Lean Design

Applying Lean Principles to the Design of Automation Systems

Rockwell Automation

June 2004

Introduction

The business world was first introduced to the term "lean" in the early 1990s, when authors James Womack and Daniel Jones published their groundbreaking book on lean production, "The Machine That Changed the World." Initially, lean initiatives focused on examining existing manufacturing processes, then re-working such processes to increase efficiencies. Today, a great many lean initiatives still take the same approach, as noted in Womack's 2003 book, "Lean Thinking." However, in recent years, lean has grown beyond the bounds of both manufacturing and post-production efficiencies, reaching into all departments and time frames of business.

In particular, today's business environment focuses increasingly on the benefits of lean design, which can be applied to three key areas: machine development, the machine itself and the process of building the machine. The greatest benefits, however, often come through a combined approach, applying lean principles to all three areas.

Lean design principles are particularly important at Rockwell Automation, where we work diligently to drive significant operating leverage through the continued implementation of programs like Rockwell Lean Enterprise. Since 2002, Rockwell Automation's Lean Masters Training program has certified 63 Rockwell Automation employees, with each individual responsible for creating $250,000 in lean-related cost savings for valued business and manufacturing partners.

Experts at Rockwell Automation and in other areas of the manufacturing industry have proven time and again that applying lean principles early in the design process can reap major benefits in terms of reduced costs and improved performance, flexibility, reliability and time-to-market. Such benefits can even extend beyond the machine and into the automation controls that govern it.

In the 1981 comedy classic "Stripes," a young John Candy tells his boot camp sergeant that he joined the Army because he wants to become a "lean, mean, fighting machine." It's a line that also applies to automation system design, where lean design can help create a "lean, mean, manufacturing machine."have no other choice but to bear the cost of compliance, what value can be derived out of such compliance efforts from plant and warehousing activity?

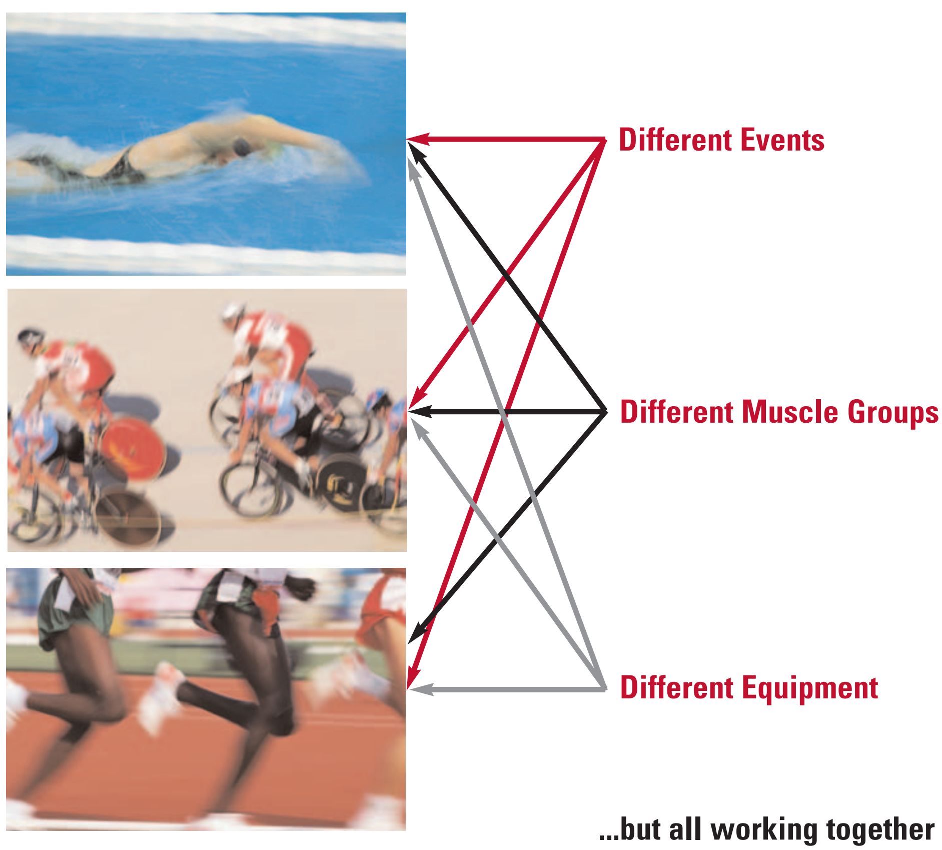
In this paper, we'll explore some of the key challenges and situations we've found through our lean design work at Rockwell Automation – applying lean principles to the design phase of automation projects for companies in a diverse range of industries. We'll work to examine some of the primary concepts behind lean design and how they can apply to automation controls. If you're looking to take a lean design approach to your next machine project, consider the following steps and tips as you move forward.

Show Me the Muda: Definitions, Myths and Misconceptions

The Japanese have a word for waste – they call it "muda." When we speak of "lean" activities, we typically mean looking at an existing process, machine, or schematic and finding places and ways to eliminate muda. Lean design, however, looks not at the finished product, but at the design phase, seeking opportunities to eliminate waste. Lean design is a process aimed at making better decisions when it matters most – early in the design stage. In a control application, this means using the most efficient component for the function and selecting an array of components that work together in the most efficient manner possible. By considering efficiencies during design, a later look to eliminate wasted effort will be unnecessary.

A triathlete tends to be the epitome of a "lean" individual. Competing in a race that includes running, swimming and biking, the best triathletes rarely try to take first place in all three events. Instead, triathletes optimize their muscle groups and athletic skills to cumulatively perform the best.

How does this apply to automation controls? Just as an athlete hones muscle groups, original equipment manufacturers (OEMs) and end users must choose control system configurations that optimize their machine performance. This requires an assessment of risk, analysis of needs and cost-effective implementation.



Applying lean design – or eliminating muda before a machine is built – is a simple enough concept, but going too far in the elimination of waste can result in over-simplification and misunderstanding. Here's a look at some of the erroneous conclusions individuals often jump to regarding lean design:

MYTH: Lean is synonymous with cheap.
FACT: Lean is often thought of as finding the cheapest possible way of doing something. This isn't necessarily true. Just as triathletes don't buy their shoes and equipment at the local discount store, manufacturers should resist equating lean with cheap.

According to James Gregory and Associates, authors of a paper on lean design, the key to success in lean design is to balance technology with cost: "In economic systems, costs and benefits are almost always at odds. Something that doesn't cost much is rarely of much benefit, and if we want to derive great benefit we usually have to invest a lot. Because businesses want to minimize costs and maximize benefits, we clearly have a conflict of goals.

MYTH: Lean design benefits only show up well beyond the design stage.
FACT: There's no question that design decisions greatly affect the final machine cost and quality. Lean design focuses on making better decisions earlier in the design process. Just as athletes need to determine their strategy at the beginning of an event, better decisions earlier mean fewer design "re-starts," more accurate ship dates, lower overall design costs and increased customer satisfaction. In other words, it pays to get the design right the first time by investing in quality and cost reduction at the design stage.

MYTH: Lean means "thin."
FACT: While lean design is meant to reduce or eliminate waste, you can take things too far – to the point where the design is so lean it ceases to be functional. Think of the triathlete who doesn't have enough muscle to finish the race. Thin? Yes. Effective? Hardly. In automation terms, a design that's too lean usually results in no flexibility, difficult integration, low reliability and high support and maintenance costs.

Key Considerations:

Assessing the Risks, Achieving Balance, Earning the Rewards

Companies implementing lean design practices need to both assess their risks and determine the appropriate middle ground between over-engineering and under-engineering their systems.

Risk generally manifests itself in several different ways:

- Technical risk deals with the degree to which the technology you've chosen is proven and reliable.
- Reliability is measured by the long-term dependability and repeatability of the components and systems you've chosen.
- Repeatability is particularly important with highly precise applications, such as those in many assembly, packaging and material handling facilities.
- Cost-risk (procurement cost) needs to be factored based on the available short-term budget, but must be balanced with the long-term consequences of systems that may end up costing more in maintenance, support and upgrades over the long haul.

Factors Determining Risk:

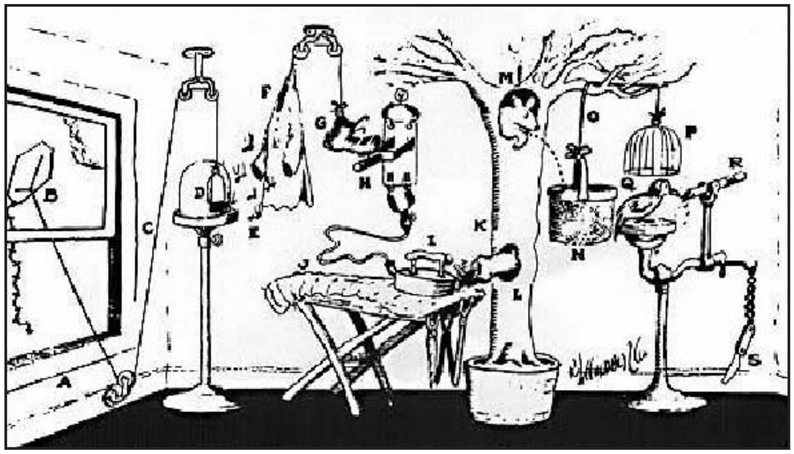
When assessing risk in lean control system design, consider the following questions to guide you through the process:

- Will the solution actually work the way I need it to?
- Is the technology available and stable?
- Can the machine I have designed realistically be built?
- Will it meet the minimum performance threshold?
- Will it eliminate waste or create waste?
- How much will it cost today?
- How much will it cost 5-10 years from now?
- Can it be implemented on time?
- Can it be easily replicated?
- Can it be cost-efficiently expanded and scaled as needed?

Once you determine the appropriate risk factors in your own lean designs, the next issue to address is striking the right balance between over-engineering and under-engineering the system.

Over-Engineering:

The over-engineered solution is easy to spot. It has every bell and whistle, features you'll never use, and a design that's so complex that it can't be replicated, supported or easily adjusted.



Rube Goldberg Pencil Sharpener
Open window (A) and fly kite (B). String (C) lifts small door (D) allowing moths (E) to escape and eat red flannel shirt (F). As weight of shirt becomes less, shoe (G) steps on switch (H) which heats electric iron (I) and burns hole in pants (J). Smoke (K) enters hole in tree (L), smoking out opossum (M) which jumps into basket (N), pulling rope (O) and lifting cage (P), allowing woodpecker (Q) to chew wood from pencil (R), exposing lead. Emergency knife (S) is always handy in case opossum or the woodpecker gets sick and can't work.

The best remedy for an over-engineered system is understanding the precise needs of the customer. Define the value of the machine to the customer – clearly. Avoid design overshoot and unnecessary features. Lean design delivers value to the customer – and nothing more. There is no design overshoot. Ask the key question: "Exactly what does the customer want the machine to do?" This may seem like an obvious question, but engineering projects often have a way of veering off course. "Feature creep" sets in, and the end result is not what the customer needed.

Be sure to identify the "must have" features, versus "nice to have" features. Keep in mind that customers may not know what is possible with today's technology. This requires an in-depth discussion regarding each requirement. Time pressures, combined with working with incomplete information, can lead to "satisficing." Satificing is defined as: "obtaining an outcome that is good enough." "Satisficing action" can be contrasted with "maximizing action," which seeks the biggest outcome, or "optimizing action," which seeks the best outcome.

Nothing is more frustrating than having a system with a host of unnecessary features, but lacking an essential one. Moreover, the elimination of unnecessary features results in a more reliable system, keeping the design as simple as possible. Complexity equals opportunity for waste and increased cost.

While over-engineering is a common problem, under-engineering can often be even more detrimental to design success.

Under-Engineering:

"Worldwide experience has shown Shell Global Solutions that about 65 percent of instrumented trip functions are over-engineered, while 10 percent are actually under-engineered and could therefore represent a weak link in the overall integrity management of the facility. The level of maintenance and function testing carried out on systems is often determined by intuition and experience which leads to far more intervention and higher associated costs than necessary."
– Shell Global Solutions

Under-engineered systems can appear in two forms:

- *First, they are designed and built using components that just barely meet the minimum performance threshold*, which virtually halts any opportunity for future expansion. These systems also use the cheapest possible components, regardless of whether or not they're reliable.
- *Second, under-engineered systems tend to use components from suppliers without a full complement of support resources*, rarely taking advantage of valuable data generated by the machine – data that can be used for production scheduling, quality assurance and predictive maintenance.

Under-engineered systems tend to be extremely difficult to integrate. Cheap components or components that don't fit well together are both a recipe for disaster. In lean control systems there are no non-essential components. If components weren't essential, they wouldn't be there. Failure begins when one weak point begins linking up with others. So, contrary to popular belief, quality doesn't always cost more – it can actually cost less, by eliminating unneeded and unreliable components.

Criticality of Components:

As Charles Perrow states in his book, "Normal Accidents," the patient reconstruction of major accidents often "reveals the banality and triviality behind most catastrophes." Control system components may seem trivial to some, but something as banal as a pushbutton malfunctioning can lead to catastrophe. While Perrow's book deals with large, complex systems such as nuclear power plants, we shouldn't be lulled into thinking that a micro-programmable controller with a small Human Machine Interface is a "simple" system.

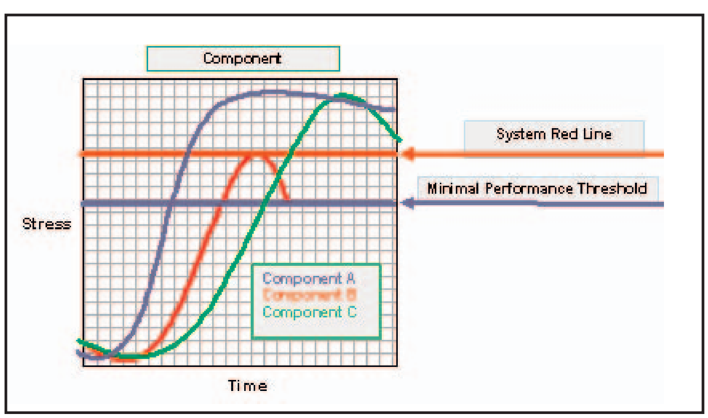
Lean Design

The continual miniaturization of technology leads us to believe that it is simpler, while the reverse is true.

The computers in the Apollo space program used about 5,000 primitive integrated circuits (if that sounds like a lot, consider that an Intel P4 has 55 million transistors). It didn't have a disk drive, only 74 kilobytes of hard-wired program memory (to change the program, you had to change the wiring) and about 4 Kilobytes of something akin to RAM. Was that a "simple" system? No, but it was lean. It may have been the first and ultimate lean design.

Photo: The Display and Keyboard unit, or DSKY, the interface for the Apollo computers

Ultimately, control systems using lean design concepts have to surpass a minimum "design threshold" – one that takes into account component performance and integration. Beyond the design threshold is the system "red line." We all know that reaching the red line on our car's tachometer means the engine is reaching the point at which the system (or, the four valves per cylinder, dual overhead cam, electronic fuel-injection engine, in this case) can experience not only failure, but a catastrophic system fracture. This is why understanding the function and stresses on each and every component of a machine is so critical.



The system's red line is the lowest red line of a component in the system. The individual peaks are the point at which the component is at 100 percent of its capacity to function.

Think each component in a system isn't absolutely essential to application success? Take a look at the following story, as reported by major news outlets in late 2003:

"Component Failure Causes Recall of 2.56 Million Vehicles"

TOKYO – [A major Japanese car manufacturer] is recalling 2.56 million vehicles worldwide because of faulty engine sensors that may prevent the vehicles from starting. No injuries or accidents linked to the defects have been reported. [The automaker] announced on Thursday a recall of 1.03 million vehicles in Japan and 1.53 million vehicles overseas. About 700,000 were recalled in the United States and another 460,000 were recalled in Europe.

Lean Development Process:

In an article for *Advanced Manufacturing magazine*, former industrial engineer and plant manager Bill Cloke outlines a series of Lean New Product Development processes that can be adapted to the development of new machines:

1. *Define value*, in this case the successful design of a new lean machine. Map out the current development process, analyze it and eliminate the muda (waste). Any activity that does not contribute to the completion of the design is waste.

2. *Cut out layers of approvals, bureaucratic paperwork and unnecessary or lengthy meetings.* Try to use frequent, informal meetings to coordinate design activities. Eliminate unnecessary documents like "status reports."

3. *Keep only a central record of the current design*, including drawings, cost models, specifications and design decisions. The central design record should be kept electronically, so the entire team can access the most current version at all times.

4. *Avoid the waste of design engineers searching for information*. Maintain a central database that includes reusable design elements and code, specifications, industry standards, supplier information, preferred parts lists, etc.

5. *Use critical path management*. Do serially only those items in the critical path. Identify non-critical items and do them in parallel.

Conclusion:

Why Be Lean?

Lean control system design is an evolutionary process – one that can't be achieved overnight, but one that still provides significant benefits along the way. Manufacturing end users and OEMs who closely analyze their systems to identify waste, accurately assess the risks and strike the proper balance between over-engineered and under-engineered systems will find themselves experiencing fewer design "re-starts," more accurate shipment dates, lower overall design costs and, ultimately, an increase in customer satisfaction. With benefits like that, who wouldn't want to be lean?

Sources:

1. Lean Design: Assessing Performance, Produce-ability, Cost and Risk Much Earlier in the Design Process. James Gregory and Associates. Presented at the 1998 Defense Manufacturing Conference.

2. Lean Products Start With Lean Design, Bill Cloke, Advanced Manufacturing, March 2000.

3. Apollo Expeditions to the Moon, ed. Edgar M. Cortright, NASA SP.

4. Alliance Lean Design/Construct on a Small High Tech Project, Robert S. Miles, 1998.

5. Inviting Disaster – James R. Chiles, 2002.

6. Lean Thinking – James P. Womack and Daniel T. Jones, 1996.

7. Rockwell Automation Lean Enterprise sources, 2001-2004.

8. The Logic of Failure – Dietrich Dorner, English translation, 1996.

9. Normal Accidents – Charles Perrow. 1984, 1999.

10. The Penguin Dictionary of Philosophy - ed. Thomas Mautner.

11. Associated Press, Oct. 30, 2003.

www.rockwellautomation.com

Corporate Headquarters
Rockwell Automation, 777 East Wisconsin Avenue, Suite 1400, Milwaukee, WI, 53202-5302 USA, Tel: (1) 414.212.5200, Fax: (1) 414.212.5201

Headquarters for Allen-Bradley Products, Rockwell Software Products and Global Manufacturing Solutions
Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204-2496 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444
Europe/Middle East/Africa: Rockwell Automation SA/NV, Vorstlaan/Boulevard du Souverain 36, 1170 Brussels, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640
Asia Pacific: Rockwell Automation, 27/F Citicorp Centre, 18 Whitfield Road, Causeway Bay, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

Headquarters for Dodge and Reliance Electric Products
Americas: Rockwell Automation, 6040 Ponders Court, Greenville, SC 29615-4617 USA, Tel: (1) 864.297.4800, Fax: (1) 864.281.2433
Europe/Middle East/Africa: Rockwell Automation, Brühlstraße 22, D-74834 Elztal-Dallau, Germany, Tel: (49) 6261 9410, Fax: (49) 6261 17741
Asia Pacific: Rockwell Automation, 55 Newton Road, #11-01/02 Revenue House, Singapore 307987, Tel: (65) 6356-9077, Fax: (65) 6356-9011

Publication CMPNTS-WP001A-EN-P – May, 2004