Proactive Reduction of Returns: Management and Metrics

By

Lucas A. Zaientz

Bachelor of Science, Transportation & Logistics
Northeastern University College of Business, 1994

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Signature of the Author.................................

Engineering Systems Division
May 5, 2000

Certified by............................................

Jonathan L.S. Byrnes
Senior Lecturer
Thesis Supervisor

Accepted by............................................

Yossi Sheffi
Director, Master of Engineering in Logistics Program
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Written in loving memory of Harry and Edith Zaientz
and in honor of Theodore and Esther Pollans

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Lucas A. Zaientz

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Abstract

Management of reverse logistics is becoming an important research area. Within this body of research, very little work has been done on proactively reducing returns. The current writing on returns management is almost exclusively efficiency focused. In essence, authors attempt to answer the question, how do we react well to errors and unaligned motivation in a system? A more proactive way of thinking of the problem is to ask how can we reduce errors and align motivation in a system so there is nothing to react to.

This paper takes a first look at the opportunities of proactively working to reduce returns in a manufacturer distributor relationship. Findings suggest that returns come from both direct and indirect drivers. Direct returns come from linked causal relationships such as damages (DOA), incorrect shipments, and off schedule deliveries. Indirect returns are products returned at the discretion of distributors to minimize several different risks. Several methods of reducing returns are discussed and metrics are proposed.

Thesis Advisor: Jonathan L.S. Byrnes
Title: Proactive Reduction of Returns: Management and Metrics
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CHAPTER 1 - Introduction

Reverse Logistics (RL) involves managing the logistics of product returns, recycling, reuse, repair, disposal, and re-manufacturing. RL is a means to capture stranded asset value and to correct errors in the Supply Chain. Product returns will be exclusively discussed in depth.

Products are returned for both direct and indirect reasons. A direct return is a unit returned because of an error in the supply chain. The supply chain error is directly used as justification for returning the product. For example, a distributor may return a box to a manufacturer because it is blemished or did not arrive on the promised delivery date.

An indirect return is a unit that is returned under a return policy granted by the manufacturer. The return policy may allow the distributor to return up to a percentage of goods purchased at the distributor’s discretion without explanation or direct cause. For instance, because the forecast is imperfect, ordering of unnecessary inventory may occur and ultimately be returned. If the forecast were perfect this condition would not exist. It is important to realize that indirect returns are just as much the result of supply chain error and inefficiencies as direct returns are.

Effective management of returns includes both proactively working to reduce returns and creating a reactively efficient network to handle the balance of returns. This paper specifically studies proactive methods for reducing direct and indirect return volumes.

The high technology industry is interesting to focus on because of short product life cycles. In this industry returns are typically considered errors. These returns are
typically categorized as DOA, warranty, return allowance, shipping error and obsolete product (see exhibit 1). This error group is alike in that they all act to reduce gross sales and increase cost. For instance, if returns are 10% of sales, gross sales will be approximately 10% less than with zero returns and costs will rise to account for the RL process. This is notable because in other types of RL such as material or container recycling, sales are not impacted and costs can actually be reduced.

These categories of returns will be studied to:

- Understand the extent of current management practice and research.
- Explore return drivers.
- Examine the system impact of returns.
- Suggest methods to reduce proactively reduce returns.
- Suggest a scorecard to measure progress.

Ultimately, the scorecard should be the culmination of learning on the topic and should be used as:

- A quantitative evaluation tool to manage RL operations
- A feedback mechanism to provide information to various teams
- A means to isolate opportunities for targeted improvement projects
- A management tool for understanding the impact of policy adjustment

Thinking in terms of system management is critical in understanding the implications of this paper and managing returns. Without a system-wide scope of management,
functional areas may become individually effective; however, as a system sub-optimal.

In the past twenty years, improvements in computing power and advances in Supply Chain thinking have changed management decision scope from functional area to system-wide. However, this growth in Supply Chain perspective has traditionally not included returns management.

"The state of development of Reverse Logistics is analogous to that of inbound logistics 10-20 years ago (Stock).

Most companies manage the system (supply chain) as if it flowed in one direction, starting with the raw materials procurement process and ending with delivery of a product. More complete systems thinking acknowledge that the policies of both the manufacturer and customers directly affect each other and cause returns. To manage and reduce returns producer and customers need to be considered collectively.

1.1 Research Overview

In some industries RL management is more developed than in others. For example, some clothing catalog companies faced with staggering returns of upwards of 50% of gross sales have found ways to physically process incoming returns more effectively. Faster distribution networks have been created to minimize the time between purchase and receipt, and improvements in sizing and quality have been proactive ways of reducing the volume of returns.

Hewlett Packard (HP) effectively uses RL to recapture value by reusing toner cartridges. For HP this decreases raw material cost and the environmental impact of cartridge disposal. HP views the toner cartridge as a piece in a
system comprised of initial cartridge filling, distribution, toner consumption, cartridge return and finally cartridge refilling.

While the HP example illustrates RL systems thinking in the High Tech industry, the majority of the industry has only begun to realize the value of good RL management. For example, at a major U.S. manufacturer of computer network products, a group with worldwide responsibility for RL is only four months old and is just beginning the challenge of developing management process and technique.

This manufacturer and others are asking the questions: What are the primary methods of reducing returns in our organization? How should we manage the residual returns? How should we measure the success of our efforts?

1.1.1 Importance

In an effort to demonstrate growth to Wall Street, managers in the High Tech industry have traditionally been guilty of pushing inventory at quarters end with sales incentives (interview). This practice combined with defective/damaged/incorrect product, incorrect shipments, and other errors generate returned goods volumes as high as 10% of gross sales (interview data).

Returns directly offset real gains in gross sales and are reflected in the income statement. The firms I have interviewed are only now developing ways of tracking the expense of the returns and accounting for it.

Improving RL management can clearly substantially reduce operating cost. RL information should also be leveraged for insights into operational deficiencies. For instance, damaged box returns may illustrate poor material handling
practice, warranty returns may highlight design flaws, and unopened returns may result from poor inventory practices. Using return information to improve process and policy may ultimately improve quality and service.

1.1.2 Need for Research

The dynamics of RL are such that it is difficult to correlate cause and effect of policy decisions.

- If we allow a higher return percentage and gross sales improve, are we more profitable?
- How much should we invest in Supply Chain quality?
- How integrated should our inventory management process be with channel partners?

One of the research products, a scorecard, will organize key issues and give managers a tool for measuring results to incremental changes in policy and process.

1.2 Hypothesis - Proactive Reduction

Any particular SKU may be returned for a number of unique reasons. The four types of returns discussed in this paper will each have drivers.

- **DOA**: Dead on Arrival or Damaged on Arrival refers to any product that is noticeably damaged or defective upon arrival at the distributor. Typically this will be from transit or material handling damage including torn, crushed or open boxes. This category will also include any recalls from the manufacturer of learned product defect.
• **Return Allowance:** It is typical in the high tech industry for manufacturers to offer distributors the option to return a percentage of the purchase. This return allowance will range as high as 10%; however, most companies operate at lower levels. While the return allowance is primarily driven by competitive pressure, it serves as a means to protect the distributor from forecast error risk driven by short product life-cycles and many new product introductions.

• **Shipping Error:** Shipping error refers to product refused at the receiving dock for one of a number of possible reasons. The most common issues are either the wrong product has been shipped or the delivery did not occur at the designated time.

• **Obsolete Product:** Given the short product life-cycles, manufacturers may have competitive interest in moving new product offerings quickly through the supply chain. If the distributor has older models in inventory, the manufacturer may take it back and move it to secondary channels for redistribution.

By understanding what drivers move return volumes for the different types of returns, insight can be gained on managing the drivers. Subsequently understanding what drivers move return volumes for the different types of returns will aid in the development of metrics.

Presumably, the drivers for pursuing proactive reduction will be different for each of the four types of returns and will yield different results. In certain cases, acting to decrease returns may cause backlash elsewhere in the system.
and prove unfruitful. For instance, if reducing a distributor’s return allowance causes the distributor to hold a less than adequate supply of inventory, sales may ultimately suffer. When this tradeoff is understood, it can be managed.

From a systems dynamics perspective, returns presumably cause more disruption to the two organizations than is superficially apparent. The research will test what drivers cause returns and what is the impact of the returns.

1.2.2 Methodology

Research will include literature reviews of relevant work, in depth analysis of the interaction a major high tech manufacturer’s process and one of its larger distributors. Also interviews of several high tech RL managers and a systems dynamics modeling simulation are included.

Specific focus is given to modeling the system impact to changes in returns level and ordering patterns. Other electronics/high tech manufacturers were interviewed to benchmark RL best metric practices within the industry segment.

1.3 Research Scope

The scope of this research includes methods of reducing product returns in the high tech manufacturing industry, with specific emphasis on non-warranty returns.

This research does not include green returns (recycle and reuse), and warranty returns. Discussion is also limited to business to business and does not consider consumers. Approaches to RL reactive management are not discussed.
1.4 Research Contribution

The intended contribution of this paper is to suggest to organizations that proactively reducing returns is a largely untapped part of the equation of RL management. The paper will provide insights into return drivers and approaches for reducing return volume, including metrics. This paper is unique in RL in that it looks at returns from a system dynamics perspective and looks at the broader impact of returns on the manufacturer and distributor.

1.5 Thesis Organization

This paper discusses proactive return reduction in terms of understanding return drivers, driver importance, driver management and driver measurement.

These issues will be addressed with a Literature Review (chapter 2), Methodology (chapter 3), Findings (chapter 4) and Conclusions (chapter 5).
CHAPTER 2 - Literature Review

This review of literature outlines research that has contributed to understanding the importance and methods of return management. The research areas discussed include current approaches to reducing RL cost, limited efforts on proactive reduction, logistics excellence, inter-company cooperation, policy and motivation, and systems dynamics Analysis. The review also shows the boundaries of current research and highlights opportunity for further analysis.

Findings summary:

- **Cost** - Returns can run as high as 5-10% of sales and cost US companies an estimated 35 billion dollars annually.

- **Reverse Logistics Cost Reduction** - Several researchers have assembled frameworks to manage reverse logistics but all have failed to include reduction.

- **Proactive Reduction** - Some approaches to returns reduction do exist including, gatekeeping, zero returns policies, improved information and integration.

- **Logistics Excellence** - Logistics excellence can reduce direct returns. There has been considerable research in this area.

- **Drawing the Box** - Cooperation and integration are discussed as means of aligning incentives, increasing sales and gaining supply chain control.

- **Policy and Motivation** - Return policies that exist have some strategic rationale, however will tend to cause distributors to overstock.
• **Systems Dynamics** - Systems Dynamics is a field that is useful for analyzing the system impacts of returns and return drivers.

The most important finding from the literature review is that no substantive research has been done on the issue of returns from a complete systems perspective. This means that policy decisions and response to returns are performed in a vacuum. An opportunity exists to research how elements in a system drive returns and how the system reacts to them.

### 2.1 Cost

The issue of reducing the RL cost of returns is important because of the fractionally high cost of returns to most manufacturers and distributors. "Overall, customer returns are estimated at 6% of sales and may run as high as 15% for mass merchandisers and up to 35% for catalogue and e-commerce retailers." (Gentry) For on-line sales, returns rates can be as high as 50%. Interviews in the high tech industry group of focus have indicated returns are running between 5%-10% of Sales. (Caldwell, Bruce)

US companies spend an estimated $35 billion annually for RL costs, according to the Executive Council for Reverse Logistics. That estimate does not include disposition management, administration time, and the cost of converting unproductive returns into productive assets. (Meyer)

### 2.2 Current Approaches to Reducing RL Cost

Companies have begun to attack these costs. Unfortunately, the approaches are almost exclusively reactive. Managers tend to develop ways to accommodate returns (errors) efficiently. Reactive efficiency is an attempt to
effectively treat symptoms, not a proactive approach to eliminating the cause of returns. For example, Rogers and Tibben-Lembke believe the key elements of RL management to be compacting disposition cycle time, RL information systems, centralized returns centers, remanufacture and refurbishment, asset recovery, negotiation, financial management and outsourcing, but fail to mention reduction.

Giuntini and Andel think about RL in terms of “Six R’s” recognition, recovery, review, renewal, removal, and reengineering. The first step, recognition, starts by acknowledging when a return enters the system. Subsequent steps address reacting to the return effectively. The final step, reengineering, does not discuss reengineering product to reduce returns, but is focused on reengineering the reverse supply stream itself. A seventh seemingly obvious R that was not included is reduction.

2.3 Limited Efforts on Proactive Reduction

Although limited, there are several approaches to proactively reducing returns. The simplest is through gatekeeping. “Gatekeeping is the screening of defective and unwarranteed returned merchandise at the entry point in to the reverse logistics system.” (Giuntini and Andel) This approach is effective for certain types of returns, however does not impact the large volume of returns caused by legitimate supply chain error.

Giuntini and Andel also suggest a zero return policy. This policy simply blocks returns from coming downstream by offering an allowance to distributors. The allowance works as a percentage for which the distributor gets return credit, whether the product is defective or not. Actual
returns do not come back through the channel, but get scrapped by the distributor.

Dell computer has approached proactive return reduction with enhancements to the main customer order website. The return rate for phone orders is 2.65% while the return rate for web orders is only 2.1%. Dell believes this to occur because web orders can be configured at the consumer’s leisure. (Caldwell, Bruce)

Schonberger and Abdolhossein believe that “Just-in-time (JIT) purchasing offers significant benefits, particularly in quality, to both buyers and suppliers. For example, small-lot quantities make it easier to detect defects earlier, thus reducing returns and rework.” JIT is a form of company integration. Schonberger and Abdolhossein see the JIT selection process as a means of bringing in vendors on the basis of the ability to work in batch quantities at high quality. They believe that JIT will improve the chances of deeper company integration.

2.4 Logistics Excellence

One approach to reducing direct returns is logistics excellence. Much research has been done in this area.

Transportation and Distribution named seven companies as winners for the 2nd annual excellence in Logistics award. 1. Mattel Toys Inc., 2. Procter & Gamble, 3. Kraft General Foods Inc., 4. Pennsylvania Power & Light Co., 5. Harris Corp., 6. Picker International Inc., and 7. Libbey-Owens-Ford Co. “If there is a consistent message from each of these companies, it is that effective logistics can not only deliver the level of expected customer service, it can help
you grow and can even win business from your competition.” (Trunick, Perry A.)

A. T. Kearney in Europe suggests that logistics excellence is based on 3 key areas: 1. developing closer ties with customers and suppliers at all functional levels, 2. integrating planning and operations, and 3. involving and empowering employees.

3Com uses software developed by BHP to help in the decision process of economical handling of returned goods. The software helps determine if it makes sense to bring the part back and also provides “cost, country-of-origin, and tracking information required by customs authorities to ensure compliance with regulations governing returned goods” (Meyer, Harvey)

Cooke adds to research on Logistics Excellence with his discussion of a logistics performance scorecard. He asserts that performance standards should be well defined and quantifiable before the contract phase of a relationship. Mercer Management adds that some areas to consider are: on-time shipment, on-time delivery, picking accuracy, order fulfillment, inventory accuracy and loss & damage.

A multi-industry consortium centered on MIT’s Center for Transportation Studies has also done considerable research on performance metrics for an integrated supply chain. This group asserts that companies are seeking improvement programs to address the increasingly fast rate of change in today’s economy. (MIT CTS Consortium)

The group from MIT suggests a framework that categorizes metrics into types (customer satisfaction/quality, time,
costs, and assets). For each category an outcome metric and a diagnostic metric is suggested. The diagnostic metrics tracks the data and events that influence a goal. This framework is very useful. (MIT CTS Consortium)

What is left unclear by the current writing, however, is that given the tradeoffs in cost and service, how much should be spent on logistics excellence to stem returns?

2.5 Drawing the Box

While logistics excellence can impact direct returns, it is not a clear solution for indirect returns. Several researchers have offered useful insight by questioning how far the planning box should be drawn not to sub-optimize a system.

From an inventory perspective, many researchers have studied multi-echelon control. Cachon created a game based on a two-echelon supply chain between a retailer and manufacturer. In the game, the retailer was given the opportunity to return product as part of the contract. Cachon found however that this was insufficient to coordinate the supply chain. A more effective contract shared lost sales and inventory costs between distributor and retailer. (Cachon)

Mercer Management Consulting suggests in the book Value Nets, that a strong relationship between manufacturers and distributors allows for greater control. They go on to suggest that, not only will this provide operational benefit but in several examples has markedly increased sales as well. “Traditionally, companies have relied on new products and aggressive marketing to drive the top line. Supply chain activities have not typically been viewed as contributors to the revenue stream. However, when superior
service levels create utility for customers, they can increase revenues through either premium prices or higher sales volume." (Bovet and Martha)

Jonathan Byrnes and Roy Shapiro tackled the issue of drawing the box head-on in their paper, "Intercompany Operating Ties: Unlocking the Value in Channel Restructuring." Several of the companies they studied which have intercompany operating ties had received substantial rewards from implementation. "These included cost reductions exceeding 30%, as well as significant increases in sales, improved supply continuity, flexibility and quicker response to changes in consumer needs." (Byrnes and Shapiro) Byrnes and Shapiro go on to provide a very useful taxonomy of different channel types, forms of demand and production operating ties.

2.6 Policy and Motivation

Drawing a larger box requires increased coordination between companies. The coordination is often useful because it aligns motivation in the entire system to a global optimum. Manufacturers have used other methods of shaping distributor behavior as well.

"As demand uncertainty grows in the marketplace, a critical issue today in most purchase contract negotiations between an independent retailer of a style-good and its supplier is the provision of a returns policy, i.e., a commitment by the supplier to buy back unsold inventory of the good at the end of its selling season." (Mantrala and Raman) One of the intents of the policies is to "encourage retailers to stock and price items more aggressively." (Anonymous.)
Padmanabhan and Png find that “when retailing is competitive and there is not uncertainty in demand, a returns policy subtly induces retailers to compete more intensely.” In the high tech world, however, demand is far less certain and can cause distributor overstocking. The more uncertain demand is, the greater the cost of a returns policy to the manufacturer will be. The tradeoff is between intense retail competition and overstocking. In the high tech industry, high demand uncertainty and high retail/distributor competition complicate this tradeoff. (Padmanabhan and Png)

This tradeoff allows for the potential to erode profits. In Borland’s annual report, "Gross margins can be strongly affected in particular periods by aggressive pricing strategies and return privileges associated with new product introductions and upgrades." (Borland Inc.)

Despite all that is at stake, it is very difficult to have a return policy that does not sub-optimize the system. Mantrala and Raman go on to say that research in return policy offers “little treatment of how exactly the retailer’s optimal order quantity decisions are affected by demand uncertainty, and how a supplier’s returns policy can influence these decisions.” One of the difficulties of the problem is that it is highly non-linear. (Mantrala and Raman) The system forces that make determining return policy difficult are the same ones that generate returns.

2.7 Systems Dynamics Analysis

One method of understanding complex systems as described by Mantrala and Raman is Systems Dynamics modeling. Systems
Dynamics is a way to understand and simulate an organization or collection of organizations. Jay Forrester started the field, and today it is used extensively by Ford and others.

Tayfun believes simulation modeling is beneficial because it can generate insights on 1. managing change, minimizing risk. 2. promoting creativity, 3. capturing system dynamics, 4. avoiding disturbance, 5. accelerating testing, 6. enhancing communication, 7. quantifying solutions, and 8. Providing total solutions.

John Sterman of MIT’s Sloan School of Business relates system dynamics as a means of “improving our understanding of the ways in which an organization’s performance is related to its internal structure and operating policies as well as those of customers, competitors and suppliers – and then use that understanding to design high leverage policies for success.” (Sterman)

2.8 Research Limitations
Research is limited for both direct and indirect returns. While several authors have discussed return policy, no substantive research has been done on the issue of reduction from a systems perspective. The lack of research in this area is incredibly important. It illustrates that conventional wisdom continues to be symptom focused, and is not actively seeking approaches to killing the disease (errors).

The team of Fleischmann and Bloemhof-Ruwaard consider RL to be “subdivided into 3 main areas, namely distribution planning, inventory control, and production planning.”
Giuntini and Andel believe RL to be the mastery of "Six R’s" to the exclusion of reduction.

Return policies, as discussed by Mantrala and Raman, treat operation symptoms and discuss the fundamental cause of returns. There is room for research to look at the basic drivers of returns from a systems perspective. This research should give insight into approaches to reduce return volume.

Most of RL writing has been centered on essentially optimizing a sub-optimal situation. Shear believes that successful RL constitutes, "1. store-level returns handling, 2. transportation management, 3. centralized processing, 4. technology, and 5. management reporting." Again, the authors continue to fail to mention reduction. There is room for research to address system impact from returns, and to evaluate the appropriate level of investment and energy to minimizing RL.
CHAPTER 3 - Methodology

The method of this research is to separate the issue of return reduction from efficient returns management. Return reduction will be studied exclusively. Generally, drivers other than returns management effectiveness determine return levels. What these drivers are and how to impact them will be the focus of the study. The completed study will be used as a basis for recommendations and performance metrics.

The metrics will be geared toward reducing returns flows from understanding return drivers and weighing the importance of each driver. The majority analysis is done in a systems dynamics context.

3.1 Understanding Return Drivers

"Return Drivers" are the forces, direct or indirect, that influence the volume of returns in a system. Drivers can vary in different industries, companies and over time. To understand how a driver is related to a reaction (a return) the interaction of drivers and other components in the system must be understood. "In fact, the most complex behaviors usually arise from the interactions (feedback') among the components of the system, not from the complexity of the components themselves." (Sterman)

To understand how different variables (components) interact with each other, RL managers representing several high tech manufacturing companies were interviewed (see exhibit 2 for interview questions). The interviews were approximately 30 minutes in length and were used as a basis of understanding how RL systems may vary among different organizations.

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1 Feedback refers to how one variable in a system will influence others, which eventually influence the first variable. For example, rain falls into the ocean, the sun warms the ocean and evaporates the water, the evaporated water forms clouds, and rain falls into the ocean again, closing the loop.
This information was compared to a more in-depth series of interviews with one particular manufacturer.

This information was recorded and mapped to create a systems dynamics model of the interactions of the system. The systems dynamics model is a means to understand the results over time of business decisions in a nonlinear basis.

3.2 Driver Importance

Ultimately, the objective is to understand what drivers yield the greatest changes in return volumes. From this information policies can be set to facilitate change. Certainly, some drivers will have a stronger influence over the system than will others. So, policy should focus on changing drivers that have significant impact towards reducing returns, without causing undesired effects. For example, a simulation may show reduced returns when the R&D budget is cut. However, this is only as a result of reduced new product sales.

The System Dynamics model is a nonlinear simulation over a set time horizon, using Vensim simulation software. The model is comprised of variables that are linked together when a relationship exists between the variables (see exhibit 3). Simulating the model and reviewing results will test driver importance.

"More exciting results show non-intuitive surprises." (Hines) A general example of this type of result is that conventional wisdom presumed that the salesman’s results directly correlate to the level of sales quota. The higher the quota, the higher the effort, and thus the higher the sales. This may be true, but perhaps the lack of reaching
the quota decreases the salesman's confidence and reduces sales. The model is created to understand this type of dynamic.

3.3 Managing Return Drivers

By testing the model under varying policies and inputs, relative driver importance can be determined. The most valuable drivers will be those that can significantly reduce returns without disturbing the remainder of the system variables.

Certain drivers will be modeled as exogenous values that act as policies. The exogenous values in this model include shipping accuracy, shipping quality, payment terms, sales quota and others. The model will be repeatedly simulated under different policy circumstances. Some policy changes will dramatically affect the model's results and some will not. In certain cases policies will prove more powerful in combination, or may mitigate the effect of each other.

It is important to note that, while the model will show results for the structure simulated, it may or may not be applicable to other strategies, products, companies, or industries. However this depends on the relative relationship of variables. However, in an effort to keep the modeling results as transferable as possible, variables will be generalized and simplified.

3.4 Measuring Return Drivers

The methodology for developing metrics for proactive reduction includes interviews with RL managers and insights from the modeling exercise. The simple logic is to determine which variables have the most impact in driving return reductions and include them on the scorecard as
metrics. Additionally, the model will be able to determine sensitivity to changes in a variable. This can be used to set bounds for the metrics and goals.

For example, the model may show many products being returned because they are damaged in transit. They are damaged in transit because they are loaded poorly. The poor loading is due to worker fatigue from a quarter end sales push. The metric may be “% damaged in transit” and may be effectively managed by leveling sales across the month by reducing incentives.
CHAPTER 4 - Findings

The hypothesis presumed that each type of return (DOA, return allowance, shipping error, and obsolete product) has different drivers. Also, certain drivers are more responsible for returns than others are. Because an action to reduce a return may have additional unintended effects in a Supply Chain, Proactive Reduction has been approached from a systems perspective.

4.1 General Interview Results

To understand the dynamics of returns RL, sales and finance managers were interviewed, and a model was created from the resulting understanding of relationships and concerns.

The interview results were consistent in that all managers interviewed viewed the RL function of their respective organization as under development. These managers represent selected manufacturing companies in the high tech industry.

The companies have the following profiles (detail about the companies has been omitted to allow for anonymity):
Company a - Top 5 in sales in Internet network manufacturing.
Company b - Top 5 in sales in computer and computer systems manufacturing.
Company c - Top 5 in sales in semiconductor manufacturing.
Company d - Top 5 in sales in network manufacturing.

The interview questions were designed to probe at the quantity of returns, how they are categorized, drivers, policies, metrics, and the level of strategic thought about returns.
The following are summaries of important remarks from the interviews and insights.

1. To understand the scale of returns in your organization, what is the total return value as a % to sales? Are returns categorized by return reason (i.e. warranty, damage, stock rotation, etc.) how does this break out in %?

<table>
<thead>
<tr>
<th>Category</th>
<th>Average Return Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock Rotation</td>
<td>48%</td>
</tr>
<tr>
<td>DOA</td>
<td>3%</td>
</tr>
<tr>
<td>Cancellations</td>
<td>5%</td>
</tr>
<tr>
<td>Wrong Delivery Time</td>
<td>2%</td>
</tr>
<tr>
<td>Wrong Product</td>
<td>2%</td>
</tr>
</tbody>
</table>

Company a: Has approximately 4.5% of sales as returns.
Company b: Stock rotation volume meets and occasionally exceeds stock rotation policy percentage.
Company c: 30% shipped to distributors, 70% shipped direct to customers. Stock rotation policy is 5% only 2% actually come back in this category.
Company d: 100% shipped to distributors. Stock rotation accounts for approximately 2.5% of sales.

Implications. The term stock rotation used in the interviews is very common in the high tech industry. This term refers to manufacturers allowing, by policy, distributors to return up to a certain percentage of sales (quite often 10% or less). Quite often there are restrictions associated with this policy, such as a requirement for a sales order to accompany a return.
The common response to why stock rotation policies are used is “competitive pressure,” or “it is standard in this industry.” The importance of the stock rotation policy cannot be overemphasized. This policy allows distributors to returns product for indirect reasons (see metrics table in exhibit.) There is no burden of proof for just cause such as damages or errors on the part of the distributor.

The distributor has the opportunity to return product for any reason up to the percentage of the return policy. In practice this policy almost structures inventory management as a consignment system, without the value of close vendor management. The distributors use this freedom to reduce inventory risk. Excess inventories can be ordered to cushion against potential lost sales and take advantage of manufacturer price discounting.

Additionally, it is interesting to note that the method of measuring percentages of returns is inaccurate. The accounting slightly over-exaggerates the percentage of returns to sales. For example, if over the course of one year a distributor orders $120 worth of widgets and returns are at a rate of $1 per month, total sales/total returns = 120/12 or 10%. However, accounting convention forces returns to be subtracted from total sales as widgets are physically returned. In this case, the new fraction would be (120-12)/12 or 11%.

2. What internal policies drive returns (return allowances, re-shelving fees, pricing, quarter end discounting)? How are they implemented?

Company a: Competitive product returns
Company b: Stuffing the channel at quarter-end through discounting, vendor screening, and component choices.
Company c: Restocking fees, diminishing quarter-end discounting, non-elastic products, and date coding, rebate levels.

Company d: Quality, rebate structure, sales goals, fulfillment quality, price protection and ordering rules.

**Implications.** Manufacturers do understand that overall sales policy will drive the quantity of returns. In some cases, such as competitive product returns, the perceived value of accepting the return outstrips the perceived cost associated with RL. With competitive product returns, a distributor is allowed to return competitors' product to a manufacturer in exchange for new sales commitments. The intent is to both increase sales and remove competing product from the inventory shelves. Ultimately, the majority of competitive returns are scrapped.

Stuffing the channel is a behavior in which products are discounted at quarter’s end in an effort to make sales quotas. This behavior has traditionally caused many problems with forward logistics and inventory control. RL managers have realized that the reflection of the quarter-end sales spike is a quarter-beginning returns spike. All RL managers interviewed discussed desire to reduce quarter end channel stuffing, although no concrete initiatives were discussed.

In an industry where products depreciate very rapidly, manufacturers have also developed some policies to share price erosion risk with the distributors. Price protection attempts to protect distributors from holding products losing value. With price protection a distributor may obtain financial satisfaction without physically returning a product for credit.
3. What external forces affect return rates?

Company a: Low sales, overbuying, customer damages, reseller service centers.
Company b: Consumer taste
Company c: Competition, sales
Company d: Components, sales

**Implications.** The primary similarity between the responses is the belief that demand is not precisely predictable. Competition may introduce alternative products, products may fall out of fashion with consumers, environmental forces may change requirements and business cycles can affect growth. The result is that distributors may overbuy, or buy the wrong product.

All of the forces the RL managers discussed as external are not entirely external, however. Many of these forces are products of manufacturer strategy and policy. A consumer’s interest in competitor products may result from an inferior manufacturer value proposition. Sales are a product of building the correct products at the correct price.

4. How is returns structured from an organizational perspective?

Company a: Controlled by separate manufacturing divisions.
Company b: Different organization depending on whether the return is for service or credit
Company c: Managed by a 3rd party, authorized by manufacturer, (typically sales group or RL group)
Company d: One global reverse logistics organization.

**Implications.** There seems to be a division between companies that have forward and reverse logistics separate and combined. The general organizational options described by RL managers are:
• One comprehensive company-wide RL organization. From discussions this seems to allow for the best operation RL control from a reactive perspective. All processes can be streamlined, secondary channels can be established, scale can be achieved from facility use and management can become focused in RL issues.

• RL organizations aligned to manufacturing units. Organizations structured in this fashion may find that closer interaction with specific divisions and more product specification can offer greater customer service and, in some cases, be more efficient. This may be the case when a manufacturing unit has a customer base in a specific limited geography. This type of structure may also be more practical when forward logistics is organized by manufacturing unit.

• Third party RL management will be suited for multiple manufacturers and geographies. Third party organizations in RL are structured around re-manufacturing and logistics.

• Some organizations will not have a unique RL organization. The organization responsible for forward logistics will also have responsibility for RL.

5. What would a channel map look like? What are the outlets for returned goods?

Company a: One central return point for North America for all returns (including in warranty, out of warranty and DOA).

Company b: Return organizations are aligned to manufacturing divisions (three divisions) and split between returns and
service groups. Other options include secondary markets and outlets.  

Company c: Uses 3rd party group to handle returns. Primarily centralized return location.  

Company d: Distributor on site re-work and central return location.

**Implications.** All manufacturers interviewed had significant physical differences in channel maps. Differences are based on strategy, geography, distribution channels, products and policies. Because the RL networks are not adequately measured at this time it is difficult to discuss which channels are most effective.

6. What data is used to manage returns? What metrics are used to chart results?  

Company a: Return days outstanding (how long it takes to get product back), material in transit, dock to receipt, inventory accuracy, scrap dollars.  

Company b: Repair cycle time, Average days from RMA until subsequent sale, % recovery of original cost, Logistics cost as % of revenue.  

Company c: Returns by category, quality of returns.  

Company d: Total returns, Returns as a % of revenue, % of asset recovery, Re-work savings.

**Implications.** Companies are taking an initial pass at developing performance metrics that will look at RL issues. The metrics fall into several categories.  

- **Cycle Time** - Some examples include Returns days outstanding (how long it takes to get product back), material in transit, dock to receipt, Repair cycle time, Average days from return authorization until subsequent sale. Is faster always better? While carrying inventory does have cost, speed has cost as
well. Speed may make sense when an outlet exists for the product such as an eager buyer. However, if the return will sit in queue to be inspected, serviced and perhaps eventually scrapped speed may not be helpful and may in fact be harmful. Some managers discussed scrapping at the Distributor’s site which reduces RL cost and removes the inventory from the books.

- Financial - Examples such as Returns as a % of revenue may be more appropriate for executive level management to use. This metric has broad drivers and the RL group may not have the ability to affect its change. The RL group can directly impact the % of asset recovery. This metric is critical to encouraging scrap reduction and returns reuse or resale. It may be even more effective when RL cost is considered in the same metric.

7. How is the return process aligned with company strategy? Are returns considered a strategic issue?
Company a: Yes, RL should not impact sales efforts
Company b: Does not know
Company c: Yes, return policies are lenient to ensure product is in distributor inventory.
Company d: Yes, return policies are lenient to ensure product is in distributor inventory.

**Implications.** In terms of strategy, all managers interviewed believe that it is critical to have inventory on the shelves at the distributor. Apparently, the threat of substitution is high. This strategy is another argument for greater collaboration between the distributor and the manufacturer.
While all managers interviewed agreed that sales volume is critical to the strategy, none knew the cost of policies such as stock rotation, which they believe enable greater sales.

8. Returned product is a window to possible process or policy problems. Is there any planned feedback from the return organization to parts of the business (manufacturing, sales, R&D, etc.)?
Company a: Working on a better process to integrate sales groups, packaging engineers, finance and RMA.
Company b: No current efforts
Company c: Feedback is more sales focused. What did the competitor sell? Why did our product get returned?
Company d: Feedback for error reasons.

Implications. Several organizations have limited feedback structure built into the return process. Feedback flows to other internal organizations. In theory, the organizations make changes and returns are reduced. However, it is not clear that any of the organizations have a good process for measuring feedback or tracking what changes other organizations have made in response to feedback input. The intent of feedback is to aid in the proactive reduction of returns. For example, it may be interesting to measure return quantity at different monthly levels of sales discounting.

4.2 Proactive Reduction

The difficulty with taking action to reduce returns is that these actions may impact other areas of the system. The approach path used to determine metrics was to understand the broader system that houses RL through interviews and model construction, simulate the model, gain insight,
discuss management options and finally offer suggestions for metrics.

### 4.2.1 Understanding Returns in the Reverse Logistics System

To quantify how different policies impact returns level, a Systems Dynamics model was created (see exhibit 4). The model was based on interview results and built over a base manufacturing systems dynamics model created by John Sterman at MIT Sloan School (exhibit 4). Attempts were made to capture both real physical relationships that exist between entities and manager decision utility. This utility is noted in tables in the model. A table will show a utility curve for a managers decision (see exhibit 5 for complete equations).

The model is a simulation and works over a set time horizon. Forces in the model will affect each other. The forces are the policies, relationships and inputs (sales) of the system. Mechanically, the forces are linked together with equations.

Rather than make the model highly specific to one company, representation of physical flow and decision making is generalized for a broader range of the high tech manufacturing industry. The model can be viewed in three distinct sections: a manufacturing organization, a distributor organization and the return flows from distributor to manufacturer.

### 4.2.2 Systems Dynamics Model Construction

To fully understand the results from the modeling process, it is important to understand the relationships in the
model. Because the model is intended to be a simple return
flow process, it will not perfectly reflect systems with
multiple returns channels or secondary markets. However,
the drivers of returns should remain informative.

This scope of this model includes the interaction of a
manufacturer and a distributor. This interaction includes a
simplified sales process, distributor inventory and order
fulfillment, simplified distributor returns process,
manufacturer inventory, order fulfillment and manufacturing
process. The model is useful for examining how a sales rate
can impact a combination of organizations. The sales rate
is determined by factors exogenous to the model. However,
the sales rate may be influenced endogenously through sales
incentives and returns.

The following illustrations are clips from the model with
description added for clarification. Text with a box around
it is considered a stock, and text without a box is a flow.
The stock can be viewed as a bathtub. The flow is the rate
water flows in and flows out. The level in the bathtub
reflects the difference in the rate of inflow and outflow.
Other text variables without a box are equations, and act to
represent operating parameters, or policies, which
ultimately determine flow rates.

The manufacturing process and manufacturer order fulfillment
portion of the model is a commonly used structure created by
John Sterman at The Sloan Business School. Original
contributions to the model include the addition of a
distributor, the sales incentive process, returns network
and the return decision point.
Illustration 4.1 shows six stocks. These stocks are points where delays occur before inventory is moved to the next operations. The stocks in sequence of process are Manufacturer WIP, Mfg. Inventory, Transportation Inventory, Distributor Inventory, Return Transportation Inventory, Returns Inventory and finally back to Mfg. Inventory. Delay length is determined by the rate of outflow versus inflow and the level in the stock.

This model assumes all WIP will become finished goods inventory and ultimately become transportation inventory. Not all transportation inventory becomes distributor inventory, however, due to return errors. Distributor inventory either will be used to fill customer orders or will be returned and end up in return transportation inventory. Transportation inventory will fill returns goods inventories. Returns goods inventories will either become finished goods inventories again or become scrapped, depending on the scrap rate.
The manufacturing portion of the model represents a simple order fulfillment system. Shipments will be filled as distributors order, unless inventory is unavailable. Expectations of orders (forecasts) will also be revised as orders come in (although there will be a delay). Expectations of future orders will be used to manage the production process. Product will be built to both meet expected demand and also to replenish decaying stocks of inventory.

Variables that can be adjusted to calibrate the model to specific operating situations are: WIP adjustment time, manufacturing cycle time, inventory adjustment time, minimum ordering processing time, table for order fulfillment.

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2 Table for Order Fulfillment is a utility lookup that begins to allocate less than the total product quantity requested as inventory levels decline.
safety stock coverage rate and time to average order rate. The equations for these variables are listed in exhibit 5.

This distributor portion of the model again represents a simple order fulfillment system. Shipments will be filled as customers order, unless inventory is unavailable. Expectations of orders (forecasts) will also be revised as orders come in. The model is constructed to allow the manufacturer to order up to 40% more product than the forecasted amount. The allowance is to account for the effect of distributor discounting.

Variables that can be adjusted to calibrate the model to a specific operating situations are: inventory adjustment time, minimum ordering processing time, table for order...
fulfillment, safety stock coverage rate and time to average order rate.

The sales process was added to the model to represent the impact of quarterly volume pressure on sales. Quota is a stock of time in a quarter that is used to count down the end time of a quota. This is compared to the actual sales in a quarter to determine the level of discounting the manufacturer is willing to give. The discount table represents a presumed utility for discounting and begins discounting if the sales quota has not been reached by the beginning of the third month of the quarter. Discount levels are then dependent on days remaining and fraction of sales compared to the quota. This process emulates typical quarter-end sales spikes in the high tech industry.
Variables that can be adjusted to calibrate the model to a specific operating situations are quarterly sales level and discount utility table.

4.3 Driver Importance

The combination of model elements captures the dynamics of a working system. This system may have dramatically different results depending on what policies (variables) are adjusted. To test what drivers are of the greatest importance to affecting levels of returns system variables are isolated and checked individually. The discussion will be grouped around the functional areas of Manufacturer testing, Distributor testing, sales process and finally the collective stock and flow structure.

A more detailed description of how the system will react to stimulus is provided in 4.12.1 Manufacturer Testing section. System reactions to amplification and oscillation are similar throughout the entire system. System reaction testing is a way to understand how different functions within the system will be motivated to behave. A function suddenly saddled with growing inventory may act to reduce it through discounting or production changes.

Ultimately, this behavior will impact the quantity and type of returns. Understanding the drivers of this behavior will be the basis for comment on methods to reduce and manage returns.

The model begins in equilibrium with sales at 10,000 units per week without any discounting or returns. Different parts of the model will be activated subsequently in the testing to determine importance.
The testing probes the Manufacturer, Distributor, Sales Process and the Basic Stock and Flow Relationship. The intent is to test presumed important issues and to study the system results. Issues are presumed to be of importance from discussion in the interviews. Detailed descriptions of test and rationale for test are in the subsequent sections. A brief description of the test pattern follows.

- **Manufacturer.** The impact of unsteady order levels on the system. The sales rate is shocked with an unexpected 20% increase. This test was chosen as a basis to understand the basic nature of how delay impacts various functions within the system.

- **Distributor.** The first test examines the impact of decreasing sales and obsolescence on the system. This test was chosen to understand if decreasing sales and obsolescence are motivating the distributor to return product. The second test examines the ability of the distributor to recover from receiving defects. This test was chosen to understand the distributor impact on delivery errors.

- **Sales Process.** The test examines the impact of sales incentives on inventory levels in the system. This test was chosen because RL managers felt that unleveled buying was a significant contributor to returns.

- **Basic Stock and Flow Relationship.** This test examines indirect motivation for returns by adding capital considerations to the model. This test was chosen to better understand indirect returns by examining inventory days on hand versus payment terms.
4.3.1 Manufacturing Testing

Test.
When there is an unanticipated 20% step increase in customer orders from 10,000 units to 12,000 units, the following was observed.

Rationale for Test.
This adjustment was used to emulate the resulting impact to a manufacturer when either a sudden order spike occurs (because of manufacturer discounting) or because a distributor orders additional inventories (to compensate for DOA or non-saleable product receipts).

Observations.
- Decline in manufacturer inventory. Inventory is used to buffer the time it takes to revise demand expectations and also to actually build the new product. The inventory stocks will decrease initially to satisfy demand. The forecast will slowly be revised until it matches demand in period eight (the time to average order rate variable is initially set at eight weeks). This means that production will be at its highest point in this period.
- Amplification of the demand shock. In order to bring the declined inventory to the new, higher desired level, Production Start Rate overshoots Customer Orders Rate.
- Desired Shipment Rate increases to 12,000 immediately and the initial Shipment Rate rises too, but the firm's ability to ship falls with the declining inventory. Therefore, the Shipment Rate drops, and the firm loses or is unable to satisfy some orders.
- The sources of the amplification are the two main manufacturing system delays. These are Manufacturing
Cycle Time and the Time to Average Order Rate. These cause amplification by delaying the two main inputs into the Production Rate.

- Structurally, the degree of amplification is caused by the change in Distributor orders versus the Manufacturing Cycle Time and the Time to Average Order Rate. This level will be affected by the Inventory Adjustment Time policy; inventory replenishment efforts can be spread out over a variable number of periods, as set by policy. The WIP Adjustment Time is also important because without WIP, production is impossible.

- Because of delays, this model will oscillate in any situation where the policy for Inventory Adjustment Time is a shorter number of periods than the Manufacturing Cycle Time. As the Inventory Adjustment Time decreases respectively to the Manufacturing Cycle Time, the Desired Production and Desired Production Start Rate increase. This happens because the Production Adjustment from Inventory increases. This activity then causes the Production Start Rate to rise in an attempt to replenish inventory quickly. Shorter Inventory Adjustment Time makes the Production Start Rate react faster and more violently.

- Due to the Manufacturing Cycle Time delay, actual replenishment takes time. When inventory begins to rise, the Production Start Rate will again act violently and also dramatically fall to a level below its starting point. At this point, inventory will have already passed the policy of 4 weeks on hand (because of the delay in manufacturing).

Implications.

- When distributor order levels are adjusted, the change has a significant impact on the manufacturer’s operation.
In the model costs have not been assigned to operation volatility. However, unstable operations have additional cost associated with them. Examples of these costs include workforce issues, capacity planning and lost sales.

- If a distributor adjusts a subsequent order to compensate for discrepancies in a previous order the manufacturer will have less ability to fill the new order because it is higher than the expected order level and will draw more than expected from manufacturer’s inventory. Essentially, errors in shipment that require replacement shipments reduce the ability of manufacturers to make replacement shipments (see illustration 4.5). This widens the gap between what distributors need to meet sales demand and what they have in inventory. The problem is compounded by the abbreviated life cycle of most high tech products.

4.3.2 Distributor Testing

Test 1.
In week 14, sales begin decreasing at a slope equal to about 1% per week until week 100 when the product becomes obsolete. This is intended to act as a crude product
lifecycle to reflect short product lifecycles in the high tech industry.

Rationale for Test.
This test is intended to simulate the high tech product lifecycle. Over a relatively brief period, a steady decline and, ultimately, obsolescence follow strong initial sales.

Observations.
- In week 14, when product sales levels fall, Distributor inventory levels will begin to rise. Inventory rises until week 30 when order and forecast adjustments begin to catch up with declining sales (see illustration 4.12.2.a)

- Weeks of on hand inventory (inventory coverage) rise exponentially over time as sales levels fall. This is caused by the delay in the forecasting system (see illustration 4.12.2.b). Desired Inventory Coverage remains at 4 weeks. At week 100 actual inventory is 10 weeks greater than desired.
- Due to additional delays in manufacturer forecasting, Manufacturer Inventory grows faster and at a larger quantity than distributor inventory. Manufacturer
inventory starts at the same level as distributor inventory rises to a peak of approximately 20% higher in weeks 35-40 and asymptotically falls to near distributor levels in week 65-70 (illustration 4.12.2.c).

<table>
<thead>
<tr>
<th>illustration 4.12.2.c</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inventory Analysis</strong></td>
</tr>
<tr>
<td>Time (Week)</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>40</td>
</tr>
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<td>60</td>
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<td>70</td>
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<tr>
<td>80</td>
</tr>
<tr>
<td>90</td>
</tr>
<tr>
<td>100</td>
</tr>
</tbody>
</table>

**Implications.**

- At the time when the distributor has the least ability to sell inventory the manufacturer has the greatest desire to reduce its own high inventory levels. This may lead to increased pressure to discount product. The return fraction may rise as distributors are enticed to buy discounted product they cannot sell.

- Without a specific plan to handle end of product life cycle issues, weeks on hand of inventory grows as sales and price fall. Inventory risk will be extremely high and distributors will be highly motivated to return product to the manufacturer.

**Test 2.**

Beginning in week 14, a problem develops with packaging. Subsequently, 20% of products distributors receive are not suitable for sale.
Rationale for Test.
This simulation will test distributor ability to adjust to variable quality of received product.

Observations.

- Distributor inventory exponentially decays from 4 weeks of inventory to an equilibrium time of 2.6 weeks. Apparently, efforts to counteract lower than desired inventory is offset at an equal level by new inventory not suitable for sale (illustration 4.12.2.d).
- Manufacturer WIP increases by 20% to prepare for manufacturing replacement products. Manufacturer Inventory initially decreases from the unexpected new demand from the distributor. As WIP becomes finished goods WIP inventories subside to an equilibrium and Manufacturer Inventories rise to an equilibrium. (illustration 4.12.2.e).

- The ability of the distributor to fulfill orders falls from 100% to an equilibrium level of 93.3%. This result occurs because the model assumes that even if today’s order was flawed, tomorrow’s order will be correct.

3 Inventory risk, defined as the potential to lose margin opportunity from excessive carrying cost or inability to sell.
Implications.

- Error returns inhibit the ability of the Distributor to sell product and also require much greater effort on the part of the manufacturer. Ultimately, manufacturer production efforts went up 20% to compensate for the non-sellable products shipped, and the distributor realized almost 7% less sales.
- Unless the distributor actively adjusts policy to accommodate reduced inventory from returns, optimal inventory levels may be off, and will increase the likelihood of lost sales.

4.3.3 The Sales Process

Test.
Maintain a constant customer demand of 10,000 units. Create a manufacturer sales incentive and quota system (illustration 4.4) that begins offering incentives to the distributor as the quarter comes to an end if the quota has not been met. Discounts are enticing enough that actual distributor orders will rise from 5%-40% (from the utility table), depending on how large the gap is between actual sales and the sales quota, in addition to the amount of time remaining.
Rationale for Test.
This test is designed to provide insight into inventory effects when policy and internal behavior distort real demand.

Observations.
- The incentive system uncouples distributor sales from manufacturer sales (illustration 4.12.3.a). Distributors buy in bulk to save money and then order less than what they normally would have the subsequent month. This will additionally drive the retailers to discount later in the month to compensate for lower than expected initial sales (illustration 4.12.3.b).

<table>
<thead>
<tr>
<th>Illustration 4.12.3.a</th>
<th>Illustration 4.12.3.b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Distributor Sales vs. Manufacturer Sales</td>
<td>Need for Additional Inventory</td>
</tr>
<tr>
<td>Manufacturer Sales Rate : step</td>
<td>Distributor Bulk Purchasing</td>
</tr>
<tr>
<td>Sales Rate : step</td>
<td>Incentive Comandram</td>
</tr>
<tr>
<td>Widgets/Week</td>
<td>Motivation to Provide Incentive</td>
</tr>
<tr>
<td>Widgets/Week</td>
<td>Sales Gap</td>
</tr>
</tbody>
</table>

- The uncoupling of inventory results in stockpiling of Distributor inventory. Inventory levels fluctuate from a planned 4 weeks or 40,000 units to greater than 43,000 units (illustration 4.12.3.c). This is less this a 10% increase despite a 40% increase in the required order due to sales incentives order. This smaller than expected change occurs because the required order has been previously revised down due to higher inventory levels.
• Although the variance in distributor inventory is not great, the return rate is still substantial. In this scenario, returns are sporadic and net to approximately 3% of Sales, which is reflective of the industry (illustration 4.12.3.d). Again, in this illustration the return rate is extremely inconsistent. Returns shadow quarterly sales peaks. This shadow effect is caused by inventory levels becoming high enough that a gap begins to form between manufacturer payment terms and days on hand of distributor inventory.

**Implications.**

• It is assumed that the distributor decides purchase quantity based on anticipated sales and current demand expectations. If this is the case, repeated cycles of discounting will cause inventory stockpiling and will lower the optimal purchase quantity of the distributor. Essentially, the policy of consistent discounting is causing the need to discount.

• Not only is the policy of consistent discounting self-reinforcing, it is self-defeating. It is a primary driver of returns, and yields inconsistent inventory levels of WIP and finished goods.
4.3.4 The Basic Stock and Flow Relationships

The stock and flow relationship is used to understand the inter-company impact of returned products. The relationship allows a closer look at how returns are generated and their affect on operations.

**TEST.**

The model is set to return products when inventory causes capital exposure (illustration 4.12.4.a). Capital exposure occurs whenever Distributor Inventory Coverage exceeds manufacturer payment terms. Manufacturer payment terms are assumed to be 4 weeks. Sales (illustration 4.12.4.b) are set to oscillate at sine amplitude of 1,000 at a period of 20 weeks. This will reflect potential sales fluctuations in competition and promotions.

**Rationale for Test.**

This test is created to gain insight into indirect return rates by analyzing distributor motivations.

<table>
<thead>
<tr>
<th>Illustration 4.12.4.a</th>
<th>Illustration 4.12.4.b</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
</tbody>
</table>
Observations.

- Oscillating sales levels cause minimal disturbance in distributor inventory levels. However, oscillations are dramatically amplified for Manufacturer WIP and Inventory levels (illustration 4.12.4.c). The oscillations come from the delays built into the model as described in the Manufacturer Testing section. Despite minimal disturbances in Distributor inventory levels, returns are generated.

- Upon closer examination, the Distributor Inventory level looks bumpy relative to the oscillating sales level. This is caused by inventory shaved off of the peaks and being diverted to returns. Because return volume is the crest of demand waves, it appears choppy and unpredictable (illustration 4.12.4.d).

- Considerable time expires for a product to move through the various areas where inventory can be held. Transportation is assumed to be 3.5 days each way. It can be assumed that each inventory stock will hold inventory for at least one day. In total, for one product to move through the channel from Manufacturer Inventory and back, the absolute minimum total time is 11 days. In reality, the product is likely to dwell in distributor inventory much longer.

- Shipping accuracy and shipping quality are assumed to not cause returns in this model run. Rates can be set in the model to make assumptions on increased return rates (illustration 4.12.4.a). The effect would be to decrease the distributor’s ability to complete orders, as described in the Distributor Testing section.
Implications.

- Inconsistent sales drive inconsistent returns. In this case, returns are the inventory crests resulting from demand waves. The inventory crests arise because of fluctuating demand or other system drivers.
- The considerable time the return process takes is problematic because of the rapid rate of price reduction of high tech products. Other means of channel management to minimize the time delay of the channel may be appropriate.

4.4 Findings Summary

**Policy and Strategy.** The application of return policy appears to act as a shock absorber for bumps in business process and quality. Note in illustration 4.12.3.c the consistency of distributor inventory levels relative to manufacturer finished goods and WIP. The shocks the manufacturers absorb cause tremendous amplification in manufacturer process and inventory.

Illustration 4.12.3a shows how sales incentive policy contributes to the system shock by causing the need to discount further.
The dynamics beg the question of the feasibility of closer collaboration to smooth shock for both manufacturer and distributor. Alternative approaches to accomplish this are discussed in chapter five.

**Business Dynamics.** In the model, the manufacturing organizations are not directly coupled because inventory replenishment is affected by both sales expectations and discounting. As discussed in 4.12.1, uncoupled systems are more prone to delays. Information and material delays can cause oscillations and amplification in systems. These conditions both increase cost and decrease system responsiveness (service).

**Operational Excellence.** Returns caused by direct errors cause the same system repercussion as indirect policy returns. As discussed in 4.12.2, errors that require replacement shipments reduce the ability of manufacturers to make replacement shipments and distributors to serve customers.
CHAPTER 5 - Conclusion

RL Managers interviewed for this paper reported return rates of 5%-10% of Sales. Researchers have begun to treat this problem by developing methods of reactive efficiency. Illustration 5a outlines another path to improving the return problem. This path highlights proactive methods of reducing returns.

Proactive reduction is an approach to minimize direct and indirect returns. Direct returns come from linked causal relationships such as damages (DOA), incorrect shipments, and off schedule deliveries. Indirect returns are products returned at the discretion of distributors to minimize several different risks.

5.1 Managing Return Drivers

Returns have been described as indirect and direct. Returned products that are categorized as indirect are returned under the guise of return allowance, even though the product was purchased in good faith. Returned product categorized as direct is returned when the manufacturer has not correctly responded to the distributor order.

The best management approach is different for the two categories.
• Indirect returns require more strategic action from executive management of both the manufacturer and the distributor.
• Direct returns require operational excellence from tactical and operations level managers.

5.2 Indirect Returns: Strategic Cooperation

Policies such as stock rotation and customer service return allowances provide distributors an opportunity to return products for no direct cause. Industry RL managers have described rationale for these policies as a result of competitive pressure.

Distributor Benefit. In the current channel structure, indirect return policies benefit distributors by mitigating exposure to capital risk, unit price erosion, obsolescence, inaccurate forecasting and scarcity of supply.

• Capital Risk. When distributor days on hand of inventory exceeds manufacturer payment terms the distributor begins self-funding inventory capital cost and has incentive to return product.

• Unit Price Erosion. Product life-cycles in the high tech industry are generally relatively short. Unit prices tend to rapidly decline over time. Distributors risk buying at a price above current market price and, in some cases have incentive to return aged product and buy new at a lower price.

• Obsolescence. A product in distributor inventory may become unsaleable when new models or competitor products are introduced.

• Inaccurate forecasting. Due to the rapid pace of change, predicting the growth and decline in the product life-cycle is difficult.
• **Scarcity of supply.** When production for a new product is ramping up, distributors are able to over-order to get a higher allocation of product.

**Manufacturer Risk.** While indirect return policies reduce exposure for distributors, risk for the manufacturer increases. Manufacturers lose physical control of inventory, may have less than desirable cash to cash cycle time and face reduced financial returns.

• **Control.** In a typical manufacturer/ distributor relationship downstream inventory is a distributor asset under distributor control until it is released as a return. However, there are several situations where downstream control of inventory may be advantageous to a manufacturer.

Because overbuying can be remedied with returns and underbuying results in lost sales, distributors may overstate sales forecasts in the ramp up phase of the product life cycle. This allows the distributor to receive a greater allocation of constrained production. Due to inflated sales expectations distributor sales rates may not actually mesh with initial allocations. The manufacturer faces lost sales because it cannot immediately act to reallocate inventory to channels with the highest real demand while production attempts to catch up. This time delay reduces the manufacturer's ability to proactively move products to secondary Markets or other channels.

• **Cash to Cash.** Assuming a distributor is billed on receipt, the simplified expected cash to cash cycle time for a manufactured product may be considered as: cash to cash cycle time = distributor payment terms + production
time + inventory dwell time + transport time - supplier
payment terms. Distributors have incentive to return
products at the end of payment terms to avoid self-
funding. Returned products cash to cash cycle may
increase by two or more times. This additional delay
results from subsequent terms with the next market plus
additional transport and inventory dwell time.

- **ROA.** Because prices, marketability and quality may
decline over time, manufacturers may have difficulty
reselling a returned product at the original price it was
sold. Beyond selling price, transporting, storing,
testing and administration of the RL process also reduce
ROA.

**Problems of Non Integration.** Non integrated operations may
cause sub-optimal behavior. The systems dynamic model has
shown other character traits of the manufacturer and
distributor relationship as well. Four problem areas are
amplification, demand inconsistency, supply inconsistency
and incentives.

- **Amplification.** As discussed in chapter four, product
purchase and return decisions are amplified through the
supply chain. Amplifications increase overall unit cost,
inventory levels and decrease supply chain performance.

- **Demand Inconsistency.** Sub-optimization may also cause
inconsistent demand. Sales incentives and resulting
quarter end demand spikes, and over-ordering to improve
allocation are examples.

- **Supply Inconsistency.** Unplanned Returned product
reentering finished goods inventory at uncontrolled
intervals and rates make production planning and
inventory management difficult at best.
Incentives. Non integrated supply chains may also be sub optimized because of silos of conflicting incentives. Manufacturer sales may have incentive to discount to reach a volume goal. Manufacturer production has incentive to level production. The distributor has incentive to overbuy to ensure product availability for sale. Indirect return policies give distributors incentive to overstock and hold inventory until the last possible moment to minimize potential lost sales. This tendency to over-purchase unfortunately aligns itself well with the manufacturer’s desire to over-sell. The bubble bursts even when sales actually meet expectations because of excessive inventory buildup.

Value of Integration. A solution to consider is to develop deeper manufacturer and distributor integration. Integration can be of value because it provides all of the benefits that the distributors already enjoy, mitigates some of the exposure the manufacturers’ face and minimizes the effects of a sub-optimized system.

Several options exist for integrating operations. The relative value of any of the options depends on the type of channel and product. Byrnes and Shapiro characterize the high tech industry as part of the “ramp up” channel. In the ramp up channel demand signals can become distorted due to distributor over-ordering. Developed products will end up in a fluctuating channel where “product consumption is variable and unpredictable, but usually within a known range.” (Byrnes and Shapiro)

From the systems dynamics model we learn that distorted signals cause system delays and eventually become amplified in terms of inventory or effort. Other problems discussed
included demand inconsistency, supply inconsistency and incentives.

One type of integration that may prove beneficial is Vendor Managed Inventory. Emigh describes Vendor-managed inventory (VMI) as "a streamlined approach to inventory and order-fulfillment. With it, the supplier, not the retailer, is responsible for managing and replenishing inventory."

Because the vendor (manufacturer) has responsibility for the inventory, VMI can also resolve issues of control, cash to cash\(^4\) and ROA for the manufacturer. VMI does not, however, diminish the benefits the distributor was previously enjoying with a generous return policy.

**Other Solutions to Reduce Indirect Returns.** Several other options are worth revisiting as well.

- **Field Repair.** Some of the interviewed companies have attempted to reduce product flow into the RL channel by rectifying any problems at the distributor site.

- **Gatekeeping.** Giuntini and Andel suggest that some quantities of returns are illegitimate and should be screened out of the channel.

- **Zero Returns.** Giuntini and Andel suggest policies that would compensate distributors for the potential need to return with a cash allowance or discount. The distributor would have the responsibility to scrap damages as required.

- **Information.** Dell has shown a reduction in returns by changing the ordering process to give more time and information to the customers.

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\(^4\)It is not intuitive that VMI would reduce cash to cash, but when days on hand of inventory at the distributor are lower than payment terms cash to cash is improved.
• **Smaller Batches.** Schonberger and Abdolhossein suggest that working in JIT or with smaller batch sizes decreases delay and reduce returns.

5.3 Direct Returns: Operational Excellence

Reducing direct returns requires operational excellence. It is a fairly simple matter to isolate and track error type and rate. The three general types of operating errors leading returns are order accuracy, product condition and delivery timing.

**Accuracy.** Accuracy refers to the ability to ship both correct quantity and correct SKU.

**Condition.** Condition essentially refers to the salability of a unit. Product may become unable to be sold because of warehouse or in-transit damage, packaging misprints and known product defects.

**Timing.** Timing refers to accuracy of delivery time to either dock appointment times or promise dates.

It is intuitive that reducing the quantity of errors in these categories will directly reduce returns. However, it is not necessarily intuitive how much effort should be made to remedy the errors, and at what expense.

Operational error impacts cost in the system. This was demonstrated in the model with resulting increased returns and inventory levels. Cost associated with remedying error may include the use of premium transportation, additional labor, different systems and process, among others.
Using this cost information to map the relative value of remedying errors is a very worthwhile exercise. Absolute precision may not be important in this analysis. Potentially, the total system cost of returns is several magnitudes greater than the cost to correct direct errors.

5.4 Measuring Return Drivers

To both instill correct manager motivation and to measure results of policy and behavior performance metrics are of use. The following metric discussion uses a framework (from a multi-industry consortium led by MIT’s Center for Transportation Studies) which uses both a diagnostic data point and an outcome metric for each operating issue. Direct and indirect returns are then added to this framework as categories of operating issues, (see illustration 5.4a)

<table>
<thead>
<tr>
<th>Illustration 5.4a - Framework Return Reduction Metrics</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Indirect Return Causes</th>
<th>Operating Issue/Risk</th>
<th>Diagnostic Metric</th>
<th>Outcome Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Return Causes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.4.1 Indirect Return Measures: Strategic Cooperation

In section 5.1 five risks were discussed that motivate distributors to return product. These risks are capital risk, unit price erosion, obsolescence, inaccurate forecasting and scarcity of supply. Creating metrics focused on reducing these risk areas should also reduce returns. Reduction of the five risk areas should also
reduce the three manufacturer risk areas of control, cash to cash and ROA.

The suggested approach is to map distributor risk areas directly to diagnostic metrics. Subsequently, one outcome metric is used to understand macro changes. The comprehensive suggested metrics formulation for indirect returns are listed in Exhibit 3. Please note that overbuying due to scarcity is combined with the poor forecasting metric.

<table>
<thead>
<tr>
<th>Distributor Risk</th>
<th>Diagnostic Metric</th>
<th>Outcome Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital risk</td>
<td>Capital Gap</td>
<td>Indirect Return Fraction</td>
</tr>
<tr>
<td>Obsolescence, Unit price erosion</td>
<td>Inventory Days of Supply</td>
<td>Indirect Return Fraction</td>
</tr>
<tr>
<td>Inaccurate Forecasting</td>
<td>Forecast Accuracy</td>
<td>Indirect Return Fraction</td>
</tr>
</tbody>
</table>

5.4.2 Direct Return Measures: Operational Excellence

In section 5.1 three direct operating errors were discussed that motivate distributors to return product. These operating errors are order accuracy, product condition and delivery timing. As with indirect returns, creating metrics focused on reducing these return conditions should also reduce returns. Again, reduction of the five risk areas should also reduce the three manufacturer risk areas of control, cash to cash and ROA.

The comprehensive suggested metrics formulation for direct returns are listed in Exhibit 3.
<table>
<thead>
<tr>
<th>Distributor Risk</th>
<th>Diagnostic Metric</th>
<th>Outcome Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Order Accuracy</td>
<td>Shipping Error</td>
<td>Direct Return</td>
</tr>
<tr>
<td>Fraction</td>
<td>Fraction</td>
<td>Fraction</td>
</tr>
<tr>
<td>Product Condition</td>
<td>DOA Fraction</td>
<td>Direct Return</td>
</tr>
<tr>
<td></td>
<td>Fraction</td>
<td>Fraction</td>
</tr>
<tr>
<td>Delivery Timing</td>
<td>Deliver to Promise</td>
<td>Direct Return</td>
</tr>
<tr>
<td></td>
<td>Accuracy</td>
<td>Fraction</td>
</tr>
</tbody>
</table>

### 5.5 Summary

This paper takes a first look at the opportunities of proactively working to reduce returns in a manufacturer distributor relationship. The findings have implications to both future research and management.

#### 5.5.1 Research Implications

Management of reverse logistics is becoming an important research area. Within this limited body of research, very little work has been done on proactively reducing returns. The current writing on returns management is almost exclusively efficiency focused. In essence, authors attempt to answer the question, how do we react well to errors and unaligned motivation in a system? A more proactive way of thinking of the problem is to ask how can we reduce errors and align motivation in a system so there is nothing to react to.

In fact, no substantive research has been done from a systems perspective. To understand the broader impact of how returns affect an organization, systems analysis is critical. This paper discusses returns from a systems perspective and provides initial insight into motivations and drivers in an organization.
The scope of research for this paper was limited. The relationship between a manufacturer and distributor in the high tech industry was discussed exclusively. A great opportunity exists to research methods of proactive reduction in a consumer environment, in other industries, and other channel structures and policies. Researching proactive reduction offers great reward, as "An ounce of prevention is worth a pound of cure." - Henry de Bracton

5.5.2 Management Implications

The findings in this paper have indicated that returns are a very costly and important issue in the high tech manufacturing industry. Only recently have researchers begun to explore approaches to this problem.

Approaches to the returns problem can be considered as either proactive methods of reduction or reactive methods of efficiency. Proactive methods of reduction can be further divided into direct and indirect returns.

This taxonomy is helpful in developing management policy because direct and indirect returns have very different realms of solutions. As discussed earlier, direct returns require operational excellence from tactical and operations level managers. Indirect returns require more strategic action from executive management of both the manufacturer and the distributor.

A fundamental problem, spanning both direct and indirect returns, is blind decision-making. Manufacturers often pursue logistics excellence; however, the payback in returns reduction is not known. Stock rotation policies are created to increase sales and ultimately profit; management, however, does not know the true cost of the policies.
For both direct and indirect returns, observations from the findings section indicate that returns cause system inefficiencies and error. The root of effective reduction is developing an understanding of what or how returns are adding to the organization or system. Different companies will have different cost structures. The model in this paper provides a framework for thinking about how returns impact a physical organization. Often, costs in these organizations are known on a micro level, they just have not been considered from a systems level.

With at least a fundamental understanding of returns cost, decisions to make changes can be considered. Examples of changes include hiring a premium transportation company, more labor for direct return minimization, or changing sales incentive policies for indirect return minimization.

The changes can then be tracked with metrics (section 5.4.2). Metrics should be used as a baseline for further analysis and action.

Ultimately, mastering returns in an organization will come from both proactive methods of reduction and reactive methods of efficiency. The analysis and insights in this paper are intended to be a first step in understanding the great, untapped opportunity of proactive reduction.
Bibliography


Cachon, Gerard P. Competitive and Cooperative Inventory Management in a Two- Echelon Supply Chain with Lost Sales. The Fuqua School of Business - Duke University. 1999


Padmanabhan, V. Png, I.P.L. "Manufacturer's Returns, Policies and Retail Competition" (Stanford, California: Graduate School of Business, Stanford University, working paper, 1995).


Exhibit 1

Return Types

**DOA:** Dead on Arrival or Damaged on Arrival refers to any product that is noticeably damaged or defective upon arrival at the distributor. This will be typically from transit or material handling damage including torn, crushed or open boxes. This category will also include any recalls from the manufacturer of learned product defect.

**Return Allowance:** It is typical in the high tech industry for manufacturers to offer distributors the option to return a percentage of the purchase. This return allowance will range as high as 10% however most companies operate at lower levels. While the return allowance is primarily driven by competitive pressure, it serves as a means to protect the distributor from forecast error risk driven by short product life-cycles and many new product introductions.

**Shipping Error:** Shipping error refers to product refused at the receiving dock for one of a number of possible reasons. The most common issues are either the wrong product has been shipped or the delivery did not occur at the designated time.

**Obsolete Product:** Given the short product life cycles manufacturers may have competitive interest in moving new product offerings quickly through the supply chain. If the distributor has older models in inventory, the manufacturer may take it back and move it to secondary channels for redistribution.

**Warranty (not discussed in paper):** Warranty Returns refer to product that has reached point of use and has been determined defective. Warranty return reasons are fairly subjective, which leads to product returns ranging from those that may actually be not functioning properly to completely functioning product in open boxes.


**Exhibit 2**

**Interview Questions**

1. To understand the scale of returns in your organization, what is the total return value as a % to sales? Are returns categorized by return reason (i.e. warranty, damage, stock rotation, etc.) how does this break out in %?

2. What internal policies drive returns (return allowances, re-shelving fees, pricing, quarter end discounting)? How are they implemented?

3. What external forces cause returns (low sales, overbuying, customer damages)

4. How is returns structured from an organizational perspective?

5. What would a channel map look like? What are the outlets for returned goods?

6. What data is used to manage returns? What metrics are used to chart results?

7. How is the return process aligned with company strategy? Is returns considered a strategic issue?

8. Returned product is a window to possible process or policy problems. Is there any planned feedback from the return organization to parts of the business (manufacturing, sales, R&D, etc.)
Exhibit 3

Metrics Worksheet

Indirect Metrics

**Capital Gap.** Measures how days on hand (DOH) of distributor inventory compares to payment terms. Capital Gap = DOH - Payment Terms. Positive numbers motivate distributors to return inventory.

**Inventory Days of Supply.** Is a measure of the speed at which a distributor can react to changes demand. Days of Supply = (Most recent quarters average inventory * 91.25)/Most recent quarter’s Cost of Goods Sold

**Forecast Accuracy.** Poor forecasting would motivate the distributor to overbuy to ensure product availability for sale. Forecast Accuracy = (Forecast Sum - Sum of variances)/Forecast Sum

**Indirect Return Fraction.** Indirect return fraction gives an indication of how effective return reduction efforts have been. Indirect Return Fraction = Most recent quarters indirect return value/ most recent quarters sales

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5 From the Multi-industry consortium recommendation.
Direct Metrics

Shipping Error Fraction. The percentage of returns coded as shipping error.

DOA Fraction. The percentage of returns coded as DOA.

Deliver to Promise Accuracy. The percentage of orders filled on the original commit day.

Direct Return Fraction. Similar to the Indirect return fraction, this fraction gives an indication of how effective improvements in logistics excellence have been. Direct Return Fraction = Most recent quarters direct return value/ most recent quarters sales
Exhibit 4
Adapted System Dynamics Model of Reverse Logistics Process

Initial Manufacturing Model Reverse Logistics Model is Based On.
Adjustment for WIP = (Desired WIP - Manufacturer Work in Process Inventory)/ WIP Adjustment Time
Units: Widgets/Week:GROUP .R1 v4
The adjustment to the production start rate from the adequacy of WIP inventory.

Capital Exposure = MAX(0,"Dist. Inventory Coverage"-"Mfg. Payment Terms")
Units: Weeks:GROUP .R1 v4
The amount of weeks the distributor is self-financing inventory

Change in Exp Orders = (Manufacturer Sales Rate-Expected Order Rate)/ Time to Average Order Rate
Units: (Widgets/Week)/Week :GROUP .R1 v4
The demand forecast adjusts to the actual order rate over a time period determined by the Time to Average Order Rate. The demand forecast is formed by first-order exponential smoothing, a widely used forecasting technique.

Change in Exp Orders 0 = (Sales Rate-Expected Order Rate 0)/Time to Average Order Rate 0
Units: (Widgets/Week)/Week:GROUP .R1 v4
The demand forecast adjusts to the actual order rate over a time period determined by the Time to Average Order Rate. The demand forecast is formed by first-order exponential smoothing, a widely used forecasting technique.

Change in Pink Noise = (White Noise - Pink Noise)/Noise Correlation Time
Units: 1/Week :GROUP .R1 v4
Change in the pink noise value; Pink noise is a first order exponential smoothing delay of the white noise input.

Desired Inventory = Desired Inventory Coverage*Expected Order Rate
Units: Widgets:GROUP .R1 v4
The desired inventory level sought by the plant. Experience suggests that to maintain customer service by providing full and reliable deliveries, the plant must maintain a certain coverage of throughput (demand), estimated by the demand forecast.

Desired Inventory 0 = Desired Inventory Coverage 0*Expected Order Rate 0
Units: Widgets:GROUP .R1 v4
The desired inventory level sought by the distributor. Experience suggests that to maintain customer service by providing full and reliable deliveries, the plant must maintain a certain coverage of demand, estimated by the demand forecast.

Desired Inventory Coverage = Minimum Order Processing Time + Safety Stock Coverage
Units: Weeks:GROUP .R1 v4
Desired inventory coverage is the number of weeks of the demand forecast the plant seeks to maintain in inventory. This inventory coverage is required to maintain delivery reliability by buffering the plant against unforeseen variations in demand or production. It consists of the normal order processing time plus an additional term representing the coverage desired to maintain safety stocks.

Desired Inventory Coverage 0 = Minimum Order Processing Time 0 + Safety Stock Coverage 0
Desired inventory coverage is the number of weeks of the demand forecast the plant seeks to maintain in inventory. This inventory coverage is required to maintain delivery reliability by buffering the plant against unforeseen variations in demand or production. It consists of the normal order processing time plus an additional term representing the coverage desired to maintain safety stocks.

Desired Order Rate = \( \max(0, (\text{Expected Order Rate} \cdot 0 + \text{Ordering Adjustment from Inventory}) \cdot \text{Distributor Order Adjustment From Discounting}) \)
Units: Widgets/Week

Desired Production = \( \max(0, \text{Expected Order Rate} + \text{Production Adjustment from Inventory}) \)
Units: Widgets/Week

Desired Shipment Rate =\( \text{Manufacturer Sales Rate} \)
Units: Widgets/Week

The desired shipment rate equals the customer order rate. In this model there is no backlog of unfilled orders: unfilled orders are lost as customers seek alternate sources of supply.

Desired Shipment Rate 0 = \( \text{Sales Rate} \)
Units: Widgets/Week

The desired shipment rate equals the customer order rate. In this model there is no backlog of unfilled orders: unfilled orders are lost as customers seek alternate sources of supply.

Desired WIP = \( \text{Manufacturing Cycle Time} \cdot \text{Desired Production} \)
Units: Widgets

The desired quantity of work in process inventory. Proportional to the manufacturing cycle time and the desired rate of production.

Direct Return Fraction = \( \text{Shipping Accuracy} + \text{Shipping Quality} \)
Units: Dimensionless

% of returns to receipts due to linked reasons

Discount Table\( \{(0,0)-(1000,2)\},(0,1.4),(0.1,1.4),(0.2,1.35),(0.3,1.35),(0.4,1.3),(0.5,1.25),(0.6,1.2),(0.7,1.15),(0.8,1.1),(0.9,1.05),(1,1),(1000,1)\)
Units: Dimensionless

This table suggests that discounting will be provided that is enticing enough to boost sales between 0% and 40%. Discounting doesn’t start until after the quarter is 70% over and rising almost linearly depending on the volume of widget sales.

"Dist. Inventory Coverage" = \( \text{ZIDZ(Distributor Inventory, "Dist. Shipment Rate")} \)
Units: Weeks

Inventory coverage is given by the ratio of inventory to shipments.
"Dist. Shipment Rate" = Desired Shipment Rate * Order Fulfillment Ratio
Units: Widgets/Week

The shipment rate is the desired shipment rate multiplied by the fraction of orders filled (the order fulfillment ratio). Shipments fall below desired shipments when the feasible shipment rate falls below the desired rate, indicating that some products are unavailable.

**Distributor Inventory** = INTEG (Receipt Rate - "Dist. Shipment Rate" - Return Rate, Desired Inventory 0)
Units: Widgets

**Distributor Order Adjustment From Discounting** = Discount Table (IF THEN ELSE (Fractional Time Remaining >= 0.7, Fractional Sales Gap, 1))
Units: Dimensionless

The inputs to determine discounting. Pressure from a gap in the sales quota to actual sales is combined with pressure of the quarter ending to become total pressure to discount to reach quota.

**Entrance Time Pressure Rate** = 1
Units: Widgets/Week

The inflow of time (weeks per week)

**Exit Time Pressure Rate** = IF THEN ELSE (Quota Pressure >= 13, 104, 0)
Units: Widgets/Week

The release rate of time. Emulates quarterly intervals.

**Expected Order Rate** = INTEG (Change in Exp Orders, Manufacturer Sales Rate)
Units: Widgets/Week

The demand forecast is formed by adaptive expectations, using exponential smoothing, a common forecasting technique. The initial forecast is equal to the initial customer order rate.

**Expected Order Rate 0** = INTEG (Change in Exp Orders 0, Sales Rate)
Units: Widgets/Week

The demand forecast is formed by adaptive expectations, using exponential smoothing, a common forecasting technique. The initial forecast is equal to the initial customer order rate.

**FINAL TIME** = 156
Units: Week

The final time for the simulation.

**Fractional Sales Gap** = MAX (0, Sales in Period/Quarterly Sales Quota)
Units: Dimensionless

Ratio of actual sales to quota. 1/1 signifies that the quota was reached.

**Fractional Time Remaining** =
Quota Pressure/Quarter
Units: Dimensionless
:GROUP .RI v4
The fraction of the quarter weeks that remain.

Indirect Return Quantity = Capital Exposure ** Dist. Shipment Rate
Units: Widgets/Week
:GROUP .RI v4
The quantity of widgets returned because of capital risk

Initial Customer Order Rate = 10000
Units: Widgets/Week
:GROUP .RI v4
Initial value of customer orders, set to 10,000 widgets per week.

INITIAL TIME = 0
Units: Week
:GROUP .Control
The initial time for the simulation.

Input=
1 + STEP(Step Height, Step Time) +
(Pulse Quantity/TIME STEP)*PULSE(Pulse Time, TIME STEP) +
RAMP(Ramp Slope, Ramp Start Time, Ramp End Time) +
Sine Amplitude*SIN(2*3.14159*Time/Sine Period) +
STEP(1, Noise Start Time)*Pink Noise
Units: Dimensionless
:GROUP .RI v4
Input is a dimensionless variable which provides a variety of test input patterns, including a step, pulse, sine wave, and random noise.

Inventory Adjustment Time = 4
Units: Weeks
:GROUP .RI v4
The inventory adjustment time is the time period over which the plant seeks to bring inventory in balance with the desired level. Initially set to 8 weeks.

Inventory Adjustment Time 0 = 8
Units: Weeks
:GROUP .RI v4
The inventory adjustment time is the time period over which the plant seeks to bring inventory in balance with the desired level. Initially set to 8 weeks.

Inventory Coverage = Manufacturer Inventory/Shipment Rate
Units: Weeks
:GROUP .RI v4
Inventory coverage is given by the ratio of inventory to shipments.

Manufacturer Inventory = INTEG (Production Rate - Shipment Rate + Return Reintroduction Rate, Desired Inventory)
Units: Widgets
:GROUP .RI v4
The level of finished goods inventory in the plant. Increased by production and decreased by shipments. Initially set to the desired inventory level.

Manufacturer Work in Process Inventory = INTEG (Production Start Rate - Production Rate, Desired WIP)
Units: Widgets
:GROUP .RI v4
WIP inventory accumulates the difference between production starts and completions.

Manufacturer Sales Rate= Desired Order Rate
Units: Widgets/Week
:GROUP .RI v4
Distributor Order is determined from ..... 

Manufacturing Cycle Time=4
Units: Weeks
:GROUP .RI v4
The average delay between the start and completion of production 

Maximum Shipment Rate= Manufacturer Inventory/Minimum Order Processing Time
Units: Widgets/Week
:GROUP .RI v4
The maximum rate of shipments the firm can achieve given their current inventory level and the minimum order processing time.

Maximum Shipment Rate 0= Distributor Inventory/Minimum Order Processing Time 0
Units: Widgets/Week
:GROUP .RI v4
The maximum rate of shipments the firm can achieve given their current inventory level and the minimum order processing time.

"Mfg. Payment Terms"=4
Units: Weeks
:GROUP .RI v4
The amount in weeks that a distributor has to pay the manufacturer

Minimum Order Processing Time=2
Units: Weeks
:GROUP .RI v4
The minimum time required to process and ship an order.

Minimum Order Processing Time 0=2
Units: Weeks
:GROUP .RI v4
The minimum time required to process and ship an order.

New Sales Rate=Manufacturer Sales Rate
Units: Widgets/Week
:GROUP .RI v4
The rate at which the distributor orders widgets

Noise Correlation Time = 4
Units: Week
:GROUP .RI v4
The correlation time constant for Pink Noise.

Noise Seed = 1
Units: Dimensionless
:GROUP .RI v4
Random number generator seed. Vary to generate a different sequence of random numbers.
Noise Standard Deviation = 0
Units: Dimensionless
:GROUP .RI v4
The standard deviation of the pink noise process.

Noise Start Time = 5
Units: Week
:GROUP .RI v4
Start time for the random input.

Order Fulfillment Ratio = Table for Order fulfillment(ZIDZ(Maximum Shipment Rate,Desired Shipment Rate))
Units: Dimensionless
:GROUP .RI v4
The Fraction of customer orders filled is determined by the ratio of the normal shipment rate to the desired rate. The normal rate is the rate current inventory permits under normal circumstances. Low inventory availability reduces shipments below customer orders. Unfilled customer orders are lost.

Order Fulfillment Ratio 0 = Table for Order Fulfillment 0(ZIDZ(Maximum Shipment Rate 0, Desired Shipment Rate 0))
Units: Dimensionless
:GROUP .RI v4
The Fraction of customer orders filled is determined by the ratio of the normal shipment rate to the desired rate. The normal rate is the rate current inventory permits under normal circumstances. Low inventory availability reduces shipments below customer orders. Unfilled customer orders are lost.

Ordering Adjustment from Inventory 0 = (Desired Inventory 0-Distributor Inventory)/Inventory Adjustment Time 0
Units: Widgets/Week
:GROUP .RI v4
The desired production rate is adjusted above or below the forecast based on the inventory position of the plant. When desired inventory > inventory, desired production is increased (and vice-versa). Inventory gaps are corrected over the inv. adj. time.

Pink Noise = INTEG(Change in Pink Noise,0)
Units: Dimensionless
:GROUP .RI v4
Pink Noise is first-order autocorrelated noise. Pink noise provides a realistic noise input to models in which the next random shock depends in part on the previous shocks. The user can specify the correlation time. The mean is 0 and the standard deviation is specified by the user.

Production Adjustment from Inventory = (Desired Inventory - Manufactuer Inventory)/Inventory Adjustment Time
Units: Widgets/Week
:GROUP .RI v4
The desired production rate is adjusted above or below the forecast based on the inventory position of the plant. When desired inventory > inventory, desired production is increased (and vice-versa). Inventory gaps are corrected over the inv.adj. time.
Production Rate = \( \text{DELAY}3(\text{Production Start Rate}, \text{Manufacturing Cycle Time}) \)
Units: Widgets/Week
:GROUP .RI v4
Production is a third order delay of the production start rate, with the delay time determined by the manufacturing cycle time.

Production Start Rate = \( \text{MAX}(0, \text{Adjustment for WIP} + \text{Desired Production}) \)
Units: Widgets/Week
:GROUP .RI v4
The production start rate is the desired production start rate, constrained to be nonnegative.

Pulse Quantity = 0
Units: Dimensionless*Week
:GROUP .RI v4
The quantity to be injected to customer orders, as a fraction of the base value of Input. For example, to pulse in a quantity equal to 50% of the current value of input, set to .50.

Pulse Time = 5
Units: Week
:GROUP .RI v4
Time at which the pulse in Input occurs.

Quarter = 13
Units: Week
:GROUP .RI v4
Weeks in a quarter

Quarterly Sales Quota = 130000
Units: Widgets
:GROUP .RI v4
Quota for one quarter

Quota Pressure = \( \text{INTEG} (\text{Entrance Time Pressure Rate} - \text{Exit Time Pressure Rate}, 0) \)
Units: Widgets
:GROUP .RI v4
The sum of time in weeks (used to represent quarterly cycles)

Ramp End Time = 1e+009
Units: Week
:GROUP .RI v4
End time for the ramp input.

Ramp Slope = 0
Units: 1/Week
:GROUP .RI v4
Slope of the ramp input, as a fraction of the base value (per week).

Ramp Start Time = 5
Units: Week
:GROUP .RI v4
Start time for the ramp input.

Ratio of Maximum to Desired Shipments = \( \frac{\text{Maximum Shipment Rate}}{\text{Desired Shipment Rate}} \)
Units: Dimensionless
:GROUP .RI v4
The ratio of the maximum to desired shipment rate. Ratios less than one indicate shipments are constrained below the desired level.

Receipt Rate = \text{DELAY1}(\text{Shipment Rate}, \text{Transit Time})
Units: Widgets/Week
:GROUP .RI v4
Rate at which widgets arrive at distributor dock

Return Process Time = 0.125
Units: Week
:GROUP .RI v4
The average time to process a return

Return Rate = \text{Receipt Rate} \times \text{Direct Return Fraction} + \text{Indirect Return Quantity}
Units: Widgets/Week
:GROUP .RI v4
The rate of weekly returns

Return Reintroduction Rate = \text{DELAY1}(\text{Returns Receipt Rate}, \text{Return Process Time}) \times (1 - \text{"Scrap %"})
Units: Widgets/Week
:GROUP .RI v4

Return Transportation Inventory = \text{INTEG}(\text{Return Rate} - \text{Returns Receipt Rate}, 0)
Units: Widgets
:GROUP .RI v4

Returns Inventory = \text{INTEG}(\text{Returns Receipt Rate} - \text{Scrap Rate} - \text{Return Reintroduction Rate}, 0)
Units: Widgets
:GROUP .RI v4

Returns Receipt Rate = \text{DELAY1}(\text{Return Transportation Inventory}, \text{Transit Time})
Units: Widgets/Week
:GROUP .RI v4

Safety Stock Coverage = 4
Units: Weeks
:GROUP .RI v4
Safety stock coverage is the number of weeks of the expected order rate the firm would like to maintain in inventory over and above the normal order processing time. The safety stock provides a buffer against the possibility that unforeseen variations in demand will cause shipments to fall below orders.

Safety Stock Coverage 0 = 2
Units: Weeks
:GROUP .RI v4
Safety stock coverage is the number of weeks of the expected order rate the firm would like to maintain in inventory over and above the normal order processing time. The safety stock provides a buffer against the possibility that unforeseen variations in demand will cause shipments to fall below orders.
Sales Aging Rate = IF THEN ELSE(Quota Pressure=13,Sales in Period*8,0)
Units: Widgets/Week
:GROUP .RI v4
This variable resets sales level back to zero at the end of a quarter.

Sales in Period = INTEG (New Sales Rate-Sales Aging Rate,0)
Units: Widgets
:GROUP .RI v4
The quantity of widgets that have been sold in one quarter.

Sales Rate = Initial Customer Order Rate*Input
Units: Widgets/Week
:GROUP .RI v4
Rate at potential widget sales become actual widget sales
adjusted to account for market price elasticity (noted in price distribution table)

SAVEPER = TIME STEP
Units: Week
:GROUP .Control
The frequency with which output is stored.

"Scrap %" = 0.3
Units: Dimensionless
:GROUP .RI v4
The % of returns the will be scrapped

Scrap Rate = DELAY1 (Returns Receipt Rate, Return Process Time) * "Scrap %"
Units: Widgets/Week
:GROUP .RI v4

Shipment Rate = Desired Shipment Rate*Order Fulfillment Ratio
Units: Widgets/Week
:GROUP .RI v4
The shipment rate is the desired shipment rate multiplied by the fraction of orders filled (the order fulfillment ratio. Shipments fall below desired shipments when the feasible shipment rate falls below the desired rate, indicating that some products are unavailable.

Shipping Accuracy = 0
Units: Dimensionless
:GROUP .RI v4
Error % of Shipping

Shipping Quality = 0
Units: Dimensionless
:GROUP .RI v4
Quality % of shipping - This variable includes shipping damages and transit damages.

Sine Amplitude = 0
Units: Dimensionless
:GROUP .RI v4
Amplitude of sine wave in customer orders (fraction of mean).

Sine Period = 50
Units: Weeks
:GROUP .RI v4
Period of sine wave in customer demand. Set initially to 50 weeks (1 year).
Step Height=0
Units: Dimensionless
:GROUP .RI v4
Height of step input to customer orders, as fraction of initial value.

Step Time=0
Units: Week
:GROUP .RI v4
Time for the step input.

Table for Order Fulfillment([(0,0)-(1000,1)],(0,0.0001), (0.2,0.2),
(0.4,0.4),(0.6,0.58),(0.8,0.73),(1,0.85),
(1.2,0.93),(1.4,0.97),(1.6,0.99),(1.8,1),(2,1),(10,1),(1000,1))
Units: Dimensionless
:GROUP .RI v4
The ability to ship is constrained by inventory availability. As the inventory level drops, the fraction
of customer orders that can be filled decreases. When inventory is zero, shipments cease.
Unfilled customer orders are lost.

Table for Order Fulfillment 0([(0,0)-(10000,1)],(0,0.0001),
(0.2,0.2),(0.4,0.4),(0.6,0.6),(0.8,0.7),(1,0.85), (1.2,0.95),(1.4,0.99),(1.8,1),(2,1),(1000,1))
Units: Dimensionless
:GROUP .RI v4
The ability to ship is constrained by inventory availability. As the inventory level drops, the fraction
of customer orders that can be filled decreases. When inventory is zero, shipments cease.
Unfilled customer orders are lost.

TIME STEP = 0.125
Units: Week
:GROUP .Control
The time step for the simulation.

Time to Average Order Rate=8
Units: Weeks
:GROUP .RI v4
The demand forecast adjusts to actual customer orders over this time period.

Time to Average Order Rate 0= 8
Units: Weeks
:GROUP .RI v4
The demand forecast adjusts to actual customer orders over this time period.

Transit Time=0.5
Units: Weeks
:GROUP .RI v4
Time to move widgets from manufacturer to distributor

Transportation Inventory= INT (Shipment Rate-Receipt Rate, Desired Inventory 0)
Units: Widgets
:GROUP .RI v4

White Noise = Noise Standard Deviation^((24*Noise Correlation Time/TIME STEP )^0.5*(RANDOM 0 1 () - 0.5))
Units: Dimensionless
White noise input to the pink noise process.

WIP Adjustment Time=4
Units: Weeks

The time required to adjust the WIP inventory to the desired level.