Chapter 3 – Process Technology

Intel Corporation – Copy Exactly! See Intel Case (case 7). For Intel, and for many other companies, process technology and how it is managed provide significantly competitive advantage.

## What is Process Technology?

Process technology is the technology used to produce products or provide services.

### Process technology in Manufacturing Companies

For a manufacturing company such as Intel, process technology may include basic production equipment and/or more advanced processes. At Intel, process technology is highly specialized to the semiconductor fabrication process, technologically advanced, very expensive, and used in an extremely complex process.

Process technology is core to converting inputs to outputs in manufacturing businesses, sometimes allowing the firm to differentiate its products or services from its competitors and often requiring a sizable capital investment.

### Process technology in Service Companies

For retailing and distribution companies, process technology comprises the equipment used to move and manage the massive flow or materials throughout the supply chain.

In short, process technology is the physical hardware – often accompanied by or inextricably intertwined with information technology or software – that facilitates the creation and delivery of goods or services.

## The experience curve

The principle behind the experience curve is that as total volume increases, unit cost decreases in a predictable way.

**Learning curve**: closely related concept. It shows relationship between number of labor hours per unit and total number of units produced. The theory of the learning curve is based on the notion that reductions in labor hours per unit arise from learning on the part of the workers themselves.

While learning can have a major impact in reducing costs over time, it is not the only way to do so:

* Labor efficiency improvement
* Standardization, specialization and methods improvement
* Process automation
* Product or service redesign
* Increased scale and volume
* Value chain improvement
* Shared experience effects

While the experience curve is largely focused on cost reduction, experience also may lead to improvements in yield and hence quality, product or service performance, environmental performance, and so forth. These improvements may in turn lead to cost improvements.

**Experience Curve Formulation:** p.77 & 78, not sure if relevant for exam.

**Using the experience curve**

Particularly applicable in two important situations:

1. **For a very new product or service that is undergoing frequent changes**

Experience curve effects are often seen in the introduction of very new products or services, as there is less known about the effects at the start of the development process, and experience proves a valuable teacher during initial rollout. Cost improvements for very new products or services may arise from two sources. First, product or service design changes can translate into production or delivery efficiencies. Example: using fewer parts and assemblies. Second, process design changes may improve the performance of the production or delivery system itself. Example: process engineers may be able to develop a better layout, an improved assignment and allocation of labor, more efficient technology and methods, and so forth.

Intel’s Copy Exactly! Program, for example, was established to eliminate start-up effects across fabs.

Although it can be difficult to predict experience curve effects accurately and quantitatively, it is important to understand them nonetheless. Understanding that they occur is the best first step to reducing any adverse effects of them.

1. **For production of large-scale projects or products that have high costs and relatively low volumes**

The experience curve effect also appears on large-scale projects where costs are high and production volumes low. A classic example of a large-scale project is aircraft engines and power plants.

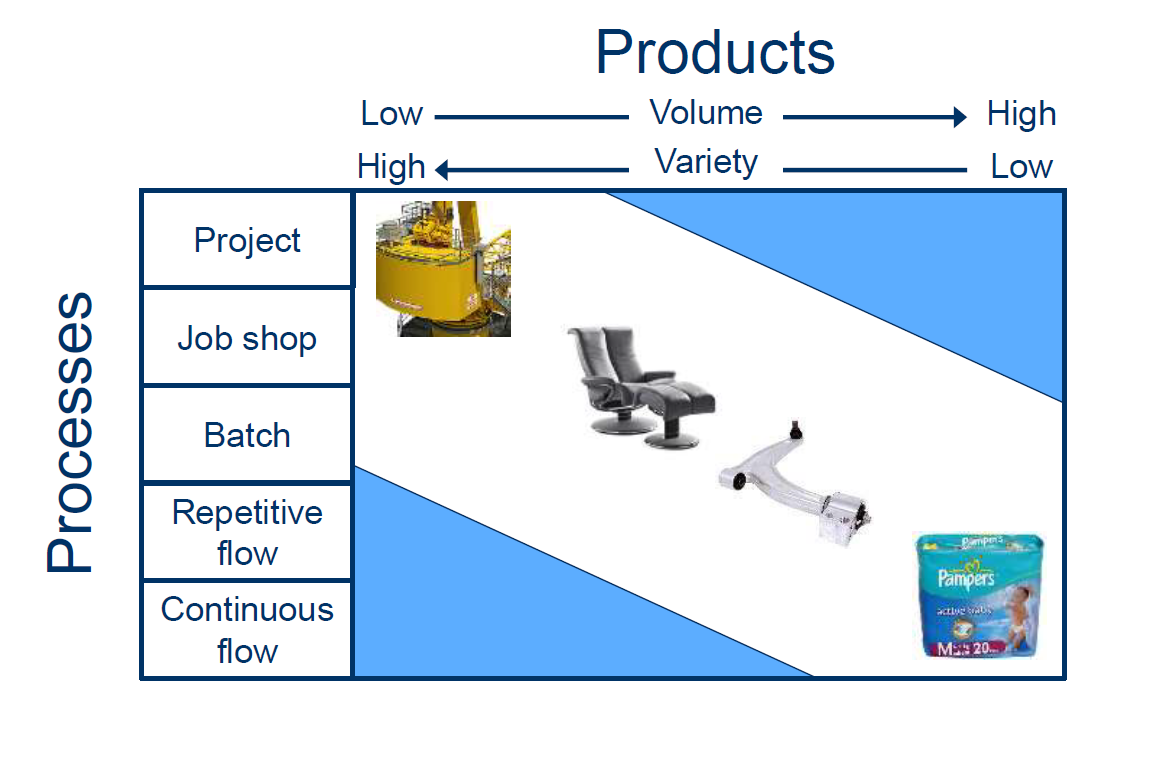
## Product-process and service process matrices

The product-process and service-process matrices are tools that facilitate the matching of processes to product or service needs. Product-process matrix focuses on the trade-off between flexibility and efficiency. As the service-process matrix is not presented in the lectures, this matrix will not be explained further here.

**Product-process matrix**

Concept underlying the product-process matrix is that the relative flexibility or rigidity of a process should match the needs of the products it is to build and that as flexibility increases, process efficiency decreases. The matrix is built around the six basic types of production processes. **See also exh.3.17 and 3.18.**

Moving diagonally down the matrix from the upper left corner toward the lower right corner, the processes become more rigid and specified and flexibility decreases. Competitive priorities are also different for each section of the matrix. In a job-shop organization, for example, customization and high-performance design are the principle competitive priorities, while in a continuous flow shop high efficiency and consistent quality are paramount. These competitive priorities drive the choice of production technology, skills sets, and methods employed in the facilities.



**Project**

Projects entail high-cost, complex sets of activities and produce very few items. Example: shipbuilding.

**Job shop**

A job shop produces a wide variety of items in single lots – therefore a large number of lots per year. Job shops are characterized by flexible equipment and highly skilled workers expert at translating customer specifications into production work. Job shops can build-to-order or build-to-stock; those that build-to-order carry primarily WIP inventory, while those that build-to-stock also carry some finished goods inventory (FGI). Job shops have high variable costs and moderate fixed costs.

**Batch**

Firms that employ batch production techniques manufacture products in higher volumes than do job shops, or can group their orders into larger quantities to form economical production batches.

**Repetitive and Continuous Flow**

Repetitive and continuous flow processes make standardized products in long production runs at very low cost. Example repetitive: discrete items such as bottles of shampoo and automobiles. Example continuous: non-discrete materials such as oil or cranberry juice.

These factories tend to be more capital intensive and thus have high fixed costs, which causes them to drive for high utilization in order to achieve economies of scale and low per-unit product costs.

**Mass customization**

Mass customization processes aim to achieve the same low cost per unit as repetitive or continuous flow processes, sometimes known as mass production processes, while producing a wide variety of products. Require specialized but flexible equipment.

Exhibit 3.16 summarizes the characteristics of these six processes:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Project** | **Job shop** | **Batch** | **Repetitive flow** | **Continuous flow** | **Mass customization** |
| **Equipment** | General purpose, flexible | General purpose, flexible | Some specialized equipment, sometimes organized in groups or cells | Special purpose | Special purpose | Specialized, but allows for rapid changeover |
| **Operators** | Specialized by function, often within subcontractors | Broadly skilled | Less broadly skilled; may need technical skills for changeovers | Troubleshooting and problem-solving skills | Troubleshooting and problem-solving skills | Flexible operators |
| **Information requirement** | Coordination and planning, specification management, costing | Product specifications, job tracking, planning and scheduling, job costing | Batch tracking, planning and scheduling, materials planning | Output rate planning, materials planning, quality management | Output rate planning, materials planning, quality management | Customer requirements, materials planning, process flow and scheduling |
| **Inventory requirements** | Mostly WIP (Work in process), some RMI (Raw Material Inventory) | Mostly WIP | Mostly WIP, sometimes some FGI (Finished Goods Inventory) if build-to-stock | Mostly RMI and FGI; fast process so little WIP | Low levels of RMI to feed process; may have FGI if make-to-stock | Low levels of RMI to feed process; little FGI as is made-to-order |
| **Costs** | Fixed low to moderate; variable high | Fixed low; variable high | Fixed moderate; variable moderate | Fixed high; variable low | Fixed high; variable low | Fixed high; variable low |
| **Job or part costing** | Time and materials by task | Time and materials per job | Time and materials per batch | Dependent on capacity utilization and allocation of overhead | Dependent on capacity utilization and allocation of overhead | Dependent on capacity utilization; dynamic and difficult to determine |

**Using the Product-process matrix**

The product-process matrix can be utilized in a number of ways. It can be used to structure operations in a single facility, creating what some call “a plant within a plant” to handle disparate product types in a single facility. It can be used to test the fit between product and process for an existing facility and cause the organization to change processes or products. Finally, it can be used to determine the appropriate level of flexibility and efficiency for a new plant or to develop a portfolio of plants with differing levels of these traits. In making these choices, however, it is important to understand that products rarely have the same requirements throughout their life cycles (see exh.3.19. Also, see lecture slides p.23)

Summary PP-matrix: represents a strategic way of thinking about

* Efficiency and flexibility trade-offs
* Range of process choices available
* How a company may align a set of plants
* How competitors in an industry align their offerings

## Process Technology Strategy Decisions

The firm must determine which process technology choices are appropriate to support the position it wishes to take in cost, quality, availability, features/innovativeness, and environmental performance, and what capabilities the firm can exploit or should develop to execute the business strategy.

### Choosing an Appropriate Technology

* **Labor intensive versus Automated Processes**

Within a given industry, one is likely to find more automated processes in Germany, Japan or the United States, where labor costs are quite high and less automated processes in Mexico, Brazil and Thailand, where labor costs are lower.

There are four sets of issues that firms should consider when making decisions about how much to automate: business, operational, social and political, and regulatory issues.

**Business issues:** link the automation decision to the overall business, focusing on return on investment, flexibility, timing and competitiveness of the automation.

**Operational issues:** associated with the technological and physical constraints placed upon the process by its inputs and outputs as well as by the humans and machines involved. The operational capabilities of the process to perform from a cost perspective (e.g. appropriate economies of scale), quality perspective (e.g. adequate precision and repeatability), availability perspective (e.g. fast enough), features/innovativeness perspective (e.g. can handle the variety of technologies, products and services to be put through it), and environmental perspective (e.g. acceptable volume of pollutants generated) must all be considered.

**Social and Political issues:** address both the way in which the automation decision is made by the organization and the way in which automation might affect the organization and its human resources.

**Regulatory issues:** virtually all companies are subject to some regulatory requirement. All automation decisions must take into account the regulatory standards that must be met.

Exh.3.22 – Considerations in making automation decisions - summarizes these issues. Degree to which issues to consider depends in part on business strategy and in part of the key drivers for the automation decision.

**Exh.3.22**

|  |  |
| --- | --- |
| **Business issues**  Fit with business strategy  Competitiveness vs. peers  Return on investment  Cost savings  Direct labor cost reduction  Flexibility and adaptability  Time to implement and ramp up  Safety | **Operational issues**  Effect on cost  Effect on quality/reliability  Repeatability of process  Precision of process  Effect on availability  Effect on features/innovativeness  Effect on environmental performance  Ability to meet internal goals (e.g. for data collection, tracking)  Security |
| **Social/Political issues**  Organizational culture  Comfort with technology  “Cool tech factor” for engineers  “Cool tech factor” for customers  Not-invented-here syndrome  “That’s the way we do things here” syndrome  Decision-making dynamics  Decision-maker bias  Workforce implications  Skill requirements  Simplification of operator tasks  Job security (reality and perceptions) | **Regulatory issues**  Regulatory compliance  Change control  Data collection, analysis, and reporting  Perception |

* **Flexible versus rigid processes**

In short: firms must determine how much flexibility is required of them and then decide how to go about obtaining that flexibility.

* **Scalability and Degree of Scale Achievable**

Should be taken into account when choosing technology. Also: see exh.3.23 – comparison of three technology scale curves.

* **Economic Evaluation of Technology Options**

NPV: formula would typically be given in the exam.

**Summary: Choosing an appropriate technology**

Choosing an appropriate process technology for an organization is largely a question of identifying the position the firm wants to occupy on the product-process or service-process matrix. Position on the matrix will suggest appropriate degrees of automation, flexibility, and scale. Within any given position on the matrix, however, firms still have choices. To make choices about degree of automation, they must consider business, operational, social, political and regulatory issues. To make choices about degree of flexibility, they must fully understand what customers want from them and make appropriate trade-offs with efficiency. To make choices about scale, they must assess their alternatives and identify the most cost-effective choice. Net present value calculations provide information about the potential cost or return to the company of investing in the technology.

### Innovator versus Follower

A related decision that a firm must make is whether is wishes to use proven, well-understood technologies or newer, more innovative ones.

Investments in advanced technology do not always result in improved performance, suggesting that the risks associated with investing in advanced technologies sometimes outweigh the benefits, especially when equivalent benefits can be achieved in other ways.

**Continuous improvement and Process Technology Choice**

Continuous improvement efforts can be limited by product or service design.

While continuous improvement efforts are often a way to achieve competitive advantage, as they allow a firm to get more out of a given investment in process technology than its competitors, innovation in products or services often requires more than just continuous improvement of process technologies. Mature industries often focus on continuous improvement as a means of reducing cost in products or services that are in decline. Industries that are earlier in the life cycle, however, may need to seek improvement through investment in new process technologies.

**Product innovation and process technology choice**

See exh. 3.24 –mapping change in process to change in product or service (product/service innovation vs. process innovation). Three categories in this matrix: *breakthrough projects or technologies, platform projects* or *derivative projects* (incremental changes).

Argument from this matrix: firms cannot generate new streams of products or services without generating periodic breakthrough projects, or at least investing in new product, service or process platforms.

Notion of using a single process platform across multiple generations of products or services is displayed graphically in exh. 3.25. The initial peak investment in process innovation occurs with the launch of the first generation product or service. Follow-on products or services benefit from the initial investment, requiring less and less process technology investment per launch.

### Develop In house or Outside?

Closely related to the decision about how innovative to be is the question of whether to develop process technology in house or not. The factors to be considered in making this decision are similar to those associated with making a vertical integration decision in general.

Question to ask: Development of the process technology: critical to achieve competitive advantage?

Developing the process in house could also build critical capabilities on which the firm could build a competitive advantage.

Any time equipment development is outsourced, all competitors in an industry can access the same technology; differentiation in this case reverts to the ways in which the competitors use the technology.

*Exh. 3.26: Process Technology Development and Acquisition Choices*

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| --- | --- | --- |
|  | **Lead using innovative process technologies** | **Follow using well-proven process technologies** |
| **Develop process technology in-house** | Expensive, but can lead to significant competitive advantage | Rare. Not much benefit in re-inventing something that is already readily available. |
| **Purchase Process Technology from Outside Vendors** | May be difficult to retain competitive advantage as vendors share technology with other customers. | Common. Often companies purchase standard technologies and then adapt them to their own internal use. |

### Managing technology in Multisite Networks: Degrees of Standardization and Centralization

When a firm has more than one production or service delivery location, it must address the question of whether it wants to standardize its processes across all locations and, if not, which sites will use which technologies.

Factors that would impose the decision of varying technologies or not:

* High volume or low volume?
* Developed country?
* Mature market or emerging market?

A firm with multiple sites may either let each site make its own process technology decisions, choosing an appropriate level of automation, degree of innovation, and extent of internal development itself, or it may choose to standardize processes across the company.

A firm may wish to centralize process technology development to gain control over development costs and ensure some degree of standardization (e.g. in equipment choice), but not worry about divergence in the process once deployed. Four paths a company might follow; summarized in exh. 3.27.

Copy Exactly! : an example of both centralization and standardization of process technology across multiple sites. The Copy Exactly! approach dictates that all fabs running a given process technology should be matched as closely as possible. Allows Intel to ramp up new facilities quickly, provides Intel’s customers products that are the same regardless of where they are produced (which reduces qualification times) and facilitates learning and resource sharing across sites.

*Exh. 3.27 – Centralization and standardization options*

|  |  |  |
| --- | --- | --- |
|  | **Standardized processes** | **Non-standardized processes** |
| **Centralized process development and management** | Reduces start-up costs, as each site can learn from those that have gone before it  Facilitates cross-plant learning, as a central organization gathers and communicates knowledge  Reduces initial capital outlays, as a single pilot facility can test and fine-tune the process before rollout | Captures some of the efficiencies of standardized processes, while allowing local sites to adapt the processes to local needs in a controlled fashion |
| **Decentralized process development and management** | Extremely difficult to do, unless a good deal of overhead is spent on coordination and sharing | Allows the local site to respond to site-specific conditions such as:  Market differences  Labor differences  Supplier differences  Eliminates the overhead associated with coordination across the corporation |

There are five key considerations to be made in deciding whether or not to standardize process technology in a multisite network:

* **Product and service standardization**

The degree to which a company can standardize its processes across multiple facilities depends in part on whether or not the products to be produced or services to be delivered by those facilities are also standardized (no shit!)

* **Stability of Technology**

Industry with stable technology 🡪 standardization strategy may be easier to implement and manage across multiple sites. A centralized structure may make more sense when change needs to be coordinated and happen rapidly across the whole organization.

* **Basis for Learning and Improvement**

When learning is technology-based, it makes more sense to standardize technology across sites so that changes and improvements in technology can be implemented at all sites. Learning in this case arguably occurs at the development site rather than at one of the remote locations and is applied to each new generation of process equipment developed (see exh. 3.28a)

When improvements are methods- and procedures-based, the sources of improvements will often come from the individuals on the front lines running the process, creating the traditionally defined learning curve effect (see exh.3.28b). In this case, it is important to give the sites autonomy to improve processes as they see fit and then to filter improvement ideas up to a central development organization or across to other sites.

Most organizations will have both types of learning and will have to sort out which is most important to advancing process performance quickly.

* **Different levels of volume and scale**

Facilities of very different sizes within one company may each need different technology and different scale.

When a company has facilities whose size and volume are essentially similar, standardization becomes more of an option.

* **Labor force impacts**

Labor costs and the availability of skilled labor may also have an effect on the decision to standardize processes globally.

Companies that can choose from a range of processes with different degrees of labor intensity, however, may find it beneficial to fine-tune the process to leverage labor rates in specific locations, using more labor-intensive processes in locations with inexpensive labor, and more capital-intensive processes in those with more expensive labor. In these situations one might see a range of process technologies and less standardization.

Access to skilled labor may also dictate choice of process technologies. Advanced process technologies often require sophisticated operators.

**Multisite Network Process Technology Management summary**

Firms managing multiple sites around the world must decide to what extent they will standardize the processes used at each of those sites and to what degree they will centrally manage the development and deployment of process technologies. To answer these questions they must consider the degree of standardization of their products or services, the stability of the process technologies they use, the basis for learning and process improvement, variability in volumes produced or delivered at their facilities, and availability and cost of labor in their local markets.

## Competing in an Environment of Dynamic Technological Change

*Disruptive technologies* (DT)– a technology/radical new type of product, service or process, that can completely change the dynamics of an industry. Example given: electric car. DT can create an entirely new scale curve such as that shown in exh.3.29 (p.112). In this case, there is little advantage to higher volumes on the new scale curve, which eliminates the possibility of competing on economies of scale and makes operations at different volumes equally efficient.

Companies most often seek disruptive product, service or process technologies in markets where customers’ needs cannot be fully met by the functionality or existing products or services.

When customers across an industry are dissatisfied with what they are getting or new entrants to the industry are experimenting with radically different solutions, it is time for the company to think about investing in the development of different and new technologies.

**Chapter summary and approach to developing process technology strategy**

Six-step plan for developing a process technology strategy

1. **Understand the business strategy and competitive environment**

The firm must understand where the business is to be positioned relative to cost, quality, availability, features/innovativeness, and environmental performance.

Management must understand the capabilities the firm wishes to develop or sustain as well.

Within operations strategy, process technology choices must be consistent with: vertical integration choices, as the firm decides whether or not to develop process technologies itself and whether or not to own them; facilities location choices, particularly where labor costs are an important factor and a simultaneous choice of process technology and facility location must be made; capacity choices, as different technologies offer different amounts of capacity with different scale economies; information technology strategies, supply chain strategies, and business processes strategies, as decisions are made how to organize and use the equipment; and human resource management choices, as technologies dictate required skill sets in the company. A key element of an operations strategist’s work is to clearly understand the interactions and dependencies among the choices made in the decision categories addressed in this book.

1. **Understand the Technology Trends in the Industry**

Seeks to evaluate the stability of the process technologies used in the industry; to identify important technological trends and assess their impact on the industry, market, and firm; and to surface any potentially disruptive technologies.

Technology can be the source of unique competitive advantage for a firm, particularly when it is not easily copied. Understanding where that advantage might lie - whether in the proprietary nature of the technology, in its ability to achieve greater economies of scale, or in its ability to disrupt the industry along some other dimension – is a critical step in developing a technology strategy.

1. **Understand the internal capabilities of the organization**

Understand the internal capabilities of the organization around process technology development and management is critical. Obtaining an understanding of how the firm presently manages the development, implementation, and improvement of its process technologies is an important input to the technology strategy decision-making process.

1. **Identify and assess process technology investment alternatives**

Assess for strategic fit and returns.

The company needs to decide whether it will develop the technology in house or procure it from an outside vendor and whether it will centralize and/or standardize the development and implementation of the technology or let individual sites make their own decisions.

1. **Develop an implementation plan**

Must take into account three critical issues:

* Role of the operator
* Structure of the planning systems that support the new technology
* Integration of the technology with the organization

1. **Implement, assess and measure results**

The firm must implement the process technology strategy as planned, measure outcomes, and check against the original plan. Some relevant questions: Is the plan consistent with other elements of the operations strategy? Is it supportive with the other functional strategies?

The firm should prepare a post mortem report on the process technology planning process and feedback to be used to improve the process in the future.

**Summary**

Technology is a critical strategic decision category, and technology strategy development requires an integrated and careful approach.

* Process technology can be a major driver of strategy in that the capabilities it provides can be the basis of competitive advantage
* Process technology is closely intertwined with many other decisions and thus the evolution of technology must be carefully managed in terms of these decisions, and
* Advanced technologies in particular provide both major opportunities and risks.

To develop a process technology strategy, a company needs to review the external technology environment, develop a good understanding of internal process capabilities, and answer the specific process technology questions: What is the appropriate technology? Should the firm be an innovator or a follower? Should the technology be developed in-house or not? How should internal technology development be managed?

Technology strategy development can and should be reciprocal. While strategy development influences and often dictates technological development, technological choices can also influence strategy.

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