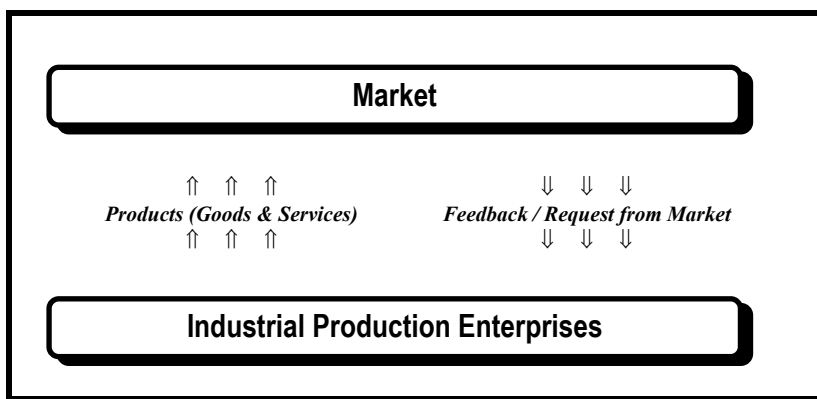


## **HOLISTIC MODEL OF TECHNOLOGICAL INNOVATION: AN INNOVATION MODEL FOR THE REAL WORLD**

‘Architecture of Knowledge’, another report of this series, studied the process of transformation of information among four industrial institutions: Production, Design and Development -D&D, Industrial Research and Development - R&D and Basic Research. This report further studies the information relationships between the above entities, as well as Market. The report then develops a new outlook towards technological innovation; referred to as the Holistic model of innovation.

### **PRODUCTION AND MARKET**

‘Dynamic Model of Production and the Evolution of the Knowledge Economy’, another report of this series, states that production is the process of transforming the ‘elements of production’ (Material, Energy, Knowledge, Artifacts and Human Resources) into ‘products’ (further classified into Goods and Services). A production enterprise is being considered as the entity that is involved in the process of production. Any product is aimed at the market and the consumer. Market, in this context, is the receiver of the production’s output.



‘Market’ and ‘Production’ have a wide set of interactive and dynamic information relationships. Market, by providing feedback information about the actual and potential needs, interfaces with production. The information relationship between market and industrial production enterprises is complicated;

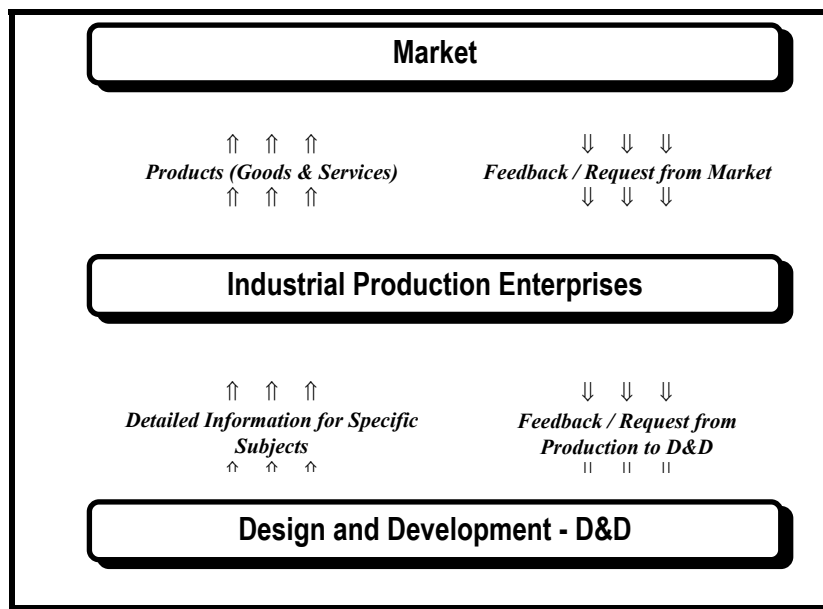
however, in a very simple manner it can be depicted as in the above diagram.

## DESIGN AND DEVELOPMENT D&D

Everyone who works in production, from line operators to managers and executives, needs information to perform their duties. A high-ranking manager, on the basis of the received information, may make decisions regarding the general programs and policies of a production unit. A middle manager may make decisions related to the execution of a project. A specialized worker may make decisions on the detail of a production process. Although the domain of various decisions is different, decision making is not restricted to the high-ranking manager. The process of decision making is based on the analysis and synthesis of information.

The main information required by production people is the ‘detailed information for the specific subjects’. The content of detailed industrial information for specific subjects may vary according to the position of a person, from advisory services for top managers, to instruction and shop drawings for specialized workers.

Detailed information about specific subjects, as an input to production, is composed and provided by a special group of firms, which are generally classified under “Design and Development”- D&D. D&D firms, covering a wide range of activities, compile, process and then prepare detailed industrial information about the specific subjects. As previously discussed, the detailed information is normally used by production units.



Design occupies a central role in the innovation process, and it includes several concepts. Broadly understood, it may convey the sense of ‘initial design’, which may reflect invention, ‘analytical design’, and ‘the study of new combinations of existing products and components, re-arrangement of processes and designs of new equipment within the existing state of the art’. More precisely it is drawings aimed at defining procedures, technical specifications, and operational features necessary for the development and manufacture of new products and processes. Design activities are not a lower level or routine activity, but one which can originate a number of linkages and

feedbacks. A design in some form is essential to initiating technical innovation, and redesigns are essential to ultimate success. In many industries, this design activity still incorporates tacit forms of knowledge and technical know-how dating back to earlier periods when production had little or no base in or support from science<sup>1</sup>.

The relationship between D&D and Production is not a one-way approach. Production units also provide feedback information to D&D firms and, in the case of need, request from them detailed information about specific subjects. The previous diagram depicts the relationships between the 'Industrial Production Enterprises' and 'Design & Development - D&D' firms, as well as the relationships with Market.

## **INDUSTRIAL RESEARCH AND DEVELOPMENT - R&D**

The people who work in the D&D firm require information to perform their duties, when they do not have access to the information on the spot. The needed information may be called 'comprehensive information concerning the specific subjects', which is too general and is not utilized directly by production units. D&D firms' main endeavors relate to economic utilization of the existing and available comprehensive industrial information and its conversion into detailed industrial information, mainly for the production units.

The Industrial Research and Development - R&D centers, the main source of comprehensive industrial information for specific subjects, perform a wide range of activities, for instance:

- Preparation of standards and norms
- Preparation of tables and norms for the specifications of various materials
- Initiation of new information and know-how for various processes and production activities
- Study and proposal of new methods of management
- Study of various procedures for increasing productivity
- Development of new quality control methods

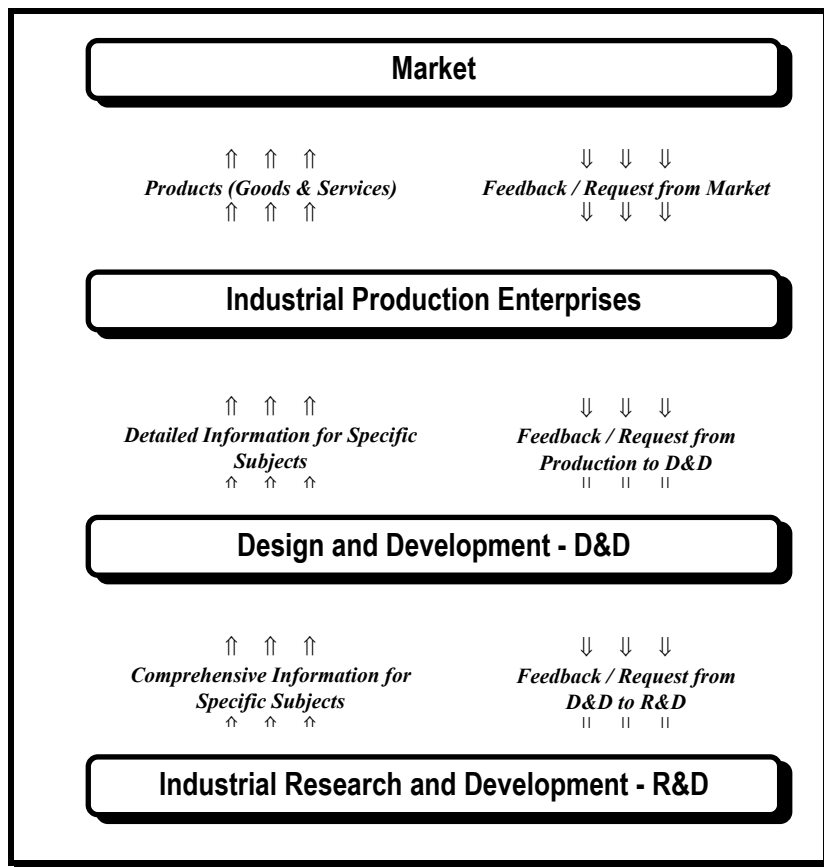
The output of the R&D centers, i.e. comprehensive information about specific subjects, comes in different forms, such as tables, curves, graphs, formulas and computer software. The information and knowledge prepared by the R&D centers should be directed at specific and applied subjects.

Considering the economic criteria governing industrial research, R&D centers do not usually deal with pure scientific endeavors. On the other hand, if the R&D centers concentrate directly on generating the information needed by the production units, thereby by-passing the D&D firms, their endeavors may become uneconomical as well. The next diagram depicts the relationships between the R&D centers and D&D firms, the Industrial Production Enterprises and Market.

The direct generation of detailed industrial information by R&D centers is usually too expensive. However, in exceptional cases, for instance if the subject is unique, the generation of detailed industrial information can be performed by R&D centers. It must be noted that such cases should be regarded as the exception rather than the rule.

Although both D&D firms and R&D centers deal with development, they have different

approaches towards development, and D&D is an activity substantially different from R&D. As an extension of research, as in R&D, development implies reducing new knowledge to practice - verifying and validating experimental results and theoretical predictions, exploring specific cases, determining the accuracy and limits of mathematical models and methods. But when coupled with design, development implies the steady refinement of quite concrete products, processes and systems through an interactive process of conceptualization, preliminary design, analysis, testing and redesign. This is the everyday technical work of private firms, often called product development or product engineering (or process development, software development, and so on). Instead of thinking of design and development - activities in which knowledge is applied - as D&D, reserving R&D for activities that generate knowledge, the latter term has entered into common use to stand for either or both. Although practitioners, understanding the distinctions, do not have much trouble communicating among themselves, the very broad range of activities encompassed by R&D in its now-common usage sometimes leads to confusion among economists, policy analysts, and other observers<sup>ii</sup>.

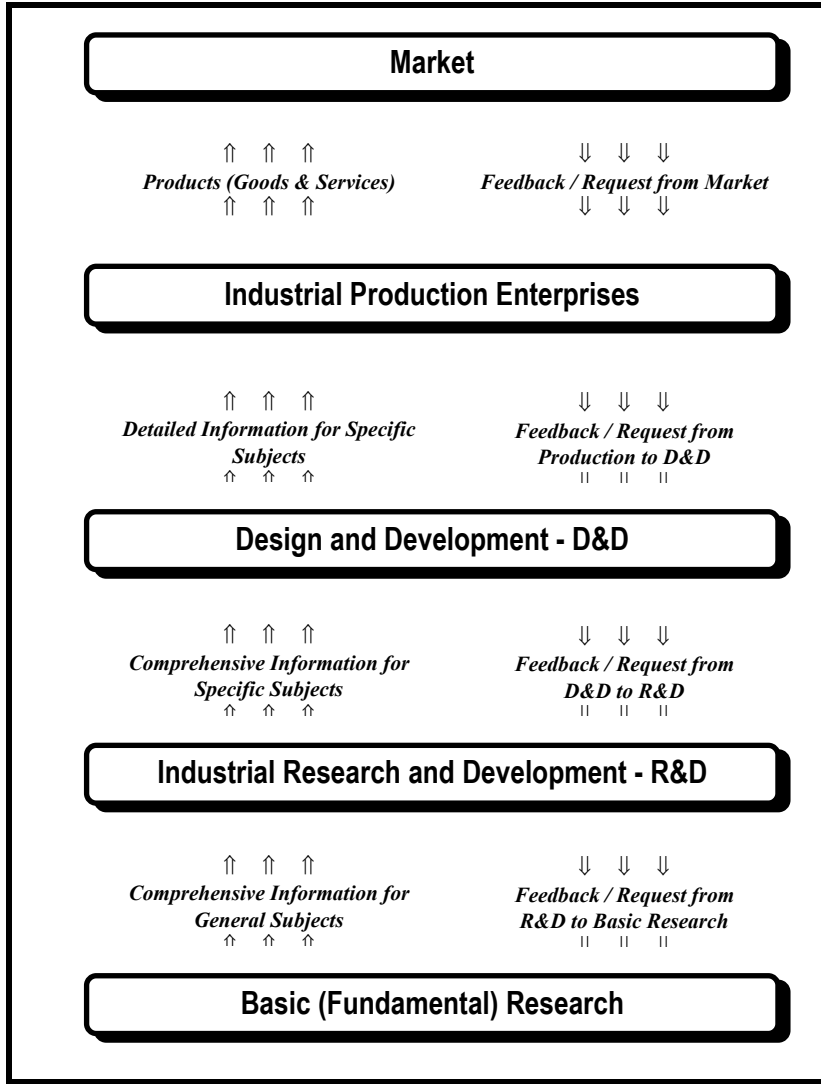


### BASIC (FUNDAMENTAL) RESEARCH

To perform their duties, R&D centers require input information which may be classified as “comprehensive information about general subjects” or briefly “scientific information”.

Scientific information is very theoretic and cannot be used directly by industrial production units or D&D firms. In an ideal case, the scientific information is in the form of mathematical formulas,

but the scientific information may also be found in the form of graphs, curves, tables, etc. Fundamental (Basic) Research Centers are the main generators of scientific information. The diagram depicts the main information relationships between Market, Production, Design & Development (D&D), Industrial and Applied Research (R&D), and Basic (Fundamental) Research.



## CLASSIFICATION OF D&D

Each of the above studied organizations, Market, Industrial Production Enterprises, D&D, R&D and Basic Research, has relevant classifications. The classification of the industrial production enterprises will be discussed in the ‘Matrix Taxonomy for Industrial Classifications’; another report of this series. The rest of this report concentrates on the classification of D&D.

The D&D stage can be made to apply widely to such activities as an enterprise’s product design, process design, equipment design, plant design and operation management. This configuration is presented in the next diagram. In addition, it should be noted that product design/development is

in practice often further subdivided into the product's function- /application, form/aesthetic, and ergonomic features.

Product	Process	Equipment	Plant	Management
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In practice, there are many ways that companies acquire or perform design/development. In general, these activities can be classified into two categories: 'Make' (technology development) and 'Buy' (technology transfer). Each procedure of acquiring technology -either Make/develop or Buy/transfer - may be further organized into a hierarchy, according to the cooperative edge of knowledge acquired and competitive advantage of economic value, as in the next diagram.

<b>Design and Development (Based on Technology Transfer)</b>				
Product	Process	Equipment	Plant	Management
Supplying/License	Engineering Services	Design Engineering	Turn-Key Project	
Buying Know-how	Buying Know-how	Buying Know-how	Feasibility Studies	Technical Assistance
Buying Patent	Buying Patent	Buying Patent	Installation	

<b>Design and Development (Based on Technology Development)</b>				
Product	Process	Equipment	Plant	Management
Copy/Imitate	Copy/Imitate	Copy/Imitate	Commissioning	Operation Management
Improvement	Improvement	Improvement	Detail Engineering	Maintenance Management
Innovation	Innovation	Innovation	Basic Engineering	Production Management
Invention	Invention	Invention	Project Management	Plant Management

By the above diagrams, we create the Holistic model of technological innovation (next diagram), which is more consistent with reality than the Linear model of innovation. The Holistic model shows clearly that innovation can occur throughout a company's operations, triggered in some cases by new knowledge, but in other cases by an opportunity to fulfill a market need.

## BEST PRACTICES

Getting knowledge from the market and learning from the competitors are among the main procedures of innovation for most businesses. 'Competitive Bench-Marking', 'Reverse Engineering', and 'Imitation' are some of the approaches to achieve the best practices, which are economically, as well as legally viable. Adopting the best ideas and practices requires distinguishing between that which is universally applicable and that which is locally viable and culturally specific.

Benchmarking is the process of finding and adapting the best practices. Consistent with this view, the American Productivity and Quality Center (APQC) looks to bench-marking as the process of identifying, understanding and adapting outstanding practices from organizations anywhere in the world to help your organization improve its performance. Benchmarking is the practice of being humble enough to admit that someone else is better at something and wise enough to try and learn how to match and even surpass them at it<sup>iii</sup>. According to Leibfried (1992) "benchmarking is an external focus on internal activities, functions, or operations in order to achieve continuous improvement. Starting from an analysis of existing activities and practices within the firm, the

objective is to understand existing processes, or activities, and then to identify an external point of reference, or standard, by which that activity can be measured or judged<sup>iv</sup>."

"Made in America" points out that the concept of "competitive benchmarking" is now become more widely accepted in American firms. At Xerox, for example, every department is expected to conduct a global survey to find the firm or organizational unit that performs its function the best. This performance level then becomes the target for the Xerox unit. Other companies have used the strategy of forming joint ventures with best-practice firms from other countries as a learning tool. Examples include the joint ventures of General Motors with Toyota, Ford with Mazda, Chrysler with Mitsubishi, and Armco with Kawasaki Steel<sup>v</sup>. On the other hand, 'The Economist'<sup>vi</sup> argues, in the past decade, companies throughout the advanced industrial world have spent learning, copying, and often improving upon Japanese methods.

Reverse engineering is the procedure to acquire knowledge from or about the competitors may have commonalties with 'bench-marking. Reverse engineering involves trying to produce legally a product similar or superior to one already available on the world market, but without direct foreign investment or the transfer of blueprints for product and process design. Almost forgotten in the linear model, reverse engineering requires an understanding of the basic mechanism behind products and the skills to copy, imitate, adapt and assimilate technologies. Japan's and Korea's technology development is not complete without addressing the crucial role of reverse engineering in innovation. After the Second World War when Japanese industry was devastated, its method of copying, imitating, assimilating and improving upon imported technology was consistent with reverse engineering. Often originally developed through reverse engineering, the Japanese approach to product and process design created a new type of innovation management. We should therefore recognize that innovation comprising both forward and reverse engineering, will profoundly affect our national innovation system and technology strategies, as well as management of technology in business.

Reverse engineering and benchmarking, are both the procedures for getting information from the market and competitors, the process that may be generalized as 'learning from the competitors.' Learning from competitors and learning from ourselves (research and development, design, ...), apparently, should be better considered as complimentary, rather than competitor.

## THE HOLISTIC MODEL OF TECHNOLOGICAL INNOVATION

**Market**

↑ ↑ ↑  
*Products(Goods & Services)*  
↑ ↑ ↑

↓ ↓ ↓  
*Feedback / Request from*  
*Market*

**Industrial Production Enterprises**

↑ ↑ ↑  
*Detailed Information for Specific*  
*Subjects*  
↑ ↑ ↑

↓ ↓ ↓  
*Feedback / Request from*  
*Production to D&D*  
|| || ||

### Design and Development - D&D

#### Design and Development (Based on Technology Transfer)

Product	Process	Equipment	Plant	Management
Supplying/License	Engineering Services	Design Engineering	Turn-Key Project	
Buying Know-how	Buying Know-how	Buying Know-how	Feasibility Studies	Technical Assistance
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#### Design and Development (Based on Technology Development)

Product	Process	Equipment	Plant	Management
Copy/Imitate	Copy/Imitate	Copy/Imitate	Commissioning	Operation Management
Improvement	Improvement	Improvement	Detail Engineering	Maintenance Management.
Innovation	Innovation	Innovation	Basic Engineering	Production Management
Invention	Invention	Invention	Project Management	Plant Management

↑ ↑ ↑  
*Comprehensive Information for*  
*Specific Subjects*  
↑ ↑ ↑

↓ ↓ ↓  
*Feedback / Request from*  
*D&D to R&D*  
|| || ||

**Industrial Research and Development - R&D**

↑ ↑ ↑  
*Comprehensive Information for*  
*General Subjects*  
↑ ↑ ↑

↓ ↓ ↓  
*Feedback / Request from*  
*R&D to Basic Research*  
|| || ||

**Basic (Fundamental) Research**

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<sup>1</sup> OECD, 1992, **Technology and the Economy, The Key Relationships**, OECD, Paris

<sup>2</sup> Alic J, August 1994, **The North American System of Innovation in Global Context**, Tri-national Institute on Innovation, Competitiveness and Sustainability, Whistler, BC

<sup>iii</sup> American Productivity & Quality Center (APQC), **Bench-marking**, 1997, APQC, Houston, Texas

<sup>iv</sup> Kathleen Leibfried and C. J. Mc Nair, 1992, **Benchmarking: A Tool for Continuous Improvement**, Harper Collins, NY.

<sup>v</sup> Michael Dertouzos, Richard Lester and Robert Solow, 1989, **Made in America**, MIT Press, Cambridge, MA.

<sup>vi</sup> The Economist, October 5, 1996, **After Japan**, P.18.

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<sup>1</sup> Last update: July 23, 1998: