton prod/ day)	Fixed investment cost (IF) (US$'000)				
Canneries	11.3	1100	8–35	0.89	Argentina	[13]
Freezing	20	2500	10–100	0.6–0.81[b]	Argentina	[16]
Average for other food freezing plant	20	3270	10–100	0.875	Several countries	[15]
Ice plants						
Flake	50	420	2–2000	0.895	United Kingdom	From [17]
Tube	50	460	10–200	0.646	United Kingdom	From [17]
Plate	50	400	2–200	0.96	United Kingdom	From [17]
Fish meal plants	50	1609	12–200	0.604	African Countries	From [21]
Fish meal plants	1.2	100	12–120	0.5	Tropical Countries	From [22]
Fish meal plants with concentration of stick water	34.5	800	13–58	0.608	European Countries	From [23]
Fish protein concentrate plants (FPC)						
Biological	6.8	1350	6–140	0.585	USA	From [24]
Alcohol extraction[a]	28	2820	6–140	0.502	USA	From [24]

[a] Isoproply alcohol.
[b] 0–100% mechanization.

plants, appeared in literature, and using least-squared estimation. The basic size Q, the basic investment cost I, the range of validity of the estimate, the power factor x and the reference country are tabulated. The sources of the investment cost information for the cost-capacity factor are compiled from published data. These data correspond to several plants of different capacity with the same technology for a given country. In Argentina, for canning plants, the cost-capacity factor is 0.89 ($r = 0.9976$). It is pointed out that the heading and gutting process is mechanical and cooking is done in a continuous cooker [13].

Table 2 shows a compilation of individual values of investment costs for different fish processing plants, in several countries, which are plotted in Fig. 1. In this graph, it can be seen that even when some of the existing plants in developing countries are artisanal, and are generally smaller than those in industrialized countries, the relationship between costs and capacities proposed in previous papers [14], still apply.

Before applying the cost-capacity factor, it is important to verify that the process under question does not represent significative technology variations. However, if technology varies there are two possible situations: when the technology is partly modified (change of one or a few stages of the process) or when the technology used to obtain the same product varies substantially. An example of the first case is cost-capacity factor variation for fish freezing plants for manual, mechanical and combination [15, 16], here the cost-capacity factor vary with the percentage of mechanization of the plant from 0.595 to 0.814 [16]; an example of the second case is shown in Fig. 1, at point (A), using the production of fish meal at artisanal levels.

Table 2
Investment cost for fish processing plants

Type of plant	Capacity (ton finished product/day)	Fixed investment US$'000)	Country	References
Fresh fish, sole	3.6	115	USA	[25]
Fish Plants	20	175	Tropical countries	[22]
Canneries				
Sardines[a]	11.3	1100	Argentina	[13]
Sardines[a]	1.25	170	Tropical countries	[26]
Tuna[a]	3	359	Indonesia	[27]
Tuna[a]	22	2088	Senegal	[28]
Shrimp	2.5 (mechanical)	810	Indonesia	[27]
Sardines	9.75 (mechanical)	2500	Norway	[29]
Freezing				
Hake[b]	20 (mechanical)	3270	Argentina	[15]
Hake[b]	20 (manual)	2500	Argentina	[16]
Filleting and Freezing[b]	12	528	Senegal	[28]
Shrimp[b]	0.9 (manual)	202	United Kingdom	[30]
Shrimp[b]	0.9 (manual)	144	Tropical countries	[31]
Catfish (live)[b]	13.36	2400	USA	[32]
Shrimp[b]	2 (mechanical)	431	USA	[32]
Drying Plants	0.2 (automated)	20	African countries	[33]
Fish meal plants[c]	209	2840	USA	[24]
Fish meal plants[c]	42	1120	USA	[24]
Fish meal plants[c]	50	1609	African countries	[21]
Fish meal plants[c]	1.2	100	Tropical countries	[24]
Fish meal plants[c]	120	1000	Tropical countries	[22]
Fish meal plants without contentration of stick water[c]	4.5	235	European countries	[23]
Fish meal plants with concentration of stick water[c]	34.5	800	European countries	[23]
Artisanal fish meal plant	0.02	0.162	African countries	[34]
Fish protein concentrate plants (FPC)				
Isopropyl alcohol	8.5	1757	Senegal	[35]
Isopropyl alcohol	28	2820	USA	[24]
Biological	6.8	1350	USA	[24]

Cost-Capacity factor
[a] Canning $x = 0.868$.
[b] Freezing $x = 0.825$.
[c] Fish Meal Plants $x = 0.610$.
Global fish processing plants, except fish meal plants $x = 0.841$.

As regards canneries, with exception of totally automatic plants, the graphic correlation shows a cost-capacity factor of 0.868 ($r = 0.9998$), while freezing fish plants have a factor of 0.825 ($r = 0.9215$) [15]. The cost-capacity factor obtained for fish meal plants was 0.610 ($r = 0.9634$), which, while being smaller than the other factors found for food processing plants, accounts for economies of scale, indicating that the plant with the greatest level of production is the most suitable. The results

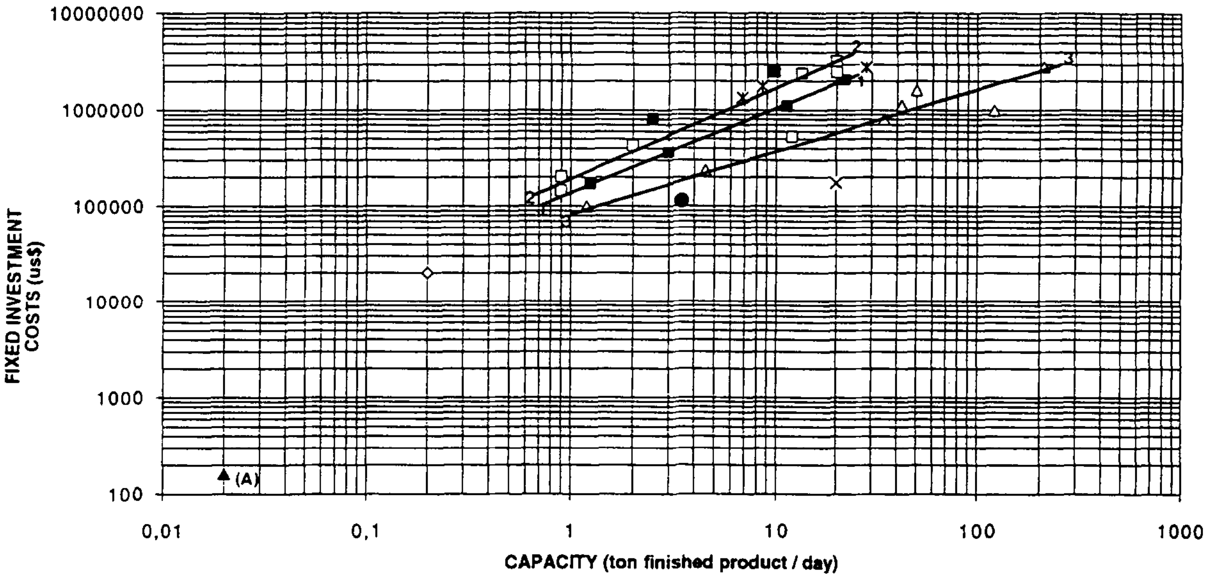

Fig. 1. Investment costs for fish processing plants.

References

Number	Symbol	Type of plant
1	■	Canning
2	□	Freezing
3	△	Fish meal
	▲	Fish meal (artisanal)
	*	Fish protein concentrate
	●	Fresh fish
	×	Fish processing
	◇	Drying

show that industrial plants of varying sizes, and although operating in different countries (conditions), show a clear correlation between investment and installed capacity, given that the similar technology is used.

The global cost-capacity factor for fish processing plants, except for fish meal plants, calculated by least-squared estimation from Fig. 1, is 0.841 ($r = 0.8153$). However, it can be concluded that for fish plants a 0.841 factor close to the 0.85 factor proposed for processes involving the handling of solid [17], is adequate when the same technology is used, while the cost-capacity factor for fish meal plants is 0.610.

The errors that occur when the cost-capacity factors 0.6 and 0.85 are used instead of actual values are summarized in Table 3, for fish plants and fish meal plants, using the methodology proposed by Remer for chemical plants [3, 5, 9].

The cost ratio for doubling the size of a fish processing plant is 1.80, and 2.52 for tripling the size, except for fish meal plants where the ratios are 1.53 and 1.95, respectively.

3.2. Investment costs for fish processing plants

Table 2 shows a compilation of investment costs for fish processing plants in developing and

Table 3
Potential errors from using 0.6 and 0.85 as cost-capacity factors

Scale up	Fish plant	Fish meal plant
Error % in using $x = 0.6$		
2 times	−15	0
5 times	−32	−1
10 times	−43	−2
Error % in using $x = 0.85$		
2 times	0	18
5 times	1	47
10 times	2	74

developed countries. The cost of the plant in a developing country compared to one in a developed country depends upon the complexity of the technology and the source of technical know-how.

The following factors are significant in analyzing capital cost differences between similar plants in different locations or countries:

Location: There is evidence that higher location factors are partly due to the need of importing specialized equipment. In heavily industrialized countries, the equipment is often fabricated in the same area where the plant is constructed; in developing countries, depending on level of technology needed, equipment is generally imported along with specialized personnel to install it, at premium prices [18].

Besides, specialized equipment tends to originate from a few well-identified locations where the necessary technology has been extensively developed, such as USA, UK and Germany [19].

Equipment: Material and equipment costs include the effects of tariffs, scale taxes and rates of currency exchange [19]. Basic equipment costs do not vary significantly, and location differences in construction costs are largely due to labor costs, specialized equipment and local factors.

It is generally believed that basic material and equipment costs are more or less uniform in all industrialized countries of the western hemisphere [18].

Indirect construction costs, transportation and handling: Construction costs depend on the availability of skilled labor and equipment [19].

Legislation: Due to the standards of most industrialized countries environmental protection typically adds 20% to plant costs and can in extreme case exceed 50% [18].

Climate: Additional costs for insulation in building and on piping and equipment [19]. Particularly cold climate increases construction requirements, as well as the level of thermal conservation needed. Hot climate boosts costs because of additional cooling requirements.

Possible lower air conditioning costs and reduction in equipment costs because of colder cooling water at the new location may occur.

Labor productivity: Differences in productivity due to differences in wage ratios, extensive overtime, material factors or indirect factors, will have a considerable effect on investment costs [18].

Even when investment costs are smaller in developing countries, production costs are usually increased. Capital costs diminish due to the technical system that is characterized by collection of rather old machines with a low manufacturing velocity and a low accuracy level. As the quality standards of the products are far below those of developed countries, manufacturing is still possible. The average figure for manufacturing delays due to machine problems is around 20% caused mainly by lack of maintenance and adequate planning techniques.

For fish processing plants, a typical case is ice production. Specialized labor for operation and maintenance is scarce or not properly trained, and equipment must be used past its technical life, because there is no capital for replacement. The energy requirements for these plants are higher than expected. Consequently, production costs are increased because of lower productivity and labor efficiency levels.

4. Minimum limit for industrial production capacity

In practice, there is a minimum limit for industrial production capacity. This limit is set by the minimum capacity of key equipment on the market. It can be seen from Fig. 1 that the minimum production scale, inside the range of the correlation, requires an investment which also correlates

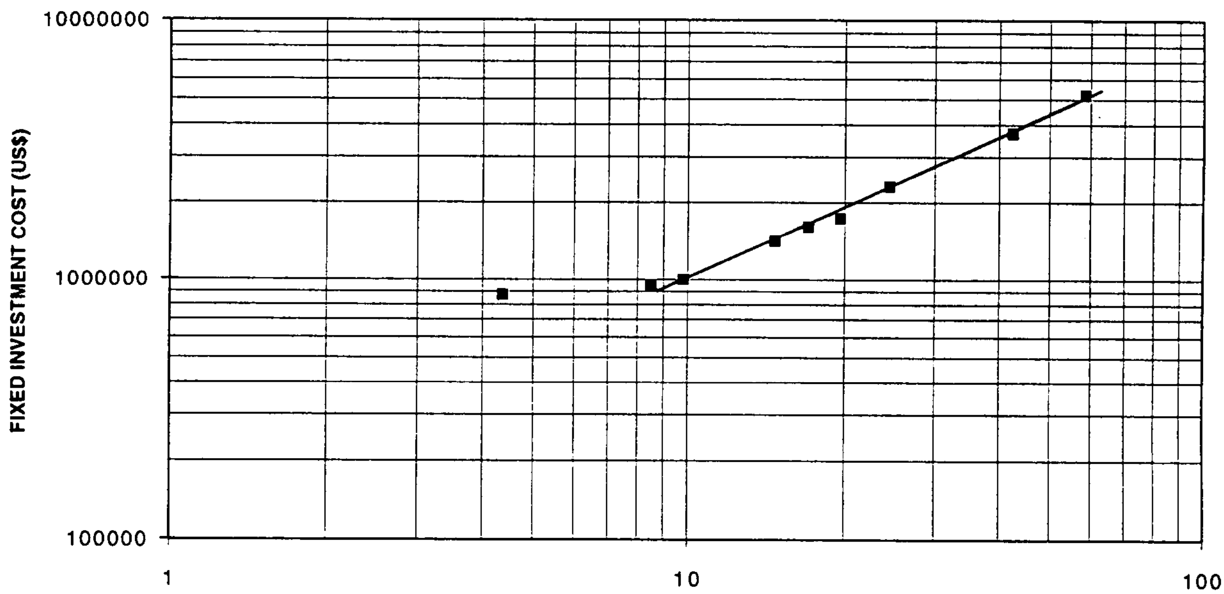

Fig. 2. Investment costs for fish processing plants.

with the maximum sized plants in developing countries, with partially modified technology, and that is no comparatively less expensive than large capacity plants in developed countries.

The concept of the minimum size has been shown for mechanized canneries [13, 20] and is also comparable to the experience of pilot plants of research institutes, in the sense that the investment costs for minimum sized plants or plants below minimum size are even higher than what would correspond to any correlation. In general, this is due to the need of incorporating one or more oversized pieces of equipment (which exceed minimum scale). Cerbini and Zugarramurdi [13] have shown that the investment costs for the smallest canneries deviate from their regression line, which indicates that sizes similar than the minimum cannot be extrapolated without incurring considerable errors. For this case, washing/scaling machine and seaming machines are oversized equipment. These results are shown in Fig. 2. Extrapolating outside the minimum capacity like for a production of 4.33 ton finished product/day, the resultant investment cost was 872 000 US$ (as calculated from suppliers information costs), while the corresponding value from the regression in Fig. 2 is 381 700 US$.

The "tails" or end parts are not usually correlated. They are taken as the maximum and minimum sizes of equipment or plants for usual production techniques. In this case, the "tails" are replaced by size restrictions. An increase in capacity over this maximum is obtained by duplication the plant or the equipment. For equipment smaller than the minimum size, the minimum size is only obtained subject to appropriate modifications. In the same way, when industrial plants are considered, pilot plants restrictions should be taken into account.

5. Conclusions

Cost-capacity factors for fish processing plants have been computed. A global value of 0.841 is being proposed for fish processing plants. For fish meal plants, it is advisable to use a factor of 0.610.

The following considerations should be emphasized when analyzing investment costs:

- Differences occur between similar plants of the same size if built at different sites.
- Local variations are at hand in the cost for labor, supervision and material.
- Different standards apply for equipment, construction and safety.

A minimum limit for industrial production capacity has been discussed, taken into account that the investment costs below minimum size are higher than would correspond to the estimated correlation. This is mainly due to the availability only of the oversized equipment.

Acknowledgements

Financial support from National Council of Scientific and Technical Research and National Institute of Industrial Technology for the completion of this research is gratefully acknowledged.

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