

Lost Sales

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***Abstract** The typical way service level is measured in industry is the demand filled over total demand. Unfilled demand becomes a backorder or lost sales. Lost sales demand is often not known or measured by the management. This paper shows how to estimate the lost sales demand, how to control the lost sales and how to measure an effective service level.*

Introduction

Most companies are unaware of the amount of lost sales that they incur and have no way to measure this important demand. This paper formulates a lost sales model and shows how to measure this demand and also how to limit and control the lost sales. The basic formulation of this paper comes from [7] where the relationship between demands, service levels, backorders and lost sales are defined.

One of the key measures that management uses to gauge their inventory performance is by way of the service level. A common way to measure the service level (sl) is the ratio of (demand filled) over the (recorded demand). This measure is also referred as the percent fill. Generally a service level of .95 or higher is sought by the management. The reported measure of service level is often computed over all or a portion of the parts in the inventory and for a particular time period as one week, one month or one year.

A fault in the above measure of the service level is that sometimes not all of the demand on the items are known or are recorded. This happens when a customer has need for an item and the item is not available in stock and the sale is lost. Here the demand is not satisfied and this unfilled demand becomes either a backorder or a lost sale. It is a backorder when the customer will wait for the stock to be replenished whereby the demand is subsequently filled. It is a lost sale when the customer does not wait for the stock to be replenished and drops the demand. In this latter case, the demand is mostly not recorded.

References [1,2,4,5,6] show how to set the safety stock to yield a desired service level. The difficulty is that the definition on the service level is not always the same from company to company. References [2,6] give methods on how to set the safety stock when the criteria is to minimize the lost sales or the backorders.

The demand model

Consider the demands associated with a stocking facility that are obtained from the total demands for a fixed period of time (here called a review time) and the total demands over a category of items. Often the only demands known are those that are recorded as sales. But the total of demands could be classified in more detail. This model uses such categories as filled demands, unfilled demands, backorder demands, lost sales demands and effective demands. This demand model identifies the category of demands and shows how they are related and how they can be measured.

The demand model also describes the service level (demand filled over total demand) and how it is related to the demand categories in the model. Some stocking facilities measure and know exactly what their service level is over all the items and over a review time. Other facilities do not measure or know this measure. In the typical industrial systems to control the inventory, the service level is set and the safety stock needed is determined accordingly. Some companies measure and know the service level they are achieving and some do not. The FIRM industrial system [3] is very accommodating since with each run, it

allows the management to set the service level to achieve, measures the current service level and also measures the lost sales of the stocking facility.

Below is a review on the various category of demands, the service level and also on the percent of unfilled demands that become backorders.

Demand categories The recorded demand (dr) is the aggregate of customer demands that is ultimately filled by a stocking facility over a period of time (year, month) and for a category of items (parts, products). The quantity could be stated in units of pieces, dollars or lines. This demand is from the customer orders that comes in and are filled immediately (df) and also from the customer orders that are not filled immediately and are placed on backorder and are filled ultimately (dbo). Note another category of demand is when the customer orders are not filled immediately and the customers cancel the order. This latter demand is here called the lost sales demand (dls). In this model, the total demand recorded is derived from $dr = (df + dbo)$ and does not include the lost sales demand. In most situations, the lost sales demands (dls) are not recorded or known. All the demands noted here are in the same units (pieces, dollars or lines).

Service level The service level (sl) is a measure of the portion of the demands that are immediately filled from the stock available. This measure is an aggregate over all the items in the category and over the time period under review. This is obtained by $sl = (df / dr)$. Notice the lost sales demand is not included here since this demand is really not known. In essence, dr is not the total demand, it is only the demand that is known and for convenience here, it is called the total demand recorded. In the event the lost sales demand (dls) was known, the real total demand would be known. For convenience here, this total demand is denoted as the total effective demand (de). This would be $de = (df + dbo + dls)$. In this paper, the service level associated with the effective demand is called the effective service level and is computed by $sle = (df / de)$.

Backorder portion of the unfilled demands This factor is really not known by the management and is like a probability with a value falling between zero and one. Although the exact value of this factor is not known, most managements can provide fairly good estimates. When a customer order comes in and the stock is not available to fill the order, the customer order is unfilled demand (du) and the customer order becomes either a backorder or a lost sales. So, pbo is the portion of the unfilled demand that becomes a backorder. This is $pbo = (dbo / du)$. The portion of the unfilled demand that becomes a lost sales thereby is derived from $pls = (dls / du)$. Note where $pbo + pls = 1$.

So using only the data typically known for a stocking facility (dr, sl, pbo), the other measures described above can be determined. This is in the following way.

$df = sl \times dr$	= demand filled (immediately)
$pls = 1 - pbo$	= portion of unfilled demand that becomes a lost sale
$dbo = dr - df$	= backorder demand
$dls = dbo \times (pls / pbo)$	= lost sales demand
$du = dbo + dls$	= unfilled demand
$de = df + du$	= effective (total) demand
$sle = df / de$	= effective service level

Example 1 Consider a location where the annual sales is \$1,000,000 and the service level is measured as 0.90. The management estimates that 50% of unfilled demands are lost and 50% go on backorder and is ultimately filled. With the notation of this paper we have:

$dr = 1,000,000$	= demand recorded
$sl = 0.90$	= service level
$pbo = 0.50$	= portion of unfilled demand that becomes a backorder

Now using the relations given above, the following measures are computed:

$df = sl \times dr$	= 900,000	= demand filled immediately
$pls = 1 - pbo$	= 0.50	= portion of unfilled demand that becomes a lost sale
$dbo = dr - df$	= 100,000	= backorder demand
$dls = dbo \times (pls / pbo)$	= 100,000	= lost sales demand
$du = dbo + dls$	= 200,000	= unfilled demand
$de = df + du$	= 1,100,000	= effective total demand
$sle = df / de$	= 0.818	= effective service level

Hence, when the service level is set to $sl = 0.90$, the annual lost sales is \$100,000 and the effective service level is 0.818.

The lost sales model Using the structure from the model presented above, it is possible for the management to specify a limit on the lost sales demand (dls) and then find the service level (sl) that is needed to accomplish this goal.

In reviewing the above demand model, the data that remains constant regardless of the setting of the service level (sl) are the effective demand (de) and the portion of backorders (pbo) from unfilled demand.. First note the effective demand is $de = (df + du)$ and although df and du will change with sl, the sum (de) remains the same. Hence, de is a constant. Further, the portion of backorders and the portion of lost sales from unfilled demands (pbo, pls) are not related to the service level. So now (de, pbo, pls) are constants and are included as data available to carry on the lost sales model. A list of the known data are below:

dls	= (specified) lost sales demand
de	= effective demand
pbo	= portion of backorders from unfilled demands
pls	= portion of lost sales from unfilled demands

Continuing with the model, the following relations lead to finding the service level (sl) needed to achieve the goal specified on lost sales demand (dls).

$dbo = dls \times pbo/pls$	= backorder demand
$du = dbo + dls$	= unfilled demand
$df = de - du$	= filled demand
$sle = df / de$	= effective service level
$dr = df + dbo$	= recorded demand
$sl = df / dr$	= service level

Example 2 Continuing with the earlier example, $de = 1,100,000$, $pbo = 0.50$, and $pls = 0.50$ are known. Suppose management also sets a goal on the lost sales demand to $dls = 40,000$ (for 50,000). So now the computations to find the service level (sl) are the following:

$dbo = dls \times pbo/pls$	= 40,000	= backorder demand
$du = dbo + dls$	= 80,000	= unfilled demand
$df = de - du$	= 1,020,000	= filled demand
$sle = df / de$	= 0.927	= effective service level
$dr = df + dbo$	= 1,060,000	= recorded demand
$sl = df / dr$	= 0.962	= service level

The results show when the goal on lost sales demand is set to $dls = 40,000$, the service level needed to achieve this goal becomes $sl = 0.962$. Further, the effective service level is $sle = 0.927$.

Summary

This paper concerns the demands, service level and lost sales that are incurred in an inventory stocking facility over a category of items (parts, products). The demands are classified as recorded demands, unfilled demands, backorder demands, lost sales demands and effective demands. The service level and the

effective service level are described and methods to measure are shown. A way to measure the lost sales demand is given and a method to control this demand is shown.

References:

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