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PERSPECTIVES ON THE TRAINING AND EDUCATION OF WORLD-CLASS ENGINEERS

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ABSTRACT

World class manufacturing implies a philosophy of manufacturing excellence. It is strongly dependent on having properly trained engineers. It is also strongly linked to the ability of a company to compete in the global market. Using Michael E. Porter's "The Competitive Advantage of Nations" as the framework together with the increasingly strict requirements of the semiconductor industry as a benchmark, this paper presents viewpoints on the training of engineers for global competitiveness. Experiences drawn from the UP and DLSU Manufacturing Linkage Programs were also used for guidance.

The critical items required for engineers to be competitive in a world class environment include: the ability to solve problems by proceeding from the basics and the ability to consider the human aspects as part of a technical solution. Additional technical aspects would be based on Total Quality Management (TQM), together with additional training on statistical concepts applied to process improvement, manufacturing and design of experiments. Finally, the training must emphasize innovativeness and even creativity.

WHAT IS "WORLD-CLASS MANUFACTURING"?

"World-class" is a difficult term to define, since it has many aspects. However, for purpose of reference it is necessary to visualize it as a concept. Perhaps, the simplest image that we can have is that of an athlete. A world-class athlete is one capable of beating anybody in his field, capable of being world champion or of competing honorably in a field composed of the best athletes. In this case, we can immediately identify whether an athlete is world-class or not. We would even be able to point to several Filipino athletes who would readily fit this description, since their performance would be readily verifiable with respect to established standards or because of their accomplishments.

For purposes of this paper, we will consider some aspects which will point the direction towards world class level in manufacturing. There are many available indicators. One of these called "World Class Metrics" was cited in "Manufacturing Engineering" a monthly publication, in September 1990. A copy of some of the metrics is shown in Table 1. This table shows some aspects of a world-class manufacturing operation.

Table 1. World-Class Metrics

(Source : Manufacturing Engineering-September 1990)

ATTRIBUTE	WORLD CLASS STANDARD
- Set-up	System: 30 Min. or less Cell : 1 min. or less
- Quality	1,500 PPM (0.15%)captured 300 PPM (0.03%)escapees Cost of quality: 3-5%
- Ratio of Manufacturing Space of Total Space	50 + %
- Work as a Function of Time	20 + %
- Material Velocity Material Residence Time	100 + turns 3 days
- Flexibility	270 parts/machine tool
- Distance travelled	300 ft.
- Uptime	95 + %

Another group of indicators is given by SGV Consulting as part of its "C/SBM World Class Manufacturing Seminar". These indicators are given in Table 2. On a more specific level, world class manufacturing was defined by Integrated Microelectronics Inc. in 1989 as it prepared to modernize and upgrade its plant. The concept is given in the following quotation:

> "World class manufacturing does not mean a highly automated production line full of robots. Although there is no definition of world class manufacturing that is generally agreed upon, it implies a philosophy of manufacturing excellence.

Table 2. Attaining World Class Level
(Source: C/SBM World-Class Manufacturing Seminar, SGV & Co.)

Offer a product of high value
- Customer's need: quality, time, cost
- Compress design time
- Customize - direct use

Build market share
- Minimum cost
- Good service - customer driven
- Improve product value continuously

Improve quality and efficiency
- Design of manufacturability
- Built-in quality
- Reduce cost inputs: maximize resource utilization
- Shorten manufacturing time
- Faster procurement

Speed up product delivery
- Eliminate storage
- Reduce transportation costs
- Reduce pipeline, inventories

Reduce overheads
- Eliminate non-value adding activities

It encompasses a set of techniques that many firms have found to enable them to substantially improve their operations and to compete better in the marketplace. For IMI, world class manufacturing means the following:

1. Quality culture
2. Employee Involvement
3. Upgraded Equipment
4. Upgraded Facility
5. Redueed Lead Time
6. Increased Flexibility
7. Upgraded Vendors
8. Process Standardization
9. Simplification
10. Focus

(H.Y. Dimacali, "IMI: on the Way to World Class Manufacturing", Buhay IMI, No. 4, August 1989, p.4)

The common aspects of all these three descriptions can be summarized as follows:

(a) Quality - zero defect. This must be obtained through design, a stable process, and a quality culture.

(b) Short turn-around-time (TAT) - The manufacturing cycle must be speeded up and adapted to the customer's business cycle.

(c) Reduced cost - This must be obtained through productivity gains, built-in quality, reduced cost of inputs and efficient use of resources.

(d) Responsiveness to customer - this includes internal and external customers and therefore relates to Total Quality Management (TQM) and a customer-driven or market oriented approach. Responsiveness would also include good customer service customization of features, process flexibility and continuous improvement.

(e) Employee involvement - Although this factor is neither directly mentioned nor directly measurable, it is apparently needed to consistently attain high quality and to sustain continuous improvement. It is a widely spoken adage that "Machines make but people manufacture".

Knowing where to go in terms of manufacturing operations and indices is important in the quest for world class manufacturing. An important strategy in this direction is "Benchmarking". This consists of looking for the best practices in a certain operation in order to emulate it in the company. This activity is an important aspect of going world-class.

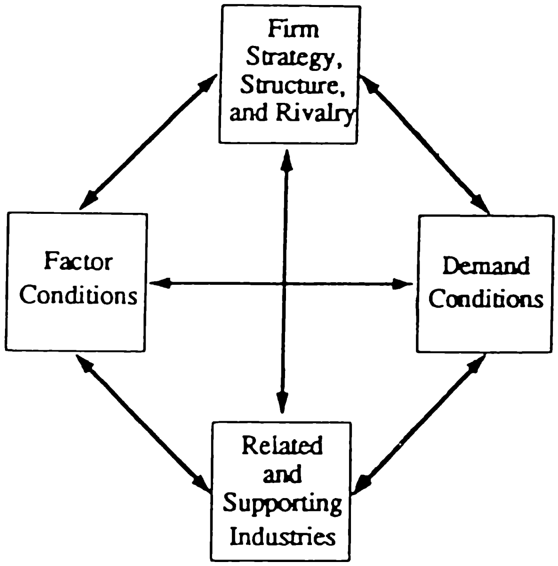
ASPECTS OF COMPETITIVENESS

The "Diamond of National Advantage"

In the quest for world class manufacturing, competitiveness is a key concept. The very nature of the adjective "world class" implies the ability to compete and survive in the world market. The major aspects of competitiveness were recently expounded upon by Michael E. Porter in his article "The Competitive Advantage of Nations" (Harvard Business Review, March-April 1990). Based on the analysis of past experience, Porter has defined the determinants of national competitive advantage and has further defined their interrelations in his "Diamond of National Advantage". (See Figure 1).:

Porter argues that there are four attributes that enable certain companies based in certain nations capable of consistent innovation. These are:

(a) Factor Conditions - These include factors of production such as skilled labor and infrastructure. A nation must create and sustain the most important factors of production. Often sustained, heavy and specialized investment is required.



- ❑ National prosperity is created, not inherited. It does not grow out of a country's natural endowments, its labor pool, its interest rates, or its currency's value

- ❑ A nation's competitiveness depends on the capacity of its industry to innovate and upgrade

- ❑ Innovation usually requires pressure, necessity, and even adversity: the fear of loss often proves more powerful than the hope of gain

- ❑ Sustaining innovation can only be achieved through:

  - relentless improvement or upgrading - to move to more sophisticated type
  - adoption of a global strategy
  - creating more sustainable advantage often means that a company must make its existing advantage obsolete - even while it is still an advantage

Figure 1. Determinants of National Competitive Advantage
Source: Michael E. Porter (1990)

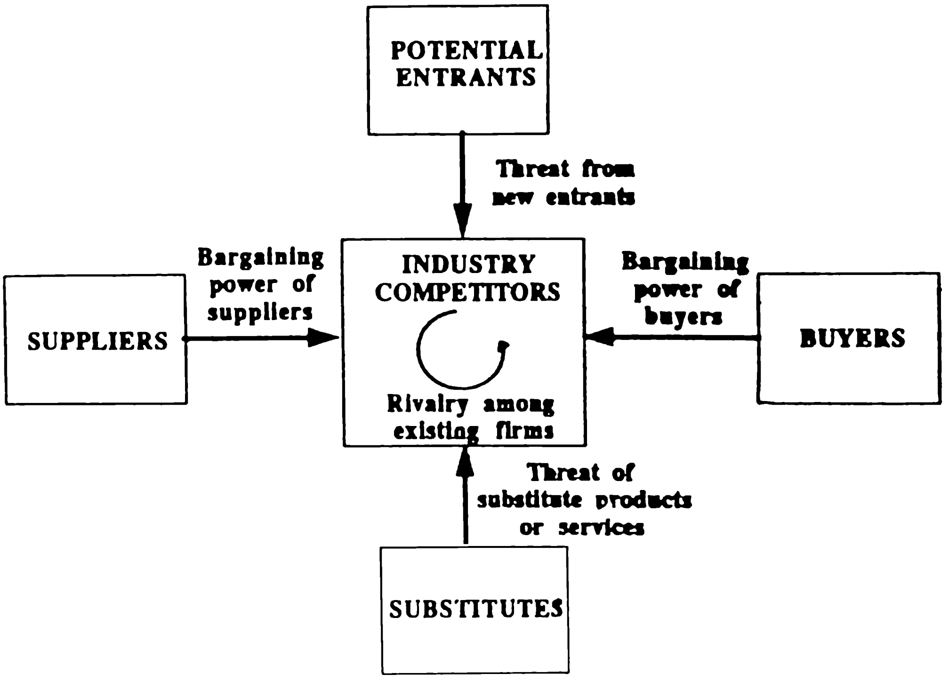


Figure 2.
Source: Michael E. Porter (1990)

(b) Demand Conditions - Where home demand consists of selective and discriminating buyers innovation is fostered leading to more sophisticated competitive advantage for the local companies.

(c) Related and Supporting Industries - These help reduce the cost of inputs and to shorten the manufacturing time. Their presence also stimulates continuing exchange of ideas and innovation.

(d) Firm Strategy, Structure and Rivalry - this refers to a combination of strategy, company management style and internal culture that must result in innovativeness. No single managerial system is universally appropriate, rather the individual firm must evolve in relation to the management modes and practices in the country and the other sources of competitive advantage.

The Need for Innovation and Teamwork

From the preceding discussion, it must now be emphasized that world class and world level competitiveness would be strongly linked to innovation. Aside from engineering excellence, there must be appreciation for and application of people-oriented management strategies, "flotilla" or module organization and continuous improvement. It is also increasingly apparent that world class status, contrary to many examples in athletics, depends strongly on teamwork. No single engineer or manager can propel his company to world class status, but a team of engineers and managers, working with the rank and file can. (Peter F. Ducker, 1991; Tom Peters, 1992; Alvin Toffler, 1992)

COMPETITIVENESS IN THE SEMICONDUCTOR INDUSTRY

To give a more concrete image of world class competitiveness, some examples will now be cited as they apply to the integrated circuit packaging companies.

Quality

(a) Assembly Yield

Year	Percent Yield
1987	96.0%
1989	97.0%
1991	98.5%
1993	99.0%

(b) Defects per million (DPM)

	%	DPM
1988	20	200 000
1989	10	100 000
1990	1	10 000
1991	0.5	5 000
1992	0.1	1 000
1993	0.01	100
1993	Automotive	10
1995	Six sigma (Motorola)	3.4

(c) Statistical Process Control

	CpK (Process Capability)	
1987	Not required	
1990	1.33	3
1993	1.67	5
Target	2.0	6

Consistent use of SPC charts and analysis of unacceptable trends is also required.

Turn-around-Time (TAT)

	D/B-FGS (In-plant)	Door-to-door (Customer)
1987	14	21
1989	9	14
1991	5	10
1993	4	9
Target	1	3

Cost Reduction

Three to five percent price reduction per year is expected inspite of increasing cost of inputs. This has to be done by increasing productivity and reducing cost of inputs.

Customer Service

Flexibility in response to technical and non-technical inquiries is expected. Rapid response to complaints and issues is necessary.

Examples of response systems for Corrective Action Requests (CAR)

(a) "1 2 12"	1 day response 2 days solution 12 days closure or update
(b) "3 3 3"	3 hours response 3 days solution 3 weeks closure or update

EDUCATION AND TRAINING REQUIREMENTS FOR WORLD-CLASS COMPETITIVENESS

"Back to the Basics"

Based on our experience in the AME Cadetship Program and the collective experience in the UP and DLSU Linkage Program, two items have emerged as critical for engineers to be competent and innovative.

(a) the ability to solve problems by proceeding from the basics; and,

(b) the ability to consider the human aspects part of a technical solution.

While the first is a bit self-explanatory, it has been mentioned at linkage meetings that some engineers lack a sound training in the basic concepts such as mechanics, thermodynamics, kinetics and related subject matter. This could be due to teaching styles which emphasize form rather than content. Since engineering can also be defined as "the ability to make technical decisions on the basis of inadequate technical information", a strong background on engineering principles is very important and cannot be under stated.

The second item deals with the tendency of engineers to think of solution to problems in abstract technical terms as seen from calculations and machine parameters. They often overlook the human aspect -- that technical solutions often involve people and cannot be implemented without their cooperation. Present educational efforts must be redirected to take this aspect into consideration.

Another concern which can be added to these basic items is the ability to communicate both in written and oral from. There appears to be a distinct trend for engineering students to de-emphasize their English, Literature and Humanities courses because "they are non-technical and will not help them become engineers". While this argument is partly right from a strict technical viewpoint, these courses actually improve an engineers communication skills and help him be a better engineer. An innovative idea can not be implemented until it is communicated, and it cannot be communicated if it is not understood.

Technical Aspects

World-class has a very strong cultural and mind setting content, so its basic foundation must be Total Quality Management (TQM). TQM must be part of an engineer's training for him to contribute effectively in the quest of excellence. TQM embodies the critical basic principles of satisfying your customer, getting things right the first time, zero defect, cost effectiveness, continuous improvement and teamwork.

Other technical methods and philosophies required would include but not be limited to:

(a) Just-In-Time (JIT)
(b) Statistical Tools for Quality Assurance
(c) Design of Experiments (DOE)
(d) Design for Manufacturability
(e) Manufacturing Engineering Concepts

Innovativeness and Creativity

Training of engineers must include and emphasize innovativeness and if possible, even creativity. The ability to "think in three dimensions" or to solve problems through "dream time" are important aspects of innovativeness. Open mindedness and an investigative spirit must be part of the orientation of engineers. To quote Tom Peters (1992) "Get Innovative - or Get Dead". One drawback however, is that there are no fixed or guaranteed methods for teaching innovativeness.

THOUGHTS ON HOW TO TRAIN

"Back to the basics" and communication skills must be re-emphasized at the college level. It is important for faculty members to be exposed to industry concerns through linkage programs or consultancy in order for them to set the proper tone and focus on the basic skills required of students. In addition, the aspects of innovativeness must be introduced into the curriculum as early as possible, together with a new emphasis on the human aspects of technical solutions.

Among the technical aspects, emphasis on TQM, as a philosophy and as an orientation should be given to college level students. Exposure to JIT, DOE, Design for Manufacturability and some supplementary concepts of manufacturing engineering should be done particularly for those who will work on the factory or shop floor. While most of the concepts could be given at the senior level, DOE should be preceded by a course on statistical tools for quality assurance. Workshop or laboratory hours may be required for DOE.

It should be noted here however, that although the concepts presented are as general as possible, there is still a certain bias towards requirements in the semiconductor industry.

CONCLUSION

In this short paper, drawing form various experiences in academe, industry and government, we have attempted to define the major aspects of world class manufacturing. In summary, they are: high quality short TAT, reduced cost, responsiveness to customer and employee involvement. We have also cited that to have world class engineers, we need to re-emphasize the basics and communications skills, foster innovativeness and introduce TQM. Other technical aspects required have also been discussed. In ending we again take note that going world class is a team effort.

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APPENDIX

WORLD CLASS MANUFACTURING
(IMI 1989)

- not a highly automated line
- implies a philosophy of manufacturing excellence
- set of techniques to substantially improve operations

(1) Quality Culture - "do it right the first time "
- target 3 DPM
- production is owner of quality
- control of variation: SPC
- robust process

(2) Employee Involvement
- training
- quality circles
- continuous improvement

(3) Upgraded Equipment
- "best wirebonder in the world"
- elimination of handling

(4) Upgraded Facility
- Class 10K, 1K under laminar flowhoods
- housekeeping
- ESD

(5) Reduced Lead Time
- concentrate on door-to-door
- JIT

(6) Increased Flexibility
- cross training
- shorter conversion time (15 mins. vs 2.5 hrs.)
- shorter set up time

(7) Upgraded Vendors
- highest quality
- limit suppliers: partnership

(8) Process Standardization
- determine highest quality process
- convert customers to this process
- materials standardization

(9) Simplification
- elimination of non value added operations
- housekeeping

(10) Focus
- choose goals
- concentrate on goals to meet them one-by-one

"WORLD CLASS"
Common Aspects

(a) Quality-zero defect
(b) Short turn-around time (TAT)
(c) Reduced cost
(d) Responsiveness to Customer
(e) Employee involvement

Note: need for benchmarking

COMPETITIVENESS

- Diamond of National Advantage
- Need for Innovation and Teamwork

SEMICONDUCTOR INDUSTRY

Quality

- Assembly Yield

Year	Percent Yield
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Target	1	3

Cost Reduction

3-5 % reduction per year

Customer Service

- flexibility
- rapid response

Example: CAR

(a) "1 2 12"
- 1 day response
- 2 days solution
- 12 days closure or update

(b) "3 3 3"
- 3 hours response
- 3 hours solution
- 3 weeks closure or update

EDUCATION and TRAINING REQUIREMENTS

1. "Back to the Basics"

   (a) the ability to solve problems by proceeding from the basics; and
   (b) the ability to consider the human aspects as part of a technical solution

2. Technical Aspects

   (a) Total Quality Management (TQM)
   (b) Just-In-Time (JIT)
   (c) Statistical Tools for Quality Assurance
   (d) Design of Experiments (DOE)
   (e) Design for Manufacturing
   (f) Manufacturing Engineering Concepts

3. Innovativeness and Creativity