

## Musings on Management of the Planning Kind: The 'Learning Curve' Conundrum<sup>1</sup>

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### **Background**

As an introverted 'only child' -- with a father away at "the War" and a mother at work most of the time -- I learned to read at an early age and spent innumerable hours alone as a 'bookworm.' Intrigued by many varieties of puzzles -- anagrams, crosswords, cryptograms, syllogisms and the like -- I endeavored to solve mentally; as well as physically disassembling then re-assembling jigsaws and mechanical objects with no pieces left over! With a limited supply of 'hardware' to play with, whenever puzzle-solving, I repeatedly disassembled and reconstructed items faster and faster each time until reaching a plateau and/or tiring of the challenge.

This penchant for problem-solving proved advantageous when -- as an English Grammar School student -- I encountered algebraic equations. Moreover, after being armed with my math master's step-by-step methodological mantra: "Figure; Given; Required-to-Prove; Construction; Proof", I was not particularly perplexed 'Proving' geometric theorems (such as Pythagoras' right-angled triangle<sup>2</sup>) especially when supplementing them with graphics. Repetitive puzzle practices also honed my manipulative motor abilities, which served me well when I served a stint as an enlisted man in the military and was called upon to disassemble, then rapidly reassemble a variety of small weapons -- *under duress*.

Still later, analytical proclivity and potential were a springboard to my selection as a Management Intern<sup>3</sup> in the U.S. Navy's Bureau of Weapons (BUWEPS) where -- amidst other rotational short-tours -- I wallowed in their Management Engineering Office (MEO), and Special Projects Office (SPO).<sup>4</sup> Then, after an extended assignment as a management analyst in the Navy Management Office (NMO) I acceded to a faculty position at DOD's PERT Orientation & Training Center (POTC) as a management systems specialist. That, in turn, -- fortuitously -- led to a career in the Foreign Service as a project management advisor, manager and evaluator with the US Agency for International Development (USAID); and ultimately as a Project Management consultant. Thus, while I continued to enjoy solving puzzles in many different forms and contexts throughout my varied career roles and responsibilities, systematic analysis was

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<sup>2</sup> "The square on the hypotenuse of a right-angled triangle is equal to the sum of the squares on the other two sides".

<sup>3</sup> The 1960's was an era of intense interest and activity in systematic program and project management; culminating in the Project Management Institute's (PMI) founding in 1969. At the outset, in 1961, Secretary McNamara imported a band of 'Whiz Kids' from the RAND Research Corporation to apply economic analysis, operations research, game theory, and modern management systems within the US Defense Department (DOD). The US Navy also hired neophytes as in-house Management Interns; inculcating them with contemporary management tools and techniques to facilitate logistical workflows in support of Fleet operations. I was fortunate to be one of those chosen few.

<sup>4</sup> Where I learned the PERT/Critical Path Method (PERT/CPM) & just-in-time Line of Balance (LOB) Technology 'in-class,' as well as on the job.

a core competency; while as an adult I continued to enjoy solving puzzles in many different forms and contexts, systematic analysis was a core competency throughout my varied career roles and responsibilities.

### **The Learning Curve**

One of the production planning tools & techniques to which I was exposed during my US Navy management internship was the **Learning Curve Theory**, and its application to planning the scheduling of production contracts for materiel procurements. Conceptually related to the '*Practice Makes Perfect*' concept, the learning curve figuratively and graphically imputes improvements in time duration and level-of-effort -- as well as concomitant cost reduction -- of processes that repetitively produce products in quantity. **So far, so good.**

**However, the theoretical aspect of the learning curve concept bemused me; namely that the pace of improvement – whatever it happened to be -- was systematic: i.e., a constant rate, rather than haphazard!** Recalling my own varied empirical experiences – (including learning touch-typing by repetitiously fingering "*The quick brown fox jumps over the lazy dog*" pangram which, albeit, I had failed to record systematically) -- after familiarity with a problem's objectives, many factors other than gradually-emerging awareness had affected my rate of learning to improve the process. So rather than systematic experimental solution-solving, most of my progress was through **highly erratic 'trial & error.'**<sup>5</sup> There were also occasional 'out-of-the-box' innovations that could not be completely discarded.<sup>6</sup>

### **But 'Who' said a constant rate was a predictable approach for forecasting?**

Well, **two principal proponents** of learning curve theory were prevalent; each with slightly different formulas.

The first, known as **Wright's Law**, was developed by **Theodore Wright** in 1936 based on statistical correlation<sup>7</sup> during his experience in aircraft manufacturing. He noted that for every doubling of airplane production the labor requirement was reduced by 10 to 15%. From that finding, Wright **generalized that for every cumulative doubling of units produced, the time**

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<sup>5</sup> Which today's project management practitioners have corralled, embraced and legitimized as the "**Agile**" process.

<sup>6</sup> A notable '*out of the box*' event was my experience with the Rubik's Cube. Despite numerous efforts from time to time to solve it, success had always eluded me, but I retained one as a colorful artifact on my bookshelf. Then one day my pre-school granddaughter Desi -- who was visiting -- asked me what it was. I told her it was a puzzle where the objective was to get all the small same-colored squares together on the sides; demonstrated how to rotate the pieces, and left her to play with it. A few minutes later she astounded us all by handing me the cube; completed! After years of frustration with the thing, this was phenomenal; undoubtedly a little genius! When I asked her how she did it so quickly, she said it was simple – **she just pulled the stickers off the little squares and replaced them on each side by their color groupings!**

<sup>7</sup> Processes which I learned later; including my mentor's methodological 'eliminate, combine, rearrange and simplify' mantra for conducting time & motion studies for predicting and planning process time & cost reduction.

[cost, &/or level-of-effort] required declined predictably, and linearly. Wright's algebraic formula -- abbreviated "CUMAV" -- is deceptively simple, as follows:

$$T = aN^b$$

**Where:** T = the cumulative average time (duration) to produce N units

a = the time (duration) to produce the first unit

N = the cumulative number of units to be produced

b = the learning rate of improvement from the first to the second unit\*

\*graphically the **slope** of the function plotted on log-log paper, computed as '*the logarithmic learning rate / log 2*'!<sup>8</sup>

Several years after Wright's 'cumulative average' theory, a team of researchers at Stanford University led by **J.R. Crawford** formulated an 'incremental unit' variation of the learning curve, modifying Wright's formula:

$$T = aN^b$$

as follows: **T = was now the incremental unit time (duration) of the batch's midpoint unit**

a = was still the time (duration) to produce the first unit

b = was still the learning rate of improvement (from the first to the second unit) and the learning rate was still the **slope** of the function

**But N = was now the algebraic midpoint of a specific production batch,**

modified as:  $N = [B(1+b)/(U2^{1+b} - U1^{1+b})]^{-1/b}$

**Where: B = the number of units in the batch**

**U1 = the first unit in the batch minus 1/2**

**U2 = the last unit in the batch plus 1/2**

If the foregoing 'formula fogs' are befuddling, you are in good company!<sup>9</sup> In essence, Crawford's theory deviated from Wright's model by assuming as the number of units produced doubled, the time required for the individual unit -- as opposed to the cumulative average unit -- decreased by a constant percentage. **In short, a continual learning curve during the doublings, so the unit**

<sup>8</sup> For example: if a worker's learning rate of improvement per batch is 90%, it means when doubling the number of batches produced, batch production time can be expected to decrease by 10%. Such a predictable methodology is obviously very useful for planning product production schedules and contractual deliveries.

<sup>9</sup> As a consultant, I soon learned the mention of logarithms, and utilization of Greek symbols in equations rapidly induced MEGO (My Eyes Glaze Over!) in my mentees, as well as most of my co-workers and clients. So, since I left the confines of academia, I retired my logarithmic tables along with my obsolescent slide-rule; and limited my approach to embedding equations in Excel templates with formulas I could more easily communicate to others.

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**time and cumulative average time do not decrease at the same rate.<sup>10</sup> Consequently, given the same input data, *their forecasts differed.***

**So which was 'correct?' Who knew?!**

Furthermore, even accepting its validity for aircraft production during the 1930's & 40's, ever inquiringly, 20 years later I questioned why this construct of constant percentage improvement should be considered a generic "**Law**" applicable to *other diverse manufacturing processes and procurement contracts* with which the Navy was currently involved. For me, the "Learning Curve" was only a theory rather than a demonstratively-provable **theorem** -- such as Pythagoras' right-angled triangle, or Newton's Laws of motion.

But my mentor abruptly informed me the learning curve theory was devised by engineers beyond my IQ, pay grade, and authority, and to accept it 'on faith' as a '**best practice.**' Thus, as an intern and junior employee confronted with two widely-accepted tools in general use for factory production forecasting and scheduling product output deliveries, I instinctively opted for the 'Wright' one as my management hammer; and subsequently dutifully sought Naval nails to pound.

During that endeavor I also encountered – *but readily resolved* – another dilemma; namely **until the first two iterations had elapsed, even the input data necessary** to establish a learning rate slope for planning purposes *was pure guesswork* on everyone's part.<sup>11</sup> However, 'crunching' even 'guessed-at' numbers on large, clunky desktop Roneo adding machines was not much fun. Moreover, while related in some manner, the rate of change for **Time, Level of Effort** and **Cost** improvement could differ; so computation was a long, lengthy, laborious and error-prone process. When I departed the Defense establishment and took up applying other aspects of systematic analysis in aid of international Development programs and projects, worldwide, the learning curve was one of the tools I let languish in my management toolkit.

However, years later -- near the turn of the Century -- I was called upon to assist in planning some emergent small 'cottage industry'-type projects in several developing countries, and resurrected the learning curve concept. Fortunately, with the advent of computer spreadsheets (complete with embedded formulas), I was able to create a Learning Curve template for **more efficient** – *if not more effective* -- general use (subsequently updated); as illustrated (*with hypothetical data*) in the following five Figures:

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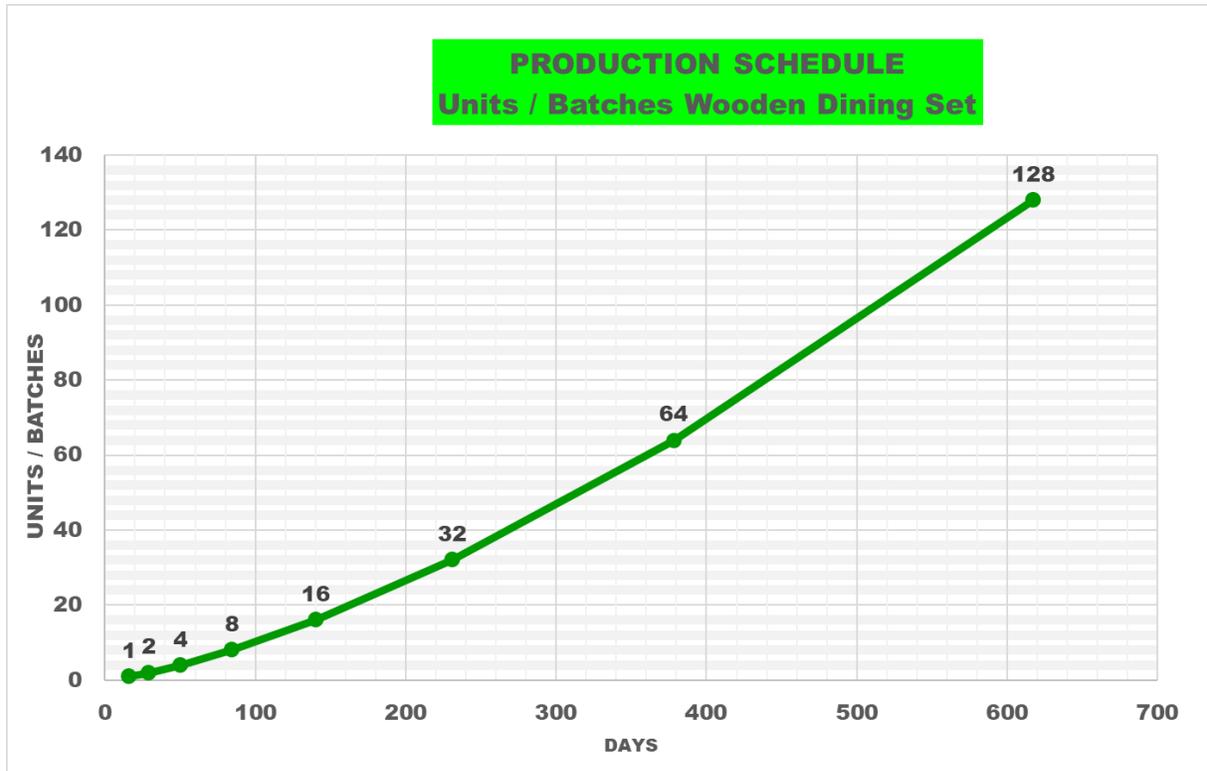
<sup>10</sup> Other distinctions noted by Crawford's team were that a program's costs are often only accounted for in batch data instead of individual units; and although learning over time created more efficiency, it did not necessarily lower costs.

<sup>11</sup> In those politically-incorrect days referred to as a "**SWAG.**" i.e. a "Scientific Wild-Ass Guess!" Nowadays, more politely a "ceiling estimate." i.e. Look at the ceiling, scratch your head in search of an answer, and hazard a guess!

**Figure 1**

<b>LEARNING CURVE THEORY ANALYSIS (Ken Smith's Forecast)</b>											
<b>WRIGHT'S THEORY:</b> As the QUANTITY of end items <b>DOUBLES</b> – produced repetitively primarily by human effort – the TIME Duration, Level of EFFORT – and hence the COST to produce it – all concurrently <b>DECREASE</b> by <b>CONSTANT PERCENTAGES</b> until 'Steady State' irreducible "Minimum Thresholds" are reached.											
© Dr. Kenneth F. Smith, PMP (Lotus123 1996, 2002); Excel 2005, 2021											
1. Write the PROJECT Title; then <b>ESTIMATE</b> the PRODUCT, DURATION, LEVEL OF EFFORT, & COST VALUES for the First TWO STAGES – i.e. Initial and 1st Doubled Quantity – in the YELLOW cells below.											
2. WHEN THE INITIAL QUANTITY HAS DOUBLED, <b>REENTER the ACTUAL DATA</b> for Each of the variables – i.e Average Time Duration, Level of Effort, and Cost per Unit - on Both Lines.											
<b>RESULT:</b> Learning Curve RATES for successive increments will then be <b>Estimated</b> .											
<b>PROJECT:</b>											
Run	UNIT:	PRODUCT & # Items / Batches	Cum # of Items / Batches Produced	AVERAGE TIME Duration per Batch / Unit Produced	CUM TIME Duration of Batches / Units Produced	AVERAGE Level of EFFORT per Batch / Unit	CUM Level of EFFORT of Batches / Units	AVERAGE Production COST per Batch / Unit	CUM Production COST of Batches / Units Divisor	CONSTANT IMPROVEMENT RATES, for FORECASTING	LEARNING CURVE SLOPE
		Wooden Dining Set	Wooden Dining Set	Days	Days	Person Days	Person Days	Pesos	Pesos	Percent Decrease	Percentage
1	Initial Quantity:	1	1	16	16	30	30	30,000	30,000	TIME	81%
2	1st Doubled Qty:	1	2	13	29	28	58	29,500	59,500	19%	
3	2nd Doubled Qty:	2	4	11	50	26	110	29,008	117,517	LOE	93%
4	3rd Doubled Qty:	4	8	9	84	24	208	28,525	231,616	7%	
5	4th Doubled Qty:	8	16	7	140	23	390	28,049	456,012	COST	98%
6	5th Doubled Qty:	16	32	6	231	21	730	27,582	897,323	2%	
7	6th Doubled Qty:	32	64	5	378	20	1,364	27,122	1,765,235	To See Graphs, Scroll down	
8	7th Doubled Qty:	64	128	4	618	19	2,549	26,670	3,472,129		

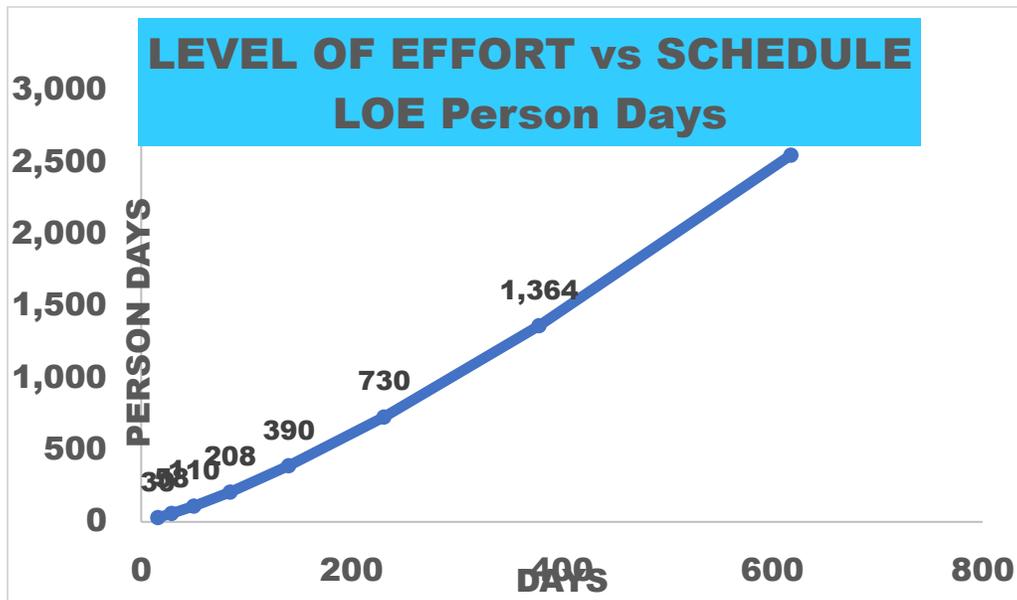
**Figure 2**



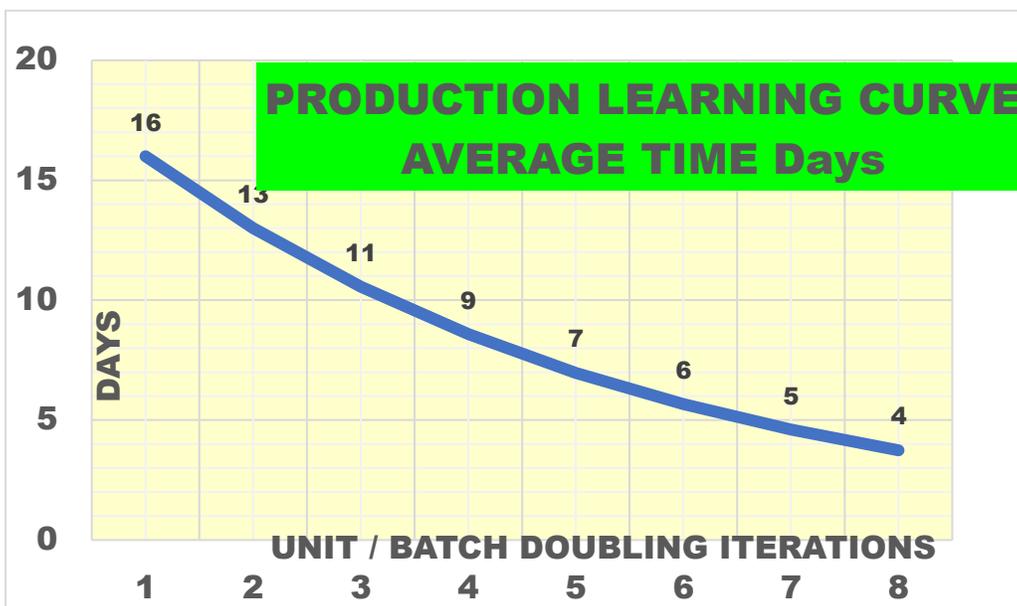
**Figure 3**



**Figure 4**



**Figure 5**



Several observations from my varied experiences with the Learning Curve are pertinent:

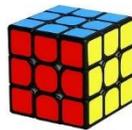
1. The learning curve was generally ineffective in high-tech automated factory-type environments and mechanically-dominated working-style processes. [Once a process is

established, *exact replication is the objective*. Variations indicate '*out-of-control*' situations.]

2. The learning curve concept was particularly useful when working with craftsmen and other business laymen to plan emerging micro, small, and medium craft 'cottage industry' business enterprises that had – or foresaw:
  - a. Manual labor for a high proportion of the process
  - b. Low technology
  - c. Highly repetitive work
  - d. Largely uninterrupted production runs
3. Learning curves generally ranged from 75% to 95%, indicating improvements from five to as much as twenty-five percent. [NOTE: A 100% curve indicates no learning at all!]
4. After seven doubling iterations Learning curves level off at **any rate -- if you can even sustain a process that long** -- without major changes in product design, or practices from out-of- the-box innovation.
5. **For better (or worse), utilization of the learning curve approach replete with a seemingly-scientific formula -- as yet another technique in the management toolkit – greatly enhanced the consultant's 'professional aura' in the eyes of the client!**<sup>12</sup>

**In conclusion**, the learning curve has been applied extensively as a '**Best Practice**' planning technique, serving as a basis for managers to establish -- and incrementally increase -- performance targets. I also accepted and applied it in the past although I never had an opportunity to validate the **Theory** by after-the-fact 'ground-truthing.'

In any event, given the prevalence of widespread computerization in today's VUCA<sup>13</sup> environment, the learning curve theory is less relevant now<sup>14</sup> but before relegation to archival obscurity, will probably continue as an archaic academic artifact & exercise for would-be industrial engineers. However, I occasionally ponder whether I inadvertently established unrealistic expectations by applying its Procrustean '*one size fits all*' approach to miscellaneous projects -- thereby penalizing performers; particularly organizational employees. But unlike my puzzlement over the rapid resolution of the **Rubik's** cube -- *which my granddaughter dispelled* -- I'll never know.



<sup>12</sup> i.e. The 'Wizard of Oz' syndrome – AKA "*blinding them with science*" as opposed to the non-tech salesman's approach of "*bafling them with BS*"!

<sup>13</sup> VUCA -- Volatile, Uncertain, Complex and Ambiguous

<sup>14</sup> If anyone is still interested in the template, it is available on request.

## About the Author



### **Dr. Kenneth Smith**

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Initially a US Civil Service Management Intern, then a management analyst & systems specialist with the US Defense Department, Ken subsequently had a career as a senior foreign service officer -- management & evaluation specialist, project manager, and in-house facilitator/trainer -- with the US Agency for International Development (USAID). Ken assisted host country governments in many countries to plan, monitor and evaluate projects in various technical sectors; working 'hands-on' with their officers as well as other USAID personnel, contractors and NGOs. Intermittently, he was also a team leader &/or team member to conduct project, program & and country-level portfolio analyses and evaluations.

Concurrently, Ken had an active dual career as Air Force ready-reservist in Asia (Japan, Korea, Vietnam, Thailand, Indonesia, Philippines) as well as the Washington D.C. area; was Chairman of a Congressional Services Academy Advisory Board (SAAB); and had additional duties as an Air Force Academy Liaison Officer. He retired as a 'bird' colonel.

After retirement from USAID, Ken was a project management consultant for ADB, the World Bank, UNDP and USAID.

He earned his DPA (Doctor of Public Administration) from the George Mason University (GMU) in Virginia, his MS from Massachusetts Institute of Technology (MIT Systems Analysis Fellow, Center for Advanced Engineering Study), and BA & MA degrees in Government & International Relations from the University of Connecticut (UCONN). A long-time member of the Project Management Institute (PMI) and IPMA-USA, Ken is a Certified Project Management Professional (PMP®) and a member of the PMI®-Honolulu and Philippines Chapters.

Ken's book -- **Project Management PRAXIS** (available from Amazon) -- includes many innovative project management tools & techniques; and describes a "**Toolkit**" of related templates available directly from him at [kenfsmith@aol.com](mailto:kenfsmith@aol.com) on proof of purchase of PRAXIS.

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