Inventory Management for Drug Discovery

By

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Submitted to the Engineering Systems Division and the MIT Sloan School of Management in partial fulfillment of the requirements for the degrees of

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ABSTRACT

This thesis documents a study carried out at the Novartis Institutes for BioMedical Research (NIBR) in Cambridge, MA. The study focused on the development of inventory management processes for laboratory consumables. The pharmaceutical R&D process is characterized by a dynamic project portfolio, which results in a great diversity of stock-keeping-units, low repeat order rates and high variability in consumption rates. These factors create significant challenges for the design of inventory management processes.

We first present an assessment and diagnosis of the current state of inventory management at NIBR, using data gathered from various NIBR sites as well as other companies. We discuss underlying drivers that influence current behavior, and identify opportunities for improvement. We then develop alternative models for inventory management and compare these models along several dimensions such as stock room location & control, inventory ownership and replenishment options. We recommend the use of consolidated department level stock rooms as the most suitable option for NIBR. Detailed implementation plans are then developed and validated through a case study. We present key findings and recommendations for implementation, and discuss opportunities for future projects.

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1 Introduction

1.1 Overview

This thesis documents a study carried out at the Novartis Institutes for BioMedical Research (NIBR) in Cambridge, MA, in conjunction with the MIT Leaders for Manufacturing Program.

Novartis is a leading global pharmaceutical company, with 2007 group net sales of over USD 38 billion, and over 98,000 employees worldwide [1]. Created by a merger between Ciba-Geigy and Sandoz in 1996, Novartis is headquartered in Basel, Switzerland. In the United States, Novartis has about 5% market share, with 2007 sales of over USD 14 billion [2].

The Novartis Institutes for BioMedical Research (NIBR) is Novartis' global research organization, and operates eight research facilities around the world [3]. In May 2002, Novartis announced that it was moving NIBR headquarters to Cambridge, MA [4]. Since its founding, the Cambridge campus has expanded rapidly and is now home to over 1000 scientists.

1.2 Motivation

Historically, the pharmaceutical industry has been very profitable, with return on assets consistently about double the median return for Fortune 500 companies [5]. For instance, in 2005, pharmaceutical companies in the Fortune 500 averaged a 10.3% return on assets, compared to a median return of only 4.7%. These numbers overstate true returns to some extent, because pharmaceutical companies are very R&D intensive[1]. However, even after adjusting for this factor, the pharmaceutical industry has been very profitable.

In recent times however, the industry has faced a number of challenges [2,5]:

- R&D spending has grown significantly (between 5-8% annually in real terms since 1980), while the number of new drugs (new molecular entities or NME) approved each year has remained relatively constant. Increased complexity has also increased the time taken to

[1] Most R&D spending is treated as a business expense and not capitalized. Also, intangible assets such as intellectual property are not taken into account in computing returns.

bring a new drug to market. Consequently, the cost to develop a new drug has increased manifold – from $138 million in 1975 to $802 million in 2001 [6].

- There is increased competition from generic drug manufacturers.
- Rapidly increasing healthcare costs, partly driven by an aging population, have created government pressure to reduce prices of drugs.

These challenges have created pressure to improve R&D performance in the industry, and companies have responded with a number of initiatives to reduce costs and improve productivity.

Since its founding in 2002, the NIBR Cambridge campus has expanded to a strength of over 1000 scientists. In the face of such rapid expansion, efficient inventory and asset management has not been a priority. Various departments and groups have put in place their own guidelines and processes for these activities. Now that the campus is fully established and has reached a steady state, the time is right to explore these opportunities to reduce operating costs and improve performance by globally optimizing processes.

Finally, the nature of the drug discovery process creates significant challenges for the design of inventory and asset management processes. The R&D process has an inherently dynamic project portfolio, which results in a great diversity of consumable stock-keeping-units (SKUs) across projects and departments, low repeat order rates and high variability in consumption rates. Similarly, the usage of laboratory instruments also varies greatly depending on the projects that are active at the time. Further, while the implementation of new management processes has great potential for cost savings and performance improvement, it is important that these processes do not adversely impact innovation which is crucial to the organization.

1.3 Problem Statement

The internship project focused on two topics in the context of the pharmaceutical drug discovery process: (1) Development of an inventory management process for laboratory consumables, and (2) Assessment of utilization of lab instruments and development of recommendations to incorporate utilization data in asset procurement, maintenance and disposal decisions. The primary focus in this thesis is the first topic – consumables inventory management.

1.4 Thesis Outline

The thesis outline is as follows. In *Chapter 1,* we provide a general background to the pharmaceutical industry and the recent trends and challenges faced by this industry. The structure and history of NIBR is briefly described and the general problem of inventory and asset management that is the subject of this thesis is presented.

Chapter 2 describes in detail the current state of inventory management at NIBR Cambridge. Data was gathered from various NIBR sites as well as other companies, to benchmark the process. We present this comparative data, and describe an assessment and diagnosis of the current state at NIBR Cambridge. We discuss the underlying drivers that influence current behavior, and identify issues with the current state and opportunities for improvement. We also include a literature survey of the body of knowledge in inventory management, as it relates to pharmaceutical laboratories and similar R&D settings.

Based on an analysis of the current state, historical data and stakeholder inputs, we develop a proposal for the future state in *Chapter 3*. We compare process alternatives (such as centralized versus local stocking of inventory), and recommend the most suitable process to effectively address the underlying issues. We then develop detailed implementation plans; these plans include recommended best practices and a proposed governance structure that addresses how to manage the processes and monitor the metrics.

The proposed processes are validated through a case study described in *Chapter 4*. We describe a pilot department stock room developed for one of the departments at NIBR (Cardio Vascular).

Finally, *Chapter 5* summarizes the key findings and conclusions from the project. We present recommendations for implementation, and briefly describe some opportunities for future projects.

2 Consumables Inventory: Process and Issues

2.1 Current Process

2.1.1 Drug discovery process at NIBR

The pharmaceutical R&D process of drug discovery and development is described in [7,8], and a pictorial representation of the process is shown in Figure 2-1. As seen, the typical process takes between 10-15 years, and costs more than $800 million per new drug. This high cost is due to the very high rates of attrition in the process – between five and ten thousand compounds are tested for every compound that is ultimately approved for use.

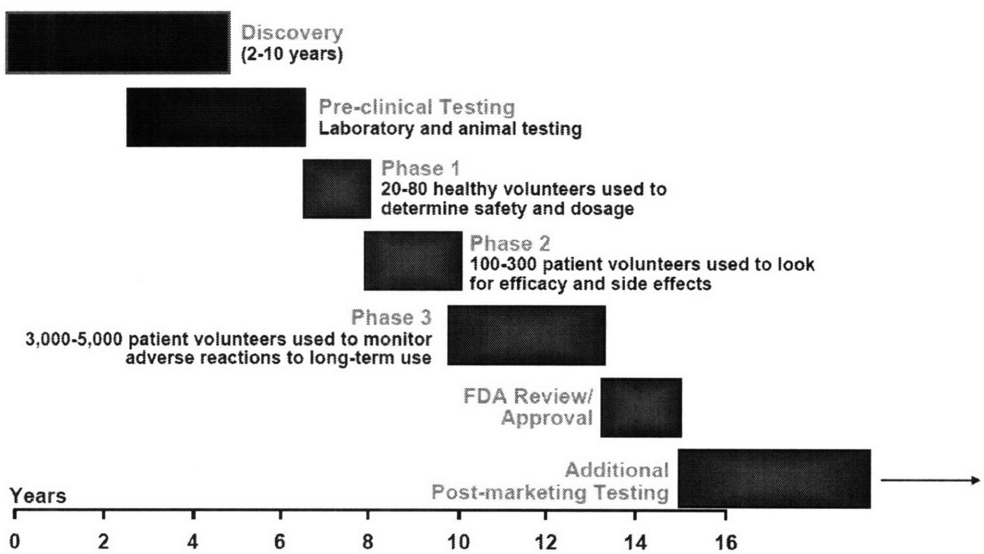

Figure 2-1: Drug discovery and development process

The focus of NIBR is primarily in the first two stages shown in Figure 2-1, namely the Discovery and Pre-Clinical testing stages. The various phases of research at NIBR are shown in Figure 2-2, and described below.

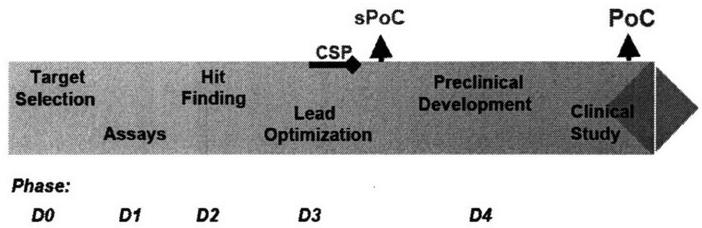

Figure 2-2: Research phases at NIBR

The research phases are as follows:

1. Target selection (D0): A target (gene and protein) is identified and its role in a disease of interest is validated
2. Assay development (D1): Assays are developed to test the inhibition or activation of the target by compounds that are potential drug candidates.
3. Hit finding & Hit to Lead (D2): In this phase, compounds from the Novartis compound library are tested against the developed assays to identify compounds that interact with the target. This is typically done by a process known as "High Throughput Screening", where about a million compounds are tested for affinity to the target. Successful compounds (called "hits") are then validated using more sensitive assays.
4. Lead optimization (D3): This phase involves iterative optimization to refine compounds for potency, efficacy, safety etc. This is done by chemists using a combination of in-vitro and animal studies. Promising compounds progress to the Candidate Selection Process (CSP) and are selected for Proof of Concept (sPOC).
5. Preclinical development (D4): Involves pre-clinical safety tests and preparation for subsequent testing in man. The output is the Proof of Concept (POC).

2.1.2 Organizational Structure

NIBR is organized into a number of research departments, in a matrix structure. In this structure, the verticals are "Disease Areas" (conducting research on a specific class of disease), and the horizontals are "Platforms" or "Centers" (application of science across disease areas). The intent is to encourage the application of new drug discoveries across several disease areas, and minimize duplication of research. This is markedly different from traditional pharmaceutical R&D where work was concentrated on specific disease areas with very little communication across areas.

The organization is fairly flat, with scientists (also called "associates") organized into groups or labs (with a lab head) which in turn report to the head of a disease area. To encourage innovation, groups and associates are given a lot of freedom in work and schedules, as well as operational policies and procedures.

In addition to the research departments, NIBR has support departments such as Accounting, Finance, Facilities, and Communications. For accounting and budgeting purposes, lab groups are assigned cost center numbers. From a central accounting standpoint, departmental spend is tracked by cost center.

2.1.3 The role of consumables

As seen from the description above, the drug discovery process is very experiment intensive. All through the process, large numbers of experiments are conducted by scientists; both large automated setups as well as smaller studies carried out manually by scientists. As such, the process requires a considerable input of consumables. For example, Heiney [9] examines the cost structure for one department (Pre Clinical Profiling), as shown in Figure 2-3. As seen, Materials account for about 21% of the costs or about half the Personnel costs.

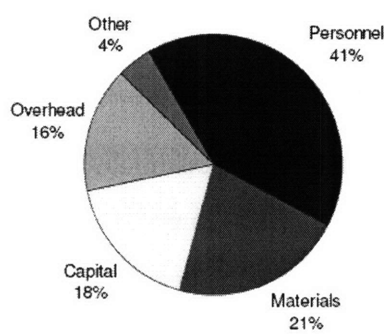

Figure 2-3: PCP expenses by category

In the accounting process used at NIBR, materials used by scientists fall under an expense category termed CRS (Chemicals, Reagents and Supplies). CRS expenses are further broken up into a number of sub-categories. Figure 2-4 shows the 2006 CRS expenditure for the NIBR Cambridge campus at a broad category level; both by number of SKUs and by percentage spend. The focus of the current project is on the *'consumables'* category primarily. This category consists mostly of dry supplies that are commonly used – such as pipettes, pipette tips, plates, flasks, tubes, dishes, gloves etc. The other categories were not investigated because they are either already part of other inventory management initiatives at NIBR (e.g. chemicals) or they are typically custom or one-of-a-kind items that are not amenable to stocking (e.g. biologicals, equipment). As seen in Figure 2-4, the consumables category is very significant, accounting for roughly half the CRS expenditure and almost 15000 SKUs.

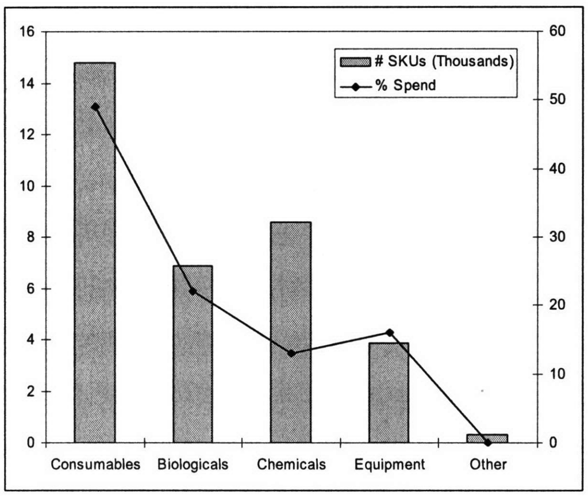

Figure 2-4: CRS Categories

2.1.4 Procurement of consumables

<u>**Order Process**</u>

Scientists typically have a local supply of consumables on their bench tops. When they need to replenish this supply, they have three options:

- Get items from a local (department managed) stock area
- Get items from one of the central (supplier managed) stock rooms
- Order the items online for direct delivery, via the Ariba e-procurement system

Currently, there is no defined sequence or priority for the use of these options. The choice is left to the scientist. The management and replenishment of inventory in these areas is described in later sections below.

Order Fulfillment

The supply of consumables is managed by Thermo Fisher Scientific (Fisher), a major global manufacturer and distributor of scientific equipment and supplies. NIBR uses an e-procurement system (Ariba) on which the Fisher catalog is available to scientists. Orders placed on this system go through a defined approval process depending on the order amount. Approved orders are received by Fisher and transmitted to the appropriate vendor/manufacturer. Items fall into three categories, based on the manufacturer and the billing arrangement:

- Fisher and Fisher-franchised: Items manufactured by Fisher Scientific or carried by Fisher Scientific as franchised brands
- 3rd party via Fisher: Items manufactured by other vendors with whom Fisher has a billing arrangement. In this case, Fisher invoices NIBR on behalf of the vendor
- 3rd party direct: Items manufactured by vendors who invoice NIBR directly. In this case, Fisher's involvement is limited to transmitting the order to the vendor.

The break up of 2006 CRS spend between these categories is shown in Figure 2-5.

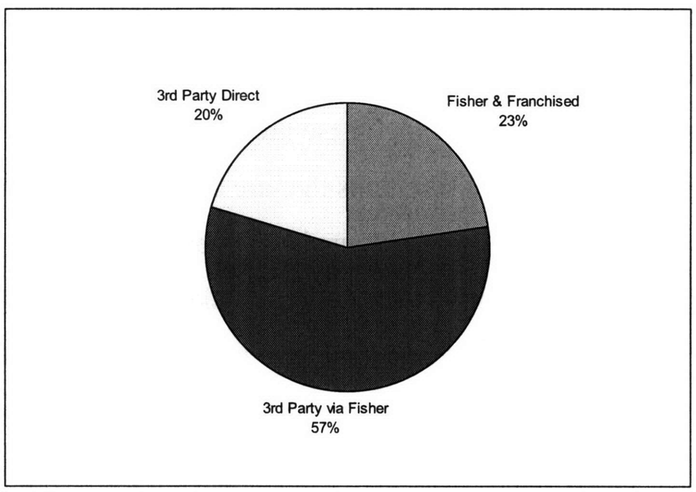

Figure 2-5: CRS categories by supplier

Lead Times

Lead times for ordered items depend on the vendor. Most Fisher and franchised items (95%) are delivered the next business day, if the order is placed before 2pm. These items are typically stocked in a regional warehouse in Agawam, MA, and delivered once a day at NIBR. For third party items, lead times range from a couple of days up to 3 weeks in some cases. About 80% of items are received within 5 days. Lead times are generally known a priori. In most cases, the actual lead times match expectations.

2.1.5 Stocking of consumables

Consumables are stocked at three 'levels' at NIBR. Details of the consumables flow are shown in Figure 2-6.

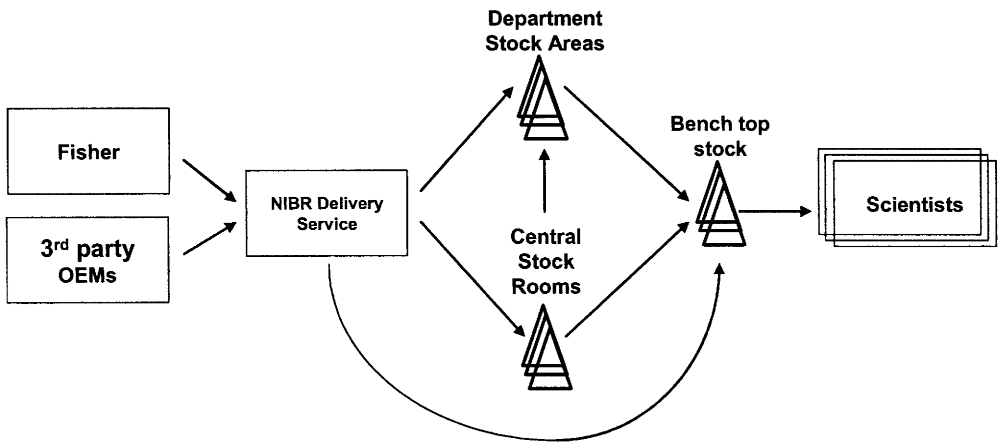

Figure 2-6: Consumables flow at NIBR

<u>Central Stock Rooms</u>

There are currently 5 central stock rooms. These are intended for use by multiple departments and typically about 75-100 items that are commonly used across departments are stocked. Inventory in these central stock rooms is on consignment from Fisher, and charged to the relevant NIBR cost center only when items are taken by scientists. The rooms are equipped with bar code scanners. Scientists are also provided with bar code ID tags. The rooms are not manned, and operate in a self-serve mode. To take out items, scientists first scan their ID tags to identify themselves to the system, and then scan bar codes placed on item shelves.

These stock rooms are treated as warehouses on the Fisher inventory management software system. A Fisher employee is responsible for the management of inventory. Once daily, the list of items scanned out during the previous day is transmitted to Fisher. The Fisher inventory system then updates the inventory levels in the central stock rooms and generates a list of replenishment orders that need to be placed, based on re-order points stored in the system. This list is transmitted back to the Fisher employee at NIBR for verification, and orders are placed. Ordered items are received the following morning.

Department Stock Areas

In addition to the central stock rooms, most departments also maintain local stock areas. In some cases, these are designated stock rooms. Often, however, stocks are stored in available storage areas such as coat closets, equipment rooms, and shelving units placed in department hallways.

Inventory in such department stock areas is owned by the department. So there is no bar code scanning of items – employees just take items they need. Usually, there is a designated department employee who is responsible for replenishing this stock. This person may do so by taking items out of the central stock rooms, or by ordering supplies via Ariba. In a few departments (e.g. Diabetes), a defined inventory management process is followed. Inventory is tracked against re-order levels and replenishment orders are placed on a daily basis. However in most departments, the replenishment process is ad hoc.

Bench top stocks

Scientists also have their own stocks of consumables. These are usually small stocks of items taken from a stock room (such as a box of gloves) that will be used up within a few days. Scientists also stock items that are not stocked in the stock rooms and have been directly ordered. Sometimes, scientists may stock larger quantities of stock-room items for the sake of consistency in a specific experiment where the same batch of supplies needs to be used through the entire experiment.

2.1.6 Initial perception of the problem

The recognition of the issue of consumables inventory came about as the result of a lab walk-through by senior management in 2006. It was felt that labs were very cluttered, with too much inventory in department storage areas as well as on scientists' bench tops. In addition to being potentially a safety issue, this was also indicative of inefficient inventory management. Scientists were also complaining about ordering processes being too cumbersome, and there were some concerns about critical inventory not being available when required. This led to discussions and the formation of a Review Team in February 2007 to investigate the issue of consumables inventory. The team of 8 people included representatives from Strategic Sourcing, Finance, Facilities and some Research departments. Information support was provided by key suppliers such as Fisher and Invitrogen. The general hypotheses were as follows:

- Central stock rooms are ineffective and under-utilized
- There are too many department stock areas, leading to high inventory levels and wasted space
- Bench top stock levels are excessive
- There is considerable inventory obsolescence

The review team conducted an initial study that included interviews with key stake holders and the collection of usage data on stock rooms, and put together a report of their findings. This report formed the starting point of the current project. Data collected by the review team forms a significant input in the analysis in the following sections.

2.2 Analysis of consumables procurement and stocking

2.2.1 Central stock room usage

A break up of 2006 consumables expenditure by source showed that only 8% (by $ value) went through the central stock rooms. Given the intention that the central stock rooms would stock commonly used consumables and be used by all departments, this seems much less than would be expected. Further analysis suggested some important reasons:

SKU restrictions in the central stock rooms:

As mentioned before, the central stock rooms are managed by Fisher and are free of cost to NIBR, except for space costs. The inventory is on consignment and is managed by a Fisher employee. In setting up these stock rooms, Fisher's intent was to increase their share of the consumables spend at NIBR. As seen in Figure 2-5, in 2006 Fisher & franchised products accounted for only 23% of CRS spend. Fisher's strategic intent is to increase this share to about 40%. To promote increased usage of their products, Fisher mostly stocks Fisher & franchised brands in the central stock rooms – 3rd party products are limited to 10% of SKUs.

This policy of restricting 3rd party items in the central stock rooms has not had the desired effect of changing users' buying patterns. Instead, scientists have continued to use 3rd party products, and as they are not stocked in the central stock rooms, they are ordered directly.

Low repeat order rates and SKU proliferation:

Interviews with Fisher employees and historical data of orders placed by scientists showed that repeat order rates are very low – less than 20% of SKUs were ordered more than once over a period of six months. A few different reasons are possible:

a) There is great diversity in the consumables needs across departments and scientists
b) Scientists have strong brand preferences, which leads to the purchase of multiple brands of functionally equivalent products
c) Large quantities are ordered, so repeat orders are not seen in the six month window
d) Scientists constantly order new SKUs – either different packaging options or new products altogether. While this is possible in cases of one-of-a-kind experiments or where new products are introduced frequently, it may not be an important factor in the case of consumable SKUs

Further analysis is required to understand which of these reasons contributes to the low repeat order rate. In any case however, this clearly results in low utilization of stock rooms.

The nature of the stocked items:

The common items that are stocked in the central stock rooms tend to be bulky but low cost items – pipettes and tips, flasks, culture tubes etc. In contrast, the more expensive supplies such as diagnostic kits are ordered directly by scientists as they are custom orders. So, when looked at from a dollar value perspective, stock room usage seems low, but from a number of units (volume) perspective it might be much higher.

Inconvenience:

One reason brought up in several interviews was the inconvenience of using the central stock rooms. These rooms are located in the basement or on a different floor of the building. So the scientist has to walk quite a distance to access these stock rooms. When scientists are in the middle of an experiment and run out of supplies, they find it easier if supplies are available at hand, right on their bench tops or at least on the same floor in a department stock room.

Another related point suggested in some interviews was that some scientists prefer to order items directly since they are delivered to their desks, and this is more convenient than having to visit a stock room. However, this is unlikely to be a significant factor – most people interviewed indicated that if a reliable stock room were available, they would prefer using it to managing their supplies themselves. Further, analysis of SKU overlap between the stock rooms and direct ARIBA orders (discussed in the case study chapter) showed a very small amount of overlap.

Stock visibility and stock room reliability

When the central stock rooms were first established, there were many stock outs of items due to inaccurate forecasting of demand (discussed in a later section). As a result, there is a lack of credibility among scientists of the reliability of central stock rooms. To compound this issue, the on-hand inventory status for the central stock rooms is not available to scientists in real-time currently. Only a list of stocked items is available on the NIBR intranet. When scientists need supplies, they cannot verify if supplies are available before walking over to the stock room. Given the history of stock outs and lack of credibility, this has led scientists to prefer local stock rooms over time.

2.2.2 Central stock room inventory turns

Based on the results of a count of the central stock rooms in January 2007, the total inventory on-hand was about 21% of annual stock room dollar value usage. This means the inventory is turning about 5 times per year overall, and at any given time there is more than 2 months of stock on-hand. Given that the lead time on stock room items is very small (in most cases these items can be delivered overnight), this would seem to be too much to hold. As a comparison, the average inventory turn rate in hospital pharmacies was found to be 9.8 [10]. Further analysis of stock room SKUs resulted in the estimated break up shown in Figure 2-7. The Figure shows the percentage of inventory on hand (by $ value) that was ordered within a certain time period. From the Figure, we see that only about 28% of the inventory was replenished within the last month.

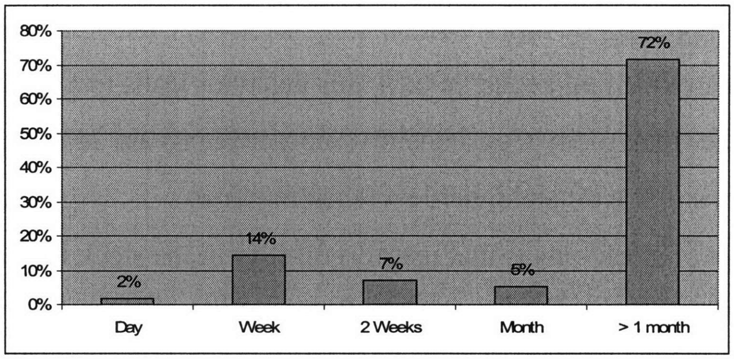

Figure 2-7: Inventory Velocity – Replenishment by time periods

Three factors contribute to this high level of inventory:

- Reorder points are too high, due to a poor understanding of consumption rates (demand) for SKUs
- Large package sizes
- The stock rooms contain SKUs that are not actively consumed by users

These factors are discussed below.

Demand

An estimate of demand for consumables has never been conducted at NIBR. Analysis of historical data is limited to tracking total spend at a cost center level. The budget for consumables is allocated to departments based on the number of FTE (full time equivalent) scientists employed and their historical spend data. This results in each cost center receiving a budget in the form of a $/FTE number. Budgets vary significantly across departments. Actual spend is then tracked against the budget based on monthly reports of consumable spend received from Fisher. As SKU level consumption rates have not been calculated, such data is not used to forecast future requirements either, and does not form an input into the budgeting process.

In the absence of such analysis, the reorder points for items in the central stock room were initially set based on perception of demand and then adjusted (usually upwards) if required. This process results in a couple of problems:

- When the initial safety stock levels were too low, there were frequent stock outs. This in turn leads to **hoarding** by users. Anticipating stock outs, users tend to take out much more stock than their real needs. In turn, this behavior leads to a **false perception of high demand** in the stock room. Consequently, reorder points are adjusted upwards, and soon the safety stock is at a much higher level than required.
- Another result of stock outs is that **user credibility** in the stock room system is eroded. Over time, this results in lower utilization levels of the stock rooms and excessive local storage of stock room items.
- When safety stock levels are too high, there is no incentive for NIBR to reduce stock levels. As the inventory is on consignment, the only cost to NIBR is the space costs. So far, stock room space has not been a constraint.

Large Package Sizes

As mentioned before, the inventory in the central stock rooms is on consignment from Fisher. As such, the package sizes of items in these rooms correspond to the smallest size that can be ordered from Fisher. The reorder points and reorder quantities are also consequently in multiples of packages. This results in a high inventory level. This issue also results in other problems discussed later – namely high local stock levels and some inventory shrinkage.

Stock room SKU content

Fisher decides the SKU content of the central stock rooms in cooperation with NIBR departments. As mentioned before, the items chosen are commonly used across departments. As such, there should not be many items in the stock rooms that are not actively used at NIBR. However, as will be discussed in the case study, we find that there are several items in the stock rooms that are very infrequently used. The main reason appears to be that the SKU list is not actively monitored and revised. Several items may have been placed initially in the stock rooms because NIBR scientists considered them to be high volume items. These items then remain in the stock room because there is no periodic review. There are also some cases where a particular department requested Fisher to stock a certain item in anticipation of high usage for a particular project, and then did not use the item because of a project cancellation.

2.2.3 Bar code scanning and inventory shrinkage

The need to use bar code scanners in the central stock rooms has resulted in some accounting problems. In the current process, scientists have to first identify themselves to the system by scanning a bar code that is issued to them, and then scan items out before removing them from the stock rooms. This procedure is straightforward and is clearly explained on posters that are placed in the stock rooms. However, there are still a couple of issues:

- The system does not operate using the user's NIBR ID. A separate bar code is required. Sometimes scientists forget to carry the bar code with them to the stock room. As the stock rooms are not close by, scientists may take out items without scanning them, with the intention of returning later to complete the scanning process. If they then forget to return later, those items never get accounted for.
- As mentioned before, the package sizes in the central stock rooms are often too large for scientists to take out. For example, a scientist might want a couple of rolls of tape, but the stock room carries a package of 24 rolls. The scientist might open the package, take two rolls and leave the opened package in the stock room. To fix this problem, Fisher has put in place a system with special bar codes for items that come in large packages. The package is broken up, and a new bar code is created to correspond to a single unit (such as one roll of tape) rather than the whole package. These bar codes are placed on the shelves in front of the item. Sometimes however users scan the bar code on the package instead of the special unit bar code. This results in incorrect inventory accounting.

Overall, the result of these issues is that stock room usage is not completely or accurately accounted for. As we will show in the case study chapter, these discrepancies are significant – sometimes up to 20% of stock room usage (by $ value). The discrepancies are currently apportioned between NIBR departments by head count. In addition to creating extra accounting work, this process is often seen as unfair by departments.

2.2.4 The cost of central stock room inefficiency

Given that the inventory in the central stock rooms is on consignment from Fisher, and the only cost to NIBR is the space used by these rooms, it would appear that low usage and high inventory levels is not of any consequence to NIBR, especially if space is not a bottleneck. In reality, these issues are important for a couple of reasons:

- The opportunity cost of not using the space appropriately. With lower inventory levels and SKU content better aligned to actual usage, a much higher user service level could be provided. Alternately, if the central stock rooms are made smaller or eliminated, the space could be put to other uses
- There is some cost currently to Fisher due to inventory obsolescence or carrying cost if items do not move quickly. This cost could lead to higher prices for NIBR.

2.2.5 Local Stock Areas

Departments maintain local stock areas for several different reasons:

- Many items are specific to the department, and so are not stocked in the central stock rooms
- The central stock rooms place a restriction on 3rd party SKU content
- Users find it more convenient to have local stocks instead of retrieving stocks from the central stock room which might be on a different floor
- Because inventory is owned by the departments, packages can be broken up so that scientists can take out smaller quantities of items
- User service level is perceived to be higher. Since the department stock area is managed by a department employee, this person serves as a local go-to person that scientists can work with when there are issues.

While all these reasons are quite valid, in current practice the local stock areas bring up a few significant issues:

- While some departments have dedicated stock rooms, in other departments inventory is kept wherever there is space – any available closets, equipment rooms or other storage areas are used. There are also shelves in hallways. Often, there are multiple stock areas on the same floor. An example is shown in Figure 2-8. A survey conducted by the initial review team investigating consumables inventory counted no less than 66 department stock areas – about 5-6 per department. This results in significant inventory duplication.

- The amount of local inventory appears to also be a function of available space due to the layout of buildings. Across the NIBR Cambridge campus, one sees a variety of interior architectures. Some buildings have a "closed" layout where there are a number of walls (and consequently more closed rooms or storage spaces). In other buildings, the architecture is more "open", and any local inventory is more clearly visible. We observe that the open layout results in much lower inventory levels.
- Observation of local stock areas shows that items stocked there are often the same items that are in central stock rooms. As mentioned before, the reasons for this could be convenience or the ability to break up packages. However, as these items are owned by NIBR departments as opposed to being on consignment in the central stock rooms, this inventory duplication results in avoidable carrying cost of inventory. Estimates indicate that inventory in department stock areas totals up to about the same level as the inventory in central stock rooms – so it is definitely a significant amount.

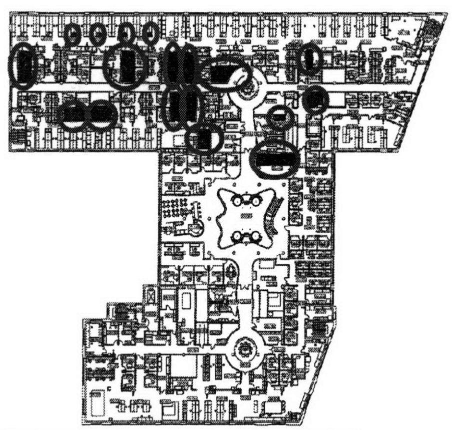

Figure 2-8: Proliferation of local stock areas

- Local stocks are managed by a designated department employee. The incentives of this person would be to maximize local service level, rather than minimize inventory cost across NIBR. This results in very high local inventory levels, and inventory duplication across departments.

2.2.6 Bench top stocks

The amount of bench top stocks maintained by scientists varies widely – both within departments, and also across departments. As in the case of department stock rooms, there are some valid reasons for maintaining bench top stocks. Items that are specific to the work of individual scientists have to be kept locally. Also, small amounts of common stocked items may be kept locally for immediate use. In some cases, scientists may keep larger quantities because of experimental needs.

Given the diversity of bench top stocks, it is very hard to estimate not only the amount of local stock in dollar terms, but also the level of inventory duplication due to local storage of common stocked items. It is also difficult to come up with metrics of what is "reasonable" amount of bench top stock, since the usage rates of items vary widely across scientists depending on the nature of their work. However, a walkthrough of NIBR departments showed several examples where bench top stocks clearly were unreasonably high – an extreme case is shown in Figure 2-9. As there are over 1000 scientists, the potential opportunity for savings from rationalizing bench top stock is large. However, it is also the hardest to address from a policy standpoint. The situation is summarized in Table 2-1.

Table 2-1: Inventory impact comparison

Inventory Area	*Potential Opportunity*	*Ability to impact/change through policy*
Central Stock Rooms	Low	High
Department Stock Areas	Medium	Medium
Bench top stocks	High	Low

Figure 2-9: Excessive bench top inventory

2.2.7 Obsolescence

Observation indicates that there is considerable obsolescence of inventory. Consumables are generally not perishable. However, in many cases large quantities of items are purchased in anticipation of high usage for a particular project. If the project needs change, the items are left unused. Because there is no system currently where such items are visible to other groups or departments, they cannot be used. They might just be kept in local storage for a while, and eventually discarded to make space for other items.

In some cases, departments create storage areas in common hallways to keep items they do not need, with a "Please take" sign. However, these are not very effective because there is no central location (such as an online forum) to post the availability of items. The system relies on passersby to see an item they need and take it – this is clearly not sufficient. As an example, the content of two such shelves was monitored during the course of the six month internship. The content hardly changed at all.

There has also been an organized attempt to promote reuse across departments. A central space was created for scientists to put stuff they no longer needed, and where others could come and take items they might need. This system failed – again due to a lack of an organized item list. Eventually, it just became a dumping ground – scientists were putting a lot of items in, but not much was being taken out. The facility was discontinued and the items discarded.

As will be discussed in a later section, it is very difficult to quantify obsolescence at NIBR. Inventory is expensed, and obsolete items are just discarded along with other waste. However, interviews indicate that the problem is significant. The only opportunities where it may be possible to estimate obsolescence are department clean ups that are done periodically, or when departments move.

2.2.8 Causal Loop Diagram

As seen from the preceding discussion, there are several related factors contributing to the poor usage of the central stock rooms. The interaction between various factors can be visualized using a causal loop diagram shown below in Figure 2-10. A review of causal loop diagrams and their use in system dynamical models can be found in [11]. In the diagram below, two reinforcing loops are seen. The first (outer) loop is the inventory management loop, where as stock room usage increases, it leads to better inventory management which in turn results in even higher stock room use. The second (inner) loop is the credibility loop, where as stock room usage increases, it leads to more effective stock rooms which further increase credibility and stock room use. The levers or drivers that can be used to influence these loops were discussed in the previous sections, are also shown in the diagram. These include better forecasting of demand, removal of SKU restrictions, local stock room management, enhanced user convenience etc.

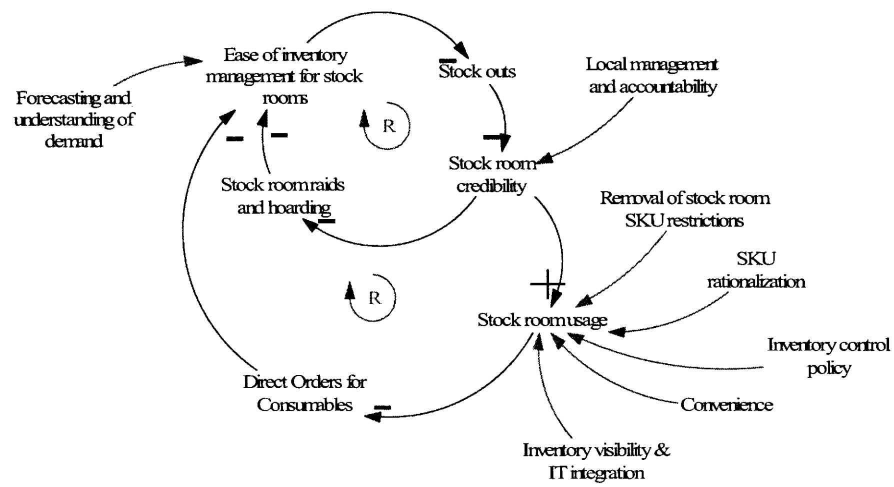

Figure 2-10: Stock room usage causal loop diagram

2.3 Underlying Issues

As shown in the previous section, the current practice of consumables inventory management at NIBR has some significant issues and areas for improvement. In this section, we discuss some of the key underlying issues that influence user behavior and lead to the current practice. The Three Lens framework [12] for organizational analysis can be used to understand the source and reasons for these issues, as they relate to the strategic design of the organization and the political and cultural environment.

2.3.1 Perception of the problem is very subjective

To understand the perspectives of stakeholders, we conducted a number of interviews across NIBR. Both scientists as well as staff from support departments such as Finance, Accounting, Facilities, etc. were interviewed. The interviews show that the issue of consumables inventory is perceived very differently depending on the person and the department.

In most cases, scientists do not see a problem at all. Their main concern is service level and convenience. Scientists do not usually understand the costs of holding inventory. Among the scientists, the culture is typical of an academic/research setting. There is an expectation of a decentralized setup with freedom to operate without restrictions. Guidelines and reporting requirements are often viewed as inconveniences and distractions, with no value addition.

On the other hand, employees in operations and finance perceive consumables inventory as a significant issue. However, they do not generally appreciate the concerns and arguments of scientists. With their past experience typically being in more predictable manufacturing settings, many are unable to understand the differences in the R&D environment. For example, the project portfolio constantly changes, leading to high variability in inventory needs. This is sometimes attributed to a lack of discipline among scientists to forecast.

2.3.2 Mission and Incentives focus on Innovation

As Novartis' R&D division, the mission of NIBR is to bring new medicines to the clinic rapidly. As such, the primary focus is on innovation and scientific discovery, not operational efficiency. It is interesting to note that the operational aspect of the business – that is the efficiency or productivity of the drug discovery process does not find a direct mention in the mission or objectives (as stated on the NIBR intranet website).

Performance incentives are aligned to the goal of faster drug discovery. Associates are measured and rewarded based on their discovery output. Company awards and external recognition in the scientific community are also strong motivators. Associates are not measured on operational metrics – such as "inventory turns" for example. As mentioned before, departments are tracked against a budget based on historical data, but few efforts have been made to measure and benchmark the drug discovery process from the operational stand point.

This situation often works against improving operations. Any effort that is (even in the short run) viewed by scientists as "creating more paperwork" or "coming in the way of innovation" might not be supported by senior management.

The decentralized structure also contributes to this issue. The incentive of department inventory managers is to improve local service levels, rather than work in concert with other departments towards improvements across NIBR. The lack of central process ownership and standardization leads to inefficiencies.

2.3.3 Performance measurement is difficult

In the NIBR R&D setup, consumables are treated as a research expense, not as "inventory" that is carried on the balance sheet. This makes it impossible to track consumable items once they are purchased. Consumables purchases can be tracked, but not their actual rate of usage. Further, as mentioned before, obsolescence cannot be measured - if an item becomes obsolete, it is simply discarded without the need for any accounting.

As the fulfillment process is outsourced to Fisher, data visibility is limited. Consumables purchase data is available from Fisher if required, and Fisher also provides periodic summary reports. However, the analysis of this data has been limited to budget tracking. The data mining required to gather useful insights about performance and use it towards performance improvement has not been done.

2.4 Benchmarks

2.4.1 Literature review

Supply chain design and planning has been a very widely studied subject. A variety of inventory management techniques and models have been proposed. A good overview of the models used in this study such as ABC analysis, periodic and continuous review models can be found in [13-16]. A brief review of applications and trends in the context of pharmaceutical drug discovery and similar settings is discussed below.

The costs of new drug development have been examined by a few authors. For instance, DiMasi et al. [17] estimated the R&D costs of 68 random new drugs from surveys of 10 pharmaceutical companies. Their study yielded an estimate of $802 million average cost per new drug to the point of approval. These studies however are limited to overall cost estimates, and do not provide details such as the cost of consumables.

Studies of inventory management of consumables and supplies for drug discovery organizations are not found in the literature. However, two very similar applications are covered – the first is hospital pharmacies, and the second is laboratory supplies. Inventory management for hospital pharmacies has been covered extensively. Most authors discuss ABC classification and the use of inventory models such as EOQ [18-20]. Application of sort-based analysis to hospital pharmacy inventories is explained by Salamie [21]. Sort-based analysis is an extension of the traditional ABC (Pareto or 80/20) analysis to further sort items by usage volume and cost. In doing this, the analysis accounts for one of the deficiencies of traditional ABC analysis – where items with the same total cost are treated identically despite having widely different volumes.

In the last decade, pharmaceutical companies as well as academic research labs have consolidated their supply bases to achieve synergies. The concept of "one stop shopping" has emerged [22], where researchers can order an entire range of laboratory goods from a single supplier from an extensive online catalog. The availability of the Fisher online catalog at NIBR is an example of such a system. A result of this development is the wave of consolidation currently happening in the laboratory supply industry, described by Miller [23]. An example is the merger of Thermo Electron and Fisher Scientific in 2006 to form Thermo Fisher Scientific.

The use of electronic data interchange (EDI) and online information systems by pharmacies is also discussed. An early example is a case study for a hospital pharmacy [24]. Kim [25] describes the development of an integrated system with online procurement and real-time information sharing to enable Vendor Managed Inventory (VMI) and reduce inventory costs.

While laboratory consumables belong to a mature industry, new trends in the design of consumables are being driven by increased automation of experiments, and by miniaturization [26,27].

2.4.2 Process data from other organizations

In order to compare the consumables stocking process at NIBR Cambridge with current practice in the industry, process data were collected from a few other sources. These included two other Novartis sites – East Hanover and Emeryville, and one external organization – Brigham and Women's Hospital. The data show a wide range of stocking scenarios and policies in use – there is no single preferred "best practice".

Novartis East Hanover

This site maintains a central stock room serving about 350 users. The room is manned and managed by Novartis employees. The inventory is owned by Novartis. Items are scanned out and charged back to departments. Users visit the stock room to pick up items, but there is some desk delivery for users in other buildings. There is no SKU restriction for items carried in the stock room. About 900 SKUs are carried – so the range is much broader than at NIBR Cambridge. Packages are broken up and individual items can be taken out by scientists. Stock room inventory is visible to users via a database, but it is not currently updated in real-time. The amount of bench top stock is estimated to be small.

Novartis Emeryville

This site has both a central stock room and satellite stock rooms. The central stock room is manned and managed by the supplier, while the satellite stock rooms are self-serve. In both cases, the inventory is owned by Novartis. Items are scanned and charged back to departments. Scientists pick up items at the central stock rooms, but can also place "standing orders" for just-in-time delivery of small item quantities on a regular basis. The amount of bench top stock is estimated to be small.

Brigham and Women's Hospital

In this case, there are no stock rooms at all. The users place electronic orders for items which are delivered directly to them. The majority of the spend goes through one major supplier who maintains an inventory of both generic and BWH specific items. Typically these items are delivered next day. There are multiple trailer deliveries per day. However, a small emergency "backup" stock is maintained at BWH, to be used in cases when the supplier is unable to deliver items. This emergency stock has about 1100 SKUs. Bench top stock is estimated to be small – about 2-3 days supply.

3 Process Development for Consumables Inventory

In this chapter, we develop a proposal for consumables inventory management at NIBR. Based on an analysis and diagnosis of the current state, a few alternative approaches are first described. We then compare the costs and benefits of process alternatives (such as centralized versus local stocking of inventory), and recommend the most suitable process to effectively address the underlying issues. A detailed implementation plan is then described for the proposed model.

3.1 Visualizing consumables inventory management models

As seen from the previous chapter, organizations adopt several approaches (or models) to consumables stocking. To compare and contrast the different models, it is useful to visualize the approach using the chart described below in Table 3-1. This chart, which we call the *equalizer chart*[2] characterizes the model along a number of dimensions. Under each dimension, there are a range of options available. Different options result in different inventory costs and performance metrics. Choices for different dimensions are often related and constrained - not all choices are feasible. For example, the ability to distribute small package sizes (individual items) might require that the inventory be owned by NIBR rather than being on consignment.

Table 3-1: Characterizing inventory management

Dimension	*Description*	*Options*
Stock rooms	Number, type and location of stock rooms	No stock rooms, department level stocking, central stock rooms or a combination
SKU range	What is stocked	Varying levels of restrictions on supplier source, range of SKUs, and package sizes
Stock room control	How inventory is controlled in stock rooms	Self-serve or manned rooms, scanning requirements
Inventory ownership	Who owns the inventory before it reaches end-users	Supplier or organization

[2] So-called because it looks like a graphic equalizer. This diagram was used to quickly convey the parameters of different models to stakeholders at NIBR.

Inventory management	Who is responsible for & bears the costs of inventory counts, updating min/max levels, placing orders etc.	Supplier, or organization or a combination
Ordering process	How ordering is done for/by end users	End users or designated employees
Ordering sequence	The priority or sequence of usage when there are multiple fulfillment options	No restrictions to a strict sequence where stock room availability is first verified
Package Sizes	The smallest item size available to an end user	As packaged & sold by supplier, or option to break up into smaller sizes
Distribution	How items reach end users	Pick up or delivery or a combination

3.2 Alternative models considered: Pros and Cons

From the analysis in the previous chapter we see that the current model of consumables inventory management at NIBR is not very efficient. One of the main issues with the current approach is the needless duplication of inventory – stocks are kept at three levels, the central stock rooms, local department stock areas, and bench tops. It should be possible to eliminate at least one of these – either the central stock rooms, or the department stock areas. Further, policy changes are required to increase the effectiveness of stock rooms. To assess the impact of proposed changes on stakeholders, a few alternative models were created. We then presented these models, with a qualitative analysis of their impact, to stakeholders from various departments at NIBR. The models considered are described in this section, and for each model we discuss the impact on inventory costs as well as end-user experience. In these descriptions, benefits, improvements and cost savings are marked with a (+) sign, and incremental costs and potential impacts to service levels are marked with a (–) sign.

3.2.1 Model 1: Discontinue central stock rooms

As our analysis indicated that the central stock rooms are underutilized, the first model examined was to close the central stock rooms. The rest of the system would remain as is. Departments would continue to manage stocks locally as they do currently, and set their own operating policies. This scenario is shown in Table 3-2 below. The table uses the *equalizer chart* format described above. The various dimensions of the model are shown in the first row. The options available along each dimension are listed underneath the row headings, and the selected option is highlighted.

Table 3-2: Discontinue central stock rooms

Stockroom	SKU	Control	Ownership	Management	Ordering	Sequence	Sizes	Distribution
Central	Small	Manned	Supplier	Supplier	Scientists	None	As-is	Pick up
Department	Large	Self serve	NIBR	NIBR	Designates	Stock first	Break up	Delivery
	Restricted	Scanning	Departments	Departments				
	Unrestricted	Walk out						

End user experience

If the central stock rooms are eliminated, departments and scientists would have to manage their own inventory. As mentioned before, many departments already maintain local stock areas, and may have employees dedicated to inventory management. There is no impact on these departments. However, there are several departments (especially smaller ones) that use the central stock rooms more actively. For scientists in these departments, this change would mean (a) a longer lead time (direct shipment would take longer compared to pick up from the stock room), and (b) more non value added work for scientists to keep track of inventory.

Inventory costs

- (+) Eliminating central stock rooms would save space for NIBR. It would also eliminate the costs and time associated with inventory shrinkage and accounting/charge-back.
- (–) However, the opportunity to pool risk for common items would be lost – this would result in higher inventory levels in departments to maintain service levels.
- (–) More direct orders would increase shipping costs.
- (–) Local inventory management and lack of visibility across departments could lead to higher obsolescence.
- (–) Departments currently using central stock rooms would have to setup their own department stock areas and dedicate resources for inventory management, leading to increased costs.

Summary

In summary, this model may only result in small inventory cost savings, but potentially significantly impact service levels.

3.2.2 Model 2: Central stock rooms only

The second model considered was the other extreme option – to completely eliminate department stock areas and use central stock rooms only. This scenario is shown in Table 3-3 below. In this model, a main central stock room would be used for each building in the NIBR campus. The central stock rooms would be manned, and carry both Fisher and 3rd party items. To address the issue of user convenience, a desk delivery system for ordered items would be available. For urgent requirements, scientists would pick-up items from the central stock rooms.

Table 3-3: Central stock rooms only

Stockroom	SKU	Control	Ownership	Management	Ordering	Sequence	Sizes	Distribution
Central	Small	Manned	Supplier	Supplier	Scientists	None	As-is	Pick up
Department	Large	Self serve	NIBR	NIBR	Designates	Stock first	Break up	Delivery
	Restricted	Scanning	Departments	Departments				
	Unrestricted	Walk out						

End user experience

- (+) Eliminating SKU restrictions would make the central stock rooms more effective. It would result in faster response for scientists – items could be picked up or quickly delivered versus direct ordering.
- (+) Central stock rooms free up scientists' time for value added research work
- (–) By providing both pick-up and delivery options, the intent is to address both the issue of user convenience, and the ability to get items urgently if required. However, feedback from interviews indicated that this may not work – scientists often run out of stock in the middle of experiments. In such cases, the stock has to be available quickly, and neither option (pick-up from a distant stock room or slow desk delivery) would work. Local stock areas would be the only solution.
- (–) User acceptance was doubtful. From past experience, scientists are skeptical of central stock rooms being effectively managed. Having a local accountable person was perceived as much more effective.

- (–) Department stock needs are quite diverse. It was felt that a central stock room could not possibly stock all the required items – making it impossible to completely eliminate department stock rooms.

Inventory costs

- (+) As a result of risk pooling, there would be lower inventory levels.
- (+) Break-up of packages would permit scientists to take out smaller quantities and avoid bench top clutter. It would also allow carrying less inventory in the stock room.
- (+) Eliminating department stock areas would result in space savings.
- (+) More centralized ordering would reduce shipping costs and also obsolescence.
- (–) Manning the central stock rooms and setting up delivery services would result in higher headcount costs.
- (–) Ownership of inventory in central stock rooms would increase working capital needs

Summary

If efficiently set up and operated, central stock rooms would result in reduced inventory levels and improved service (with increased headcount costs). However, it may not be possible to completely eliminate department stock rooms. Further, central stock rooms do not address the issue of user convenience, and users are skeptical that they can be managed effectively.

3.2.3 Model 3: Central stock rooms + small department stock areas

To address the issues of user credibility and convenience, we considered a hybrid model. In this model, the central stock rooms would still be used as the primary stock areas, but small department stock rooms would also be used. The intent of the department stock rooms is two fold:

- Stock items that are specific to the department, and a few high volume common items so that they are available conveniently.
- Provide an area for drop-off of ordered items from the central stock rooms. Delivery to this room would be easier than desk delivery. Users would be informed by e-mail when their orders are available for pick-up from this area.

After further discussion and analysis, we rejected this model. The main reason is that it would be very hard to determine what the size and composition of the "small" department stock rooms should be. Since department needs vary significantly, it could end up being no different than the current scenario, with the added cost of department delivery.

3.2.4 Model 4: Consolidated department level stock rooms

From the analysis of the models proposed so far, it became clear that department level stock rooms are inevitable. However, as seen from the first model, simply eliminating the central stock rooms without making changes at the department level does not yield much benefit. This led to the final model – eliminate the central stock rooms, but also consolidate all stock areas to a single managed stock room in each department. This model is depicted below in Table 3-4.

Table 3-4: Consolidated department stock rooms

Stockroom	SKU	Control	Ownership	Management	Ordering	Sequence	Sizes	Distribution
Central	Small	Manned	Supplier	Supplier	Scientists	None	As-is	Pick up
Department	Large	Self serve	NIBR	NIBR	Designates	Stock first	Break up	Delivery
	Restricted	Scanning	Departments	Departments				
	Unrestricted	Walk out						

In this model, there will be one consolidated stock room per department. As mentioned earlier, there are numerous department stock areas currently – typically about 5-6 in each department. All these local stock areas will be cleaned out and eliminated. Minimal bench top stock will be permitted. The inventory in the stock room will be owned by the department, and managed by a designated department employee.

<u>End user experience</u>

- (+) Eliminating SKU restrictions will make the stock rooms more effective.
- (+) Managed stock rooms free up scientists' time for value added research work
- (+) By having stock locally available, user convenience and the ability to quickly replenish stock is ensured.
- (+) Having a local accountable person results in high credibility among users.
- (+) Department level stock rooms can cater to department specific needs.

- (–) Departments that currently rely on central stock rooms will need to establish their own stock rooms. If not, this change will result in longer lead times and more non value added work for scientists to keep track of inventory.

Inventory costs

- (+) Since departments already own inventory, there is no need to scan items out. This will eliminate the costs and time associated with inventory shrinkage and accounting/charge-back.
- (+) Break-up of packages will permit scientists to take out smaller quantities and avoid bench top clutter. It will also allow carrying less inventory in the stock room.
- (–) The opportunity to pool risk for common items will be reduced – this may result in higher inventory levels in departments to maintain service levels.
- (–) Overall, there will be more stock rooms – requiring more space. However, as the numerous local stock areas will be consolidated, the space saved might make up for the extra space required.
- (–) Department ownership of inventory may increase working capital needs. However, this applies only to the central stock room inventory currently on consignment, since the departments already own other stock. As seen before, this accounts for only a small percentage of consumables spend – so the incremental working capital needs should be minimal.
- (–) Increased headcount costs for departments as they will have to allocate time to inventory management. This again may not be a significant incremental cost, since most departments already have designated employees managing inventory.

Summary

Overall, we see that this model addresses many of the shortcomings of the current practice. It also scores very well on end-user experience. However, it will entail increased headcount costs for departments, and may require extra space. **Based on feedback from various stakeholders, this model was recommended as the best one to implement at NIBR.** The following section will discuss the implementation of this model in more detail.

3.3 *Implementation Plan*

3.3.1 Creating a *pull* for the change initiative – a pilot project

The proposed model will significantly impact end user behavior at NIBR. Scientists will have to adapt to using a stock room instead of maintaining their own local inventories. Based on their prior experience of stock rooms, users may be skeptical about their effectiveness. Having to rely on a stock room may be seen as inconvenient and a loss of freedom as well. Further, most scientists do not really appreciate the impact of inventory costs and may see the entire initiative as just additional procedures and paper work, without real value addition. As such, significant user resistance can be anticipated in the implementation of the new model.

On the one hand, a top-down ***push*** approach can be used. This includes laying out policies and procedures for consumables inventory, and putting in place an organizational structure to administer the policy and ensure compliance via audits and monitoring. While this is definitely required, it is not sufficient. For true and sustained change, it is important that a ***pull*** is created in the organization – that is, the end users must want to change and appreciate the positive impact of the change [28].

To create a pull for this change initiative, two motivating factors come into play:

- The current tough business climate: As discussed earlier, the industry is facing significant challenges in recent times, with increased development costs and reduced ROI. As such, scientists and department heads at NIBR are facing budget cuts and looking for solutions to cut expenses and improve performance. Initiatives to reduce material costs will result in savings that can be used to fund projects, which directly impacts research output.
- Productivity improvements for end users: The proposed inventory management process is not about just cutting costs, but will significantly improve productivity. Scientists can focus more on the value added work of research, rather than wasteful administrative work.

While the inefficiencies of the current state are apparent and the proposed model can be seen to be better in qualitative terms, it is critical to demonstrate the positive impact to end users. A pilot implementation was seen as an effective way to convince end users of the benefits and create an environment for roll out of the new process across NIBR. This is described in the next chapter.

3.3.2 Process Details

Inventory Control

- Stock will be consolidated into one room per department. In the case of small departments, a stock room may be shared by two departments. All other stock areas in departments will be cleaned out.
- Access control will use employee badges. Access will be limited to department employees. Users will avoid "tailgating" – i.e. one person holding the door open for multiple people to enter the stock room without using their badges.
- There will be no bar code scanning. Users will just walk out with items. This will not be an issue typically since the department already owns the stock. In the case of shared stock rooms, inventory will be owned by NIBR Operations until checked out, and will be charged back to departments based on headcount.
- Users will take only "reasonable" quantities of items. In case they take an unusually large quantity, they will inform the manager via email to enable replenishment.
- Users will report any other issues via email or a whiteboard placed in the stock room.

Inventory guidelines and ordering policy

- Bench top storage of stock room items will be minimized. Suggested amounts will be 2-3 days supply or the smallest unit (such as a case).
- Regular, random inspections of bench tops will be conducted by the department inventory manager to prevent build up of bench top stock. These inspections will also be linked to HSE (Health, Safety, & Environment) guidelines.
- Direct orders (via ARIBA) for stock room items will not be allowed. Users will be directed to the stock room if they attempt to do this. Over-rides may be allowed in special cases.
- For items that are not stocked, users will order only required amounts, and not attempt to take advantage of bulk discounts. For Fisher items, as there is no shipping cost, only

small quantities will be ordered. Periodic audits of ARIBA orders are proposed to ensure compliance.

Inventory Management

- There will be a department employee designated as the inventory manager. At steady state, the workload is estimated to be about 1-2 hours per day.
- Initial stock lists will be established based on an ABC analysis of historical usage of consumables. High volume SKUs short listed by the analysis will be identified as candidates for stocking if they are widely used. Inventory will be managed using a periodic review base stock policy (described in Appendix A). For high volume SKUs, a daily review will be used, while lower volume SKUs will be reviewed weekly. Base stock levels will be determined based on estimates of item demand and lead times. Service levels will be decided based on user perception of how critical items are.
- Stockroom usage will be charted and used to adjust SKU lists as well as inventory policy parameters over time.
- Once daily (before the order deadline for next-day delivery from Fisher), the manager will assess inventory on hand (visually) and place re-orders as required.
- Discrete, separate orders will be placed for each item. Blanket orders will be avoided to ensure data visibility.
- Every morning, the manager will receive shipments and re-stock shelves.
- Periodically, the manager will (a) conduct full inventory counts and reconcile inventory, and (b) do random walkthrough inspections of benches to ensure compliance to policy, and assess needs to change stocking list.
- Visibility across different department stock rooms will be developed to enable transfer of common items in cases of urgent need.

Organizational Structure for roll out across NIBR

- NIBR Operations will be in charge of setting stock room policy and guidelines. A stock room program manager will oversee the stock rooms and ensure compliance. The stock room program manager will lead a team that is tasked with development of policy guidelines. The team will include members from other departments such as Strategic Sourcing and HSE.

- Departments will bear the head count costs for stock room management. This could be done in two ways, depending on the workload demands: (a) departments designate an employee as inventory manager and that person dedicates a certain amount of their time to maintenance of the stock rooms, or (b) NIBR Operations will employ the inventory manager and charge departments based on size/volume of usage.
- In both cases, inventory management staff will report (directly or dotted line) to the NIBR Operations stock room program manager.

4 Case Study

In this chapter, we validate the proposal for consumables inventory management using a case study. A pilot department stock room is developed for one of the departments at NIBR (Cardio Vascular). We first present an analysis of historical data for the CV department. Based on this analysis, guidelines for the implementation and management of a department stock room are developed. We also propose metrics to monitor and evaluate the performance and benefits of this department stock room.

4.1 Stock room for Cardio Vascular (CV) department

Following the development of the new stock room model, we presented the proposal to a number of stakeholders at NIBR to gage interest in a pilot implementation. During the course of these presentations, we discovered that one of the departments at NIBR – DM (Diabetes) was using a similar model already. DM used a department stock room that was actively managed by a designated employee. Access to the room was limited to DM employees, and there were no SKU restrictions of items carried in the room. A walk through of the DM lab space showed that the level of department stock and bench top supplies was quite low – an indicator that the stock room was effective.

Coincidentally, another NIBR department – CV (Cardio Vascular) had been working towards setting up a department stock room along the lines of the DM stock room. At the time, CV was using one of the central stock rooms primarily, but also had significant inventory around the department. Usage of the central stock room was limited due to some of the factors discussed in earlier chapters. The intent was to form a CV specific department stock room that would be more effective. This scenario presented a good opportunity for a comparative case study of the proposed stock room model. By looking at usage levels and user experience in the current stock room versus the department stock room once it was set up, the effectiveness of department stock rooms could be assessed.

For the case study, we proposed to convert one of the existing central stock rooms (primarily used by CV, and to some extent by other departments) into a CV specific stock room. To do this, CV would take over the inventory and the management of the stockroom on a target date. Access to the stock room would be limited to CV employees. At that point, users from other departments would use other central stock rooms or order replenishments directly.

4.1.1 Issues addressed through this change

In converting an existing central stock room to a department specific stock room, several issues coming in the way of effective use of the central stock rooms are addressed. These are summarized again below:

- SKU alignment with usage patterns: The new stockroom will have CV department specific items in stock. As there will be no SKU restrictions, 3rd party items will also be stocked.
- Elimination of shrinkage and charge-back issues: As the inventory in the stock room is already owned by the CV department, and access to the room is limited to CV employees, there will be no need for items to be scanned out. This will eliminate problems related to incorrect use of the bar code scanner etc.
- Package size break up: Department ownership of stock will permit break up of packages in the stock room. This results in two benefits: (a) Scientists can take out smaller quantities of items as needed, instead of taking out whole packages. This reduces bench top stock. (b) Lower safety stock levels can be kept in the stock room, as amounts are no longer limited to multiples of packages.
- Convenience: The stock room will be located close to the scientists' work areas. This will permit easy and quick access to the stock room, and should help reduce the amount of bench top stocks that scientists keep. With an effective stock room, scientists will also reduce direct ordering, which will yield shipping cost savings and also reduce the non value added work for scientists.
- Credibility: The stock room being managed by a department employee will improve user credibility.

4.1.2 Benefits from data visibility

The benefits and costs of using department specific stock rooms have been listed in previous sections. An additional, important result is increased visibility of consumables usage. As mentioned before, due to the current practice of outsourced fulfillment and expensing of consumables inventory, there is very little visibility within NIBR of the actual usage patterns of consumables. With the effective use of stock rooms, a significant portion of consumables spend will go through the stock room and this will enable analysis of consumables usage patterns by department. This opens up significant savings opportunities – SKU rationalization, negotiation of better prices due to increased volume, better forecasting and budgeting of consumables needs.

4.2 Determining SKU list and inventory parameters

Consumables spend overview

As a first step, historical data for consumables orders were obtained from Fisher and compiled. The time period covered by the data was January to June 2007. The data included both central stock room usage, as well as ARIBA direct orders. The break up of spend by these two sources is shown below in Figure 4-1. We see that 23% of consumables spend by the CV department came out of the central stock room. This is a much higher percentage than the NIBR wide average (8%). This is perhaps due to the fact that the central stock room is located on the same floor as the CV scientists work areas, thereby solving the issue of user convenience.

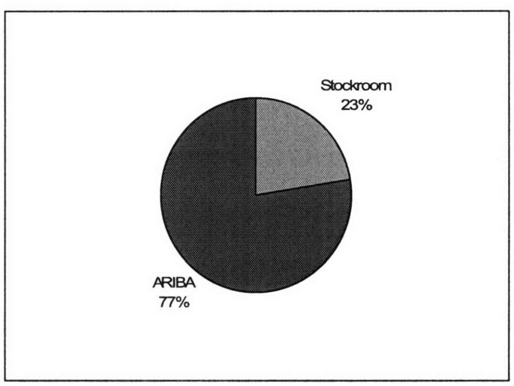

Figure 4-1: CV consumables spend by source

ARIBA Data Analysis

As mentioned before, we obtained historical data for ARIBA orders from Fisher for the time period January to June 2007. This data set encompassed all the ARIBA orders from all departments at NIBR, and included all non-capital spend categories. So the data set had to be pruned first to extract just the relevant data – that is consumables spend by the CV department. This was done in a series of steps, as described below:

1. We first filtered the data set to include only CV non-stock room transactions. This was a straight forward step, as individual transactions had an associated cost center number, and the set could be filtered based on the cost centers used by CV.
2. We then categorized the data by order type – Fisher/Franchised, 3rd party via Fisher, and 3rd party direct, and by vendor. Categories and vendors not relevant to the analysis were filtered out.
3. We then removed blanket orders, since the amounts and prices on these are incorrect.
4. Finally, we categorized all remaining transactions by the type of item purchased, and only the types that were relevant were retained. These types included consumables, chemicals, diagnostics and biologicals, as shown in Figure 4-2.

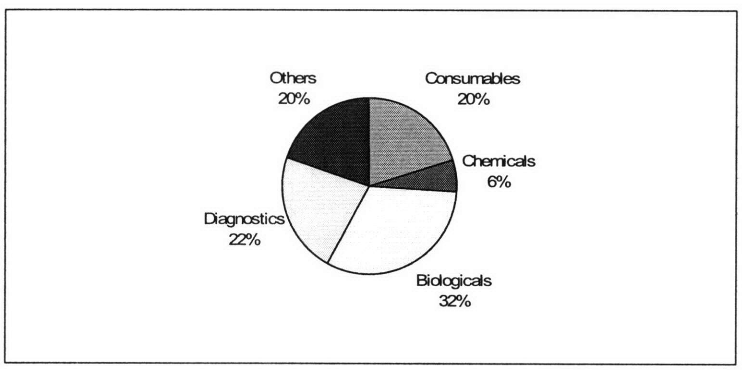

Figure 4-2: Break up by categories

An ABC analysis was done on the filtered data set. Out of 1674 SKUs in the data set, we found that only 239 were ordered more than once in the time period. The data were then further divided to examine just the consumables category. In this category, we see that 402 SKUs were ordered in the six month time period, out of which only 88 (about 20%) were ordered more than once. These 20% of SKUs also contributed to more than 70% of consumables expenditure. Two observations can be made from these results:

- The repeat order rate is very low. As discussed earlier, this could be due to SKU proliferation, or simply due to large order quantities resulting in infrequent orders
- The Pareto (80/20) pattern fits very well – 20% of the SKUs contribute to more than 70% of spend.

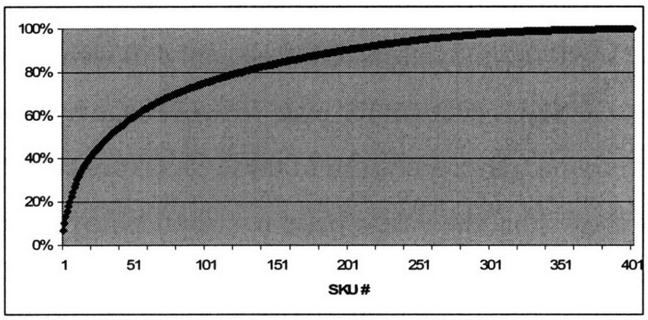

Figure 4-3: SKU contribution to $ Value

One of the arguments in support of department stock rooms was that removal of SKU restrictions would enable stocking of 3rd party items, and this would greatly reduce bench top clutter. To validate this claim, the repeat orders in the data set above were broken up by vendor source. This break up is shown in Table 4-1 below.

Table 4-1: Category wise break up of item source

Item Category	*3rd Party*	*Fisher/Franchised*	*Total*
Biologicals	51	26	77
Chemicals	15	9	24
Consumables	23	65	88
Diagnostics	40	4	44

From the table, we see that 75% of consumables SKUs are Fisher/Franchised. The percentage of 3rd party SKUs is higher only for the other categories, not for consumables. Since currently the central stock room consists mostly of consumables, this indicates that the removal of 3rd party SKU restrictions is unlikely to result in a significant reduction in bench top clutter. To truly realize this benefit, CV should consider expanding the scope of the stock room to try and include other categories beyond consumables.

Stock room usage analysis

We analyzed usage of the central stock room for the same time period as the ARIBA data – January to June 2007. The filtering of data was easier in this case as all stock room transactions were associated with specific purchase order numbers, and the data set could be filtered based on this. Analysis of the data showed that over the six month period, 64 SKUs were taken out of the stock room by users. Of these, only 40 were taken out at least once a month. Further, about 20 SKUs account for over 75% of usage by dollar value. 20 SKUs also account for over 75% of the transactions (16 of these SKUs are common with the high $ value SKUs). This shows that the Pareto pattern is applicable here as well, and there is significant scope for improvement by eliminating slow moving items from the stock room. The data is shown in Figure 4-4 and Figure 4-5 below.

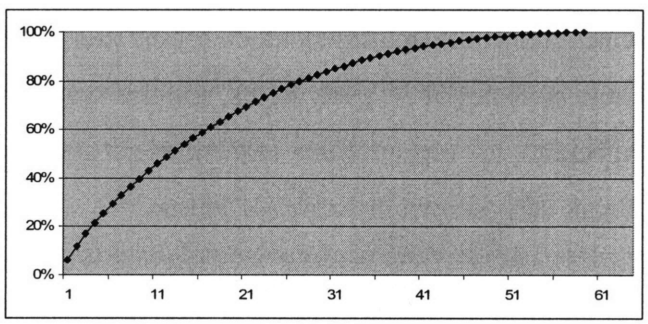

Figure 4-4: Stock room SKU contribution to $ Value

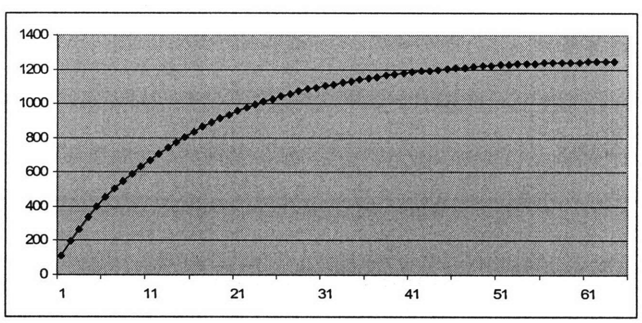

Figure 4-5: SKU contribution to # of transactions

The stock room data set also contains information on item quantities and a break down by individual users. This allows further analysis.

Setting inventory model parameters from historical usage data

The demand for various stock room items can be determined based on the data set. Over the six month period, we can see how many items were taken out, and use this number as an indicator of the demand. For SKUs that are taken out of the stock room many times over the six month period, we can use this data to get a mean and standard deviation estimate of the usage. Inventory model parameters such as reorder points, quantities and safety stock levels can then be determined from this data. The problem however is that many items are taken out only a few times over the six months – for these items we do not have enough observations to obtain a reasonably accurate estimate of the parameters. In such cases, it is best to use the observed data as a rough indicator of mean demand, and then calculate inventory levels based on an assumed coefficient of variation.

Stock room usage by employee

The stock room usage data contains employee ID for each transaction. This enables us to analyze usage patterns by individual users and by different departments using the stock room.

The issue of **"shrinkage"** related to the incorrect use of the bar code scanner to scan out items was discussed before. To understand if this is a significant issue, all stock room transactions in the data set were examined against a current employee database at NIBR. We found that for about 20% of the transactions by dollar value, the employee ID field was either a special code used by Fisher to indicate corrective entries, or could not be matched. This indicates that the shrinkage rate could be as high as 20%. In converting to a department specific stock room and eliminating the need to scan out items, this issue will be resolved. This is a significant benefit.

Another measure of the effectiveness of the stock room is **item commonality** - **how popular or widely used** stocked items are. It makes sense to stock an item only if it is used by a significant number of people across the department. If an item is used only by a couple of people, even if it is a high volume, high dollar value item, it would be better for those individuals to stock it locally instead of using up space in the stock room. A histogram of SKU usage by number of users is shown in Figure 4-6. As seen, there are 25 SKUs in the stock room that were taken out by 5 or fewer people. These SKUs must be examined carefully to determine if it makes sense to stock them centrally, or if they should just be stocked locally by the scientists that use them.

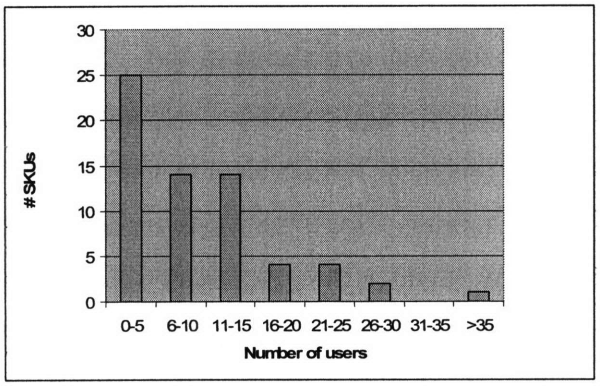

Figure 4-6: Histogram of SKU usage in stock room

The usage data above could be misleading however, due to the practice of some employees taking stuff out of the stock room on behalf of an entire group. For example, in each group or lab, **employees might take turns** in visiting the stock room to bring back items for the whole group. This would make the usage statistics inaccurate.

The usage data by employee also suggests that this is happening. The stock room being analyzed caters to about 80 scientists. Over the course of the six month data window, almost every scientist used the stock room at least once. However, the **amount of usage varies** quite a bit – the data showed a coefficient of variation of 1.25, and the top users took out about 10 times the median amount.

Another concern brought up during presentation of the proposal to stakeholders was the potential impact to other departments. To check if this would be significant, the stock room usage was broken down by department. The data showed that CV accounted for almost 80% of the stock room use by dollar value. **So the impact on other departments should be minimal.**

Comparison of ARIBA and Stock room

In the discussion earlier, two hypotheses were stated to explain why the central stock room usage is low. These were: (a) that scientists order items directly because they are not stocked due to 3rd party SKU restrictions, and (b) that scientists prefer ordering directly because of the convenience of desk delivery compared to having to walk over to the stock rooms. To examine these hypotheses, we compared the ARIBA data to the stock room usage data to determine how many items were common to the two data sets. The comparison is shown in Figure 4-7, and clearly indicates that there is very little commonality between the two SKU sets. **This shows that scientists are not ordering directly on ARIBA for convenience reasons; rather they do so because the stock room does not carry these items.**

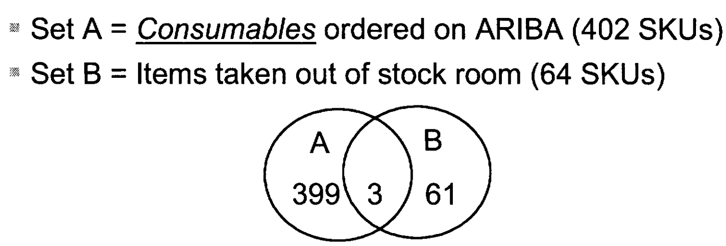

Figure 4-7: Commonality between ARIBA and stock room SKUs

Summary and Recommendations

Based on the analysis of historical stock room usage and ARIBA purchases, we make the following recommendations as guidelines for the stock room conversion:

- Keep only the top 40 SKUs from the current Fisher stock room. These items were taken out by 5 or more people in the last six months, and account for over 90% of stock room use. If there is a space constraint, the number of SKUs can be further reduced to just the top 20 SKUs. This will still account for 75% of stock room use.
- From the Pareto analysis of the ARIBA consumables purchases, start with the top 20% of SKUs as potential stock room items. Based on a department survey, establish the commonality of usage of these items to decide if they should be stocked. This initial list can then be refined over time.

- Consider expanding the scope of the stock room to include other categories beyond just consumables – that is diagnostics, biologicals and chemicals SKUs. A significant benefit of the changeover to a department stock room is seen only if the scope is expanded.

4.3 Stock room implementation

The initial proposal was to implement the change over of the stock room during November and December 2007. This would enable measurement of stock room performance and a comparison of before/after performance metrics. Unfortunately, due to a number of year-end constraints, implementation was pushed back to early 2008. So the impact of the change over could not be measured before the internship period ended.

Performance Metrics

We propose the following metrics as measures of the impact and performance of the stock room, once the change over is complete and the stock room is operating at steady state.

Short and Medium Term:

- **User satisfaction** can be assessed via a survey of users on the effectiveness of the department stock room as compared to the central stock rooms. **Productivity** should also improve as users spend less time on inventory management and interacting with ARIBA – this can also be measured via a survey.
- **Bench top and local stock levels** can be qualitatively measured by conducting a walk through of the department.
- Stock room usage as a **percentage of consumables spend** should increase. Related to this, the **total number of ARIBA orders** in the department should decrease, which will also reduce **shipping costs**.

Long Term:

- **Obsolescence** can be estimated based on future periodic clean ups. Over time, obsolescence should decrease.
- **Consumables spend per researcher** should also decrease over time, as efficiencies are gained from the effective stock room and from SKU rationalization.

5 Conclusions and Future Work

5.1 Key Findings from project

In this project, we studied the process of consumables inventory management at NIBR. This topic assumes importance in the current context of the pharmaceutical industry facing significant challenges of increasing development costs and lower ROI. More efficient inventory management has the potential to both reduce material costs and enhance productivity. Further, the NIBR Cambridge organization is in steady state after a period of rapid expansion, creating a good opportunity for process optimization initiatives.

The study showed that the current process for consumables inventory management at NIBR is quite inefficient. Stocks are maintained at three tiers - central stock rooms, department stock areas, and scientist bench tops. The supplier managed central stock rooms are underutilized and account for only a small fraction of consumables spend at NIBR. To a large extent, these rooms are used to replenish local department stock areas. Inventory turn rates in the central stock rooms are poor and in many cases there is clearly too much stock on hand. There are also too many local stock areas in departments, often holding duplicate stocks of SKUs that are in the central stock rooms. Bench top inventory is also often excessive. Finally, there is considerable obsolescence of consumables stock, but this is very hard to quantify given the current process.

The study revealed a number of reasons for the poor utilization of central stock rooms. A primary reason is SKU diversity across NIBR departments. A large number of SKUs were used, but the repeat order percentage is very low. Scientists have very strong brand preferences, which results in a proliferation of SKUs as different brands of functionally identical items are used. The dynamic nature of projects in an R&D environment also leads to high variability in demand for consumables. This makes it difficult to set up effective central stock rooms. The problem is compounded by SKU restrictions placed on the central stock rooms. As they are supplier managed, the number of 3rd party items is limited causing further misalignment between what is carried in these stock rooms and the actual needs of scientists.

We also found lack of user credibility and inconvenience of use to be possible factors. The inventory position in the central stock rooms is not visible to scientists. While the central stock rooms are self-serve and are available all the time, they are often located at a distance from users - on a different floor or in the basement of the building. Scientists prefer to make sure that a required item is available before walking over to the stock room. Further, when they are in the middle of experiments and need to replenish supplies urgently, scientists cannot pause the experiment in order to visit the central stock room. So scientists prefer to have local stocks on hand. Finally, frequent stock outs especially when the central stock rooms were initially set up have resulted in a lack of credibility among scientists. This results in users either avoiding the use of the stock rooms or taking out more stock than they need in anticipation of future stock outs.

We also found that scientists would much prefer to have a local accountable person whom they could approach with their needs, rather than deal with a central inventory manager. Given the diversity in department needs, a local person would have a much better understanding of their needs and provide more effective service.

Some of the underlying drivers that influence the current behavior were also discussed. Perception of consumables inventory as a "problem" is very subjective. Employees in departments such as Sourcing and Finance recognize the system inefficiency but do not fully appreciate the needs/constraints of scientists. On the other hand, scientists do not understand the costs of inventory and are concerned only with service levels and convenience.

Objective performance measurement is very difficult. There is no central process ownership or standardization of the consumables inventory process, and each department sets their own policies and procedures. The fulfillment process is outsourced to Fisher, so visibility and data availability is limited. Consumables are expensed and not carried on the balance sheet as inventory. This makes it impossible to track actual consumables usage, and as a result obsolescence is very hard to quantify.

As the primary focus at NIBR is on drug discovery, performance incentives target innovation and scientific output. Associates are not measured on operational efficiency, so there are no incentives to globally reduce inventory. Departments operate independently with incentives to improve local service levels.

5.2 Recommendations for change

The study examined a few different options for stocking consumables inventory. Based on an analysis of the costs and benefits as well as impact on end users, the study recommended that department level stock rooms are established. In this model, the central supplier managed stock rooms will be discontinued and all local stock areas will be consolidated into one stock room per department. The inventory in these stock rooms will be owned by departments, and managed by a designated department employee. We developed a process to determine the SKU lists and the inventory control parameters based on ABC analysis of historical spend data. Stocks will be replenished based on a periodic review inventory model, and usage will be monitored to adjust SKU lists and inventory levels over time.

While departments will own and operate their own stock rooms in the proposed model, the study recommended the creation of a governance structure to set overall policy and guidelines and for ongoing program management. A stock room program manager employed by the Operations Department will have responsibility and authority to develop and enforce inventory policies. The stock room program manager will lead a team that will include members from other departments such as Strategic Sourcing and HSE. Department inventory management staff will report to the program manager.

Finally, in order to achieve and sustain change across NIBR, an environment has to be created to facilitate adoption of the new process. End user buy-in has to be developed by demonstrating benefits of inventory management both in terms of material cost reduction as well as productivity improvement. A pilot implementation is an effective way to do this. Also, organizational incentives and performance metrics have to be modified to encourage scientists to pursue operational efficiency.

5.3 General Applicability

This study was carried out in the context of pharmaceutical drug discovery. However, the findings and recommendations are more broadly applicable in a number of settings such as laboratories, research institutions and hospital pharmacies. In all these settings, while inventory management is important to reduce operational costs, it is not the over-riding priority of management. Further, the dynamic nature of demand and diversity across the organization makes forecasting and the use of centralized inventory management challenging. Finally, there are typically strong cultural barriers in these organizations which makes implementation of operational excellence initiatives particularly difficult.

5.4 Implementation and Future Work

We developed a pilot implementation of a department stock room as a proof of concept of the recommended changes. This involved the conversion of an existing central supplier managed stock room to a department specific stock room. In implementing this conversion, the performance and impact of both models could be compared. While the data analysis for this implementation was completed, the conversion itself could not be done during the course of the internship project.

The first step therefore is to complete the implementation of the pilot stock room, and measure its performance once it is operating at steady state. This will validate and demonstrate the benefits of department level stock rooms. The pilot stock room can then be used as a model to roll out the proposed model across NIBR.

While the establishment of department stock rooms will result in some immediate benefits such as the reduction of local inventory levels and improved productivity, it also enables long term savings opportunities that may be much more significant. With the effective use of stock rooms, a significant portion of consumables spend will go through the stock room, enabling better analysis of consumables usage patterns. This will make possible a number of initiatives that can be undertaken in the future - including SKU rationalization, negotiation of better prices due to increased volumes, and better forecasting and budgeting processes.

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Appendix A

Base Stock Inventory Model

This model operates with a periodic review of inventory (on-hand as well as on-order). Upon each review, an inventory replenishment order is placed to bring the inventory level back up to a "base stock" or "order up-to" point. So there is a fixed time between orders, but the order quantity varies each time, based on the actual usage since the last order. The parameters of the model are explained below.

Parameters:

r = review period

B = Base stock level

L = Fixed lead time to receive orders

Demand is assumed to be normally distributed with mean μ and standard deviation σ

The Base stock level is determined as the sum of expected demand over the review period & lead time, and a safety stock to account for variability in demand.

$B = \mu(r+L) + z\sigma \cdot \text{sqrt}(r+L)$

Here z corresponds to the point where the cumulative distribution function of the standard normal distribution $\Phi(z) = \alpha$ where α is the coverage probability (also called Type-1 Service Level) desired. In Microsoft Excel, this is obtained using the formula: z = NORMSINV(α).

As an example:

z = 1.64 provides 95% coverage probability

z = 2 provides 98% coverage probability

z = 3 provides 99.9% coverage probability

The expected inventory level E[I] in this model is given by:

$E[I] = \mu(r/2) + z\sigma \cdot \text{sqrt}(r+L)$ = cycle stock + safety stock