The efficiency of production systems in developing countries : a case study in Peruvian metalworking industry

The Efficiency of Production Systems in Developing Countries: A Case Study in Peruvian Metalworking Industry

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This paper presents part of the results of a research into the effectiveness of Peruvian metal-industry. More specifically the efficiency of production has been analysed in 23 firms. It appears that significant differences exist between two types of production systems: the product oriented system on the one hand and the process oriented system on the other hand. Not only the physical lay-outs of these systems differ, but also differences in efficiency and related organisational effects have been found. It seems that occurence of these types is only weakly related to characteristics of the product-mix.

1. INTRODUCTION.

A research project on the subject of the effectiveness of Peruvian metal-industry in its contribution to the development of el Perú was started in 1975. The project was a joint operation by the departments of economics and of engineering within the Pontificia Universidad Católica del Perú at Lima on the one hand and the Development Research Institute of the University of Tilburg and the Industrial Engineering Department of the University of Technology at Eindhoven on the other hand.
The project was financed through the Netherlands' Universities Foundation For International Cooperation.
Investigating the effectiveness of production systems we were primarily interested in the relation between technological characteristics of the production systems and the resulting effectiveness. Studying this relation we hoped to contribute to existing theories concerning choice of technologies in developing countries [1].
A large part of the data gathered in some 23 firms related to the efficiency of the production system and it is the aim of this particular paper to describe the findings from this sub-set of data and to draw some conclusions from them.

2. THE SAMPLE OF FIRMS.

First of all it must be stated that the 23 firms studied do not constitute a representative sample of Peruvian metal-industry. On the other hand, the 23 firms are not exceptional ones and are fairly representative of some 80 firms which have been visited in the course of the project.
The following tables serve to illustrate the position of the 23 firms within Peruvian metal industry.

Table 1. shows the total number of firms in Peruvian metal-industry distributed over type of industry and number of employees.
Table 2. gives the distribution of our sample over the same categories, both in numbers and percentages.

Table 1. Distribution of firms by type and size.

number of employees	5-19	20-49	50-99	100-499	500+	total
primary products	7	7	4	4	-	22
fabricated products	99	59	22	20	-	200
non-electrical mach.	25	33	7	12	-	77
electrical mach. and equipment	27	19	15	16	3	80
transportation equip.	4	13	14	6	4	41
total	162	131	62	58	7	420

source: Ministry of Industry and Tourism Lima, 1973.

Table 2. Distribution of sample by type and size.

number of employees	5-19	20-49	50-99	100-499	500+	total
primary products	0(0)	0 (0)	0 (0)	0 (0)	0(0)	0(0)
fabricated products	1(1)	5 (8)	4 (18)	3 (15)	0(0)	13(7)
non-electrical mach.	1(4)	1 (3)	1 (17)	1 (9)	0(0)	4(5)
electrical mach. and equipment	0(0)	0 (0)	1 (0)	1 (7)	0(0)	2(3)
transportation equip.	0(0)	1 (8)	2 (14)	1 (17)	0(0)	4(0)
total	2(1)	7 (5)	8 (13)	6 (10)	0(0)	23(5)

Between brackets: percentage of numbers in table 1.

In Perú industry in general contributed 25,6% to the Gross National Product in 1975. Metal industry accounted for almost one quarter of this (1973: 23,4%).
Products made by firms in our sample are: nuts and bolts, tins for paint, cookers and cooking-ranges, forks knives and spoons, hand-tools, steel furniture, winches and pumps, pans, vacuum cleaners, refrigerators, car-parts and agricultural equipment. On the whole the somewhat more durable consumer goods, semi manufactured goods and smaller capital goods are represented. Enterprises manufacturing inflation-sensitive capital goods were not included.

3. RESEARCH MODEL.

The efficiency of a production system is primarily determined by
- organizational support of direct labour;
- equipment;
- work-methods;
- skill and effort of operatives.

The quality of organizational support can be deduced from the amount of time spent by the workers for organising their own job or for carrying out work which is not part of their specialised job and which should be carried out by others. Waiting for material, tools, repairs and orders also may be attributed to weakness of the organizational support.

Work sampling was carried out in all but five of the firms in our sample. The results allow a quantification of the quality of organizational support.
The quality of equipment used has been analysed as an integral part of work sampling by determining the amount of time spent waiting for machine-repairs or break-downs. Also a subjective rating of a number of machines was carried out.

Inlfuence of work-methods has been estimated by analysing a number of selected jobs, the same applies to the evaluation of performance of the workers.

The main findings of our investigations are described in the following sections.

4. QUALITY OF ORGANIZATIONAL SUPPORT.

The observations made in work sampling can be summarised in the classification of table 3. The values are averages of the total set of 45.000 data, weighed for the number of workers in each firm.

Table 3. Relative time spent on four main classes of activities of direct workers.

Class	Average	Range
Technical work	65%	44 - 86%
Organizational work	21%	5 - 41%
Personal care	12%	1 - 21%
Unknown	2%	0 - 7%
Total	100%	

From the large ranges it becomes evident that enormous differences exist between firms. The value of the average percentages therefore is rather limited, especially when one realises that the relative use of time is not a direct measure of productivity or efficiency.
In the next section we will see that the total set of data can be divided into two sub-sets of significantly different character.
At this point especially the causes of the so-called organizational work are of interest. They can be described as follows:

- more than 1/3 of delays are caused by problems with material-provision;
- 1/3 of the organizational work comes into being because of lack of clear orders for the workers;
- 1/5 of organizational work is due to problems with machines and tools.

So in two cases out of three the reason for a worker not being at his specific job is attributable to the fact that the firm is not able to provide the worker with a) clear information as to the job he has to perform and b) materials needed for that job, even though these are available inside the firm.

Only 2,3% of the total set of data related to problems with machines, which result was rather surprising for us, since preventive maintenance was not practised in any firm. However, some explanation can be found in the relative abundance of machines in these firms. Only half of the number of machines present was used regularly. In almost all firms one can see machines standing still.
Many of these are old (average age 15 years), but with a bit of improvisation they can be used. In case of machine break-down there usually is a substitute available in a very short time. This low level of utilization may partly be accounted for by the rather high level of integration within most firms: if you want to make everything yourself you need many machines which will be used occasionally only. A high level of integration, however, makes sense in an environment where sub-contractors cannot be trusted to deliver the requisite quality on time, for whatever reasons [2].

The causes of organizational work mentioned so far, indicate a lack of results from planning and scheduling activities. Still, the number of "indirect" employees per "direct" worker (1 per 4,2) should justify some expectations from their work. Work sampling of the indirect workers in a number of firms, however, resulted in an average "efficiency" of their time consumption of 50% or less. Yet between firms significant differences could be observed.

After these more general comments on the average values of worksampling results, a more detailed analysis is called for.

Two types of production systems.
To characterise the production system of a firm, a number of variables was accumulated, such as: type of product, type of materials used, number of different products made, type of lay-out, complexity of end-product etc. etc.
In the analyses it turned out that only one variable discriminated very significantly between two different patterns of relative time-spending by direct workers. This variable is a characteristic of the production system lay-out. At one end of the scale the lay-out is strictly product oriented, as in line- or flow-production; at the other end the lay-out is process oriented, as in the so-called functional lay-out. In our sample:
- in one case only the production system could be defined as strict line-production
- in eight cases the production system could be regarded as more or less product-oriented
- in eleven cases the production system had to be classified as: definitely process-oriented.

By grouping the work sampling data into two groups:
A. Product oriented lay-out
B. Process oriented lay-out
a rather interesting difference in relative time-consumption comes to light:

Table 4. Relative time, spent on four main classes of activities of direct workers.

Type of lay-out	Product oriented		Process oriented	
Class of activity	%	Range	%	Range
Technical work	74	65-89	56	48-71
Organizational work	11	5-18	30	17-45
Personal care	14	3-21	11	1-20
Unknown	1	0-6	3	0-6
Total	100		100	

From table 4 it follows that the two types of production systems are not only different in lay-out, but evidently show a marked difference in relative time-consumption by direct labour [3]. Further analysis revealed that differences between the two types showed up in a number of other variables, as shown in table 5.

Table 5. Characteristic difference between product- and processoriented production systems.

Variable	Product-or.	Process-or.
Ratio direct/indirect labour	7,0	3,3
Price of most characteristic machines	132.000 $	233.000 $ [x]
Sick-leave and absence	2,7%	8,7%
Organizational work, relating to:		
- provision of materials	5,3%	9,8%
- information on jobs to be done	1,1%	9,7%
- problems with machines	0,4%	4,1%
- problems with hand-tools	1,2%	1,5%

[x] $ means: Soles. Average purchase prices corrected for inflation, except for machines bought prior to 1971.

Furthermore indications were found for the following statements to be true:

In product-oriented production systems
- utilisation of machine capacity is better,
- quality of machines and tools is somewhat higher,
- average wages for skilled and semi-skilled workers are about 6% higher,
- salaries of middle-management are somewhat higher,
- efficiency of indirect labour is better,
- ratio of rejected end-products is lower,
- performance of direct workers is estimated to be somewhat higher.

5. INFLUENCE OF EQUIPMENT ON EFFICIENCY.

What has been said before on the subject of machine-related delays may be misleading. Although relatively little time is wasted due to break-down of machines, this does not mean that the machines were in good working order or that they could be used to the limits of their production capacity. A qualitative evaluation of the quality of machines and tools was made in a number of cases. In each case it was found that this quality was rather low and left much to be desired. A comparison, however, is impossible since in many cases no standards of quality are defined for the end-products. One could safely state that in most cases end-products would not be accepted if inspected in accordance with standards of industrialised countries [4]. Lack of adequate measuring instruments was the rule rather than the exception. It is thought to be impossible to derive a firm conclusion from these findings as regards the influence of equipment on efficiency.

6. INFLUENCE OF WORK-METHODS ON EFFICIENCY.

The influence of work-methods on efficiency has been studied in five firms. Typical operations were: press-work, machining, assembly and cold forming. In press-work is was found that no great improvements were possible. In all other operations, however, substantial improvements could be made, increasing productivity up to 100% [5].

7. INFLUENCE OF PERFORMANCE ON EFFICIENCY.

In those cases where a comparison with similar work in factories in the Netherlands was possible, no significant differences were observed. One could say, rather, that in many cases the pace of work in our sample firms was quite high and would have been much appreciated by production managers in Europe.

8. CHARACTERISTICS OF THE TWO TYPES OF FIRMS.

When two types of firms exist, having distinctive characteristics as regards lay-out and operation, it stands to reason that one looks for variables such as lot-sizes, types of product, extent of standardisation, variety of products etc. as explanations.
However, no clear cut interdepencies between these variables and the type of lay-out appears from the data. The following will illustrate this point.

8.1. Main products (> 80% of turnover).

Product-oriented lay-out
1. Cutlery
2. Refrigerators
3. Cookers and Stoves
4. Light-metal car wheels
5. Tins for paint
6. Nuts and bolts
7. Pots and pans
8. Steel furniture
9. High quality bolts

Process-oriented lay-out
1. Cutlery
2. Cookers and stoves
3. Vacuum cleaners
4. Wheel-barrows, spades
5. Car-parts
6. Heavy machinery
7. Exhausts, car axles
8. Metal structures
9. Agricultural equipment
10. Cable shoes
11. Pumps, hoists.

8.2. Number of different parts in mainproduct.

Categories: less than 11 parts : 0
more than 10, less than 26 parts: 1
more than 25 parts : 2

Number of firms in each category:

Product-oriented	Cat.	Process-oriented
7	0	5
-	1	1
2	2	5

8.3. Number of operations in main production process.

Categories: less than 11 steps : 0
more than 10, less than 26 steps: 1
more than 26 : 2

Number of firms in each category:

Product-oriented	Cat.	Process-oriented
5	0	4
2	1	1
2	2	6

8.4. Production to inventory or to customer.

Sometimes a mixture of the two systems is to be found in one and the same firm. Also, sometimes, whereas the firm tries to produce to inventory, in actual fact production is controled largely by customer's orders.

Categories:
production to inventory : a
to inventory and to customer : b
if possible to inventory, but.. : c
to customer : d

Number of firms in each category:

Product-oriented	Cat.	Process-oriented
4	a	3
1	b	2
2	c	-
2	d	6

8.5. Number of different product-types.

A product-type characterises products with a specific function. Some firms produce only one product type, although in different models. Other firms produce a variety of product-types.

Categories:
1 product type : 1
2-5 types : 2
6-10 " : 3
11-20 " : 4
> 20 " : 5

Number of firms in each category:

Product-oriented	Cat.	Process-oriented
6	1	-
2	2	6
-	3	2
1	4	1
-	5	2

8.6. Number of different product-models in main product-type.

Categories: less than 26 models 0
more than 25, less than 101 : 1
more than 100 : 2

Number of firms in each category:

Product-oriented	Cat.	Process-oriented
5	0	5
3	1	2
1	2	2

9. CONCLUSIONS.

The efficiency of a number of production systems of metal-working firms in Perú has been analysed. No general formula, relating efficiency in Perú to the same in Europe, can be given.
In some cases Peruvian firms seemed to have the same efficiency as comparable firms in the Netherlands, notably those based on press-work, making knives, forks and spoons for instance.
In other cases efficiency in some Peruvian firms should be estimated to be less than half the efficiency of similar firms in the Netherlands, although difference in quality of end-products renders a comparison rather hypothetical.

Based on their lay-out, however, two types of production systems could be distinguished: one product-oriented and the other process-oriented.
These two types differed markedly in a number of aspects, indicating that efficiency and productivity may be expected to be higher in the product-oriented type.
At this point the authors would like to offer a tentative explanation of this phenomenon which in their opinion, is highly plausible although it does not have the status of a proof.

In a product-oriented lay-out, subsequent operations on products are arranged geographically in the sequence in which they are performed. This means that a worker at his work-station can see the work arriving at his station directly from the previous operation and he can also observe his work being fed into the next work station. Communication with his neighbours on matters of pace, properties of materials, peculiarities of design etc. are not only possible but self-evident: they are a matter of course. Such a situation may be said to possess a high level of clarity for the worker. Laboratory experiments at our University of Technology on the influence of clarity in the work situation have proved that there is a relation between this clarity and the behaviour of workers in a production system [6]). More specifically clarity fosters mutually helpful behaviour if it is possible and permitted.

Also a product oriented lay-out facilitates appreciably coordination of activities, control of material flow, transportation etc.

In the process oriented lay-out, on the contrary, little clarity exists and coördination, not being incorporated in the lay-out hardware, is a most difficult job to perform. No wonder results often leave much to be desired. Correction of defective coördination is patently impossible for the workers, who are very much aware of the adverse consequences of such defects: a situation leading to frustration and/or indifference.

It would be very wrong to think that the difference described between the two types of production systems is the difference between a smooth running mass-production flow-line and a confusing chaotic job shop. No firms in our sample possessed the characteristics of such proto-types. No firm was involved in anything like mass-production, no firm made only one product in large series. It required more than casual observation to find out whether a production system belonged to type A or type B, the first impression almost invariably being one of chaos. In fact two firms making cutlery in roughly the same variation and lot-sizes and with the same type of equipment belonged to different types. The degree of mechanisation or machine-utilisation had no relation with the lay-out either. It would seem that a product oriented lay-out can often be realised within largely different sets of constraints and the authors would like to draw the attention to this fact for the benefit of efficiency in production systems of developing countries.

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FOOTNOTES.

1). For literature on this subject see
- Boon, G.K. Choice of Human and Physical Factors in Production (North Holland Publishing Co. 1964)
- Stewart, F. Technology and Underdevelopment (The MacMillan Press LTD, 1977)
- Strassman,W. Technological Change and Economic Development (Cornell University Press, 1968).

2). A low utilization rate of machines however means a national waste of scarce capital. An analysis of factors influencing the utilization of capital goods one finds in: Enseluk, M., Case studies of the courses of excess capacity in Industry (Industrialization and Productivity, nr. 15, K.N. New York 1970).

3). This fact should be considered in view of the famous hypothesis of Albert O.Hirschmann, who states that productivity differences between developed and developing countries are less in machine-paced technologies. See: Hirschman, A.O. The strategy of Economic Development, (New Haven, 1958).

4). In so far as low quality of end products results in a shorter lifetime this means for the national economy that capital, human as well as physical, is wasted.

5). This seems to confirm the hypothesis stated in footnote 3.

6). Bronckhorst, B.van, Effecten van verschillende maten van zichtbaarheid van de voortgang van het werk op enige produktiekarakteristieken voor kleine werkgroepen (De Ingenieur, mei 1969).