



Decision Criteria for New Technology Investment

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Decision Criteria for New Technology Investment

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Executive Summary

1. **By contrast to the case in which technology is a known quantity, when decisions are being made on the purchase and implementation of technologies that are new to a company and often new to the world, the purpose of investment is often different and the knowledge framework of the investing company is distinctly different.**

New technology investment is unlikely to be a reaction to changes in the short-term economic environment as is often the case with capital investment. There is a larger and more complex set of factors, related to shifting fundamentals of cost pressures and other types of globalization-induced market pressures.

2. **With new technology investment, the benefit side of the return-on-investment (ROI) equation contains a broader set of factors than is the case with a fixed technology frontier.**

Investing when the new technology is working its way into the industry production structure can provide critical value by helping the individual company establish differentiation and/or remain cost competitive. There are also multi-layered benefits deriving from an improved production cost / product quality picture as well as the increased productivity of capital.

3. **Similar to the benefits, the potential costs of a new technology investment include additional considerations beyond traditional measures.**

Among the broader set of cost factors to consider are the potential risks associated with investing in an evolving technology and implementation impacts on the supply chain.

4. **Automation investment is one case of new technologies being implemented in a way that is distinctly different from capital investment.**

While automation investment has some aspects of capital investment in the sense of placing physical assets into a production structure, automation investing requires an expanded view and is often tangential to process innovation. The survey data discussed in the second paper in this research series show that in terms of automation technology evaluation, the lowering of production costs and improvement in product quality were the dominant performance criteria.

Major Findings

1. Economic theory identifies the importance of a number of drivers of corporate capital investment demand, including the output of the company's goods and services, the cost of capital (generally defined as a weighted average of the cost of equity and debt financing of capital), the expected revenue from the use of capital assets, and the market value of capital assets.
2. Standard capital investment analysis and the standard use of the return-on-investment (ROI) project decision tool assume that the technological frontier is fixed. Technology is, in essence, a known quantity. By contrast, in the case where decisions are being made on the purchase and implementation of technologies that are new to the company and often new to the world, the purpose of investment is often different and the knowledge framework of the investing company is distinctly different.
3. New technology investment is unlikely to be a reaction to changes in the short-term economic environment. There is a larger and more complex set of factors at work, related in part to shifting fundamentals of cost pressures and other types of globalization-induced market pressures.
4. Automation investment is one case of new technologies being implemented and used in a way that is distinctly different from capital investment.
5. In many ways, new technology adoption is a complete break from the accelerator model of investment. Potential users might see the benefits as *changing* the productivity of capital or the capital/output ratio.
6. With new technology investment, the benefit side of the return-on-investment (ROI) equation contains a broader set of factors than is the case with a fixed technology frontier. Investing when the new technology is working its way into the industry production structure can provide critical value by helping the individual company establish differentiation and/or remain cost competitive. There are also multi-layered benefits deriving from an improved production cost / product quality picture as well as the increased productivity of capital.
7. The potential costs of a new technology investment include additional considerations beyond traditional measures. Among the broader set of cost factors to consider are the potential risks associated with investing in an evolving technology and implementation impacts on the supply chain.

Abstract

This article considers the appropriate decision framework for corporate capital investment projects when the technologies are new to the company or new to the world. I use an overview of the known drivers of capital investment and an exploration of the significant differences in motivation and framework between ordinary capital investment and new technology investment to form a decision-making flow chart for both capital investment and new technology investment.

I find that in the case of new technology investment, the cost side of the return-on-investment equation contains a larger and broader set of factors than is the case with a fixed technology frontier, under which all technologies are known as previously employed capital. But the benefits of a new technology investment are potentially as broad as the costs. In essence, the diffusion implications of the cost-benefit balance for new technology investment depend on corporate decision-maker flexibility regarding the payback period of the investment and an adjustment to the propensity to take a wait-and-see posture toward purchase and implementation.

Section 1

Introduction: Confronting an Expanded Technology Frontier

This is the third and final paper of a MAPI Foundation [research series](#) on manufacturing productivity performance. In the [first paper](#), I used industry-level data to consider the broad U.S. manufacturing productivity evolution of recent decades and revealed the results of a statistical analysis that was intended to identify and quantify the macro drivers of manufacturing productivity growth on an industry level. The [second paper](#) analyzed the results of a national survey of manufacturers that was designed to gauge automation investment activity as well as plans for investment and to identify the primary drivers of the U.S. manufacturing automation dynamic.

This final report considers a decision challenge faced by manufacturing executives at this time of rapid technological advancement and disruptive process innovation. The ever-changing global business environment already burdens manufacturing enterprise executives with increasing complexity in their business investment decision making. Classic decision paradigms must be applied with nuance to the vagaries of multi-country investment decisions. Increasingly, with a growing set of new technologies available for use in

manufacturing supply chains, executives are also confronted with the need to evaluate the investment returns of implementing technologies that are certainly new to their company and often new to the world.

The purpose of this article is to consider whether state-of-the-art business decision tools such as the return-on-investment (ROI) metric logically apply when technological frontiers are expanding. In the next section, I outline the many challenges surrounding equipment investment decisions on the corporate level and provide an overview of the basic economic theory that identifies investment drivers. I then briefly discuss ROI as a tool for investment decision making. Subsequently, I consider the unique problems of new technology investment and identify a very different set of drivers from the case of a fixed technological frontier, leveraging results from the [second paper](#) in this research series. From this, I offer two decision schematics, one for the case of ordinary capital investment and one for new technology purchase and implementation. I conclude with a discussion of the technology diffusion implications of my proposed decision framework for new technology investment.

Section 2

The Challenges and Drivers of Corporate Equipment Investment

At a given point in time, a company chooses to employ a certain volume of capital assets with which to generate revenues and profits. But the framework is not static. The often unpredictable dynamics of the business climate force a constant rethinking of the desired capital stock. Economic conditions evolve. Political and policy conditions change. Atypical weather events and natural disasters occur. Investment, by definition, is the process of adjusting the actual capital stock to the desired capital stock as the latter shifts with shifting conditions.

Objectively speaking, what is the *optimal* capital stock for a given company at a given time? This is the question that business executives confront almost daily, particularly in the increasingly capital-intensive, rapidly globalizing manufacturing sector. Why is this such a complex question? Consider the many variables that enter into consideration of the optimal capital stock for any company. They include the economic outlook, current and future demand for the company's output, changing industry conditions, and policy and market variables (taxes, regulations, interest rates, the state of technological advancement, etc.). Assessing many of these variables requires engaging in the error-prone process of developing a forecast.

Amidst the haze of business investment decision making, what have emerged as the known drivers of capital spending? Economists have attempted to model and estimate business fixed investment with varying degrees of success. While a unified framework still eludes economic theory, well-established schools of thought that have remained in the economics literature for decades provide useful insights into an area of economic activity that has been especially weak since about 2000.

The accelerator model of investment derives from the simple principle that a company desires a fixed capital/output ratio. In this school of thought, investment responds primarily to output changes. If a company's output is growing, then its investment demand will be growing in some fixed proportion. More sophisticated work has modified the accelerator model to account for the notion that the gap between actual and desired capital stock is bridged over multiple periods, not all at once.

The neoclassical paradigm of investment is straightforward. Economic theory states that investment behavior should depend on the cost of obtaining and using capital as well as the stream of revenue that a firm expects to earn from an addition to its capital

stock. Professor Dale Jorgenson of Harvard showed that the solution to what is essentially a dynamic maximization problem could be reduced to a sequence of static conditions in which firms at every moment attempt to set the productivity of labor equal to the wage and the productivity of capital equal to the real user cost of capital. It should be noted that this neoclassical framework provides a benchmark by solving for the optimal path of capital in the absence of uncertainty or adjustment costs, both of which complicate any company's understanding of its optimal capital stock.

Nobel prize-winning economist James Tobin offered an alternative paradigm that is in some ways a derivative of neoclassical theory. He argued that the rate of investment, the speed at which companies wish to adjust their capital stock, should be a function of the value of capital relative to its replacement cost. The ratio of the value of capital relative to capital's replacement cost is " q ." Tobin argued that if q is greater than 1, the firm has an incentive to invest.

“ The accelerator model of investment derives from the simple principle that a company desires a fixed capital/output ratio ”

These major schools of thought highlight the importance of several drivers of capital investment demand, including the output of the company's goods and services, the cost of

capital (generally defined as a weighted average of the cost of equity and debt financing of capital), the expected revenue from the use of capital assets, and the market value of capital.

Section 3

ROI as a Central Tool for Project Evaluation

Return on investment has long been the central paradigm for business evaluation of capital investment projects as well as for many other decisions. In a basic sense, ROI analysis is used to measure the efficiency of an investment or to compare the efficiency of a number of different investments. To calculate ROI, the net benefit of an investment is divided by the net cost:

$R(Est) = (B(Est) - C(Est)) / C(Est)$ where:

B(Est)=Benefits expected from project implementation over a given period of time

C(Est)=Financial and nonfinancial costs of project implementation

The advantage of the ROI tool is its conceptual simplicity, which allows for easy comparisons between and among investment projects.

The challenges and the drawbacks relate to the considerable difficulty of estimating benefits and costs. Even small errors, which can certainly be expected when forecasting a range of costs and benefits, can have large implications for project assessment.

Section 4

The Unique Challenges and Complex Drivers of New Technology Investment

Standard capital investment analysis and the standard use of the ROI project decision tool assume that the technological frontier is fixed. Technology is, in essence, a known quantity. By contrast, in the case where decisions are being made on the purchase and implementation of technologies that are new to the company and often new to the world, the purpose of investment is often different and the knowledge framework of the investing company is *certainly* different.

New technology investment is unlikely to be a reaction to changes in the reality or the expectations for the short-term economic environment. There is a larger and more complex set of factors at work related in part to changing fundamental cost pressures, other types of globalization market pressures, and industry-specific conditions. And, as noted in literature, the temporal geometry of decision making is different. At any point in time, the choice being made is often not a choice between adopting and not adopting but rather

between adopting now and deferring the decision until later. This is because the benefits from adopting a new technology are received throughout the life of the investment while the costs are up-front and generally unrecoverable. Such a decision space creates an option value to waiting.¹

Paradoxically, while incentives for investment are more complex when the technology is new, the knowledge base of the investor is diminished. There is less of a track record on the technology in question. There is less of an understanding of the likely implementation path of the new technology through the company's supply chain and its industry sector. The company, in short, faces a broader set of unknowns and risks with new technologies than with established technologies.

The aggregate result of these very different decision factors for new technology investment is the "S" curve as an apt descriptor of new technology diffusion. When the number of users of a new product or invention is plotted

1. See, for example, Bronwyn H. Hall and Beethika Khan, "Adoption of New Technology," *New Economy Handbook*, November 2002.

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against time, it has been observed that the resulting curve is S-shaped. Generally, this is because adoption is slow at first, accelerates as it spreads throughout the pool of potential adopters, and then slows as the relevant population becomes saturated.

Automation investment is one case of new technologies being implemented and used in a way that is distinct from capital investment. The survey data from the [second paper](#) in this productivity research series are useful for illuminating the drivers and incentives of new technology decision making. Questions were asked about the drivers of automation

investment. Among the top five were “use by competitors,” “use by customers,” and “use by suppliers,” suggesting something of a network effect that can at least partially account for the rapid spreading of automation investment revealed by the survey. High among the reasons for *not* engaging in automation investment was the inability of mostly smaller manufacturers to clear an ROI hurdle. It was difficult for a number of smaller company respondents to justify the high financial and nonfinancial up-front costs. And in terms of technology performance evaluation, the lowering of production costs and improvement in product quality were the dominant performance criteria.

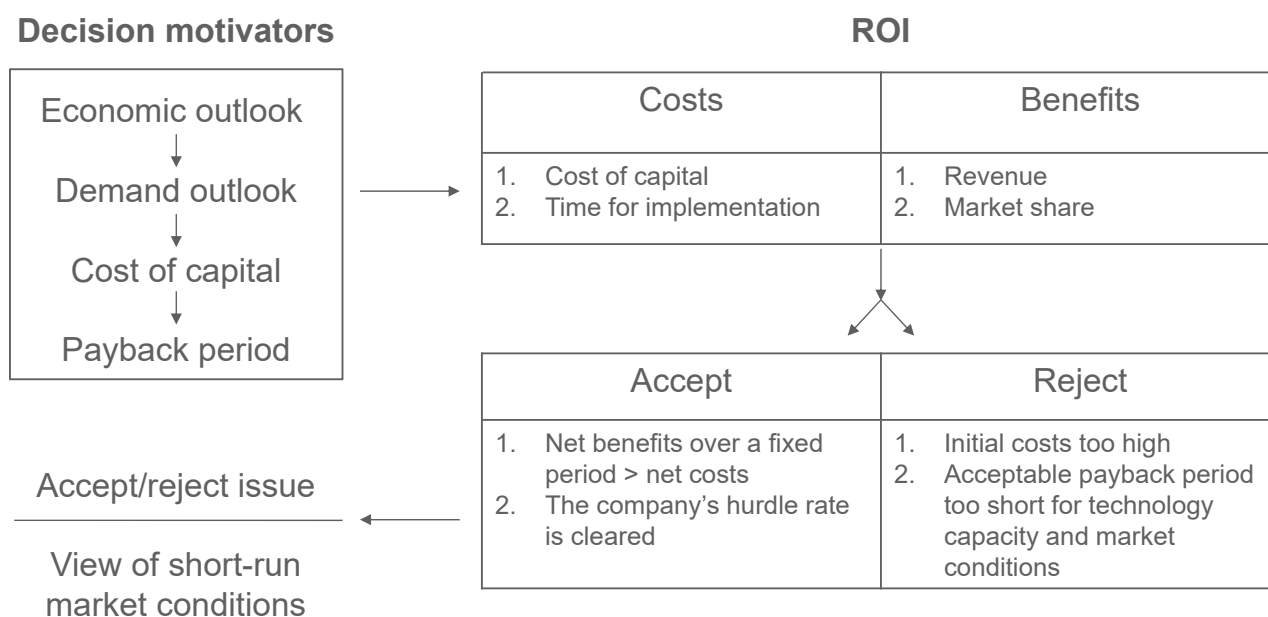
Section 5

The Decision Flow: A Known Technology Scenario Versus the Case of New Technology Investment

In many ways, new technology adoption is a complete break from the accelerator model of investment. Potential users might see the benefits as *changing* the productivity of capital or the capital/output ratio. Figures 1 and 2 show a decision schematic for capital investment projects. Figure 1 does so for a fixed technology scenario, while Figure 2 considers the case of new technology investment. Both are based in well-accepted theory and the logic discussed in this article.

As shown in Figure 1, the drivers of capital spending under a fixed technology scenario are short-term economic dynamics, primarily the economic and product demand outlook, the cost of capital, and the desired payback period for the new capital asset(s). These drivers feed into an ROI metric where the key costs are the financial cost of capital and the time cost of capital asset implementation, the latter being a relatively straightforward matter under a

Figure 1 – ROI for a Fixed Technology Frontier



Source(s): MAPI Foundation

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scenario where technology does not change. The benefit side of the equation consists of the revenues generated by new capital assets and the maintenance or the increase in market share.

Acceptance of the project under the constant technology scenario would occur if the net benefits over a desired period are greater than the net costs. Rejection might come from too high initial costs of capital and implementation and too short of an acceptable payback period for the capital asset. Key issues for the accept/reject decision line come simply from shifting views of short-term market conditions.

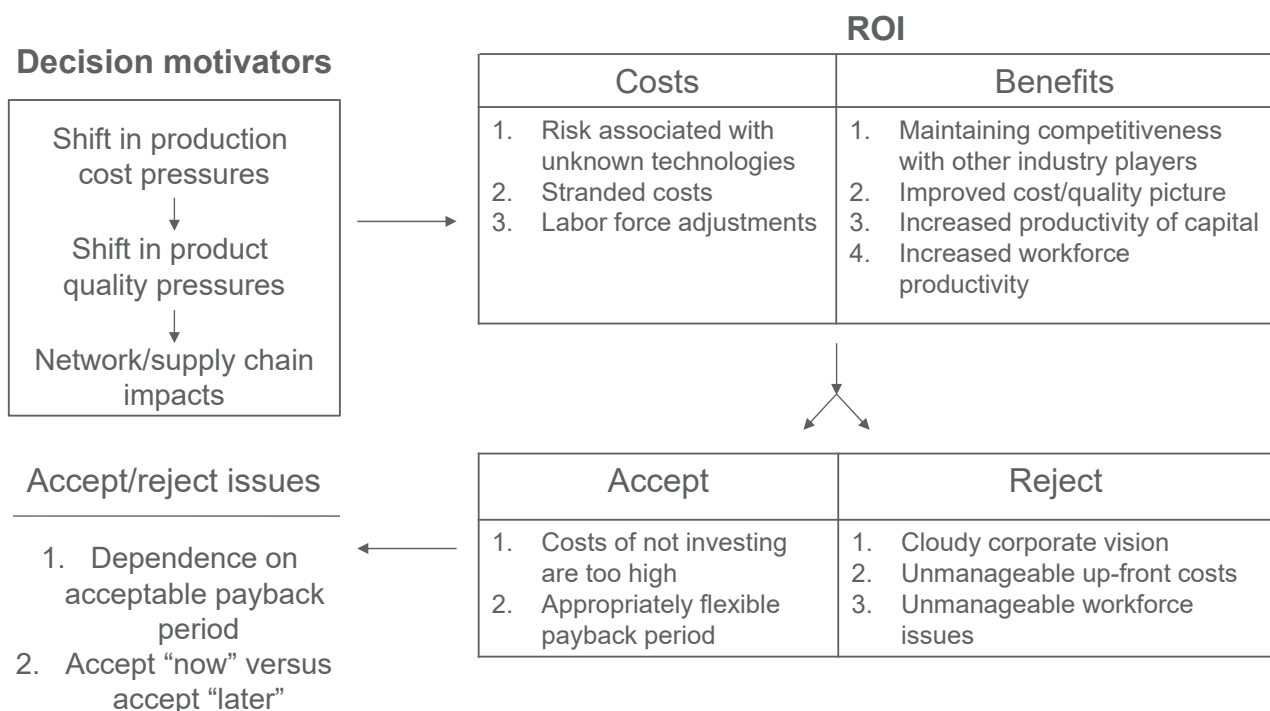
Figure 2 shows a parallel schematic for the case of investment in technologies that are new to the company and often new to the world. As discussed, the drivers of new technology investment aren't short-term shifts in market conditions but rather long-term changes in business pressures, well evidenced by the automation survey data from the [second paper](#) in this series. Such factors include marked changes in production cost pressures and product quality pressures as well as the

spreading of the new technology through the industry and/or supply chain.

With new technology investment, the cost side of the ROI equation contains a larger and broader set of factors than is the case with a fixed technology frontier. They include a set of risks associated with a technology for which there is below-average knowledge regarding capabilities. And the supply chain transformations that are needed for incorporation of the new technology amplify the unknown. These include the unrecoverable stranded costs of old technologies that must be discarded as production adapts to a new technology as well as the often difficult labor force adjustments that are needed in the wake of a technological shock to production.

But, as the schematic shows, the benefits of a new technology investment are potentially as broad as the costs. First, the failure to invest when the technology is working its way into the industry production structure would mean potentially large opportunity costs of not being fully competitive. Thus, investment of the technology in question has the

Figure 2 – ROI for an Expanding Technology Frontier



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benefit of competitive parity. There are also the broad benefits of an improved production cost / product quality picture as well as the increased productivity of capital and the potential increase in workforce productivity over time.

While the accept/reject function is complex, it is certainly the case that if the costs of *not* investing in the new technology are too high and if the company has an appropriately flexible concept of the “acceptable” payback period for the new capital asset, then the impetus for acceptance is strong. Rejection might come from uncertainty over the long-run path of the

company itself, which would certainly cloud the complex decision over a new technology investment. Or rejection might come more fundamentally from unmanageable initial capital and implementation costs or workforce issues deemed to be insurmountable, at least at the time of the decision.

There are two primary accept/reject issues for the new technology decision paradigm. The first is the company’s flexibility on the payback period for recouping the initial investment costs. Also at issue is the option of waiting and making a strategic decision about when, not if, to invest.

Section 6

Conclusions: Impact of a Modified ROI

Will a modified ROI for new technology investment have significant diffusion impacts? On one side, there are additional risks associated with any relatively untested technology and with the stranded costs of old technologies that may be unrecoverable as a new production paradigm, often associated with a new technology, takes hold. Labor force adjustments, which can be especially stressful for smaller companies that are generally less competitive in skilled labor markets than larger ones, are an additional cost consideration.

Nonetheless, the potential additional value from the benefit side is compelling. While early adopters can establish differentiation, the often observed spreading effect of new technologies means that eventually most companies will likely need to engage in the implementation of the increasingly used new technology to maintain production cost competitiveness. For

the holdouts there is certainly a wait-and-see option. But with successful new technologies, waiting might become increasingly costly. The more direct quantifiable benefits are potential improvements in the productivity of capital, product quality, and supply chain efficiency, to name a few.

In essence, the implications of the cost-benefit balance for new technology diffusion depend on corporate flexibility regarding the payback period for the investment and an adjustment to the propensity to take a wait-and-see posture toward purchase and implementation. If periods of disruptive process innovation motivate corporate decision makers to implement a broader approach to their assessment of new technologies, then diffusion for many new technologies could be more dynamic than most expect.



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