Design Methodology in the Development of Mechatronic Products
- Part 1

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Agenda

- On the Industrial Development of Products
- Some Basic Concepts Regarding Design and Development
- The Generic Development process by Ulrich and Eppinger
- Adapting the Generic Product Development Process
- Choosing an Organizational Structure
On the Industrial Development of Products
- Prolog
Input – Output to the Industrial Development Process

Material Need → ? → Product on the Market
What is a Product – in the Given Context?

**Product** – is something *sold by an enterprise to a customer* – here an artifact!

**Product development** – is a *set of activities* beginning with the perception of a market opportunity and ending in the production, sale and delivery of the product.

**Products** – are here constrained to those *engineered, discrete and physical!*
Who Designs and Develop Products?

The main functions in a company involved in the development and design of products are:

- **Marketing** – mediates the interactions between the firm and its customers.

- **Design** – plays the lead role in defining the *working principle and the form of the product* to best meet customer needs. Includes both Engineering design as well as Industrial design.

- **Production** – is primarily responsible for designing and operating the production system in order to produce the product. Includes both Manufacturing and Assembly.
Who Design and Develops Products?

Core Team:
- TEAM LEADER
- Manufacturing Engineer
- Mechanical Designer
- Electronic Designer
- Purchasing Specialist
- Industrial Designer
- Marketing Professional

Extended team:
- Finance
- Sales
- Legal
- Purchasing Specialist
- Manufacturing Engineer
- TEAM LEADER
- Electronic Designer
- Mechanical Designer
- Industrial Designer
- Marketing Professional
- Sales
- Legal

Finance

Sales

Legal

Manufacturing Engineer

Purchasing Specialist

Electronic Designer

Mechanical Designer

Industrial Designer

Marketing Professional

TEAM LEADER

Extended team
The Development Process and the Product Technology

Is the origin of the technology applied in a product influencing the structuring and contents of the development process – especially with focus on engineering design?

Consider the following main product areas:

- Electronics
- Software
- Mechanical products
- Civil Engineering products
- Pharmaceuticals
- Food and Diary products

What about MECHATRONICS?
Characteristics of Successful Product Development

The following 5 dimensions – all ultimately related to profit - are commonly used to evaluate the performance of a product development project:

- **Product quality** - How good is the product resulting from the development effort?
- **Product costs** – What is the manufacturing cost of the product?
- **Development time** – How quickly did the team complete the product development effort?
- **Development costs** – How much did the firm have to spend to develop the product?
- **Development capability** - Are the team and the firm better able to develop future products as a result of their experience with the product development project?
## Duration and Cost of Product Development

<table>
<thead>
<tr>
<th></th>
<th>Stanley Tools Jobmaster Screwdriver</th>
<th>Rollerblade In-Line Skate</th>
<th>Hewlett-Packard DeskJet Printer</th>
<th>Volkswagen New Beetle Automobile</th>
<th>Boeing 777 Airplane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual production volume</td>
<td>100,000 units/year</td>
<td>100,000 units/year</td>
<td>4 million units/year</td>
<td>100,000 units/year</td>
<td>50 units/year</td>
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<tr>
<td>Sales lifetime</td>
<td>40 years</td>
<td>3 years</td>
<td>2 years</td>
<td>6 years</td>
<td>30 years</td>
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<tr>
<td>Sales price</td>
<td>$3</td>
<td>$200</td>
<td>$300</td>
<td>$17,000</td>
<td>$130 million</td>
</tr>
<tr>
<td>Number of unique parts (part numbers)</td>
<td>3 parts</td>
<td>35 parts</td>
<td>200 parts</td>
<td>10,000 parts</td>
<td>130,000 parts</td>
</tr>
<tr>
<td>Development time</td>
<td>1 year</td>
<td>2 years</td>
<td>1.5 years</td>
<td>3.5 years</td>
<td>4.5 years</td>
</tr>
<tr>
<td>Internal development team (peak size)</td>
<td>3 people</td>
<td>5 people</td>
<td>100 people</td>
<td>800 people</td>
<td>6,800 people</td>
</tr>
<tr>
<td>External development team (peak size)</td>
<td>3 people</td>
<td>10 people</td>
<td>75 people</td>
<td>800 people</td>
<td>10,000 people</td>
</tr>
<tr>
<td>Development cost</td>
<td>$150,000</td>
<td>$750,000</td>
<td>$50 million</td>
<td>$400 million</td>
<td>$3 billion</td>
</tr>
<tr>
<td>Production investment</td>
<td>$150,000</td>
<td>$1 million</td>
<td>$25 million</td>
<td>$500 million</td>
<td>$3 billion</td>
</tr>
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</table>
The Challenges of Product Development

- **Trade-offs**
  An airplane can be made lighter, but this action will probably increase manufacturing cost.

- **Dynamics**
  Technologies improve, customer preferences evolve, competitors introduce new products, and macroeconomic environment shifts.

- **Details**
  The choice between using screws or snap-fits on the enclosure of a computer printer can have economic implications of millions of dollars.

- **Time pressure**
  Any one of these difficulties would be easy manageable by itself given plenty of time, but product development decisions must usually be made quickly and without complete information.

- **Economics**
  Developing, producing, and marketing a new product requires a large investment. To earn a reasonable return on this investment, the resulting product must be both appealing to customers and relatively inexpensive to produce.
The Challenges of Product Development cont.

- **Creation**
  The product development process begins with an idea and ends with the production of a physical artifact. When viewed both in its entirety and at the level of individual activities, the product development process is intensely creative.

- **Satisfaction of societal and individual needs**
  All procedures are aimed at satisfying needs of some kind. Individuals interested in developing new products can almost always find institutional settings in which they can develop products satisfying what they consider to be important needs.

- **Team diversity**
  Successful development requires many different skills and talents. As a result, development teams involve people with a wide range of different training, experience, perspectives and personalities.

- **Team spirit**
  Product development teams are often highly motivated, cooperative groups. The team members may be collocated so they can focus their collective energy on creating the product. This situation can result in lasting camaraderie among team members.
The Benefits of a Well-Defined Development Process

- **Quality assurance** - A development process specifies the phases a development project will pass through and the checkpoints along the way. Assuming that these phases and checkpoints are chosen wisely, following the development process is one way of assuring the quality of the resulting product.

- **Coordination** - A clearly articulated development process acts as a master plan which defines the roles of each of the players on the development team. This plan informs the members of the team when their contribution will be needed and with whom they will need to exchange information and materials.

- **Planning** - A development process contains natural milestones corresponding to the completion of each phase. The timing of these milestones anchors the schedule of the development project.

- **Management** - A development process is a benchmark for assessing the performance of an ongoing development effort. By comprising the actual events to the established process, a manager can identify possible problem areas.

- **Improvement** - The careful documentation of an organization’s development process often helps to identify opportunities for improvement.
The Generic Development Process – According to Ulrich and Eppinger

- Corporate strategy
- Assessment of technology
- Market objectives

- Needs of target market
- Alternative product concepts chosen

- Architecture of the product
- Subsystems lay-out
- Preliminary process flow diagram for assembly process

- Complete specification of the product parts
- Process plan and tooling

- Prototype
- Production needs

- Production system
The Product Planning Process

Phase 0: Planning
- Identify opportunities
- Evaluate and prioritize projects
  - Portfolio of projects
- Allocate resources & plan timing
  - Product plan
- Complete pre-project planning

Phase 1: Concept Development
Phase 2: System-level Design
Phase 3: Detail Design
Phase 4: Testing and Refinement
Phase 5: Production Ramp-up
**Concept Development – the Front End Process**

**Phase 0: Planning**
- Identify Customer needs
- Establish target specifications

**Phase 1: Concept Development**
- Generate product concepts
- Select product concept(s)
- Test product concept(s)
- Set final specifications
- Plan downstream development

**Phase 2: System-level Design**

**Phase 3: Detail Design**

**Phase 4: Testing and Refinement**
- Perform economic analysis
- Benchmark competitive products
- Build and test models and prototypes

**Phase 5: Production Ramp-up**
## Adapting the Generic Product Development Process

<table>
<thead>
<tr>
<th>Process Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generic = Market-Pull Products</strong></td>
<td>Sporting goods, furniture, tools</td>
</tr>
<tr>
<td><strong>Technology-Push Products</strong></td>
<td>Gore-Tex rainwear</td>
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<tr>
<td><strong>Platform Products</strong></td>
<td>Automobiles, Computers</td>
</tr>
<tr>
<td><strong>Process-Intensive Products</strong></td>
<td>Chemicals, semiconductors</td>
</tr>
<tr>
<td><strong>Customized Products</strong></td>
<td>Motors, switches, batteries</td>
</tr>
<tr>
<td><strong>High-Risk Products</strong></td>
<td>Space systems</td>
</tr>
<tr>
<td><strong>Quick-Build Products</strong></td>
<td>Cellular phones</td>
</tr>
<tr>
<td><strong>Complex Systems</strong></td>
<td>Airplanes, jet engines, automobiles</td>
</tr>
</tbody>
</table>
Adapting the Generic Product Development Process

What kind of development process is expected to be used when developing air-conditioners for private use – in homes – given that:

The company has never before developed air-conditioners?

The company has, since long, been developing air-conditioners for offices?
Adaptation of the Product Development Process Flows

(a) Generic Product Development Process

(b) Spiral Product Development Process

(c) Complex Systems Development Process
Choosing an Organizational Structure

- Functional Organization
- Project Organization
- Lightweight Project Matrix Organization
- Heavyweight Project Matrix Organization

(Adapted from Hayes, et al., 1988.)
Choosing an Organizational Structure

Is it possible to work within a functional organization and, simultaneously, within a project organization?

If yes, given an example!

If no, why not?