# DYNAMIC RESOURCE APPLICATION FOR SUSTAINABLE TECHNOLOGY IMPLEMENTATIONS

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**ABSTRACT**

*Government environmental regulations, along with increasing awareness and demand from customers for firms to be sustainable, are driving firms to implement new technologies to enhance the sustainability practices of their firms. Given a finite implementation horizon and a target improvement level, a project manager must decide when to apply resources to a project. We develop an optimal control model to specify when to apply resources under different operating cost differentials, taking into account resource cost. We find that technologies that are more efficient are optimally implemented with a front-loaded schedule to achieve cost savings quickly. Conversely, technologies that are more expensive, but mandated, are ideally implemented on a back-loaded schedule.*

**JEL:** C02, C61, M10, O21

**KEYWORDS:** Sustainability, Technology Implementation, Project Management, Green, Resource Loading, Optimal Control

## INTRODUCTION

Due to imminent regulation, a market mandate, or a desire to increase market share, a company should want to improve its sustainability levels. Sustainability improvements, after implemented, provide cost savings over time as they reduce waste, rework, and potential liabilities. Implementation of these improvements has a cost; however, using the appropriate amount of resources and minimizing disruption to daily operations are ideal. A project manager needs to determine whether to front-load, back-load, or smooth the implementation resource load. Rather than using limited personal experience or rules of thumb, a project manager can optimally determine how many resources to apply each period over the project horizon to minimize total costs while ensuring that the target improvement is met by the deadline.

We use dynamic optimal control to determine the optimal implementation effort and optimal technological capacity per period. We demonstrate that the expense of implementation resources has an effect on the optimal resource loading. In addition, we investigate the following scenarios: (a) The new technology has a lower operating cost than the legacy technology; (b) The new technology and old technology have equivalent operating costs; and (c) The new technology is more expensive to use, but is mandated by market forces or government regulation.

Our model provides equations to show the technology capability over time, the resources to apply over time, and the marginal benefit (to the technology improvement goal) over time. Regardless of the cost parameters a company faces, our equations hold. Therefore, the final three equations presented can be used in any scenario to provide optimal implementation cost. We continue in the next section with a literature review. We then introduce the model notation and formulas. Next, we show numerical examples to illustrate the three scenarios mentioned above. We conclude with managerial implications and suggestions for future research.

## LITERATURE REVIEW

Implementation of environmental management technologies has become an increasingly important topic due to new regulations. For example, the REACH regulation enacted in June 2007 requires businesses that produce, use, and sell significant quantities of chemicals in the European Union to show that those chemicals are safe for both humans and the environment (Lockwood, 2008). One method of categorizing environmental technology includes two categories: end-of-pipe technology and cleaner production (Frondel, Horbach, & Rennings, 2007). End-of-pipe technology is an add-on to existing technology to reduce pollution, and cleaner production decreases pollution at the source. Klassen and Whybark (1999) included a third category, management systems (training, modified procedures, and environmental management systems), along with pollution control (end-of-pipe) and pollution prevention (cleaner production). Frondel et al. (2007) found that companies implemented end-of-pipe technology more frequently as a response to environmental regulations, and cleaner production technology more frequently to reduce costs. Bansal and Gangopadhyay (2005) studied investment in cleaner production technology and determined that when a regulator makes a commitment to an environmental regulation (a standard and a penalty) and then sticks with the commitment regardless of the existing technology at companies, this commitment will motivate companies to invest in R&D and to make environmental investments to attract environmentally aware customers from whom companies can extract greater profits. In addition to the reasons for investing in environmental technology, another issue important to companies is the timing of those investments.

The timing of an environmental investment is critical to both controlling costs and increasing profits. Fischer, Withagen, and Toman (2004) argued that the timing of this investment depends on factors such as the marginal damages of pollution decay rate, the capacity depreciation rate, and the initial state of a company's production environment (clean or dirty). They considered only technologies that are more costly to operate and to create than existing technologies. They concluded that in a clean initial environment, clean capacity would be built up gradually. If depreciation rates were low, environmental technology capacity would be added; and if the marginal damages of pollution were to decrease, clean capacity would be built up gradually. In a dirty initial environment, clean capacity would be added aggressively. Higher marginal damages of pollution would lead also to a quicker increase in investment in capacity. Another study by van Soest and Bulte (2001) recommended that companies postpone investments in energy saving because technological advances are uncertain and irreversible, i.e., a company would be better off by waiting for even better technology. Conversely, Cora (2008) suggested that additional short-term expenditures would lead to more long-term corporate value and that waiting to invest in clean technology (thereby missing regulatory deadlines) would lead to higher long-term compliance costs. Lopez-Gamero, Claver-Cortes, and Molina-Azorin (2008) suggested that proactive managers would want to be the first to adopt environmental practices to create barriers to entry, to attract ethical customers, and to take advantage of subsidies or low-interest financing. Primary options for accelerating the investment and implementation of environmental technology are discussed next.

Two options for accelerating a project's implementation are fast-tracking and crashing. As described by Sommerhoff (2000, p. 51), "In its most literal sense, fast-tracking means delivering a project from design to completion, with a compressed time frame." Sommerhoff (2000) also suggested that fast-tracking is no longer the exception. Some authors (e.g., Cupryk, Takahata, & Morusca, 2007) have argued that crashing a project—decreasing the project's duration by adding more resources—should be considered only after fast-tracking or overlapping all tasks as much as possible. A project manager needs to be careful when crashing by adding more resources or by working overtime. Singh (2003) described how overmanning leads to a reduction in work efficiency due to a decrease in workspace for workers and poor communication, and overtime leads to losses in efficiency along with increased costs.

Prior literature regarding implementation of sustainable technologies seems to have focused primarily on theoretical rules of thumb (Landberg & Simeone, 2002) or team dynamics from a framework perspective

(Yeoh, Koronios, & Gao, 2008). Our research takes a strategic view of this technology implementation and provides specific guidance on how a project manager should load a project over time to minimize costs.

In the next section, we present a model illustrating a closed-form solution to the timing of investment in resources for three different types of sustainable technology scenarios: (1) The new technology reduces operating costs; (2) The new technology has operating costs equal to those of the legacy technology; and (3) The new technology increases operating costs. After that, we provide three numerical examples. Finally, we discuss managerial implications.

## MODEL

The model involves three main equations and cost parameters. The first equation defines the level of technology at each point in time (it is a state equation). The second equation shows the resources required at each phase of the project (it is a control equation). The third equation shows the marginal value of improving technology at a given point in time in the project. Along with these equations, there is a cost differential for operating the new technology versus the legacy technology that is being replaced. In addition, there is a cost for resources and a penalty for trying to do too much at any point in the horizon. These three equations define the optimal implementation timing for a project.

Variables

$x(t)$ The level of sustainability capability in place at time $t$. A state variable.

$u(t)$ The improvement effort at time period $t$. A control variable.

$x'(t)$ The rate of change of the level of improvement. A state equation.

$x'(t) = u(t)$. The level of improvement effort $u(t)$ is the rate at which our level of capability increases at time $t$.

$\lambda(t)$ The adjoint variable. Similar to the Lagrange multiplier in calculus. The adjoint variable is interpreted as the marginal value to the objective of an additional unit of the state variable (sustainability capability at time $t$).

$c_1$ Cost to implement sustainability improvements per unit ($c_1 > 0$).

$c_2$ Cost savings per period for a given amount of sustainability capability in place (negative means operating cost savings; positive means increased operating costs).

$x(0)$ The sustainability capability at time 0 (the beginning of the horizon).

$x(T)$ The sustainability capability at the end of the horizon ($T$).

We want to minimize costs in achieving the required sustainability capability by the end of the desired time horizon ($T$). The objective function and constraints are shown below:

$$\min \int_0^T [c_1 u(t)^2 + c_2 x(t)]dt \tag{1}$$

s.t.

$$x'(t) = u(t) \tag{2}$$

with $x(0) = 0$ and $x(T)=B$. $u(t) \geq 0$ for $t \varepsilon [0, T]$. $T$ is known.

The quadratic term infers that larger concurrent implementation efforts (resources) are much more disruptive than smaller efforts during any period. This may be disruption to the business or implementation loss of efficiency by having too many resources (Singh, 2003).

Solution

The problem is presented as an optimal control problem. The dynamic change in the state variable is expressed as a differential equation. The Hamiltonian is similar to the Lagrangian in calculus.

The Hamiltonian for our problem is given as:

$$H = -c_1 u(t)^2 - c_2 x(t) + \lambda(t) u(t) \tag{3}$$

The necessary conditions for optimality with optimal control theory are stated below:

1) $$\frac{\partial H}{\partial u} = 0 \tag{4}$$

$$-2c_1 u(t) + \lambda(t) = 0 \tag{5}$$

$$u(t) = \frac{\lambda(t)}{2c_1} \tag{6}$$

2) $$-\frac{\partial H}{\partial x} = \lambda'(t) \tag{7}$$

$$\lambda'(t) = c_2 \tag{8}$$

$$\lambda(t) = c_2 t + k_1 \tag{9}$$

3) $$\frac{\partial H}{\partial \lambda} = x'(t) \tag{10}$$

$$x'(t) = u(t) \tag{11}$$

Combining Equations (6) and (9) provides:

$$u(t) = \frac{c_2 t + k_1}{2c_1} = x'(t) \tag{12}$$

Integrating $x'$ gives us the expression for $x$.

$$x(t) = \frac{c_2}{4c_1} t^2 + \frac{k_1}{2c_1} t \tag{13}$$

It is given that the company needs to reach capability threshold *B* by time *T*, *x(t) = B*, which leads to the following:

$$\frac{c_2}{4c_1}t^2 + \frac{k_1}{2c_1}t = B \tag{14}$$

$$k_1 = -2c_2T + 2c_1\frac{B}{T} \tag{15}$$

Therefore,

$$x(t) = \frac{c_2}{4c_1}t(t-T) + t\frac{B}{T} \tag{16}$$

$$\lambda(t) = c_2t - \frac{c_2}{2}T + 2c_1\frac{B}{T} \tag{17}$$

$$u(t) = \frac{c_2}{2c_1}\left(t - \frac{T}{2}\right) + \frac{B}{T} \tag{18}$$

*u(t)* is valid only for non-negative values. We can apply only zero or some positive effort towards implementing new technologies. We cannot have negative work effort. Increasing *u* at any particular time *t* is analogous to crashing the project.

We have examined the necessary conditions for optimality in optimal control. We now explore the sufficiency conditions for optimal control. The necessary conditions above for a minimum cost solution are sufficient if any of the following hold:

(i) $-c_1u(t)^2 - c_2x(t), \lambda(t)u(t)$ are both concave in *x* and *u;*
$\lambda(t) \geq 0$ for $t \varepsilon [0, T]$. (19)

(ii) $\lambda(t)u(t)$ is linear in *x* and *u*;
$\lambda(t)$ is unrestricted;

$-c_1u(t)^2 - c_2x(t)$ is concave in *x* and *u* for $t \varepsilon [0, T]$. (20)

(iii) $-c_1u(t)^2 - c_2x(t)$ is concave in *x* and *u*;

$\lambda(t)u(t)$ is concave in *x* and *u*;

$\lambda(t) \leq 0$ for $t \varepsilon [0, T]$. (21)

The switching time, denoted by *t**, is defined as the time that *u*(*t*) switches from a positive to a zero value, or vice versa. Therefore, we solve for *t** such that u(t*) = 0 holds.

$$u(t^*) = 0 = \frac{\lambda(t^*)}{2c_1} \rightarrow \lambda(t^*) = 0 \tag{22}$$

$$\lambda(t^*) = 0 = c_2 t^* + k_1 \rightarrow k_1 = -c_2 t^* \tag{23}$$

We have introduced another decision variable, $t^*$, and another condition: $u(t^*)=0$. This new condition permits us to obtain a solution for $k_1$. Substituting for $k_1$ into the expression for $\lambda(t)$, we have:

$$\lambda(t) = c_2 t - c_2 t^* \tag{24}$$

This can be rewritten as:

$$\lambda(t) = c_2 (t - t^*) \tag{25}$$

From Equation (25), we know the following about the optimal solution for $u(t)$:

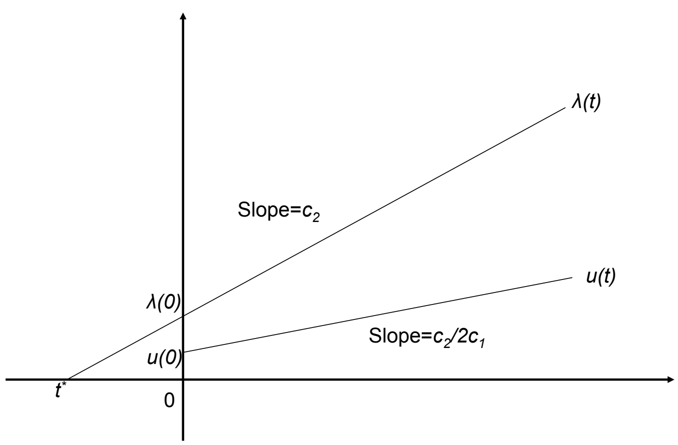
$\lambda(t) > 0$ and $u(t) > 0$ for $t > t^*$, and $\lambda(t) \le 0$ and $u(t) = 0$ for $t \le t^*$.

We know $\lambda(t) = c_2 > 0$, so that $\lambda(t)$ increases at a constant rate over time. Therefore, if a switch occurs, the direction of the switch for $u(t)$ is from zero to a positive value.

For $u(t) > 0$, we know $u'(t) = c_2 / 2c_1 > 0$. Therefore, the rate of increase in $u(t)$ over time is less than the rate of increase in $\lambda(t)$, if $c_1 > 1/2$ holds. We have two possible solutions for $t^*$: 1) $t^* \varepsilon [0, T]$, or 2) $t^* < 0$ holds. We do not need to consider $t > T$. If that were the case, then $u(t) = 0$ over the entire horizon and $x(T) = 0$, violating $x(T) = B$. In other words, we know that $t^* \le T$ holds. This tells us that $\lambda(T) = c_2 (T - t^*) \ge 0$. The two possible cases to consider are shown below.

Case 1: $t^* < 0$ holds so that $u(t) > 0$ over the entire planning horizon.

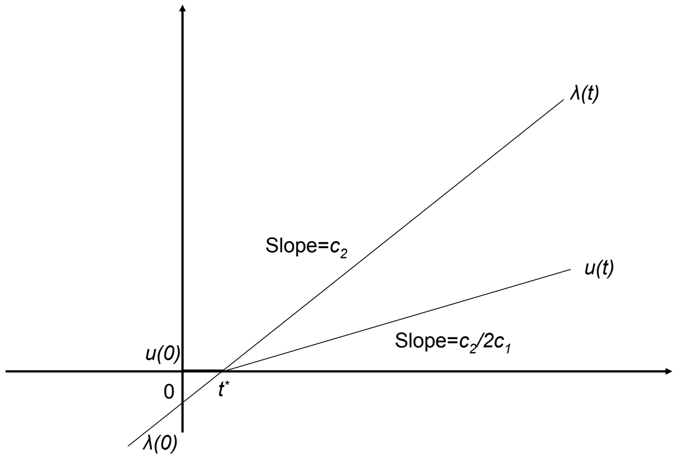
Figure 1: Non-zero Resource Load Applied over Entire Time Horizon




*This figure shows the case where the optimal start time of the implementation effort (t*) is before time 0. This indicates that at all times during the project time horizon, a positive level of resources (u) should be applied.*

Case 2: $t^* \geq 0$ holds so that $u(t) = 0$ for $t\varepsilon[0,t^*]$ and $u(t) > 0$ for $t\varepsilon[t^*,T]$.

Figure 2: Zero Resource Load Applied over a Portion of the Time Horizon




*This figure shows the case where the optimal start time of the implementation effort (t*) is beyond the current date (t=0). This indicates that at some portion of the time horizon, no resources (u) will be utilized.*

We use both cases in examples in the following section. Which case applies depends on the sign of $\lambda(0)$. If $\lambda(0)$ is negative, we are in Case 2; otherwise, we are in Case 1. We first solve the problem assuming we are in Case 2, so that $t^* \geq 0$ holds. We obtain the control variable solution:

$$u(t) = \begin{cases} 0, for\ t\varepsilon\ [0, \dot{t}] \\ \frac{c_2\ (t-t^{\cdot})}{2c_1}, for\ t\epsilon\ [\dot{t}, T] \end{cases} \tag{26}$$

From the above and given $x'(t) = u(t)$, we obtain the solution for the state variable $x(t)$, the level of capability implemented at time $t$.

$$x(t) = x(0) + \int_0^t x'(\tau)d\tau = 0 + \int_0^t u(\tau)d\tau \tag{27}$$

Over the time interval $t\varepsilon[0,t^*]$, we know $u(t)$=0 thus $x(t)$=0 for $t\varepsilon[0,t^*]$.

Next, over the time interval $t\varepsilon[t^*,T]$, we have

$$x(t) = x(t^*) + \int_{t^*}^t u(\tau)d\tau = 0 + \int_{t^*}^t \left\{\frac{c_2(\tau - t^*)}{2c_1}\right\}d\tau$$

$$= \frac{c_2}{4c_1}\left[t^2 - 2t \cdot t^* + t^{*2}\right] \tag{28}$$

$$x(t) = \frac{c_2}{4c_1}\left(t - t^*\right)^2, \text{ for } t\varepsilon[t^*, T] \text{ and } x(t)=0 \text{ for } t\varepsilon[0, t^*]. \tag{29}$$

To find the optimal switching time $t^*$ for the control solution, we use the terminal condition $x(T)=B$.

$$x(T) = \frac{c_2}{4c_1}\left(T - t^*\right)^2 = B \tag{30}$$

$$t^* = T - 2\sqrt{\frac{c_1 B}{c_2}} \tag{31}$$

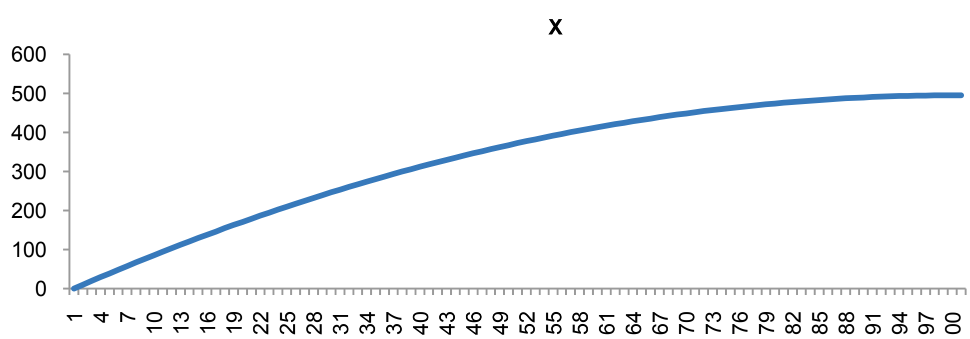
If Equation (31) $\geq 0$, then Case 2 holds. Alternatively, if Equation (31) is violated (including where $t^*$ is an imaginary number), we know that $u(t)$ is positive over the entire planning horizon and, therefore, Case 1 holds.

## NUMERICAL EXAMPLES

New Sustainable Technology Reduces Operating Costs

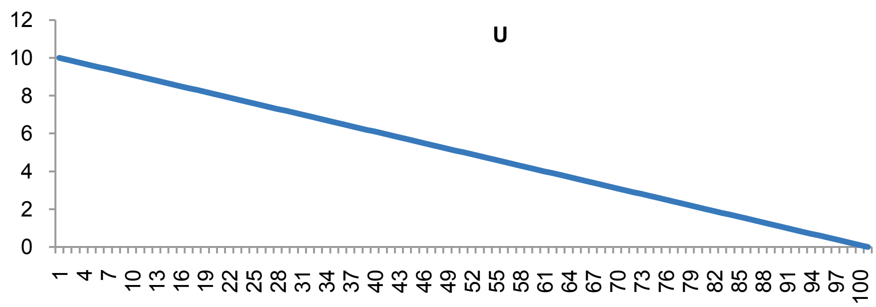
For illustration, assume $B$ is a level of 500 and $T$ is 100 periods away. Assume that $x(0) = 0$ and we start at level 0. In essence, $B$ is the goal, so $x(0) = 100$ and a $B$ of 600 is then equivalent to $x(0) = 0$ and $B = 500$. We can set $x(0)=0$ without loss of generality. If the cost to implement improvements ($c_1$) is \$5 per period and the benefit per unit of improvement is \$1 per period ($c_2 = -1$), then we get the following curves (Figure 3):

Figure 3: Level of Technical Capability by Time



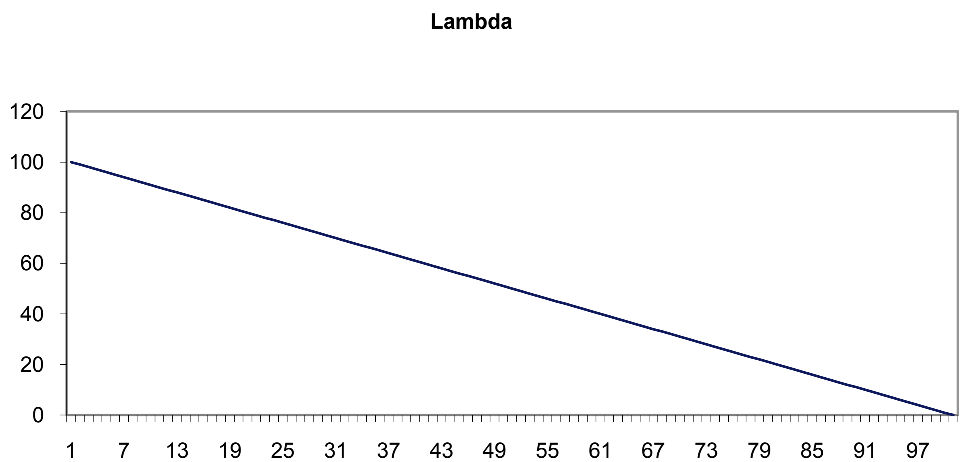

*This figure shows an increase in sustainable capability over the entire time horizon. However, because the technology is expensive to operate, it makes sense to implement quickly early in the horizon to reap cost savings as soon as possible.*

Figure 4: Implementation Resources Utilized by Time




*This figure shows that the project is front-loaded. As mentioned in Figure 3, it is cost beneficial to implement quickly. Therefore, we see that the resources (u) are utilized earlier in the time horizon, diminishing in time.*

Figure 5: Marginal Value of Capability Improvement by Time



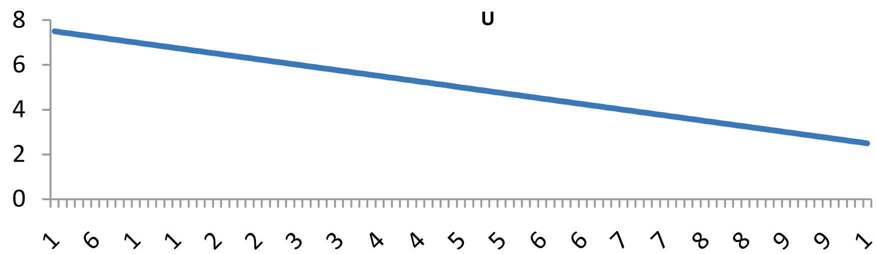

*This figure shows that it is worth more to implement the technology improvement earlier, rather than later, in the horizon. Because we can use the less expensive technology as implemented, it follows that it is worth more to begin using the cheaper technology sooner.*

We reach our capability goal $B$ at time $T$, doing more work up front. This allows us to get the new technologies in place and to reap the cost savings throughout the horizon. We linearly decrease our resources applied to the implementation effort. The $\lambda$ graph shows the marginal value of an additional unit of improvement to the state variable $x(t)$. Notice that is it more cost beneficial to implement the improvement earlier in the horizon so that the cost savings in operations can be utilized throughout the remainder of the horizon.

<u>New Sustainable Technology Reduces Operating Costs (but project resources are very expensive)</u>

If the implementation cost $c_1$ is increased significantly over the first example ($c_1 = 10$, $c_2 = -1$), the implementation curve (x) is similar in shape to Figure 3, but flatter. This would be a project with a positive net present value, but with a longer payback than the prior scenario. The resource load in the u graph shown in Figure 6 shows that fewer resources are applied during the early part of the project, but more resources are utilized in the latter part of the project compared to Figure 4.

Figure 6: Implementation Resources Utilized by Time on an Expensive Effort



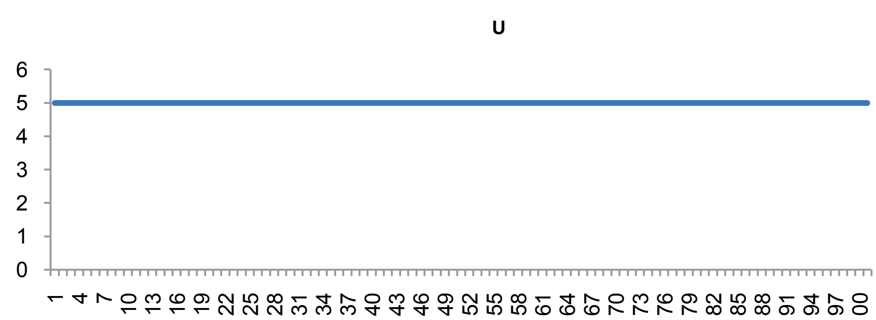

*This figure shows that resources are front-loaded as in Figure 4, but the differential between the resources utilized at the beginning of the project and at the end is less.*

Notice that we still achieve our goal of $B$ at time $T$, but do so with the effort spread more smoothly over the time horizon. The curve in the $x$ graph is flatter and indicates that we do not front load the schedule to reap operating improvements early. The cost of disruption from doing too much improvement work per time period offsets any benefits in operating savings due to the new technology. The adjoint variable $\lambda(t)$ is linearly decreasing over time, as in our first case. It is more beneficial to implement the new technology earlier in the horizon.

<u>New Sustainable Technology Has Same Operating Costs as Legacy Technology</u>

If we had to implement the technology to meet a regulation or to placate a customer, but there was no internal payback (reduction in cost due to capability), then we would observe the situation shown below where $c_2 = 0$. The new technology is as efficient to operate as the current technology.Notice that the implementation effort is applied evenly across the horizon to minimize disruption. Recall that the implementation effort cost ($c_1$) is squared ($c_1 u(t)^2$) to account for the dramatically increasing cost due to disruption from doing too much implementation in a single time period. The lowest cost implementation in this scenario is one that smooths the effort over the entire time horizon. In this case, $\lambda$ is constant for the entire horizon.

Figure 7: Implementation Resources Utilized by Time on a Parity Implementation

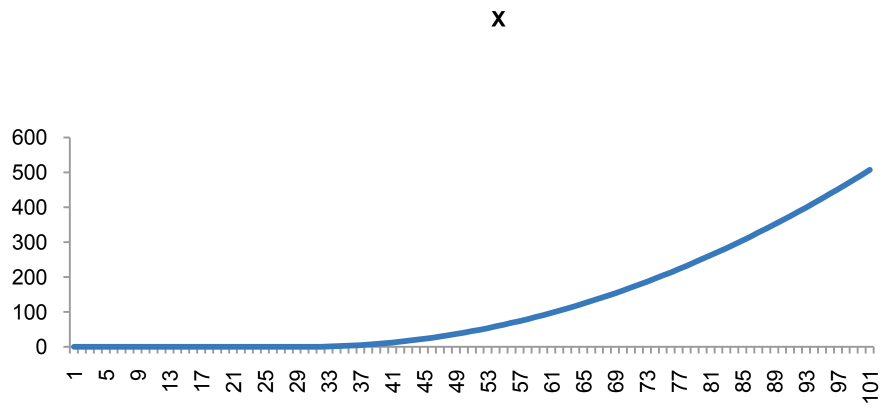



*This figure shows the case where the optimal start time of the implementation effort (t*) is beyond the current date (t=0). This indicates that at some portion of the time horizon, no resources will be utilized.*

New Technology Is More Expensive to Operate than Legacy Technology

What if the new technology were actually more costly to use than the legacy technology? If $c_2$ is now 2 (positive indicating that the new technology adds cost – more expensive to operate) and $c_1$ is at 5, we get the graphs below. We are in Case 2 from section 4 above. An example of this is a retrofit of a HEPA filter on an existing HVAC system. The air quality would improve after the implementation, but the air resistance would increase, consequently the power required to run the system would increase.

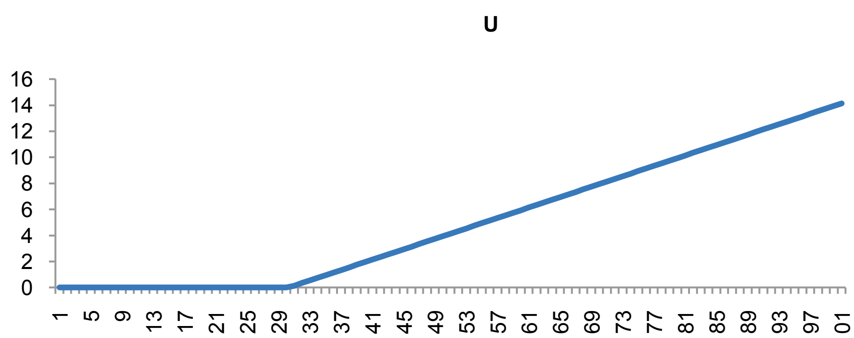
Figure 8: Level of Technical Capability by Time to Replace Low Cost Technology




*This figure shows that the optimal strategy is to implement the technology in a just-in-time fashion. The new technology will be more expensive to operate, so we postpone implementation as much as possible to continue using our legacy, less expensive, technology.*

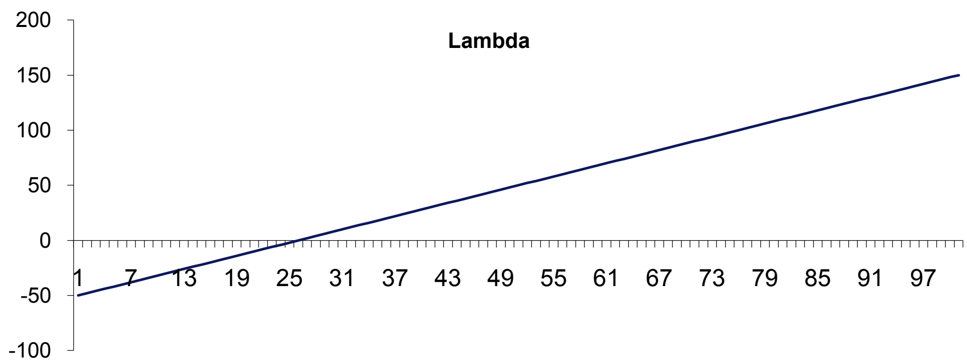
Notice that we increase our capability at an increasing rate after we switch from not implementing at all to beginning the implementation at $t^*$ (at time $t$ = 29.3 in this example). Because the new technology is more expensive to operate than the legacy technology, we delay implementation towards the end of the horizon – a more just-in-time approach. The graph of implemenation effort $u(t)$ shows linearly increasing implementation effort toward the end of the horizon. The $\lambda$ graph shows that it becomes increasingly more beneficial to implement the new technology later in the time horizon.

Figure 9: Implementation Resources Utilized by Time to Replace Low Cost Technology




*This figure demonstrates that we back load the resources (u) to meet our just-in-time implementation schedule shown in Figure 8.*

Figure 10: Marginal Value of Capability Improvement by Time to Replace Low Cost Technology




*This figure shows that there is no benefit (<=0) to implement the new technology before a certain point in the project time horizon.*

Interpretation of Equations

From Equation (16), we know $x(t) = \frac{c_2}{4c_1} t(t-T) + t\frac{B}{T}$.

The final term, $t(B/T)$, is 0 at $t = 0$ and increases linearly until the term equals $B$ at time $t = T$. The first term, when $c_2$ is negative (operating cost improvements from the new technology), is a concave parabola. When $c_2$ is positive, the first term is a convex parabola with all points on the line non-positive.

From Equation (17), we know $\lambda(t) = c_2 t - \frac{c_2}{2}T + 2c_1\frac{B}{T}$.

The first two terms can be combined to $c_2(t - T/2)$.

If $c_2 > 0$ (the new technology is more expensive to operate), the term above will be negative for the first half of the horizon $(0, T/2)$ and positive for the second half of the horizon $(T/2, T)$. This term is a line that crosses the x-axis at T/2. Otherwise, when the new technology is less expensive to operate, the above term will be positive for the first half of the horizon and negative for the second half of the horizon.

$B/T$ is positive, as is $c_1$. Clearly, as the goal $B$ increases, the marginal value at any time $t$ increases. Because the final term does not vary with t, if $c_2 = 0$, $\lambda$ does not change over the time horizon. Given the first term includes $t$, if $c_2$ is > 0, then $\lambda$ is increasing in time. Conversely, if $c_2 < 0$, then $\lambda$ is decreasing in time.

From Equation (18), we know $u(t) = \frac{c_2}{2c_1}\left(t - \frac{T}{2}\right) + \frac{B}{T}$.

If $c_2 / c_1$ is negative (given that $c_2$ is negative), then $u(t)$ is decreasing over time. Conversely, if this ratio is positive (given that $c_2$ is positive), then $u(t)$ is increasing over time.

## MANGERIAL IMPLICATIONS AND CONCLUSIONS

Regardless of a company's motivation for embarking on an improvement initiative, meeting the desired capability by the deadline is critical. However, the project implementation cost varies with how the resources are loaded throughout the horizon. We have provided a model that minimizes the total implementation cost by optimizing the resources that need to be applied at each period. Equations for the level of capability, resources, and marginal benefit of applying resources also were given in the prior section.

If the implementation of new, green technologies and capabilities improves operating efficiencies (lowers cost), then implementation front-loaded in the horizon makes sense. The closer the ratio $c_2/c_1$ is to zero, the flatter the state variable curve $x(t)$ is. This means that as this ratio gets farther from zero, the curve becomes more concave, indicating that the implementation effort should be front-loaded in the horizon. The improvement gap is modeled via the $B$ parameter and is taken into account in our resource allocation per time in Equation (17), directly leading to the capability implemented at time $t$ in Equation (16).

Whether implementing new sustainable technology to lower operating costs, to meet market or regulatory requirements, or due to a mandate from the executive level, there is an optimal way to time the application of resources toward the implementation of the new technology. We have shown the closed-form analytical solution to the timing of the implementation given the cost parameters for implementation resources and operating cost differential between legacy and new technologies.

A limitation of this paper is that it assumes that the capability improvement comes immediately as resources are applied. However, in some situations, there is a time lag between implementation and realized benefit. In addition, we assumed that the number of resources is a continuous variable, whereas in practice resources are added in discrete units. Future research could model this lag to show mathematically how much resources need to be pulled forward in time. Synergistic effects with other green initiatives and competition effects in the marketplace also are suggested as potential research areas.

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