A Systems Thinking Perspective on
A Manufacturing Base Restoration Initiative

June 14, 2002

(revised 7/23/02)

Bob Powell, Ph.D., MBA
Continuous Improvement Associates
6992 Blackhawk Place
Colorado Springs, CO 80919
Phone (719) 599-0977
Fax (719) 599-0564
E-mail: scuba@usa.net

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[1] 7/23/02 – For those who have the original version: This draft revises the section on "Barriers to improvement":

First, there was a typo in the first draft: the link in R1, Productivity Investment, between "throughput pressure" and "effort allocated to improvement program" should have been labeled with an "O" not an "S" for this loop. In the earlier diagram, labeled correctly, the Productivity Investment loop is valid.

However, second, a fundamental change is made is to show two different central loops in the model. There is a loop for which the above-mentioned link is an "S." Instead of showing a loop, R1, Productivity Investment, and a loop, B2, Effort Squeeze, the model now shows loop B1, Working Smarter, and loop, R2, Effort Squeeze.

These two central loops are not as shown in "Overcoming the Improvement Paradox," however the primary loop B1, "Work Smarter" is more fundamental to the dynamics being discussed: long-term improvement to reach "target throughput." Also, B1 shows the impact of "effort allocated to improvement program" on "process problems & defects," rather than on "productivity improvement," which is a result of less "process problems & defects." All the loops correspond to loops in other papers by Repenning & Sterman "Capability Traps and Self-confirming Attribution Errors in the Dynamics of Process Improvement"(2002) and "Nobody Ever Gets Credit for Fixing Problems that Never Happened: Creating and Sustaining Process Improvement," (2000). Download them at http://web.mit.edu/nelsonr/www/. Send e-mail for an analysis of the parallels.

A Systems Thinking Perspective on
A Manufacturing Base Restoration Initiative

Overview

Specific comments on Rocky Scott e-mail:
Subject: Manufacturing in Colorado Springs - A Community Challenge, May 15, 2002

- Essentially, we'd better get with the program. Not only do our companies and our community depend on restoring the manufacturing base, our national economic vitality and quality of life depend on doing so.

How to improve: The Exponential Improvement Technique for Manufacturing and Engineering

- The only way to make manufacturing competitive and keep it in the U.S. is to get down the learning curve as quickly as possible in manufacturing … and in engineering![2] We must learn faster than our competitors. We must win by working smarter, instead of by working harder.[3]
- The way to do this is using the half-life technique that I call exponential improvement. It is much faster than learning that depends on cumulative volume. There are very few "sure things" in the world, but this is one of them.
- Without the most rapid learning possible, the U.S. will continue to lose manufacturing jobs to out-of-country locations with much lower-cost labor.

Why it's important: Interactions between Manufacturing and Engineering

- While we typically consider engineering and manufacturing separately, they are tightly coupled. Feedback from each can help the other learn.
- Engineering processes are, however, more difficult to improve because they are more complex than manufacturing processes. Because of this, they are subject to increased pressures that can cause them to fail.
- An improvement paradox: As manufacturing gets more efficient it produces idle production capacity that creates pressure for layoffs, and layoffs kill enthusiasm for improvement. It also puts pressure on engineering for more products to utilize the idle capacity, so engineering doesn't have time for improvement. Because of the tight coupling between engineering and production, it's possible a company can collapse financially if the focus is primarily on manufacturing improvement without carefully considering other system policies and effects.
- It may be that the most important way to improve manufacturing, and the company as a whole, is to improve engineering processes to more efficiently "fill the factory", keep assets working and keep indirect, as well as direct, costs low.

Why innovation alone isn't enough: Profiting from Technological Innovation

- The more easily innovations can be imitated, the more an innovating firm risks ceding a significant share of the returns from innovation to customers, imitators and owners of complementary assets (e.g., manufacturing). To prevent this, the innovating firm itself must focus on protectable innovations, focus on products /services for which the necessary complementary assets are already under its control, or establish appropriate plans for contracting/leasing or integrating the necessary complementary assets. As will be also seen in the next section, managers must become adept in understanding their organizations and markets as dynamic systems.

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[2] Why is explained in the section on Interactions between Engineering Design & Manufacturing.
[3] Quality initiatives do not only increase quality, they also reduce costs. Quality and cost are "trade-ons" not "trade-offs."

- For the same reasons that control of complementary assets, such as manufacturing, are important to companies, they also matter to innovating nations. In regions of weak appropriability, innovating firms without the requisite manufacturing and other specialized capabilities may fail and, similarly, innovating nations may allow competing nations to capture the lion's share of the profits from the innovation.

Barriers to improvement: Challenges That Must Be Met and Overcome

- Processes exist within the context of a system. While the root causes of process problems are most often independent and can be considered and corrected separately, this is not the case for systems problems. For systems, the "root causes" of our messes (set of problems) are feedback loops. This section describes many of the root causes of improvement initiative failures.
- The greater the scope of an improvement initiative (and the scope of a manufacturing base restoration initiative would be quite large), the less effective are improvement efforts. In addition, the organizational complexity of such an initiative would cause it to have quite a long half-life (on the order of five or so years, if not longer). The ability to set realistic goals is critical for success, as is an ability to cope with the feedbacks that cause complex, long-term improvement initiative failures. As Sterman writes, " … managers must become adept in understanding their organization as a dynamic system."[4]

What's driving the loss of manufacturing: The Economic Environment and National Economic Policy

- A manufacturing base restoration initiative would exist in the context of a national and world economy. The forces driving manufacturing out of the U.S. are already enormous and will likely increase considering government policies and the tendency of companies to take the "low road" of low wage labor instead of the "high road" of more highly paid "value-added" labor.
- These are powerful forces, the only hope I see to oppose them is to work a great deal smarter than competing nations. And the only hope I see for that is to use exponential improvement, and become adept in understanding our organizations and economies as dynamic systems to develop more effective policies with a long-term focus.

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[4] Elizabeth K. Keating, Rogelio Oliva, Nelson P. Repenning, Scott Rockart, and John D. Sterman, " Overcoming the Improvement Paradox," *European Management Journal*, Vol. 17, No. 2, 1999, pp. 120-134, http://web.mit.edu/jsterman/www/

Specific comments on Rocky Scott e-mail:
Subject: Manufacturing in Colorado Springs - A Community Challenge, May 15, 2002

[See comments at the ◆ bullets.]

From: Rocky Scott
To: Will Temby, George Kreigler - Quantum, Joe Rallo - CU-CS
Subject: Manufacturing in Colorado Springs - A Community Challenge
Date: Wed, 15 May 2002 14:23:30 -0600

The following originated in a conversation George and I had over lunch this week. Subsequent brief discussions on the subject with Joe Rallo and Will Temby have led to this email, as promised.

This summary is provided for your review and comment.

Situation:

1. Colorado Springs has lost over 4000 manufacturing jobs in the last year. The multiplier effect has resulted in probable total related job losses exceeding 12,000.

2. Most of those manufacturing jobs will not be coming back (Quantum, Agilent, LSI Logic, Rockshox....)

3. Manufacturing offers a community a high multiplier (many vendors and suppliers have been badly hurt), higher than average wages, and a tax base that disproportionately supports community needs (Gallagher ratio, etc.)

4. The world has changed in many ways. Future U. S. manufacturing won't look like current/past U. S./Colorado Springs manufacturing.

Conclusions:

1. It's not OK to leave this gaping, and growing, hole in the economy, i. e. to not work proactively to restore our manufacturing base.

- ◆ This is a serious national problem (see the AP Stories attached). A national policy of high real interest rates has produced a strong dollar that magnifies low wage effects to make U.S. manufacturing noncompetitive.

2. A community response requires an understanding of legitimate future manufacturing opportunities and a restructuring of community capacity to take advantage of those opportunities. That understanding includes the following:

A. We can't compete in the manufacturing of commodities (mature tape drives, e.g.). That manufacturing will be done in areas with low labor costs-mostly overseas. Therefore we must compete in the product phase which provides higher margins, i.e. early in the product cycle.

- ◆ It is true we must be better at competing early in the product cycle. But, unless companies have an iron lock on the intellectual property behind the product, the returns from the innovation are at risk. "Innovators must turn to business strategy if they are to keep imitators/followers at bay."[5] To get the returns from innovation, companies and countries must control the required complementary specialized assets, which can include manufacturing. If innovations are not completely protectable, companies must develop business strategies for how to acquire the necessary complementary assets. If the required assets are generic, the less the innovation is protectable, the less likely the innovation will yield returns to the innovator. Business strategy consideration would include directing innovation to areas that are protectable, and to the extent they are not, assuring control of the needed complementary assets. See the section on Profiting from Technological Innovation.

B. Successful manufacturing requires a very close link between design and manufacturing functions. Geographic separation of the two functions puts the enterprise at risk.

- ◆ Yes, because it makes learning more difficult. See the Sections on Interactions between Engineering Design & Manufacturing - Combined Exponential Improvement and Overcoming "The Quality Improvement Paradox".

[5] David J. Teece, "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy, Research Policy, 15 (1986), p. 285-305

C. We must strive to maximize returns on investment of time, talent and money in product manufacturing which means developing capacity to:

- innovate (university role)
- start up new enterprises (venture capital/university role)

◆ The CITTI diagram describes the feedback loops that could be nurtured.

- design (talent attraction and aggregation)

◆ An initiative could identify and engage the large number of unemployed and underemployed technical and managerial personnel in the area and connect them with opportunities. At the time of our work in Nov. 94, registrants at the Colorado Springs Job Service in the professional, technical, and managerial (PTM) category were 31% of the total registrants (which was 8,497 people). I thought to ask a few months ago and it turns out that the workforce center has changed its database and it is no longer possible to track this statistic.

- manufacture (capital investment, talent attraction and aggregation)
  - sustain the manufacturing base through agility in response to markets, i.e. rapid reskilling response for workers who are displaced by weakening markets in one sector to allow them to transition effectively into markets that are emerging/growing (instrumentation, storage devices, medical equipment, etc.)

Next steps:

1. Convene a focus group/workshop of leaders in the industry that can provide guidance on the thesis provided above and recommend a course of action.

◆ Consider using the Facilitating Group Action process to efficiently gather a broad spectrum of high-quality ideas and achieve consensus.

◆ Explore with the group many of the concepts in this paper.

2. Engage, in the thesis evaluation effort, partners that would need to be involved in a proactive manufacturing base restoration initiative (university, community college, elected leadership.....)

◆ Identify solid support for an implementation plan, including funding and project management support to track and report progress. A manufacturing base restoration initiative would be a complex and difficult undertaking; if adequate support isn't available, it may be best to not even try.

◆ A workshop could be around identifying problems, causes and actions, understanding that for systems problems (such as this), "causes" are most often feedback loops, not "simple causes" (separable and independent). Models that would be useful in thinking about these problems could be
  - Economic clusters model
  - CITTI model
  - Workforce system model
  - Innovation model (see section on Profiting from Technological Innovation)
  - Manufacturing & Federal Reserve policy model (see section on National Economic Policy).

◆ Obviously, such an initiative needs a funded (incentivized?) entity whose memory is longer than the memory of the individual firm and whose perspective is much broader. A university could fill this role, however a lack of resources and organizational inertia may cause universities to be so bound to what they have been teaching that it's difficult to add needed capabilities, perspectives, and approaches (e.g., systems thinking and system dynamics).

◆ An initiative could address barriers, such as:
  - Some say that all we need is great innovation and do not understand that manufacturing can be necessary for reaping the returns from innovation.
  - Manufacturing is not respected. One manufacturing client says that, while manufacturing engineers in the U.S. have relatively lower status and pay, in Japan it's the opposite. The perceived low of status manufacturing engineers may perpetuate a self-fulfilling prophecy, preventing the U.S. from being better at it.
  - Some may perceive that manufacturing is already a "lost cause"
  - There can be logical resistance from current manufacturers, because they can suffer in the short term when a large manufacturer moves in. While they understand there is a long-term benefit (years or even a decade later), in the short- and medium-term they must cope with higher turnover and wages. Some may even file lawsuits when they lose a large number of employees, who take what they consider to be valuable intellectual property to incoming companies.

How to improve:
The Exponential Improvement Technique for Manufacturing and Engineering

Summary:

The only way to make manufacturing competitive and keep it in the U.S. is to get down the learning curve as quickly as possible in manufacturing … and in engineering![6] We must learn faster than our competitors. We must win by working smarter, instead of by working harder.[7]

The way to do this is using the half-life technique that I call exponential improvement. It is much faster than learning that depends on cumulative volume. There are very few "sure things" in the world, but this is one of them.

Without the most rapid learning possible, the U.S. will continue to lose manufacturing jobs to out-of-country locations with much lower-cost labor.

Figure 1. Manufacturing Improvement Feedback

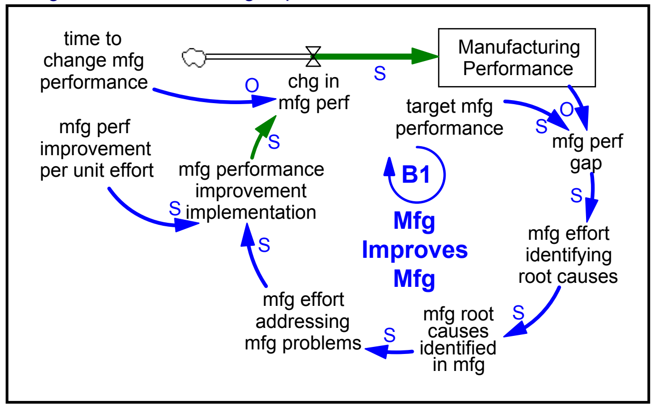
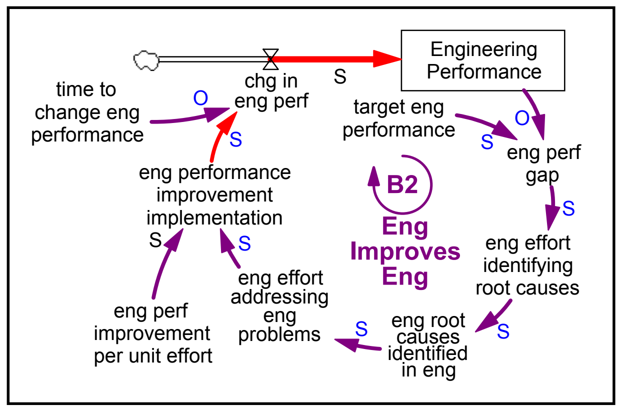


Figure 2: Engineering Improvement Feedback



Exponential Improvement:

An emphasis on exponential improvement in manufacturing is necessary for the most rapid learning. It allows an organization to agree on targets for *how much* improvement to expect and *how long* it will take. It sets up a tracking system that allows the team and management to *monitor that improvement is on schedule*. This tells us when most of the potential improvement has been achieved and *when it's time to focus our efforts on another process*. It also gives management a logical rationale for creating appropriate team rewards.[8]

This approach sees learning as a function of time, independent of cumulative volume. The learning feedback process for manufacturing is shown in Figure 1.[9] This is dynamic is driven by TQM initiatives. The same structure applies to engineering improvement (Figure 2).

An improvement initiative that is truly continuous gives exponential improvement with an improvement "half-life" that increases with organizational and technical complexity (Figure 3).[10]

Figure 3: Half-life Matrix

Matrix Half-life (months)		Organizational Complexity: Low	Organizational Complexity: Med	Organizational Complexity: High
Technical Complexity	Low	1	7	14
Technical Complexity	Med	3	9	18
Technical Complexity	High	5	11	22

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[6] Why is explained in the section on Interactions between Engineering Design & Manufacturing.

[7] These are the "high road" and the "low road" described by Bennett Harrison in *Lean and Mean, The Changing Landscape of Corporate Power in the Age of Flexibility*, New York: BasicBooks, 1994. "[T]he "low road" is outsourcing work to companies that use temporary and part-time workers who get low wages and little/no benefits … what British economists Deakin and Wilkinson refer to as a 'low productivity trap' where companies' dependence upon undervalued labor provides a way by which inefficient producers and obsolete technologies can survive and compete. … and the process may become viciously circular … ." p. 212

[8] For more on the exponential improvement method, see the *CIA* paper on Exponential Improvement.

[9] For an explanation of how to read stock & flow and causal loop diagrams, see our *CIA* paper on A Brief Introduction to Systems Diagrams.

[10] Based on a diagram in Sterman, J., Repenning, N., and Kofman, F., "Unanticipated Side Effects of Successful Quality Programs: Exploring a Paradox of Organizational Improvement." http://web.mit.edu/jsterman/www/ADI/ADI.html, 8/94

Figure 4 shows half-lives that can be expected from data at Analog Devices, Inc.[11] Note that organizational complexity produces half-lives almost three times those caused by technical complexity.

Figure 5 shows the "improvement potential." Figure 6 shows the improvement equation and the corresponding structure in the form of a system dynamics stock and flow diagram.

Figure 7 shows the definition of the terms, the solution to the differential equation, and the equation for the half-life, .[12] The reason for the exponential behavior is that the solution to an integral (or differential) equation for a feedback loop is an exponential function. This the only function that can maintain its form around a feedback loop.[13]

A simulation of the stock and flow structure is shown in Figures 8 and 9. As with radioactive decay, the behavior is exponential. Figure 8 shows a plot with a linear vertical scale and Figure 9 shows the same output with a logarithmic vertical scale.

Figure 4: Half-life dependence on technical & organizational complexity

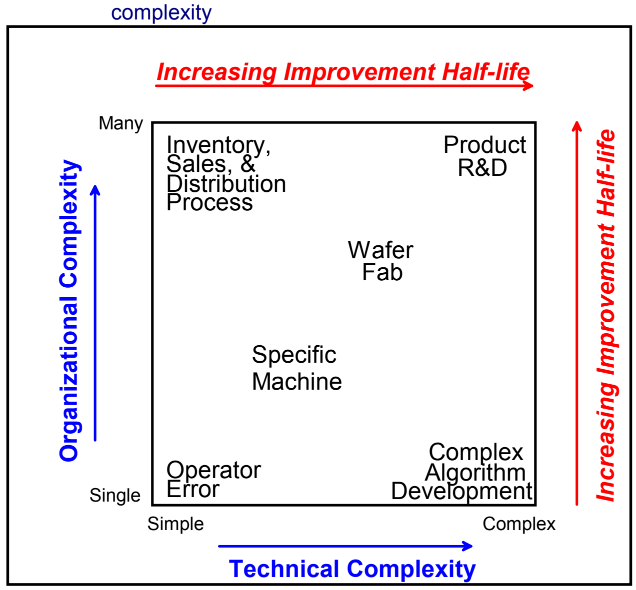


Figure 5: Improvement Potential

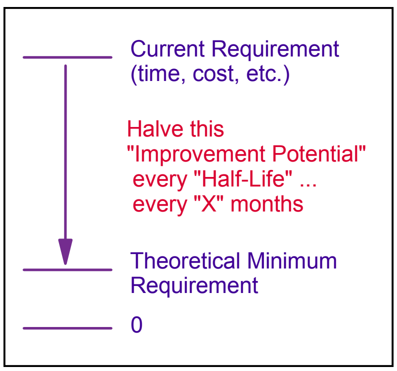


Figure 6 : Equation & Stock & Flow Diagram

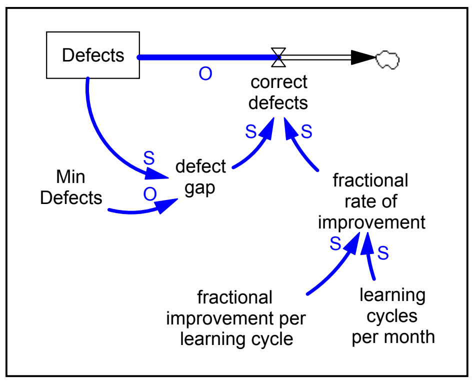


Figure 7: Equation Solution & Half-Life

$$\frac{1}{2} = \frac{D_{t_h} - D_{min}}{D_{t_0} - D_{min}} = e^{-\phi \cdot (t_h - t_0)}$$

where:

D = defects at time, t

D_{t_h} = defects at the half-life, t_h

D_{t_0} = defects at t_0

D_{min} = minimum defects

The half-life is:

$t_h = \ln(2) / \phi$ … where

ϕ = fractional rate of improvement (defects / month)

and $\phi = I * L$ … where

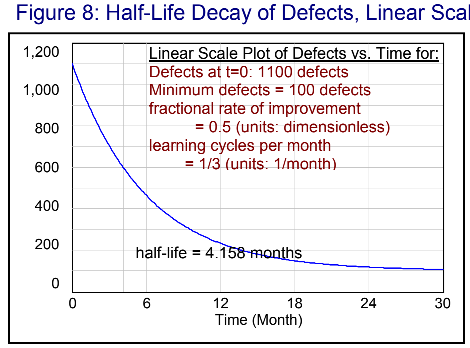
I = fractional improvement / learning cycle

L = learning cycles / month

These simulations use a fractional improvement rate of 0.5 per learning cycle. A 50% improvement per cycle may seem like high, but part of the power of the exponential improvement approach is that, while individual problems are addressed, the main focus is on *categories of problems*. Not only is this more efficient, it allows identification and prevention of problems *like the ones being addressed*, but which have not yet been reported.

However, it is difficult to know in advance the improvement rate per learning cycle. If it were 0.25, then the half-life would be ~ 8.3 months. Therefore, half-life is highly dependent on the resources and attention management gives to an improvement initiative, as well as on the enthusiasm of those who are working to improve the process.

Figure 8: Half-Life Decay of Defects, Linear Scale



[11] Schneiderman, A., "Setting Quality Goals," *Quality* Progress, April, 1988. For experience using this technique at Analog Devices, Inc., see Stata, R., "Organizational Learning --- The Key to Management Innovation," *Sloan Management Review* Vol. 30, No. 3, Spring 1989.

[12] Among the advantages of a system dynamics representation is that it makes the structure more explicit for examination by those with non-technical backgrounds and that the behavior can be determined by simulation for structures for which a closed solution is impossible.

[13] This can include complex exponentials, like sines and cosines.

Figure 10 shows a later, more expansive estimate of half-life for increasing organizational and technical complexity.[14] This diagram shows half-life estimates that are considerably longer.

A manufacturing base restoration initiative could well be expected to fit to ward the top right. However, where possible, dividing an initiative into decoupled sub-initiatives can reduce complexity and result in a lower overall half-life.

Figure 11 shows that this approach does not simply mean to comprehend what's considered to be "typical continuous improvement," that is, incremental improvement of processes "as they are." It includes re-engineering, as necessary, to eliminate problems, cut costs and reduce delays as opportunities are discovered.

Figure 9: Half-Life Decay of Defects, Semi-log Scale

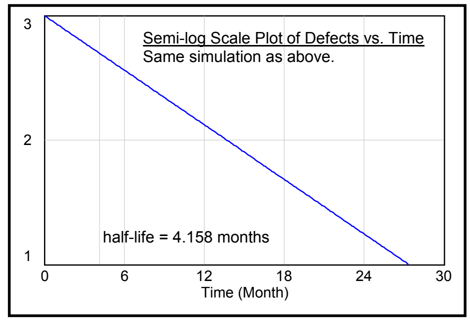


Figure 10: Improvement half-life from "Overcoming the Improvement Paradox"

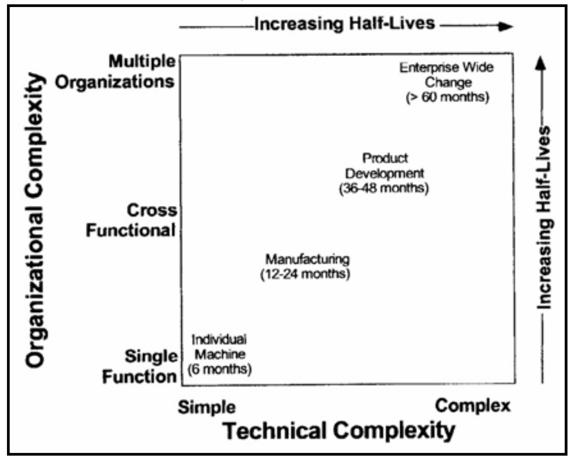
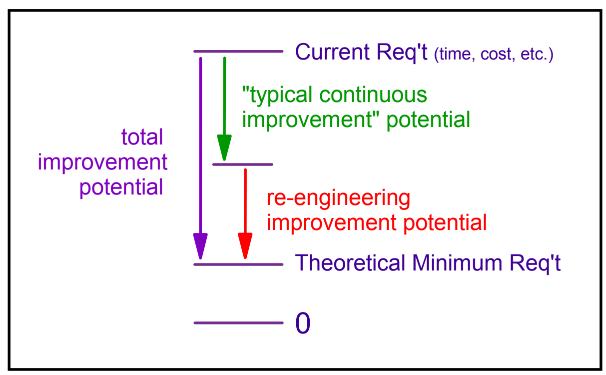


Figure 11: Continuous improvement plus re-engineering



[14] Keating, Oliva, Repenning, Rockart, and Sterman, "Overcoming the Improvement Paradox," *European Management Journal*, Vol 17, No. 2, pp. 120-134, 1999. Also http://web.mit.edu/jsterman/www/.

Interactions between Manufacturing and Engineering: Combined Exponential Improvement & The Quality Improvement Paradox

Summary

While we typically consider engineering and manufacturing separately, they are tightly coupled. Feedback from each can help the other learn.

Engineering processes are, however, more difficult to improve because they are more complex than manufacturing processes. Because of this, they are subject to increased pressures that can cause them to fail.

An improvement paradox: As manufacturing gets more efficient it produces idle production capacity that creates pressure for layoffs, and layoffs kill enthusiasm for improvement. It also puts pressure on engineering for more products to utilize the idle capacity, so engineering doesn't have time for improvement. Because of the tight coupling between engineering and production, it's possible a company can collapse financially if the focus is primarily on manufacturing improvement without carefully considering other system policies and effects.

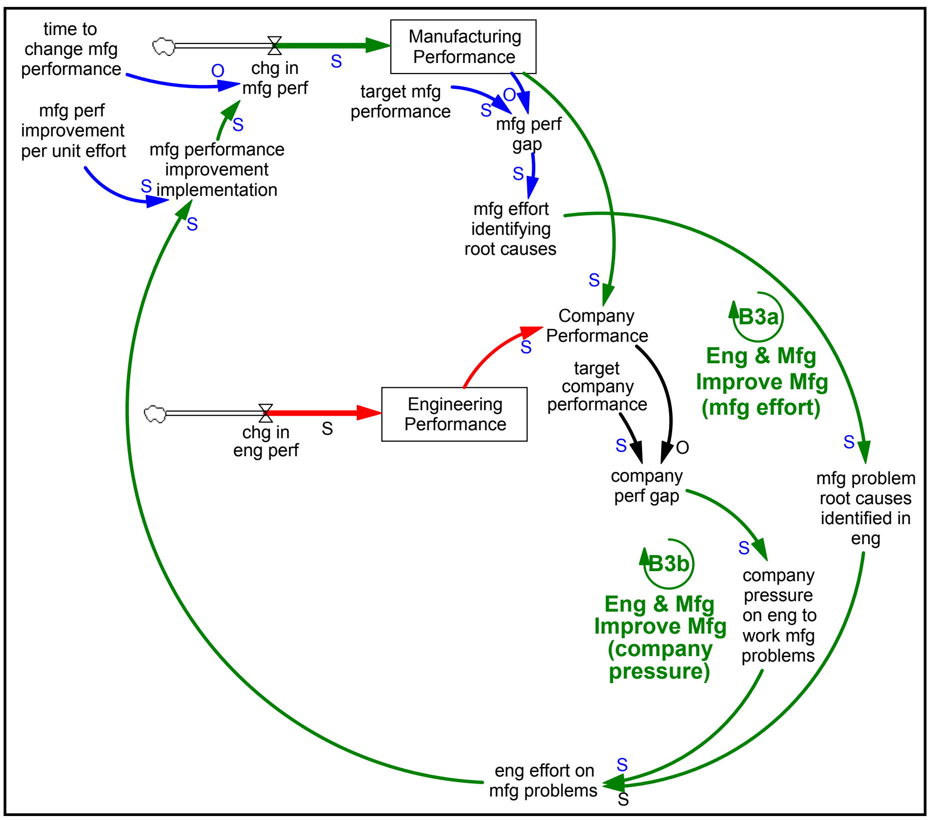
It may be that the most important way to improve manufacturing, and the company as a whole, is to improve engineering processes to more efficiently "fill the factory", keep assets working and keep indirect, as well as direct, costs low.

Synergy between Manufacturing and Engineering

We all know that manufacturing and engineering are not independent. Figures 12 and 13 show the interactions explicitly.

Figure 12 shows that manufacturing identifies some problems with root causes that require engineering effort to resolve (**B3a**). There are problems (or inefficiencies) in manufacturing that require engineering effort to resolve. Engineering effort will be applied if engineering both knows of the problems and feels a need to do something about them. Therefore, if company performance is less than desired, the company can provide engineering with incentives to apply the effort necessary to resolve the manufacturing problems (**B3b**).

Figure 12: Engineering helps improve manufacturing



Doing so requires the company to see the big picture interactions, to have the needed policies, and to provide the needed resources (including the needed time allocation for long-term improvement). If manufacturing is physically far removed from engineering, this will be more difficult, perhaps extremely difficult.

Similarly, Figure 13 shows that engineering identifies some problems with root causes that require manufacturing effort to resolve (**B4a**). If company performance is less than desired, the company can put pressure on manufacturing to apply the effort necessary to resolve the engineering problems (**B4b**).

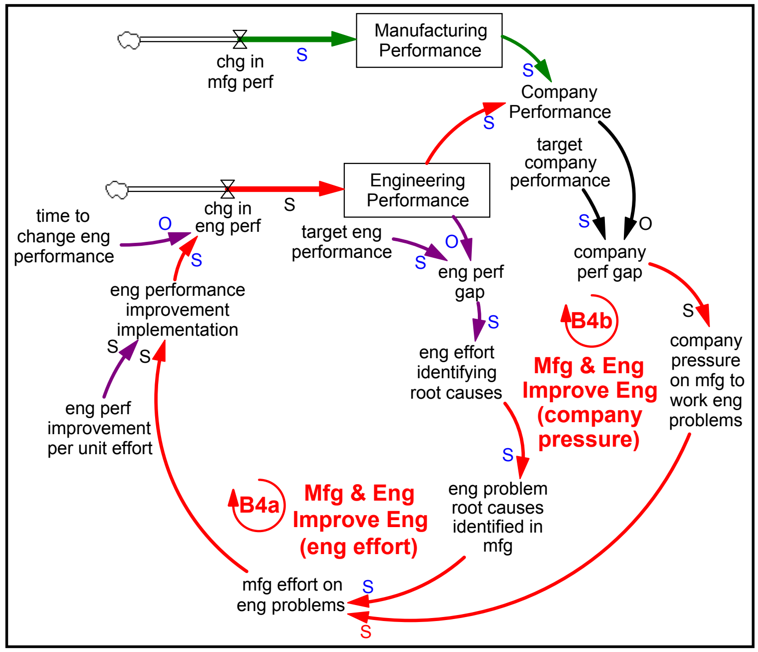
These interactions are

obvious. However, as described in the next subsection, other interactions that are almost surely unanticipated … interactions that might well be described as perverse.

The "Quality Improvement Paradox" - an example of the perversity of systems

An example from a study at Analog Devices, Inc. (ADI) is described by John Sterman, et al., in the paper, "Unanticipated Side Effects of Successful Quality Programs: Exploring a Paradox of Organizational Improvement."[15] From the abstract:

Figure 13: Manufacturing helps improve Engineering

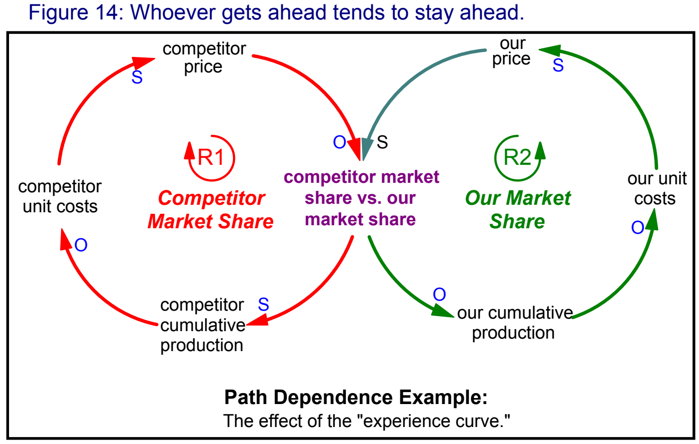


> Recent evidence suggests the connection between quality improvement and financial results may be weak. Consider the case of Analog Devices, Inc., a leading manufacturer of integrated circuits. Analog's TQM program was a dramatic success. Yield doubled, cycle time was cut in half, and product defects fell by a factor of ten. However, financial performance worsened. To explore the apparent paradox we develop a detailed simulation model of Analog, including operations, financial and cost accounting, product development, human resources, the competitive environment, and the financial markets. We used econometric estimation, interviews, observation, and archival data to specify and estimate the model. We find that improvement programs like TQM can present firms with a tradeoff between short and long run effects. In the long run TQM can increase productivity, raise quality, and lower costs. In the short run, these improvements can interact with prevailing accounting systems and organizational routines to create excess capacity, financial stress, and pressures for layoffs that undercut commitment to continuous improvement.

This dynamic caused severe financial stress at ADI.

> In 1985 operating income was $46.6 million. In 1990, during the recession, it fell to $6.2 million. A senior manager estimated that, with its depressed market value, Analog could have been acquired for about three years cash flow from operations.

Figure 14: Whoever gets ahead tends to stay ahead.



The story begins with looking at the share of improvement support and investment in engineering and vs. production. The relevant structure is called "path dependence" in system dynamics and the more descriptive, "success to the successful," in systems thinking. This structure is composed of two interacting positive feedback loops as shown in Figure 14 where each competitor vies for greater market share.

In "Chapter 10: Path Dependence and Positive Feedback" of *Business Dynamics* by John Sterman, he begins:[16]

> *For unto every one that hath shall be given, and he shall have abundance; but from him that hath not shall be taken away even that which he hath. — Matthew XXV:29*
>
> This chapter explores path dependence, a pattern of behavior in which small, random events early in the history of a system determine the ultimate end state, even when all end states are equally likely at the beginning. Path

[15] Sterman, J., Repenning, N., and Kofman, F., "Unanticipated Side Effects of Successful Quality Programs: Exploring a Paradox of Organizational Improvement." http://web.mit.edu/jsterman/www/ADI/ADI.html, 8/94.

[16] John Sterman, Business Dynamics: Systems Thinking and Modeling for a Complex World, Irwin/McGraw-Hill, 2000, p. 349.

dependence arises in systems whose dynamics are dominated by positive feedback processes. The chapter explores the circumstances in which positive feedback can create path dependence, the role of random events early in the history of a path-dependent system, and the ways in which a path-dependent system can lock in to a particular equilibrium. Feedback theories of path dependence and lock in are developed for a number of important examples in business, technology, and economics.

Figure 15 shows that in this case the disequilibrium is not initiated by random disturbance, but by a natural desire of those pursuing TQM initiatives to show early results (to "pick the low-hanging fruit"). This builds enthusiasm for more improvement and prompts additional requests for assistance.

Because of the greater organizational and technical complexity of an engineering process, its half-life (~ 36 months) is longer than that of a production process (~ 12 months). Therefore **R2**, **Improve Production**, yields earlier and better results than **R1**, **Improve Eng'g Design**.

This improvement imbalance results in "excess production capacity" sets off interactions that nearly led to the demise of Analog Devices.

Figure 15: Investment tends toward the side that shows earliest returns

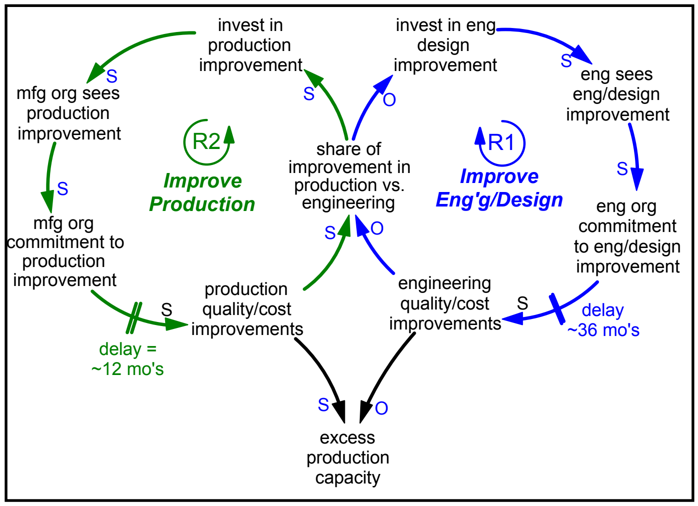


Figure 16 shows that the excess production resulted in production layoffs that reduced the commitment of those in production working on improvement initiatives. **B3**, **We Need Fewer People**, limited production improvement.

B4, **Wall Street Frowns on High Costs**, shows that Wall Street added even more pressure. Analysts saw high fixed costs as reducing income below what it apparently could be.[17]

> Analog's stock price fell as earnings dropped and as investment analysts responded to the rising indirect cost fraction by criticizing what they took to be ADI's apparent lack of cost control. Value Line's reports were typical: "Sales may be difficult to predict, but it is hard to understand why Analog can not cope with this problem by adjusting expenses[18] accordingly."

Figure 16: Investment tends toward the side that shows earliest returns

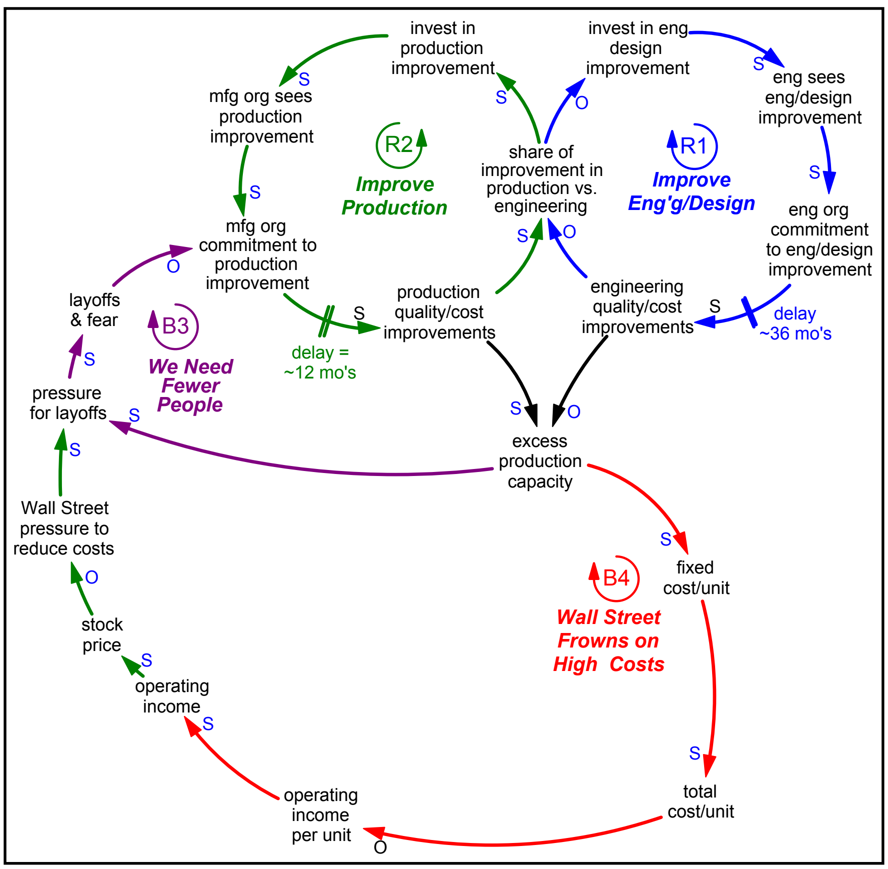
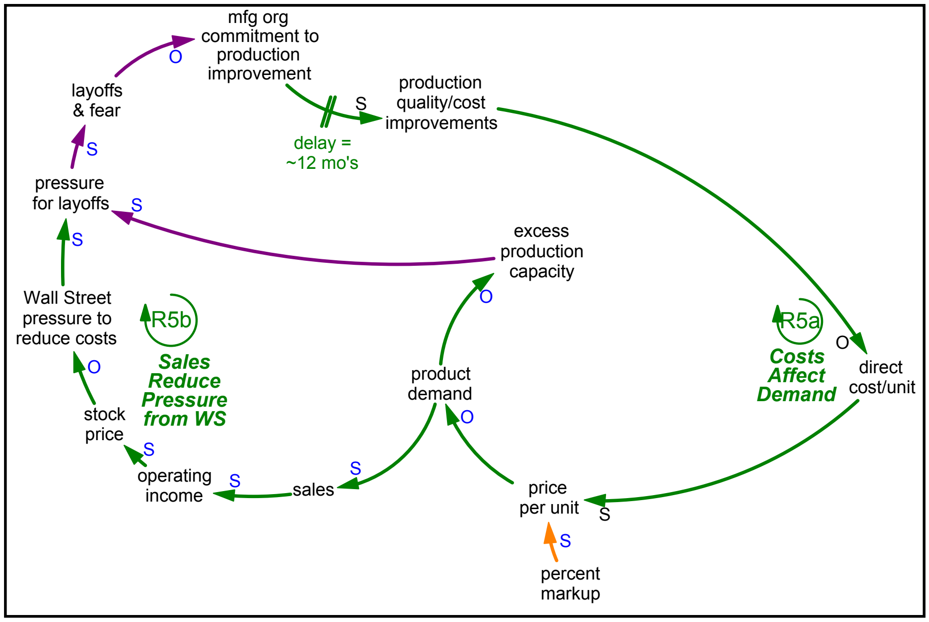


Figure 17 shows that this negative impact could be counteracted by the reduced direct costs resulting from the dramatic cost reductions achieved by the quality improvement initiative. **R5a**, **Costs Affect Demand**, shows

[17] Sterman, et al., "Unanticipated Side Effects of Successful Quality Programs"
[18] This "adjusting expenses" is code for layoffs.

the lower direct costs could increase demand, reduce excess production capacity and decrease pressure for layoffs.

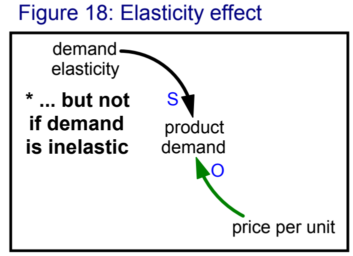
Figure 17: Lower direct costs could create more demand and reduce pressure from Wall Street



Also, **R5b**, **Sales Reduce Pressure from Wall Street**, shows the increased sales would increase "operating income" and make Wall Street happier.

Unfortunately, this did not happen because ADI did not increase market share … competitors were matching ADI's lower prices and making their own improvements ("Analog's competitors were not standing still. TQM knowledge is not privately appropriable.")

Figure 18: Elasticity effect



Also, a 17% average price reduction for ICs in 4 years did not significantly increase demand for the much more expensive equipment in which the ICs were used … demand is a function of price *and* demand elasticity (Figure 18).

Figure 19 in loop **B6**, **Fixed Markup Policy Limits Income**, shows that, because the same percent markup was used to set price as costs fell, "operating income" fell as well. Without a counterbalancing increase in demand to generate more income, pressure increased from Wall Street for layoffs.

Figure 19: Fixed markup reduces price as direct cost falls … but profit drops, too.

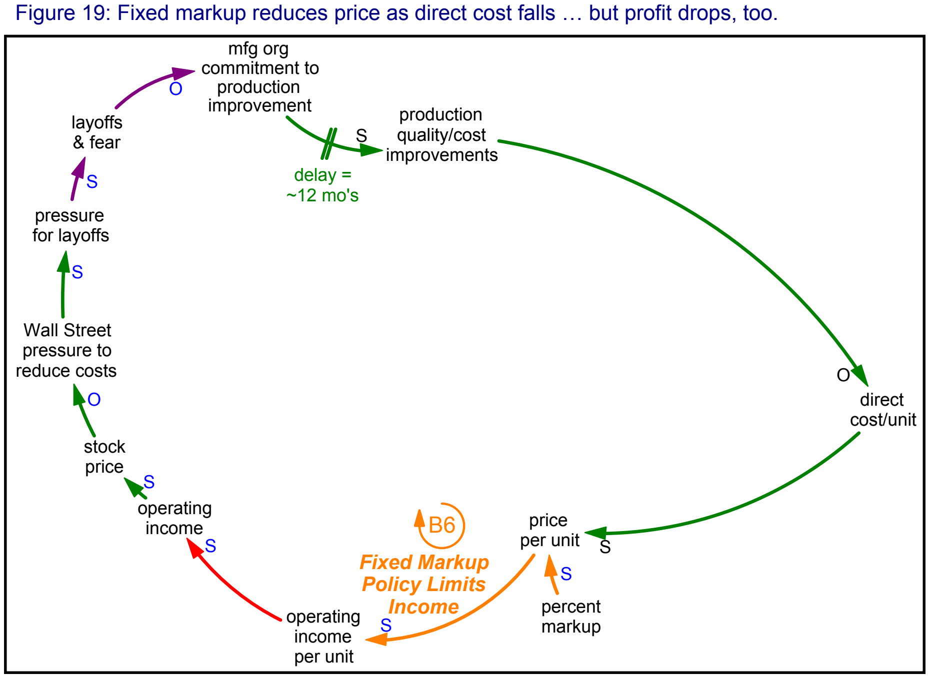
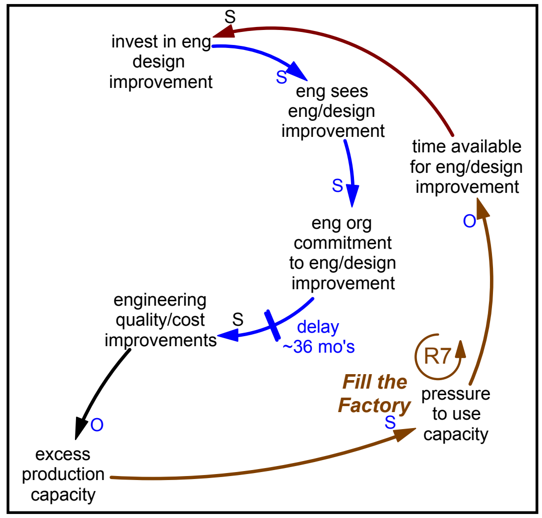


Figure 20 shows (**R7**, **Fill the Factory**) that the hope would be to increase sales by turning out an increased number of new, innovative designs to "fill the factory." However, this increased pressure on engineering to produce more products, so they didn't have time to work on their own improvement initiatives. This further increased the imbalance between engineering and production improvement. And, even if engineering improvements were emphasized, the results would not show up for years.

Figure 21 shows the combined structure. As noted earlier, this is an excellent example of the perversity of systems:

The core of the dilemma is the belief that people will not participate in new programs like TQM unless they can see the benefits right away. On the one hand, academics and practitioners assert that “successful change programs begin with results” (Schaffer and Thomson 1990). Early results are widely advocated to demonstrate the validity of a program, kick-start diffusion and boost the virtuous cycle of commitment and effort (Shiba et al. 1993). On the other hand, a focus on quick results biases decisions against innovations with long time delays and leads to myopic resource allocation. Focusing on early results may lead to excess capacity, financial stress, downsizing and the collapse of commitment to the program. Improvement programs can fail not in spite, but precisely because of their early success.

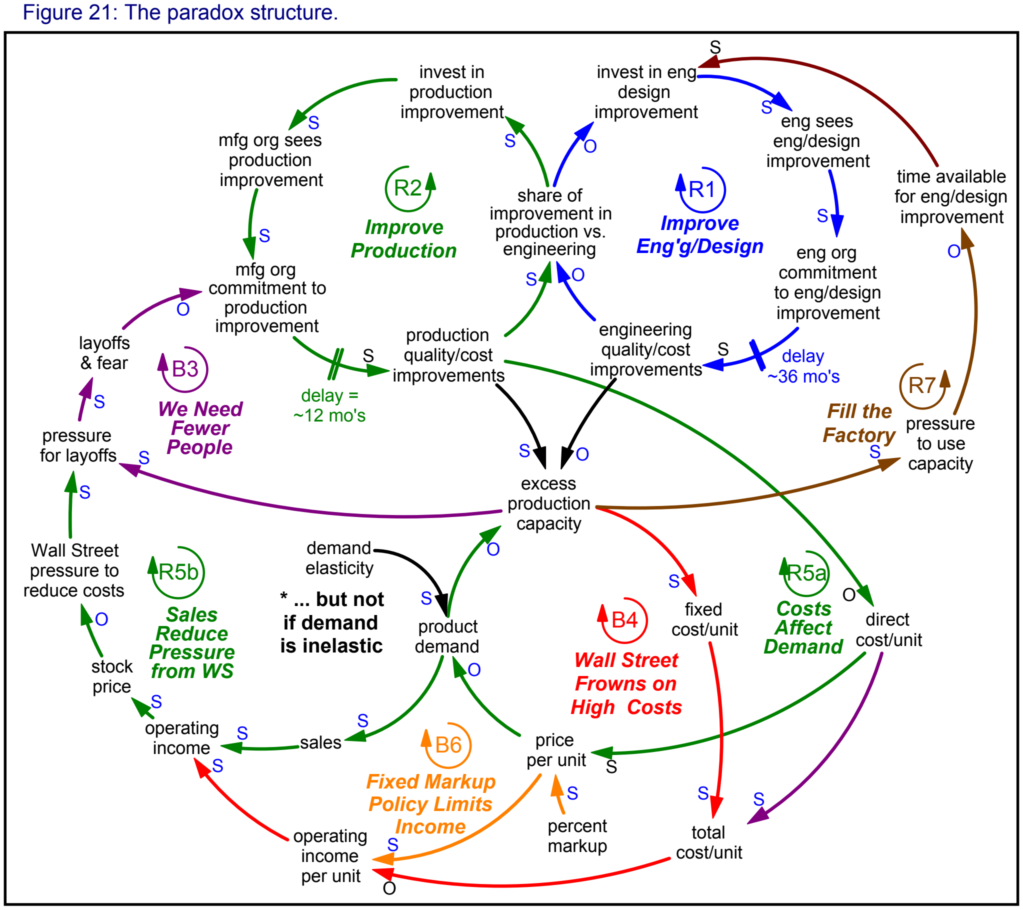
Figure 20: Pressure on engineering for more designs



The following are implications of this study:

TQM represents a significant advance in tools for organizational learning. Yet TQM is also limited. TQM relies on tools and processes that assume the separability of causes in the system under study. TQM as currently practiced assumes a quality improvement team can rank the causes of defects for a given process and address them sequentially. Tools such as Pareto charts and Ishikawa diagrams produce lists of causes of different defects. Efforts to improve different processes often progress independently of one another - a plant might have dozens of different improvement teams operating simultaneously. TQM implicitly assumes that the world can be decomposed into independent causes generating independent effects.

Figure 21: The paradox structure.



Decomposition is a time-honored problem solving strategy (Simon 1969). It often works effectively, provided the process under consideration is not strongly coupled to other systems in the environment. When couplings are strong, however, decomposition may lead to ineffective policies. Worse, piecemeal policies may intensify the problem (Forrester 1971, Ackoff 1978) or even lead to catastrophe (Perrow 1984). Decomposition methods ignore feedback processes and interactions, and discount time delays and side effects. Decomposition in complex, tightly coupled dynamic systems optimizes the parts at the expense of the whole and the present at the expense of the future.

> While many couplings on the factory floor, where TQM evolved, are weak, couplings at the upper management level are strong. Customer needs assessment, product development, strategic planning, organization design, and resource allocation involve high technical and organizational complexity. For example, a product development team is tightly coupled with other functions within the firm (process engineering, marketing, finance, etc.) and with many organizations outside the firm (customers, vendors, competitors, etc.). Experiments to evaluate different ways to translate customer requirements into product specifications take months to carry out, and face many confounding variables (see Burchill 1993 for a compelling example). Available TQM tools can not lead to rapid improvement when couplings are tight, time delays are long, and feedback is ambiguous. Tools and processes to help redesign complex activities like product development are less mature than the TQM methods that proved so effective on the factory floor. Stata commented “The thing that hung us up for the longest time in the product development [PD] area is that we didn’t have anybody in the company who had a clue as to how to improve PD. It wasn’t that we didn’t think it was important, but how do you do it?”

TQM is an excellent tool, but it’s not enough. There’s evidence that what may help manufacturing most, as well as overall company success, is TQM in manufacturing ***and*** TQM in engineering ***plus*** systems thinking to comprehend and deal with dynamic complexity.

Why innovation alone isn't enough: Profiting from Technological Innovation

Summary

This treatment is based on a paper by David J. Teece on "Profiting from Technological Innovation."[19]

The more easily innovations can be imitated, the more an innovating firm risks ceding a significant share of the returns from innovation to customers, imitators and owners of complementary assets (e.g., manufacturing). To prevent this, the innovating firm itself must focus on protectable innovations, focus on products/services for which the necessary complementary assets are already under its control, or establish appropriate plans for contracting/leasing or integrating the necessary complementary assets. As will be also seen in the next section, managers must become adept in understanding their organizations and markets as dynamic systems.

For the same reasons that control of complementary assets, such as manufacturing, are important to companies, they also matter to innovating nations. In regions of weak appropriability, innovating firms without the requisite manufacturing and other specialized capabilities may fail and, similarly, innovating nations may allow competing nations to capture the lion's share of the profits from the innovation.

Why These Concepts are Important for Companies

"Profiting from Technological Innovation" is an important paper. This subsection contains some key points for companies. The message for nations will end this section.

> The analysis provides a theoretical foundation for the proposition that manufacturing often matters, particularly to innovating nations. Innovating firms without the requisite manufacturing and related capacities may die, even though they are best at innovation.

Innovators, the first to the market with a new product or process, often lose to competitors who profit more from the innovation than the innovators. As he says, this is troubling. His paper explains:

> … why a fast second or even slow third [follower] might outperform the innovator. The message is particularly pertinent to those science- and engineering-driven companies that harbor the mistaken illusion that developing new products which meet customer needs will ensure fabulous success. It may possibly do so for the product, but not for the innovator.
>
> The innovator can improve its total return to R&D, however, by adjusting its R&D investment portfolio to maximize the probability that technological discoveries will emerge that are either easy to protect with existing intellectual property law, or which require for commercialization cospecialized[20] assets already within the firm's repertoire of capabilities. Put differently, if an innovating firm does not target its R&D resources towards new products and processes relative to potential imitators and/or followers, then it is unlikely to profit from its investment in R&D. In this sense, a firm's history — and the assets it already has in place — ought to condition its R&D investment decisions. … It is therefore rather clear that the R&D investment decision cannot be divorced from the strategic analysis of markets and industries, and the firm's position within them.

Along this line, he explains that history matters:

> As technologically progressive industries mature, and a greater proportion of the relevant cospecialized assets are brought in under the corporate umbrellas of incumbents, new entry becomes more difficult. Moreover, when it does occur it is more likely to involve coalition formation very early on. Incumbents will for sure own the cospecialized assets, and new entrants will find it necessary to forge links with them. Here lies the explanation for the sudden surge in strategic partnering now occurring internationally, and particularly in the computer and telecommunications industry. Note that it should not be interpreted in anticompetitive terms. Given existing industry structure, coalitions ought to be seen not as attempts to stifle competition, but as mechanisms for lowering entry requirements for innovators.

---

[19] David J. Teece, "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy, *Research Policy*, 15 (1986), p. 285-305

[20] Some definitions. Generic assets are general-purpose assets that need not be tailored to the innovation. Specialized assets are either assets upon which the innovation depends for its success or assets that are specifically tailored to and depend on the innovation for their usefulness. Teece's specialized example: Containerized shipping depends more on trucking than trucking depends upon containerized shipping; it's not expensive to convert trucks to flat beds. Cospecialized assets are assets that are both depended upon by, and depend on, the innovation. Teece's cospecialized example: Mazda's rotary engine and rotary engine repair facilities depend upon each other. The diagrams use the term specialized to include both the specialized and cospecialized categories.

In industries in which technological change of a particular kind has occurred, which required deployment of specialized and/or cospecialized assets at the time, a configuration of firm boundaries may well have arisen which no longer has compelling efficiencies. Considerations which once dictated integration may no longer hold, yet there may not be strong forces leading to divestiture. Hence existing firm boundaries may in some industries — especially those where the technological trajectory and attendant specialized asset requirements has changed — be rather fragile. In short, history matters in terms of understanding the structure of the modern business enterprise. Existing firm boundaries cannot always be assumed to have obvious rationales in terms of today's requirements.

Feedbacks Promoting Profitability from Technological Innovation

While Teece's paper is important, it's also complicated. Because of that, it's not all that easy to gain from it an integrated perspective of all the factors described as important for realizing the returns from innovation.

These diagrams display such an integrated view.[21] Showing the considerations as feedback loops is important because getting returns from an innovation is not a "one-shot deal;" it requires ongoing reinforcing processes that maintain and increase competitive advantage.

The first series of diagrams reflect the feedbacks important for profitability. The second series show the many considerations that go into deciding which of the approaches for controlling complementary assets should be taken.

Figure 21: Product sales and appropriability are needed for profitability.

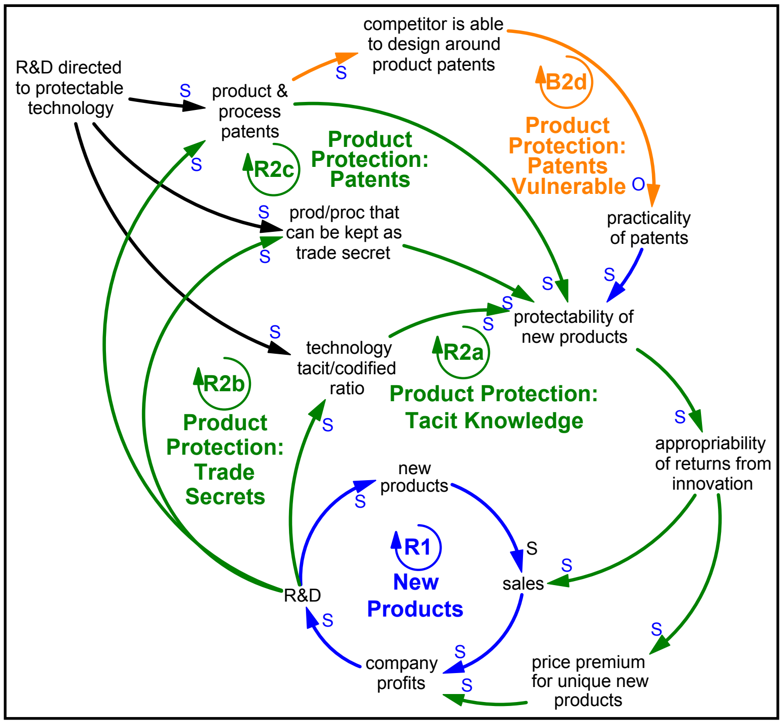
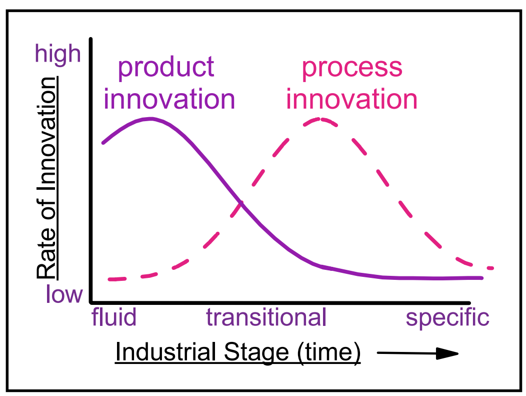


Figure 21 shows that two things are needed to profit from innovation: new product sales and appropriability, the ability to command a price premium for the sales of the new products. If the products are easily imitated, imitators will make some of the sales and erode the price the innovator can charge.

Figure 22: Utterback's industrial stages



R1, New Products: R&D develops new products.

There are three ways shown to protect the intellectual property embedded in the new products.[22]

R2a, Product Protection: Tacit Knowledge: This is less easily imitated than codified, explicit knowledge.

R2b, Product Protection: Trade Secrets: Especially possible when the innovation is embedded in the processes that create a product.

R2c, Product Protection: Patents: These provide some protection … however …

B2d, Product Protection: Patents Vulnerable: Patent protection is limited because they can often be designed around. This is a relatively unattractive alternative.

To examine considerations for increasing returns from an innovation it's useful to consider Utterback's description of

[21] These diagrams have undergone several iterations and are, I believe, much improved over earlier versions. Nevertheless, as is often the case with such diagrams, errors and inconsistencies likely remain; I will appreciate any that you might bring to my attention.
[22] Copyrights could be added.

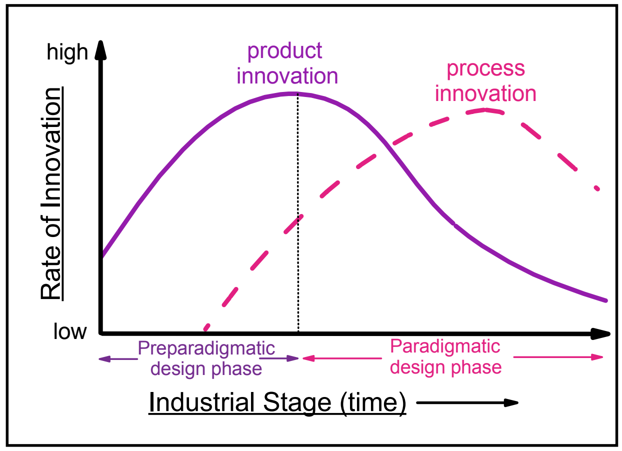
Bob Powell, Ph.D., MBA ▪ Continuous Improvement Associates ▪ 6992 Blackhawk Place ▪ Colorado Springs, CO 80919
Phone (719) 599-0977 ▪ Fax (719) 599-0564 ▪ E-mail: scuba@usa.net ▪

industrial stages in Figure 22.[23] Initially, the emphasis is on product innovation and later on process innovation. Figure 23 shows Teece's similar diagram where he defines two stages:

- the Pre-Paradigmatic Stage, in which there is competition among designs at relatively low volume.
- the Paradigmatic Stage, in which there is competition based on price at high volume.

A company wishes to come out of the first stage with the winning design *and* to have the most efficient processes in the second stage for the lowest cost. Obviously there are different considerations for each stage.

Figure 23: Innovation over the product/industry life cycle

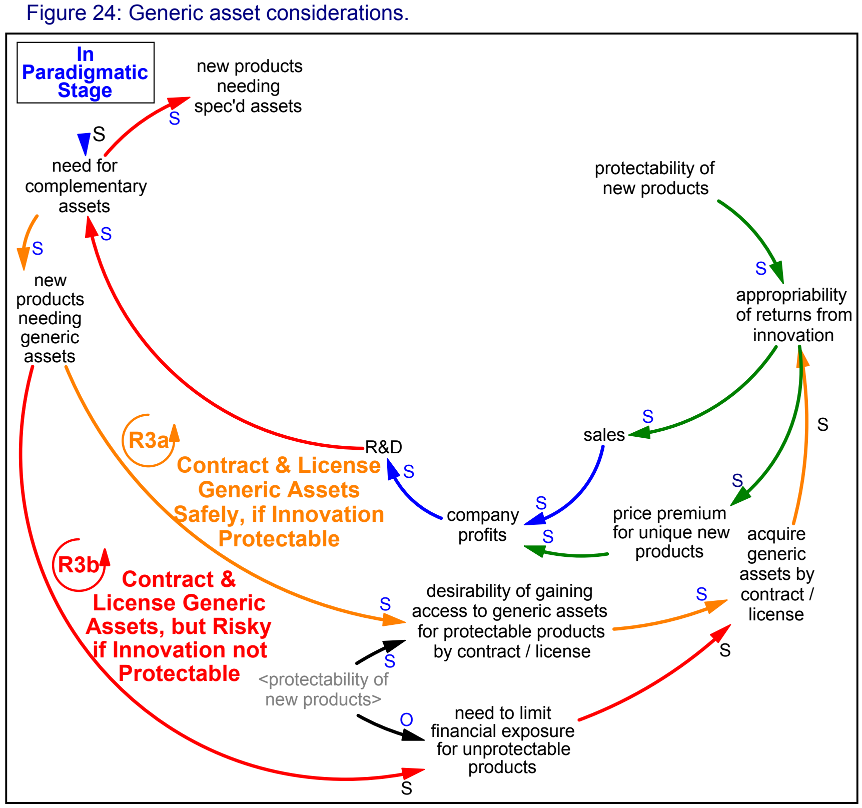


In the Pre-Paradigmatic Stage an innovator needs to allow design to adapt until standards emerge. In Paradigmatic Stage it's necessary to have access to the required complementary assets to facilitate high volume production at the lowest cost.

First, though it's somewhat backwards, let's examine the appropriate approaches for gaining access to the needed complementary assets in the Paradigmatic Stage.

To produce products in volume there's a need for complementary assets which are either specialized for the innovation or generic. Figure 24 shows the feedback loops for the generic case.

Figure 24: Generic asset considerations.



In both cases, it's desirable to contract for the needed assets, but there's a difference depending on whether the innovation is, or is not, protectable.

R3a, Contract & License Generic Assets Safely, if Innovation Protectable: If the innovation is protectable, it's better to contract and license because there's no need to acquire the asset, if they're competitively available.

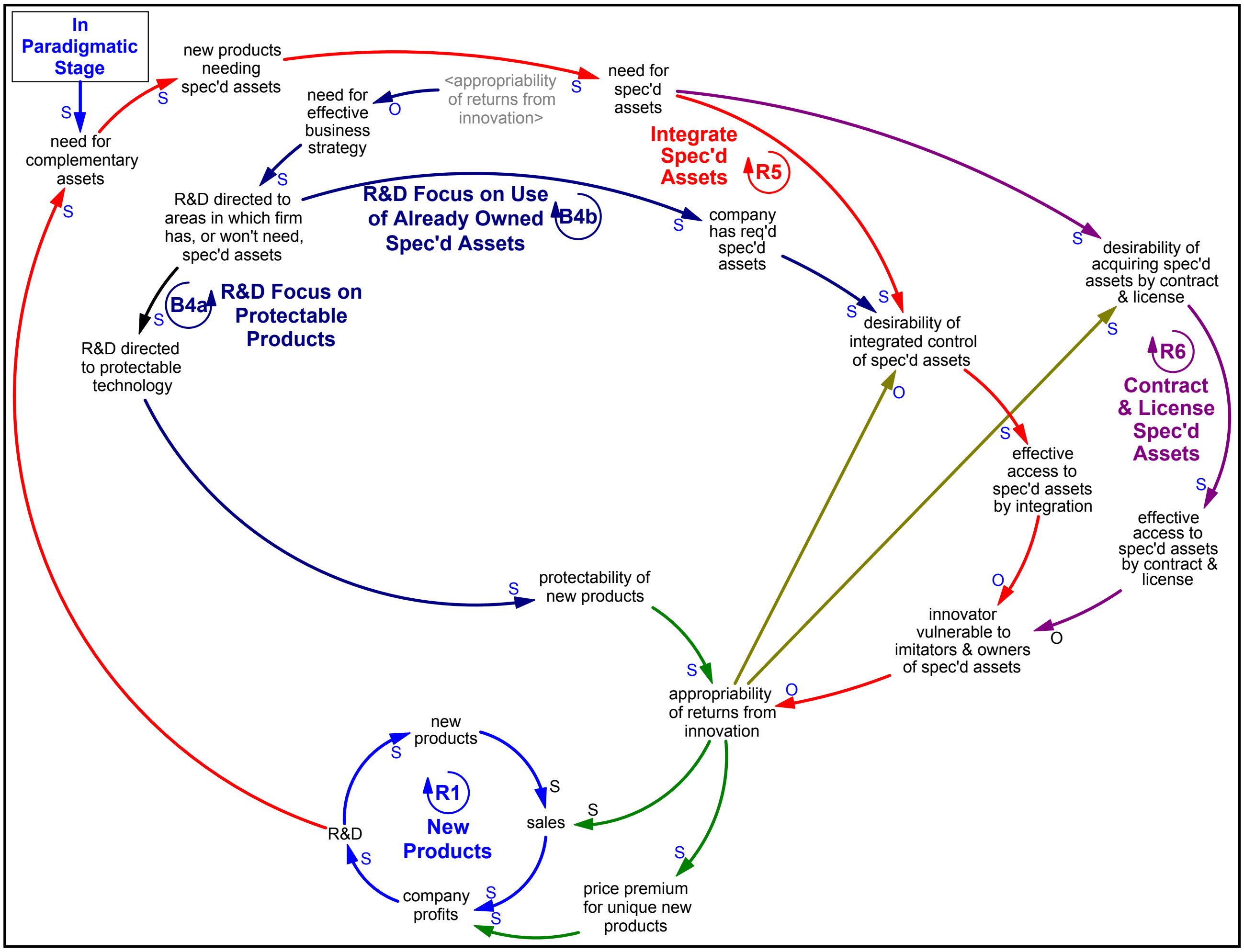
R3b, Contract & License Generic Assets, if Innovation not Protectable: If the innovation isn't protectable, it's better to contract and license to avoid the risk of losing your shirt. This is not a strategically attractive position and it might be better to just forget it, because the risk is high.

Figure 25 shows the feedback loops when the needed complementary assets are specialized to the innovation. First, B4a and B4b show feedbacks that can compensate if appropriability is low.

B4a, R&D Focus on Protectable Products: If "appropriability of returns from innovation" is low, there's more "need for effective business strategy" that directs R&D to protectable technology.

[23] James Utterback, Mastering the Dynamics of Product Innovation: How Companies Can Seize Opportunities in the Face of Technological Change, 1994

Figure 25: Feedbacks for getting access to needed specialized assets

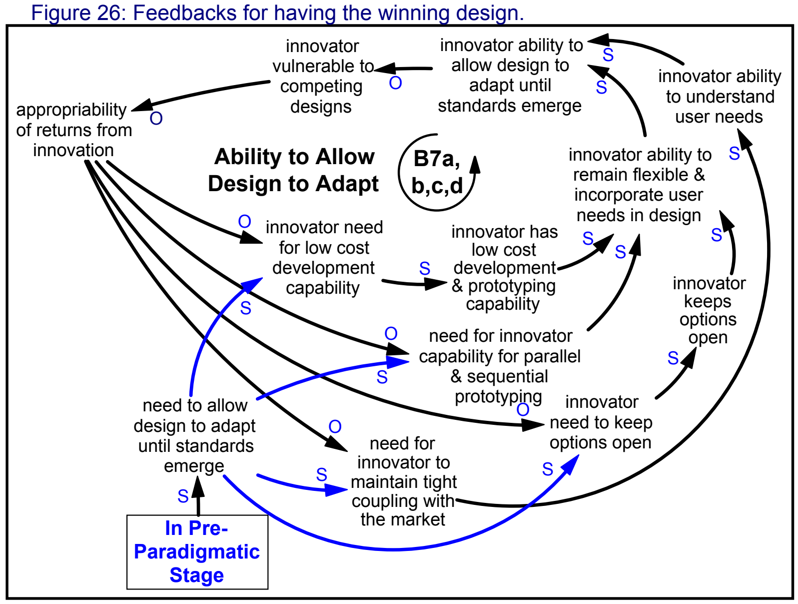


B4b, Focus on Use of Already Owned Spec'd Assets: Similarly, if "appropriability of returns from innovation" is low, there's more "need for effective business strategy" that directs R&D to innovations that can use assets on hand.

There are two basic ways to accommodate the "need for spec'd assets": acquire them and integrate them into the company or contract/license.

R5, Integrate Specialized Assets: The lower the appropriability, the more important it is to integrate the needed specialized assets. Otherwise, the company risks making competitors out of those to whom the work is contracted or licensed.

Figure 26: Feedbacks for having the winning design.



R6, Contract & License Specialized Assets: The higher the appropriability, the more attractive it is to get access to the needed specialized assets by contract/license. Why invest when there are attractive alternatives?

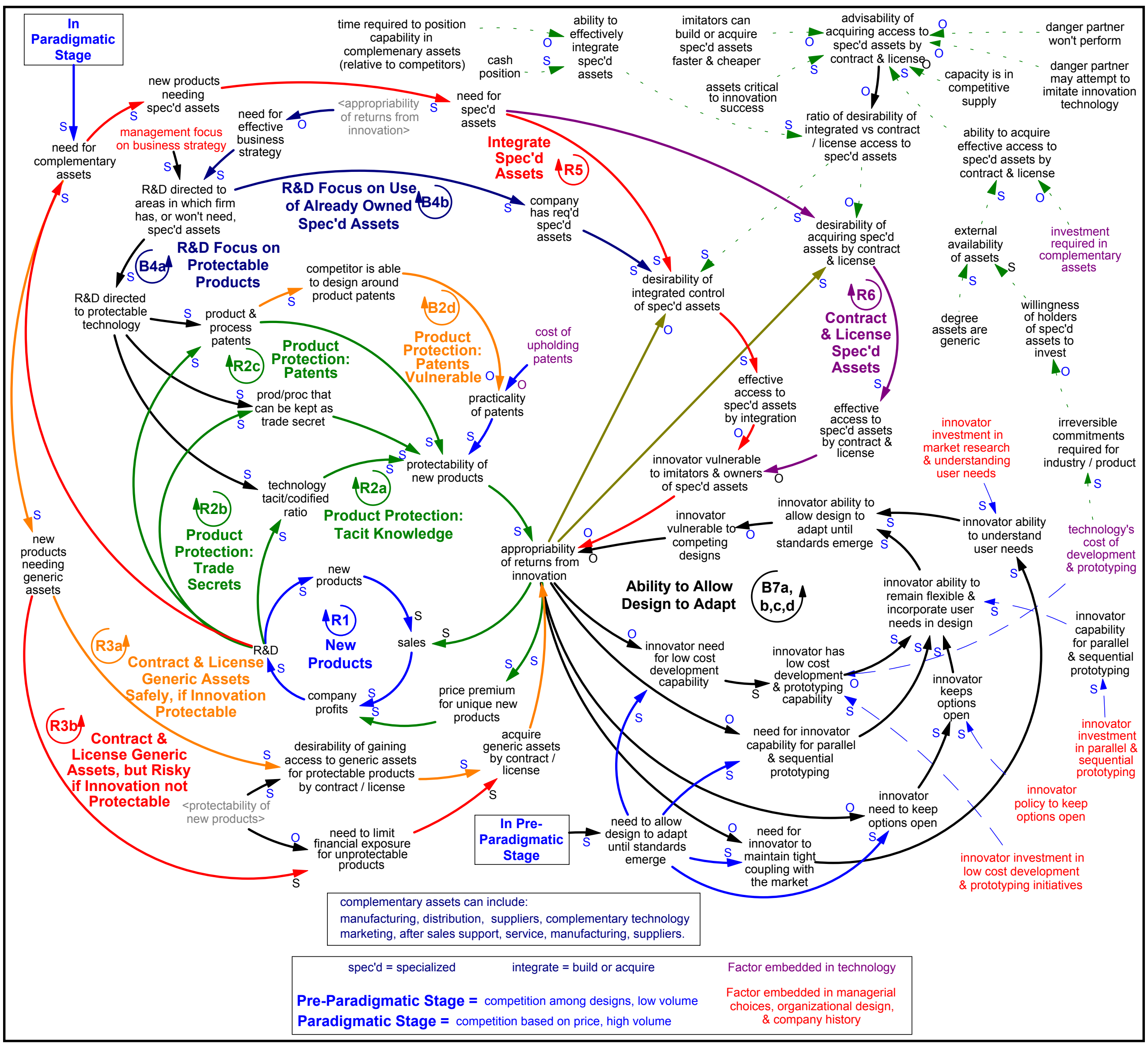
Figure 26 shows the considerations in the Paradigmatic Stage, when coming out with the winning design is critical.

B7a,b,c,d, Ability to Allow the Design to Adapt: The innovator needs low cost development capability, parallel & sequential prototyping capability, tight coupling with the market to know what customers need, and to keep options open.

Figure 27 shows the combined feedback loops and some of the many factors that go into making the necessary strategic decisions. Obviously, none of these conditions is simply black or white: innovations are more or less protectable, assets are more or less generic, there's more or less risk of turning a contractor into an imitator, etc. The red variables indicate factors embedded in managerial choices, organizational design, and company history. The purple variables are factors embedded in technology.

The systems approach is to determine management policies that will make foster feedback loops in working for the company, rather than against it.[24]

Figure 25: Feedbacks for getting access to needed specialized assets



Why These Concepts are Important for Nations

When appropriability is low, nations, as well as companies, are vulnerable to imitators. This is such an important point that I can do no better than quote Teece. Particularly important passages are in green:

> In a world of tight appropriability and zero transactions cost — the world of neoclassical trade theory — it is a mater of indifference whether an innovating firm has an in-house manufacturing capability, domestic, or foreign. It can simply engage in arm's-length contracting (patent licensing, know- how licensing, co-production, etc.) for the sale of the output of the activity in which it has a comparative advantage (in this case R&D) and will maximize returns by specializing in what it does best.
>
> However, in a regime of weak appropriability, and especially where the requisite manufacturing assets are specialized to the innovation, which is often the case, participation in manufacturing may be necessary if an innovator is to appropriate the rents from its innovation. Hence, if an innovator's manufacturing costs are higher than those of its imitators, the innovator may well end up ceding the lion's share of profits to the imitator.
>
> In a weak appropriability regime, low-cost imitator-manufacturers may end up capturing all of the profits from innovation. In a weak appropriability regime where specialized manufacturing capabilities are required to produce new products, an innovator with a manufacturing disadvantage may find that its advantage at early stage research and development will have no commercial value. This will eventually cripple the innovator, unless it is assisted by governmental processes. For example, it appears that one of the reasons why U.S. color TV manufacturers did not capture the lion's share of the profits from innovation, for which RCA was primarily responsible, was that RCA and its American licensees were not competitive at manufacturing. In this context, concerns that the decline of manufacturing threatens the entire economy appear to be well founded.
>
> A related implication is that as the technology gap closes, the basis of competition in an industry will shift to the cospecialized assets. This appears to be what is happening in microprocessors. Intel is no longer out ahead technologically. As Gordon Moore, CEO of Intel points out, "Take the top 10 [semiconductor] companies in the world. . . and it is hard to tell at any time who is ahead of whom.. . . It is clear that we have to be pretty damn close to the Japanese from a manufacturing standpoint to compete."[25] It is not just that strength in one area is necessary to compensate for weakness in another. As technology becomes more public and less proprietary through easier imitation, then strength in manufacturing and other capabilities is necessary to derive advantage from whatever technological advantages an innovator may possess.
>
> Put differently, the notion that the United States can adopt a "designer role" in international commerce, while letting independent firms in other countries such as Japan, Korea, Taiwan, or Mexico do the manufacturing, is unlikely to be viable as a long-run strategy. This is because profits will accrue primarily to the low-cost manufacturers (by providing a larger sales base over which they can exploit their special skills). Where imitation is easy, and even where it is not, there are obvious problems in transacting in the market for know-how, problems which are described in more detail elsewhere.[26]
>
> The trend in international business towards what Miles and Snow[27] call dynamic networks — characterized by vertical disintegration and contracting — ought thus be viewed with concern. (Business Week, March 3, 1986, has referred to the same phenomenon as the Hollow Corporation.) Dynamic networks not so much reflect innovative organizational forms, but the disassembly of the modem corporation because of deterioration in national capacities, manufacturing in particular, which are complementary to technological Innovation. Dynamic networks may therefore signal not so much the rejuvenation of American enterprise, but its piecemeal demise.

Teece goes on to describe the implications for the international distribution of benefits from innovation.

> Even when the specialized assets are possessed by the innovating firm, they may be located abroad. Foreign factors of production are thus likely to benefit from research and development activities occurring across borders. There is little doubt, for instance, that the inability of many American multinationals to sustain competitive manufacturing in the United States is resulting in declining returns to U.S. labor. Stockholders and top management probably do as well if not better when a multinational accesses cospecialized assets in the firm's foreign subsidiaries; however, if there is unemployment in the factors of production supporting the specialized and cospecialized assets in question, then the foreign factors of production will benefit from innovation originating beyond national borders. This speaks to the importance to innovating nations of maintaining competence and competitiveness in the assets which complement technological innovation, manufacturing being a case in point. It also speaks to the importance to innovating nations of enhancing the protection afforded worldwide to intellectual property.

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[24] See the *CIA* paper on From Causal Loops to Action on how to use feedback structures in strategic and project planning.

[25] "Institutionalizing the Revolution," Forbes, June 16, 1986, p. 35.

[26] Teece, "The Market for Know-how and the Efficient International Transfer of Technology."

[27] R. E. Miles and C. C. Snow, "Network Organizations: New concepts for New Forms," *California Management Review*, Spring 1986, pp. 62-73.

> However, it must be recognized that there are inherent limits to the legal protection of intellectual property, and that business and national strategy are therefore likely to be the critical factors in determining how the gains from innovation are shared worldwide. By making the correct strategic decision, innovating firms can move to protect the interests of stockholders; however, to ensure that domestic rather than foreign cospecialized assets capture the lion's share of the externalities spilling over to complementary assets, the supporting infrastructure for those complementary assets must not be allowed to decay. In short, if a nation has prowess at innovation, then in the absence of iron-clad protection for intellectual property, it must maintain well-developed complementary assets if it is to capture the spillover benefits from innovation.

Teece concludes:

> The above analysis has attempted to synthesize from recent research in industrial organization and strategic management a framework within which to analyze the distribution of the profits from innovation. The framework indicates that the boundaries of the firm are an important strategic variable for innovating firms. The ownership of complementary assets, particularly when they are specialized and/or cospecialized, help establish who wins and who loses from innovation. Imitators can often outperform innovators if they are better positioned with respect to critical complementary assets. Hence, public policy aimed at promoting innovation must focus not only on R&D, but also on complementary assets, as well as the underlying infrastructure. If government decides to stimulate innovation, it would seem important to clear away barriers which impede the development of complementary assets which tend to be specialized or cospecialized to innovation. To fail to do so will cause an unnecessarily large portion of the profits from innovation to flow to imitators and other competitors. If these firms lie beyond one's national borders, there are obvious implications for the internal distribution of income.

Manufacturing is vital for the success of firms and nations. From a community standpoint, it will be difficult to maintain a tax base that supports community infrastructure needs with declining returns to U.S. labor.

Barriers to improvement: Challenges That Must Be Met and Overcome

Summary:

Processes exist within the context of a system. While the root causes of process problems are most often independent and can be considered and corrected separately.

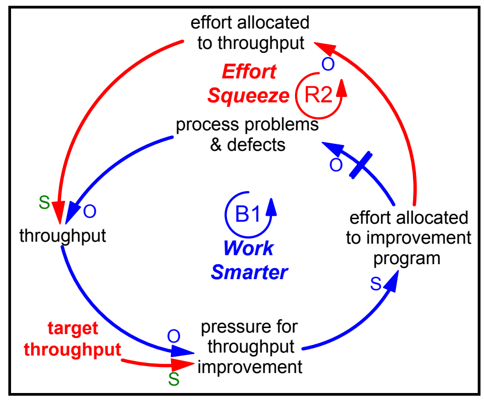
This is not the case for systems problems. For systems, the "root causes" of our messes (set of problems) are feedback loops. This section describes many of the root causes of improvement initiative failures.

The greater the scope of an improvement initiative (and the scope of a manufacturing base restoration initiative would be quite large), the less effective are improvement efforts. In addition, the organizational complexity of such an initiative would cause it to have quite a long half-life (on the order of five or so years, if not longer). The ability to set realistic goals is critical for success, as is an ability to cope with the feedbacks that cause complex, long-term improvement initiative failures. As Sterman writes, " … managers must become adept in understanding their organization as a dynamic system."[28]

Barriers to Process Improvement

More complex, longer half-life improvement programs present an imposing challenge. The half-life technique works for engineering design improvement initiatives also, but the longer half-life subjects engineering improvement initiatives to a host of influences that can cause them to fail. These influences, and guidance for managers seeking to design sustainable process improvement programs, are described in "Overcoming the Improvement Paradox" from MIT.[29]

Figure 28: Productivity Investment is limited by Effort Squeeze



Each of the feedback loops is shown here.[30] Reading through the description of the loops tells the "stories" of the dynamics involved.

The first set of loops, starting with Figure 28, describes effects within improvement programs themselves. The next set of loops, starting with Figure 33, describes interactions of improvement programs with other company initiatives.

Effects within Improvement Programs

In Figure 28:

B1, Work Smarter: when "throughput" is below "target", pressure to improve leads to more "effort allocated to improvement" to reduce "process problems & defects." This balancing loop corrective action is meant to continue until we reach the target. This is Exponential Improvement. More production can be achieved by investing in a productivity improvement program. The dual line across the link between "effort allocated to improvement program" and "process problems & defects" indicates there is a significant delay before "process problems & defects" actually decline.

R2, Effort Squeeze: Investing in an improvement program yields benefits in the long run, but in the short run it takes away effort from current production. This is painful and it's this tension between the long term and the short term that causes improvement programs to fail.[31]

In Figure 29:

R3, Results Create Employee Pull: The more problems that are found and corrected, the more the program will be perceived to be of value. This increases commitment and the effort on improvement.

Overcoming a mindset against improvement is a major challenge, especially among engineers … and it's on the longer term engineering improvement programs that a positive attitude toward improvement is needed. Sterman describes how

---

[28] Elizabeth K. Keating, Rogelio Oliva, Nelson P. Repenning, Scott Rockart, and John D. Sterman, "Overcoming the Improvement Paradox," *European Management Journal*, Vol. 17, No. 2, 1999, pp. 120-134, http://web.mit.edu/jsterman/www/

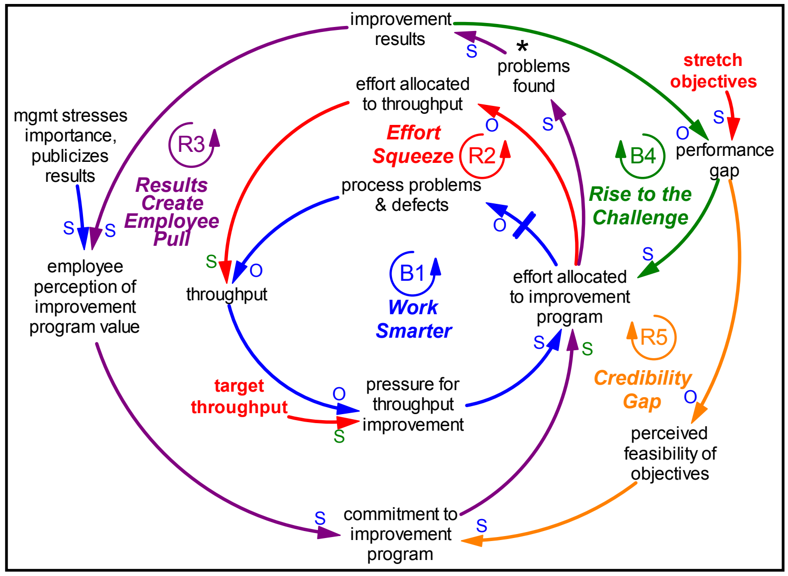
[29] "Overcoming the Improvement Paradox", p. 33.

[30] A plus a few others are shown as well; asterisks indicate variables and loops that are added.

[31] This is the dilemma of addiction: we tend to do what gives short term relief and put off correcting the root causes of our difficulties. See the series of *CIA* papers on "The Crisis Syndrome."

this attitude is often hostile:[32]

Figure 29: Results Create Employee Pull, Rise to the Challenge, and Credibility Gap



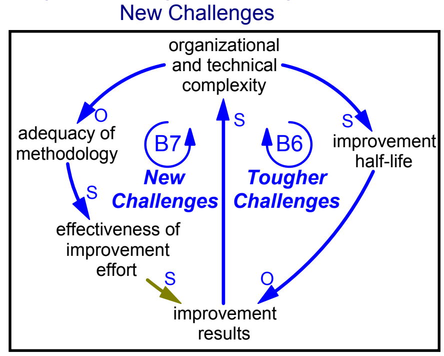
> In addition to improving operations, Analog had to restructure its strategy and capabilities to align better with changes in technology, competition, and customer needs. These efforts included shifting R&D effort towards [different products], attempts to speed product development, and changes in distribution channels. However, intrinsically greater complexity means improvement half-lives for these activities are long. Worse, commitment to improvement in the product development area lags behind manufacturing, since results have not yet been observed and inadequate support leads to frustration. Schneiderman said "Many engineers didn't think TQM could improve product development and thought it interfered with their autonomy. The requests for help we received came primarily from the operations side." Stata was more blunt: "There is some closeted cynicism about quality in the company. Among the engineers, it isn't even closeted. They think it's crap". Due to poor support and low commitment reported product development times do not exhibit [in modeling and simulations that closely track actual performance] appreciable improvement, despite the assumed potential to fall with a half-life of 24 months.

Many engineers view what they do as a virtual art form that should not be constrained by process, much less process improvement. But to the contrary, process is a foundation on which creativity can build.[33]

B4, Rise to the Challenge: To address low commitment and increase effort, organizations often set "stretch objectives." The larger the gap between "stretch objectives" and the "improvement results" obtained, the greater the effort allocated to the program. Note this is a balancing loop; as the gap is closed, effort tends to fall and limit improvement.

R5, Credibility Gap: However, if the "stretch objectives" are *too stretched*, they will be perceived as infeasible and negatively influence commitment to improvement.

Figure 30: Tougher Challenges and New Challenges



In Figure 30:

B6, Tougher Challenges: Because the easiest challenges (the "low hanging fruit") tend to be addressed first, as time goes on the more complex problems remain. The half-life to improve them increases to reduce results.

B7, New Challenges: As the organizational and technical complexity of the problems being addressed increases, the tools needed to address them become less familiar and less well developed (e.g., the need to move from TQM for addressing simple, independent root causes, to systems thinking for addressing complex, interdependent root causes that are feedback loops). This increasingly limits the effectiveness of the improvement effort.

In Figure 31:

B8, Diffuse Benefits: As complexity increases, more diffuse results are more difficult to observe. They are improvements to the "commons" which help everyone a lot, but each individual only a little. This limits commitment.

B9, Scope Creep: As results increase, there's a tendency to increase program scope to get even more benefit from improvement. But this can extend the effort to problems for which the approach is less well-suited and reduce the

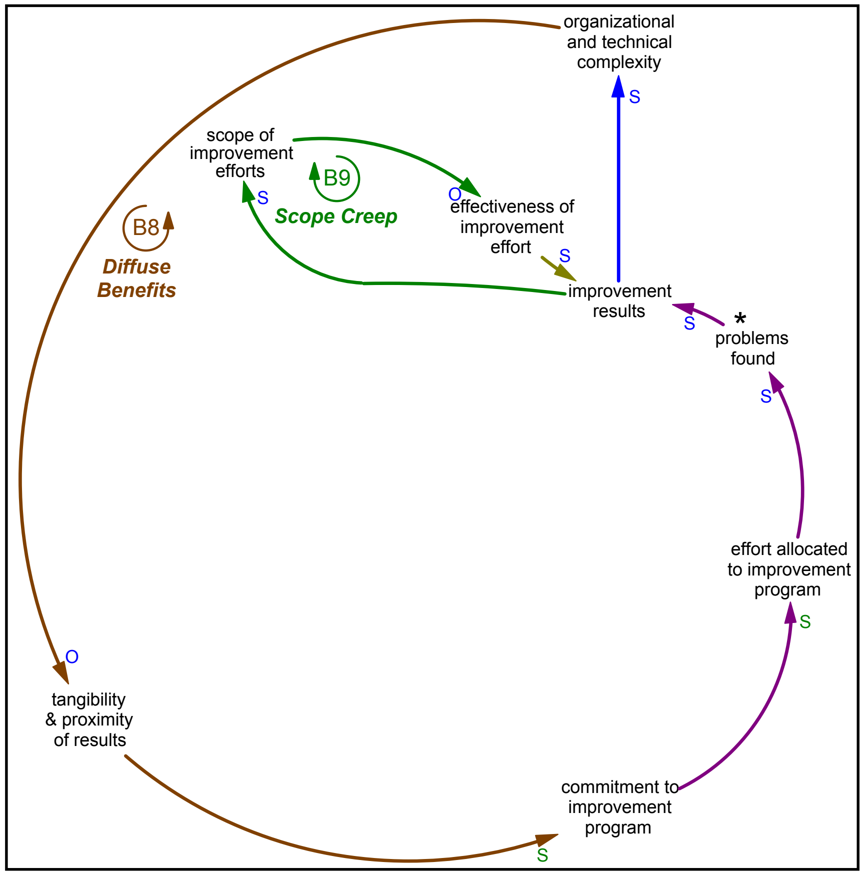
---

[32] Sterman, J., Repenning, N., and Kofman, F., "Unanticipated Side Effects of Successful Quality Programs: Exploring a Paradox of Organizational Improvement." http://web.mit.edu/jsterman/www/ADI/ADI.html, 8/94.

[33] See the *CIA* paper on "Organizational Evolution (and Revolution)."

benefits obtained.

Figure 30: Results Create Employee Pull, Rise to the Challenge, and Credibility Gap



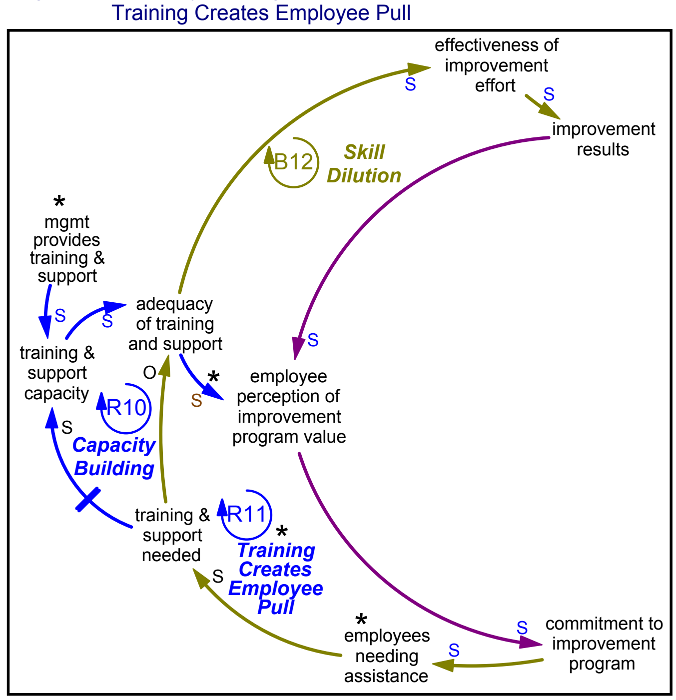
In Figure 32:

R10, Capacity Building: The greater the commitment to improvement," the greater the "training & support needed," and (management willing) the more "training & support capacity." This increases "improvement results" and "employee perception of improvement program value."

R11, Training Creates Employee Pull: Increasing the "adequacy of training & support" directly increases "employee perception of program value" to build commitment.

B12, Skill Dilution: But **Capacity Building** takes time. The more "training & support needed," the more the training organization and resources can be overwhelmed. Without the needed support, the "effectiveness of the improvement effort" and the "employee perception of improvement program value" are lowered to reduce "commitment to the improvement program."

Figure 32: Capacity Building, Skill Dilution, and Training Creates Employee Pull



Interactions of Improvement Programs with Other Company Initiatives

In Figure 33:

B13, Fear of Layoffs: Increased productivity creates "excess capacity" to decrease "job security" as employees see themselves working their way out of a job. Understandably, this reduces "commitment to the improvement program."

R14, Better Products: Better products can increase "market share" and increase demand to use the additional capacity made available by the improvement program.

R15, More Products: Similarly more products can increase overall industry demand as new applications are created.

B16, Who's at Fault?: A limiting effect can be that, as problems are discovered and corrected, it can activate "defensive routines," if there is an atmosphere of "blame."[34] Those who feel blamed for the problems discovered will fear for their jobs and their commitment

[34]See the *CIA* paper on "Defensive Routines" on a dynamic described by of Chris Argyris.

to improvement will be reduced.

For learning, "survival anxiety" (the fear we won't make it without change) must exceed "learning anxiety" (the fear we'll look stupid or won't succeed).[35] This can be done either by threats to increase "survival anxiety" or by creating a safer environment for unlearning and new learning to decrease "learning anxiety." If the former, then organizations are more likely to activate defensive routines.

Figure 26 combines the feedback loops described. The reinforcing loops can either promote improvement in a virtuous cycle, or they can kill improvement in a vicious cycle. When the reinforcing feedbacks are promoting improvement, they can be held back by the limiting balancing feedbacks. The feedback loops can be considered as internal driving forces. See the *CIA* paper on From Causal Loops to Action for an explanation of

Figure 33: Fear of Layoffs, Better Products, More Products, and Who's at Fault?

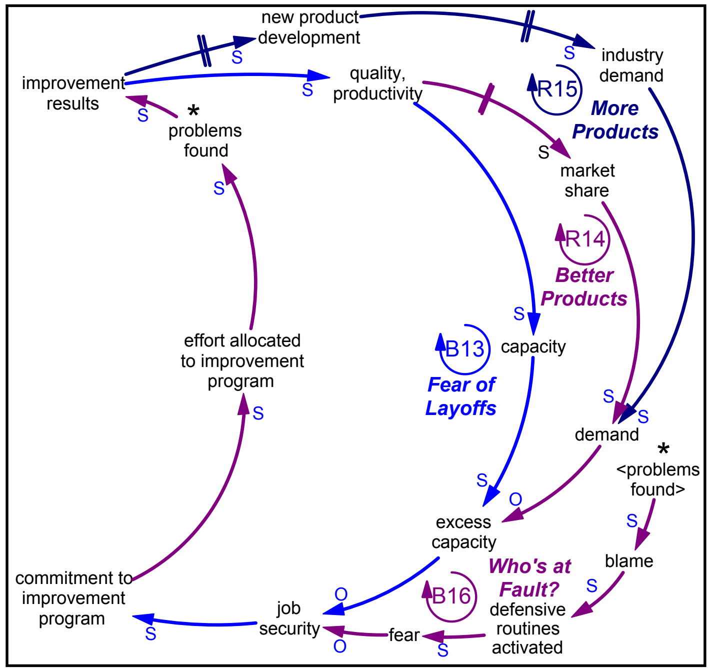
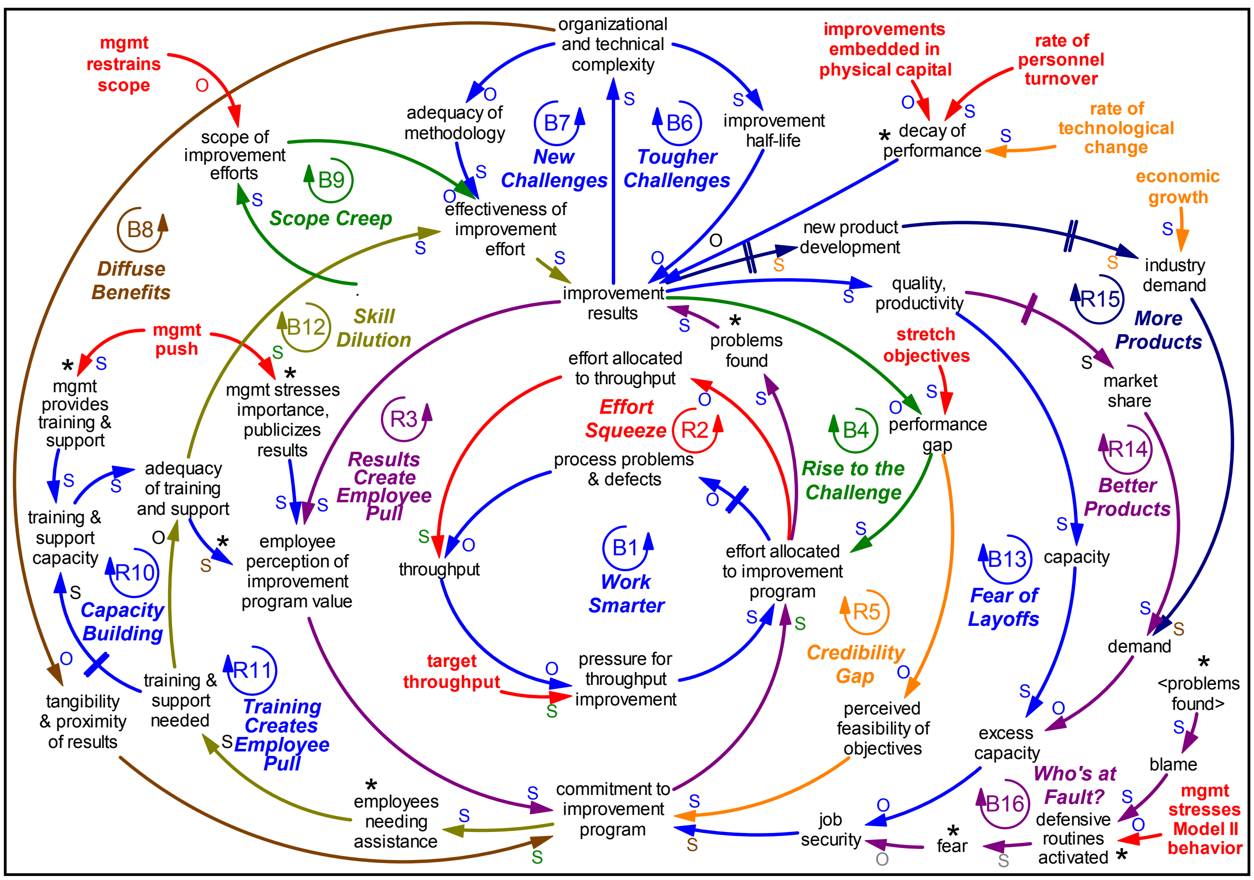


Figure 34: Overcoming Challenges to Process Improvement



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[35] Interview with Ed Schein from the MIT Sloan School on "The Anxiety of Learning," *Harvard Business Review*, March 2002

how to use these internal and external driving forces in strategic and project planning.

The orange variables in Figure 34 represent two of the external environmental influences that can affect the improvement effort. These can be considered external driving forces. In strategic planning management can consider different scenarios for different combinations of driving forces.

The red variables in Figure 34 represent some of the management policies that can affect improvement initiative success. Managers must become adept in understanding their organization as a dynamic system and develop policies that will work in the long run.

The Economic Environment and National Economic Policy

The Effect of High Real Long-Term Interest Rates

A manufacturing base restoration initiative would exist in the context of a national and world economy.[36] A dollar made strong by national economic policy has important effects. From the AP stories at the end of this section, "**Treasury Secretary Defends Strong Dollar Policy to Lawmakers**" and "**Dollar Faltering After Seven Years**", it's clear that a strong dollar helps some and hurts others. Figure 35 shows how Federal Reserve policy affects manufacturing. Influences on the "Health of U.S. Mfg" are shown in the top left corner.[37]

Definitions:
- **real long-term interest rates** = (long-term interest rates) - (the rate of inflation)
- **real rate of change in national productivity** = (change in national productivity) - (real long-term interest rates)

The effects of high real long-term interest rates:

- Restrains the economy in the "fight against inflation." The stated purpose is to avoid inflation that might result from a "wage-price spiral." This policy limits the number of jobs available and assures that there are more people than jobs. The effects of a "more people than jobs" policy are:
  - Regions compete for the jobs that are available by offering lower taxes and less regulation than competing regions. This results in taxes insufficient to provide needed infrastructure and regulation inadequate to protect public health and quality of life.
  - People compete for the jobs that are available, which depresses wages at all levels to some extent, and drives wages at the bottom to zero.[38]
- Increases the strength of the dollar. The effects of a strong dollar:
  - A strong dollar creates financial advantages for companies to move manufacturing offshore to take advantage of lower labor costs, costs that are already lower and artificially even lower still due to a strong dollar.
  - Increases the U.S. trade deficit. This cannot continue to accumulate forever; eventually the dollar must fall or the U.S. will default on its trade debt.

The effects of a low "real rate of change in national productivity":

- Increases returns on financial assets relative to real assets (such as manufacturing)
- If the "real rate of change in productivity" is positive: there is a predisposition to invest in real assets, such as manufacturing, to create new wealth; net debtors will on average be able to create new wealth.
- If the "real rate of change in productivity" is negative: there is a predisposition to invest in financial assets.[39] Net debtors go further into debt when productivity increases don't exceed real interest rates.[40]

High real long-term interest rates lower the real rate of increase in productivity making it more attractive to invest in financial assets than in real assets such as manufacturing. In addition a strong dollar has driven, and is driving, manufacturing out of the U.S.

As described in the section on "Profiting from Innovation", manufacturing is important. Just as manufacturing is often necessary for innovating companies to profit from innovation, so too it is necessary for innovating countries. It may best serve the U.S. to reserve investment tax credits for companies that keep manufacturing in the U.S.

These are powerful forces, the only hope I see to oppose them is to work a great deal smarter than competing nations. And the only hope I see for that is to use exponential improvement, and become adept in understanding our organizations and economies as dynamic systems to develop more effective policies with a long-term focus.

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[36] This draws from a paper in progress on "The Federal Reserve and the U.S. Economy: A Dynamic Analysis" that details the feedbacks in our economic system. Clearly, this is a large topic and only brief comments are included here. The U.S. economy is like a car with two drivers, one working the accelerator, the other the brake.

[37] For more detail: Figure 36 shows the feedbacks that the Federal Reserve uses to monitor the economy. Figure 37 shows the effects of Federal Reserve policy on the economy. Figure 38 shows the combined feedbacks.

[38] Taxes can be seen as the "regional wages" that support providing a given quality of life. There are infrastructure backlogs for the same reason that there is poverty. For more on this, see *The Tangle of Growth*, Bob Powell, (unpublished).

[39]This drove the leveraged buyouts and junk bonds of the 80s.

[40] "Only if growth in indebtedness is matched by growth of income-producing assets can the lender be sure that productive use is being made of his funds and that the debt service can be sustained in years to come." Quoted in *Secrets of the Temple by* William Greider, p. 581 from a speech by Federal Reserve Board Governor Henry Wallich's on 6/2/81. William Greider notes: "Wallich's warning was actually directed at commercial banks when they were lending vast sums to less-developed countries, but the logic applied just as well to American families that borrowed more than their future incomes could pay back or businesses that did the same or, for that matter, the American economy as a whole."

AP: Treasury Secretary Defends Strong Dollar Policy to Lawmakers

http://www.nytimes.com/aponline/national/AP-ONeill-Dollar.html

May 1, 2002, Filed at 3:41 p.m. ET
Treasury Secretary Defends Strong Dollar Policy to Lawmakers By THE ASSOCIATED PRESS

WASHINGTON (AP) — A strong dollar is in the best interests of the United States, and the Bush administration won't change its policy on the subject anytime soon, Treasury Secretary Paul O'Neill told Congress on Wednesday.

"There's no intent in anything that I say to give comfort to those who think we're going to change our policy today," O'Neill testified to the Senate Banking Committee.

The hearing was called to air complaints from American companies that say they are being hammered by the high value of the U.S. dollar, which has priced their goods out of overseas markets.

O'Neill said the United States could reduce imports to help bring down the trade deficit but that would hurt consumers and the economy as a whole.

"Lots of people come to Washington and tell us how they are hurting, and I think we have to be sympathetic with that, but at the same time we are better off to help the casualties if it produces a better economic outcome for the whole society," he said.

Sen. Paul Sarbanes, D-Md., committee chairman, continued to press O'Neill, saying he was "really taken aback" that the Treasury secretary was not alarmed by the trade deficit.

"At some point it is a problem," Sarbanes said.

O'Neill responded, "I don't find it appealing to suggest we cut off our arm because we might get a disease."

The Bush administration's allegiance to a strong dollar follows the same commitment from the Clinton administration. Both maintained that the U.S. economy reaps enormous benefits from a strong dollar, which helps to hold down inflation, provides consumers with a wealth of product choices from all over the world and attracts the billions of dollars in foreign investment the country needs to offset its huge trade deficits.

O'Neill took issue with a recent warning by the International Monetary Fund that the country's huge trade deficits were one of the biggest risks facing economic recovery in the United States and the rest of the world.

The committee heard a far different view from officials of the National Association of Manufacturers, the AFL-CIO, farmers groups and others, which warned that the huge U.S. trade deficit is a threat to the economy and has already cost thousands of jobs. They blamed much of the increase in the deficit on a 30 percent rise in the value of the dollar since early 1997.

"Many of these jobs will never come back," said Richard Trumka, the AFL-CIO's secretary-treasurer. "These are higher paying jobs that have been the ladder to the American dream for millions of Americans. But now we are kicking away that ladder."

NAM President Jerry Jasinowski said the administration needs to work with U.S. allies to gradually reduce the dollar's value against other currencies, such as the Japanese yen and the European euro.

"The overvalued dollar is … perhaps the single most serious economic problem facing manufacturing in this country," Jasinowski said. "It is decimating U.S. manufactured goods exports, artificially stimulating imports and putting hundreds of thousands of Americans out of work."

C. Fred Bergsten, who heads the Institute for International Economics, a Washington think tank, said that every 1 percent rise in the value of the dollar produces an increase of at least $10 billion in the current account trade deficit. He estimated that the dollar is overvalued by 20 percent to 25 percent.

The U.S. current account deficit, the broadest measure of trade, stood at $417.4 billion last year, near its all-time high of $444.7 billion set in 2000. If the dollar remains overvalued, Bergsten said, the deficit is likely to approach $500 billion this year and could hit $800 billion by 2006, an amount equal to 7 percent of the entire U.S. economy.

"It is time for the administration to change its policy toward the dollar … to reduce the risk of the much more severe adjustment that will inevitably hammer us later if it continues to ignore the problem," Bergsten said.

AP: Dollar Faltering After Seven Years

http://wire.ap.org/APnews/?SITE=CODEN&FRONTID=HOME MAY 29, 2002 18:34 ET

Dollar Faltering After Seven Years By MARTIN CRUTSINGER, AP Economics Writer

WASHINGTON (AP) — The high-flying dollar, which has given Americans price breaks on everything from Paris vacations to imported cars and television sets, is losing altitude.

Over the past three months, the dollar has slipped by 6 percent against major currencies, raising concerns that this could be the end of a heady seven-year run as the world's supercurrency.

"I think we are at a turning point for the dollar, and we are looking for an extended period when the dollar will be declining in value against other currencies,'' David Wyss, chief economist at Standard & Poor's Co. in New York, said Wednesday.

For American shoppers, the past seven years have been a great ride. The dollar stood 40 percent higher in value against the major currencies of the world in January than it did at its low point in the spring of 1995 — quite a price break on foreign goods for American consumers.

American manufacturers, however, have a different story to tell. The dollar's strength has opened them to intense competition from lower-priced imports and made their exports more expensive overseas.

The National Association of Manufacturers, leading a drive to pressure the Bush administration to change its policy on the dollar, estimates that the overvalued dollar has cost U.S. companies $140 billion in lost export sales over the past 18 months and resulted in half a million job layoffs.

So far, Treasury Secretary Paul O'Neill, the administration's spokesman on the dollar, has been unwilling to waver from the policy set by his Clinton administration predecessors, Robert Rubin and Lawrence Summers, whose mantra remained: "A strong dollar is in the best interests of the United States.''

O'Neill, with his usual bluntness, told the Senate Banking Committee on May 1, "There is no intent with anything I say to give comfort to those who think I am going to change our policy.''

But even with those words, the dollar has continued to fall on the world's currency markets, where $1.2 trillion worth of currencies change hands daily. The drop against the yen was so sharp last week that an alarmed Japanese government intervened to sell yen and buy dollars to prop up the greenback.

Some analysts believe O'Neill, while maintaining he was not changing dollar policy, signaled a subtle shift with his comments at the hearing that he did not believe intervention, a government's buying and selling of its own currency, could work over the long term.

"Exchange markets are picking up on the fact that O'Neill doesn't believe in currency intervention, that a country's currency should reflect economic fundamentals,'' said Frank Vargo, the National Association of Manufacturers' vice president for international affairs.

Vargo said that NAM would like to see the dollar decline in value by about 20 percent. "We don't want it to collapse. We just want to see a gentle glide path to a more appropriate level,'' he said.

Such a change would make U.S. products more competitive and make imports more expensive and less desirable for American consumers, helping to narrow the country's massive foreign trade deficits.

The weaker dollar will also mean higher inflation in this country. But with consumer prices rising by a tiny 1.6 percent last year, there is room for inflation to move higher without serious problems, economists said.

They said the biggest danger in coming months is that a declining dollar will make foreigners less willing to invest in the United States because of fear their earnings will be worth less when converted into their home currencies.

"The fear is that foreign investors could all run for the door at the same time, sending the dollar plunging,'' said Mark Zandi, chief economist at Economy.com.

Such a development could send stock prices sharply lower and cause a huge jump in long-term interest rates. Foreigners hold about 10 percent of U.S. stocks and 35 percent of U.S. Treasury bonds.

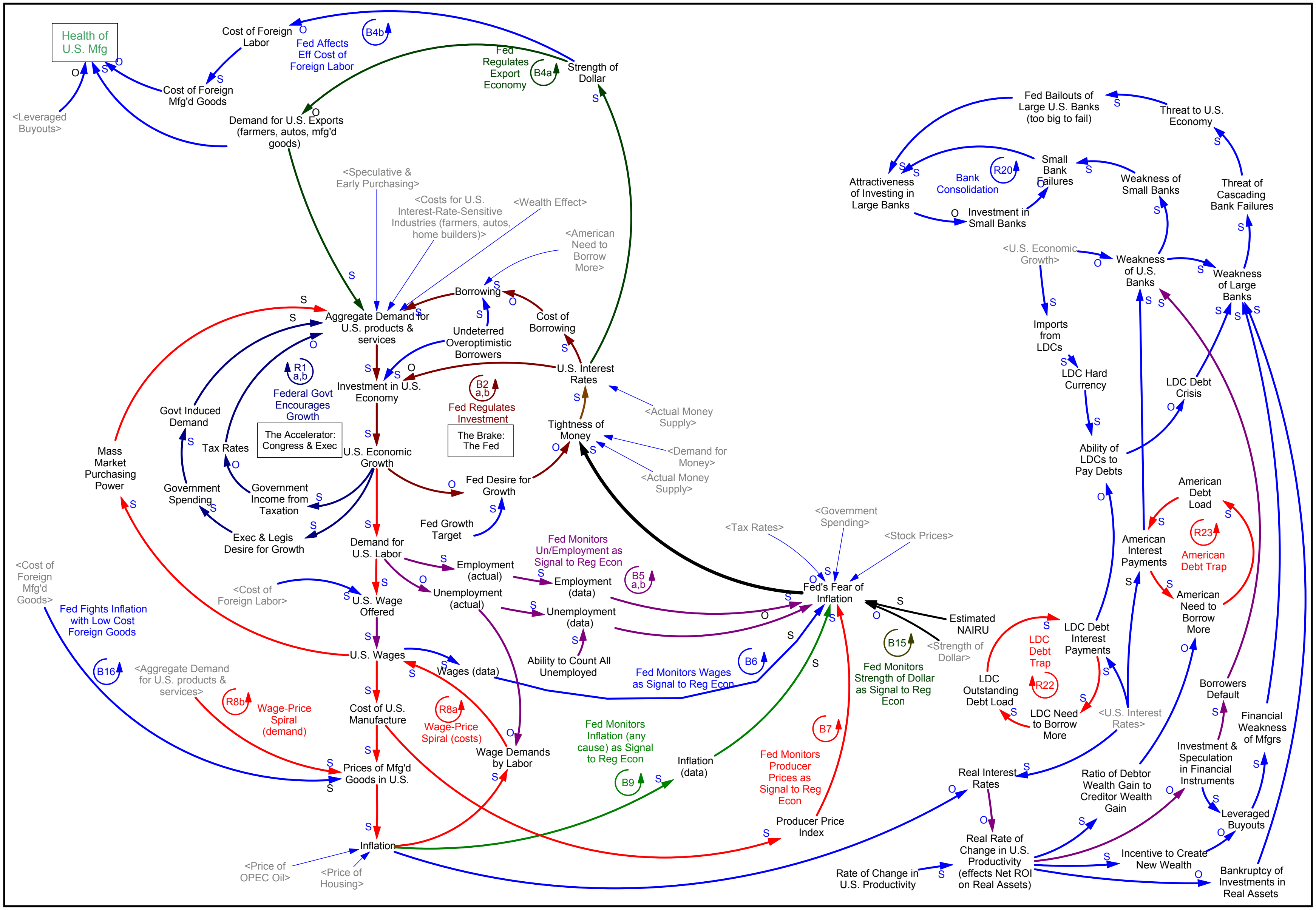
Most analysts view that as a remote possibility, saying this country still offers better rates of return on investments than either Europe or Japan.

"The dollar has peaked, but a precipitous drop is not in the cards,'' said Sung Won Sohn, chief economist at Wells Fargo in Minneapolis.

Wyss said he looked for a gradual decline in the dollar, with a chance of "triple parity'' a year from now.

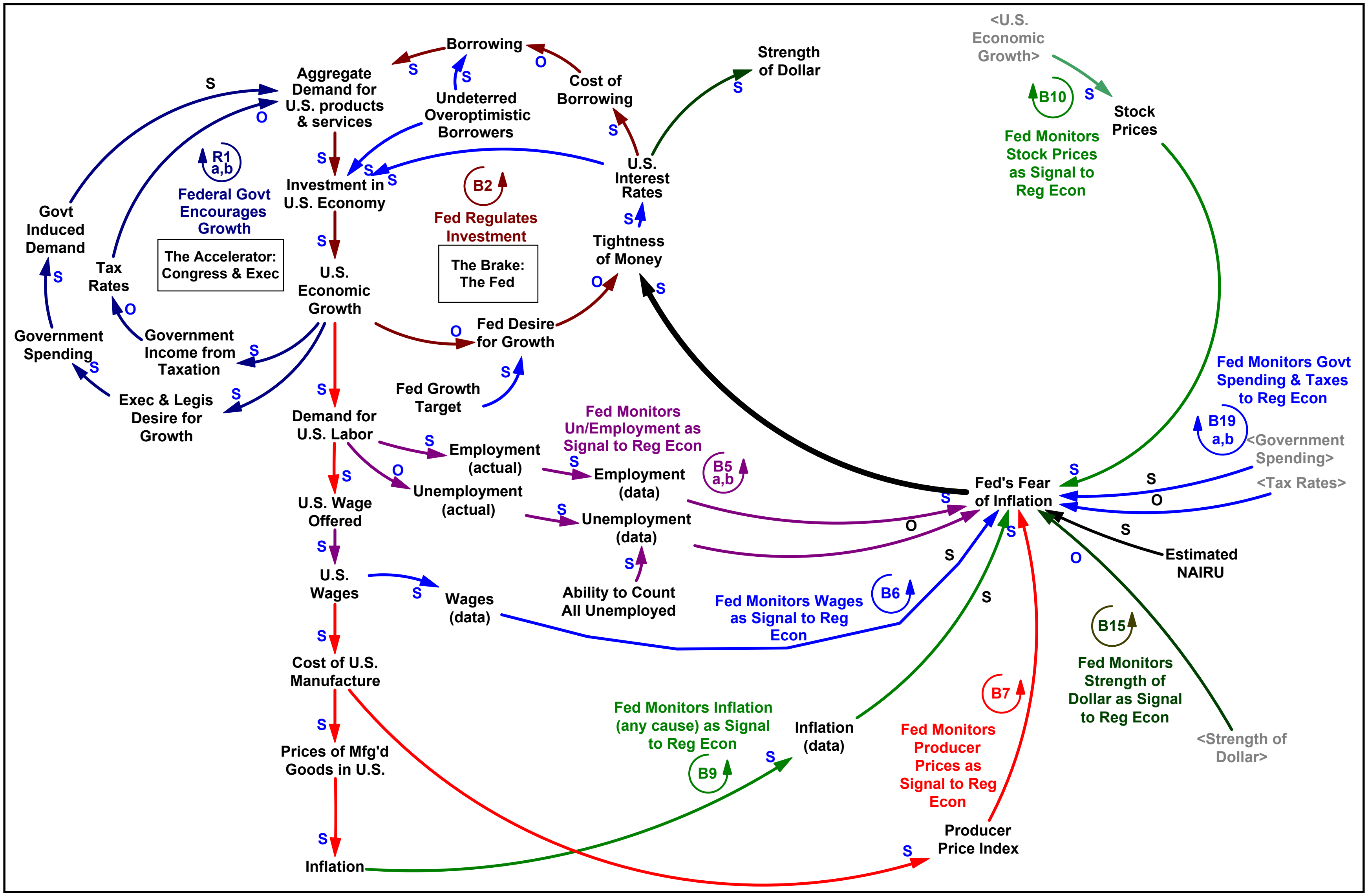
By that he meant that one dollar would buy one euro and 100 yen. In late trading Wednesday, the dollar fell against both the euro and the yen. It required 93.65 cents to buy one euro, compared to 92.91 cents on Tuesday, and one dollar was fetching 124.34 yen, compared to 124.47 yen in late New York trading Tuesday.

Figure 35. Manufacturing and Federal Reserve Policy



Bob Powell, Ph.D., MBA ▪ Continuous Improvement Associates ▪ 6992 Blackhawk Place ▪ Colorado Springs, CO 80919
Phone (719) 599-0977 ▪ Fax (719) 599-0564 ▪ E-mail: scuba@usa.net ▪

Figure 36. How the Federal Reserve Monitors the Economy



Bob Powell, Ph.D., MBA ▪ Continuous Improvement Associates ▪ 6992 Blackhawk Place ▪ Colorado Springs, CO 80919
Phone (719) 599-0977 ▪ Fax (719) 599-0564 ▪ E-mail: scuba@usa.net ▪

Figure 37. Effects of Federal Reserve Policy on the Economy

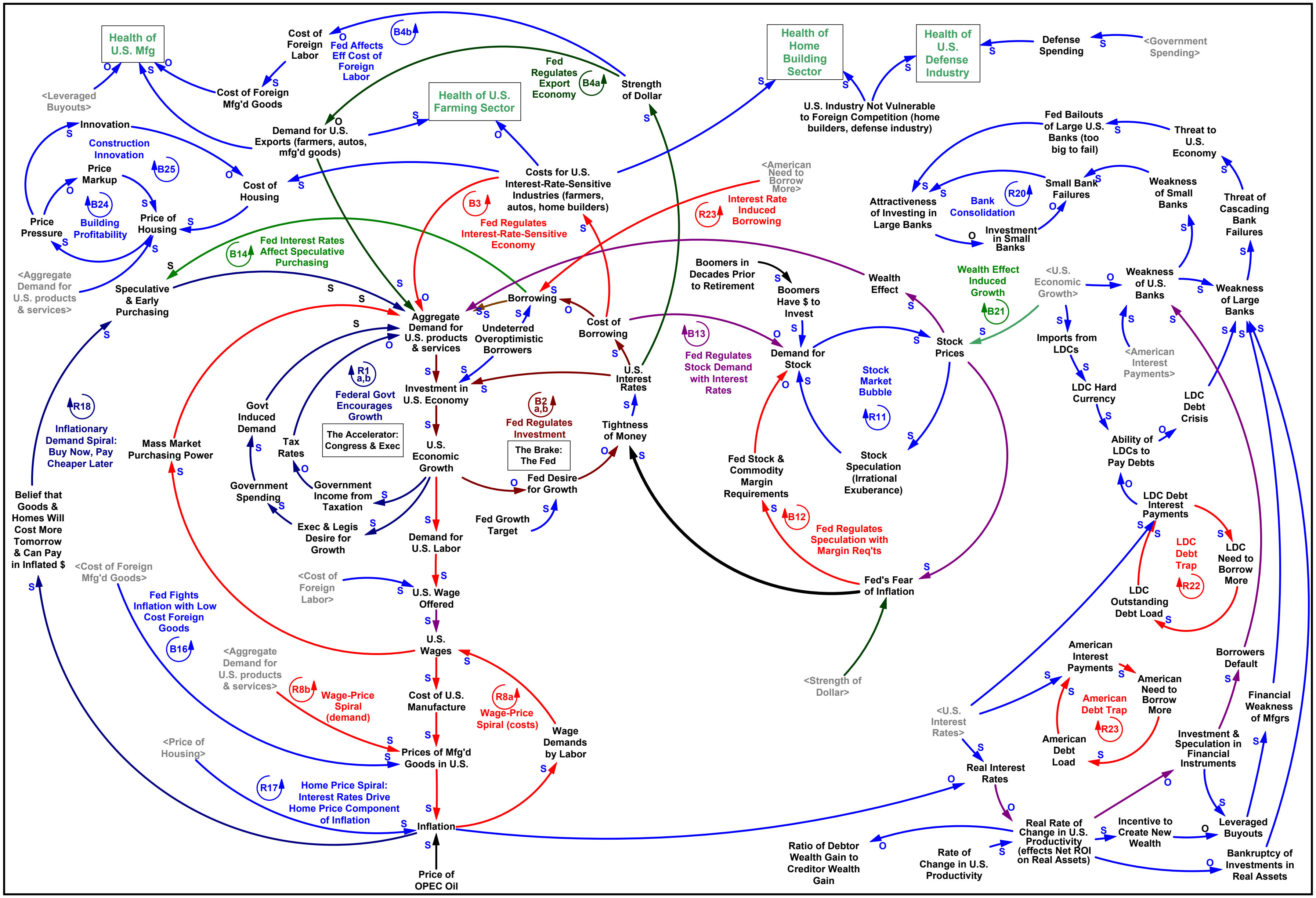
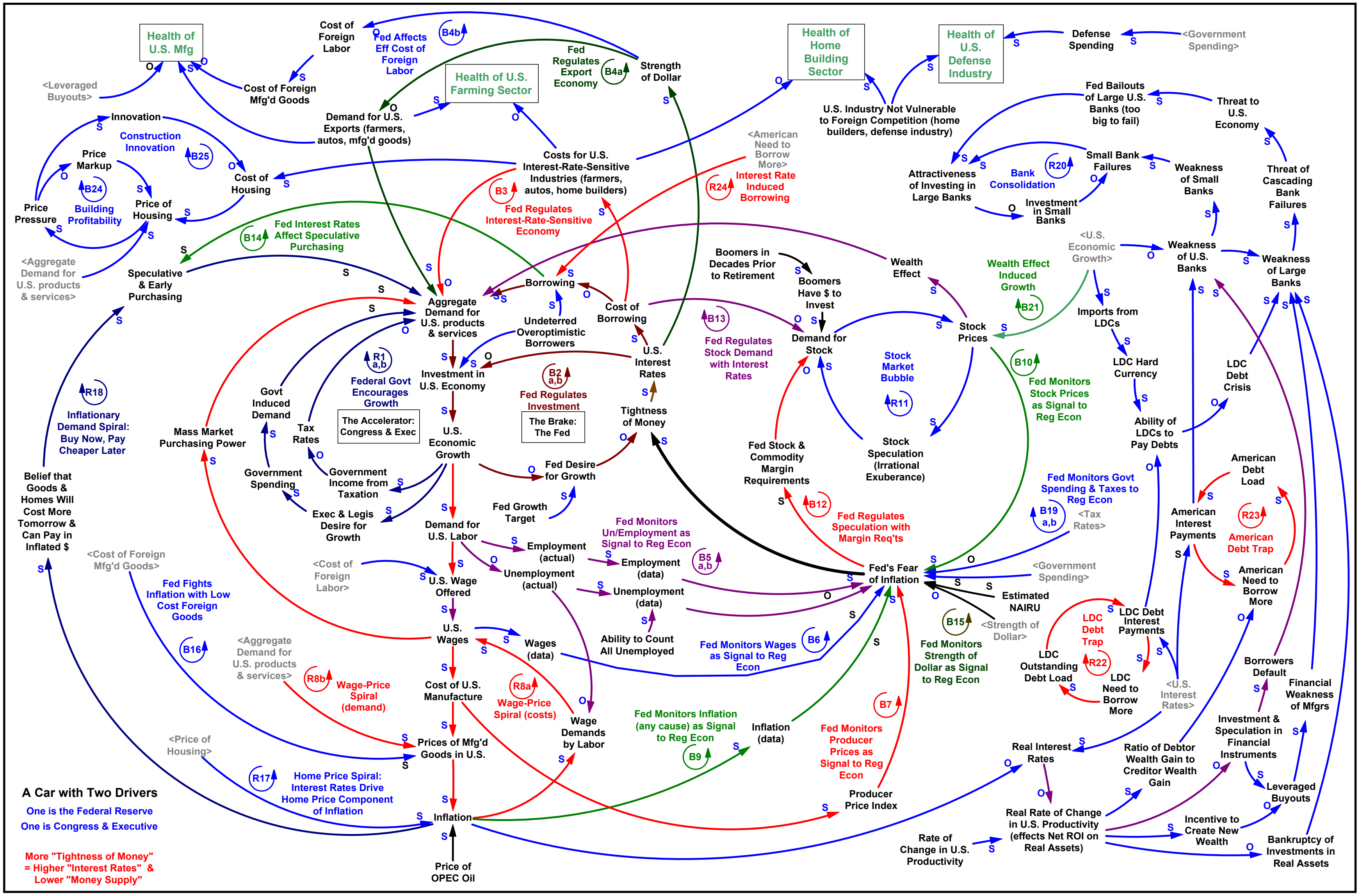


Figure 38. Combined Monitoring and Effects of Federal Reserve Policy on the Economy



Bob Powell, Ph.D., MBA ▪ Continuous Improvement Associates ▪ 6992 Blackhawk Place ▪ Colorado Springs, CO 80919
Phone (719) 599-0977 ▪ Fax (719) 599-0564 ▪ E-mail: scuba@usa.net ▪