Technology adoption - Total Cost assessment

The failure of CASE (and other tools) is often considered due to poor management. There are other possible causes - consider the costs of adopting a new technology -

\[ C_{TP} \] - Cost of the technology - products - i.e. S/W, H/W, manuals etc.

\[ C_{TTT} \] - Cost of training - courses etc. that are required to bring people to an appropriate level of competence - external costs.

\[ C_{TTe} \] - Cost of long-term training - this could show up as reduced productivity, or/and internal training.

The first two items are readily measurable - the second is hard.

Another way of looking at this is through the lost productivity resulting from the use of a new technology - this can be considered to be a traditional learning curve model - i.e. exponential.
Let $P_0$ be the productivity in
output/time (e.g., LOC/week, LOC/month)
output/person-time (e.g., LOC/person-month)

Let $P_0'$ be the productivity after adopting
the new technology.

We assume $P_0$ is constant: $= P_0$

We assume $P_n(t) = A(1 - e^{-kt}) \quad (1)$

That is — the productivity after adopting the new
technology increases with time $t$.

To obtain a value for $A$, —

From (1), when $t \to \infty$, $P_n(t)$ is
effectively constant since $e^{-kt} \to 0$

$\therefore P_n(t) = A = P_n$ as $t \to \infty \quad (2)$

$\therefore P_n(t) = P_n(1 - e^{-kt}) \quad (3)$

The output $O$ can be calculated as

$O = \int_{t_0}^{t} P(t) dt \quad (4)$
ie. the integral of the performance product of productivity and time is time.

The increase in output is of simply \( O_n - O_0 \), denoting original output.

being more formal after some time \( \tau \),

\[
\Delta O(\tau) = O(\tau) - O_0(\tau)
\]

Alternatively -- -- the increase in output is the integral over time of the increase in productivity. The result is the same.

\[
\Delta O(\tau) = \int_0^\tau [p(\tau) - p_0(\tau)] d\tau
\]

Substituting \( p_n(\tau) \) and \( p_0(\tau) \) \( \Delta O(\tau) = \int_0^\tau [p_n(1 - e^{-k\tau}) - p_0] d\tau \)
\[ 
\begin{align*}
\Delta \theta(\tau) &= \left[ P_0 \left( \tau + \frac{1}{k} e^{-k\tau} \right) - P_0 \tau \right] \frac{T}{k} \\
\Delta \theta(\tau) &= P_0 \left[ \frac{P_0}{\theta} \left( \tau + \frac{1}{k} e^{-k\tau} \right) - \tau \right] - \frac{P_0}{\theta} \cdot \frac{1}{k} \\
\Delta \theta(\tau) &= P_0 \left[ \tau \left( \frac{P_0}{\theta} - 1 \right) - \frac{P_0}{\theta} \frac{1}{k} (1 - e^{-k\tau}) \right] 
\end{align*}
\]

We can approach (12) as follows to obtain a useful value of \( k \).

Reverting to equation (3)

\[ P_0(\tau) = P_0 \left( 1 - e^{-k\tau} \right) \]

we can obtain a value for \( k \) in terms of some useful project parameters, e.g., the value of \( \tau_c \) (\( T_c \)) at which the productivity is 95% of its maximum, i.e., \( T_c \) is the point in time of which learning is complete.
\[ P_n(\tau_c) = 0.95 P_n \]
\[ P_n(1 - e^{-k\tau_c}) = 0.95 P_n \]
\[ e^{-k\tau_c} = 0.05 \]
\[ e^{+k\tau_c} = 20 \]
\[ k = \frac{\ln 20}{\tau_c} \]
\[ \ln 20 = 2.9956 \approx 3 \]
\[ k = \frac{3}{\tau_c} \]

Substituting \( k \), we obtain
\[ \Delta O(\tau) = P_o \left( \frac{\tau}{\tau_c} \left( \frac{P_n}{P_0} - 1 \right) - \frac{3}{3 P_0} \left( 1 - e^{-\frac{3 \tau}{\tau_c}} \right) \right) \]
\[ = P_0 \left( \frac{\tau}{\tau_c} \left( \frac{P_n}{P_0} - 1 \right) - \frac{\tau_c}{3} \frac{P_n}{P_0} \left( 1 - e^{-\frac{3 \tau}{\tau_c}} \right) \right) \]

If we extract \( \tau_c \) — we have
\[ \Delta O(\tau) = P_0 \tau_c \left( \frac{\tau}{\tau_c} \left( \frac{P_n}{P_0} - 1 \right) - \frac{P_n}{3 P_0} \left( 1 - e^{-3 \frac{\tau}{\tau_c}} \right) \right) \]

\[ \frac{P_n}{P_0} = \text{is the productivity improvement ratio} \]
\[ P_0 \tau_c = \text{original output that would have been completed with no improvement} \]
We can call $P_0 T_c = O_{\text{one}}$

$\therefore \Delta O(\tau) = O_0 \left[ \frac{\tau}{T_c} \left( \frac{P_0}{P_0} - 1 \right) - \frac{P_0}{3P_0} \left( 1 - e^{-3\tau/T_c} \right) \right]$ \hspace{1cm} (18)

n.b. $\frac{\tau}{T_c}$ is the normalized time in terms of $T_c$, the learning complex time.

& Behaviour based on best--worst case of "learning".

The best possible result is learning is completed before the adgphas occurs--i.e. $T_c = 0$

The worst possible result is that learning is never complete.

From equation (16) $\Delta O(\tau) = P_0 \left[ \frac{\tau}{T_c} \left( \frac{P_0}{P_0} - 1 \right) - \frac{T_c}{3} \frac{P_0}{P_0} \left( 1 - e^{-3\tau/T_c} \right) \right]$ \hspace{1cm} (19)

$\Delta O(\tau) \bigg|_{T_c = 0} = P_0 \left( \frac{P_0}{P_0} - 1 \right)$

Actually, $T_c$
In the first case ($T_c = 0$) use equation 16:

$$\Delta o(T) = 10 \left[ T \left( \frac{T_c}{T_c} - 1 \right) - \frac{T_c}{3T_c} \left( 1 - e^{-\frac{3T_c}{T_c}} \right) \right]$$

$$T_c \to 0 \Rightarrow \Delta o(T) \to 10 T \left( \frac{T_c}{T_c} - 1 \right)$$

Second case ($T_c \to \infty$) use equation 17:

$$\Delta o(T) = 10 T_c \left[ T \left( \frac{T}{T_c} - 1 \right) - \frac{T_c}{3T_c} \left( 1 - e^{-\frac{3T_c}{T_c}} \right) \right]$$

when $T_c \to \infty$, $\Delta o(T) \to 0$ since

$$1 - e^{-\frac{3T_c}{T_c}} \to 1 - e^{-T_c} \to 0$$

(in practice - the worst case is simple)

Project completion time $T_c$ for $T_c \to \infty$ does not have much meaning.

Looking at equation 16, we find some difficulty in interpreting what happens to the term $\frac{T_c}{3T_c} \left( 1 - e^{-\frac{3T_c}{T_c}} \right)$ when $T_c \to \infty$.
when \( n_c \to \infty \), \( n = \frac{3 \tau}{n_c} \to 0 \\
\exp \left( -\frac{3 \tau}{n_c} \right) \to 0 \\
\left( 1 - \exp \left( -\frac{3 \tau}{n_c} \right) \right) \to 0 \\
\text{but } \frac{n_c \rho_n}{3 \rho_0} \to \infty \text{ i.e. we have } \\
\infty \cdot 0 \text{ The means that this is not clean -}

However, we are discussing \( n_c \) v. large, really, not \( n_c \to \infty \) i.e. \( \frac{3 \tau}{n_c} \) v. small

Hence we should look at \( \exp \left( -\frac{x}{n_c} \right) \)

\( \exp x \), \( x \) v. small (\( x \ll \ll 1 \))

We can use the power series for \( \exp x \)

\[ \exp x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots + \frac{x^n}{n!} \]

\[ \exp (-x) = 1 - x + \frac{x^2}{2!} - \frac{x^3}{3!} + \ldots \]

\[ x = \frac{s \tau}{n_c} \quad \text{and } \quad n_c \gg \gg \tau \]

then \( x \ll 1 \ll 1 \), hence

\[ \exp (-x) \approx 1 - x \]
If \( \frac{3T}{\pi} \) = \( \frac{1}{10} \) \( e^{-2c} \) = 1 - \( \frac{1}{10} \) \( \frac{1}{2.1000} \) \( - \frac{1}{10} \) \( \frac{1}{2.1000} \) 

So we substitute \( e^{\frac{3T}{\pi}} = 1 - \frac{3\pi}{\pi} \) 11:06

\[ \Delta O(c) \mid_{T_c \to \infty} = P_0 \left[ \tau \left( \frac{P_n}{P_0} - 1 \right) - \frac{\tau_c}{3} \frac{P_n}{P_0} \left( 1 - (1 - \frac{3\pi}{\pi}) \right) \right] \]

\[ = P_0 \left[ \tau \left( \frac{P_n}{P_0} - 1 \right) - \frac{P_n}{P_0} \right] \]

\[ = -P_0 \tau \]

(\text{This is the hard way—consider using the hint back to } P_n(c) = P_n \left( 1 - e^{-\frac{3\pi}{\pi}} \right) \text{)}

\[ \tau_c \to \infty \quad \text{ke} \rightarrow P_n(c) \mid_{\tau_c \to \infty} = 0 \]
Consider equation (17)

\[ \Delta \phi(\tau) = P_0 \tau_c \left[ \frac{\pi}{\tau_c} \left( \frac{P_0}{P_0} - 1 \right) - \frac{P_0}{3P_0} \left( 1 - e^{-\frac{3\tau}{\tau_c}} \right) \right] \]

and we can obtain

\[ \Delta \phi(\tau) \]
Consider equation (17)

$$\Delta \theta(\tau) = P_0 \tau_c \left[ \frac{\tau}{\tau_c} \left( \frac{P_n}{P_0} - 1 \right) - \frac{P_n}{3P_0} \left( 1 - e^{-\frac{3\tau}{\tau_c}} \right) \right]$$

Assume \( \frac{\tau}{\tau_c} \gg 1 \) (i.e., \( e^{-\frac{3\tau}{\tau_c}} < 0.05 \))

$$\Delta \theta(\tau) \approx P_0 \tau_c \left[ \frac{\tau}{\tau_c} \left( \frac{P_n}{P_0} - 1 \right) - \frac{P_n}{3P_0} \right]$$

To solve for \( \Delta \theta(\tau) = 0 \)

$$0 = P_0 \tau_c \left[ \frac{\tau}{\tau_c} \left( \frac{P_n}{P_0} - 1 \right) - \frac{P_n}{3P_0} \right]$$

$$\frac{\tau}{\tau_c} \left( \frac{P_n}{P_0} - 1 \right) = \frac{P_n}{3P_0}$$

$$\frac{\tau}{\tau_c} = \frac{P_n}{3P_0} \frac{P_0}{P_n} = \frac{1}{3} \frac{P_n}{P_n - 1}$$

$$= \frac{P_n}{3P_n - P_0} = \frac{1}{3} \frac{P_n}{P_n - 1}$$

Finally, \( \frac{P_n}{P_0} > 1 \) must hold.

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<th>Positive Increase</th>
<th>( \frac{P_n}{P_0} )</th>
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<tr>
<td>( \frac{P_n}{P_0} )</td>
<td>( \frac{\tau}{\tau_c} )</td>
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<table>
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<th>( e^{-\frac{3\tau}{\tau_c}} )</th>
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