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What Do You Mean by Automation Ratio?

— Definitions by the Japanese Auto Makers —

by

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1. Research Questions

It has been often pointed out that definitions of automation ratio, or degree of automation, are different across the companies and across the types of processes. In one of the European plant known for its advanced automation, for example, the engineers at the company claimed that automation ratio of their final assembly line was about 50%. An engineer of a Japanese company, who visited the same plant recently, admitted that the assembly line in question was one of the most advanced in the world, but reported that the automation ratio was estimated to be about 10%. Another engineer from a different Japanese auto maker estimated it to be about 15%. Of course no one is telling a lie, and no one is making a bluff in this case. This seems to be a simple matter of difference in definition.

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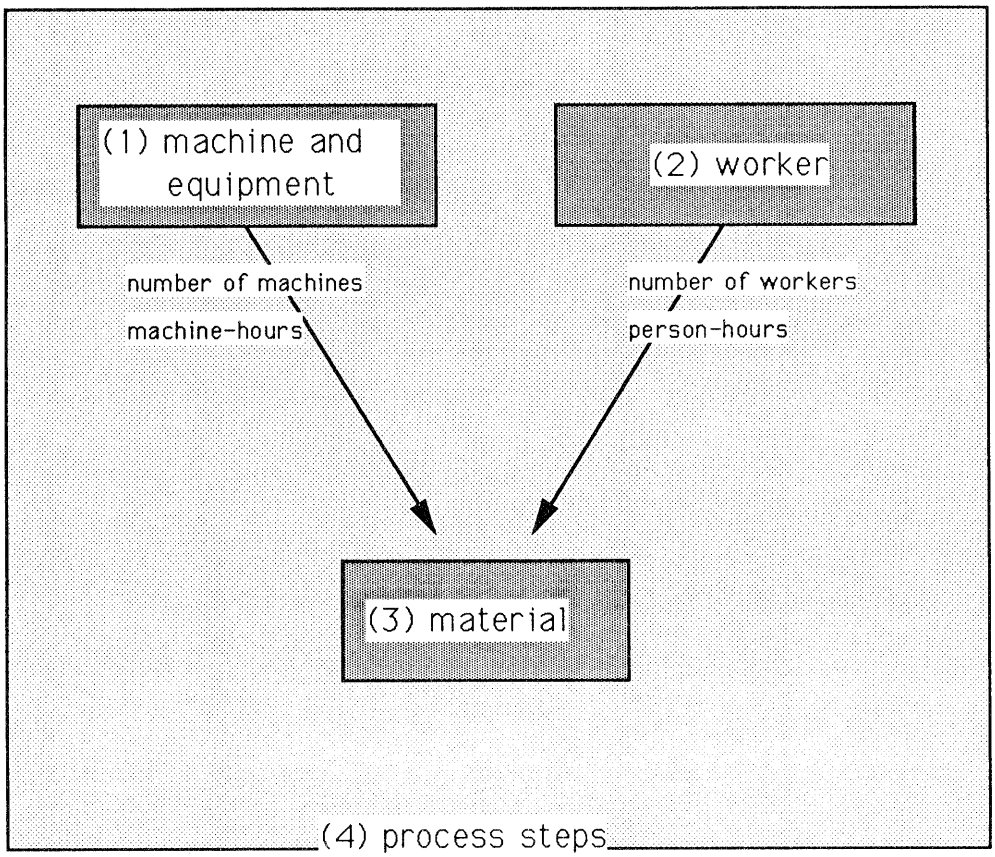
[1] This paper is based on a survey conducted by the Committee for Research on Optimal Automation Systems in the Automobile Industry, which is chaired by Professor Koichi Shimokawa of Hosei University and is organized by Japan Technology Transfer Association (JTTAS). Professor Hisanaga Amikura of Chiba University and Mr. Takashi Matsuo, Doctoral Candidate at Tokyo University, were particularly instrumental in compiling the data. Mr. Seigo Onishi and the staff of JTTAS facilitated distribution and collection of the questionnaire. The author is grateful to the respondents of the survey, as well as the above people.

Automation ratios are often reported in trade journals and other publications. Auto companies often disclose the numbers about automation ratios when they announce start-up of their new factories. And yet, production engineers of the Japanese auto companies do not seem to take these numbers seriously. One reason for this disregard by experts may be that automation is a complex phenomenon that cannot be summarized by a single number called automation ratio anyway. While this argument may be valid, it still seems to be desirable to have compatible definitions of automation ratio. After all, automation ratio, whatever it is, is the most commonly used indicator when patterns of automation are compared among multiple factories. Once the numbers are disclosed, non-experts tend to compare them across the plants and companies anyway and draw some conclusion out of them without taking the difference in definitions into account. Thus, it is important for researchers and practitioners to be, at least, aware of the potential differences in the definitions, and, if possible, use a common set of definitions when describing and analyzing automation across companies.

Disseminating a common definition is not an easy task in reality. Each company has its own history of using a certain definition of automation ratio for internal purposes, so it tends to stick to the existing set of definitions in order to keep consistency in time series analyses inside the company. It may be possible for each company to develop a dual system, one for internal use and the other for external use just like management accounting and financial accounting, but it tends to be reluctant to do so because the double standard may create confusion on the factory floor. It seems to be nonetheless meaningful to report the difference of the definitions the actual auto companies are using as a reminder of this problem. This brief paper will describe and analyze different types of definitions of automation ratio that the eleven Japanese auto makers are using as of 1992 in the following nine production processes: stamping, body welding, painting, final assembly, engine assembly, engine machining, engine casting, engine forging, and plastic

Figure 1. A Framwork on Definition of Automation Ratio



injection molding. After discussing types of automation ratios, the paper will present actual data on how often each type of definition is used by the companies.

2. Types of Automation Ratio

As discussed above, automation ration can be different across companies and across processes. Theoretically, though, we can classify the operational definitions of automation into some categories. Suppose that *workers* and *machines* (equipment) transform *materials* at each *step of the production process*. Automation ratio can be measured by either of the four process elements shown above (see the figure).

(1) Machine-based definition: Ratio of automated machines or machine-hours.

(2) Worker-based definition: Ratio of workers or person-hours saved by automation.

(3) Material-based definition: Fraction of the materials that was transformed by automated equipment. Ratio of automatically welded spots, ratio of automatically painted areas in a body, ratio of automatically assembled parts, etc.

(4) Process-step-based definition: Ratio of process steps or work stations that were recognized as automated. The criteria of automation may be determined by the companies in question.

Again, which definition is to be used may depend on the types of the processes, companies, timing, etc.

3. Outline of the Survey

The survey was conducted in the late 1991 to early 1992 by the Committee on Optimal Automation Systems in the Automobile Industry at JTTAS (Chaired by Professor Shimokawa of Hosei University). All of the 11 auto assembly companies in Japan participated in the survey, in which 9 were car makers and 4 were large and

medium truck makers (Two companies made both types). The questionnaire asked individual engineers of each company about how they define automation ratio for each of the 9 production processes.

4. Summary of the Results

The result of the survey is presented in Table 1. As expected, types of definitions were different depending upon the companies and processes. There were some processes where one definition was used by almost all of the Japanese companies (e.g. welding), while there were other processes where consensus virtually did not exist (e.g. painting, final assembly). The most frequently used definition for each process was as follows:

Stamping: Number of automated steps (process-based)

Welding: Number of spots welded automatically (material-based)

Painting: Number of workers saved (worker-based)

Final Assembly: Number of person-hours saved by automation (worker-based)

Engine Assembly: Number of person-hours saved by automation (worker-based)

Engine Machining: Number of automated steps (process-based)

Casting: Number of automated steps (process-based)

Forging: Number of automated steps (process-based)

Plastic: Number of automated steps, or Number of workers saved

As the table shows, worker-based definitions tend to be used for relatively labor-intensive processes (e.g. assembly), while process-step-based definitions are chosen frequently in machine-paced operations such as stamping, machining and casting. Overall, however, there seems to be little consensus for definitions of automation ratio.

This appears to be particularly the case with painting and final assembly. In painting, different Japanese companies defined automation ratio in terms of number of

Table 1 Distribution of Definitions of Automation Ratio

definition type \ process		stamping	welding	painting	final assembly	engine assembly	engine machining	casting	forging	plastic molding
machine -based	number								1	
	hours	1								1
worker -based	number	2		4	1			1	1	3
	hours		1	2	6	5	1	1	1	
material -based			9	3	3	1				
process -step -based	process -steps	5		2	1	2	4	4	5	3
	overall evaluation						1			
others; n.a.		2			1	2	3	3	2	2
automation ratio of the most advanced lines by the above definitions (average of 9 car makers)		94%	91%	51%	10%	55%	93%	79%	90%	73%

workers, person-hours, areas of finish coating, and number of automated process steps. In final assembly, the definitions used by the Japanese included person-hours saved by mechanization, ratio of bolts automatically screwed, ratio of parts automatically assembled, and ratio of automated work stations. Thus, we have to be particularly careful when we interpret automation ratios of these processes that the companies disclose.

In the case of process-step-based definitions, a potential problem was how to draw a line between automated steps and non-automated ones. In defining automated stamping processes, for example, one Japanese company regarded a stamping line as automated only when there was no operator, whereas another company excluded palletizing operations at the end of press lines from the criteria of automation. Thus, a tandem stamping line which has fully automated transfer mechanisms between the machines but does not have an automatic palletizer may be judged as "automated" at the latter company, but it may not be so at the former.

5 Implications: Multiple Indicators for Automation Ratio

This brief paper pointed out that definitions of automation ratio, or degree of automation, tended to differ across companies and processes in the case of the Japanese auto industry. What follows from this finding might be a proposal to unify the definitions across companies and countries, if not across processes. In Germany,, according to Jurgens et al. (1986), "degree of automation" is defined by German Industrial Norm (DIN) #19233 as "percentage of mechanized or automated functions in the total number of functions." The report of International Motor Vehicle Program (1990) used "number of direct steps" as a uniform definition of automation ratio in its international comparative study of assembly plants. In Japan, though, there is neither industry-wide standard (e.g., JIS) nor shared understanding in the engineering community about what automation ratio is. As international comparative studies of

automation practices become increasingly common in the 1990s, we may need some kind of definitions that apply internationally and across the companies.

It would be unrealistic to propose a formal and totally uniform set of definition across companies and countries, though. Each company may already have accumulated data of automation based on a certain firm-specific definitions for the purpose of internal control. Some countries (e.g., Germany) already have industry norms, while others (e.g., Japan) don't. In this situation, any efforts to disseminate a uniform definition would face friction and resistance.

What is more realistic for the auto manufacturers seems to be informal knowledge sharing among them, rather than a formal agreement for the standard, on multiple indicators for automation ratio. If each company measure the degree of automation by more than one indicator, for example, it would become easier for the practitioners and researchers to do meaningful bench-marking studies between competitors.

Adoption of multiple indicators would be desirable not only because it facilitates meaningful inter-firm comparison, but also because automation itself is a multifaceted phenomenon which is hard to capture by just one indicator. In spot welding, for example, the ratio of automatically welded spots has been widely used, as Table 1 indicates. However, now that the automation ratio by this definition is nearly 100% in many of the recent welding lines, where the workers are mostly indirect ones, the definition focusing on direct jobs does not seem to measure the real degree of automation effectively. The definition based on the spots was apparently selected because of its clarity and reliability, but it cannot capture such important aspects of welding automation as indirect jobs, sealing operations, arc welding, finishing, etc. Thus, it seems to be desirable to have at least two definitions of welding automation: the existing one based on number of spots, and a new one based on, say, person-hours saved.

It would not be necessary for each company to measure automation ratio by all the definitions listed in Table 1. As the table indicates, for example, just two definitions for each process seem to cover most of the current practices. For example:

Stamping: (1) Ratio of the number of automated press lines (i.e., with automatic transfer mechanisms, palletizers, moving bolsters, etc.) to total number of press lines (including transfer press machines) ; (2) Ratio of workers or person-hours saved by automation to the ones necessary for a totally non-automated process.

Welding: (1) Ratio of spots automatically welded to total spots welded in-house; (2) Ratio of workers or person-hours saved by automation to the ones necessary for a totally non-automated process.

Painting: (1) Ratio of area that was automatically welded to total painting area; (2) Ratio of workers or person-hours saved by automation to the ones necessary for a totally non-automated process.

Final Assembly: (1) Number of parts assembled automatically in the main line (excluding bolts and fasteners) to total number of parts assembled; (2) Ratio of workers or person-hours saved by automation to the ones necessary for a totally non-automated process.

Engine Assembly, Machining, Casting, Forging, Plastic Molding: (1) Number of totally automated work stations to the total number of the stations in the line; (2) Ratio of workers or person-hours saved by automation to the ones necessary for a totally non-automated process.

That is, if each company measures the degree of automation by a few (instead of just one) indicators, it may be possible to make meaningful bench marking without destroying the existing measurement system.

To sum up, when inter-firm and international comparison of automation practices become increasingly important to practitioners and researchers, the auto companies might benefit from mutual understanding of each other's definition of automation, as well as adoption of a multiple indicator system for measuring the degree of automation. Again, what is important seems to be informal knowledge sharing, rather than formal agreements, among the auto companies.

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