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Title: A Critical Review of "Comparison of Manufacturing Performance of Three Team Structures in Semiconductor Plants"

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Abstract: A paper titled "Comparison of Manufacturing Performance of Three Team Structures in Semiconductor Plants" is critically reviewed in this individual report.

A Critical Review of "Comparison of Manufacturing Performance of Three Team Structures in Semiconductor Plants"

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1 SUMMARY AND CONCEPTS

In the last two decades, American firms tried to adopt almost all of the manufacturing practices that their Japanese peers had in place, including Just-in-Time Manufacturing, Total Productive Maintenance and the use of teams in improvement programs. They hoped that they could be implemented regardless of the work culture; therefore this would improve their productivity and therefore make them more competitive in the marketplace [7].

This paper examines the effect of teams on throughput and quality in the semiconductor industry. Throughput was collected by production workgroups (such as photo, thin films, diffusion and etch in the semiconductor industry) where teams belong due to the availability of such data. On the other hand, scrap was observed at the factory level. Moreover, the differences in team characteristics between different team types, such as autonomy level, task content and training level are also investigated. As the author also indicated, semiconductor companies have also jumped on the bandwagon of "teams" as a possibility for being as competitive as their Japanese peers and perhaps taking the lead in the 90's [11], [12].

Three types of teams have been of concern in this paper: Continuos Improvement Teams (CIT), Quality Circles (QC) and Self-Directed Work Teams (SDWT). CIT teams were formed by operators of several functional areas with an objective of coming up with a solution set for problems identified by management or themselves. QCs differ from CITs that members are selected from the same functional area and they last forever rather than disbanding at the end of problem resolution as CITs [17]. SDWTs are composed of members of the same shift from the same functional area. They are held responsible for their own performance and work on more technical problems. As QCs, they are ageless. Please refer to Table 1 and Table 2 for the comparison of these three team types.

Eight fabs (equivalent term for the factory in the semiconductor industry) were included in the sample. Technology-wise, these fabs were putting out similar products, primarily logic devices. All of them have already ramped up to the high-volume manufacturing capacity. No fab employed more than one type of the above-mentioned teams.

Data for productivity and quality were of historical while other data were collected from surveys and interviews. The author, Dr. Bailey conducted multiple visits to each site to conduct interviews and perform surveys with team members.

The analysis of the collected data has revealed that in contrary to the expectations, SDWTs had the lowest productivity and quality. As for the team characteristics, SDWTs displayed the higher level of technical and administrative autonomy, followed by QCs and CITs. As expected and stated in [13], team members of QCs and SDWTs were shown to have been involved in side activities that were not the typically outlined in the operator job description, such as problem solving and preventive maintenance. Because of this, they were provided with more team and cross training [16] than members of CITs while task training was higher for CIT members than those of the other two team types.

Program	Work Group	Improvement Team	Overseen By
CIT	Several Functional Area Work Groups Associated With… OP OP OP OP	…Each Continuous Improvement Team (CIT) ET OP E M/S	Human Resources Personnel
QC	Each Functional Area Work Group Associated With… OP	…Its Own Quality Circle (QC) ET OP E M/S	Production Shift Supervisors
SDWT	Each Self-Directed Work Team (SDWT) Associated With… OP	…Its Own Technical Sub-team E OP ET	Cross-Functional Management Teams

Table 1: Comparison of team programs from an organizational point of view (Adapted from [4])

2 METHODOLOGY

2.1 Research and Survey Design

Hypothesis: SDWT programs outperform CITs and QCs as SDWT programs provide the highest degrees of autonomy, training and modified task content. The performance metrics is not actually the performance of teams as the author claimed that they lacked a quantifiable end product, but the performance of functional areas where these teams belong. As mentioned earlier, eight fabs were included in the sample, representing seven major semiconductor firms. The breakdown of different team types in these eight fabs is as follows: 3 fabs with CITs, 2 fabs with QCs and 3 fabs with SDWTs.

The author has familiarized herself on work organization and manufacturing practices in one of these fabs employing a QC program. During this visit, she has piloted her survey on operators of this fab and made corrections on the original survey design based on feedback she has collected from pilot survey users.

Characteristic	CIT	QC	SDWT
type	off-line	off-line	on-line
lifespan	short-term	infinite	infinite
participation	voluntary	voluntary	mandatory
training	little needed	problem solving, preventive maintenance, some group dynamics	problem solving, preventive maintenance, group dynamics, administrative
evaluation of member performance	none	through subjective terms such as "teamwork" and "helpfulness" as determined by the supervisor	peer review, included in determination of pay and bonuses
membership	cross-functional	by functional area	by shift and functional area
job titles	mostly operators, but engineers, technicians, service personnel (e.g., payroll), etc. may also participate	operators	operators, sometimes merged with technicians
focus	fab-wide problem	functional area problem	functional area or area/shift problem
coordination/supervision	human resources representative	production supervisor	production supervisor or management team
cost	none (inexpensive)	moderate	expensive
change in job content	none	job management	job enrichment

Table 2: Characteristics of team programs (Adapted from [4])

2.2 Data Collection

Data were of two types:

- Quantitative Data

They were gathered from production records within six months of the site visit and were shown below:

- Direct Labor Productivity (DLB) which is wafer processed per operator hour
- Indirect Labor Productivity (ILB) which is wafers processed per employee hour (This measure is less than DLB since the dividing factor includes operators as well as supervisors and managers)
- Scrap (Percentage of wafers that have been scrapped)

- Qualitative Data

The author has conducted more than 100 interviews with employees at different levels of management hierarchy. She has participated in at least three-team meeting at each site and had four-hour unguided tour within the factory to allow her to informally talk with operators on the floor. Surveys were given to individuals selected by the production supervisor. They were mainly asked to indicate the level of autonomy, level of modified task content and level of training on a 1-to-5 Likert scale, "1" indicating none and "5" indicating very high. The responses of individuals from the same group were averaged out to serve as the group response.

2.3 Analysis methods

Descriptive statistics, such as mean and variance for each variable were heavily used in this paper. To test the existence of a significant difference in one variable among different groups (such as whether there is a significant difference in the amount of training among different team types in a particular functional area), analysis of variance (ANOVA) technique has been used.

3 RESULTS OF STATISTICAL ANALYSIS

3.1 Performance Variables

Each variable was analyzed at the production workgroup (functional area) level, except scrap: photo, etch, diffusion and thin films. The results of this analysis are shown on Table 3 (The lower the rank, the higher the performance):

Performance Variable	**Functional Area**	**Rank for CITs**	**Rank for QCs**	**Rank for SDWTs**	**Significant difference at less than 1% significance level**
Direct Labor Productivity	Photo	1	2	3	
	Etch	1	2	3	
	Diffusion	1	3	2	Yes
	Thin Films	1	3	2	Yes
Indirect Labor Productivity	Photo	1	3	2	
	Etch	1	3	2	
	Diffusion	1	3	2	Yes
	Thin Films	1	3	2	Yes
Percentage of Scrap	All areas	1	2	3	

Table 3: Statistical Results of Performance Variables

Direct Labor Productivity: CITs showed the highest performance in this category across all functional areas with a significant difference in both diffusion and thin films.

Indirect Labor Productivity: For this category, CITs were found to be the "winner" as well with a significant difference in both diffusion and thin films. The difference in performance between the three team types was smaller in this case, since in the QC and SDWT operators take on more technical and administrative tasks.

Scrap Percentage: This could bot be measured at the functional area level due to the lack of data at that level. Fabs with CITs had the lowest scrap performance (highest quality) than those with QCs and SDWTs. No significance difference among three team types in this performance variable was reported.

These results are actually not in line with the expectation that SDWTs would have the highest performance of all team types.

3.2 Self-Report Variables

Table 4 illustrates the difference between three different team types across all self-report measures. The higher the rank, the higher level of this variable is observed.

Variable	Rank for CITs	Rank for QCs	Rank for SDWTs
Autonomy			
Technical Autonomy	1	2	3
Administrative Autonomy	1	2	3
Modified Task Content			
Time in Meetings	1	3	2
Time in Preventive Maintenance	1	2	3
Time in Problem-Solving	1	3	2
Training			
Task Training	3	2	1
Team Training	1	2	3
Cross-Training	1	2	3

Table 4: Statistical Results for Self-report Variables

Autonomy: As expected, SDWTs showed the highest level of both technical and administrative autonomy. Due to the nature of such teams, members are expected to solve problems, formulate solutions for even technical problems and participate in decision making. Therefore, they would be more autonomous than CITs.

Modified Task Content: In parallel with the results of the autonomy variable, QCs and SDWTs spent the more time in preventive maintenance and problem solving since these tasks were expected of members of QCs and SDWTs.

Training: Due to the nature of CIT programs, workgroups in CIT fabs had the lowest team and cross training levels. Since members of QCs and SDWTs are expected to be an integral resource for addressing problems in a variety of problems, they will consequently need team and cross training.

The author also analyzed whether these results were due to the education and experience level of members that make up these teams. The ANOVA analysis of such variables revealed no significant difference among three teams.

4 CRITIQUE

4.1 Strengths

The author has chosen a good industrial segment, namely semiconductor industry where people can make a lot of difference in terms of productivity through participation in decision making. This has been achieved via the formation of different teams. No other research has selected the sample from a single industry.

Moreover, in previous studies [1], [9], [15], the perceived effect of teams on productivity and satisfaction has been measured through subjective measures. This research attempts to associate teams' success with the quantifiable productivity measures, such wafers processed per operator hour.

It is also important to note that characteristics of different team programs (e.g. level of autonomy, level of training etc.) have been found to be as expected. Similar conclusions have been drawn in the previous studies as well [3], [4], [9], [15]. In that respect, this study can be considered as a field study that proves the "generalizations" that have been made earlier in the literature.

This research also gives a good insight as to how teams differ from each other in terms of specific features (i.e. lifespan, participation etc) and organizational structure. These factors are important to know when initiating a team since the outcome of a team program is highly dependent on the team program type among many other factors, such as selection of right team members, management support and so on.

The author has also seemed to have spent a lot of time and energy to conduct this research as explained in the research design section. This increases the credibility of the collected data and the author's ability to interpret data.

4.2 Weaknesses:

Interestingly, some strengths of this research can be considered as weaknesses when looked at from a different perspective. For example, although the author attempts to connect the team success with quantifiable metrics, such as the factory productivity and quality and see what team programs results in the best programs, one can ask whether it is appropriate to make this association. There are many factors besides workgroups and teams that contribute to the factory productivity, such as process maturity, integration between engineering and manufacturing, proper planning and scheduling practices, sufficient staffing levels and so forth. The inclusion of such factors would make the statistical analysis more difficult to analyze and interpret due to interaction effects between these variables.

In spite of the quality of data collection process, having eight companies in the sample (sample size) is another concern to question the validity of the statistical analysis. Especially, when eight companies are broken into three team programs, there are at most three data points for each variable for a single category.

It was also a little awkward to know that there was only one team type in each company in the sample. None of the eight companies employed more than one team program. This is almost in contrary to intuition and what has been concluded in [10]. One would expect companies with complicated manufacturing processes, such as semiconductor industry, to take advantage of different team programs depending on needs or hybrid team programs, that would take advantage of "good" features of certain team programs. Had there been multiple team programs at each site, the author would not have been able to conduct the same analysis and therefore draw conclusion based on the statistical analysis.

From this research, one can not conclude whether teams directly affect, even better the company performance. It is assured in this paper that teams will some how contribute to the success of the company (productivity). It takes this factor for granted without even questioning that as most of previous research studies in the literature did. With this assumption, it seeks an answer to what team program would improve the factory productivity the most. It even analyzes the productivity by functional area.

It was also interesting to note that supervision or facilitation of CITs is done by human resources personnel. I thought this fact does not support the meaning that the "Continuous Improvement Team" implies. Due to the lack of my experience in the semiconductor industry, when I have spoken about this with one of my relatives who is relatively knowledgeable about manufacturing practices in this industry, he has indicated that to his best knowledge that no manufacturing teams are supervised by human resources personnel. In any team process, their main role is to ensure that teams follow a systematic approach in problem solving process and use quality tools (such as fishbone, pareto) during their team meetings [18].

Finally, in this study, the author does not report whether teams she included in this study really fit to the definition of a team. [14] defines a team as a group of individuals with a common purpose and a set of objectives, who have established appropriate measurement practices to measure progress. There are many workgroups / task forces in the industry that consider themselves "teams". They do not have the right structure to be called a team.

4.3 Comparison with Similar Research Studies

There have been numerous studies [5], [6], [9], [15], [19] in the literature that analyze the relationship between team / participative decision making and the company production as well as the job satisfaction. However, these studies did not include quantitative data for the factory productivity, Self-report measures usually in the form of perception constituted the data that have been analyzed in these studies. In previous studies, when evaluated by the perceived productivity, SDWTs have stood out to be the winner. One of the author's previous studies [4] has concluded that SDWTs have been perceived to outperform the other two team programs in both organizational performance and satisfaction with a significant difference. In this study, though, in most cases, SDWT's performance, measured by the direct productivity, indirect productivity and percentage of scrap, was usually the lowest regardless of the functional area. The author has also implied that results of this study were out of expectations. By the nature of the team design, SDWTs would score the highest in almost all variables, which was the author's main hypothesis.

The other part of the statistical analyses across self-report variables was in sync with the results of the previous studies that were similar to the one in question. SDWTs were shown to have the highest degree of autonomy, modified task content and training.

Another striking difference between this research and its peers is that it has combined the results of team efforts at multiple sites and conducted statistical analysis to find out which team program contributes the most to the factory performance. Most others [2], [11], [12], [21] could not have gone beyond being a case study from mostly one company. The impact of the team performance on the factory performance (such as cycle time reduction, on-time delivery improvement, throughput improvement) has been described at the descriptive level.

Some research studies [8], [10], [21] have sought an answer for the impact of teams on company productivity and job satisfaction and have identified a significant correlation between the two. In this paper, this is not he main hypothesis. Assuming the significant correlation, the research has attempted to find out whether the team type (program) would make any difference. It is interesting to note that, in spite of the abundance of research studies claiming that a significant correlation exists between teams and productivity, one study has raised the question of "practical" significance rather than the statistical one. After analyzing this, statistically significant correlation is obtained due to the combined (profound) effect of marginal practical significance. In other words, in a way, significance is inflated when it comes to reporting perception on the impact of teams on productivity.

Dr. Bailey has found out in her previous study CIT programs face substantial design and implementation obstacles. Interestingly, in this research, she concludes based on the statistical analysis that CITs impact on factory performance is the highest almost regardless of the process area in the fab.

5 CONCLUSIONS AND FUTURE RESEARCH

This research has pointed out the importance of the team program structure on the potential results that a particular team could generate. Three main team programs were included in this study, namely CIT, QC and SDWT. The author has, once again, proved the higher autonomous and training level in the SDWTs due to the nature of such programs than its peers. For this reason, it was expected that SDWTs would yield higher performance at the work place. However, the analysis of performance data indicated that this expectation does not hold true and even less structured, more informal and less trained team programs, such as CITs will outperform others. As explained earlier, this might be because the set of performance variables (i.e. wafers processed per operator hour and percentage of scrap) is not appropriate to compare the team performance against each other. It is obvious that there are other factors (i.e. scheduling practices, integration between manufacturing and engineering, automation level etc) for performance measures in this study.

Future research might attempt to measure the team performance by using other metrics, such as perceived or measured success of projects that teams have undertaken, rather than labor and factory productivity. The author might also investigate the existence of other factors (i.e. use of advanced planning and scheduling systems) in the eight sites where she conducted this research to explain why some fabs outperformed others' productivity. This will actually explain why she could not obtain the expected results for SDWTs. It might be the case that it is not the team program in a fab with a CIT that improves productivity, but the availability of various Computer Integration Manufacturing systems.

Furthermore, a future study might look into the impact of hybrid teams that combine features of different team programs on the company performance and difference between this study's team programs and hybrid teams.

Finally, it would also be important to examine reasons why organizations deploy certain team programs. The factors that impact the selection of the team programs will provide more insight into reasons for preference.

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