

Methodological problems of productivity measurement in the construction industry

J. Iwamatsu

Sato Research Institute, Japan

K. Endo

Dept. of Architecture, Kogakuin University, Japan

ABSTRACT: As the infrastructure of Japan's economy should grow up on the total output of its construction industry, there should be a strong demand for its high productivity so that its national economy could stay healthy. Yet, the construction industry has been generally understood as one field where sizable improvement of the labour productivity can hardly be expected. From a microscopic viewpoint, meanwhile, the Japanese construction industry on its individual production scenes have done fairly well in remarkably boosting the productivity when they endeavored in introducing such management/control tools as prefabrication, mechanization, automation or "robotization" and other technologies. Also, the subject of productivity should be explored differently at each level of the industry. Therefore, it may be said that productivity indices need to be found for productivity measurement suitable at any levels of the construction industry. In this research, existing knowledge of productivity measurement methods have been summarized from a wide perspective. Firstly, existing problems of productivity measurement as being practically used in business or in economical research were analyzed. Secondly, taking up some typical examples of productivity measurement in the construction field, we discuss problems being faced in the actual stage of measurement. Then, it is necessary to distinguish the factor of stagnation of labour productivity; the distinction of "technical problems in measuring productivity", "what should be proper as the method of productivity measurement of the construction industry", "the problem of the industrial structure", etc. Also, we show various indices of productivity measurement that are being used in the actual business. Lastly, we discuss about what the significant productivity indices are for the construction industry and how it should be correctly evaluated.

1 THE BACKGROUND AND PURPOSE/OBJECTIVES OF RESEARCH

1.1 *The background*

In discussing about "Productivity," the inevitable focus is to clarify how it can be boosted up or improved. Generally, it always takes an assumption that productivity improvement should lead to a higher economic livelihood for the people in general. Particularly from the perspective of the entire industrial world, productivity trend in the construction industry seems to be actually being closely watched by other industrial circles, so that it will not serve as a bottleneck on the part of the entire national economy. It is because of the wide realm of the construction industry that inherently deals with the infrastructure essential to many other industrial areas.

However, the construction industry, with its labour-intensive nature, is being considered as an area where

productivity improvement efforts cannot easily be made. Even if it is so, a considerable amount of improvement efforts seems to be bearing fruits when we look at the first-line activities at individual construction sites.

We should note here that there are various levels of productivity measurement and evaluation, ranging from a microscopic level of measuring "unit productivity in man-hours" (man-hour productivity) or other data from respective construction sites to a higher macroscopic level of evaluation for the entire industrial world.

For instance, "productivity in man-hours" of first-line work-sites can be used to express productivity at a microscopic level. As preliminary forecasting of required amount of labour in observing the construction contract terms, some typical examples of "man-hour productivity" data are being developed according to specific work styles or technical project types. Such data is what the actual data accumulated by the contractors themselves has been standardized. In this

process of standardization, the related quantity surveyors have taken the central role in collecting needed data, developing formats of classification, etc.

The data on the macroscopic level of productivity, on the other hand, is being used not only in the in-house historical benchmarking activities but also in such wider scopes as inter-industrial evaluation and international comparison of productivity. The aforementioned macroscopic level of evaluation for the entire industrial world is being made on this level.

It should be added here that individual general contractors, sub-contractors and related supplier-makers have each developed their own methods of productivity evaluation to be used for benchmarking purposes. There are cases where general contractors use the accomplished amount of contract work or project rather than the added value data, as they are related to the business models, methods of cost & profit control. These can be placed in between the microscopic and macroscopic levels. Their productivity indexes will be discussed later in this paper.

1.2 *The purpose and objectives of research*

The main purpose of this research is to study the present state of productivity from a rather macroscopic viewpoint so that a more realistic direction of our present methodology of productivity measurement and evaluation can be predicted.

2 PRODUCTIVITY MEASUREMENT METHODS IN THE CONSTRUCTION INDUSTRY

2.1 *Definition of productivity*

Historically, productivity research as such can be dated back to the "Post WWI productivity movement" as triggered by the Marshall Plan (the European Recovery Program). In 1951, the Productivity Committee of the European Productivity Agency was formed, which was later absorbed into OECD. In Japan in 1955, the Japan Productivity Center – JPC (now renamed as the Japan Productivity Center for Socio-Economic Development – JPC-SED) was founded as the center of productivity research in Japan.

OECD definition of productivity is "Productivity is the numeral value of produced amount (or output) divided by one of the factors of production." This can be further expressed as follows:

Provided that Equation $Productivity = Output/Input$ can be applied, and from the viewpoint of productivity measurement, the following four combinations can be possible, depending on whether its quantity is a numerical quantity or a numerical value:

① Quantity by Quantity

- ② Monetary Value by Quantity
- ③ Quantity by Monetary Value
- ④ Monetary Value by Monetary Value

Here, it can be said that ① and ② are measures of physical productivity and ③ and ④ are those of economic strength (or profitability).

There are a variety of specific definitions of productivity, some typical examples of which are shown below:

Multi-factor productivity

Amount produced/Total amount invested (labour, capital equipment, fuel for power generation, raw materials) – Because of the different units to express these different factors, conversion of stated values is necessary.

Labour productivity

Frequently used factor. Amount produced/Amount of labour input, Amount produced/labour cost. Only the factor of labour among all factors of production is used as the criteria of evaluation.

Capital productivity

Used in reviewing the degree of valid technical use of the invested capital amount. Amount produced/invested amount of tangible fixed assets, Amount produced/number of equipment units operated, Amount produced/number of hours of operation, Amount produced/number of horsepower, etc.

Intermediate inputs productivity

Most meaningful to the management pattern that heavily relies on the raw materials (such as iron & steel industry). If the denominator is amount of energy being used in the production process, this can be called Energy Productivity, and is one of the most up-to-date topics such as "global environment."

2.2 *International comparison of construction labour productivity*

For the purpose of knowing where Japan's construction labour productivity can be ranked in the international arena, the construction labour productivity by world nations, as easily obtained through the GDP statistics as published by OECD and labour-related KILM data base published by ILO, are graphically shown in the research. Labour productivity, as quoted here, is the product of the construction sector GDP (the total of the figures representing "Housing, Other Construction" from among OECD's GDP statistics) divided by Number of construction workers (the total of male/female labour populations under "Construction" category of the ISIC Industrial Classification by KILM) and further by annual total working hours (the weekly labour working hours by construction workers converted to annual working hours) from KILM's Labour Force Survey by nations), which merely represents a largely macroscopic view of the situation. Evidently,

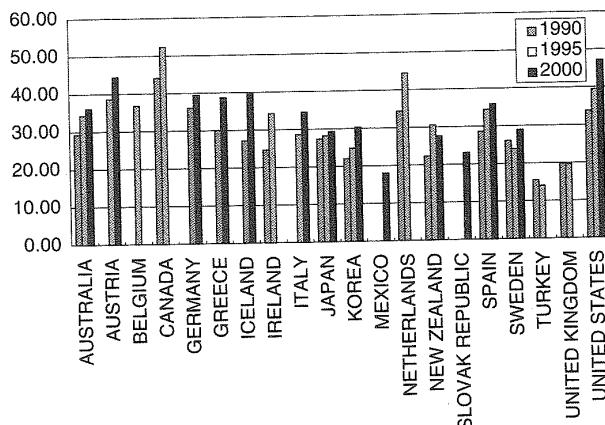


Figure 1. Nominal comparison of construction labour productivity by nations (conversion at current purchasing power prices).

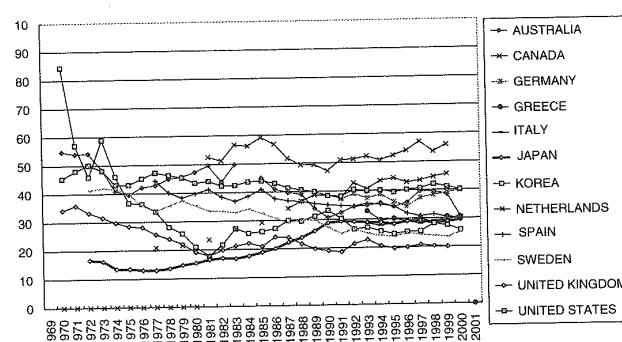


Figure 2. Transition of construction labour productivity in major nations (conversion at 1995 prices).

any comparative survey on an international scale would end up with more or less different results as it depends on different rates used in the conversion of monetary data. Figure 1 was based on Average Purchasing Power Parities (PPP) in US Dollars. The unit used in the figure is US\$/man-hour.

It can be said that the apparent figurative differences by nations can be traced back to various complicated factors inherent in the national differences such as in the basic built-up structures of respective construction industries. Figure 2 illustrates 30-year trend of labour productivity at 1995 market prices. Circumstantial changes affecting the construction industry in many countries over those years may be seen from the chart, where many countries are experiencing either sideway or declining changes with Japan as an exception as its labour productivity showed a remarkable growth during the 1980s.

2.3 Value-added productivity and related problems

Using Value Added notion to express Output or Amount Produced as the numerator, "Value Added

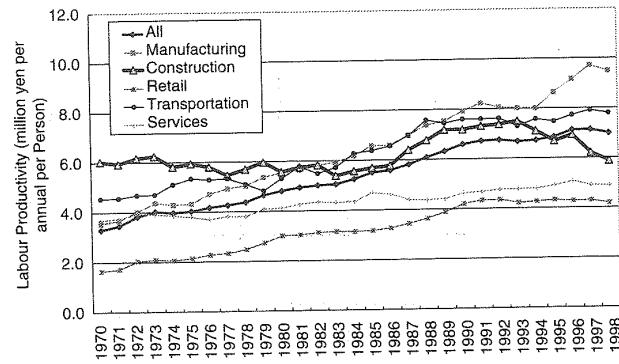


Figure 3. Labour productivity transition by major industry in Japan 1970–1998 (68SNA; Real 1995 price value).

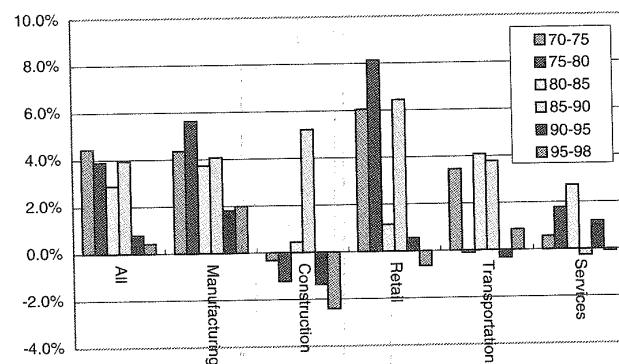


Figure 4. Average annual labour productivity rate by major industry in Japan.

"Productivity" is relatively well used in comparing productivity on an inter-industrial basis. Even in a rather simple comparison of productivity between the construction industry on one hand and all other industries on the other, Value Added Labour Productivity is used, as shown in Figures 3 and 4.

Figure 3 illustrates 30-year trend of Net Value Added Productivity by six major industrial groups and Figure 4 shows their growth rates by every 5 years, both are based on the product of the statistical data of Net Domestic Product by Industries (from SNA or system of national accounts by Cabinet Office of the government) divided by Number of Employees by Industries (from the "Labour Force Survey" by the Ministry of public Management).

These figures tell us that the growth rate of Japanese construction industry is lower than that of manufacturing and some other industries, a similar situation in other major industrialized countries.

Whereas the use of statistical data, as described above, can easily enable us to obtain needed productivity data, there are a few problematic inconsistencies involved, which are stated below in the rest of this chapter.

There are three different ways to calculate productivity or added value for the construction industry,

Table 1. Different formulas to calculate added value per person.

Formula 1 by Ministry of Land, Infrastructure & Transport (the Construction Industry Information Center)
– Amount of Construction Work Added Value per Person Engaged in Construction Business:
In companies capitalized at 1-billion yen or over = 1.727 billion yen per person
(Source: "Management Analysis of Construction Business")
Formula 2 by Japan Construction Surety Company
– Amount of Added Value per Person = Total Added Value/Number of Personnel
In companies capitalized at 5-billion yen or over = 1.063 billion yen per person
In companies capitalized at 1-billion yen up to 5-billion yen = 0.899 billion yen per person
(Source: "Financial Statistical Index for Construction Industry")
Formula 3 by Ministry of Finance
– Amount of Added Value per Person (Labour Productivity)
In companies capitalized at 1-billion yen or over = 1.188 billion yen per person
(Source: Financial Statements Statistics of Corporations by industry)

each being published and rather well known. For example (as shown in Table 1), you get three different answers as the amount of Added Value per Person as calculated for Fiscal Year 1999 (which happened to be the latest year when necessary data for the three modes of calculation was made available).

While it can be pointed out that above statistical formulas are applied to different organizational echelons, the problem to be rather noted here is that different definitions of "added value" as an economic term are being used among the users of those statistical formulas, as quoted in Table 2.

This means that nobody has ever clarified what "Value Added" should mean to everybody as a standard expression. A research book on productivity by H. Satomura (1971) argued on the following two points and more on the subject.

1. That Added Value consists of the two contradictory concepts together, that is, the concept of cost (such as wages, interests, rentals) and the concept of profit, and it can take an extreme argument that value added can be made larger even when profit becomes zero.
2. That the term Value Added is being wantonly used by everybody without knowing the definitive differences such as described in Table 2.

Similar contradiction can be seen also in the use of the denominator term "Amount of Labour."

One of the problems that can be pointed out about Value Added, as used in the statistics by the Ministry

Table 2. Different statistical definitions of the term "Value Added".

• Statistics on Construction Undertaken (annual survey) Added Value = Value of Finished Construction Work minus (Material Cost + Labour Cost + Supplier Cost)
• Financial Statements Statistics of Corporations by industry Added Value = Operating Cost (Operating Profit minus Interests Paid · Discounts) + Executives Remunerations + Employees Salary + Employee Fringe Benefit + Interests Paid · Discounts + Property · Realty Leases + Taxes & Other Public Imposts
• Census of Manufactures Added Value = Output Value minus Domestic Consumer Taxes minus Amount of Raw Materials Use minus Depreciation Cost
• Input-Output Tables Added Value = (Amount of Domestic Products minus Intermediate Input) minus Non-housekeeping Expenses
• National Accounts (Quarterly National Income Statistics News: QE & others) Added Value = Amount of Output minus Intermediate Input

Note: These are quotations from the statistical publications.

of Land, Infrastructure & Transport (such as Statistics on Construction Undertaken and some other data), is the way Outside Supplier Cost (which is to be deducted from Value Added) is being treated.

Supplier Cost data includes that of labour cost and that of materials cost. In measuring labour productivity, the labour cost is thought to be a factor that should also be somehow converted to a number of workers to be calculated as part of the denominator. In particular, the ratio of Supplier Cost against Work-completed Value (single construction) is so high at some 70% level, and so is Supplier Cost. Then, this factor should not be ignored in the measurement.

Added to above situation, the vagueness of Value Added definition is leading to wide spreading of ratios, such as in Supplier Cost ratios at 58.7% through 81.0% (up to March 1998) and in Labour Cost at 0.1% through 19.8%.

Another problem here is that Labour Force as used in Labour Productivity Index is treated as homogeneous data. In reality, however, some factors (such as skill levels, work potential and adaptability) are essentially varied by individual workers.

The competent ministry itself has pointed out a problem in this regard in its 1983 report saying that figures of construction workers in their data could be excessively counted mainly due to the fact that many construction workers are listed in plural groups (or under plural employment).

Above observations can lead to a conclusion that labour force figures as used in labour productivity index merely represent abstracted statistical concepts.

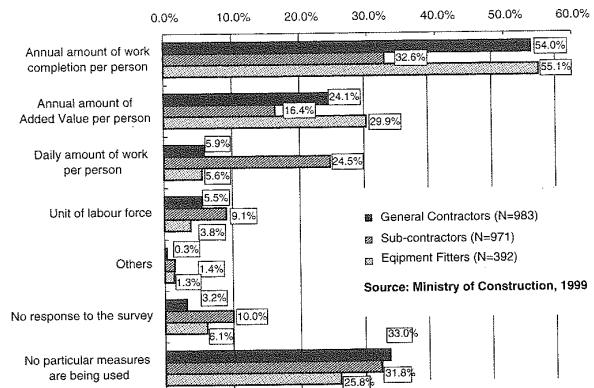


Figure 5. Labour productivity measures as used in the Japanese construction industry.

3 USE OF PRODUCTIVITY INDEX IN THE CONSTRUCTION INDUSTRY

3.1 Productivity indexes being practically used

Figure 5 is the result of a research of Productivity Measures as used in Japanese Construction Firms in three different groups. It is characteristic in that: 1) Gross Output per Person index and Value Added per Person index respectively revealed high percentages in the General Contractor group, and 2) Completed Construction Expenses per Person per Day index showed a high percentage in the Subcontractor group.

Then, A Furusaka/Endo research conducted in 1992 over 8 major general contractors and prefabricated housing products makers extracted 24 different productivity-related indexes, as shown in Table 3.

This table indicates that construction productivity and effectiveness at the major construction firm level mainly take up such measures as related to [completed work expenses], [working floor space], [profit], [schedule] and [cost].

3.2 Classification of productivity measures in the construction industry

As discussed in the above sections, there are a variety of productivity measures being used in the construction industry. Specific objects of productivity analysis relating to construction industry can be largely classified sequentially from microscopic through macroscopic levels.

This discussion is consistent with the 1993 research report by the Japan Federation of Construction Contractors (JFCC) which stated that productivity should not be judged by a single measure but rather generally by plural measures suitable at each of such unit levels as construction work, corporation, business type and the entire construction industry."

In 1999 the Ministry of Construction (now, the Ministry of Land, Infra-structure and Transport), reflecting on the above mentioned problem awareness,

Table 3. Types of measures for project evaluation.

Evaluation measures	No. of Firms
1. Amount of Accomplished Work per Employee	1
2. Amount of Accomplished Work per Engineering Person	4
3. Amount of Accomplished Work per Field Office Person	5
4. Construction Work Space per Employee	1
5. Construction Work Space per Engineering Person	1
6. Construction Work Space per Person	1
7. Number of Field Office Employees per Total Floor Space	1
8. Amount of Accomplished Work per Field Worker	—
9. Construction Work Space per Field Worker	3
10. No. of Field Office Workers per Total Floor Space	2
11. Scheduling Ratio (Ratio of a contract designated schedule against the standard schedule)	3
12. Operating Ratio	1
13. No. of Days as Scheduling Allowance	1
14. Work Combination Ratio	1
15. Design Efficiency	1
16. Quality Capability Index for Major Processes	1
17. Cost Ratio	3
18. Recovery Ratio	5
19. Profit Ratio	8
20. Estimation Efficiency	1
21. Composition Ratio of Project Cost	1
22. Quality Saving Ratio	1
23. Safety Saving Ratio	1
24. Value Added Labour Productivity	—

Source: Furusaka/Endo, 1992.

began reviewing the added value productivity theme only on the subject of "labour productivity." Table 4 summarizes the discussions as have been rendered in their 1999 report and on-going review to look over specific types and characteristics of productivity measures suitable to every phase of construction industry. This table lists up specific examples and their characteristics of productivity measures classified according to each category of comparison (from the entire construction industry down to the first line work sites).

In brief, we should bear in mind that labour productivity cannot be simply taken as an all-purpose term but it must be based on such awareness as which phase of industry is being dealt, what elements consist of the measure, and how it was calculated from what kind of source data.

4 SUMMARY AND FUTURE IMPLICATIONS

This paper first described the general trend of productivity research in the construction industry and

Table 4. Productivity indexes to fit the categories of Japanese construction industry.

Category	Example of productivity index	Notable characters [(O)Merits/(X)Demerit]
Construction Industry as a Whole	Average Annual Labour Productivity	O Suitable not only for checking historical changes but also for inter-industrial and international comparison. X Needs carefulness if comparing among different Industries because the term "value added" has different definition among the statistical tools being used.
Each of Industries & each of Construction groups	Total of Orders Received by Industry divided by total no. of employees Raw Materials Productivity (Energy Productivity, etc.)	X Historically viewed, impact from the cycle of economic prosperity could be seen. Need to be careful. O This is an index easy to perform evaluation from such aspects as waste treatment, ecology, etc.
Each company	Amount of Work Accomplished per Person Amount of Value Added per Person	O Labour Productivity covering not only construction sites but also the clerical side of the industry can be known. X Impact from the cycle of economic prosperity is not avoidable.
Each Work-site	Amount of Physical Labour Productivity ... Yield: Labour Input per Project Construction Unit (or its reciprocal) Original Unit of Labour Power ... Amount of Labour Input per every 1 million yen of the evaluation of total project cost	O Least vulnerable to the impact from the cycle of economic prosperity. O Reflects better effectiveness being caused by human efforts on work skills and technology. O Reflects better effectiveness being caused by human efforts on work skills and technology. X Since this is a comparison based on monetary values, it is vulnerable to the impact of economic prosperity, changes in material prices, etc.

Note: This table is a summary of the Ministry of Construction report, 1999, combined with the additional examples and a "Demerit line" added by the researchers.

various productivity measures that are being practically used elsewhere, then focusing on the productivity measures as practically used in the Japanese construction sector. The main points in these descriptions can be summarized as follows:

- As one aspect of the productivity measure is that the measurement uses some kind of actual data, it is necessary to have a sufficient understanding of the restraints imposed by the data being used and of the specific meanings of the measurement formulas to be used (so as not to be confused by more than one definitions of the term Value Added for one).
- In conducting productivity measurement, it is necessary that appropriate measures and data be selected and modified to suit the purpose of their use.
- There are some negative factors slowing down the construction business, such as technical problems in measurement methods, adequacy of measurement methods as applied in the construction industry, and pending issues in the industrial structure. So, it is necessary that such problems and factors be strictly discerned with each other.

As briefly touched on at the beginning of this paper, there have been cases of some positive improvements in productivity if on such microscopic levels

(work-unit or work-site levels). However, one characteristic of the construction industry is that such first-line improvements have not been perceived on the macroscopic levels (corporate or industry levels). Aside from the construction sites known for their higher productivity as being operated by major construction firms, such a corporate-level unawareness, as mentioned above, seems to be caused by some existing facts about Japanese construction industry, say, 1) the largest portion of construction investment is still being absorbed by medium/small construction firms where their productivity is generally low; 2) even including major corporations, cost control at their management level still remains to be of a budget-allocation type and cost-consciousness in its real meaning is not fully spread; 3) the nature of "build-to-order type industry" where cost competitiveness is not always considered as a merit on the part of both owners and contractors. It can be conclusively said that those abovementioned factors altogether may be contributing to the ambiguity of the real meaning of productivity measurement.

Future implication in our research on this theme should be for us to newly find out more suitable measures based on our findings about existing productivity measures and use more specific data so that

productivity can be accurately measured. These efforts will meet the purpose of perceiving the characteristics of our construction industry as compared with other industries, and of using the findings in some sort of analysis within the construction industry. Further, it is hoped that our findings be used in comparing productivity on a global level, as was briefly touched on earlier in this paper.

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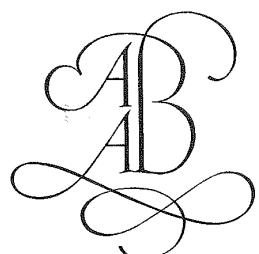
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