Business Administration

Lecture No. 6: History of Product and Production System: With Focus on Automobile (2)

1. History of American System of Manufacturers
2. Ford System
3. Taylor System
4. Evaluation on Contemporary American Manufacturing Industry
5. Lean Production System

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1.History of American System of Manufacturers

“American System of Manufacturers” in 19th century

(1)interchangeable parts

(2)special-purpose machines

British in mid 19th century paid an attention.

But concept and reality should be viewed separately.

Said, but not done. (ハウンシェル説)

History of American System of Manufacturers

(Abernathy, Clark and Kantrow, Industrial Renaissance, 1983)

First Period: Around 1800, originated by the weaponry industry

Production of Musket guns by Eli Whitney
Said to be the pioneer of the interchangeable parts, but was it really a good system?
(Was a production of Springfield guns more important?)

Second Period: First half of 19th century
Through the machine tool industry as an intermediary, the system was transmitted from the weaponry industry to typewriters, etc.
A key player was Singer's sewing machines.
In addition to an interchangeability, parts were common-use among plural number of models.
But the real level of interchangeability was not very high. (role of fitter) Or, a true key to Singer's success was a good marketing?

Sewing Machine Factory in mid 19th century

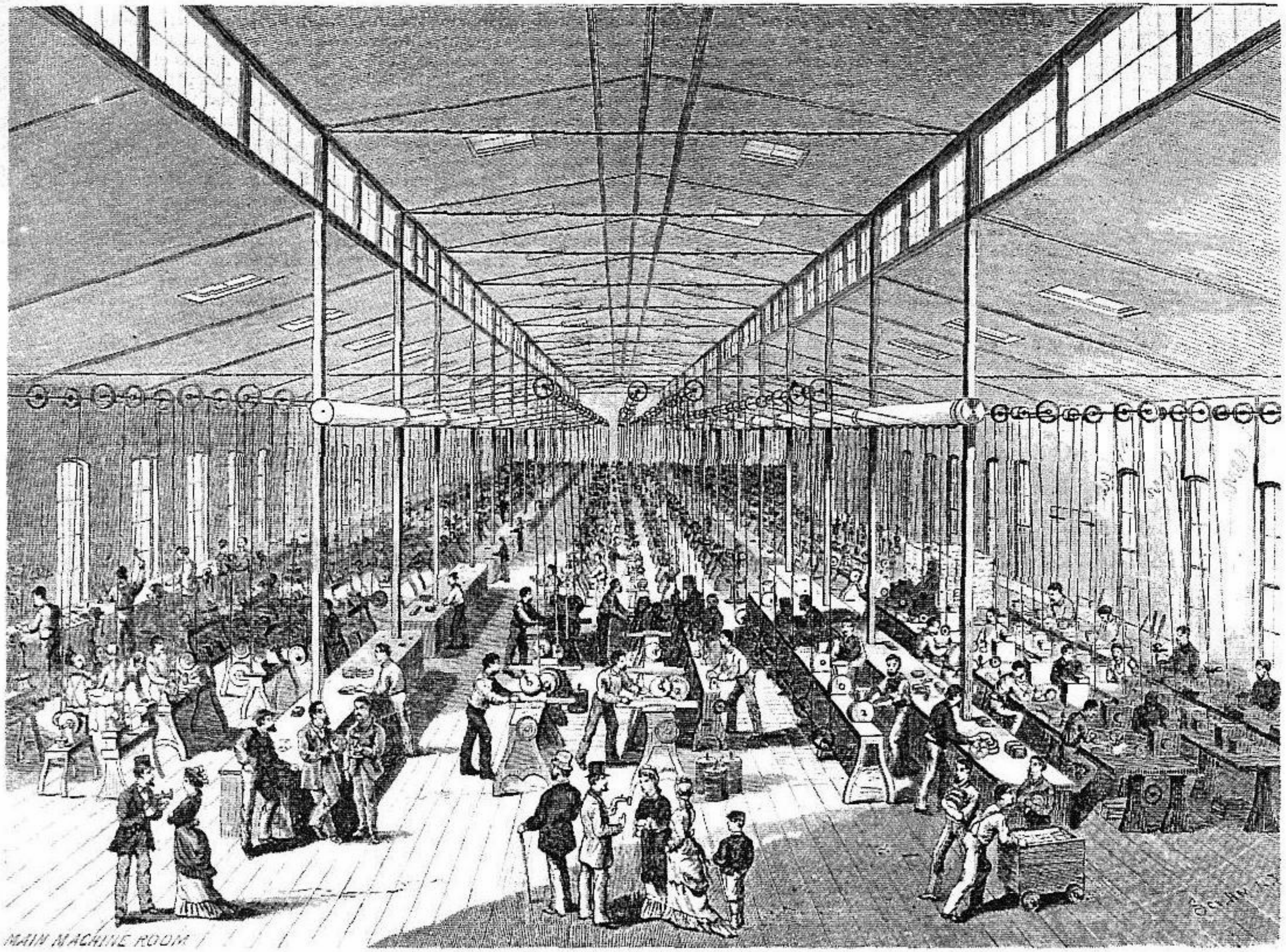


FIGURE 2.1. Machine Shop, Wheeler and Wilson Manufacturing Company, 1879. (*Scientific American*, May 3, 1879. Eleutherian Mills Historical Library.)

Machine tool was belt-driven and the power was concentrated at one spot.

Sewing Machine Factory in mid 19th century

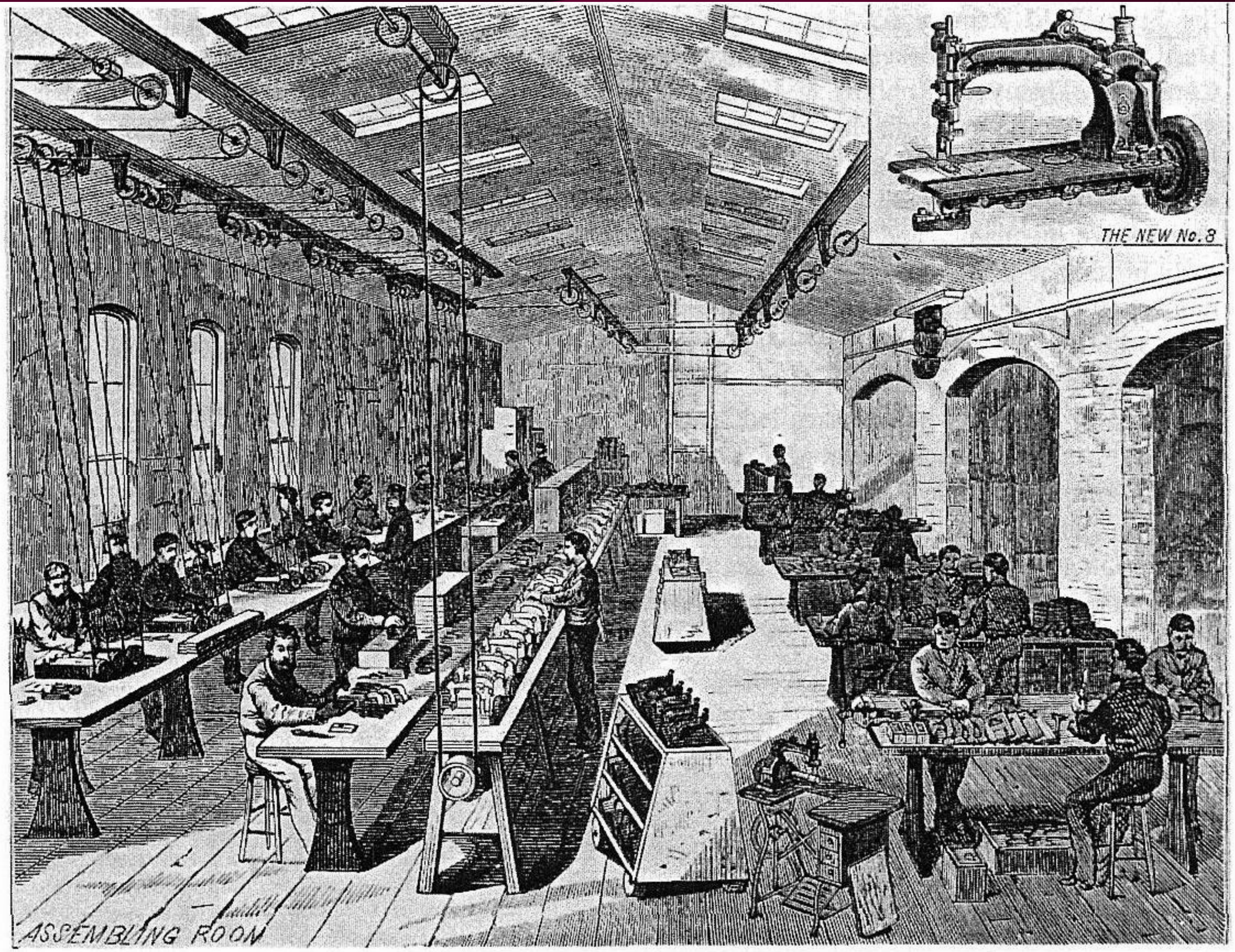


FIGURE 2.2. Assembly Room, Wheeler and Wilson Manufacturing Company, 1879. As depicted in this illustration, workmen individually assembled the Wheeler and Wilson sewing machine at worktables. Contrary to the earlier claims of the company, files and vises are evident. The bearings of finished sewing machines lined up down the center are being broken in by running the machines. (*Scientific American*, May 3, 1879. Eleutherian Mills Historical Library.)

Sewing Machine Factory in the mid 19 century

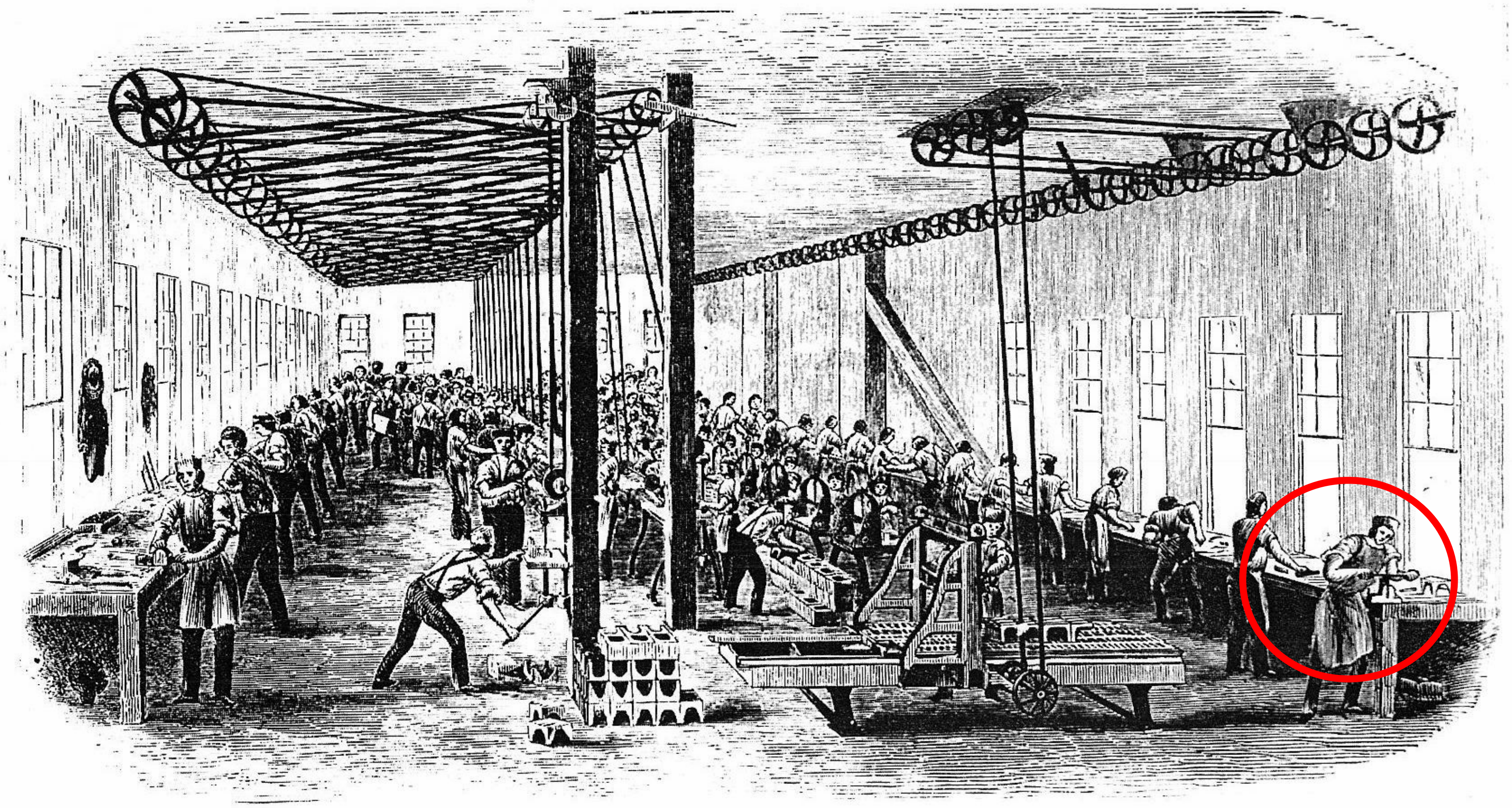


FIGURE 2.10. I. M. Singer & Co.'s New York Factory, 1854. Note the scarcity of machine tools compared to the large number of hand filers and fitters. (*United States Magazine*, September 15, 1854. Smithsonian Institution Photograph.)

Look at the fitter who is filing! Parts were not interchangeable yet.

Third Period: Mid 19th century

Key play was the Colt's guns (also McCormick's agricultural machines)
Introduced a concept of model change.
Common uses of parts among old and new models beyond generations. (diversion)
But, in reality, parts' interchangeability and special-purpose machines were still Imperfect

Fourth Period: 19th century end; era of bicycles, horse carts, and infant autos

Compatible and multipurpose parts become available beyond boundary of companies. (primitive open architecture)

Relatively large parts maker, and many minor assembly makers (patchwork assembly system)
Transmit technologies on production and products from bicycles and horse carts.
Press and resistance welding came from bicycle.
Seats, steering, and breaks from horse carts; wire wheels from bicycles

Transition of American System of Design/Production in 19-20 Centuries

(perspective of compatible design and manufacturing compatibility)

	Parts only for model	Common parts between models (for making to many varieties)	Common parts between generations (for restyling)	Common parts between enterprises (industry-wide standard parts)
Part interchangeability none (Though the concept was advertised.)	E..Whitney (beginning of the 19th century)	Singer sewing machine (In the latter half of the 19th century.)	Colt gun MacCormick (middle of the 19th century)	Bicycle (1890's)
There is part interchangeability. (enough processing accuracy achievement)	Spring Field gun (beginning of the 19th century)			
Mass production, lowering the cost, and synchronization	Ford method (1910's)	Sloane method of GM (full line and annual restyling)(1920's)		Modern bicycle (Open Architecture product)

Author making (reference: Abanashe Clark Cantoror, Haunshel)

2.Ford System

The star in the American system of manufacturing came on board. (Abernathy's 5th period)

It's characteristics:

(1)Enhanced processing precision of special-purpose machines → Achieved real "interchangeable parts"

(2)In-house press process

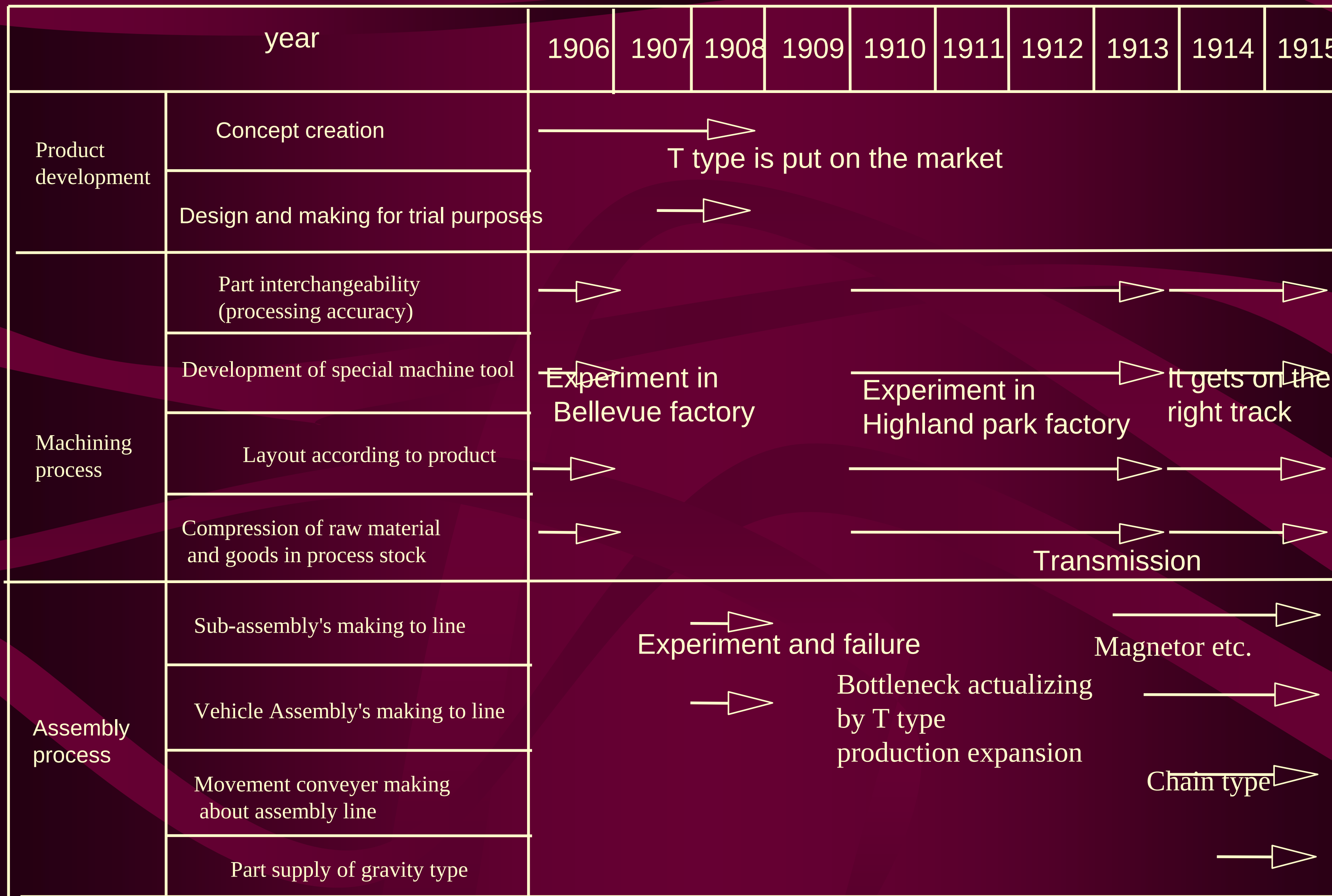
(3)Moving assembly line

(4)True mass production based the above factors.

Completed in/around 1913. While the key player was Henry Ford, the result was practically attributable to innumerable experiments, trials and errors, process improvements conducted by production engineers and floor workers of the Ford company.

Notice that the Ford System was not just the moving assembly line.

Formation of Ford Production System



Author making (reference: Haunshel)

Moving Assembly Line --- Reversed Idea (Move auto bodies, not parts and people)
Chart describing one-unit flow at Ford's

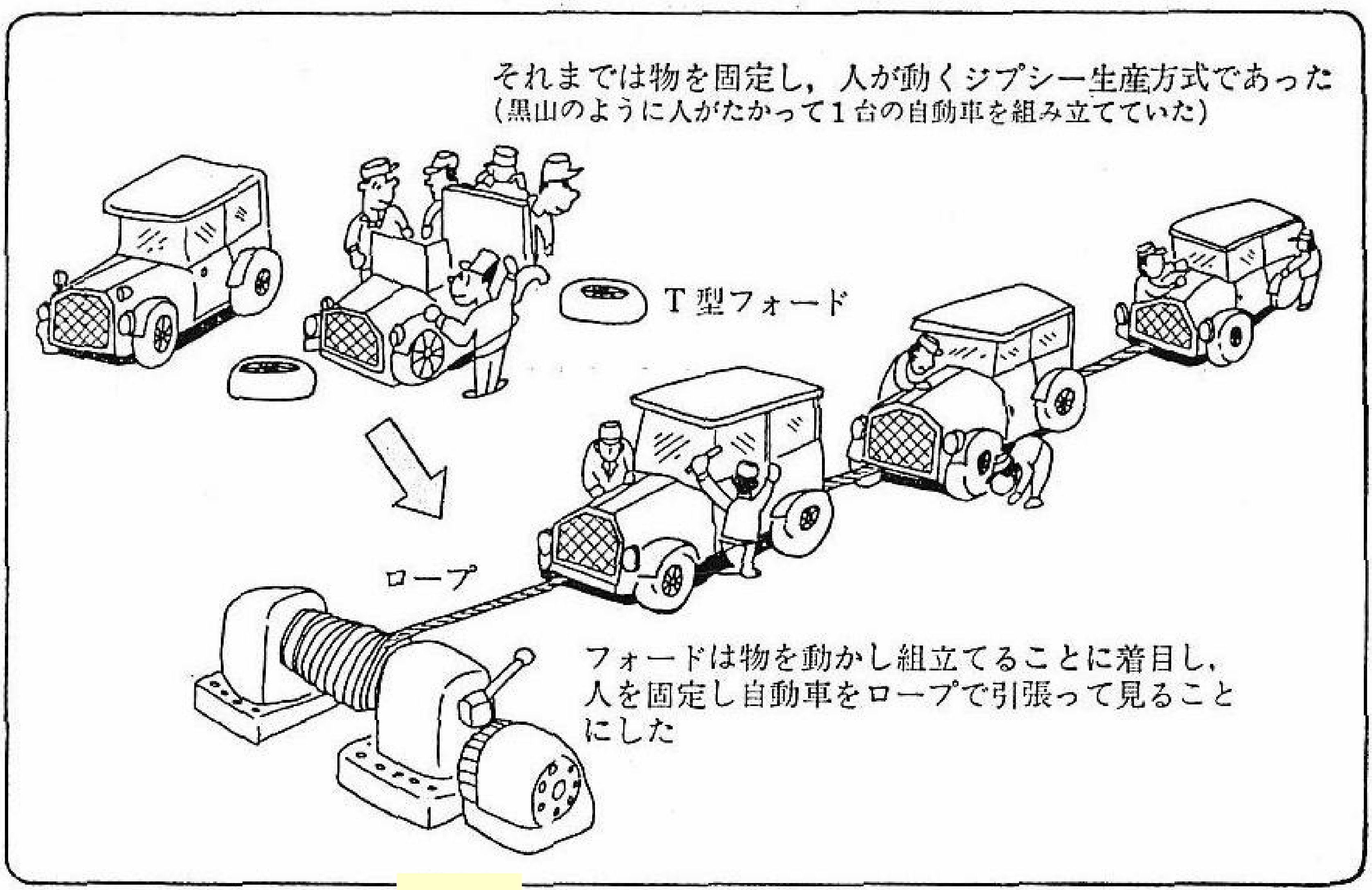


図 12·1　フォードの１個流し誕生の図

Hint for the moving assembly line originated from a "slaughter line" of a meat packer in Chicago.

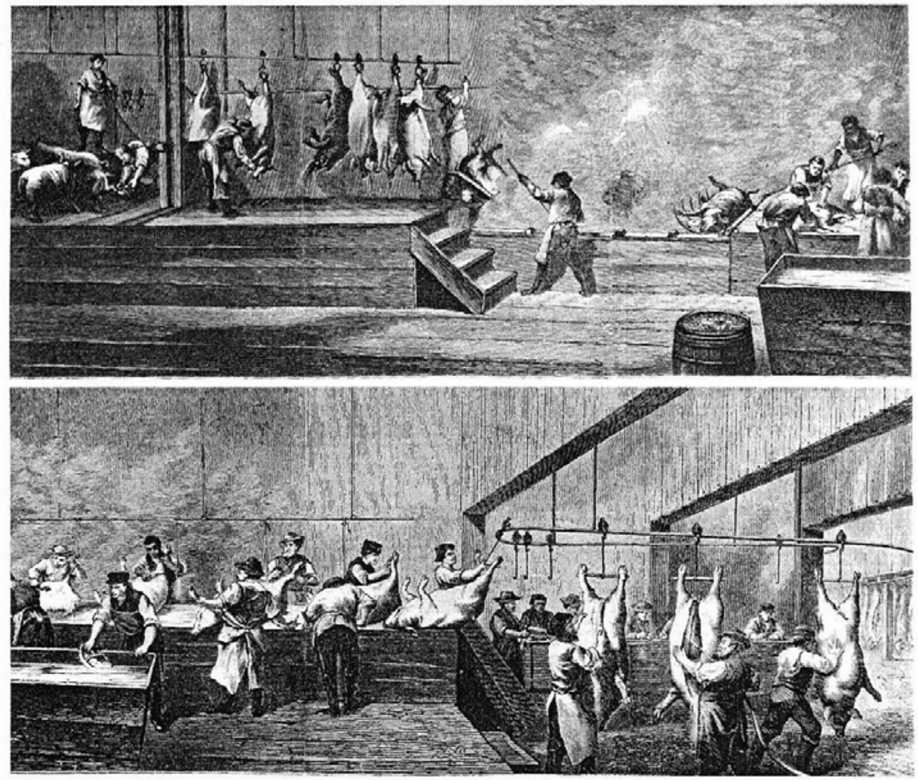


FIGURE 6.18. "Disassembly" Line, Slaughterhouse, 1873. An early example of "flow" production, slaughterhouses such as this one began first in Cincinnati and later became famous in Chicago, the "hog-butcherer of the world," in the era of Henry Ford. (*Harper's Weekly*, September 6, 1873. Eleutherian Mills Historical Library.)

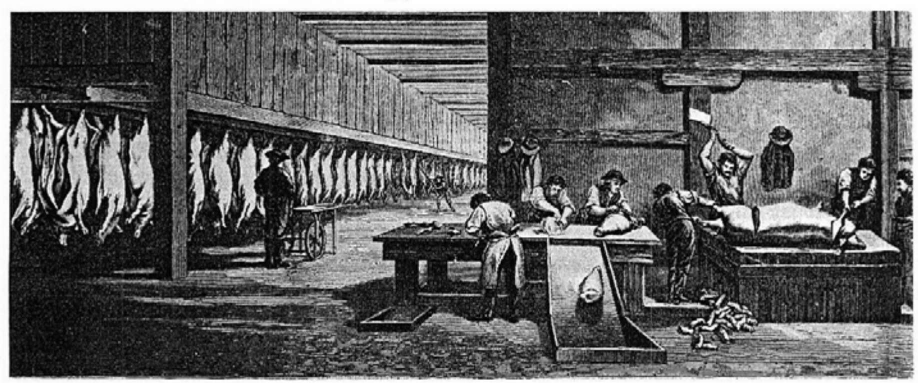


FIGURE 6.19. "Disassembly" Line, Slaughterhouse, 1873. Note the ham traveling down the gravity slide. (*Harper's Weekly*, September 6, 1873. Eleutherian Mills Historical Library.)

Ford system was born from experiments, trails and errors by engineers at work sites

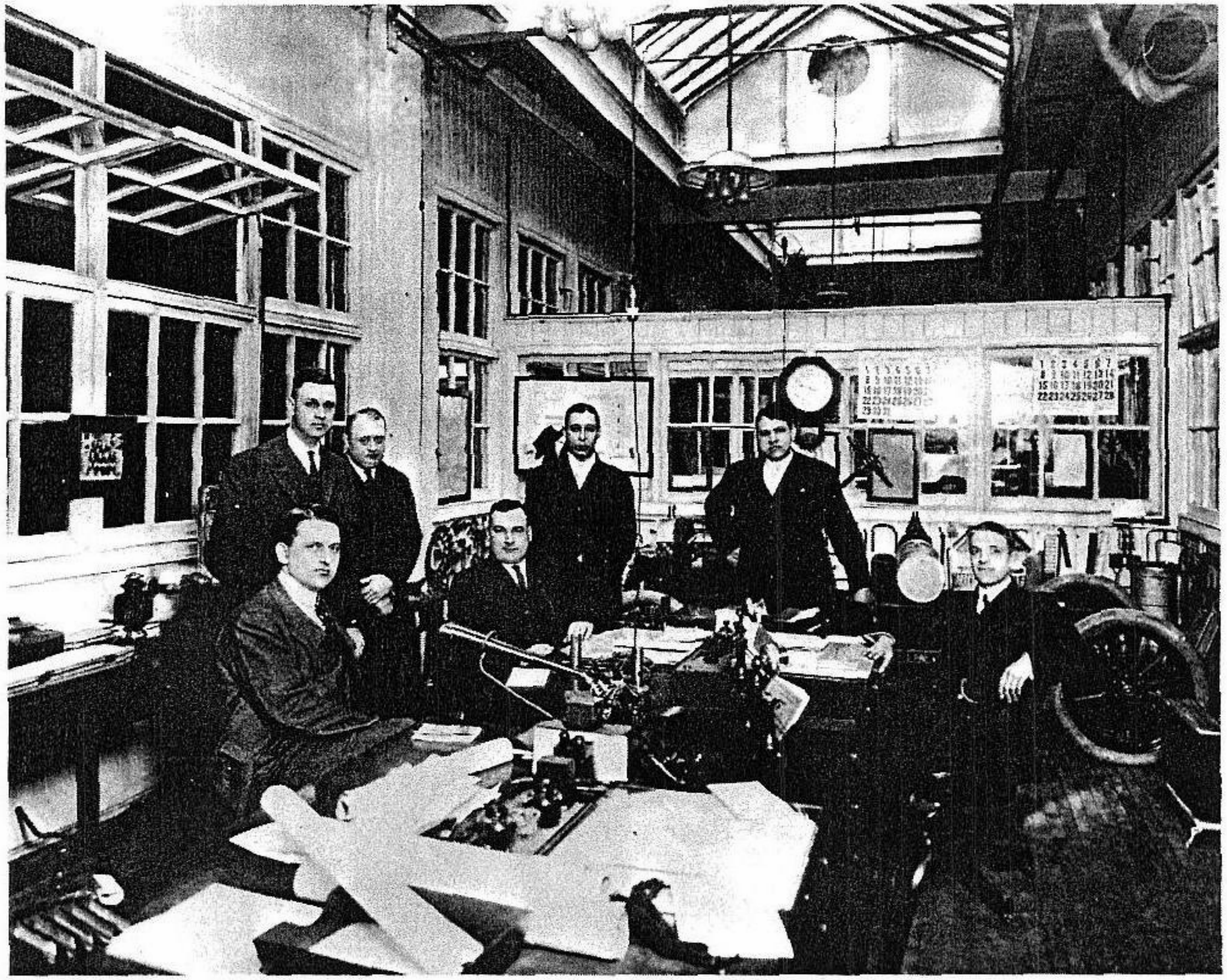


FIGURE 6.22. Some of the Principal Creators of Mass Production at Ford Motor Company, 1913. This is the superintendent's office at the Highland Park factory. Seated (left to right): Charles Sorensen, P. E. Martin, and C. Harold Wills. Standing directly behind Sorensen is Clarence W. Avery. Note the Model T chassis in the rear of the office. (Henry Ford Museum, The Edison Institute. Neg. No. 833-697.)

Ford's Experiment: Road to Highland Park Factory

Picket Avenue Factory (1904) = Run by multi-purpose machines and skilled workers. Incomplete interchangeability. Assembly at fixed spots. Team of assembly mechanics moved around.

Experimented at a new engine factory in Bellevue were interchangeability, special-purpose machines, by-product layout, inventory reduction, distribution improvements, etc.

In 1908, an assembly-line feasibility was tested with "Model N", which resulted poorly.

Model T first introduced in1908 was assembled by the fixed-spot method. Still, operations were subdivided due to highly interchangeable parts.

Experiments continued at Highland Park new factory for 1910-1913:
Precession in machine processing :
Standardization of jigs/tools and quicker set up, concentrated arrangement by product, special-purpose machine tools, self-manufacturing, higher precision/multi-axial
Moving assembly line almost complete (1913-1914):
Magnet generator, transmission, and car assembly. Initial movement by hand push, later, driven by chain, and parts supply by gravity.

Early Ford Model T was assembled in the fixed-position system. (Team of assembly mechanics moved around.)

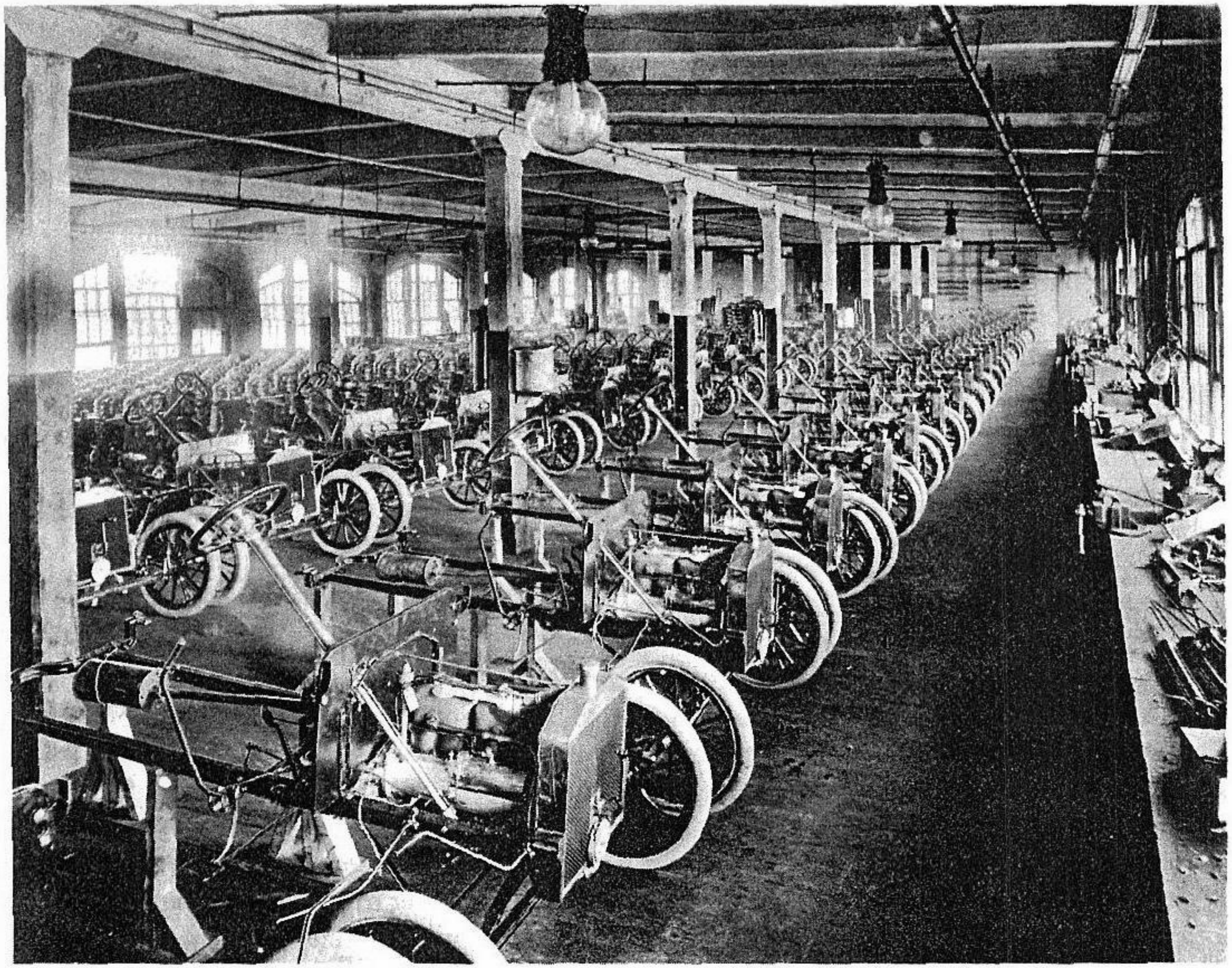


FIGURE 6.2. Static Assembly, Model N, Ford Motor Company Piquette Avenue Factory, 1906. The cramped condition of the Piquette Avenue factory would soon lead Henry Ford to expand the plant in 1907 and build the Highland Park plant, which opened in 1910. (Henry Ford Museum, The Edison Institute. Neg. No. 833-37306.)

Early Ford Model T was assembled in the fixed-position system. (Team of assembly mechanics moved around

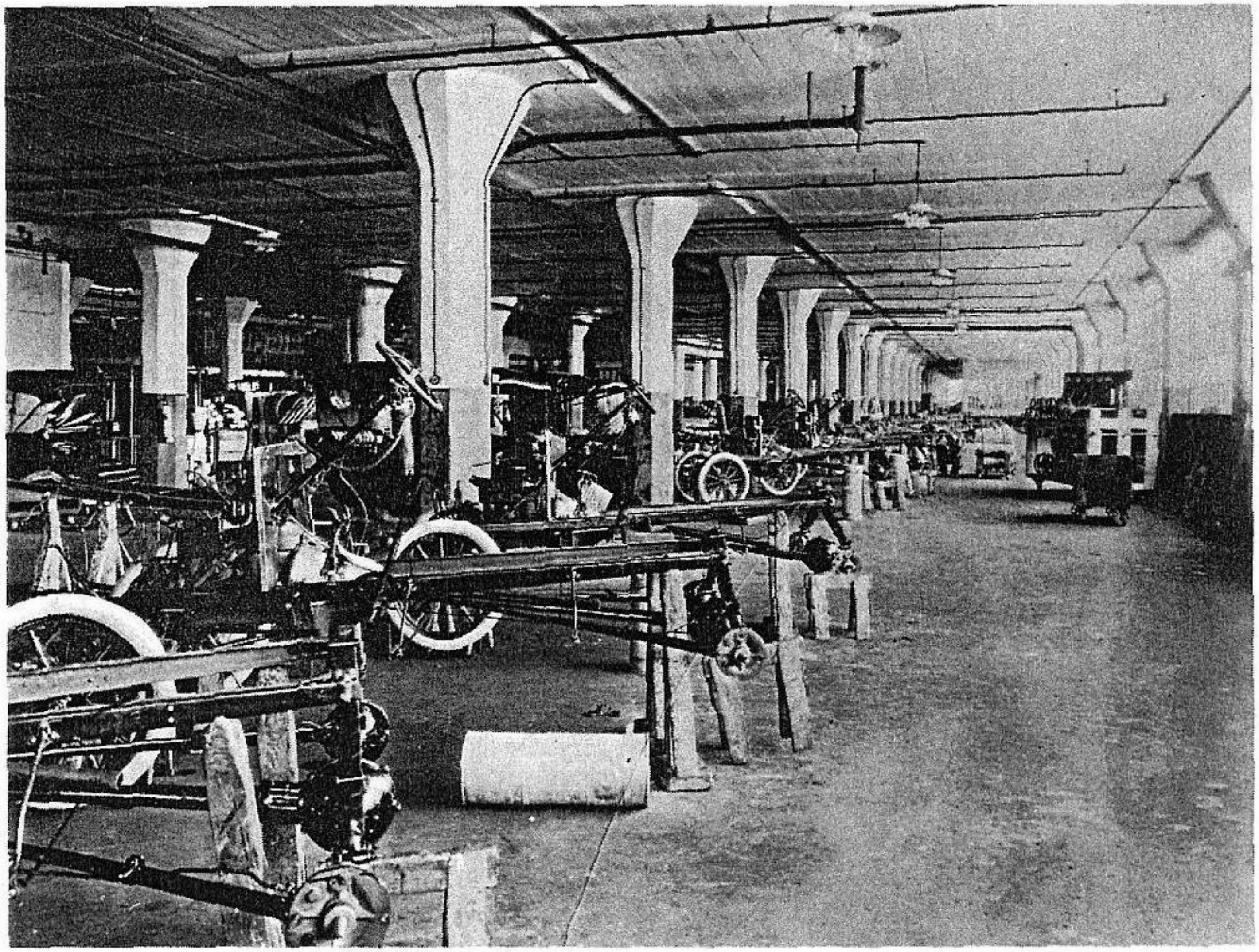


FIGURE 6.14. Static Assembly of Model T Chassis, 1913. Unfortunately, the moving assembly gangs were not included in the photograph. (Henry Ford Museum, The Edison Institute. Neg. No. 0-1267.)

Ford Highland Park Factory: Mecca of Ford system

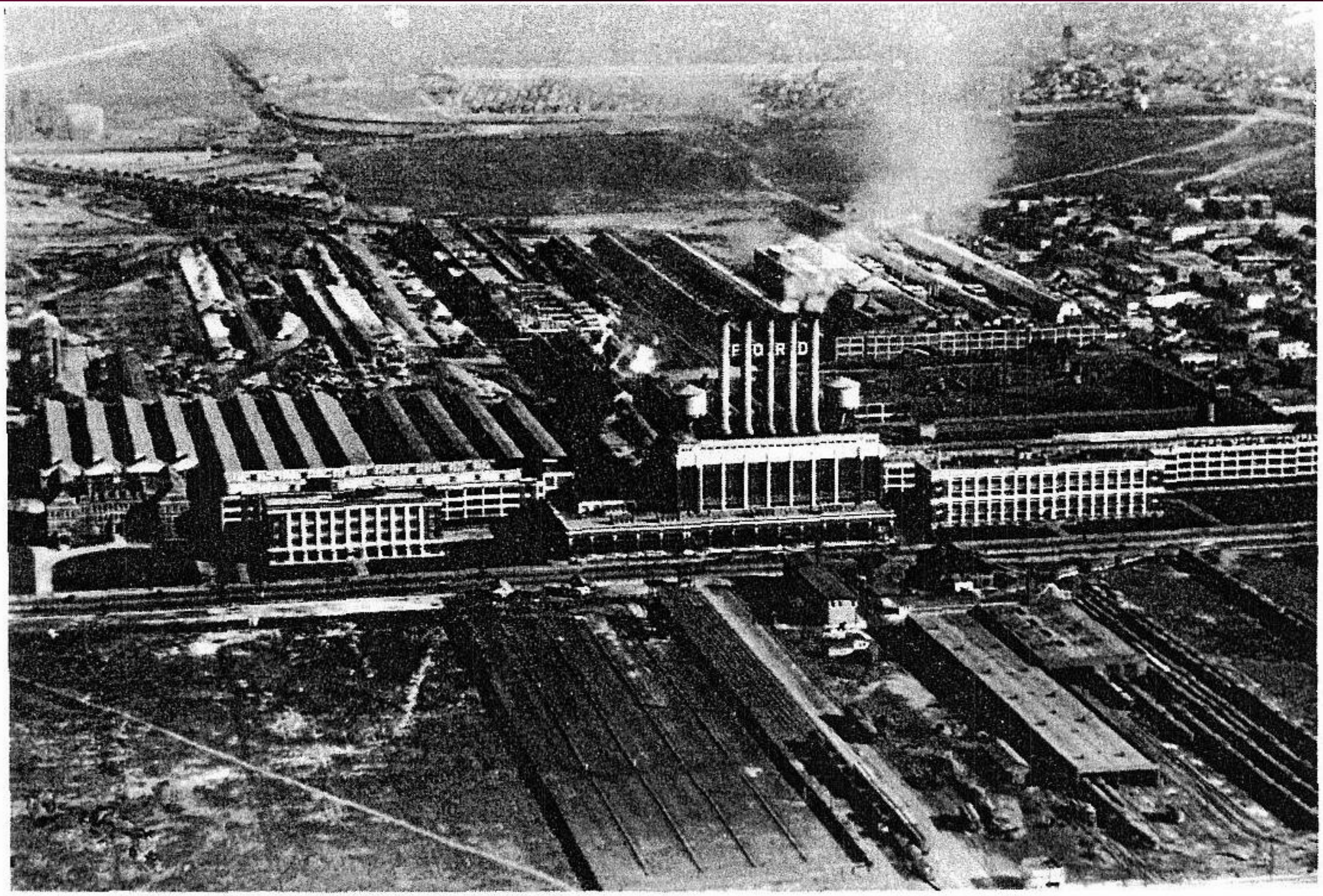


FIGURE 6.5. Highland Park Factory, 1923. This aerial photograph was taken at the peak of Highland Park's production. The 8,000-horsepower power plant is in the center of the photograph and the sawtoothed roof of the machining area is visible at the left. This area was connected by a glass-enclosed craneway to a four-story building 865 feet long and 75 feet wide. (Henry Ford Museum, The Edison Institute. Neg. No. 833-34974.)

Engine Assembly Workplace in Highland Park (1913) --- still, one-man assembly at the fixed-position

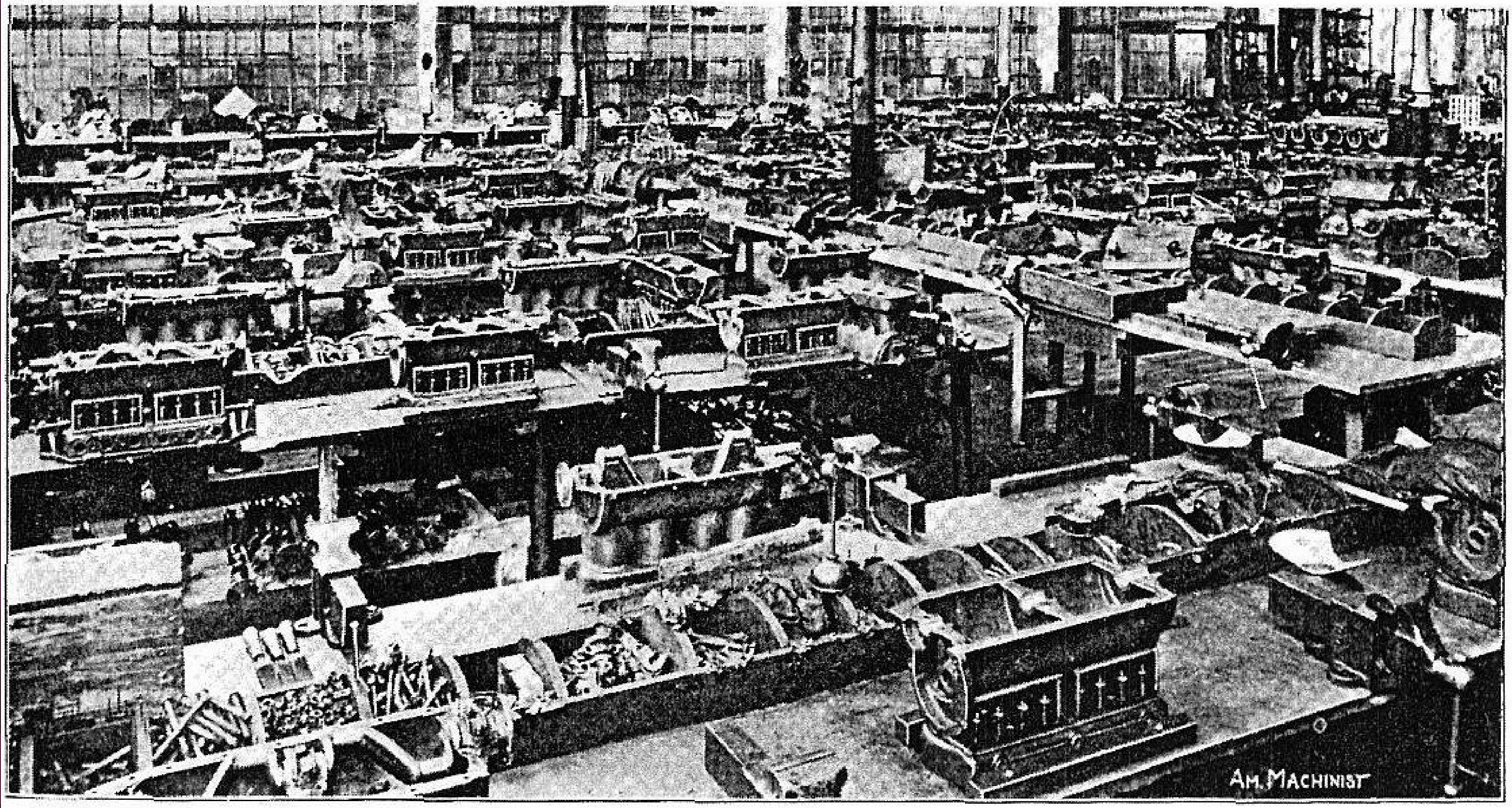


FIGURE 6.11. Engine Assembly, Highland Park, 1913. Individual workmen assembled entire engines by themselves. Unlike most of the photographs used by Fred Colvin in 1913, the original print of engine assembly no longer survives in the Ford Archives. (*American Machinist*, June 12, 1913. Eleutherian Mills Historical Library.)

Highland Park's Magneto (generator) Assembly Line: birthplace of moving assembly line?

FIGURE 6.23. "The First Magneto Assembly Line," 1913. This is a photograph of what Allan Nevins, among many other historians, called the first magneto assembly line. In his text, Nevins said that the magneto coil assembly was the first subassembly to be put on a line basis, but this illustration shows assembly of the flywheel magneto, the other half of the entire Model T magneto. (Henry Ford Museum, The Edison Institute. Neg. No. 833-167.)

Assembly Line for Ford Model T in Highland Park Factory (1914)

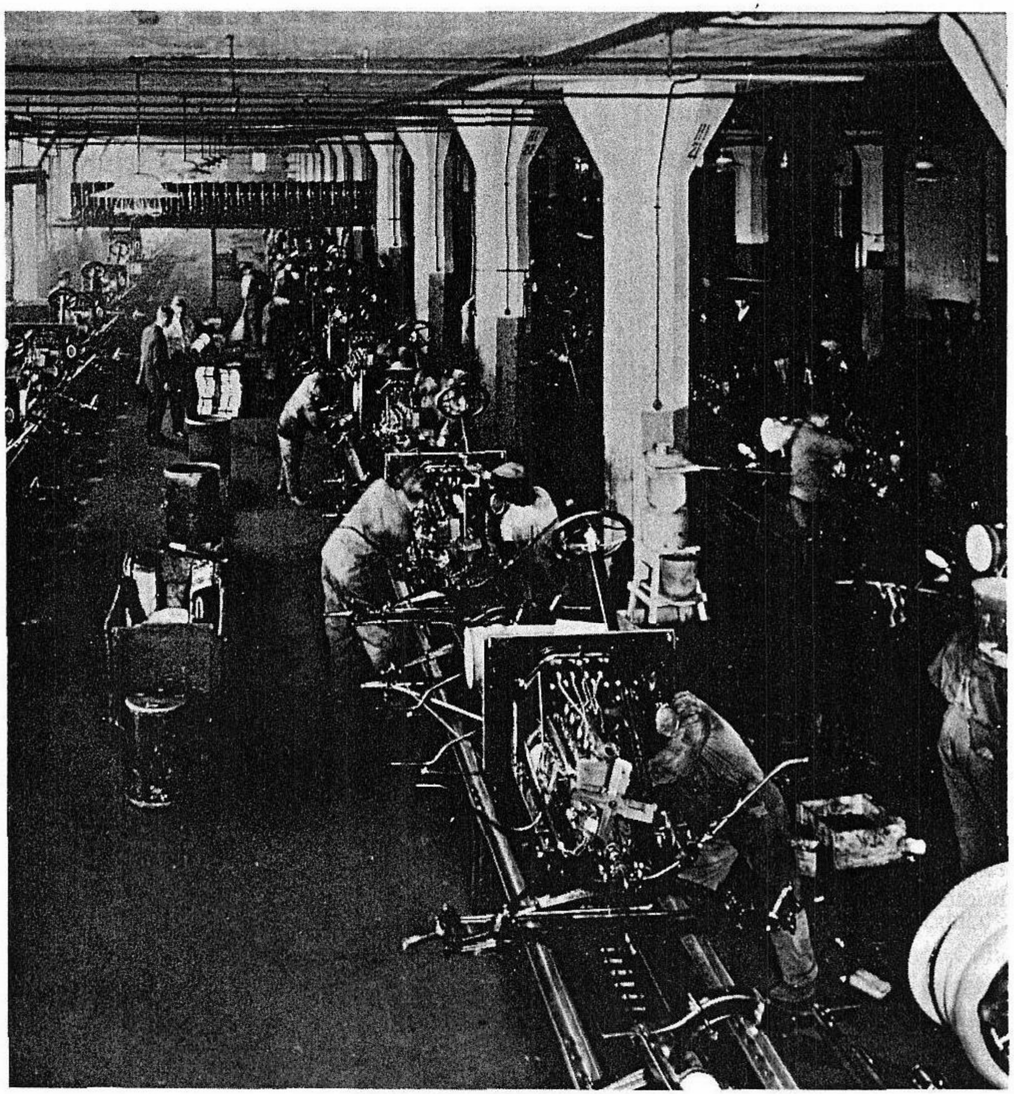


FIGURE 6.32. General View of "The Line," Highland Park, 1914. When Horace Arnold toured the Highland Park factory in 1914 and wrote of the assembly line that assembled a car in ninety-three man-minutes, this is the line of which he was speaking. (Henry Ford Museum, The Edison Institute. Neg. No. 833-987.)

Assembly Line for Ford Model T in Highland Park Factory (1914)

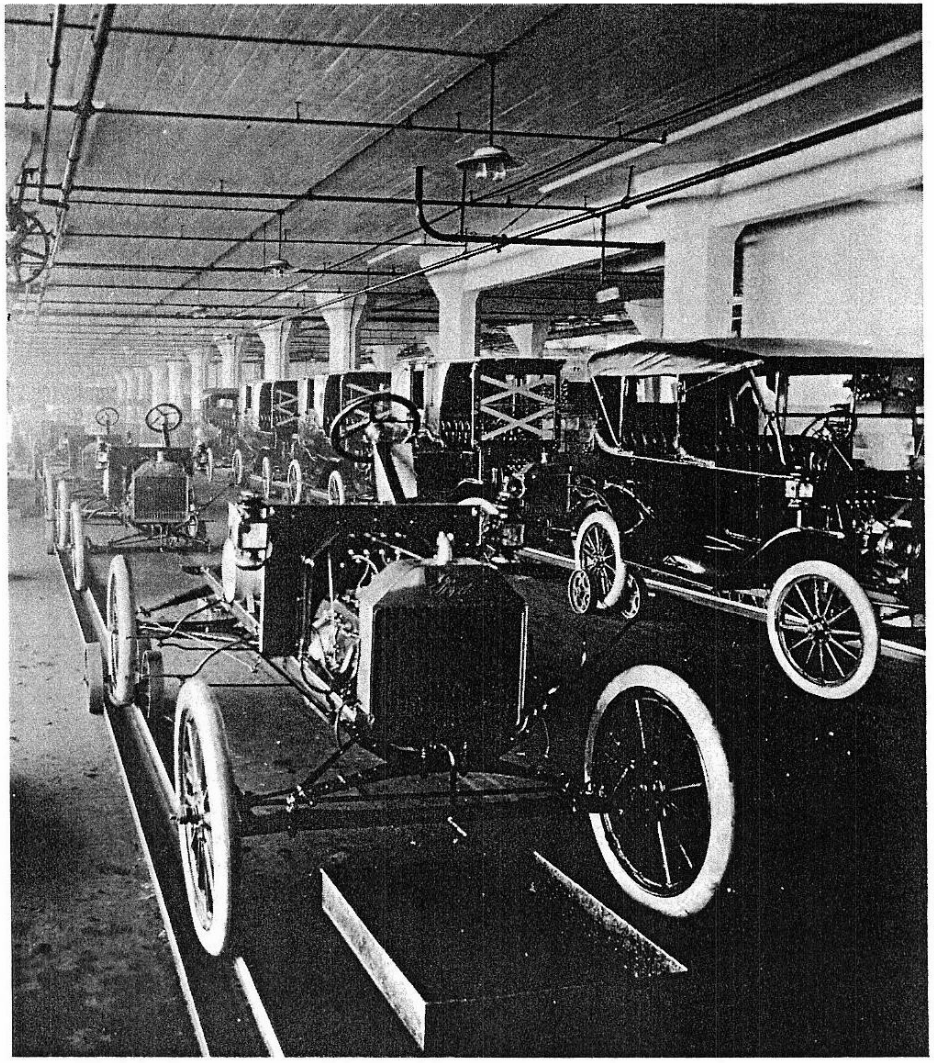


FIGURE 6.28. End of the Line, Highland Park, 1913. As in Figure 6.27, final assembly operations had not yet been put on the ''chain system'' when this photograph was taken. Note that Model T car bodies are being put on the chassis on one of the assembly lines. Those not receiving bodies were destined for rail shipment without bodies. (Henry Ford Museum, The Edison Institute. Neg. No. 0-3342.)

Ford's Engine Manufacturing (1913)
--- fast and accurate with special-purpose machine tools (multi-axial drill board)

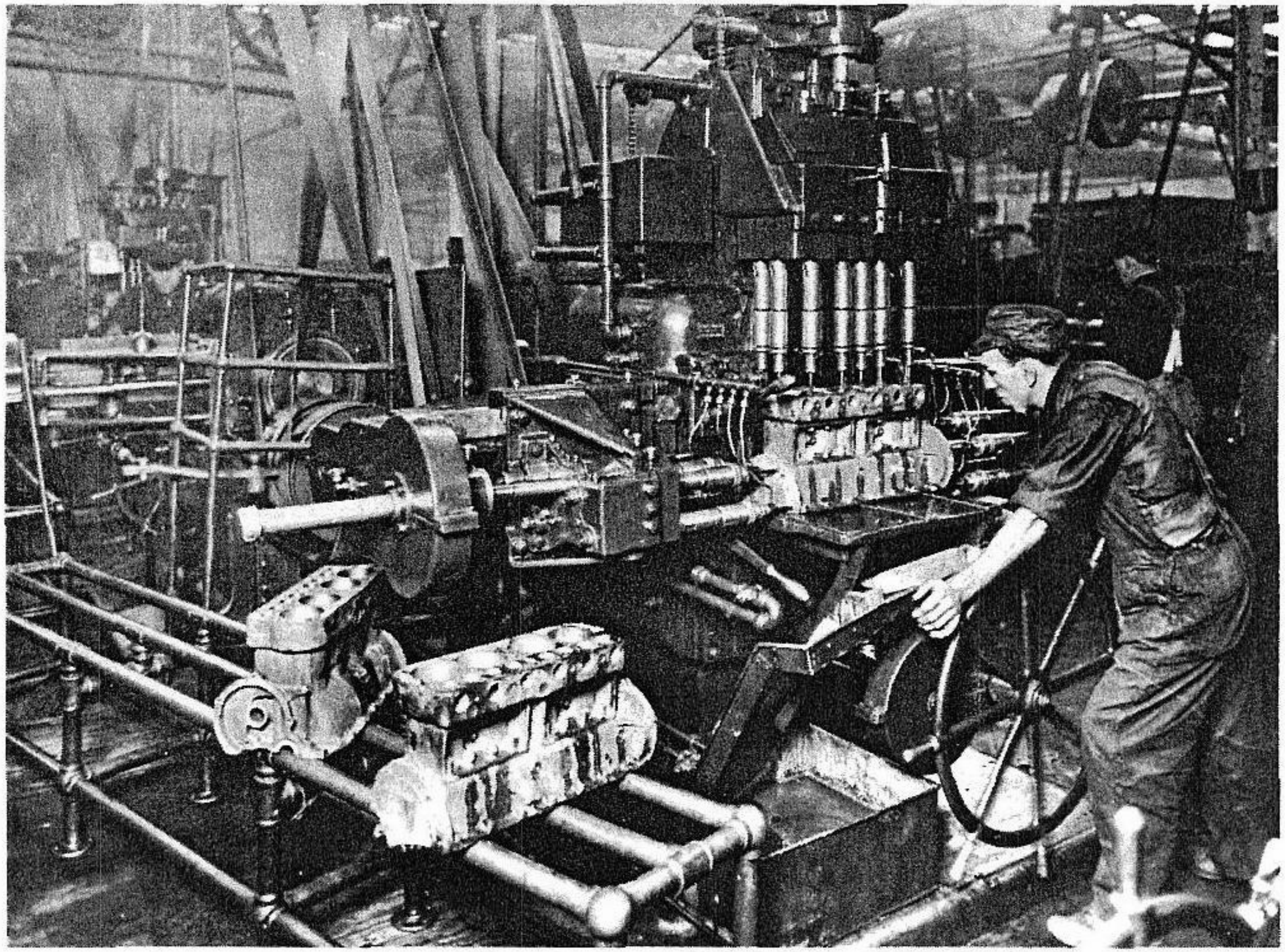


FIGURE 6.9. Drilling and Reaming Engine Block, 1913. This is one example of multiple spindle drilling and reaming machinery designed to machine the Model T engine block. (Henry Ford Museum, The Edison Institute, Neg. No. 833-219.)

In-House Press Process in Highland Park Factory (1913)

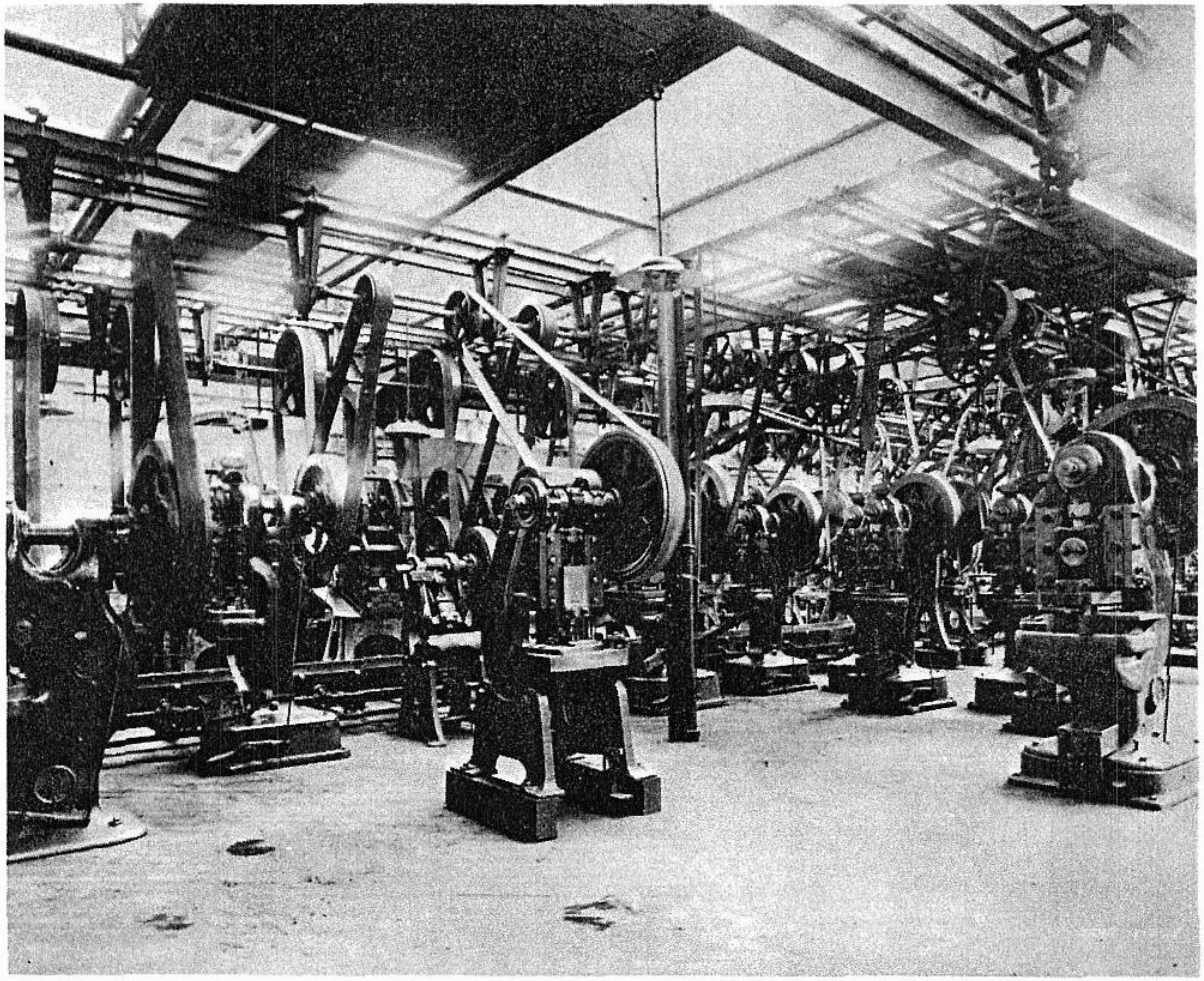


FIGURE 6.4. Punch Press Operations, Highland Park Factory, 1913. (Henry Ford Museum, The Edison Institute. Neg. No. 833-2295.)

Ford River Rouge Factory
--- Extreme Vertical Integration (two days from iron to car)

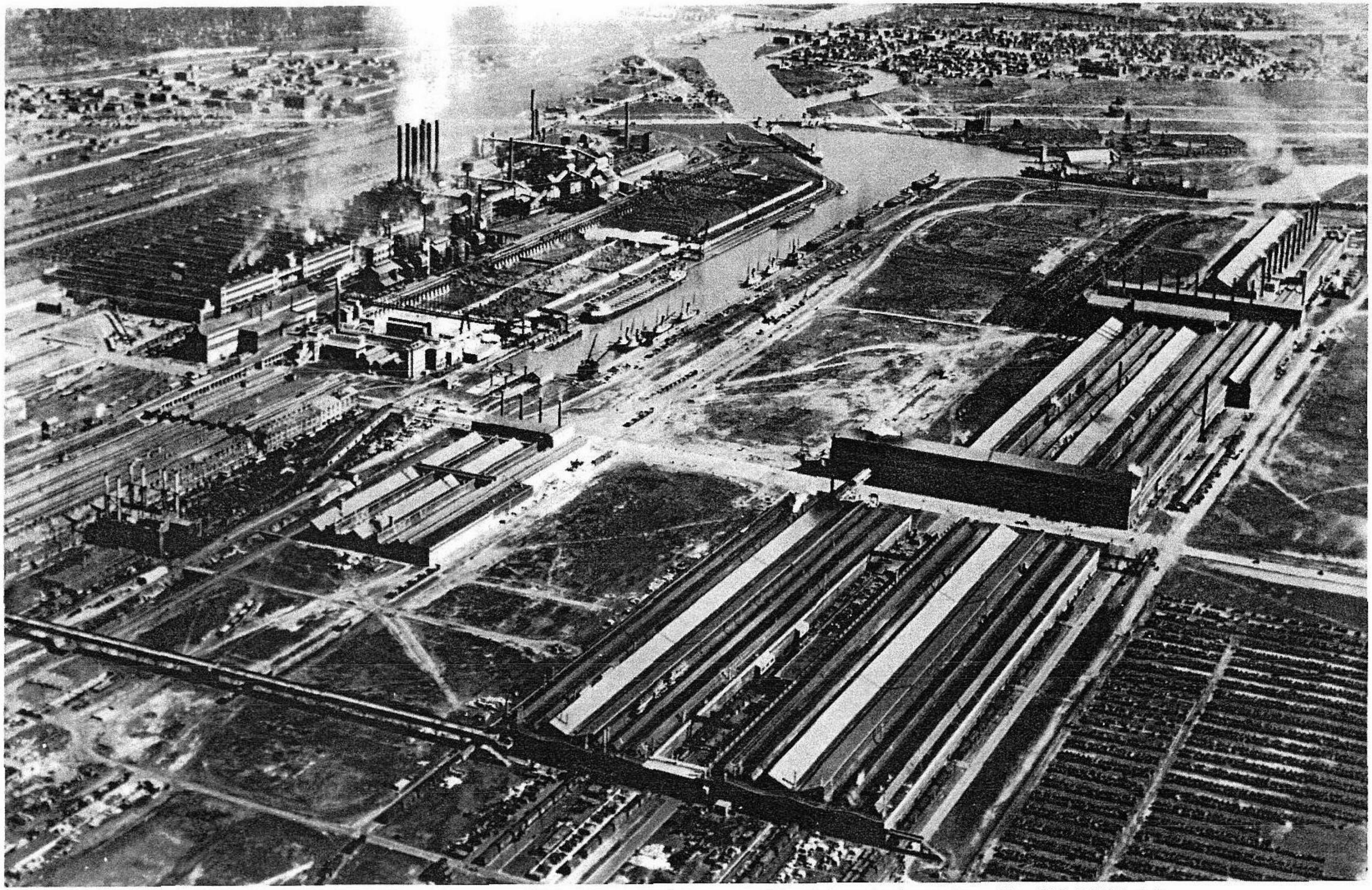


FIGURE 7.1. Ford Motor Company's River Rouge Factory, 1930. (Henry Ford Museum, The Edison Institute. Neg. No. 833-55282-A.)

River Rouge Factory and Limitation of Ford System

Construction of huge River Rouge Factory (1919)

Vertical integration in extreme (in-house ironworks and glass factory), and

synchronized production flow (two days from iron ore to automobile!)

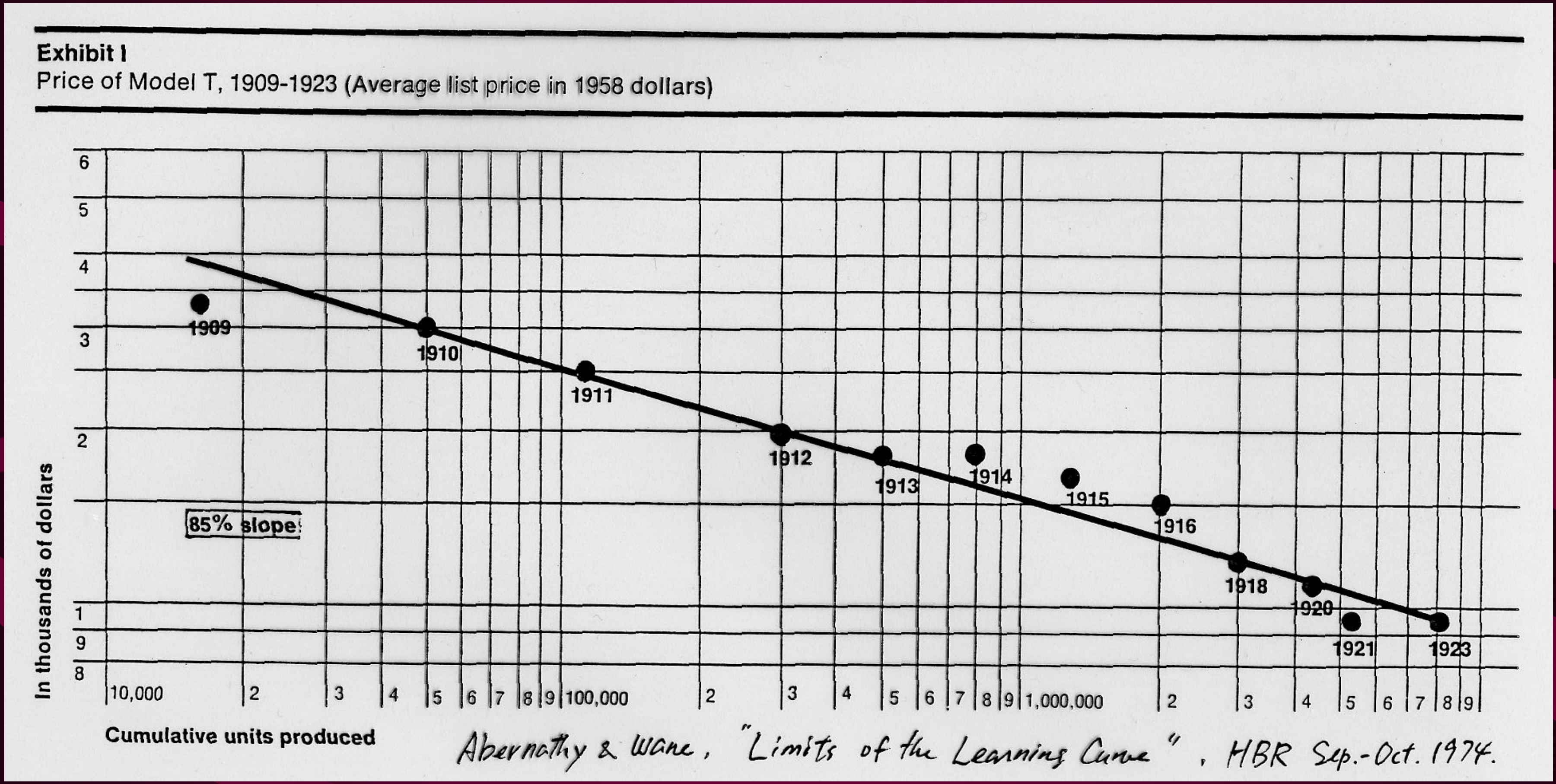
But low flexibility in switching and expanding products: "productivity dilemmas"

Ford in "defense" --- rigid system

Excessive pursuit for mass-production, vertical integration, special-purpose machines,

Single-skill workers, labor problems, huge drain of skilled workers, excessive division of Labor, vertical separation between managers' level and workers

Leaning Curve for Model-T Ford (1909-1923)
--- a foreshadow of productivity dilemmas



Flexible Mass-Production (GM's Sloan doctrine)

General Motors, led by Alfred Sloan, reversed the position.
It's characteristics:

Full-line policy: multiple models to respond to variety of needs

Policy to change models periodically

Common parts for plural models and old/new models

→ parts produced in mass, yet

Somewhat flexible production line, but basically seeking for a mass-production

In terms of multi-model productions, model changes, compatible parts, employment of suppliers, etc., is this on an extended path of the American System of Manufacturers in 19th century?

(Ford system completed its parts' compatibility by special-purpose tools. Was Ford an exceptional case in other areas?)

Comparison of Ford System in Early Phase and GM System (flexible mass production) (recapitulation)

	Ford System in Infancy (era of Ford's Model T)	GM's Sloan Method (flexible mass production system)
Response capability to minor changes	Fit (renewed Model T's body and parts technology without altering undercarriage)	Fit (model change every year without altering undercarriage)
Response capability to major changes	Low (took about one year to switch Model T to Model A	Rather high (2 weeks to switch engine from 4 cylinders to 6 cylinders
Machine tool	Exclusive use (exclusive to T-shape cars)	Versatile
Process layout	By product (machines laid out with extreme density)	By product (basically same with Ford's)
Vertical integration	Vertical integration in extreme degree (Rouge Plant)	Relatively high share of outsourced parts
Product development capability	Rather weak. Too much dependence on Past data; confusion in start-off production due to skipping pilot production	Relatively strong. Reinforced design function. Structure aligned for product improvements resulting from planned model changes

Abernathyのアメリカ技術史観･･･進化史観(progress)

Age	The 0th stage	The first stage	The second stage	The third stage	The third stage	The fifth stage
	The end of 1700's	1800		1850	1890	1910
Feature	British factory System	British factory System	Part flexibility (for many varieties)	part flexibility (for restyling)	Supplier management (part sharing between enterprises)	Mass production Assembly line
Representative firm	Cottage Company	Whitney	Singer	Colt	Bicycle, wagon, and car	Ford
Product		Standardization(interchangeability)				It persists by Ford.
Part interchangeability	None					
Many varieties parts Flexibility			Common parts(making to modular)			GM
Restyling Flexibility				Restyling		Interruption GM
Sharing between enterprises of parts					Supplier network	
Process						It persists by Ford.
Division of labor betw	Self-conclusion process					
Layout according to model						
Layout according to product						Assemblyline operatio

Abernathy, W. J., K. B. Clark, and A. M. Kantrow 'Industrial Renaissanace' 1983

3.Taylor System

Frederick Taylor is:

Founder of "Scientific Management" (?)

Originator of Industrial Engineering (IE)

Inventor of high-speed tool steel

Background of Taylor System---

Labor disputes in American machinery industry in the latter part of 19th century

How should laborers' work content and pace be controlled?

Limitation on an internal contracting system: labor problem (problem of playing truant)

Two Approaches

(1)Machinery mechanics: "control business as precisely as machines" (payroll system)

(2)Group voicing to improve labor-management relations: "treat workers as human" (welfare, union, environmental improvement)

F. Taylor and Formation of Taylor System

Year		1874 ~	1889 ~	1896 ~	1901 ~	1915 ~ Now
Generation		Era of freshman machanics	Era of consultants	Era of Bethlehem Steel	Era of missionary	(what's left now)
Factors of Taylor system	Tool refinement, layout improvement	Absorbed in inventions	Always engaged	Invented high-speed tool steel		High-speed tool steel
	Time study		Sometimes un-engaged	Improved shovels	Behavior study	In form of "IE"
	By-function foreman system	Trial at ミッドベール社				Died out
	Placement of production planning dept.					Production management dept.
	Discriminate performance-based payroll		Sometimes un-engaged	Resistance from work floor		Died out
	Principle of "scientific management"				"Walk alone" somewhat	Not estblished

Author making (reference: Nelson 1980, etc)

Factors of Taylor System Generated Little by Little

- Taylor as floor supervisor/engineer (period with ミッドヴェール社)
  - Time study
  - Discriminating performance-based payroll
  - Foreman by function
- Taylor as consultant (corpus by Bethlehem Steel Corp.)
  - (1)Firstly, improve machinery, tools, layout, etc. (tangible results→earn trust)
  - (2)Next, change systems on production control, const control (production control department, foreman by function)
  - (3) If possible, also execute time study and discriminating performance-based payroll (not forceful when resisted)

Practical steps as consulting business. But is it scientific, or, systematic?

- Taylor as missionary

  Writing books, henchmen, debates with labor union---Taylor doctrine walking alone

4.Evaluation on Contemporary American Manufacturing Industry

1980s: Self-Evaluation of American Manufacturers

Self-Reflection by MIT in "Made in America"
Abernathy's (Cumulative) Evolution Hypothesis:
"OK till Ford in the early stage" "Base is firm" "Unwary later on""Disciple surpasses master" "Back to basics"
Paradigm Change (evolutional change) Hypothesis:
"Paradigm of mass production in 20th century became obsolete from its base"
"Start again from scratch" "Retrogression to the era of engineer-management in 19th century"
Piore/Sabel's Second Industrial Divide Hypothesis:
"Mass-production system came to a deadlock after 1970s"
Bifurcation to re-employ production system
Toward "flexible specialization"
レギュラシオン派のポスト・フォーディズム論：Praised Volvo（ウッデバラ）system

Diagnosis and Prescription for American Mass-Production System---Revolution or Progress?

	Evolution Theory	Revolution Theory
Major advocates	Abernathy, etc.	Skinner, etc.
Basic perspective on progress of production sytem	View as evolution Emphasize learning "Problem solution" is done little at a time on confronting issues	View noncontiguous change in paradigm as revolution Emphasize unlearning Old paradigm obstinately lingers on, which covers problems
Diagnosys and prescription on American manufacturing industry in 1980s	Base of American production system is around; it just took the wrong direction on its way Get back to basics of "Mono-Zukuri" If some Japanese firms are seriously executing basics, learn from them	American production system has become queer from its basis. Dismiss old "mass production paradigm from its foundation

Author making (reference: Abanashe , Skinner, etc)

5.Lean Production System

The system was proposed in a report on International Motor Vehicle Program by MIT in USA (Womack and others, 1990). In 1990s world's auto industry embarked on its partial
 Introductions.

Its base is "Toyota's Production System".
In terms of Mono-Zukuri in the category of automobiles, a Japanese company achieved the world standard.

High productivity, quality, and flexibility have been simultaneously attained. Organizational capability behind the scene.

International competitiveness was manifested as a problem of total system.

Phase theory describing Craft→ American System of Mass-Production→ Lean System

It was rather too simple, and praised Toyota, but captured managements of world's auto companies.

Lean Production System v.s. American System of Mass-Production

Table Production System Characteristics

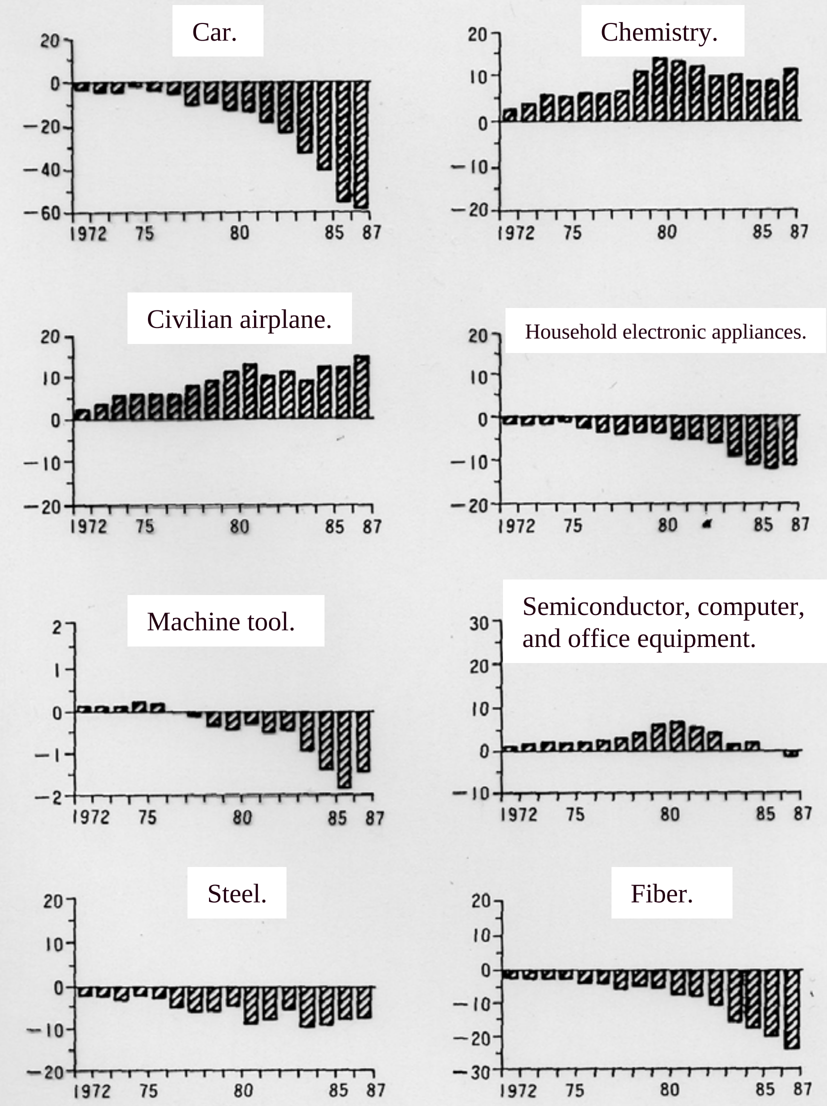
	Craftsmen	Pure Fordism (フォード)	Recent Fordism （GM)	TPS (リーン)
Work Standardization	Low	High, by managers	High, by managers	High, by tems
Span of Control	Wide	Narrow	Narrow	Moderate
Inventories	Large	Moderate	Large	Small
Buffers	Large	Small	Large	Small
Repair Areas	Integral	Small	Large	Very small
Teamwork	Moderate	Low	Low	High

John Krafcik “Triumph of the Lean Production System”, Sloan Management Review, Fall 1988

Competitiveness Declined for American Manufacturing Industry in 1980s

図1・4　調査対象産業別貿易収支

（10億ドル）

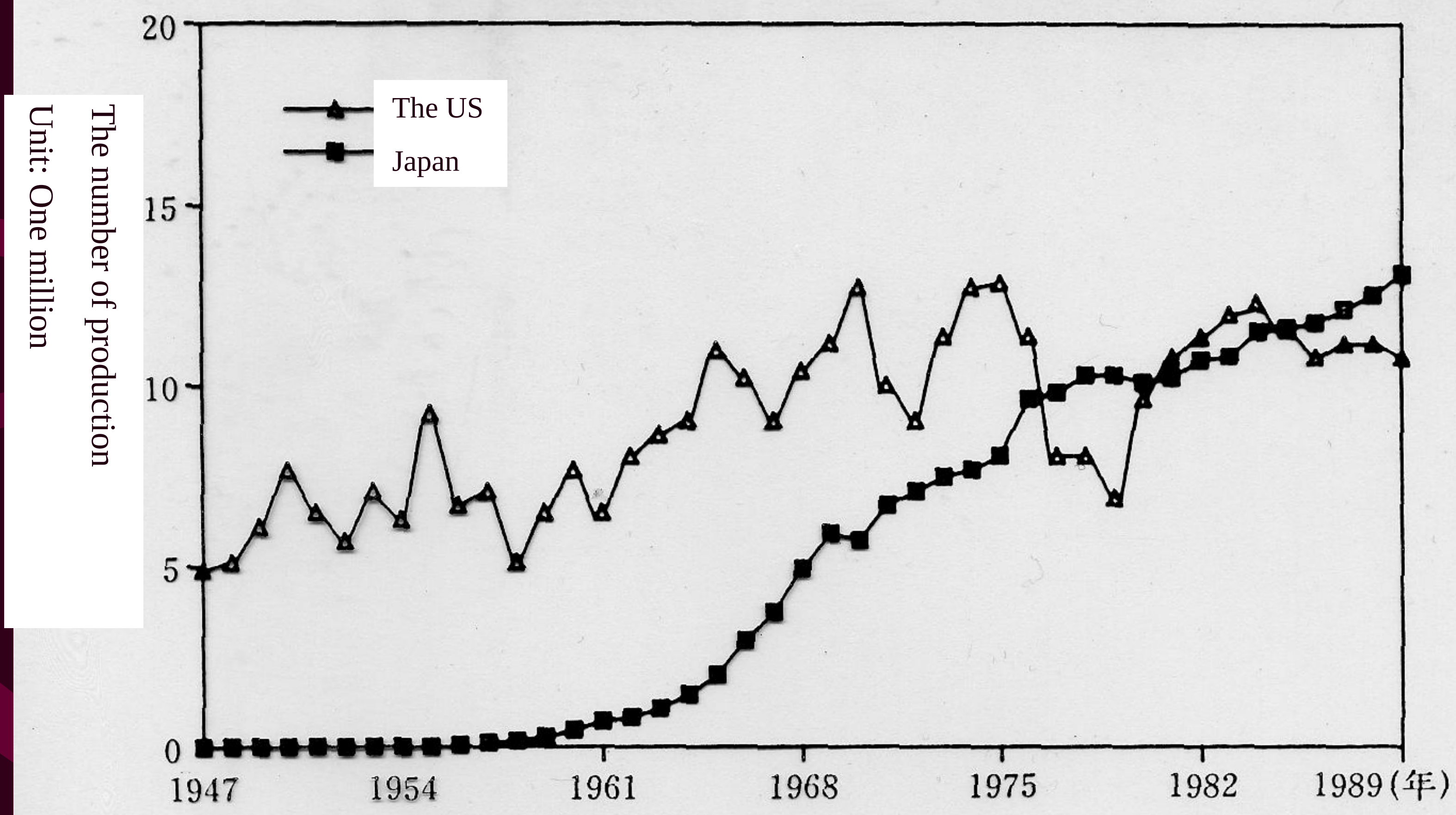


出所：アメリカ商務省、国際貿易局、貿易情報分析部から入手したデータより作成。

「Made in America」　ダートウゾス他　草思社　P31

In 1980s, Japan Became Top Auto-Producing Nation in the World

Ups and downs of the number of car production in Japan-U.S. the two countries(1946～1989)



Source: Automotive News Market Data Book

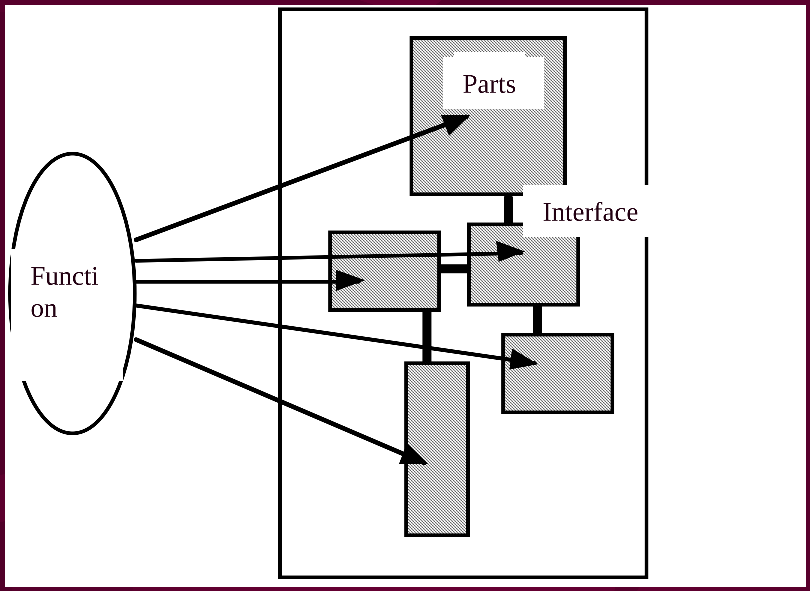
Source: MIT (IMVP)

“Strong manufacturing companies” of Japan: Architecture and Competitive Axis f

But prescriptions differ by industry and product --- “architecture” and “competitive axis”

Product Architecture

Basic design idea regarding how to assign the functions required for the product on each structural portion (parts) of the product, and how to design interfaces among those parts.



Types of Product Architecture

(1)Modular Architecture:

“Combination” model. Patchwork design can be functional.

(2)Integral Architecture:

“Lapping” model. Requires optimum designing of parts

(a)Open Architecture: Patchwork designs beyond companies are possible based on the Industrial standardization of interfaces

(b) Closed Architecture: Conclude basic designs within a company

Learn from Learning Methods of American Companies

"Over confidence" in 1990 → "no confidence" in 1999
Overreaction is not constructive. Discuss industry theories calmly based on data.

- Learn from overseas leading cases
- Re-learn from domestic "master companies"
- Learn from own history