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MANAGEMENT REVIEW

Management without theatre.



STRATEGY

THE LEARNING CURVE: EVERY REPETITION COUNTS

Wright's 80 percent, a car plant whose defects fell from about 70 to 20 a car in eight weeks, why the curve follows doublings and not the calendar, the second shift that did not start from zero, what an organisation forgets, and a card.

80%

of the average labour cost per aeroplane remained each time the quantity doubled, on Wright's curve.

WRIGHT, 1936

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NO. 103 · STRATEGY

In this issue

A new process, a new site, a new person: the first weeks are slow, and every plan has to guess how fast they will speed up. The guess decides staffing, targets and the patience a manager shows. This issue asks what is known about that speed, and where the learning is kept once it is made.

Wright's rule of 1936 ties the fall in labour to doublings of the quantity made. A test on 62 technologies found it forecast best of six such laws. In a car plant, defects fell by about 70 percent in eight weeks, and the second shift began below the first. An airliner shows the other side: experience fades. A card closes the issue.

Stiven Janaqi EDITOR · STIVEN CATALYST

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HOW TO READ THIS ISSUE

Figure
Every figure has its source and year at the foot of its page.

Our reading
Where the editor interprets rather than the research, it says so.

Practice
The steps and the card are proposals to try, not research results.

COVER STORY

Wright's 80 percent

T. P. Wright began to study how cost varies with quantity in 1922, from the two or three points his firm's production of one model allowed. The curve was corrected for years as new orders came in. In February 1936 he published it in the Journal of the Aeronautical Sciences.

WHAT REMAINS OF THE COST AT EACH DOUBLING OF THE QUANTITY, WRIGHT'S CURVES (1936)



On log-log paper the labour curve is a straight line. Its 80 percent is the factor by which the average labour cost for a quantity is multiplied to give the average for twice that quantity. Wright named where the fall comes from:

01	**Practice**	Workers grow more skilled with repetition, more so with time studies.
02	**Fewer changes**	Larger runs bring fewer changes to disturb the work.
03	**Tools and set-ups**	Set-up time is spread over more units, and more tooling pays.

OUR READING

The rule counts units made, not weeks passed. A slow month teaches little; a busy one teaches more.

Source: T. P. Wright, Curtiss-Wright Corporation, Journal of the Aeronautical Sciences 3, 1936

Wright (1936), read in full. The bars are his factors per doubling; a lower bar means a steeper fall; the whole aeroplane's curve later flattens to 90%. Rows: his list for labour, shortened. Averages from one firm's estimating curves of the 1920s and 1930s, not measurements of today's work.

THE NUMBERS

Seventy defects, then twenty

Steven Levitt, John List and Chad Syverson followed nearly 200,000 cars through one assembly plant of a major carmaker over a model year. The model had just been redesigned and the line reorganised into teams, so the plant was, in effect, starting over.

AVERAGE DEFECTS PER CAR, ONE ASSEMBLY PLANT, ONE MODEL YEAR (2012)



−0.3
learning rate: ten times the cars, about half the defects

>80%
of defects came from the fifth of stations with the most

OUR READING

Most of the fall came early and from a few places. A ramp-up plan can say where to look first.

Source: Steven D. Levitt, John A. List & Chad Syverson, National Bureau of Economic Research, 2012

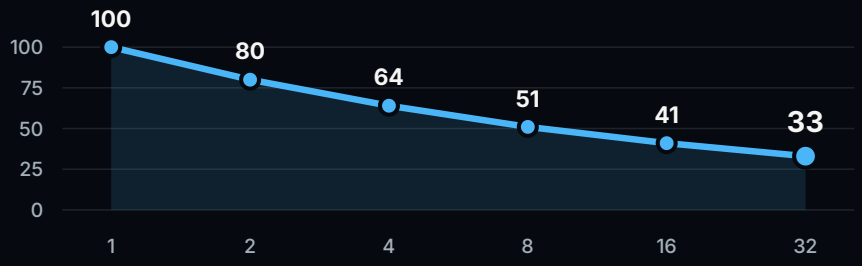
Levitt, List & Syverson (2012), NBER working paper, read in full; the plant and years are not named. Columns are rounded figures from their text; weeks with fewer than 100 cars are left out. The study counts defects, not cost, because line speed moved with demand.

THE MODEL

Doublings, not the calendar

Béla Nagy, Doyne Farmer, Quan Bui and Jessika Trancik tested six proposed laws of falling cost on 62 technologies, each followed for 10 to 39 years, by forecasting the past from earlier data. Wright's law, cost tied to cumulative production, gave the best forecasts; Moore's law, cost tied to time, was not far behind.

AN 80% CURVE: AVERAGE LABOUR PER UNIT, FIRST UNIT = 100, BY UNITS MADE (EDITORS' ARITHMETIC)



Each step needs as many units as all before it, so gains look fast at first and slow later, though the rate is the same. The authors found production tends to grow exponentially; then Wright's and Moore's laws become hard to tell apart.

OUR READING

A team that has done a task 500 times needs 500 more for the next step. Expecting the early pace later is the mistake.

Sources: T. P. Wright, Curtiss-Wright Corporation, Journal of the Aeronautical Sciences 3, 1936; Béla Nagy, J. Doyne Farmer, Quan M. Bui & Jessika E. Trancik, PLOS ONE 8(2), 2013

The line is the editors' arithmetic from Wright's definition (exponent 0.322), not data. Nagy et al. (2013), PLOS ONE, read in full: unit cost after inflation; forecast errors grew with the horizon for every law. The first weeks of a new process are also the subject of pilots (No. 69).

WHAT THE RESEARCH SAYS

The second shift

Seven weeks after the start, the plant added a second shift of new workers, trained by watching the stations for a week. It did not start at 70 defects a car. From the outset its rate was below the first shift's that same week, and over the year about 5 to 10 percent lower.

DEFECTS PER CAR IN THE LAST 12 WEEKS OF THE YEAR, BY MODEL VARIANT (2012)



A new variant did restart the learning, and while Model 3 ramped up, defects on its closest cousin rose by almost 30 percent. Absences of workers raised defects too, but only a little. The authors conclude that much of what was learned sat in the plant's physical and organisational capital rather than in particular workers.

OUR READING

A new person can start near the team's level if the learning is in the station. A new product starts the curve again.

Source: Steven D. Levitt, John A. List & Chad Syverson, National Bureau of Economic Research, 2012

Levitt, List & Syverson (2012), one plant, one year. They cannot rule out that the first shift passed its knowledge on in the week of watching. The linked essay is the author's question whether results last once the manager leaves. How to teach a task is No. 42.

More in the essay When improvement fades

HOW IT IS MEASURED

What an organisation forgets

Lockheed built 250 L-1011 TriStars from 1970 to 1984, in four models, at 4 to 42 a year. Labour fell along a classic curve to unit 112, in the fifth year, at about one sixth of the first plane's hours. Then it rose. Lanier Benkard measured why.

61%
of the firm's stock of experience survived one year (0.96 a month)

up to 10
positions could change when one job opened, under the seniority rules

Benkard links the loss to layoffs when output fell, to rehiring new people when it rose again, and to turnover. Wright had warned of the same in 1936: a repeat order after a break costs more, because of new set-ups and labour turnover between orders.

OUR READING

Count repetitions and gaps together. A task done once a month is not on the curve of a task done daily.

Sources: C. Lanier Benkard, National Bureau of Economic Research, 1999; T. P. Wright, Curtiss-Wright Corporation, Journal of the Aeronautical Sciences 3, 1936

Benkard (1999), NBER working paper, read in full; one aircraft, one firm. The 61% is his estimate for the firm's stock, not an individual's skill, and he links it partly to rarely repeated tasks. Wright estimated a repeat order between the cost for new plus 0.8 of the old quantity and that of the new order alone.

TOOL OF THE ISSUE

The learning curve card

One card for each new process, site or person on a task. The Time Study tool records a task cycle after cycle; write down the times of the 1st, 2nd, 4th, 8th and 16th repetition and the curve shows itself.

01	**The task and its unit**	one repetition counted the same way each time: an order, a room, a pallet
02	**Times at 1, 2, 4, 8, 16**	or errors per unit; the same measure every time
03	**What remains per doubling**	time at 8 divided by time at 4; near 0.8 is Wright's curve, near 1 is a plateau
04	**Where the learning is kept**	in a fixture, a layout, a written method, or only in one person
05	**Breaks and changes**	weeks without the task, a new variant, new people: expect a step back
06	**The target and when**	the time expected, at which repetition, set from the curve, not from the first day

Sources: T. P. Wright, Curtiss-Wright Corporation, Journal of the Aeronautical Sciences 3, 1936; Steven D. Levitt, John A. List & Chad Syverson, National Bureau of Economic Research, 2012; C. Lanier Benkard, National Bureau of Economic Research, 1999

The card is the editors' proposal, built on Wright's doublings, the plant study and Benkard's forgetting; it is not a tested instrument. How to write the method down is in No. 35; why watching is not yet being ready, in treatise volume 8.

Open the tool: Time Study stivencatalyst.com/tools/time-study/

SOURCES AND METHOD

Every figure has a source.

The figures in this issue come from the sources below. The year shows how recent each one is.

Factors Affecting the Cost of Airplanes
T. P. Wright, Curtiss-Wright Corporation, Journal of the Aeronautical Sciences 3, 1936
https://doi.org/10.2514/8.155

Statistical Basis for Predicting Technological Progress
Béla Nagy, J. Doyne Farmer, Quan M. Bui & Jessika E. Trancik, PLOS ONE 8(2), 2013
https://doi.org/10.1371/journal.pone.0052669

Toward an Understanding of Learning by Doing: Evidence from an Automobile Assembly Plant (NBER Working Paper 18017)
Steven D. Levitt, John A. List & Chad Syverson, National Bureau of Economic Research, 2012
https://www.nber.org/papers/w18017

Learning and Forgetting: The Dynamics of Aircraft Production (NBER Working Paper 7127)
C. Lanier Benkard, National Bureau of Economic Research, 1999
https://www.nber.org/papers/w7127

EDITORIAL METHOD

Each figure was checked for its year, its publisher and what it measures, in the full text where it could be opened. A source read only in a summary, an abstract or excerpts is marked “via”. A figure not confirmed in what was read is marked so on its page, or left out. The editor's interpretation is marked “Our reading”.



MANAGEMENT REVIEW

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Every issue, one management question, checked against the best research.

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Edited by Stiven Janaqi, who answers for it; “the editors” in this publication means him. Its texts, translations, layout and the checking of figures against their sources are done in working sessions with Claude, an AI model by Anthropic.
stivencatalyst.com/how-this-is-made.html