Dynamics of Lean Accounting Innovation on Future Performance: May "Accelerated" Accounting Lead Astray?

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Abstract

This research explores the effects of implementing a lean production system in a government facility that is formally governed by accounting practices which delay recognition of production savings but which informally promotes its lean efforts through attention-getting, off-the-books, "innovative" accounting. We state three propositions relating to customers effects of the lean improvements and the financial approaches. We then state four hypotheses relating to unintended effects of these measures as a facility's workload varies, and test the hypotheses employing a system dynamics simulation. We identify minor effects upon customer behavior and labor rates oscillation, thereby filling gaps in the literature relating to government productivity improvements, and expanding knowledge relating to lean labor savings, work demand, and employment effects.

Introduction

In order to save his U.S. Army depot and its jobs from probable extinction, a newly-assigned depot commander introduced lean production methods. He needed to publicize resulting lean successes promptly, before base closure decisions were made, but Department of Defense accounting rules are designed to account for productivity gains only over a multi-year period. Those rules aim to offer depots' customers predictable "stabilized rates," although their mechanism in fact builds in some degree of oscillation across overlapping multi-year funding and accounting periods. With support from his superior officer, the commander catalyzed lean efforts, introduced an innovative accounting practice to "short cut" the multi-year accounting delay, and in the end managed to preserve the depot's existence.

Several principles have come to be textbook learning in system dynamics. Systems may exhibit varied patterns of behavior, including stasis or equilibrium, random behavior, locally-stable damped oscillation, locally-unstable limit cycle oscillation, and chaotic oscillation (Sterman, 2000: 127-133). Oscillations in a system are created when its structure provides for balancing feedback across a significant time delay. "In an oscillatory system, the state of the system constantly overshoots its goal or equilibrium state, reverses, then undershoots, and so on." (Sterman, 2000: 107, 114) The amplitude of a system's variance from its goal is a function of its negative feedback structure and the length of the feedback period. While targeting a system's behavior to maintain a goal value is common and often desirable, as in the case of conditioning air temperature through a thermostat, overshooting and undershooting a goal often enjoy negative connotations, being seen as excursions from target behavior. Yet in some cases delays may be inserted intentionally into systems so as offer useful buffers against precipitous action, as in the cases of "cooling off" periods in labor disputes (Gunderson et al., 1989) or international finance (Taylor, 2002), or to ameliorate expected outcomes, as in medical care (Shah et al., 2006).

The "innovative accounting" and specifically its operation over time raise questions of interest with respect both to accounting controls generally and to accounting for operational improvements that are brought about through approaches like lean management. Not previously considered in the published academic literature, they are of interest to government parties including the U.S. Department of Defense, to lean practitioners and to system dynamics practitioners. This research fills gaps in the government accounting and finance literatures relating to productivity improvements in a DWCF environment, and expands theoretical knowledge relating to lean labor savings, work demand, and employment effects.

This research initiates a framework for examining the dynamics of competitiveness of military facilities seeking to obtain commercial contracts. It also opens the systems discussion of the "less employees are needed" phenomenon of lean promotion in a governmental context. Analysis of these dynamics will have clear relevance for governmental and quasi-governmental institutions. In the United States, the military, postal service and state governments may take note.

Accounting Context: Department of Defense

The United States Department of Defense ("DoD") has prescribed accounting principles, standards, policies and practices for defense facilities through its Financial Management Regulations ("FMR") and its Statement Of Federal Financial Accounting Standards ("SFFAS"), which are considered generally accepted accounting principles for government agencies. Under the FMR, a defense working capital fund is established for each service branch, consisting of activity groups managed at various sites to provide goods and services on a reimbursable basis to DoD and non-DoD customers. For the Army, there is a separate Army Working Capital Fund ("AWCF"), the specific context of this paper. AWCF activities operate on a break-even basis, and customer rates developed by depots, arsenals and ammunition plants are established on an end product basis when feasible. Rates are required to be established at levels to recover, over the long term, the cost of products or services provided, as well as approved surcharges. Stabilized rates and prices are among nine enumerated objectives of DWCF: "Establish, whenever feasible, standard prices or stabilized rates and unit prices for goods and services furnished by DWCF activities, thus enabling ordering Agencies to more confidently plan and budget." Because they may occur as a result of variations in program execution, gains and losses of prior periods "…generally are reflected in offsetting adjustments to stabilized rates established in subsequent fiscal years." (FMR, 2002)

As described in Labedz and Harvey (2006), the FMR prescribe for depot facilities certain budget practices and mechanisms, including their maintenance of annual net operating result ("NOR") and ongoing accumulated operating result ("AOR") accounts. The NOR account is zero-based each 1 October, when the federal Fiscal Year ("FY") begins, and the AOR account is zero-targeted through the "offsetting adjustments" process. For the depots, each FY sits midway in a seven-year cycle, as depicted in Figure 1. (Subscripts here and throughout this paper refer to government fiscal years in sequence: FY_{n-1}, FY_n, FY_{n+1}, etc.) In light of the overlapping cycles' length, oscillations in the system are to be expected, as the balancing feedback of offsetting adjustments operates across a significant time delay. These mechanisms in fact have been designed to provide controlled oscillation in the labor rates which depots charge their customers. (Jargowski, 1985)

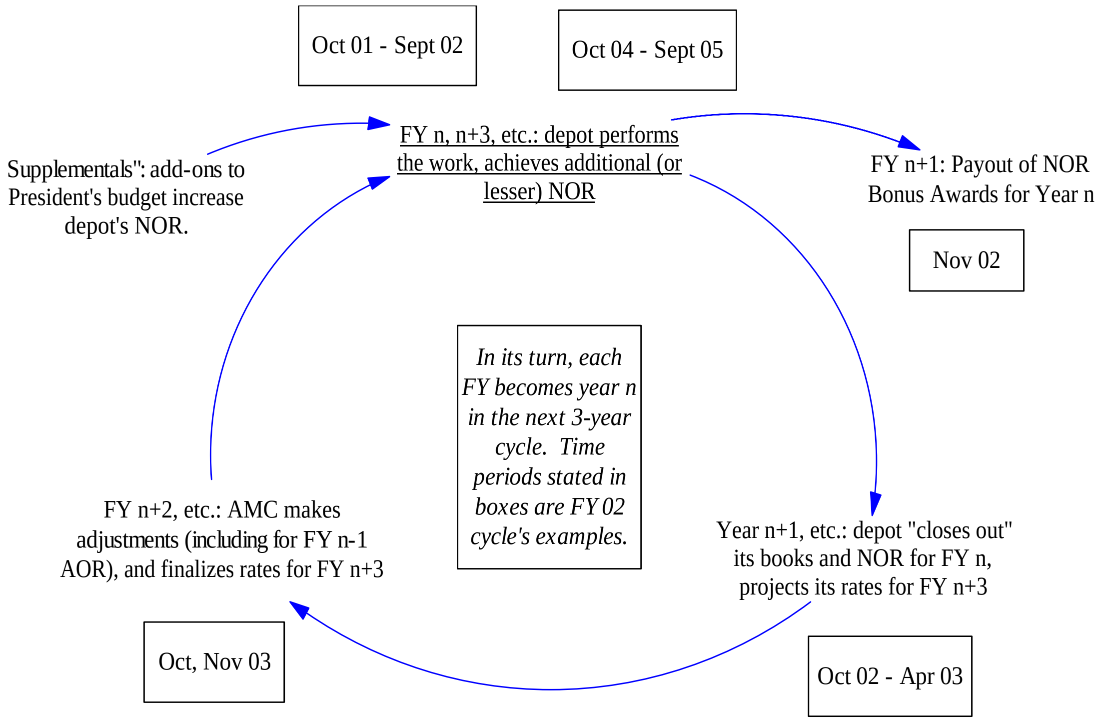

Fig. 1. The multi-year cycles of depot performance and rate estimation and adjustment.

Like similar facilities, Letterkenny Army Depot (“LEAD” or the “depot”) in Chambersburg, Pennsylvania sells its services chiefly through fixed price contracts: it receives a fixed price for its services, whether its actual costs turn out to be higher or lower than that price. If the depot reduces in practice its expenses in a given year, it will increase its NOR (which is very similar to profit/loss in the private sector) for that year. Under the FMR, however, depots are not designed to “make money” over a multi-year period. Instead, after each 30 September FY end, two financial operations occur at the depot. First, the depot closes its books for the just-concluded fiscal year. (For example, the FY 2002 books closed during the early weeks of FY 2003, effective as of 30 September 2002). Second, over the next few months, the depot calculates prospective rates for the FY that is two years after the current fiscal year and loads them into the Army budget system. (Continuing the example, proposed FY 2005 rates were loaded around the middle of FY 2003). In the beginning of the following FY (i.e., early in FY 2004), Army Materiel Command (“AMC”) reviews and adjusts the rates proposed by its depots for the next-to-begin fiscal year (i.e., for FY 2005). The overall intent is to hold rate growth fairly steady (i.e., predictable) while “giving back” to future depot customers approximately half of the positive NOR previously earned by the depot or, in the case of negative NOR, surcharging them. In sum, FY 2003 serves as the work period in which FY 2002 numbers are closed out and FY 2005 rates are estimated, proposed and “locked in” at the depot, and FY 2004 as the period in which AMC finalizes the FY 2005 rates, budgets and NOR targets of all depots.) Thus, positive or negative variance from a depot’s targeted NOR in a FY is formally recognized and reversed through rates applicable to the work it performs three years later. Intent under the FMR is to maintain each depot’s multi-year AOR near zero; that is, to target the cumulative sum of a depot’s annual NOR amounts to be as close to a zero balance as possible. In the end the depot as a government agency neither makes nor loses money.

Algebraically, we state the relationships among these rate factors in simplified terms as follows:

$$\text{Proposed Rate for FY n+3 in FY n+1} = \text{Base Rate} * (1+ \text{Labor Rate Escalator})^{3}$$

$$\text{AMC-adjusted Rate for FY n+3 in FY n+2} = \text{Proposed Rate} - \text{AOR Adjustment}$$

$$\text{AOR Adjustment} = \frac{(AOR_{FY\ n-1} + NOR_{FY\ n})}{(DDGE_{FY\ n+3} * DSWH_{FY\ n+3})}$$

where DDGE stands for the Depot's "direct" government employees headcount and DSWH means the Depot's assumed annual standard work hours per employee. These two elements averaged 687 workers and 1,615 hours per employee respectively over the ten FYs ending 30 September 2008.

Lean Implementation and Innovative Accounting at LEAD

In prior research, the first author collaborated in describing and assessing an aggressive program of lean improvement which avoided LEAD's business failure and closure (Harvey and Labedz, 2006). As recounted there, LEAD embarked in August, 2002 on a rapid deployment of lean six sigma ("L6σ") practices to try to save the depot and its 1,100 to 1,500 regionally-well-paying jobs from likely extinction just three years later. Given the overall seven-year budgeting cycle, it was probable that even massive productivity improvements would go unnoticed until well after the 2005 Base Realignment and Closure ("BRAC") Commission had made its base closure recommendations for Congressional approval. As one of the Army's poorer-performing, higher cost depots, LEAD likely would be shrunk (as it had been in 1995) or closed entirely. Its commander, Colonel William Guinn, needed both to overcome industrial inefficiency and to avoid DoD-designed delays in depot accounting to bring to light the gains made by the workforce under L6σ.

The nature of the depot's work is threefold: repair, recapitalization (complete equipment disassembly through restoration "zero hours, zero miles") and servicing (including upgrading and up-armoring) of military systems. Thus, its final customers also provide the equipment on which it works. In the pursuit of efficiencies through lean practices, managers and analysts aim to trim non-value-added waste or *muda* from a system's design and operation. Steps to reduce or eliminate system delays, through focus on such measures of speed as reduced waiting time (Murman et al., 2002) and synchronous *takt* time (Womack and Jones, 1996), are important tools for lean practice. Depot leadership not only introduced and drove lean operational improvement but devised a method to take advantage of the resulting financial savings more than two years before the AWCF accounting system otherwise would recognize them.

As a result of Letterkenny's lean efforts and its finance innovation, its customers began to benefit almost immediately. In the first instance, lean efforts predicted the completion of contracted work 2.5 months (20%) ahead of schedule, with $1.2 million of direct labor unused. Because the contract was on a fixed price basis, the unused funds were LEAD's to keep. In fact, under Army regulations, the depot could not simply give the unused dollars "back" to its customer, and it had no authority to perform additional work. The depot commander approached his customer with a suggestion: Letterkenny would memorialize a portion of the savings on a form known as a military interdepartmental procurement request or "MIPR". This form serves essentially as a "check between military agencies" (48 CFR 2917.501, rev. 2004; Labedz and Harvey, 2006: 10). If the customer would endorse the "check" back over to Letterkenny with a request for added work, the depot could provide more services at no charge. These services would be performed under a new work order number, opened immediately. This procedure meant that the depot would receive both a request for added work and a "check" to fund it. Not only did the customer like the idea of "free work," but it found $300,000 in additional funds to supplement LEAD's lean savings.

LEAD's customer refund innovation telescoped the Army's multi-year AOR stabilized rates process by putting spendable current year budget dollars back in the hands of current customers. The depot translated the additional dollars into additional, current product deliveries to its customers. Figure 2 below shows this innovation superimposed with arrows on a portion of figure 1. In this example, FY_n is represented as FY 2003, the first year in which Letterkenny employed its finance innovation. Note that all entries in figure 2 refer to that single fiscal year, rather than to multiple years of a three-year cycle as in figure 1.

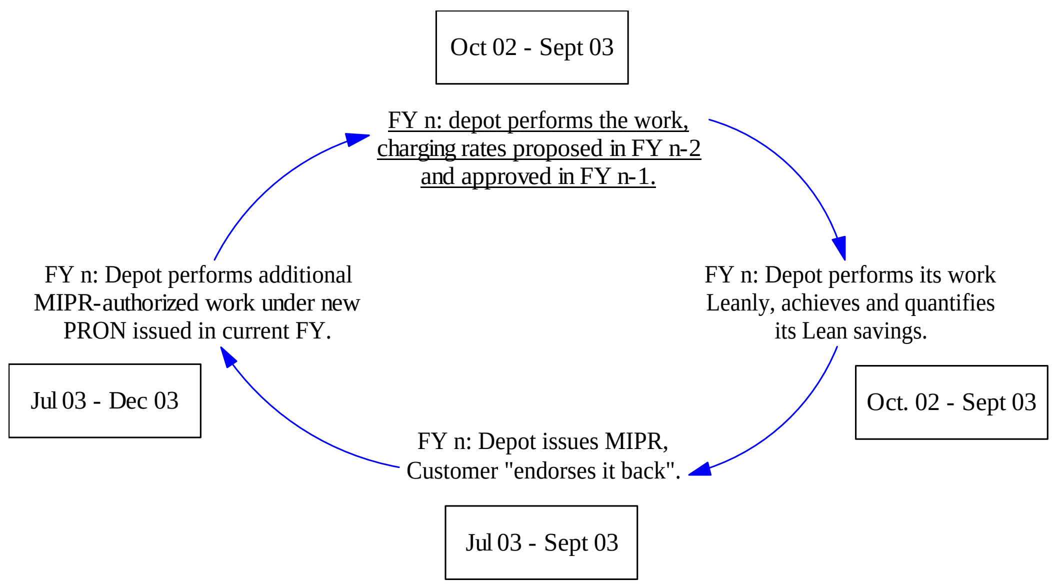

Figure 2: Letterkenny's financial innovation: rapid realization of emerging savings.

Since 2003, LEAD used this approach three more times to put additional spendable budget dollars back in customers' hands. Its procedure identified refund amounts on a timely basis so customers could spend their refund dollars during the current fiscal year. The depot made available 60% of its savings dollars to its customers, because its leadership decided to retain the balance to hedge against any savings setbacks and to invest in depot infrastructure. LEAD has passed back $5 million in total to its customers.

LEAD's receipt back of endorsed MIPRs and resulting over production did not represent new depot revenues nor add anything to its NOR. In order to generate surplus NOR, the depot needed to receive supplemental-to-budget hours ("SBH") or to bring in truly new work, military or commercial. Development of surplus NOR was desirable to Colonel Guinn. In order to develop and maintain workforce commitment to lean efforts, he had renegotiated the basis for annual cash bonus payments to LEAD employees, basing these on achieving NOR in excess of the depot's target figure. To meet employee expectations and pay cash bonuses he needed more NOR, and lean efforts could help to deliver it. The renegotiated bonus program bore the hallmarks of a gain sharing incentive program (Ross and Ross, 1991), and the implementation of such programs is a tool commonly used in developing workforce commitment to organizational transformation efforts like lean (Kling, 1995).

Both new business hours ("NBH") and supplemental appropriations offered to add to NOR. To the extent that newly-contracted work re-engaged direct labor that had just been freed up by lean efforts, it would bring a double benefit to NOR. First, within capacity limits, it adds top-line revenues without adding any labor expense. And because the depot's overhead expense already is paid within the President's budget hours ("PBH"), the overhead rate portion of added dollars "drops to the bottom line". Supplemental appropriations often add direct workforce headcount; in such a case, the benefit of twice-paid overhead costs adds to NOR. Labedz and Harvey (2006:14) explain these NOR effects in greater detail.

We must note that non-military (i.e., commercial) work does not share in the depot's lean-permitted practice of placing additional spendable dollars back in customers' hands. Labor rates for commercial work are approved only by the depot, and not by its AMC headquarters. Commercial work is not subsidized by in-year depot savings. Commercial work is priced to be cost recovered in the year of execution.

Research Questions

The depot's coupling of lean practice with its accounting innovation seems to offer a double benefit: eliminations of delay that – per basic systems theory – may cause unintended consequences in later periods, and elimination of financial, labor and materiel waste that such delays often introduce into production processes. Nonetheless, the second case study identified certain questions regarding unintended consequences and limiting conditions (Labedz and Harvey, 2006: 14-20), which this paper explores through qualitative research and a system dynamics model simulation:

1. Under what circumstances may this accelerated accounting-for-lean innovation, or resulting changes in labor rates, engender changes in expectations and purchasing behaviors of current or prospective depot customers?
2. Under what circumstances may this innovation introduce unintended (and undesired) oscillation levels into future depot labor rates?
3. Generation of surplus NOR by a depot requires both efficiency improvements and the capturing of additional work for its freed-up labor to perform. The dynamics of this accounting-for-lean innovation are unclear when funding for such work is level or declining. Should we expect depot labor rates to exhibit greater / lesser sensitivity to budget levels as a result?

Sterman (2000) among others cautions that a modeler should model a specific problem and not a system. This article varies from that "inductive" guidance, inasmuch as it models the likely incidence and *prospective* magnitude of unintended, unfortunate financial consequences *before* they have had an opportunity to emerge. Gröβler and Milling (2007) contend that "deductive" dynamics modeling may be considered a valid "academic" use of systems modeling, subject to appropriate safeguards and cautions. The approach of the current paper lies between these two approaches. It aims to model "pragmatically" a specific empirical context, but one which has been modified in two known respects: acceleration of operational information feedback, and managerial action thereon.

Lean Improvements, Accounting Innovation and Customer Satisfaction

Published systems research has not explored the dynamics of accounting as a management system. However, researchers in accountancy have begun to investigate lean + accounting topics. Lockamy and Smith (2000) contend that both traditional and activity-based cost management practices are deficient in conjunction with lean methods, and they offer an economic framework for replacing these in supply chains with "target costing" processes aimed at increasing end-customer satisfaction. Kennedy and Brewer (2006) and Maskell and Kennedy (2007) respectively have explored the relationship between "traditional" accounting and lean practices and the nature of "lean accounting." (We distinguish between two possible meanings of "lean accounting": accounting for results of lean, which we study, and the lean practice of accounting duties, which we do not. Because Maskell and Kennedy investigate the latter, we exclude their work from further discussion.)

Systems researchers however have considered the dynamics relating to lean production systems (Gonçalves, Hines and Sterman, 2005) and to custom building and service supply chains (Anderson, Morrice and Lundeen, 2005). Croson and Donohue (2005) contrasted the effects of directionality of inventories information flows upon oscillations of orders within a supply chain. Understanding of the "bullwhip effect", in which information delays across a supply chain lead to magnified inventory variances (Lee, Padmanabhan and Whang, 1997), emerges as a common theme in this research. Croson and Donohue distinguish, in the well-known "beer game" context (Sterman, 1989), between the systemic effects of accelerated upstream and downstream data sharing. In downstream sharing data are provided, with lesser information delay than usual, from earlier in the serial stages of: raw goods procurement, final goods production, distribution and retail. Conversely, in upstream sharing, retailers' and other later stage data are shared more promptly or concurrently with earlier supply chain actors.

LEAD's lean accounting innovation provides accelerated downstream data sharing, relative to its labor productivity and available hours, to existing and prospective customers and ultimately to the BRAC Commission's staff. Croson and Donahue found that downstream data sharing decreased order oscillations throughout a traditional supply chain and predominantly in its earlier stages. *Decreases* in supply chain oscillation are additive to firms' value, permitting reductions in the twin evils of excess inventories and prolonged stock-outs. Inasmuch as its end-user customers provide the equipment on which the depot works, LEAD's accelerated data sharing can advise them – as prospective customers, too – of the depot's emerging capacity to reduce faster their inventories of service-required materiel.

LEAD's accounting for lean success increases customer satisfaction, as Lockamy and Smith promote. When will the depot's saved labor hours actually translate into such satisfaction among current customers? Because the official accounting system is fixed price, their satisfaction likely increases only when they themselves can take advantage of the depot's lean efficiencies. In the absence of additional funds to purchase more depot services, they can take such advantage only when three conditions coincide.

We address the first research question (customer considerations) through a simple diagram that mixes causal loops and stocks and flows, and we state propositions based thereon. We address the balance of the research questions (depot financial effects) through a full stocks and flows simulation that permits null hypothesis testing. Figure 3 presents the customer considerations.

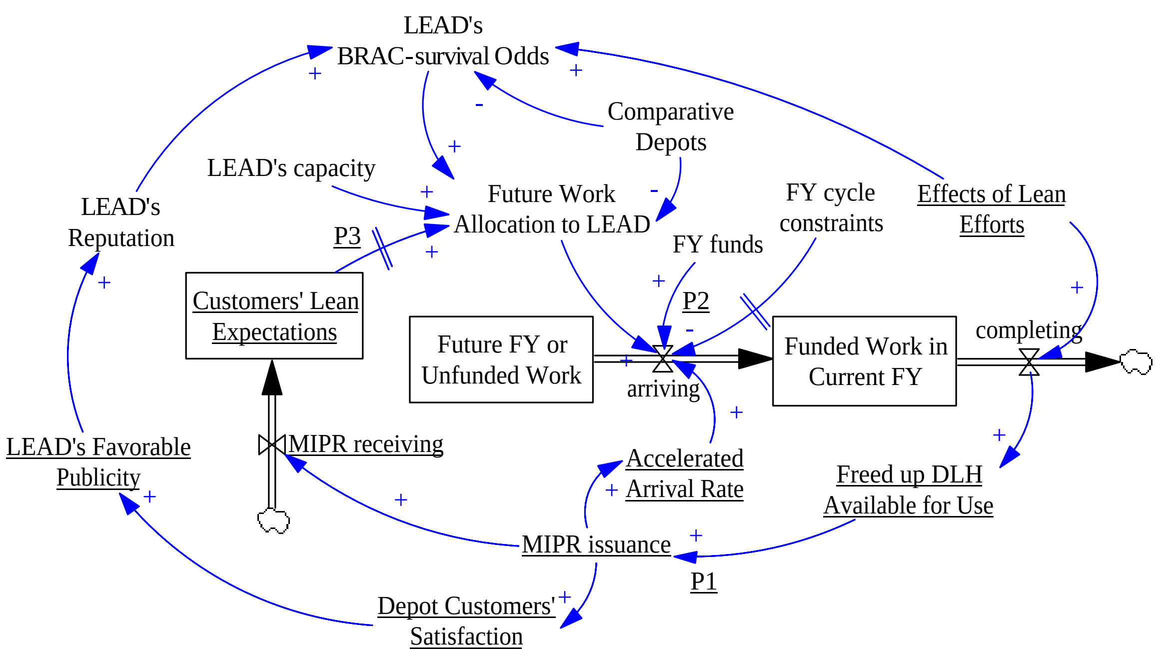

Figure 3: Mixed Diagram: Customer Satisfaction with Lean's Fruits.

In this figure, the solid arrows and regular font define relationships existing in the depot world prior to lean's introduction by LEAD. All of the dotted arrows and underscored text represent relationships added through the dual mechanisms of LEAD's lean improvements and its MIPR give backs of unused DLH to customers.

In the first case, current military customers will enjoy the fruits of LEAD's improvements only when they have work to be performed in excess of funding authority ("Future FY or Unfunded Work" backlog) and the depot's lean or other efficiency efforts have freed up direct labor hours to perform at least some of it through MIPR issuance (P1 in figure 3).

Proposition 1. Current military customers' satisfaction with lean efficiencies increases when the depot's current uncommitted lean savings and MIPR "give-back" willingness, plus customers' backlogs of service-required materiel, coincide.

If however additional funds exist (P2), as through supplemental appropriations, the depot's give-back willingness is not central. In that case, only the depot's freed-up or newly-added direct labor capacity and customers' unaddressed needs matter.

Proposition 2. Current customers' satisfaction with lean efficiencies increases when the depot's uncommitted labor capacity (including through its prior lean efforts), plus customers' back "inventories" of service-required materiel and unspent appropriations, coincide within a fiscal year.

So long as they have work that needs to be performed and funds to pay for it, prospective customers look first to the depot's capabilities and capacity to do the work, whether that capacity has been freed up by lean successes or through other causes. If such parties understand the depot's lean path and its potential for "give-back" actions in future years (P3), however, they may be more likely to place work orders with LEAD in the first instance.

Proposition 3. Prospective customers' satisfaction with lean efficiencies develops later, only as their follow-on work requirements are met through the depot's uncommitted lean savings in future periods plus the availability of either MIPR "give-back" willingness or of unspent customer funds.

We do not test these propositions, but will return to them in the light of the cited case studies during the discussion section below.

Lean Savings, Revenue Sources, and Rate Stabilization

The rate factor equations presented above suggest that our quantitative system dynamics modeling effort focus on the behaviors of two variables: Proposed Rate for FY_{n+3} in FY_{n+1} and Depot FY_n NOR. The current NOR alters the subsequent Proposed Rate through the intervening AOR Adjustment. NOR is affected by the quantities of the depot's authorized labor hours and their varied sources, and by the effect of LEAD's lean implementation in making FY Aggregate Surplus Hours available and visible for re-use, and thus for generation of additional NOR, all within the current FY.

LEAD's lean implementation and accounting innovation seem poised to promote *increases* (i.e., greater variance from target) in annual NOR while simultaneously adding to the depot's value in the form of its efficiency. Assuming continuing levels of the work (SBH and NBH) in which opportunities to earn NOR through lean savings are rich, we predict increased variance between rates as proposed and rates as applied after NOR-based adjustments.

Hypothesis 1. Where SBH and NBH are available at constant levels across successive fiscal years, lean implementation and the surplus hours accounting innovation further decrease Depot-applied rates in FY_{n+3} below proposed and adjusted labor rates.

As mentioned, lean savings on already-contracted work do not add to NOR. In order to generate it, the depot needs to gain work that is funded either through SBH or NBH or both. The overhead portion of the depot-applied rates has already been funded through PBH and so that portion falls directly to the depot's bottom line. Still, such added SBH/NBH work offers even richer NOR opportunities if lean savings can be achieved, because the depot gains the opportunity to re-sell unused direct labor. If SBH and NBH are large or are increasing, NOR opportunities abound, but such "profits" will need to be given back through rate adjustments in later years. Lean savings will add to those, so that the subsequent rate decrease contributions may be expected to be even greater.

Hypothesis 2. Where SBH or NBH are increasing across successive fiscal years, lean implementation and the surplus hours accounting will produce greater reductions between rates proposed and subsequently-applied rates.

Conversely, diminished or diminishing streams of SBH and NBH reduce NOR-earning capacity, and with lesser NOR comes lesser contribution to rate adjustments in future years. Even in this diminishing case, lean savings and resulting direct labor hours re-sale will contribute to NOR and thus to any subsequent downward rate pressure.

Hypothesis 3. Where SBH or NBH are diminishing across successive fiscal years, lean implementation and the surplus hours accounting will contribute an increasing share of reductions between proposed and subsequently-applied rates.

Because SBH work tends to appear late in FYs while NBH historically have been available unpredictably across the year, the decrease-to-NOR effect of diminishing NBH should be greater. Labor savings made available throughout the year by lean efforts may be absorbed more promptly in supporting new business opportunities than in awaiting late-in-the-fiscal-year supplemental appropriations. If NBH are less available, then re-use of labor hours occurs less-promptly.

Hypothesis 4. Lean implementation and the surplus hours accounting innovation will produce the smallest rate reductions where NBH allocations are diminishing across successive fiscal years.

Model Description and Research Site

We address the second and third research questions and the four hypotheses through a stocks and flows simulation. We developed our models in the Vensim systems simulation software (Ventana Systems, 2003) within the space of six model views (in Vensim parlance), three of which are reproduced as figures 4, 5 and 6 in this paper. All simulation model equations are available from the first author, but we use Vensim's "hide" feature in this paper's figures to conceal some incidental model elements, such as certain assessment tests (Sterman, 200: 859 ff), for the sake of the drawings' clarity.

Our data were provided by depot leadership, covering ten FYs ending 30 September 2008. Data includes PBH, SBH, NBH, NOR, AOR, labor rate escalator, standard work hours and headcount values for each year. While we thus know the yearly variances across the data, we generally employ average values, given our research questions. In the simulation used to test hypothesis 1, PBH and NBH values are introduced for all years, but SBH are introduced only beginning in FY 2004, consistent with the depot's experience.

Figure 4 presents the emergence of surplus direct labor hours in a FY through lean savings or, generically, other performance improvements. In it, supply (the top stock, contracted workforce hours) and demand (the bottom stock, customers' orders translated at job-standard hours) grow, but these offset one another unless lean production savings (the middle stock) or other departures from standard work pace occur. If "lean savings pct" equals 10%, for example, then FY Aggregate Surplus Hours are "emerging" each month as hours are posted, until the surplus is zeroed out in the year-end closing of books. This stock may be expected to develop in a non-linear first-order manner because the depot's work from varied sources (PBH, SBH and NBH) arrives on distinct timetables ("incidence") in a typical FY.

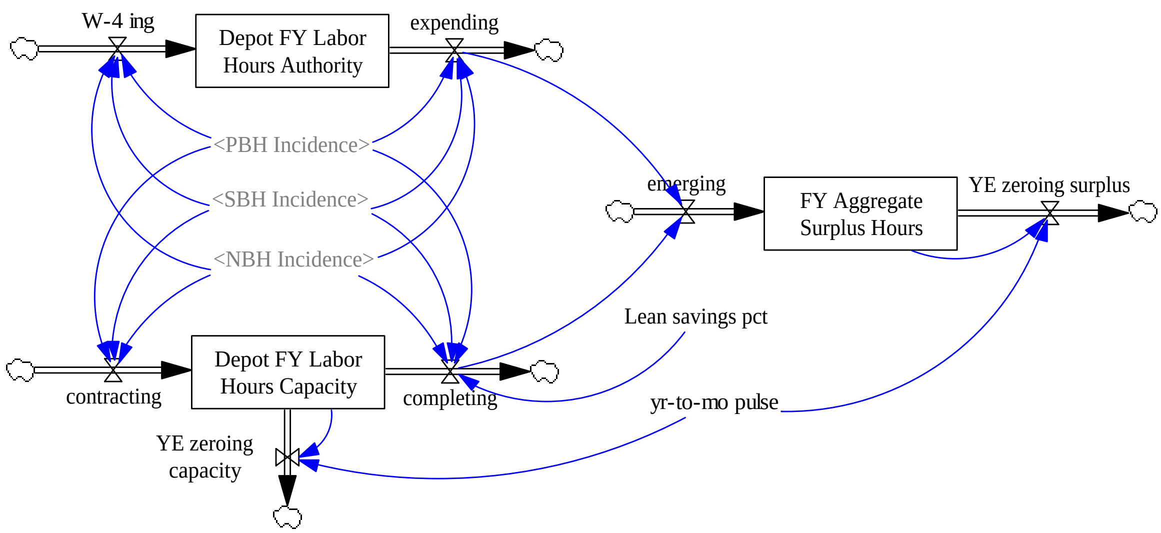

Figure 4: Emergence of Surplus Labor Hours through Lean Efforts.

Figure 5 shows the proposal, adjustment and implementation of depot labor rates for FY_{n+3} over recurring, overlapping cycles of three FYs. Simultaneous reference to figure 1 may be helpful. The model generates a new annual Depot-proposed Rate in FY_{n+1} as the product of the rate it proposed most recently (in FY_n) and the labor rate escalator factor taken to the third power for the intervening years.

Seven months later, in the next fiscal year, AMC adjusts that proposed rate to reflect the Depot's AOR variance in FY_{n-1}. It receives this feedback through the model's yearly-pulsed <adding> flow, developed in figure 6. Thus FY_{n+3} rates are taken directly from FY_{n+1} rates, as increased by the compounding, constant "labor rate escalator" and as adjusted by AMC for NOR effects. The possibility of greater oscillation in Depot-applied labor rates as a result of lean savings and of their return by the depot for customer use was the initial dynamic hypothesis of the overall model.

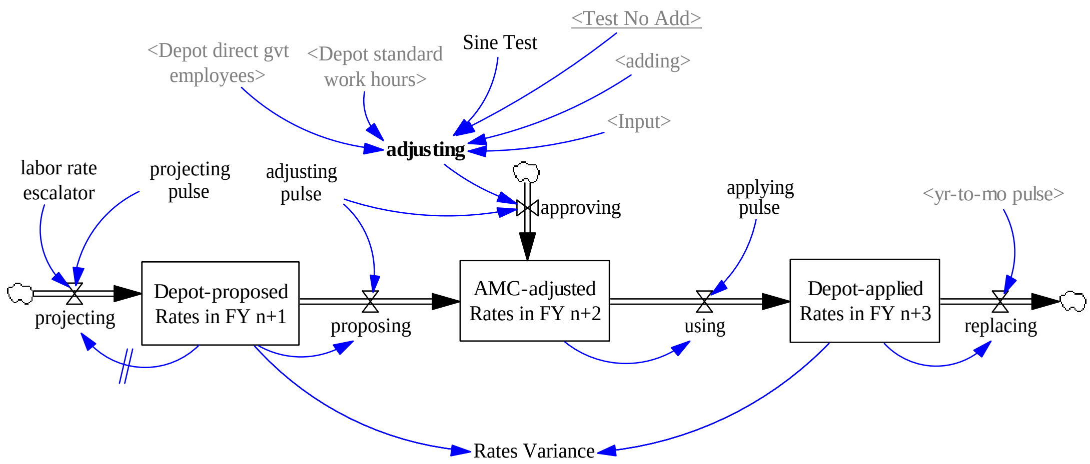

Figure 5: Three-year Development Cycle of Depot Labor Rates.

Figure 6 depicts the development annually of FY NOR and its contribution, effective as of year-end, to the depot's AOR within the AWCF regime. While PBH Incidence, SBH Incidence and NBH Incidence deliver income inputs to NOR through the "authorizing" flow, "expensing" does not include the "Overhead ratio" portion of Depot-applied Rates provided by SBH or NBH. The zero-targeted, "giving back" approach to AOR serves to create the oscillation of depot labor rates.

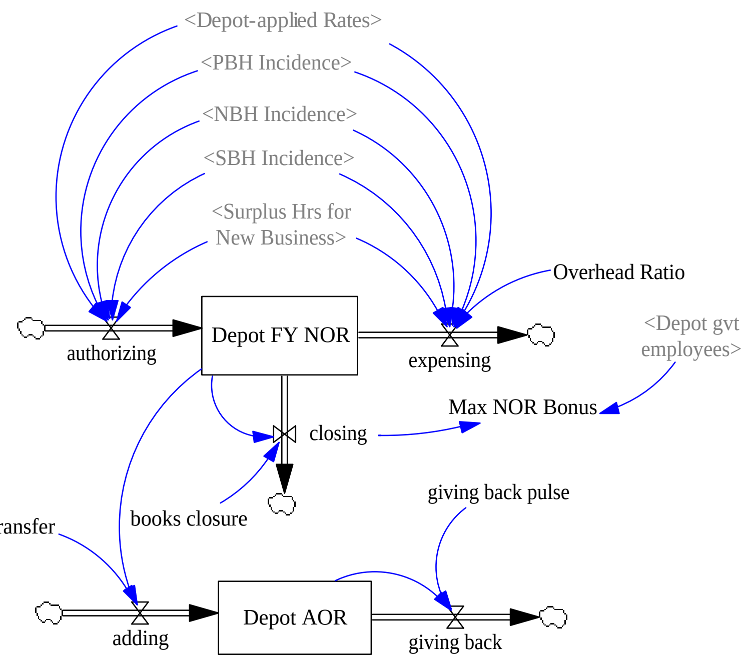

Figure 6: Emergence of FY NOR and its Zeroing-out to AOR Annually.

The model conforms to basic laws applicable to system dynamics, such as conservation of matter. For example, in figure 4 the simulation generates declining monthly balances each year in the depot's supply of direct labor hours, from levels authorized by presidential budgets or supplemental allocations down to zero balances on each September 30. Provided as they are by branches of government, rather than generated by depot activity, these budgets are treated as exogenous pulsed inputs to the model. Table 1 presents sample simulation results for PBH and SBH during two FYs. Savings of labor hours due to lean practices, depicted at right in figure 4 and allocation of these savings to depot and customer purposes is described later.

Table 1. Model's Generation of Declining Labor Hours Supply from Exogenous Inputs

FY months closed:	0	2	4	6	8	10	12
FY ending 30 Sept:							
2004	2,407,136	1,642,697	1,314,157	985,618	657,079	328,539	0
2005	3,131,500	2,178,583	1,742,867	1,307,150	871,433	435,717	0

As explained above, the AWCF approach aims to hold AOR (i.e., the integral of annual NOR pulses) as close to zero as possible by "giving back" to future depot customers most of any positive NOR which a depot earns or by surcharging future customers in the case of negative NOR. The positive or negative variance from a depot's targeted NOR in a FY is recognized and reversed through rates applicable to the work it performs three years later.

Working together, figures 5 and 6 accomplish the balancing feedback by which current NOR is given back to customers in the setting of future labor rates, through a third-order information delay. The rate projection process in FY_{n+1} compounds three years of estimated exogenous labor trends (i.e., external labor market conditions) onto the hourly rates charged in FY_n. A year later, those projected rates are subject to adjustment before they are locked into the Army's depot work loading system. "Adjusting" here spreads the depot's FY_n NOR over the expected direct labor hours under the President's budget for FY_{n+3}, and then "adding," as described in the next paragraph, amends the hourly rate projection. (Units of measure consistency is preserved here, as it is elsewhere within the model: the three hourly rates are measured in dollars per hour, and the flows between them are measured with reference to the time step of the model: dollars per hour per month. By accounting practice these flows are not continuous, however, so we use the three pulse train inputs in figure 5, each measured in 1/month, to ensure that rates change only once in each annual stage of the process.) Note too that beginning in figure 8 the annual accounting pulse will turn curvilinear outputs into step rate changes.

The mechanism for spreading FYn NOR as referenced in the previous paragraph is the underscored model element "adding", which appears in both figures 5 and 6. In figure 5 "adding" supplies the numerator of the amount by which the rate projection made in FYn+1 for FYn+3 becomes adjusted for the depot's actual operational experience, closing the 3-year-long feedback loop between results and rates. Simultaneously, in figure 6, "adding" accretes within the depot's accounting books once each year aggregate FY NOR into AOR, this timing controlled by the annual pulse train "NOR transfer".

Before leaving figure 5, we note Sine Test, in the upper right. Per textbook modeling practice, we first assessed the operation of this structure merely by sending a test input (here a sine wave of amplitude $20/hour and period 48 months) and observing the resulting behavior across an eight-year period. Table 2 presents behavior reproduction data for the simulation, contrasting the depot's actual and model-estimated values of applied hourly direct labor rates, NOR and AOR, and assessing model fit. The foundation for behavior production lies first in ensuring that the model simply replicates labor rates as trended by the depot's actual labor rate escalator, which varies annually, and further replicates them as affected by the test input. Section a of table 2 presents, on its diagonals, this replication of compounding within each consecutive three-year rate process. Section b then introduces the sine wave as an "adjusting" input to the compound labor rates. In both these tests, model-produced rates were <u>identical</u> to predicted values of all three labor rates, at all points across 96 to108 months of test.

Table 2. Behavior Reproduction Tests of Model's Labor Rate Results

a. Equilibrium test state without "adjusting" inputs

FY:	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7
Annual labor rate escalator	0.8%	1.2%	1.5%	1.7%	0.8%	1.3%	2.0%	2.4%
Depot-proposed Rates	**100.00**	103.64	108.37	113.99	116.75	121.37	128.79	138.29
AMC-adjusted Rates		**100.00**	103.64	108.37	113.99	116.75	121.37	128.79
Depot-applied Rates			**100.00**	103.64	108.37	113.99	116.75	121.37

b. Non-equilibrium test state: oscillation introduced through "adjusting" sine inputs

FY:	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8
AMC-adjusted Rates without test pulses	100.00	100.00	103.64	108.37	113.99	116.75	121.37	128.79	138.29
Test pulses as introduced through "adjusting"	0.00	20.00	0.00	-20.00	0.00	20.00	0.00	-20.00	0.00
<u>Predicted</u> AMC-adjusted Rates with test pulses	**100.00**	**120.00**	**103.64**	**88.37**	**113.99**	**136.75**	**121.37**	**108.79**	**138.29**
<u>Simulation-delivered</u> AMC-adjusted Rates with test pulses	**100.00**	**120.00**	**103.64**	**88.37**	**113.99**	**136.75**	**121.37**	**108.79**	**138.29**

We turn now from labor rates to operating results. In figure 6, Depot FY NOR equals the integral of all FY funding in-flows through "authorizing" minus all appropriate FY outflows through "expensing". These inflows and outflows are unequal whenever the depot has received Supplemental Dollars or New Business Dollars, because the depot retains as NOR the "overhead load" components from these sources of funds. This differentiation of NOR portions is accomplished through the expensing formula,

"Depot-applied Rates"*(PBH Incidence + ((SBH Incidence + NBH Incidence +

Surplus Hrs for New Business)*(1-Overhead Ratio))),

and through underlying PULSE functions. Pursuant to depot experience, these spread PBH and NBH equally each month, but supply SBH only within the last four months of each FY in which supplemental-to-budget appropriations usually are made by the government. Lastly, the "closing" flow in figure 6 drains FY NOR annually, once its 30 September value has been added to or subtracted from accumulated Depot AOR through "adding" in figure 5.

By way of confirmation and summary of the NOR calculations, we present figure 7, which contrasts seven distinct patterns of NOR. Tests 1 through 4 assume constant annual average PBH [200,000] and no lean savings. These tests develop NOR simply through permutations of annual values of SBH [0; 1,400,000; 0; 1,400,000] that begin as pulses late in the sixth fiscal year (FY 2004), and of NBH [0; 0; 2,000,000; 2,000,000] which are funded throughout the simulation period. Tests 14 through 16 restate tests 2 through 4 while assuming a 10% Lean Savings Percentage ("LSP") and reflecting additional NOR generated through Surplus Hours for New Business as made available through those lean efforts.

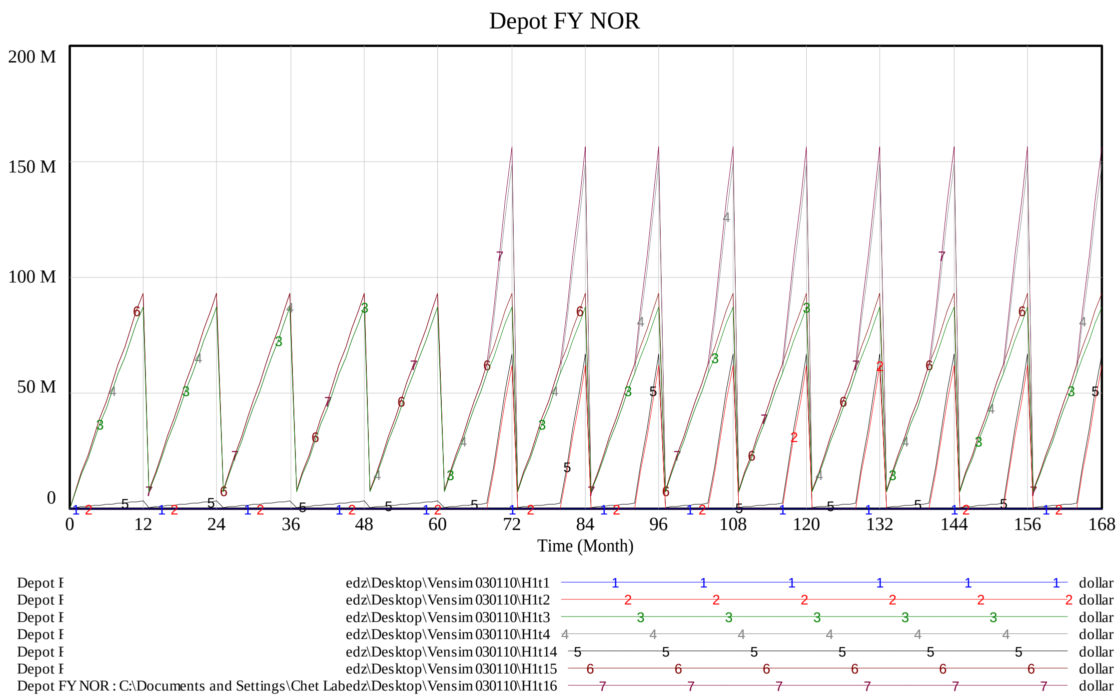

Figure 7. Sample Development of NOR as Lean Savings and Labor Hours Vary.

In the interest of conserving space, the depot's "give backs" to customers of portions of lean-produced savings are not depicted. That omitted model view provides for the allocation of emerging FY Aggregate Surplus Hours each fiscal year, net of retained surplus hours as determined by the depot, across its current and new customers, whether military or commercial.

Results

In testing hypothesis 1, we contrast annual labor rates resulting from the sixteen permutations of LSP, Test No Add, SBH switch and NBH switch that were excerpted in figure 7 and are presented here in table 3.

Table3. Derivation of Test Cases Resulting from Variable Permutations

Case:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LSP	0	0	0	0	0.1	0.1	0.1	0.1	0	0	0	0	0.1	0.1	0.1	0.1
TNoA	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
SBH	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
NBH	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1

In figure 8, we present non-redundant patterns of Depot-applied Rates in FYn+3; tests 1 through 9 (excerpted in graph patterns 1 through 5) delivered redundant rates. While all cases reflect the step rate increases caused by the constant annual Labor Rate Escalator, test 11 (pattern 7) incorporates a steep rate decline after 24 months, tests 10, 13, 14 and 15 (patterns 6, 9, A and B) build in lesser declines after 84 months, and tests 12 and 16 (patterns 8 and C) reflect both drops.

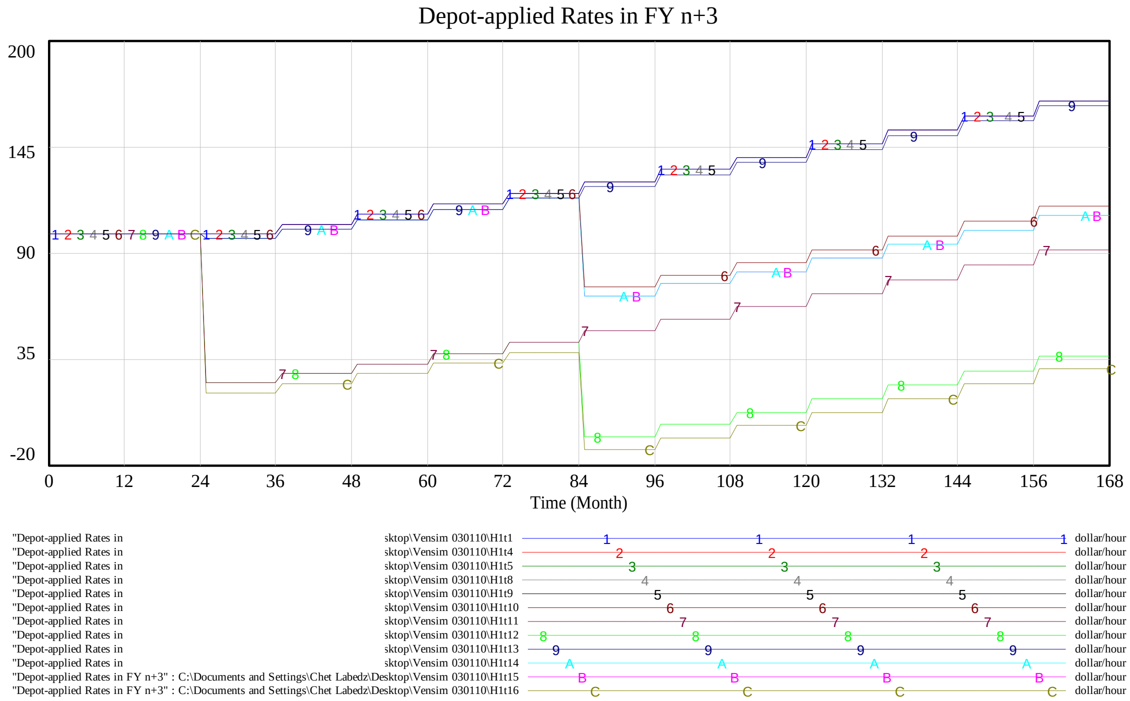

Figure 8. Depot-applied Rates as Lean Savings and Labor Hours Vary.

Stated as Rates Variance ratios (applied rates minus proposed, over proposed), the cases present similar patterns in figure 9. Case 13 (graph pattern 9) traces case 9 (pattern 5) at a slightly greater percentage variances, cases 14 and 15 (patterns A and D) similarly shadow case 10 (pattern 6), and case 16 (pattern E) traces case 12 (pattern 8) but at slightly increased variance percentages. Each of the four shadow cases differs from its mate by virtue of the 10% LSP, so we conclude that H1 is supported.

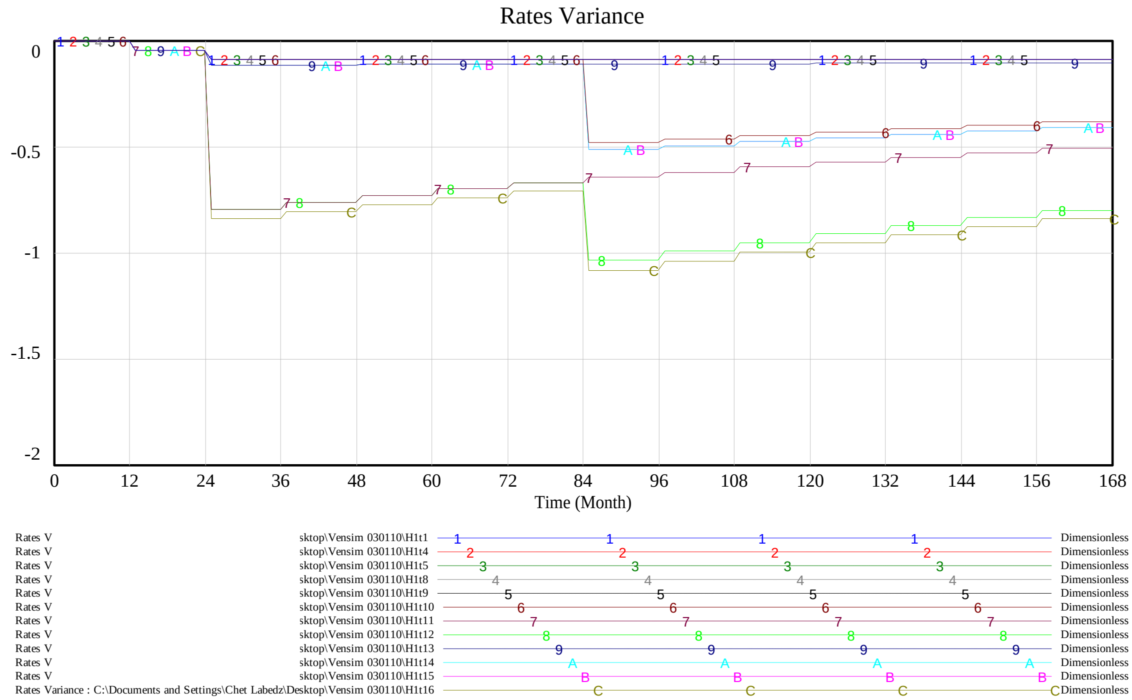

Figure 9. Rates Variance Ratios as Lean Savings and Labor Hours Vary.

In testing hypotheses 2 through 4, we substitute other patterns of NBH and SBH for the constant or two-step constant patterns we assumed above. Now these exogenous inputs ramp up from zero to annual rates of 1.4 million (SBH) and 3.0 million (NBH) hours annually over the three years beginning with month 37, and ramp back down to zero over three years beginning with month 121. (The substituted values reflect average actual values across periods of years within the depot's recent history.) Because depot rates are established annually not monthly, however, these ramp patterns translate in effects into three years each of step rate increases, constant levels, and then declining budgets. Assuming those new patterns of SBH and NBH, figure 10 presents percentile differences of Depot-applied Rates in FY_{n+3} as introduced by lean savings on non-lean rates.

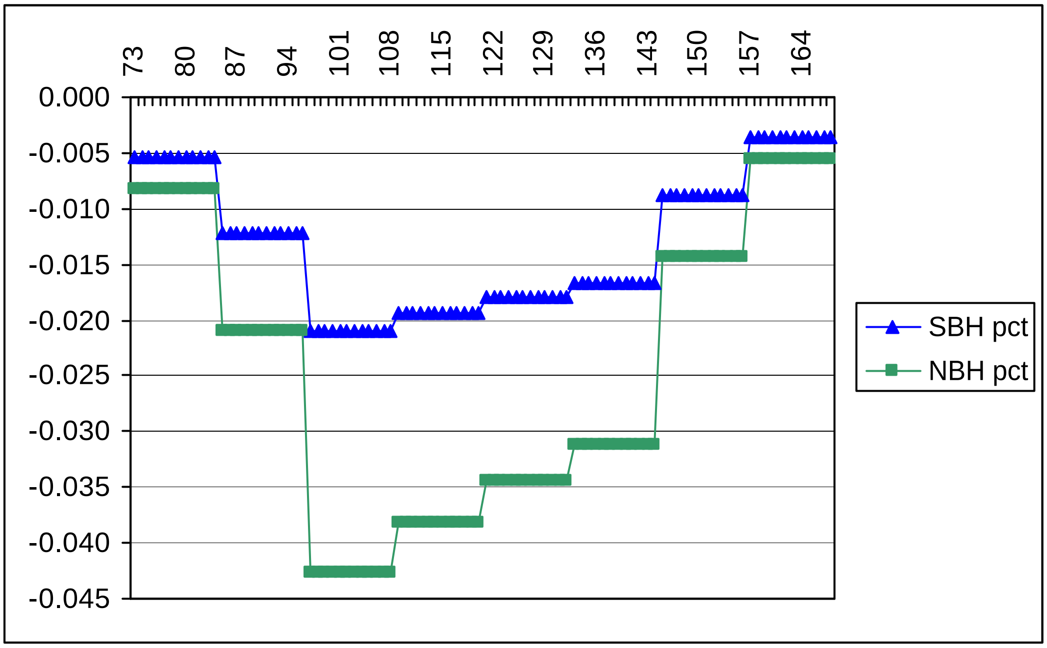

Figure 10. Percentile Differences in Rate Effects, With and Without Lean Savings.

The upper line segments portray percentile differences ((lean minus non-lean) / non-lean) where SBH alone are introduced, and the lower segments portray such differences when only NBH are funded. In testing hypothesis 2, the patterns across months 73 through 108 indicate greater reductions, as percentages of proposed rates, in the aftermath of increasing SBH and NBH allocations. H2 is supported.

In testing hypothesis 3, the patterns across months 145 through 168 indicate decreasing magnitudes of adjustment, as percentages of proposed rates, in the aftermath of decreasing SBH and NBH allocations. The trend had begun 48 months earlier when stable funding worked its way through the multi-year rate-setting process, and it accelerated as SBH and NBH were cut. Of the rate adjustments that remain, those that reflect NOR contributions due to the savings and re-sale of assumed-constant direct PBH must provide increasingly greater parts, so H3 is supported.

In testing hypothesis 4, we compared the same magnitudes of adjustment as percentages of proposed rates as non-PBH funds shrank. Table 4 presents the ratios of these magnitudes of adjustment, relating to NBH and SBH respectively

Table 4. Ratios of NBH to SBH Percentiles of Lean-based Rate Adjustments

Month	NBH %ile	SBH %ile	%ile Ratio
1	0.0000	0.0000	
73	-0.0082	-0.0053	1.546
85	-0.0209	-0.0121	1.727
97	-0.0427	-0.0210	2.039
109	-0.0382	-0.0194	1.974
121	-0.0344	-0.0179	1.920
133	-0.0311	-0.0166	1.873
145	-0.0144	-0.0088	1.634
157	-0.0055	-0.0036	1.507
168	-0.0055	-0.0036	1.507

The %ile Ratio calculation indicates that at all times in the simulation including the declining funding months (145-168), the contribution to rate reduction of lean savings, as a percentage of non-lean rates, is greater for NBH work compared to SBH work. The smallest rate reductions, noting that the percentile values are negative after month 72, occur as the final one-third reduction in NBH funds affects rates in the final twelve months of the simulation. H4 is supported.

Discussion

We proposed first that the depot's current military customers would enjoy the fruits of its lean improvements only when they have work to be performed in excess of funding authority and the depot's efforts had freed up direct labor hours to perform at least some of it through MIPR issuance. Second, if additional funds existed as through supplemental appropriations, we suggested that only the depot's freed-up or newly-added direct labor capacity and customers' unaddressed needs would matter. Third, we proposed that in examining the depot's capacity to do the work, prospective customers that understood the depot's lean path and its potential for "give-back" actions in future years might be more likely to place work orders with LEAD in the first instance. We did not test these propositions, but we address them here in light of the depot's subsequent work orders history.

In follow-on discussion three years after the case studies, depot leadership advised that LEAD through its lean practices had indeed re-captured industrial space, reused it, and sought added space. It had not, however, "given back" any hours beyond those four instances cataloged in the first case study. The depot's MIPR-issuing behavior toward its customers had not continued, and its customers' ordering behavior had not been further influenced by LEAD's lean successes. If null hypotheses relating to the three propositions had been developed and tested here, they would not have been rejected.

By contrast, our four hypotheses were "supported" through the simulation. LEAD's lean implementation and accounting innovation led to greater positive variances from annual NOR targets and to greater reductions between Depot-proposed Rates in FY_{n+1} and Depot-Applied

Rates in FY_{n+3}. These lean effects were increasingly prominent when NBH (H3) and especially SBH (H4) allocations declined in successive years. When such additional-to-President's Budget Hours allocations were constant (H1) or increasing (H2) in successive FYs, lean efforts still affected future rates. Those effects were dwarfed, however, by the usual contributions to positive NOR (and years later to reductions in applied labor rates) that SBH and NBH make. When two-fifths or so of an hourly rate becomes NOR because depot overhead has already been covered by the President's budget, supplemental and new business dollars make an outsize contribution to NOR.

Taken together, the propositions and the test results suggest that LEAD's lean successes and accounting innovation had an important but brief effect on the depot's viability. At a critical moment in its history, LEAD's efforts and innovation effectively called attention to the depot, painting it in a more-flattering light mixed of efficiency, contribution, success and the public honor of multiple Shingo Prizes. Its increased NOR also funded its employees' annual NOR cash bonus, instrumental in "selling" the lean approach there. While LEAD's new practices could continue to promote it during years of level budgets, the depot's participation in the extraordinary supplemental and new business opportunities that arose beginning in FY 2004 contributed the lion's share of NOR increases and labor rate reductions. In FY 2002 and 2003, as lean ramped up at LEAD, the accounting innovation contributed more to successfully marketing LEAD than to exacerbating rates oscillation. To the question we posed in the title of this paper, we give the answer: "not substantially". SBH and NBH contribute more substantially to labor rates oscillation than does the accelerated "give back" of lean-induced savings.

Finally, the operation of the year-end closing of books of accounting within a system dynamics model merits modelers' attention. The current simulation employs the "pulse train" function to zero out several stocks, for example in figure 4 as "YE zeroing surplus" clears the "FY Aggregate Surplus Hours" stock each September 30. Although this stock may be expected to increase in a non-linear first-order manner because the depot's work from varied sources arrives on various timetables in a typical FY, the stock's reduction occurs – per accounting practice – as a discrete event, so that use of such continuous functions as "smooth" would be inappropriate. Similarly, depot-proposed rates grow continuously through the influence of a "labor rate escalator" but then are captured in figure 5 as discrete events, through the "adjusting pulse" and – twelve months later – "applying pulse" auxiliaries. These pulse train mechanisms account for the step function-like "lack of curviness" in figure 8 and subsequent figures even though the underlying "Depot FY NOR" stock value increases in eleven out of every twelve months.

Limitations and Future Research

Based on extensive empirical research, our simulation models several patterns of key exogenous inputs, such as SBH, NBH and LSP at LEAD. Other inputs, and simulated patterns of their values over time, could also be analyzed. Thus, one limitation of this research is its ties to the depot's particular situation; other inputs and structures are not examined, and the model could be generalized in subsequent work.

To simplify somewhat the model, we have treated other LEAD values as constants, although they are not, and we assigned them mean values in the simulation. These include such workforce elements as depot direct government employees, depot indirect government employees, and depot standard work hours. DSWH is clearly a lean-influenced variable, because the depot's estimate of "standard" work hours to complete a particular assignment will show a reduction once *muda* is eliminated. Still, we believe variation within such variables would not materially affect our specific findings.

Designing a system of accounting controls to permit, and even to accept as natural, oscillation in annual labor rates would be exceptional in a commercial setting. Oscillation results from negative feedback within a system plus significant delay in any part of the negative loop. It is an excursion from a target value, and is associated with various unfortunate conditions (over- and under-supply and the resultant costs of each, for example) and often is considered a behavior to be shunned. In the AWCF context however, the target value (equal to zero) is Accumulated Operating Reserve, because the service branches do not promote ongoing profitability of their maintenance facilities. To promote such AOR stability, through giving back prior years' profits, rates are intentionally designed to oscillate. This research therefore opens the system dynamics discussion of financial controls and rate or financial indicators oscillation in not-for-profit, including governmental, contexts. It provides a model for identifying and describing the sorts of feedback structures designed to control their key financial indicators. It proposes tests appropriate to examine unintended consequences of interventions in such systems of control, including other DoD branches.

This research also initiates a framework for examining the dynamics of competitiveness of military facilities seeking to obtain commercial contracts. Parts of the model structure may be extended to reflect depots' separate accounting for government and commercial contracts while allocating the productivity benefits of lean implementation among its varied customers.

Finally, we note a common objection to lean implementation in commercial businesses: the likelihood of ensuing workforce reductions. Skeptics announce that "lean" stands for "less employees are needed". In commercial contexts, the need to continually add "new work" to absorb lean-freed business resources (including workers) has been identified as an antidote. Our model and hypotheses open the systems discussion of this phenomenon in a governmental context. Our findings, citing the dominance of SBH and NBH effects, hint at a similar issue – the threat of lean-induced layoffs – in a governmental context. Analysis of the dynamics through ongoing research thus has clear relevance not only for the military, but for other major governmental and quasi-governmental institutions. In the United States, the postal service and state governments may take note.

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WHEN MOVING TO LEAN ACCOUNTING, CPAs may want to supplement the companyâ€™s standard financial statements with additional information that captures the resulting improvements. Most CPAs will find the cost information they need to prepare lean financial statements already is available in the company accounting systems.Â The benefits generally are lower costs, higher product quality and shorter lead times. As a company implements this approach to doing business, its financial statements often show a temporary hit to the bottom line as deferred labor and overhead move from the inventory account on the balance sheet to the expense section of the income statement, lowering profits. (See the glossary for definitions of key terms.) Lean accounting, however, takes into account the fact that unused inventory can actually be detrimental to the well being of your business because it takes up space and requires labor and materials expenditures that you could be using instead to fill a more current order. What Are the Concepts of Lean Manufacturing? The concepts of lean manufacturing revolve around paring down manufacturing and inventory to streamline your operations toward filling current orders with as little turnaround time as possible. This approach redefines efficiency, focusing on throughput (completing and delivering fi