5-2017

Are Single Tier Inventory Systems Still Relevant in the Business World Today?

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<u>Table of Contents</u>

Thesis Summary……………………………………………………………………………… 3

Abstract……………………………………………………………………………………….. 5

Introduction……………………………………………………………………………… 5

Why MultiTier Systems Aren't Always Better……………………………………………… 6

P System vs. Q System………………………………………………………………………… 7

Single Tier P Systems……………………………………………………………………….. 9

Newsvendor Model…………………………………………………………………….. 9

Order Up to Model……………………………………………………………………. 11

Fill Rate vs. Service Level………………………………………………………………….. 13

Single Tier Q System……………………………………………………………………….. 14

Hybrid Systems……………………………………………………………………………... 16

Optional Replenishment System……………………………………………………… 16

Base-Stock System…………………………………………………………………….. 17

Safety Stock…………………………………………………………………………………. 18

Incorporating Seasonality………………………………………………………………….. 19

Conclusion…………………………………………………………………………………... 20

Works Cited…………………………………………………………………………………. 21

Graphs……………………………………………………………………………………… 22

Thesis Summary

In today's ever competitive business climate people keep looking to find the next best thing that could give them an upper hand on their competitors by either raising their revenue or lowering their costs. An ever-present cost that is frequently the target of these attempts is inventory holding costs as initially it seems simple, just hold less inventory. Upon closer inspection, it becomes much more complicated as one has to identify the bare minimum level of inventory to hold while still fulfilling as many sales as is profitable given the inventory level needed and the amount of profit made by each sale.

To this end, companies and supply chain scholars have spent much time and resources to determine the "best" method for finding and maintaining this inventory level. This led to the advent of single tier inventory management systems. The single tier designation means simply that they are ultimately only optimizing the inventory level at one location, the final destination at the end of the supply chain. This was continually refined as the technology became more advanced and supply chains became more interconnected and spread across the world, especially for large multinational corporations, spurring the research of more complex multitiered systems that are in vogue today. This raises the question: are single tier inventory management still useful, for who, and how should they be used?

In short, single tier inventory systems are still very much useful for most every business in one way or another. Small and some medium businesses can benefit from the use of these systems to manage their inventory. For the most part these are businesses that are unlikely to have overly complex supply chains meaning that it is unnecessary and a waste for them to have employees spend time mastering these complex inventory systems that frequently come with high implementation costs. The single tier systems match up better with the inventory characteristics of these businesses better as well. Since they are relatively easy to understand extensive training is not needed either, further increasing the benefit of not using a multitiered system when its unnecessary. Even large companies using the multitiered systems can benefit from the use of single tiered system as a check for the more complex systems. A single tier model can provide a sort of sanity check for the overall system as well as the inventory being held between stages within the system itself. While it would be crazy to assume that the numbers would be the same, they should still be in the same neighborhood. If they are not, that is a sign that the multitier model and its assumptions should be double checked to make sure all of it makes sense. If the single tier check is consistently returning a significantly lower level than the multitier model, then there may be an opportunity to reduce inventory. If it is consistently returning a much higher level, one should make sure that the desired percentage of customers are still being served as one may be running a higher than desired risk of stock outs.

The matter of choosing what single tier inventory management system best suits one's inventory is a crucial part of this equation so the most popular models are then grouped by their defining characteristics and discussed. This includes their strengths and weaknesses as well as how to best use them. Briefly, Newsvendor model is a periodic review system for goods with a short time horizon and the Order Up to Model is a periodic system for goods with an indefinite time horizon (non-perishable/ don't become quickly obsolete). The continuous review system then follows a section outlining the importance and difference in cycle service level and fill rate (cycle service level only counts the occurrences of a stock out while fill rate is about the number of sales missed due to stocking out). The thesis is then concluded with a brief description of two hybrid systems; the Optional Replenishment system and Base-Stock System.

Abstract

The goal of this paper is to identify whether single tier inventory management systems are still effective and useful for businesses in today's more globalized economy. Multitier inventory management systems are very popular, especially for researchers who have mostly forsaken single tier systems in recent years so there was reason to question the viability of single tier systems. However, to determine whether these inventory management systems are still viable, I would also have to identify at least one significant business sector that would benefit from their use, as well as exploring their assumptions and mathematical background to identify the inventory characteristics that they could be best suited for. Ultimately, the findings confirmed that these single tier inventory management systems could function as originally intended for many small to medium sized businesses (depending on the complexity of their supply chain) as well as checks for multitier systems and the types of systems most likely to be used.

Introduction

It seems obvious to state that the world has changed drastically since the 1980s but little has changed in terms of literature on single tier inventory management systems since then. This is in a large part due to the increasingly global and complex supply chains used by large companies both domestically and abroad. These large companies have researched and developed intricate multitiered systems to better track the inventory they have at multiple points (or tiers) along their supply chain. These systems then minimize the inventory level at each of these points and thereby overall inventory in their system. These systems were the ones being researched and refined with much less attention being devoted to single tier systems which are designed to minimize inventory but consider all inventory that has been ordered but has not arrived as one lump sum instead of dividing it out like multitier systems. This begs the relatively simple question, are single tier inventory management systems still useful or have they been entirely supplanted in usefulness by multitiered inventory management systems? And if single tier systems are still effective, how and in what forms?

Why Multi-Tier Systems Aren't Always Better

Who should use these single tier systems and why? After all, everyone want to become a huge, successful company so why shouldn't everyone manage their inventory like a huge, successful company? Ultimately no because it's an unnecessary use of time and resources for organizations with supply chains with relatively uncomplicated supply chains. The simpler inventory management systems allow a more effective use of resources as the benefit of multitiered systems would be marginal at best with no value added. Time would be better spent in other functions. Additionally, theses single tier systems are tried and true methods and can even be useful for these multinational conglomerates if used as check for more complex systems or between inventory stages or tiers.

With all of the fancy and complex formulas now available to these multinational corporations and research continuing to focus on developing the latest and greatest multitier inventory system, it's fair to ask how these more basic systems could prove beneficial to these large companies. The answer is twofold, firstly that the more complicated models are frequently derived from these single tier models so they can provide a sort of sanity check for these advanced models. While the results from any of these models are obviously going to be different from one calculated from a multi-tiered system the overall results should be at least in the same ballpark. If they aren't, then that's a sign that the complex model should be looked at more closely to see if all its assumptions are correct and reasonable and that the data is consistent with real world experience.

If the single tier model suggests an inventory level much lower than the multitiered system this suggests that there may be an opportunity to cut inventory and therefore holding cost but will indicate what area is the problem and should be improved and by how much. Merely that the existing model should be re-examined. The multitier system may be accounting for multiple inventory build ups within the supply chain not adequately covered by In-Transit inventory or may be accounting for a type of variation that the single tier model is not. However, these single tier models are still a good enough approximation to justify using to check the performance of multitiered systems, especially when breaking down this system into its component parts.

The main users of these single tier systems however shouldn't be large corporations but small and medium sized businesses looking to control their inventory and minimize their costs, as all businesses should. These are the type of businesses most likely to have, at least as far as they are concerned, a single tier supply chain or a relatively simple multitiered supply chain that is easily and accurately approximated one of the aforementioned systems. For these simpler supply chains, it is a waste of time and resources to use more advanced systems with the exception of high turnover inventories or complex inventories to the point where software becomes necessary to assist in inventory control. Even then, single tier systems can form the basis of this software and provide the same sanity check purposes that it would for a large business as previously discussed.

P System vs Q System

The first decision to make is how frequently the inventory in question is going to be reviewed and reordered. There are ultimately two choices; either a periodic review or a continuous one (sometimes referred to as a perpetual review system). A periodic review is fairly self-explanatory, it is a system where the inventory level is evaluated after a reoccurring set amount of time (Johnson & Flynn 2015 208). This could be every three days, once a week, once a month, once a year (not particularly advisable under most circumstances), or any length of time as long as the amount of time between reviews remains consistent and inventory can be ordered at that point (Johnson & Flynn 2015 208). A continuous review is just that, continuous. Inventory level is monitored either at least daily or constantly as an item is counted as eliminated from inventory as soon as it is purchased by a customer (Krajewski, Ritzman, & Malhorta 2016 320). Once the inventory level dips below the reorder point established by the particular model an order is placed to replenish (Krajewski, Ritzman, & Malhorta 2016 320). Periodic review systems can be denoted as a P system while a Q system refers to a continuous review system.

Each system has its own strengths and weaknesses and a good business owner or manager should weigh both type of systems pros and cons carefully. P systems typically take less time as they are done less frequently and can help establish a routine delivery as the orders are always placed at the same time and therefore delivery become predictable for both the purchaser and supplier (Johnson & Flynn 2015 208). Similarly, the P system makes it easier to purchase and receive deliveries of multiple items bought from the same vendor since the purchase orders can be combined where the Q system would create separate purchase orders at different times complicating delivery (Krajewski, Ritzman, & Malhorta 2016 328). Additionally, Q systems can be expensive, especially if a perpetual review is used as this is normally predicated on the use of a computerized tracking system (Krajewski, Ritzman, & Malhorta 2016 320). However, Q systems allow for lower safety stock levels to be held since there is no need for the inventory to have to last until a review point in the future to be replenished, a new order is placed as soon as the inventory level drops below the preset reorder point (Krajewski, Ritzman, & Malhorta 2016 329). This also means that the order size in a Q system is set and generally will not change allowing for potential volume discounts a P system is unlikely to be privy to and allowing its user to place orders in sizes closer to the economic order quantity (EOQ), which is the order quantity that minimizes both ordering costs and annual holding costs (Estep 3). The key to choosing what kind of single tier inventory system to implement is to choose the system whose strengths align most closely with one's inventory characteristics and priorities. A good manager should also be aware of the limitations of their chosen inventory management system and monitor these areas of weakness. With a P system, this means making sure that forecasts are accurate and monitoring factors that affect demand such as a big event or a seasonal downturn to prevent overstocking or a stock-out (Estep 9). Q system managers should monitor if irregular delivery patterns affect their operations or the cost of the deliveries, as well as the amount of time they and their employees spend implementing and using the Q system (Krajewski, Ritzman, & Malhorta 2016 321).

Different Types of Single Tier Periodic Review Inventory Management Systems

Newsvendor Model

So if a business has decided that a P system would suit their inventory and business needs the best, the next step is to decide what kind of periodic review system is best for them to use. The Newsvendor model is great for inventory that becomes obsolete quickly, much like the newspapers that gave this system its name (Adelman, Barnes-Schuster, Eisenstien 2). Therefore, the best items to use the Newsvendor Model for are seasonal and perishable goods since they are severely diminished in value once a certain amount of time has lapsed (Adelman, Barnes-Schuster, Eisenstien 2). The crux of this model is that it compares the cost of overstocking with the cost of understocking in order to determine what should be the ideal purchase order or stocking level to maximize profit and reduce overall system costs (Adelman, Barnes-Schuster, Eisenstien 4). This is accomplished through the calculation of a "critical ratio" (given by $\frac{Cost\ of\ Underage}{Cost\ of\ Overage+Cost\ of\ Underage}$ or $\frac{C_u}{C_o+C_u}$) which determines whether it is best for the inventory to potentially err on the side of over or understocking and by how much (Cachon & Terwiesch 20).

A critical ratio less than .5 would signify that the cost of stocking out is less than the cost of being stuck with obsolete inventory (Cachon & Terwiesch 19). This is going to be most likely when there is no resale option or any value to the goods whatsoever when the good have reached obsolescence. Some examples this of would be products like perishable food stuffs, newspapers, or calendars which clearly have no salvage value past their point of usefulness. On the other hand, a critical ratio of greater than .5 would be representative of goods where the costs of stocking out are greater than the costs of excess inventory (Cachon & Terwiesch 19). These are more likely to be seasonal goods such as winter jackets or bathing suits where the goods still retain value after becoming obsolete and can be sold at a discount. Goods with very high profit margins are also likely to have a critical ratio of greater than .5 due to the fact that a missed sale opportunity is more impactful to a business than the holding costs of the goods (Adelman, Barnes-Schuster, Eisenstien 4).

Another aspect of the critical ratio is how far away the calculated value is from the .5 divider as this will determine how much potential over or understock should be prepared for (Cachon & Terwiesch 23). Critical ratios closer to .5 will result in a lower percentage chance of stock-outs or excess inventory which on first glance sounds good but is not suitable for inventories with very high holding or stock-out costs (Adelman, Barnes-Schuster, Eisenstien 4). These goods would end up with a critical ratio closer to 0 or 1 respectively as the system looks to minimize overall costs and reduce the possibility of this occurring (Adelman, Barnes-Schuster, Eisenstien 4). The flip side is that the reduced chance of these costly stock outs or excess inventory depending on what side of .5 the critical ratio falls on is that the probability of the opposite occurring increases. In these cases, it is important to remember that the system is designed to minimize the overall cost but is not actively reducing either the holding cost or the cost of a stock out so a manager should be still looking at how to reduce these costs and improve demand forecasting to make the Newsvendor model even more successful for one's business.

Order Up to Model

The Order Up to Model is the answer for a manager looking to do a periodic review system but without the limited time horizon and obsolescence that occurs in the Newsvendor Model. The Order Up to Model assumes random demand, an infinite time horizon, a variable order quantity, and allows for the possibility of back orders within the model (Babiloni, Guijarro, Cardos 303). More simply put, this model is useful for periodic review if the goods in question don't go bad (due to spoilage, becoming quickly outdated, or seasonality) and one expects to remain in business for an extended amount of time (Babiloni, Guijarro, Cardos 303). The model's ability to accommodate backorders is also a plus as they are a part of many businesses' daily reality and therefore is necessary to address (Babiloni, Guijarro, Cardos 302). It is important to also note that if backorders are not possible in one's business, the Order Up to Model is still a viable option for an inventory management system, one can simply eliminate the part designed to account for backorders.

The Order Up to Model can be separated into two component parts; safety stock and cycle stock each of which preform an important role in the model. The safety stock functions as on could guess from the name alone, it is inventory that provides a buffer, or safety against the possibility of a stock out as shown in Figure 1 attached at the end (King 33). This is necessary because with very few exceptions, demand is random and therefore difficult to predict so it would be crazy to think that one could accurately and consistently order exactly the right amount of inventory to meet a business's needs with no inventory left over (King 34). Safety stock allows for this random variation in demand and reduces the possibility of a stock out by holding more inventory than is forecasted as necessary for the period (Estep 4). This is not just a random or flat number either, in this model safety stock is calculated through the use of the desired cycle service level or fill rate (the difference between these two will be discussed in the next section), the standard deviation of the demand across the review time plus the lead time (called the protection period), length of the review period, and the lead time (King 34). The lead time and stock level/fill rate are both very influential on the safety stock level in this model as the service level/fill rate signifies how acceptable stock outs are and the safety stock must be sufficient to cover variation across the entire protection period so the longer this period is the higher the safety stock level needs to be (King 35). The cycle service level should be chosen carefully as the inventory level necessary to satisfy a customer service level is an exponential function and increases steeply as it approaches 100% as can be seen in Graph 1 attached at the end of the document (Estep 9). Therefore, before choosing a high service level it is necessary to compare the holding costs of the inventory to the cost of a stock out when using cycle service level to optimize the model. In the Order Up to Model the safety stock essentially functions as a suggested minimum inventory level. It is ok to dip below this level, that's what it's for, but if a manager finds themselves stocking out more than expected or getting to the end of their safety stock frequently or never dipping into the safety stock at all, they should reevaluate their demand forecasting, service level/fill rate, and recheck the model to ensure it is using the most accurate and recent data as they are probably either holding too much or too little inventory.

The cycle stock level is simply the amount of the inventory expected to be sold in the protection period (Estep 3). This is calculated with the use of the average demand over the protection interval and is then added to the safety stock calculation to create a theoretical max for the inventory based on the model (Krajewski, Ritzman, & Malhorta 2016 327). At no point should one's inventory position (On-Hand + In-Transit – Back Orders) be greater than the cycle stock level plus the safety stock as according to the model, this is the maximum amount of inventory necessary to satisfy one's desired service level or fill rate (Krajewski, Ritzman, & Malhorta 2016 327). The combination of the cycle stock level and the safety stock is referred to as the Order Up to Level as the model operates by subtracting the inventory position at the time of review from the Order Up to Level to create an order quantity that is then placed for that amount (Krajewski, Ritzman, & Malhorta 2016 328). The intuitiveness of this model is appealing however since it does not directly account for the costs of stock outs or holding costs directly within the model, instead asking the user to account for this in the service level/fill rate selection, there is an increased chance of holding too much or too little inventory with this system.

Fill Rate vs Service Level

As previously discussed the selection of a cycle service level or a fill rate is very important in the Order Up to Model and they sound similar so what is the difference? While both are measures of customer fulfillment, they are quite different. Cycle service level answers the question of how often was there a stock out or not (King 34). So a cycle service level of 95% for example means that an inventory manager would expect to stock-out 5% of the time so if the system were implanted and used for 100 weeks a stock out would be expected in five of those weeks. Fill rate is different in that it shows much was filled vs how much was ordered (King 35).

A very basic example of this would be is there was an inventory reviewed once a week of 100 items and demand for that week was 105 items then the fill rate was $\frac{Initial\ Inventory - Demand\ in\ Excess\ of\ Inventory}{Initial\ Inventory}$ so in this case $\frac{100-(105-100)}{100}$ which works out to be a fill rate of 95% (Babiloni, Guijarro, Cardos 301). Despite ultimately arriving at the same percentage for both cycle service level and fill rate, they were calculated in very different ways and present different information. The cycle service level did not inform the user of the amount of sales lost or how long or impactful the stock out really was. There could be 100 lost potential sales due to the stock out or it could have occurred a minute before the resupply but both would be marked in the same way. However, fill rate requires more data and time to calculate in addition to being more prone to factor in unusual or one time spikes in demand and therefore result in higher than necessary inventory level for the true fill rate resulting in unnecessary holding costs (Babiloni, Guijarro, Cardos 301).

Single Tier Q System

One of the biggest differences in P and Q systems, aside from the obvious difference in the frequency of reviews, is that order sizes in P systems are variable whereas the order size in a Q system is set at a fixed quantity due to the fact the order is always placed at a certain inventory position. Ideally this fact can be leveraged into quantity discounts since orders can be consistent in their size and larger than those done on a P system, especially one with frequent reviews (Krajewski, Ritzman, & Malhorta 2016 328). Unlike the P systems where there was both the Order Up to Model and the Newsvendor model, the Q system is more adaptable and the principle of the system remain the same. The Q system can handle both lead time and demand being constant (pretty unrealistic in terms of real world application), consistent lead time coupled with variable demand, and both as variable parameters (Krajewski, Ritzman, & Malhorta 2016 320-

324). Throughout the model though, there is always a reorder point that is calculated and safety stock that is used to accommodate variability (Krajewski, Ritzman, & Malhorta 2016 320-324).

When calculating R and placing orders it is important to account for the fact that this is not based off just the on-hand inventory but also that which is in-transit so a manager should not panic and order more; if the system is being used correctly, there's probably some already on the way. The reorder point is calculated by multiplying average demand during the lead time by the lead time (or average lead time for variable lead times) and adding this product to the safety stock (Krajewski, Ritzman, & Malhorta 2016 320-324). The safety stock calculation is similar in that one of the biggest drivers of this safety stock is the selection of the cycle service level/fill rate as the formula for reorder point with constant lead time is $number\ of\ standard\ deviations\ needed\ to\ meet\ service\ level *$ $standard\ deviation\ of\ demand\ during\ the\ lead\ time$ (Krajewski, Ritzman, & Malhorta 2016 323). When calculating a reorder point based on a system based on both variable demand and variable lead time $standard\ deviations\ to\ meet\ service\ level * \surd($ $⟦average\ lead\ time * standard\ deviation\ of\ demand⟧\ \hat{}2 +$ $⟦aveage\ demand\ during\ lead\ time * standard\ devaition\ lead\ time⟧\ \hat{}2\ )$, clearly much more complex in order to account for this increased variation (Krajewski, Ritzman, & Malhorta 2016 324). Therefore, the increased uncertainty in the latter scenario means that the safety stock is going to be higher when compared to the former even with all other aspects remaining identical.

One of the best ways to visualize how this model really works is by envisioning all of the inventory in two distinct groups or bins with the idea being that as soon as one bin is depleted an order is placed for another bin of the exact same time (Krajewski, Ritzman, & Malhorta 2016

324). That way the inventory position is always 2 bins worth and orders are always placed in the quantity of one bin once the inventory in a bin has been depleted. Clearly this is just an crude approximation of how the model works in theory as the vast majority of products would be much too large to hold and this two bin system would hold much more inventory than specified by the model creating significant issues for all items that are not both small and with insignificant holding costs. Still it is an effective tool for helping wrap one's mind around the general idea of the concept.

Hybrid Systems

There are also a couple single tier inventory management systems that marry aspects of both P and Q systems, primarily the Optional Replenishment system and the Base-Stock system. This further permits a manager to match their inventory's characteristics with a system that will minimize the total costs. While these two systems allow a user more flexibility by presenting alternatives to P and Q systems, they provide very specific benefits and thence are best for only certain types of inventory, limiting their general usefulness.

Optional Replenishment System

The Optional Replenishment System is basically a P system with one or two Q system characteristics mixed in. In this system, periodic reviews are conducted but in a major break with the Order Up to Model, orders are not placed at the end of each review (Krajewski, Ritzman, & Malhorta 2016 329). Instead orders are placed if and only if the inventory position has dropped below a preset minimum level essentially functioning as a Q system reorder point (Krajewski, Ritzman, & Malhorta 2016 329). This order is then sized to be just big enough to account for expected demand until at least the next review with the amount of inventory remaining below this minimum level functioning as the safety stock for the system. This allows for larger order sizes and less frequent deliveries than would occur under the Order Up to Model making this a good model for inventories with high ordering costs. Additionally, the ability to use a reorder point while not perpetually reviewing the inventory system helps eliminate review costs as well, making this inventory control system particularly well suited to goods and inventories with both high ordering and review costs (Krajewski, Ritzman, & Malhorta 2016 329). This is especially true for bulk goods like chemicals as they can be difficult to assess as inventory with accuracy so continuous or very frequent reviews are unnecessary and unwise.

Base-Stock System

The idea behind a Base-Stock system is to hold the absolute lowest inventory position possible without sacrificing one's fill rate or service level (*On Exact Calculation* 196). This system is best for very expensive items with high holding costs as the safety stock is razor thin and typically orders are very small and placed very soon after an item leaves the inventory if not immediately (Krajewski, Ritzman, & Malhorta 2016 329). In a Base-Stock system, one is essentially running a Q system but with a variable order size and with the reorder point equal to the maximum inventory position permitted by the system (*On Exact Calculation* 199). The base-stock level functions as this maximum and reorder point in this system and is normally set to the small safety stock level plus expected lead time across a given lead time, thereby minimizing cycle stock (*On Exact Calculation* 200). Due to this very low cycle stock level and the small safety stock level in addition to the relative frequency of the orders, this system is used mostly for expensive items to maximize cash flow within a business and reduce the possibility of overstocking (Krajewski, Ritzman, & Malhorta 2016 329).

Safety Stock Calculations

Safety Stock is a crucial part of every inventory management system because it helps businesses deal with the variation they see in demand. However, there is a fine line businesses must walk in order to have enough inventory to deal with this variation in order to meet their target cycle service level/fill rate and holding too much inventory and incurring unnecessarily high holding costs as a result. This is due in large part to the multiplicative effect of the service level/fill rate has on safety stock level and the diminishing returns of the higher stock levels as illustrated in Graph 1. The higher the service level/fill rate, the high the safety stock has to be to accommodate the greater, but rarer, variations in demand. At a certain point a business needs to make a decision on at what point a stock out is better for business than holding enough inventory to accommodate it and eating the resulting holding costs.

Given the importance of safety stock, it is no surprise that there are multiple ways that it can be calculated depending on one wants to address it. According to Alin Radasanu in his article *INVENTORY MANAGEMENT, SERVICE LEVEL AND SAFETY STOCK* there are four main method for calculating safety stock: the standard method, ultraconservative method, percentage method, and a statistical method (Radasanu 148-152). The standard method is the easiest to wrap one's head around as it is *Safety stock = safety factor * average replenishment lead time* assuming that demand is accurately approximated by a normal distribution (Radasanu 148). In this method, the safety factor is usually the amount of standard deviations from the mean that corresponds with a particular service level/fill rate as this covers how demand is expected while waiting for a new order and permits room for variation when combined with the expected lead time (Radasanu 148). The ultraconservative method creates an excess of stock and is therefore a method that is best for only incredibly unpredictable or absolutely necessary and critical items as it is computed by multiplying maximum daily consumption by maximum lead time to ensure that the worst-case scenario would be covered (Radasanu 148). The percentage method is predicated on the involvement of an experienced inventory manager trusted by the organization as they choose a safety factor between 20% and 40% based on experience and estimation to use in the equation *Safety stock = average consumption * average replenishment lead time *safety factor* (Radasanu 148-149). Clearly, if the inventory manager is incorrect in his guess, the company could suffer a rash of stock outs and lost profits or excess inventory and holding costs. The statistical method is perhaps the most complex method as it is derived through complex statistical derivations to create statistics-based equations varying according to the exact inventory characteristics and business needs of the company (Radasanu 149-152). There are options for minimizing safety stock level while meeting service levels with both independent lead time and demand, $\textbf{Safety stock} = \mathbf{Z} * \sqrt{\left(\frac{LT}{T} * \sigma_D^2\right) + \left(\sigma_{LT} * \mathbf{D}_{\text{avg}}\right)^2}$ as well as for the same parameters in a non-independent scenario: $\textbf{Safety stock} = \left(\mathbf{Z} * \sqrt{\frac{LT}{T}} * \sigma_D\right) + \left(\mathbf{Z} * \sigma_{LT} * \mathbf{D}_{\text{avg}}\right)$ (Radasanu 151-152).

Incorporating Seasonality

Seasonality is an important inventory characteristic that is not inherently addressed by these single tier inventory management models but is certainly an important variable to account for. This can be accomplished by combining these models with a seasonality measurement to create a seasonally adjusted inventory management model. Without seasonality, these inventory models output a single recommended inventory level that is theoretically accurate across a whole year which is useful but does not account for patterns across a period, which is referred to as seasonality (Estep 13). This means that in periods of high demand, one is likely to see stock outs at a higher rate than the target service level and is likely to waste money holding excess inventory in periods of lower demand. Applying a seasonality factor helps address this problem.

The oldest method of applying seasonality is known as Winter's Model (Estep 13). While this model is known to be less accurate than other methods the easiness to understand and use this model keeps it in use today (Estep 13). This model is applied by compiling several years of demand or sales data and finding an average demand of each period and dividing this average by the expected demand for the period if there was no seasonality to create a seasonal index (Estep 13-14). This index for each period is then multiplied against the inventory level given by the inventory management model to create a seasonally adjusted inventory level for each desired period (Estep 14). If more information is available as well as the software to do so, regressions will return much more accurate seasonal data that can then be applied to the level returned by the model (Estep 14). The idea of dividing data out into discrete periods remains the same but more complex calculations are applied to return more accurate and therefore more useful information, one of the premier regression models in this regard is the Fourier Seasonal Profiles but all regression work in the same way, they create the best fit for each point based on previous years' data (Estep 14). In the end, it is important to include seasonality in order to account for this reoccurring fluctuations in demand and prevent excess inventory or stock outs and there are different ways to calculate this based on the businesses time and monetary constraints.

Conclusion

In summary, it is a mistake to assume that single tier inventory management systems are obsolete in today's complex, globalized world. These systems can be adjusted to fit just about every inventory characteristic and provide managers with a great wealth of tools with which they can attempt to minimize their overall inventory. From the Newsvendor Model to the Base-Stock system there is certainly a model that can be used as either inventory control system in and of itself or as a benchmark to measure more advanced systems and the internal steps and logic of those processes. No matter what the business is, it could find a use for a single tier system somewhere.

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Graphs

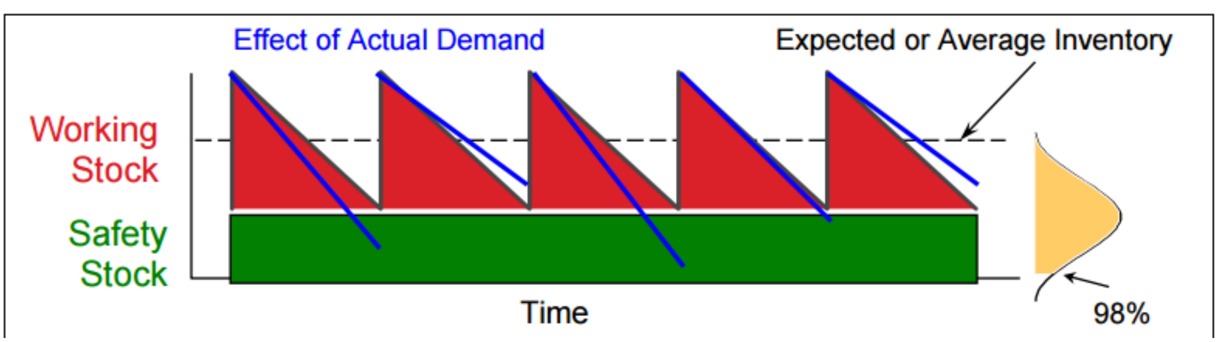
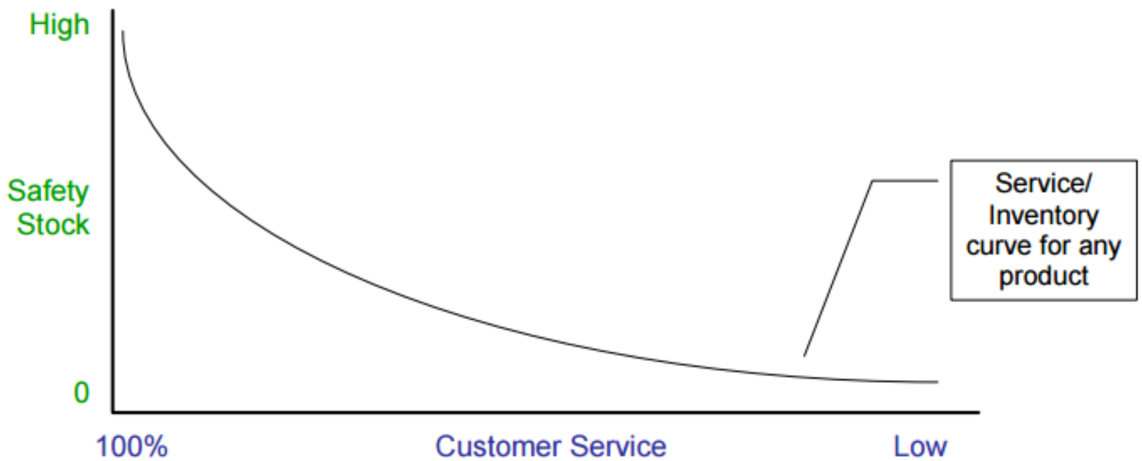


Figure 1 Demonstration of Safety Stock (Estep 4)



Graph 1 Safety Stock needed to satisfy a given Customer Service Level