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Sales and Operation Planning

Optimizing and Scheduling production plans

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Abstract

Thesis presents the methods mainly used for Forecasting and Manufacturing plans. These methods were quantified and practically executed by many companies.

Many organizations are now too focused and believe that Sales is the most crucial department that generate revenue but forget that all the logistics and upstream parts are the strong legs for any companies to standup and move forward in the market competition. There are methods and formulas were plotted and discussions were unveiled in concrete that hopefully companies can perceive a precise picture about sales and operation planning as well as using appropriate procedures in a suitable situation

The work was done by discussing about many different Manufacturing planning controls environments as well as dynamic perspectives about each activity taking place within the MPC context. Furthermore, there were formulas introduced and examined for Forecasting, Master Production Schedule and Materials Requirement Planning.

Based on the methods were tested for the processes, an integrated view can be understood as Forecasting uses information from Demand management to generate predictions for future demand, which then consumed by the Master Production Schedule for finished items. Next, Materials Requirement Planning will according to the proposals derived from MPS that create another strategy for sub-assemblies and components.

The entire integrated procedure and mathematical calculations and optimization were executed in Excel spreadsheet and applied the methods to help an SME bike company with the manufacturing plans.

Keywords/tags (subjects)

Miscellaneous (Confidential information)

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1 Introduction

As a manufacturing organization, regardless what kind of product or services that has been executed, anticipating the future needs or specific occasions is a challenging duty. However, comprehending self capability so that all the demand, especially the exigency ones are fulfilled efficiently and economically is even more arduous. It requires a particular expertise method / field which encompasses all these perspectives and activities generally taking place in a supply chain – Sales and Operation Planning. A company has an effective and consistent SOP process will be ensured to run smoothly and reward a profitable business.

Acquiring an adequate availability and fast delivery time are the keys that certainly satisfy customers. They tends to be more knowledgable and volatile than before, since there are many choices in the same market area that possibly they will switch whenever they feel unpleased, which probably bring a lot of uncertainties to any business. On the other hands, every organization has been encountering with a high pressure in cost efficiency, which leads to the differences in operating processes as well as strategies used to reach their own customer segmentation such as low inventory, lean and agile, or higher researching and contacting with customers and the market in overal. A good SOP process will reliably assists a company, specifically the C-suite, in making better decisions that balancing the business profitablity (dealing with costs issues) and customer satisfaction; more importantly, balancing the supply and demand which is a compromise between internal capability and future customers ordering's forecast.

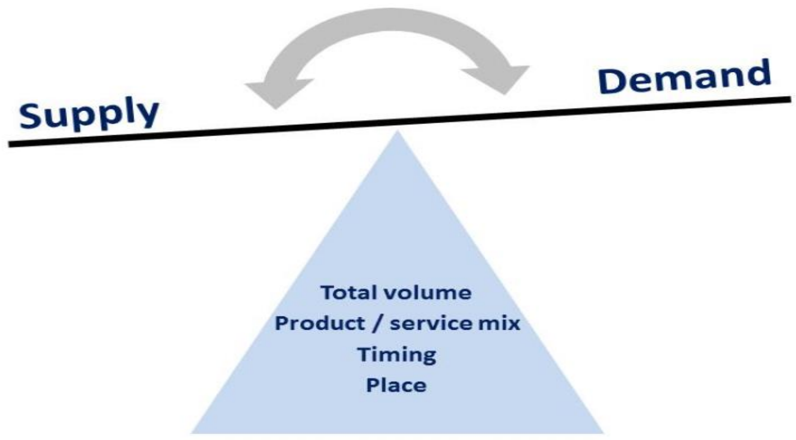


Figure 1: Balancing Supply and Demand

Decisions are made based on credent common understanding and information communicating between supply chain involved parties, especially between different departments and functions within a company. SOP will support the information visibility and assure all the parties and silos in generating the mutual understanding as well as goals, expected future demand, uncertainties or seasonal variances will be indentified consensually.

As the matter of fact, regardless what kind of products or services are orderd, there will be involving a complex set of activities from upstream to downstream in order to meet the needs at the right time, right place at right price.

Figure 2: Activities involved in suppy chain

At downstream, a company needs to get associated with customers and the related market as much as possible in order to penetrate deeper and get a better understanding, which extremely crucial for the accuracy of information that dictate the follow through processes such as demand management and forecasting. At upstream, company has to find the balance between capability and the future forecasting so that costs would be under controlled while customers's demands are still executable. It heavily requires many optimazations and intergrations through out processes. The optimal output from any activity will be used to calculate as an input for the next one, depends on type of supply chain, backward or upward. Any methods manipulated, at the end of the day, it is vital for any organization to apply and develop an effective SOP process that streamline all the connected activities, gaining better visiblity which thankfully guild them to finer decisions that lower the costs as much as possible while capable of maintaining a certain level of satisfied customers, evetually get them a considerable competitive advantage in a long run in such fierce environment.

2 Motivations and Objectives

In the fast-changing supply chain environment, companies have been confronting with many fierce situations concerning extreme variation in demand that driven by many factors. Therefore, balancing the supply source to fulfill the customers' needs is substantially crucial than ever. Essentially, the chain is manageable by efficiently controlling the manufacturing plan with the predicted sales. Specifically, demand will be relatively predicted in advance in the persistence of carry out a sufficient amount of stock as well as fully apprehend the downstream by appropriately address the customers' needs and historical sales evaluation from which valuable data will be derived.

In fact, synchronize the entire supply chain is never effortless, there must be an absolute integration and strictly constant communication required so that all the departments are aware of the ongoing case. Forecasting must generate suitable and approximately accurate models which acts as an input for Sales and Operation Planning in which the vital Master Production Schedule taking place. In addition, MPS will result in the level of desired inventory and safety stock, also, it is a communication between production planning and sales, smoothly run these functions possibly gain a huge advantage in the market, increase the production utilization by prior knowledge about future demand, flexibly meet the unexpected one as well as retrieve a massive amount of revenue for any company.

This thesis elaborates many procedures in the context of Sales and Operation planning; to be more specific, it examines the several sets of useful functions and formulas in term of Forecasting, optimization in Master Production Schedule and Materials Requirement Planning analysis that certainly assist companies in hunger for specific and proper perspectives in supply chain. Companies will gain a precise vision about how products are calculated and accomplished in the entire processes before arriving to customers.

3 Methods

The methodology implemented in the thesis is desk research. According to Management study guide, desk research is the technique of acquiring information dominantly from online, books and articles. Desk research can be considered as the most economical methodology to particularly collect any set of data, also, it can be extremely effective if an executer has an adequate knowledge on the investigating field. All the text and formulas will be exploited mainly via reliable sources of articles, books and reputative supply chain management online courses. (Management Study Guide, 2008).

4 Manufacturing and planning control system

Obviously, the manufacturing and planning control (MPC) system is concerned with planning and controlling all the related activities that happening in the manufacturing process. The direction of these activities will be according to the strategic business plan of that company in a certain period of time, that consist of managing inventory levels, controlling all the materials, scheduling people, arranging machines, intensifying the relationships with supplier and key customers. These activities are not static but could be flexible and modified based on the market environment, seasonal demand. An effective MPC system allows a company to be always one step ahead with the market changes, ensure competitive advantages gained.

According to ‘’Manufacturing and planning control’’ by Robert Jacobs, Thomas Vollman, the essential task of the MPC system is to manage efficiently and proficiently flow of materials, control and utilize the human resources and equipment, and to respond as fast as possible to customers by utilize the internal own capacity and facility as well as from our suppliers. Besides that, there are many important sub-activities such as gathering the information of the manufacturing process so that calculation and notification about delivery date for customers will be made. Noticeably, there is a confusion and misunderstanding, MPC does not control the operations or make effective decisions itself, in fact, an efficient MPC system provides managers an exquisite tool for a superior diverse dominance over processes, as well as assist them with a wiser visibility, that they can exhibit finer decisions. (Thomas Vollman 2011, 2-5).

4.1 General support activities from MPC.

The assistance in activities matter in supply chain of MPC can be split into 3-time horizons: long term, medium term and short term.

Figure 3: MPC Planning activities

In the long term, MPC will provides all the information to make decisions according to the current situation of internal capacity, which includes people, equipment, materials, suppliers and so forth, to meet the sales plan in the future according to forecasting. In this period, many parameters will be set based on these decisions such as flexibility or level of service. Furthermore, long term planning will give a company an important comprehensive overview about whether or not the combination between human resources capabilities, equipment and technology utilization, or even geographical locations are appropriate for a long run competition. Also, the internal facility and capabilities have to be well-designed since it is going to have a huge influence on many future events, such things could not be changed or replaced easily and immediately. On the other hand, companies using outsourcing have to be even more careful in picking the right suppliers. Planning suppliers' capacity is even more critical, it requires a tight relationship as well as an efficient integrated communication so that all the data are available and managed effectively and explicitly (VMI could be an example in this case). In anyway, capabilities have to be assured and customers' demand ought to be identified accurately, also, market research has to be taken into account seriously and repeatedly, these affairs dictate the strategies and capacities for MPC system in whole.

In the intermediate term, the balance between supply and demand will be the main concentration. Once the future demand has been calculated, the exact amount of materials and production capacity must be clearly clarified in order to identify and optimize backwardly when and how many should the items are made, or ancillary/raw materials orders from suppliers should be placed. This process has a substantial impact on the entire operation, because if there is an unidentified imbalance take place during the processes, either there are customers will not be satisfied or aggressive unplanned overtime will be announced in order to chase the demand, both mentioned consequences are extremely costly, especially in a long run. Another job that is part of an intermediate term is providing customers a candid information about expected delivery date as well as communicating to suppliers the correct quantities and date of arrival of those materials they supply. Any steps that happen in this period mismatched can lead to a disaster, so that MPC is a bonding tool which correspond and coordinate all the information flow and planning capacities that everything will be smoothly manipulated and executed.

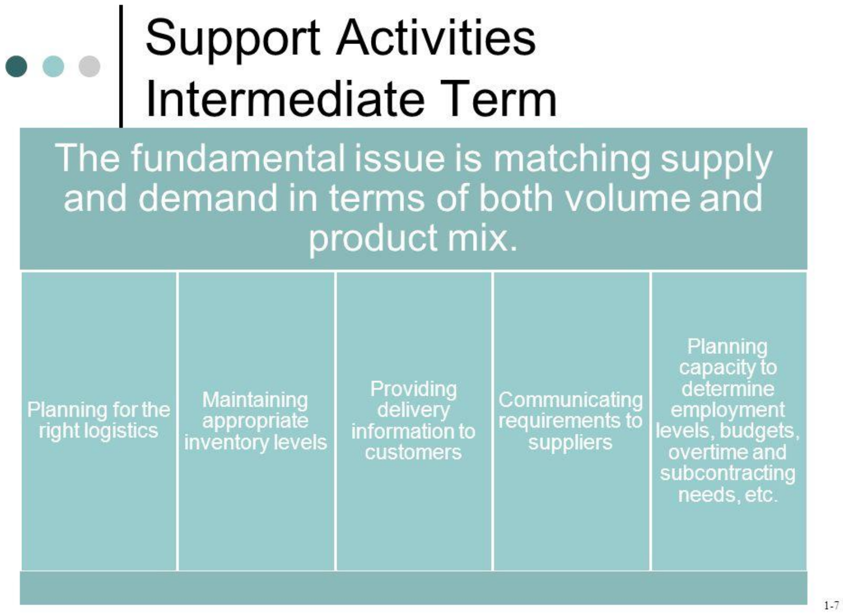


Figure 4: Intermediate term activities

In the short term, the detailed scheduling of resources as well as capacity will be concretely determined and modified if needed to meet to production plans. The capacity mentioned above includes time in months, weeks or even days, human resources, shifts, materials, facilities. The importance in this period is arranging people controlling right equipment doing right things. As all the activities and processes taking place everyday. MPC is responsible for keep tracking all the materials and resources availability, as well as its consumption, utilization and customers orders completion rate, and all the other parameters that measure the manufacturing performance. If there is any exceptional case occur, such as customers are more aware of the instability that force them change their mind, or in converse case, they unexpectedly order more, MPC has to issue the information immediately to top-tier managers, suppliers and even to customers about current circumstances, so that resolutions, on-time communication and modifications could be undergone. (Thomas Vollman 2011).

	A	B	C	D	E	F	G	H	Q	R	S
1	**Materials Requirements Planning**										
2	Name:		PQR								
3	Horizon:		12	**Master Production Schedule**							
4	MPS:		3	Independent Demand		1	2	3	12		Demand
5	Parts:		12	P-400		120	70	70	150	P-400	105
6	Interest:		0.001	Q-450		0	10	70	10	Q-450	41.667
7				R-250		40	90	10	110	R-250	62.5
8											
9	Part No.		P-400	Period		1	2	3	12	Part	P-400
10	Level		0	Gross Requirements		120	70	70	150	Demand Rate	105
11	BOM Parts	PP	1	Scheduled Receipts		0	0	0	0	Setup Cost	200
12		300	1	Projected On-hand	130	10	0	0	0	Holding Cost	0.205
13		350	1	Net Requirements		0	60	70	150	Avg. WIP & OH	190
14	Lead Time		1	Planned Order Receipts		0	310	0	0	Avg. Setups	0.3333
15	Lot Method	FOP	3	Planned Order Releases	0	310	0	0	0	Inv. Cost	105.62
16	Cost Added		0	Inventory On Hand	130	10	250	180	0	EOQ	453
17	Unit Cost		205	Work in Process	0	310	0	0	0	EOP	4

Figure 5: Basic MRP

4.2 Main MPC Framework.

When it comes to detailed jobs at specific stages, there is a framework for MPC, which has been evolved throughout time in knowledge, technology, unstable markets. The MPC now has been getting involved by more departments and silos within a firm to meet the strategies. However, many essential tasks that construct the frame for MPC still required to be performed similarly, just more optimally.

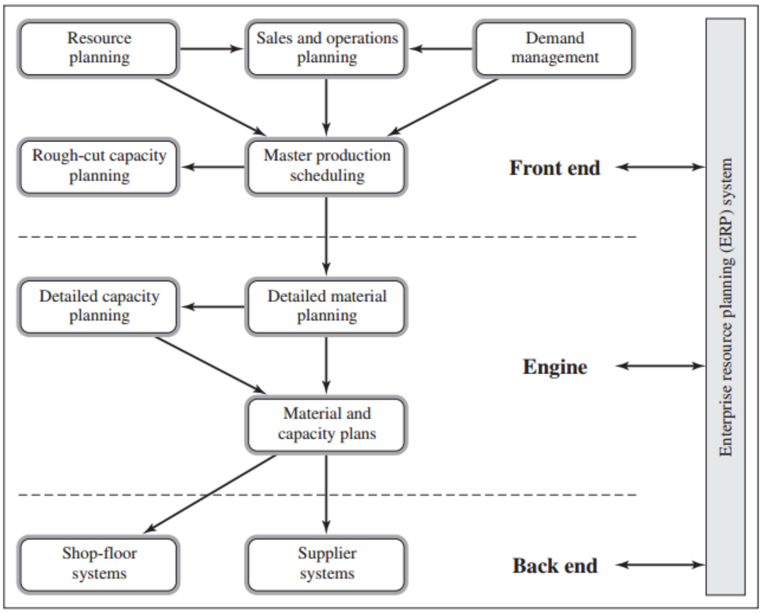


Figure 6: MPC Basic Framework (Thomas Vollman 2011, 4)

The figure above is basically a set of essential activities that performed in MPC within a company. It is divided into 3 main parts: front end, engine and back end. The top third, or front end is set of activities that determine the overall direction of a company. Demand management includes forecasting of the customers or end products' demand, this step has to be perceived seriously since its output will dictate relatively everything. Furthermore, demand management specifies the order entry, spare parts and raw materials stipulation, workforce requirements, plant expansion decision and so forth. Essentially, demand management will provide information that coordinate and employ all the involving activities in manufacturing process.

When the demand is specifically identified, SOP will balance the sales plan and the manufacturing plan with the available resources in order to be the most optimal. Actual demand is repeatedly compared to the sales plan to make a better forecasting in the future, besides, marketing is also connected with the manufacturing and finance department for a finer plan. During this process, managers have to make many decisions in term of trades off between supply and demand so that it is balanced as much as possible, then it feeds the related issues to Master Production Schedule (MPS).

MPS is a process that concretely answer 2 questions: how many items should you make? And when do you make it to be the most optimal? The answers for these questions strategically require a production plan as well as optimization at individual end product. Furthermore, the process depends not only on manufacturing time but also lead times, the inventory on hand, etc... MPS provides a master schedule for specific products with configurations, dates and quantities. In this stage, capacity validity plays the most important role, since it is impossible to have a schedule that internal facility cannot deliver. Also, managers have to make a trade off between cost of profitability, they can employ more workload to offset the production in low season for the high ones. (Nguyen Kim Anh, 2015).

The middle third – engine, encompasses many activities that related to detailed planning for materials and capacity, so-called Material Resource Planning (MRP). The process uses bill of materials to determine that kind of raw materials, components do end products require to place orders for suppliers. It keeps tracking of current inventory status of each materials so that recommendations about replenishment time would be make, depends on strategies of a company that they can have low or high stocks.

The bottom third, or back end, depicts what happens next after MRP - detailed raw materials, components are classified and identified, those output would be an input for purchasing (supplier system) department. Purchasing, or procurement, is responsible for establishing and controlling the flow of materials. The level of complication and concreteness is high since in is directly involving individual components and orders, encompassing reviewing schedule and revising them as needed, at this stage, constant communication with involved parties is strictly necessary. The supplier system will be in charge placing orders to suppliers, also, the information about updated priority which based on current situation, from the company and maybe from customers, will be transmitted to suppliers. In many cases of close proximity in relationships between parties, information possibly includes future plans, or anticipations, which helpfully assist suppliers understand the comprehensive circumstances as well as expected demand. (NAV Insights. 2014).

In term of using MRP systems, the execution and calculation of materials and capacity involve straightly detailed scheduling of workforce, machines and other ancillary activities. The schedule must exhibit concrete real-time routine for each individual item as starting and finishing orders and manufacturing for parts, components and any problems that expectedly occur, such as breakdowns or downtimes. Real-time data are crucially important in manufacturing whose processes are complicated and relatively rigid to be instantly modified, also, customers' promising delivery time is a big object that consequently derived from it.

4.3 MPC system adapt in real fierce environment.

Obviously, there are many vital requirements for any MPC systems, however, those has been changing dependent on the nature of market, customers' expectation and the company itself. The MPC has to be integrated with other systems from different departments and silos within the company, so that it has to be well considered and designed in term of serving the overall objectives as a whole. The requirements are not static, they evolving/changing as a competitive environment; customers' satisfactions, a suitable way to measure the performance of system, including speed of delivery, products' reliability, cost, products' flexibility, and so forth. As an example, a company wants to expand their diversity of products offer, MPS and detailed MRP are severely required in order to be effective and time-saving; in addition, a company prioritizes the speed of delivery as an competitive advantage may be subjected to continuously enhance physical facility for smoother execution, and constantly researching/penetrating into current market to closely monitor and contact with customers. The value proposition is determined and basically driven by these factors, in other words, customers' satisfaction and the market environment are the crucial key that need to be adeptly examined, since these are the primary reasons lead change in MPC systems. (Thomas Vollman, 2011).

Beside these things, there are several significant reasons that force change in MPC, such as the development of technology, or outsourcing strategy. The present trend in technology results in more online data accessibility, it offers multiple advantages, especially between parties in a chain. Internet-based systems are becoming indispensable in a way of transmitting information and communicating between firms. As a result, the papers required when moving between departments or even companies is considerably decreases. Inventories information between partners are more inspectable with faster information flow, or even utterly controlled by others (VMI as an example). In the other hands, MPC has also react to physical changes internally taking place. Outsourcing probably transforming the way MPC traditionally work, it could be economically and efficient for companies if they can utilize Internet and technologies.

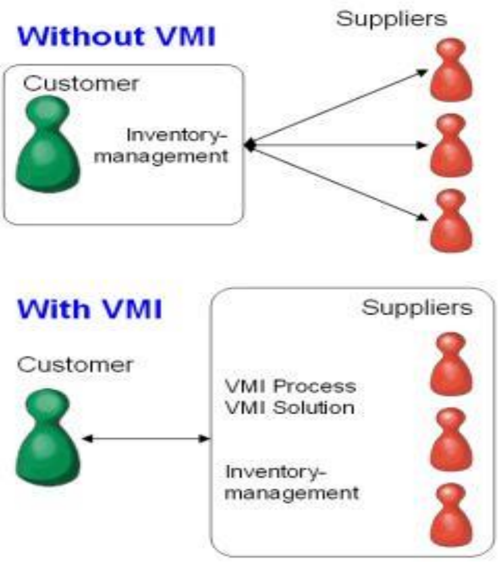


Figure 7: VMI systems

5 Demand management

There is an essential connection between upstream and downstream in supply chain in every company, which is so-called Demand management. It is considered as a key communication gateway in MPC; a conversion from customer demand to manufacturing plan. In this crucial stage, all the information is strategically gathered and computed such as forecasting customers demand, informing and placing orders, determining products quantity requirements and so forth. Furthermore, it takes place in this process that we contact and keep in touch with customers about the promising delivery date, order status and immediate notifications about changes when needed.

In fact, these activities that occur in this phase are extremely important since it dictates most of the following ones. For example, a company must well defined and anticipate the future demand, or analyze regularly between forecasting and actual demand so that explicit and understandable visions about market trends would be clearly pointed out, it directly has a massive influence on company's perspectives in which it perceives and studies about customers behaviors, or more importantly, it affects the way company is being maneuvered in term of capacity planning, geographical plant open/expansions and so forth. Also, planning and control process will be executed in this stage. (Romano Luca, May 2016).

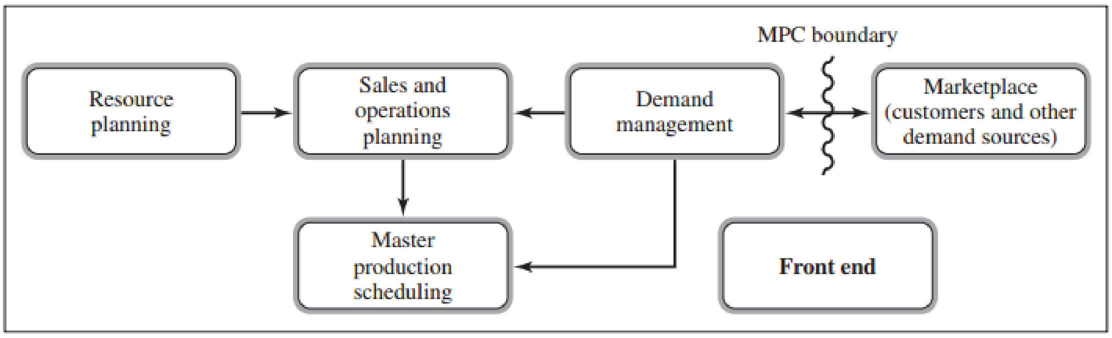


Figure 8: Demand management as a gateway in supply chain (Thomas Vollman 2011, 46).

Planning part involves determining the sufficient capacity and facility supposed to be available to fulfill the forecasted future customers demand, most of this step taken place in SOP process. On the other hands, controlling is the way that company manages to converse these prepared available capacity and workforce into actual manufacturing and eventually products are made on the right time at the right place. Moreover, in this controlling process, managers will have to evaluate the actual demand and forecast errors so that mandatory modifications will be pulled off. The majority of the controlling phase is conducted in Master Production Scheduling. Both SOP and MPS substantially require a reliable source of information that provided via demand management gateway.

In fact, there is a severe confusion and misunderstanding between 2 terms which are forecasting and planning. Forecasting is an anticipation and calculation for a pattern of demand in the future, in demand management, forecasting process might encompasses the quantities and timing of a certain amount of product, such as there will be a demand of 500 pieces of product A in June. On the other hand, planning is the strategy a company develops to response to these available estimations from forecasting. It means despite the forecasted amount of product is known, a company might execute different plans to achieve the goal, as long as the need is met appropriately, planning is usually for a long term, not for that month only. There are several important plan strategies such as chasing, which is trying to minimize the inventory and back orders by matching the production capacity with forecasted demand; leveling, the opposite with chasing, attempting to maintain a balance constant workforce and capacity consistently throughout a period of time, using built-up inventory to offset others; and lastly is hybrid, a combination of chasing and levelling, in this strategy, inventory is intelligently calculated to cover up few months, laying off workers in low season or hiring temporary ones to reinforce the capacity in high season is a rationale situation. (Thomas Vollman, 2011).

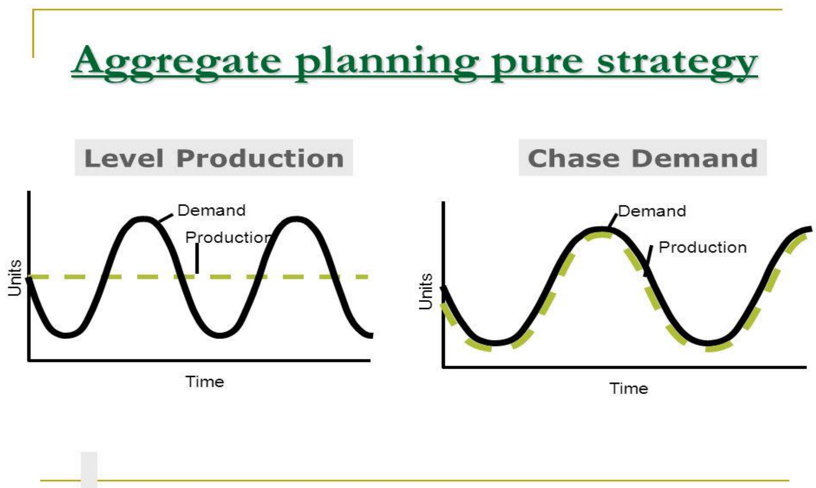


Figure 9: Level and Chase Strategy

Essentially, it is crucial to be aware of the distinction between forecasting and planning, there are 2 main reasons to state that. Firstly, a manager should not be blamed for a wrong forecasting, theoretically, forecasting is just an estimation/guess, however, a manager is certainly held responsible for choosing and directing the plan strategy. In an essence of MPC, forecasting is just a tool to provide managers the means and all the reliable as well as genuinely calculated information that helpfully assist them in coming up with executable plans. When the marketplace situation changes, the controlling department must be informed and changed flexibly as well. For example, a weatherman is hardly in charged for claiming there is rain today, as mentioned above, forecasting is just a computed assumption. Nevertheless, if the forecasting is rain, an intelligent plan would be carrying along an umbrella, if your plan is un-obey, it is nothing to feel sorry when you get wet. The plan and execution are controllable and changeable according to the essence of market circumstances, not the demand. And that is coordinated with the second reason of this point. The demands from customers is the independent demand, it means those demands are the decisions that derived from customers themselves which is out of company action. In fact, those demands could be somehow managed and influenced, such as via promotions, advertising, discounts incentives and so forth, still, the final call is relied utterly on them. On the other hands, if a company has computed and come up with a plan that 500 bicycles will be produced and delivered in July, all the components that assembled on it are dependent demands (1000 wheels, 500 frames are needed etc..). When there is something wrong, independent demands from customers could not be changed, instead, company has to examine it and figure out again a new plan that certainly ensured those demands are met, which obviously affect and construct a new dependent demand. (Thomass Vollman, 2011).

It is also important to diligently determine all sources of demand information, appropriately feeding forecasts for new products or market trends. Independent demands are both challenging and opportunity for any company, as long as techniques used are effective and sufficient. Collecting data and customer trends are the tasks that need to be carefully and seriously evaluated, flaws could lead to disaster outcomes, however, it is also a gateway that connect company with customers, assisting in penetrate deeper in marketplace. Understanding and comprehending own customer segmentation desires as well as embrace the interests in marketplace that could easily lift a company gain such massive competitive advantages in a long run. These processes are taken place cautiously in demand management module. The correlation between it and other planning sites such as SOP, MPS indicating the significance of a reliable information provision both for and from forecasting, affording the accuracy in details of any level in the manufacturing planning (raw materials, spare parts, facility, inventory, stock, marketing and so forth).

An efficient demand management system is a back bone of any profitable organization. However, it cannot happen in the way it wants to be, instead, the system must follow and comply with the business strategy to reach the final expected goal. Therefore, different strategies and environments result in differences of demand management procedures. In order to catch this difference, the broad classification of manufacturing environments is developed. The key for this classification is a concept of customer order decoupling point, or order penetration point.

This concept can be apprehended at the point which demands change from independent to dependent, also, this is the point where company make the decisions on the timing to place or make the orders in how many quantities. Let’s take a tailor shop as an example. If there is a customer walk into the shop and buy an available suit that from the racks, the order penetration point of this customer is finished goods, it means the decision to buy available suit from rack is independent, the fabric requirements to make that suit is dependent. On the other case, if the customer does not look at the available suit on the rack, but, the catalog of fabric is considered and make a request for the tailor to produce a specific suit, the order penetration point then is raw materials, it means the fabric demand is independent, since it is customer’s choice, but the raw materials that constructed is dependent. Moreover, customer may possibly ask the tailor to make the specific fabric base on specific raw materials, the order decoupling point in that case is supplier, on other words, customers request the tailor’s supplier to engineer specific raw materials for their own preference (raw materials is an independent demand).

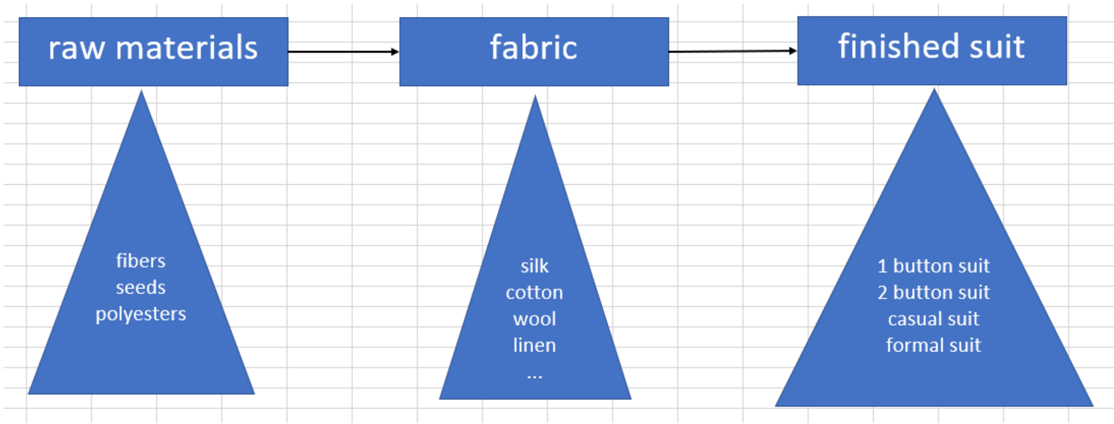


Figure 10: the materials that constructed a suit from raw to complete

In this example, both customer and suppliers have a considerable influence on the decisions of appearances that the suit the tailor manufactures might look like. The more backward the customer interfere into how the suit he/she wants to look like, the deeper that customer get involved in the tailor's supply chain. It moves from finished goods through all the way to even raw materials. The difference in customer decoupling points result in different manufacturing environments, which has a huge affect on the method company is run and strategy is directed.

Inventory location	Suppliers	Raw materials	Work-in-process (WIP) parts and components	Finished goods
Customer order decoupling point	△	△	△	△
Environment	Engineer-to-order (ETO)	Make-to-order (MTO)	Assemble-to-order (ATO)	Make-to-stock (MTS)

Figure 11: order penetration point defines different environments

A company that serves their customers from the available finished goods inventory is make-to-stock (making sandwiches, sewing finished clothes etc..). One that offer the opportunity to combine many options from work in process (WIP) or components to meet their specific preferences on goods is assemble-to-order (WIP such as fabric in the above example, the tailor will have to put together all the chosen ones according to customer's selection). One that manufacture customer's final products from raw materials is make-to order. And Engineer-to-order will work and discuss with customers the design a unique product that made from purchased raw materials, parts and components. In fact, many organizations will serve a mixed combination of these provisions and environments, but few will do it separately simultaneously.

5.1 Make-to-stock environment (Push system)

Essentially, they key activity of Demand management in make-to-stock environment is maintaining the finished goods inventories. In this circumstance, customers will purchase the products directly from the available ones, it means customer service KPI is determined by whether the wanted item is in stock or not. As the mentioned tailor example, inventory of finished goods are suits that available from the racks, however, unlike the tailor, the manufactured goods inventory of many big organizations maybe located very far from the manufacturing plant, furthermore, there are possibilities that they have multiple locations that customers can purchase the products, on other words, geographical dimensions and physical distributions have a massive influence on maintenance of finished goods inventory.

The crucial element for an efficient inventory maintenance is a determination of when to order in how much quantity, and how to replenish the stock in specific locations. This is a vital task that happen mostly in forecasting and physical distribution planning. In forecasting, demands for each location will be determined, also the amount of safety stock needed. Physical distribution will deal with problems regarding physical flows of goods to be the most cost-effective, deliver products to the right place at the right time in the right quantity. Management of this supply chain substantially requires the constant information on the status of inventory for various locations, strong relationships with transportation providers so that plans could be executed efficiently, and more importantly, updates from each area about customer's demand and actual sales so that forecasting can manipulate significantly the rest of operation.

The common issue in satisfying customer in this environment is the balance between the level of inventory/safety stock versus the level of customer service. If unlimited inventory can be kept in the warehouse costless, it would be insignificant and trivial. However. It is not the real case. Stocking more inventory apparently increases costs, hence, the trade-offs between the inventory cost and level of customer service must be implemented. Trade-offs could be enhanced by a better forecasting system so that future demand would have less risk, also, flexibility in transportation and production certainly gain a huge advantage. Depending on the level of customer service and the inventory costs a company willing to invest, different strategies would be considered, agile or lean manufacturing. Agile would undoubtedly "sacrifice" the inventory costs to utterly achieve the highest possible level of customer service (k factor could be more than 90%), on the other hand, lean strategy certainly focuses on eliminating all the wastes and redundant costs so that the organization and processes are streamlined and skimmed, that result in a lower level of customer service, but still, demands must be met appropriately. Regardless how the trade-offs decisions are made, or whatever strategy a company opt to follow, the main concentration of demand management in make-to-stock environment is on offering finished products to the right one in the right place at the right time. (Samantha Cook, John Pickett. 2007).

5.2 Assemble-to-order environment.

Imagine ourselves buying a laptop or want to assemble a personal computer, we might want to opt for the components, that availably offered such as RAM, hard disk, chip and so forth, for our finished one; that kind of form is assemble-to-order (ATO). In this environment, the primary and crucial task of Demand management is to determine the customer's orders so that their desires for final products is clarified.

There are many organizations manufacture the similar method as mentioned computer example. It is also significantly important to understand that components and options must be assured they can be physically combined as a whole goods, this activity can be known as configuration management, this is a critical step since there are actually many component and elements that impossibly assembled together. For example, in a car industry, it is not practical to install wheels for a passenger normal car into a sport car, that can probably cause many troubles while riding with a much powerful motor in high speed, also, it is unacceptably viable in term of beauty.

One of the capabilities that essential for success in this kind of circumstance is engineering so that as many components, options or modules can be combined as possible in a considerable wide flexibility. This environment also clearly points out the extreme request for strict communication between customers and firms (demand management department especially). Customers must inform the allowable desire for their final goods. The orders then are configured, and customers would receive notifications about the status as well as the promised delivery date. In ATO, the independent demand for the final item is transformed into dependent ones for those chosen components and parts. The important inventory, which dictates the customer level of service as well as potentially satisfy customers, is the inventory of components, not the one for finished products. the reason for that is rationale, number of finished products that can possibly combined is considerably greater that the number of parts. Consider again as a computer company, the permissible provisions encompass 4 chips alternatives, 3 hard disk options, 2 possible speaker systems and 5 monitors available. If the combinations of these all 14 parts are possible, it would be 120 different personal computers can be assembled. Obviously, maintaining 120 computers in inventory is much tougher and complicated than just 14 components which eventually have the same outcome. (Logistiikan Maailma. 2018).

5.3 Make-to-order (MTO) environment (Pull system)

The focus of demand management in the make-to-stock and assemble-to-order circumstances is substantially relied on inventory of finished products or components that potentially satisfy customers. However, in the make-to-order (MTO) case, there is another issue that must be seriously taken into account- engineering. Moving the customer order decoupling point to raw materials or even suppliers that provokes the independent demand penetrating further in organizations and consequently reduces the scope of dependent demand (since raw materials are independently picked by customers in this case). Unlike the buying methodology from customers of other two environments, determination of time and quantity, in MTO case, products are not identified yet, procedures of communication and information sharing between customers and the firm must be carefully executed, therefore, wishes and desires from customers' final products have to be translated into products specifications so that manufacturing department utterly understand and effectively conduct, on other words, the main duty of Demand management in MTO environment is collaborate and merge the customer's wanted product information and engineering capability. (Samantha Cook, John Pickett. 2007).

Engineering function means establishment a course of actions about type of materials required, steps that going to happen in manufacturing process and costs. Noticeably, the materials needed are not always available from the company's inventory, such situation flexibly requires purchasing, strong and constant relationships with suppliers incredibly assist in this moment.

5.4 Communication and Information from Demand management.

Regardless of the environments that organization are in, Demand management has a very crucial responsibility in term of internal and external communication, it plays a role as a middle gateway to circulate information through departments within a company. Forecasting information must be delivered and apprehended to Sales and Operation Planning. Similarly, details about future demands and orders must be provided to Master Production Scheduling, so that the manufacturing plan could be designed, promised delivery date then calculated and informed to customers.

Data exchange, operational plans and financial status are crucial for an effective collaboration through silos. According to Mouritsen et al (2013), information sharing and integration in demand management facilitate the business to visualize customer future demands, inventory situation, and manufacturing capacity. For example, SOP department will be noticed about demand forecasting information. Then, the operational strategies will be executed to fulfill the predicted needs, however, it is not that simple. Demand management and SOP have also communicating to each other constantly to determine not only the timing and quantity but also the resources required such as spare parts, raw materials, plants etc… to get a broad picture as well as comprehensive knowledge about manufacturing capabilities. (Mouritsen 2013)

Melo & Alcantara (2012) also emphasized the importance of sharing information between departments that stimulate the opportunity to reap the benefits from understanding and knowing individual potential and goals. It allows all the silos come together and endeavoring for mutual purposes. MPS requires the ultimate reliable information from demand management to get action, satisfy customers with the expected KPIs, in order to reach that, demand management has to do the market research, evaluation actual sales in order to come up with the approximately accurate figures to provide for MPS. All the departments certainly boosted when the circumstance comes to mutual-goal orientation. (Melo & Alcantara 2012).

5.5 Information used in Demand management

In Demand management, customer actual orders, forecasts, invoices, payments and even behaviors are consumed by order entry to the company system, which is used as the historical data. When the supply chain partnership is created between parties such as suppliers and customers, there is one mutual goal which is accelerate and expanse the competitiveness as a team, not for one company only. Alongside with the historical data that constantly updated and evaluated, it allows involved partners to operate with knowledge of other company's needs. For example, there are many cases that supplier has the forecasted demand, also the knowledge of some important customers such as their inventory status (when executing VMI) or production schedule. Those knowledges empower the relationships as well as enables suppliers to know and understand more deeply about their customers when orders are placed, this opportunity allows the less dependency on forecasts for further future production plans.

6 Forecasting

Essentially, supply chain management is all about matching the supply and demand, hence comprehending and being able to forecast the future demand is extremely critical. But before diving deeper into forecasting, let's take a quick look on the intimate coordination between demand and forecasting.

6.1 Demand exists Forecasting.

Importantly, always remember that it does not matter which type of environments or objectives a company is following, forecasting is not an end game, but there are obviously reasons to forecast, such as determining inventory, planning the transportation, preparing the capacity and so forth. In order for forecasting to be present, there must be customers' demand for a certain products / services. (Thomas Vollman, 2011).

There are many ways that a product's existence can dictate Forecasting, the most understandable would be 5P, which includes Product, Packaging, Promotions, Pricing and Place. The Product must be created to serve the needs of a certain group of people / customers, Packaging concerns about how the goods appears like, both of these will shape the demand since it is a vital key to differentiate whether or not customers are interested in it. Packaging, pricing and place are the considerable elements to boost and encourage the demand, for example, examining on how the products demand look like in a normal grocery store and a big mall center, or 45% of a certain product type of a notorious brand is sold under promotion (in order to get attraction and trust from customers that will potentially tempt them aware of the rest 55%). Promotions will stimulate a massive swing on customers (psychology that leads customers re-thinking to buy the goods), and that absolutely has a huge influence on demand, simultaneously and importantly, Forecasting as well. (Susann,2011).

Given this circumstance that 5P does create a product that customers are cognitive about, what is the demand going to happen? At this stage, forecasting is all the matter about to happen as a critical key, it is considered as a game changer for the market competition. A company has a better forecasting is more likely to win the race as it drives the cost economically, access to their own customer segmentations efficiently. However, there are many factors that must be seriously evaluated in order to apprehend a proficient forecasting path.

Firstly, there are 3 main levels of Forecasting that must be clearly distinguished and executed: Strategic, Tactical and Operational. Noticeably, these 3 kinds of forecasting levels are different based on the time horizon. In more details, Strategic forecast is constructed for a year or even years ahead. The purpose of this activity is for investment strategy or capacity planning. Obviously, all the tools and facility have to be 1 or even 10-year predicted and acquired according to the products' characteristics that company is manufacturing; or in the pharmaceuticals, the strategical forecasting must be plotted a year out which based on the lifetime of drugs and medicines.

Getting down to the Tactical forecasting, they are all the matter of affairs that planned and modified within quarter in a year, or months / weeks. For example, labor capacity planning, in term of hiring or laying off manpower in high and low seasons, or sales and short-term capacity planning for the next 3-6 months.

Lastly, Operational forecast will deal with all kinds of activities within days or even hours such as transportation planning based on the current manufacturing process, or production planning for the next 3 days according to the customer orders. (Thomas Vollmann, 2011).

In a matter of fact, those time horizon levels are not solely concentrated, there must be considered internal and external factors so that forecasting can be both appropriately subjective and objective. The internal factors are practically anything a company performs to shape a demand (setting up the 5P, for example) such as how the promotion is run, the discount policy and so forth. On the other hands, external factors concern with the market competitors, considering and analyzing other organizations that have same customer segmentations.

Importantly, forecasting must reflect on those factors, it means depending on the market research, customers, competitors and business strategy that dictate the forecasting computing, not the internal capabilities, on other words, forecasting would never rely on the available facilities and workforce, forecasting cannot predict the demands which a company desires to happen, it will be biased and constrained. (Thomas Vollmann, 2011.).

6.2 Aggregated forecasting benefits

Sometimes, companies are not aware of the perk of aggregated forecasting, which is always more accurate.

When talking about aggregation, SKUs, time and location would be the very first elements that considered. To clarify this statement, one critical metric would be mentioned – Coefficient of Variation (CV). It is defined as the equation between standard deviation over the mean, on other words, it is computed as a spread of the distribution divided by the average valuation. CV provides an extremely helpful measurement of uncertainty and volatility; the higher CV, the higher volatile the forecast is; also, CV is non-negative. (Supply chain Fundamentals Course, 2017).

$$CV_{individual} = \frac{\sigma}{\mu}$$

For example, there are 2 products in the market competing each other which are Red and Blue.

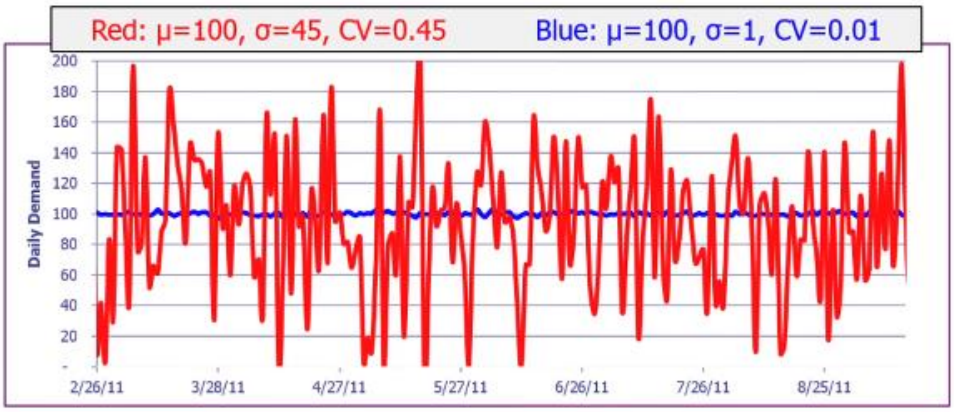


Figure 12: forecasting outline of two different products

As the figure and numbers shown above, the CV of the Red product is 0,45, which is much higher than the Blue's, just 0,01; which means Red product is more complicated to get the correct forecast for the future demand than Blue since it is considerably volatile (forecasting for the Blue is much easier since the value just be around 100, the standard deviation is only 1, much insignificant compare to 45 of the Red).

There is an example of a coffee shop which using aggregation to improve the forecasting track. The demand for Large, Medium and Small cups are different results in a difficult determination for suitable lids used for each size.

Large: N(80,30) -- CV= 0,38

Medium: N(450.210) -- CV= 0,47

Small: N(250,110) – CV= 0,44

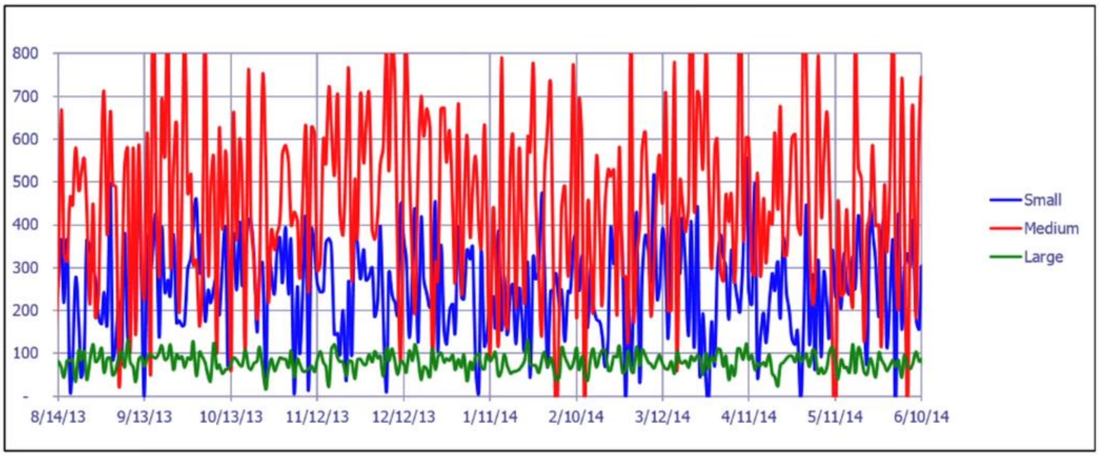


Figure 13: three sizes of coffee cups' lids forecasting

The demands for cups are normally distributed.

As the picture illustrated above, the Medium has the highest CV, meaning it is the most volatile; comparing to the least one, which is the Large that CV is 0.38, seems to be much more stable.

However, the problem here is every cup has their own lid, which is obviously disaggregated, what if there is only one standardized lid that fit for all size.

μ = 80+450+250 = 780 units / day

σ = sqrt($30^2 + 210^2 + 110^2$) = 239 units / day

Hence, standardized lid: N(780,239) – CV = 0,31

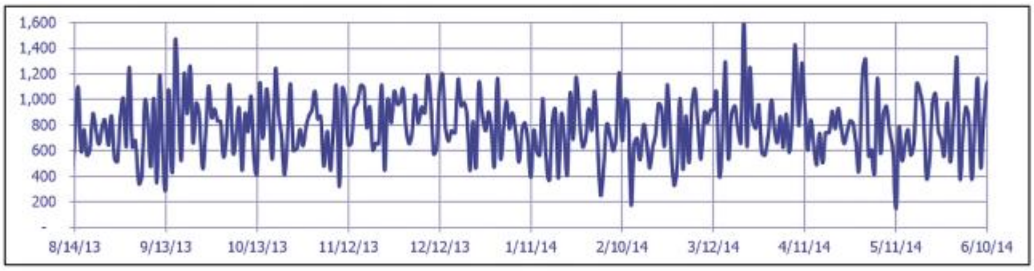


Figure 14: Aggregated forecasting for standardized lids

Fortunately, the CV of standardized lid drops to 0,31 which is much more uncomplicated to manage than the individual ones. The noticeable matter here is that aggregation on SKUs brings a huge benefit which is lower the risk of demand unsteady – this methodology is known as Risk Pooling; meaning the volatility and total variability of 3 different sizes offset each other. Risk pooling is a fantastic method which assists any company in term of diminishing the demand instability, encouraging the forecasting preciseness and minimizing the required safety stock. In fact, many manufacturers may have unique designs for special goods, however, it certainly comes with some components and parts that similar and common across the wide range of products, that idea is rational, reducing the variability and boosting the accuracy of forecasting.

On another side, instead of doing aggregation on SKUs, timing horizon would be a great possibility as well. As calculation above, the lid's demand for one day is N(780,239), which results in CV = 0,31. However, what if daily demand is not what a company wants to manage but weekly demand instead, which is demonstrated as the following figure:

Figure 15: Weekly aggregated forecast

Or even monthly demand:

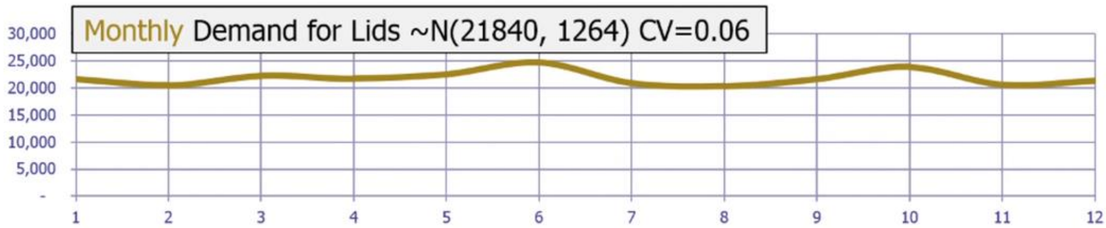


Figure 16: Monthly aggregated forecast

Obviously, by aggregating the demand from daily to weekly and monthly, the forecasting for the required lid is gradually more accurate and dramatically less volatile.

Additionally, aggregation on locations is worth considering also. Suppose there are 3 coffee shop that weekly require N(5458,632) CV=0,12 individually. The solution here could be establish a Distribution Center that serves the demand for all 3 stores by Risk Polling, a new model would look like this:

DC weekly demand: N(16374,1095) – CV = 0,07

Figure 17: Aggregation in location

Apparently, CV is 0,07 is considerably less unstable and easy to manage than individual with almost doubled CV.

Back to the Coefficient of Variation formula, the more aggregated (on SKUs, time or location), the lower CV will be achieved.

$$CV_{ind} = \frac{\sigma}{\mu} \qquad CV_{agg} = \frac{\sigma\sqrt{n}}{\mu n} = \frac{\sigma}{\mu\sqrt{n}} = \frac{CV_{ind}}{\sqrt{n}}$$

The Coefficient of Variation of individuals will determine the volatility for the demand forecasting, the aggregated CV will be steadier than the individual one by the k factor, which is equal square root of n (n is the number of aggregating elements).

6.3 Forecasting accuracy – error metrics

Again, all the events happened in supply chain come down to trade-off, and forecasting is not an exception.

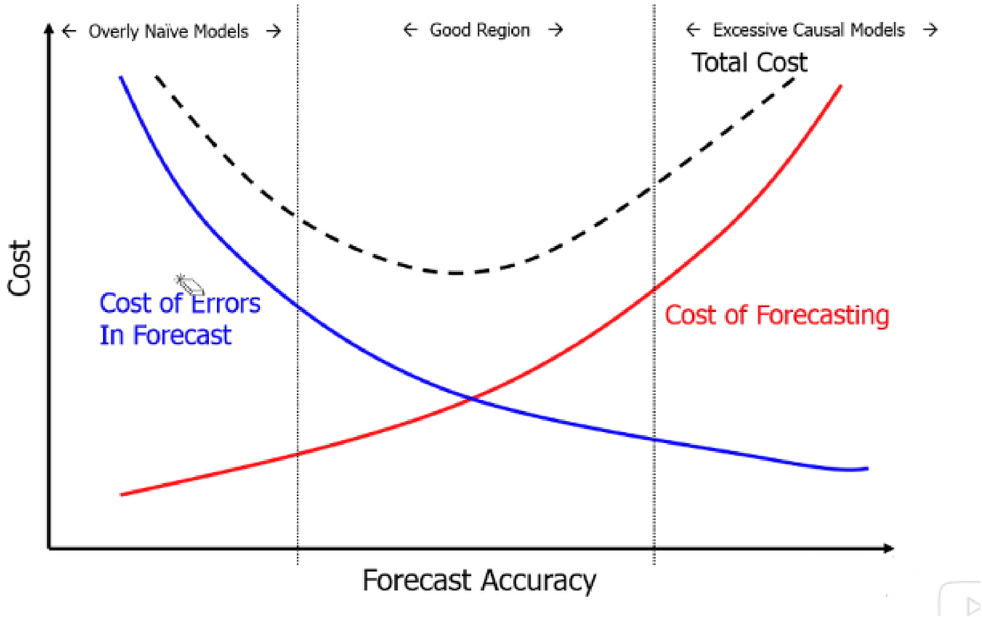


Figure 18: Cost and Accuracy in Forecasting

Firstly, the cost of errors in forecast is decreased as the accuracy of the forecast increases, obviously. However, there is an important trade-off that in order to boost the efficiency and preciseness of the forecast, there is a truly sophisticated mechanism required, regardless the effort, endeavor and a lot of time spent to evaluate many results and computations. As a result, increasing the forecasting accuracy significantly reduce the costs of errors, such as rework costs, or even remove items, whilst rising the costs that certainly occurred when an advanced system is put into work. Ideally, when total cost is beheld, sticking into the middle path between two costs is an excellent solution.

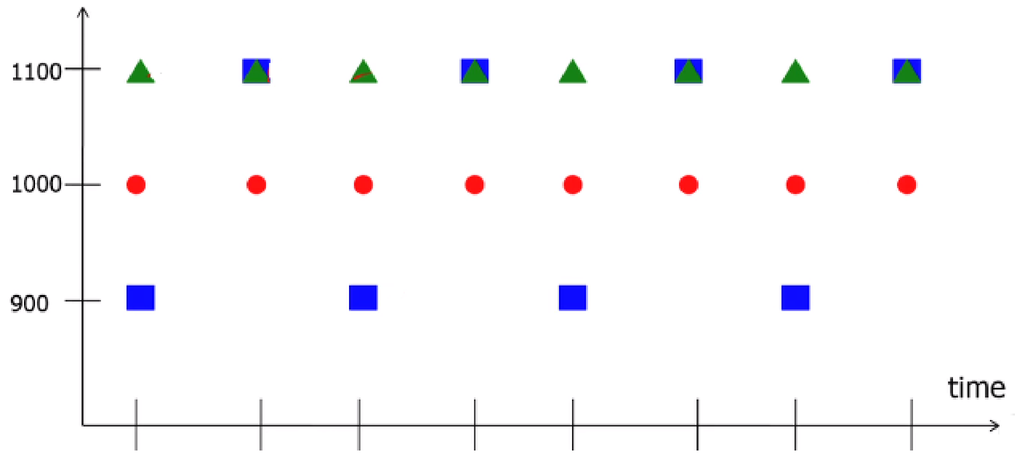


Figure 19: two forecasts comparing with actual sales

In term of quality of forecasting, there is an example in which two forecasts are performed as blue square and green triangle, the red circle is an actual demand. Basically, these 2 forecasts have a same level of accuracy, meaning they always have concisely 100 units off the actual demand, whether is a shortage or excessiveness. However, there is an extremely bold difference between them, they green triangle forecasts are always above the actual demand while the blue square ones fluctuate up and down. On other words, the green forecasts are bias, positively biased in this case since it is all up. Crucially in supply chain, biased forecasting should be avoided.

There are several momentous metrics are being used in supply chain, but they all derived from the error term.

$$e_t = A_t - F_t$$

Notation:

A_t = Actual value for obs. t
F_t = Forecasted value for obs. t
e_t = Error for observation t
n = Number of observations

The error term is defined as the difference between what actually happened, actual sales or demand, and the forecasted value, both aimed for a same time period.

Getting deeper in to the metrics, the simplest one used to measure the forecasting quality is called Mean Deviation (MD):

$$MD = \frac{\sum_{t=1}^{n} e_t}{n}$$

It is computed by adding up all the errors observed n times in a period t divided by the number of observations n.

There are few more developed metrics which are Mean Absolute Deviation (MAD):

$$MAD = \frac{\sum_{t=1}^{n} |e_t|}{n}$$

Mean Squared Error (MSE):

$$MSE = \frac{\sum_{t=1}^{n} e_t^2}{n}$$

Mean Percent Error (MPE):

$$MPE = \frac{\sum_{t=1}^{n} \frac{e_t}{A_t}}{n}$$

Root Mean Squared Error (RMSE):

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n} e_t^2}{n}}$$

and importantly Mean Absolute Percent Error (MAPE):

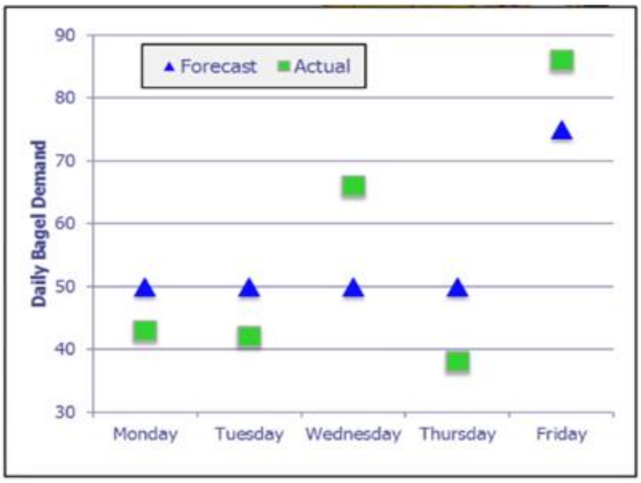
$$MAPE = \frac{\sum_{t=1}^{n} \frac{|e_t|}{A_t}}{n}$$

A particle example would be illustrated to apprehend how these metrics are manipulated:

	Forecast	Actual
Monday	50	43
Tuesday	50	42
Wednesday	50	66
Thursday	50	38
Friday	75	86

Figure 20: Example about error term

A coffee shop opens normally in weekdays only has few historical data about last week incidents when the shop's owner did capture the data both about actual sales happened and forecasted values.



	F_t	A_t	e_t	$\lvert e_t \rvert$	e^2	$\lvert e_t/A_t \rvert$
Monday	50	43	-7	7	49	16.3%
Tuesday	50	42	-8	8	64	19.0%
Wednesday	50	66	16	16	256	24.2%
Thursday	50	38	-12	12	144	31.6%
Friday	75	86	11	11	121	12.8%
		Sum	0	54	634	104%
		Mean	0	10.8	126.8	21%

Figure 21: Example's result

A summarized table is executed, according to that, important metrics could be easily calculated:

MAD = 54/5 = 10,8

RMSE = sqrt (126,8) = 11,3

MAPE = 104% / 5 = 20,8% ~ 21%

6.4 Moving average method

In fact, there are two easiest ways to forecast the future demand which either taking an average value of the entire historical actual sales (known as cumulative) or solely believe what happened yesterday is going to be the demand for today plus some error range (known as naïve). However, instead going entirely back to all the history or only getting the most recent one matter, there is a hybrid method which is moving average, its benefit is derived from the recent historical data in M period backward (M is an independent number of days that the model uses for calculation).

$$\hat{x}_{t,t+1} = \frac{\sum_{i=t+1-M}^{t} x_i}{M}$$

In short, the demand that made in time t for time t+1 is equal the average of all the actual sales happened over the last M period of time.

Let's look at the same example at the bike shop illustrated above:

t	x_t	Naïve	M2	M4	M6	Cum
1	109	109				109.0
2	92	92	100.5			100.5
3	98	98	95.0			99.7
4	96	96	97.0	98.8		98.8
5	104	104	100.0	97.5		99.8
6	98	98	101.0	99.0	99.5	99.5
7	109	109	103.5	101.8	99.5	100.9
8	99	99	104.0	102.5	100.7	100.6
9	94	94	96.5	100.0	100.0	99.9
10	96	96	95.0	99.5	100.0	99.5

Figure 22: Coffe shop example with additional MA results

Crucially, as calculation demonstrated above, the M2 model cannot start at first since there needs to be historical data for at least 2 periods, which is not obviously available, the same for M4 and M6, which compulsorily inquire for 4 and 6 periods of data respectively.

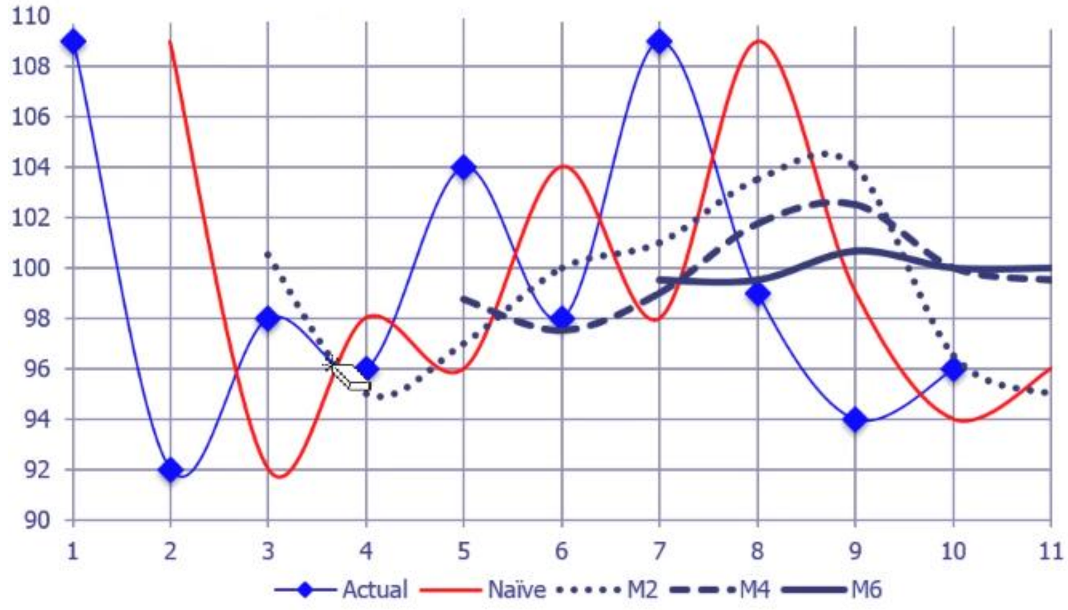


Figure 23: Graph shows difference in three mentioned models

In addition, as the M gets bigger, the model is approaching cumulative, meaning it becomes calmer and more stable gradually, and that is where the managers have to take into account the decision about M, if M gets too small, it approaches naïve which is extremely responsive to the market but volatile, if M gets too big, it is basically a cumulative model, calm and steady but significantly slow, result in many severe consequences, possibly huge inventory, for instance.

One risk the Moving average model might encounters, which is lag in the market. Since the level (a) is assumed to be the only element that encompassed in the model, if there is any trend happening, it would be considered as noise; that can causes company a very costly price since it possibly miss out the chance to catch up or even get upfront any fatal trend while any competitors still struggling the level (a), additionally, the bigger the M becomes, the longer the lag would be, and also harder to adjust, considering such an inadequate aim that any company desires to become in this fast-changing environment.

6.5 Exponential smoothing

As the models introduced above, they all possess different procedures to come up with any forecasting value, however, in term of treating the historical data, they are basically similar, meaning all the data would be executed equally, does not matter it was derived from 2 days ago or 2 years ago, it is equivalently the same. In another perspective, it is not so right, conventionally, does data get less valuable when degrade over time, or should the newer data be weighted more than the older one? On other words, historical data should be treated differently as it ages, the further backward it is, the less reliable the model will confide in, and that opinion results in a new method – exponential smoothing – the model acquires historical data, treat them as observations, and these observations are weighted, the weights decrease exponentially as it age:

$$\hat{x}_{t,t+1} = \alpha x_t + (1-\alpha)\hat{x}_{t-1,t}$$

Essentially, the formula has a smoothing factor, which is alpha (α), that dictates the weight on value of historical data, in this case it counts on the actual latest observation, which is x_t, the most, and the further data would be degraded as 1-α. In short, the forecasting in today as time t, for tomorrow as (t+1) is equal alpha multiply with what actually happened today, plus (1-α) multiply with the forecasting made in yesterday for today.

As the formula illustrated above, the exponential smoothing model will relies on the newest data the most, and then the older age it gets, the less dependent the model will be on (in fact, a number value less than 1 and greater than 0, when multiply itself, it gets smaller, which is the coefficient (1-α) in this case).

Obs.	α=0.2	α=0.4	α=0.6
t	0.2	0.4	0.6
t-1	0.16	0.24	0.24
t-2	0.128	0.144	0.096
t-3	0.1024	0.0864	0.0384
t-4	0.08192	0.05184	0.01536
t-5	0.065536	0.031104	0.006144

Figure 24: Three different alpha values

For instance, there are for 3 different alpha values shown in the table. If the alpha is 0,4, it means the model treats the most recent observation 40% reliability, then the rest 60% is aggregated from all the history. Furthermore, as the alpha value gets bigger, the model relies more considerably on the most recent data (prove by taking the comparison at time t between alpha 0,2 and 0,6) and the older data valuation would be significantly deficient.

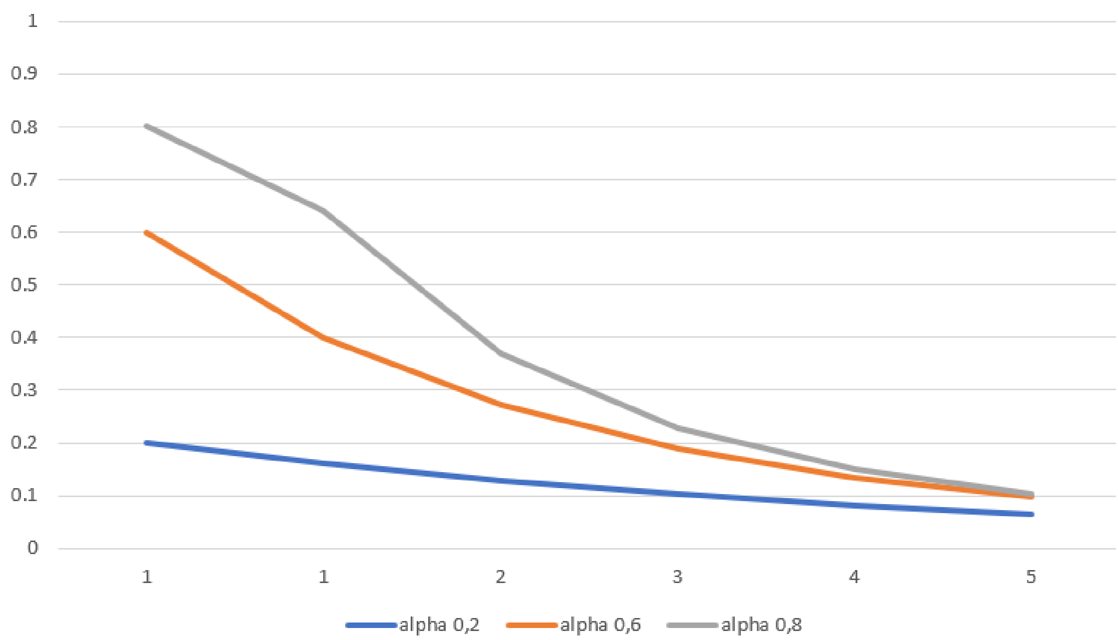


Figure 25: Graph shows difference in alpha values

As the alpha gets bigger, forecasting for tomorrow will mainly hinge on what happened today, meaning there is trade-offs between completely weighting on the latest data, which usually leads to a volatile model, versus not only just moderately evaluate the most recent one, but also take into account order historical data, which results in a much calmer model (as seen in the graph demonstrated above). The alpha value is extremely crucial for the model, as it dictates the valuation and the proportion between new and old data; if α approaches 1, meaning this is fast smoothing model (volatile, unstable and nervous – basically naïve), on the other hand, if α gets closer to 0, there will be a slow smoothing model (calm, stable – basically cumulative). In short, alpha is essentially a smoothing tool to control and dictate the forecasting speed.

6.5.1 Exponential smoothing: Level and Trend (Holts's method)

In fact, in many cases, using a forecasting methodology which derived solely from stationary factor is not enough (like the moving average).

		$x^{\wedge}_{t,t+1}$ Forecasts	
t	x_t	Alpha = 0.3	MA = 3
1	95	*95.0*	
2	102	97.0	
3	117	103.1	104.7
4	123	109.0	113.9
5	139	118.1	126.5
6	143	125.5	135.0
7	164	137.0	148.6
8	160	143.8	155.4
9	162	149.3	161.8
10	169	155.2	163.6

Figure 26: Stationary exponential smoothing and MA comparison

There is a quick example of a coffee shop's actual sales data, and they are using both simple smoothing and moving average as their testing for a better fitting forecasting system

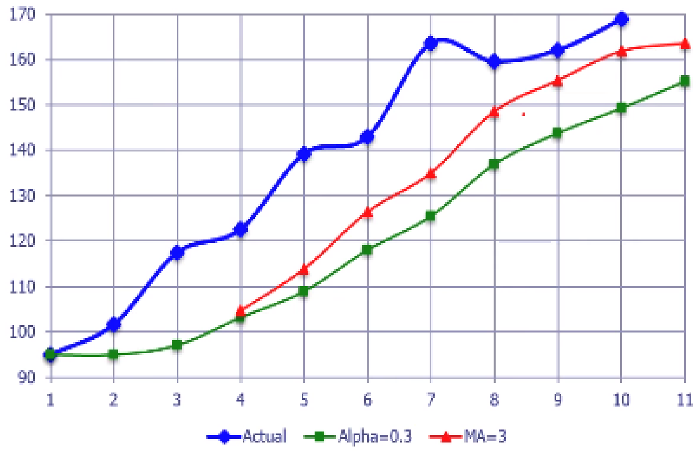


Figure 27: Graph illustates above exmaple

As the graph illustrated above, the moving average has a closer prediction for future demands compare to simple smoothing, however, either case, there is always a certain gap between what actually happened and anticipation. The reason for that is both methods just only rely on the stationary level, which means everything is happened on a straight path plus or minus error terms. These thoughts/assumptions are obviously really deadly for any business, since it can cost a fortune if a company is incapable of forecasting a trend level that taking place in the market

$$\hat{x}_{t,t+1} = \hat{a}_t + \tau\hat{b}_t$$

Where: $\hat{a}_t = \alpha x_t + (1-\alpha)(\hat{a}_{t-1} + \hat{b}_{t-1})$

$$\hat{b}_t = \beta(\hat{a}_t - \hat{a}_{t-1}) + (1-\beta)\hat{b}_{t-1}$$

Essentially, the forecasting made in today for tomorrow is equal the ‘a hat of t’, which is the prediction of stationary level, plus the number of time period, which is τ, multiply with ‘b hat of t’, the prediction of future demand’s trend level, whose coefficient is β (0 < α,β < 1).

t	x_t	$\hat{a}_t$	$\hat{b}_t$	$\hat{x}_{t,t+1}$
100	92	90	8.5	98.5
101	95			

Figure 28: Quick example to describe HOLT's functionality

There is a situation for a better understanding the method, there is a local coffee shop which needs to predict the demand for tomorrow cups, period 102, suppose there has been 95 cups sold today. Given α = 0,3 and β = 0,1

Firstly, the predicted stationary level has to be came up with

$$\hat{a}_{101} = (0.3)x_{101} + (0.7)(\hat{a}_{100} + \hat{b}_{100})$$
$$= (0.3)(95.0) + (0.7)(90.0 + 8.5) \approx 97.5$$

This is a simple math with all given information. Secondly is the new crucial calculation for this Holt's method, prognostication for trend level

$$\hat{b}_{101} = (0.1)(\hat{a}_{101} - \hat{a}_{100}) + (0.9)\hat{b}_{100}$$
$$= (0.1)(97.5 - 90.0) + (0.9)(8.5) \approx 8.4$$

As the formula demonstrated above, the subtraction between 2 stationary levels (97,5 - 90) is actually the divergence between 2 starting points of a graph, meaning there is possibly a trend happening, in this case the divergence is 7.5, which implies there is probably a positive trend increasing the demand, in fact, there is feasibly a negative trend.

As the determination of these two vital elements for the method, result can be easily computed by a simple addition

$$\hat{x}_{101,102} = 97.5 + 8.4 = 105.9$$

In this case, period of time τ is equal 1, in some situation, there could be a possibility to forecasting much further than just period, for example, sitting in time 101 and predicting the future sales for time 110, meaning τ = 9

$$\hat{x}_{101,110} = 97.5 + (9) * 8.4 = 173.1$$

6.5.2 A coffee shop example

There is an owner of a coffee shop that require us to develop monthly forecasts for a year, the item in target is SKU number 4, which is Cappuccino. After evaluating the historical data, there are a bunch of definitions will be pointed out; firstly, the alpha α value will be 0.2, beta β value is 0.15; in addition, in January (t=0), the estimated level $a\text{^}_0$ for February will be 657 cups, and trend level $b\text{^}_0$ will be 1.15 cups.

The forecasted demand for February will be:

$$x\text{^}_{JAN,FEB} = a\text{^}_{JAN} + (1) * b^{\hat{}}_{JAN} = 657 + 1 * 1{,}15 = 658{,}15 \text{ cups}$$

In fact, there are 660 cups that sold in February, and the following is the calculation in spreadsheet:

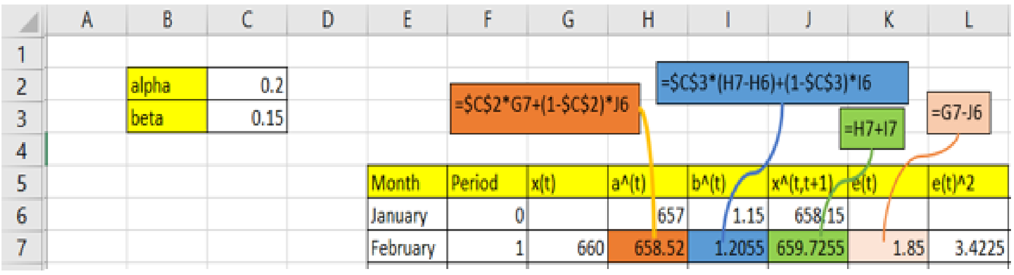


Figure 29: Spreadsheet illustration

And the ahead months' demand until the end of year:

alpha	0.2
beta	0.15

Month	Period	x(t)	a^(t)	b^(t)	x^(t,t+1)	e(t)	e(t)^2
January	0		657	1.15	658.15		
February	1	660	658.52	1.2055	659.7255	1.85	3.4225
March	2	662	660.1804	1.273735	661.4541	2.2745	5.17335
April	3	659	660.9633	1.200111	662.1634	-2.45413	6.022779
May	4	661	661.9307	1.165208	663.0959	-1.16342	1.353544
June	5	662	662.8768	1.13233	664.0091	-1.09594	1.201092
July	6	665	664.2073	1.162058	665.3693	0.990915	0.981913
August	7	669	666.0955	1.270978	667.3664	3.630675	13.1818
Septembe	8	666	667.0932	1.229985	668.3231	-1.36644	1.867153
October	9	668	668.2585	1.220291	669.4788	-0.32314	0.104416
November	10	665	668.583	1.085927	669.669	-4.4788	20.05964
December	11	667	669.1352	1.005858	670.141	-2.66897	7.123377

Figure 30: Calculated results

As applying the procedures of exponential smoothing method and error term definition, owner of the coffee shop now can understand the overall picture of forecasting as well as the fluctuations between actual sales and estimations, by which modifications can be evaluated, for example, forecasted value is calculated, however, by the selling experiences of the owner that the value will be plus or minus a certain range (based on the historical error term mostly) to come up with a new value which hopefully increase the confidence zone.

6.5.3 Damped trend

In real business situation, a trend does not either go up positively or down negatively for good, in fact, it is changing and restricted, a linear trend can possibly become a disaster since trends will be curved out as the longer it goes, or even damped which eventually results in over-forecasted values if a manager has no investigation about current market research as well as customer behaviors toward that trend, especially for a long horizon.

Forecasting Model $$\hat{x}_{t,t+\tau} = \hat{a}_t + \sum_{i=1}^{\tau} \phi^i \hat{b}_t$$

Updating Procedure $$\hat{a}_t = \alpha x_t + (1-\alpha)(\hat{a}_{t-1} + \phi \hat{b}_{t-1})$$
$$\hat{b}_t = \beta(\hat{a}_t - \hat{a}_{t-1}) + (1-\beta)\phi \hat{b}_{t-1}$$

Figure 31: Damped model

Actually, damped calculation model is just a slight add-on to the exponential smoothing, which has an additional element phi ɸ (0 < ɸ < 1). Obviously, as evaluating deeply into the formula, the stationary level will be assumed to be the same, however, the trend level will have a difference, since it is now multiplied with ϕ^i, i values go from t=1 to t=τ, meaning the bigger the τ value is, the smaller the ϕ^i would be (a number greater than 0 but less than 1 will get smaller as it is squared or cubed or so forth).

With the same coffee shop example, recently the owner is aware of this characteristics of the trend and decides to append the phi factor (ɸ=0.9 in this case) into his formula:

Month	Period	x(t)	a^(t)	b^(t)	x^(t,t+1)	e(t)	e(t)^2
January	0		657	1.15	658.035		
February	1	660	658.428	1.09395	659.4126	1.965	3.861225
March	2	662	659.93	1.062178	660.886	2.587445	6.694872
April	3	659	660.5088	0.89938	661.3182	-1.886	3.557013
May	4	661	661.2546	0.799895	661.9745	-0.31825	0.10128
June	5	662	661.9796	0.72067	662.6282	0.025498	0.00065
July	6	665	663.1026	0.719757	663.7503	2.371795	5.625411
August	7	669	664.8003	0.805271	665.525	5.249654	27.55887
Septembe	8	666	665.62	0.738993	666.2851	0.47498	0.225606
October	9	668	666.6281	0.716541	667.273	1.71489	2.940846
November	10	665	666.8184	0.576697	667.3374	-2.27298	5.166415
December	11	667	667.2699	0.508905	667.7279	-0.33741	0.113844

Figure 32: Results with phi factor

Through the comparisons and evaluation, the damped model slightly has a better advantage compare to exponential smoothing in this case, meaning it has a closer forecasting to what really happening to the shop

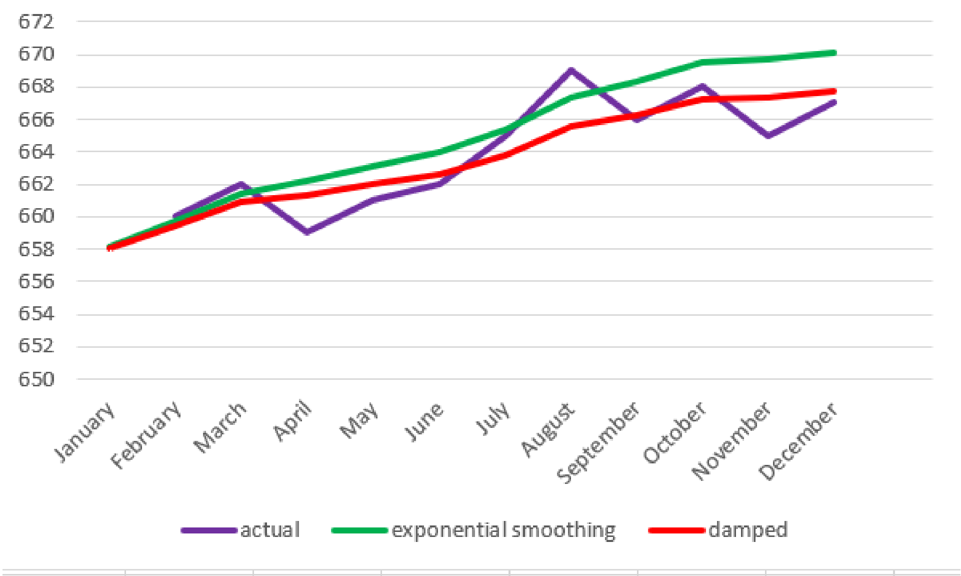


Figure 33: Exponential smoothing and Damped

Also, the error is lower on damped model

MSE in:

Damped model: 5,077

Exponential Smoothing: 5,5

Essentially, there is no common rule that assure to use which model in a any certain situation, in fact, the manager and forecasting department must do serious and careful investigation on the current market environments as well as constantly reinforce the relationships with suppliers and key customers. Using a damped model to forecast in an exponentially growing trend can lead to a huge disadvantage and easily passed over by competitors, more importantly, losing customers into rivals, on the contrary, applying linear exponential smoothing to predict a trend which has been gradually ignored can cost a company a massive wasted inventory, probably disoriented direction eventually.

6.5.4 Triple exponential smoothing (Holt-Winter model)

Apparently, the Holt-Winter method is an ultimate one that encompasses all the elements that feasibly have an influence on future demand; or affect the customer's behavior toward any type of product or service.

Forecasting model: $\hat{x}_{t,t+\tau} = \left(\hat{a}_t + \tau\hat{b}_t\right) * \hat{F}_{t+\tau-P}$

Where:

$$\hat{a}_t = \alpha\left(\frac{x_t}{\hat{F}_{t-P}}\right) + (1-\alpha)(\hat{a}_{t-1} + \hat{b}_{t-1})$$

$$\hat{b}_t = \beta(\hat{a}_t - \hat{a}_{t-1}) + (1-\beta) * \hat{b}_{t-1}$$

$$\hat{F}_t = \gamma * \frac{x_t}{\hat{a}_t} + (1-\gamma) * \hat{F}_{t-P}$$

P: number of time periods with the same seasonality

$\hat{F}_t$: multiplicative seasonal index

$$\sum_{i=1}^{P} \hat{F}_i = P$$

6.6 Forecasting for special cases

6.6.1 Casual analysis

Casual method is used to forecast a demand which is believed to encounter a random correlation with other variables that can possibly be surrounding environments or artificial events, meaning these variables must be tracked, stored and evaluated. For example, there is a car maintenance company wants to predict a future demand for next year, a variable potentially has a big influence can be weather (snow, slippery street surface) that probably raise the car accident rate; or a grocery store wants to foresee the demand for particular items that can be affected by promotion, or discount. Those factors are firmly believed to have an immense impact that either force or diminish the sales promise.

The procedure used in this method is by analyzing the entire historical data which encompasses observed demand and sales, from which a linear correlation is constructed based on regression function, or so-called ordinary least square method.

$$y_i = \beta_0 + \beta_1 * x_i + \varepsilon$$

The pair (x,y) are the observed data, y represents for demand (dependent variable in the equation) and x is the independent one. The method aims to run a regression to look for two factors that bring a considerable correlation between x and y, β_0 is a stationary level and β_1 is a slope or trend.

There is a quick example of a coffee shop near a university that can be examined briefly to achieve acquaint about the procedure.

	A	B	C	D	E	F
1	Demand	Time Period	Forecast Average Temp	Year	Month Name	School in Session
2	3025	1	37	1	Jan	No
3	3136	2	39	1	Feb	Yes
4	3414	3	46	1	Mar	Yes
5	3502	4	56	1	Apr	Yes
6	3736	5	67	1	May	Yes
7	3661	6	77	1	Jun	No
8	3553	7	82	1	Jul	No
9	3691	8	80	1	Aug	No
10	3474	9	73	1	Sep	Yes
11	3876	10	62	1	Oct	Yes
12	3865	11	52	1	Nov	Yes
13	3967	12	42	1	Dec	Yes
14	3596	13	37	2	Jan	No
15	4345	14	39	2	Feb	Yes
16	4413	15	46	2	Mar	Yes
17	4086	16	56	2	Apr	Yes
18	4377	17	67	2	May	Yes
19	4220	18	77	2	Jun	No
20	4238	19	82	2	Jul	No
21	4007	20	80	2	Aug	No
22	4086	21	73	2	Sept	Yes
23	4536	22	62	2	Oct	Yes
24	4291	23	52	2	Nov	Yes
25	4427	24	42	2	Dec	Yes

Figure 34: Coffee shop sales record and related data

The owner of the shop desires to know is there any way that he can be actively aware of the demand in advance, on other words, historical data as illustrated above is all the matter the shop possesses, and the demand is crucial to be computed ahead of time.

With the available data, it is convinced that there is a strong relationship between demand and the shop's age:

$$y_i = \beta_0 + \beta_1 * x_i$$

Demand = level + trend * time period

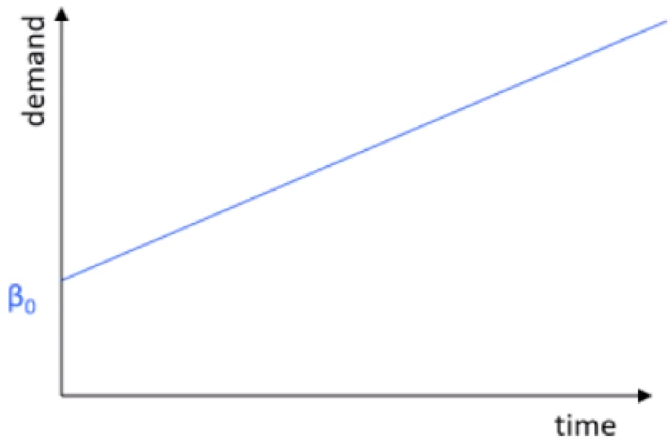


Figure 35: Demand is depend on time period

After running a regression on the spreadsheet, the results are demonstrated as below:

R^2	0.881
adj R^2	0.776
S_e	204.2
RSS	917,500
TSS	4,093,071

	Coefficient	Std Error (s_{bi})	Lower CI (95%)	Upper CI (95%)	t-stat	p-value
Intercept (b_0)	3,240	86	3,061	3,418	37.6	<0.0001
Time (b_1)	53	6.02	40.1	65.0	8.7	<0.0001

Figure 36: Final Results after running Regression

As inspecting the figures shown above, the built model has a very strong adjusted R square, which cover almost 80% of all the variable movement in the graph, also, the p-value of both variables is extremely reliable (null hypothesis is hardly occurred), so that the demand function is firmly proclaimed as:

$$y_i = 3240 + 53 * x_i$$

Obviously, it is stated in the function that demand will be started at 3240 cups and going to have a boost up of 53 cups more each month.

In fact, it is possible to add more than one independent variable into the model, essentially, demand is not usually driven solely by one factor.

$$y_i = \beta_0 + \beta_1 * x_i + \beta_2 * x_j$$

Demand = level + trend * time period + temperature.

R^2	0.881
adj R^2	0.776
S_e	209.0
RSS	917,074
TSS	4,093,071

	Coefficient	Std Error (s_{bi})	Lower CI (95%)	Upper CI (95%)	t-stat	p-value
Intercept (b_0)	3,255	175	2,891	3,618	18.6	<0.0001
Time (b_1)	52.6	6.2	39.7	65.6	8.4	<0.0001
Temp (b_2)	-0.272	2.75	-5.991	5.448	-0.099	0.922

Figure 37: Results of regression with two indepentdent factors

Examining the results, every factor seems to be similar with the previous, except the added temperature; visually, it is stated that the higher the temperature is, the lower the sales would be deducted by 0.272 cups, obviously it does not make any sense.

Mathematically, the temperature's p-value is substantially high, which means null hypothesis has a massive opportunity to happen, on other words, the hypothesis claiming temperature has an influence on demand is rejected.

Indeed, regression is a considerably helpful tool that assist company to find any correlation amongst complicated available variables, however, correlation in the past is not supposed to be what will happen in the future, meaning over-fitting with the historical data should be avoided. Furthermore, regression is easily supportive but require a sophisticated book keeping system since all the data must be reliable which used to build the model, unlike exponential smoothing, data is weighted over time so historical one may not be so vital as it is in regression.

6.6.2 New product forecasting

As understanding the customer desires and needs, new product can be a game changer that any company wants to launch to transform the so-called market opportunity that hopefully become a competition leader by increasing the market share. The products can be both tangible (phone, laptops) and intangible (service, education). Obviously, this is a massive opportunity to get a company to the world but simultaneously a risky challenge that can possibly collapse everything into dust. A broad set of knowledge and expertise are strictly required to leverage it into a whole new level of success, which consists of customer knowledge, awareness of competition, market nature, self-capability, lead time, total cost and so forth; these factors have an incredible impact on how the new products will be delivered to customers as well as the reactions and behaviors from them.

As a matter of fact, new product is still considerably a broad picture that does not obtain any specific perspective which likely result in confuse or even worse misunderstanding for customers when conducting introduction. Fundamentally, new product is classified into six different categories which determined according to 2 criteria: market and technology. The first type of new product is named New-to-world product, in term of market and technology, this type is put into completely new for both, these products are unprecedented inventions that disclose a brand new customer segmentation in the market (such as what Tesla did when be the pioneer to introduce to the all the human being in the planet about electronic vehicles that efficiently function). The second type is relatively narrower which is New-to-company. It is also considered as new for both market and technology division. In reality, a company impulses to stimulate the market share as well as penetrate deeper into the competition by expanding its current segmentation, introduce a product that has never been in the company but already existed or even succeeded by other competitors (Razer company is well known for electronic computer devices such as mouse, CPU and so forth, last year, they just launched a so-called 'Razer smart phone' into the market with unique specifications aim to broaden its own horizon in the market). The third type of new product is Line extension, it is understood as adding a new technology to current product line but target is still remained in the same market (like smart watches have been lately a trend for tech people which synchronized with smart phone). The fourth type is Product repositioning, meaning with the same technology but try to penetrate another different market segment (many soap and shampoo company always start with a product which solely used for 1 gender and then expand it for everyone that can be male, female and even children). The fifth category of new product is Cost reduction. This is the least innovative amongst the mentioned classes. It is considered as staying with the same technology and aiming the current existing customer group, the reason why it is stated as a new product is moderately fair, offering customer with the same product which might have considerable modifications in term of design or constructed components, that possibly lower the price; still, performance is assured to be identical. The remaining category will be Product Improvement. It is easily perceived as the name itself – improve the current product while sticking with the same old segment, such as new smart phones are competitively thrown into the market annually, including upgraded hardware or software which probably achieve a higher performance and completion compare to predecessors.

Obviously, these different categories of new products require different forecasting methods. In term of Cost reduction and Product improvements, adhering to the similar market is considerably a benefit since all the historical data is available, forecasting methods could be simply time series or running a regression. When Line extension is taken into account, the method here is to look at similar affairs, a yogurt company wants to add a strawberry flavor might want to see how the performance of blueberry flavor was previously, on other words, carefully evaluate similar prior experiences that possibly possess ''looks-like'' analyses or analogous approaches. Looking into the Product repositioning, since market penetration is the main concentration of this new product type, that customer and market research are incredibly on point, understanding the driving factors and customer behaviors probably lead to massive advantages when entering the new environment. Lastly, and as importantly, forecasting for New-to world and New-to-company are relatively similar since there is no accurate historical data available, all the computations are made by the market research as well as credible assumptions which collected from potential respondents. Also, unlike other mentioned category, this unique forecasting approach is based acceptably upon subjective perspectives from the company, which obviously inheres many uncertainties and risks, but still, market dynamics and driving factors are also seriously indicated and elaborated in this case.

Questionably, new products are intrinsically dangerous for any company, still, there are thousands of them are launched regularly. The reason is rationale – money. In fact, after throwing a new product into the market, companies reward a significant amount of revenue, from 21% to 48%, and profits, from 20% up to nearly 50% within 2 years of launching. Indeed, technology companies can earn roughly 47% more in term of revenue, following by the healthcare industry and fast-moving consumer goods that sold in grocery stores or supermarket. New products in these areas have been increasing the money for companies, however, these pricing does not last forever; as mentioned earlier, trends are definite that the pricing system eventually driven down over time, on other perspectives, it is a stimulation for innovation that company endeavors to introduce or invent more new products that appropriately meet the market's demands.

6.6.3 Real case study of new product introduction and forecasting process

During the 1960's, Xerox Corporation was a huge reputative giant in the photocopy film manufacturer and plain paper office copier industry. Throughout these years, the development of the company was described as exponential growth. In 1969, it acquired a company called Science Data System, after which Xerox defined themselves as an ''architecture of information''. However, in 1975, for the first time since 1950, Xerox revenue deducted. After five consecutive years of declination in its own ''used-to be unbeatable'' strength, they had to sell the business with a huge minus in the revenue report. Meanwhile, many companies have jumped in the same market, offering a better service with a lower operation cost, regardless newer technology; and IBM was one of them, with the ''high speed scanning laser computer printer'' which obviously knocked Xerox out of the market easily. Indeed, Xerox management nearly went collapsed and terminated the company. However, in that chaos situation, there was a fund that supported the company just enough money to carry on the key elements of the technical team for only one more year, with a massive project called ''9700 Electronic printing system''. This project was undergone by adapting the printing laser technology into its current engine which possibly reduce the paper cost for user as well as more efficient in term of usage. Noticeably, the first thing they did was design and assemble a credible forecasting system for this new technology. The system is complicated and sophisticated, but in short, it evaluates and shapes the preferences and behaviors of potential market respondents which assist Xerox in the aspect of customer's needs understanding. Also, the forecasting system predict the probability of customer's choice when buying an item based on studies which inquire people about alternatives choices (asking them to choose a product based on descriptions, no brand name leaked), so that Xerox would basically apprehend the standard criteria a product should possess to attract customers, furthermore, they were also triggered by customers about the influence and importance of brand name by which they could build a product with a logical reason and appropriately address the customer's needs. Lately, with an incredible work of the market research which constantly provided information for forecasting purposes, as well as the customer analyses are executed accurately and rationally, the 9700 is a spontaneously successful project that believed to bring over billions in revenue for the company. Essentially, the forecasting system has set a higher standard for the market evaluation process, more interestingly, it also has a considerable impact on the design and quality of new product line, since the system learns information derived from genuine customers. (Shmuel Oren 1980).

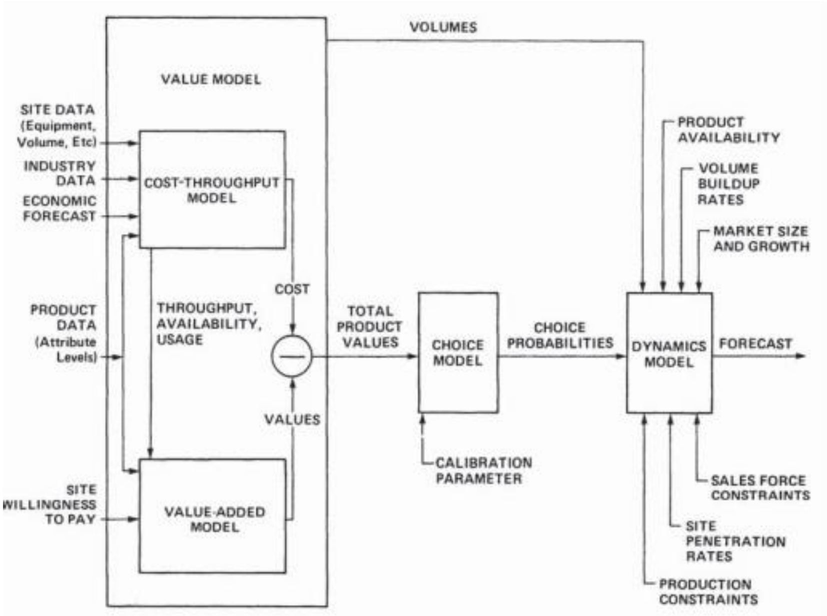


Figure 38: Xerox's Forecasting system for digital printing technology (Shmual Oren 1980, 80).

6.6.4 New product developemnt process

Fundamentally, when a company desires to come up with any new product idea and launch them, approaches are probably different between companies which the processes are dependent on which type of area or industry a company is in, however, there is a common procedure that every approach is based upon, and it shapes like a funnel, meaning when new ideas are presented, there are lots of those, then all of them have to be evaluated and undergone through many stages in which idea has to meet a standard in term of criteria to be considered to the next stage, eventually, just few of the initial ideas are executed and implemented.

Figure 39: Funnel acts as an idea filtering

Specifically, the new product development funnel is divided into many gates, in each gate, there are certain bunch of criteria and metrics that only ideas and concepts that appropriately address and meet the standard requirements allowed to go through. Those criteria and indicators probably encompass financial targets, feasible costs, return on investments, revenue valuation, size of the market, economical scale and so forth. The further it goes in the funnel, the more difficult and demanding metrics the ideas are validated. There are two main reasons for it, one is to ensure only good practical ideas are examined, secondly, and more importantly, the funnel helps companies stay away from inappropriate ideas which can cost a fortune or even incurable when implement it.

There may include many stages which differ from companies, but generally there are 6 main steps that should be seriously taken into account. The first stage is called Discovery and Idea generation in which any new innovative ideas are welcomed, following by Scoping and Pre-Technical evaluation in which the potential market size and future customers are quantified and carefully analyzed. Next, a business case could be developed that revenue promises from the targeted market is computed, and then Development stage is afterward in which prototype of the new product is built. Test and Validate the product in the actual environment is done before the final stage which is official Commercialization to the public. In short, the practical executable ideas will be refined, flourished and commercialized throughout the funnel.

Essentially, forecasting method distinct at every stage since the output purposes are different. At the first two stages which aiming to quantify and scoping the population of the targeted market, so that the forecasting basis is all about anticipate the potential total market revenue, for example, the coffee industry in Finland is considerably growing, market size can be estimated around 1 billion euros. The second group in the funnel is the next 3 steps, in which deeper detail about promising flow of money is calculated, companies now want to be aware of the potential firm sales revenue, on other words, forecasting will serve as a tool to determine the desired rate of market share, for example, company A wants to sell Espresso coffee, there are 25% in the market love Espresso (around 250 millions), and the company might want to forecast specific unit sales so that revenue hopefully achieve 5% in the 250 million of euros. Lastly, a more specific forecast for unit sales by location is strictly required in the Commercialization stage since distribution center, transportation problems, product marketing are now in the top concern for companies.

In fact, according to a survey that conducted by 168 companies about forecasting method used for new product development, the results are shown as follow:

Customer/market research	57%	Exponential smoothing	10%
Jury of executive opinion	44%	Experience curves	10%
Sales force composite	39%	Delphi method	8%
Looks-like analysis	30%	Linear Regression	7%
Trend line analysis	19%	Decision trees	5%
Moving average	15%	Simulation	4%
Scenario analysis	14%	Others:	9%

Figure 40: Forecasting methods for new products

Obviously, customer/market research, executive opinion and sales force composites are the most heavily used; in fact, during the first stages, market size determination request lots of investigation and C-suite's assessment on strategies and procedures that promising to be implemented, furthermore, dependent on the type of new product that forecasting models will be chosen, nevertheless, subjective approaches as these top three are most suitable since there is not many objective information or actual data to rely on. Interestingly, company when launching a new product does not usually confide in one model but possibly many, and apparently, the selection on forecasting system must be aligned with the position of that company in the funnel, also, B2B and B2C strategy has a considerable affect. When executing a forecast for B2B, it is going to be more subjective than B2C, the reason is that B2C obviously has more customers that result in more historical data to rely on, moreover, B2B requires a longer horizon time of forecasting since (34 months) compare to 18 months on B2C.

There is one regular understandable method used in many companies, which is looks-like analysis or analogous forecasting. Essentially, the analysis simply executes evaluations on a similar type of product that has been thrown out the market before. The comparable products can be confronted and constructed a similar forecasting data by month or week, which mostly based on the resemble old product's sales record. In fact, analogous approach is an advanced method of looks-like analysis which a data base of all the historical products launch and sales are bookkept and tracked. The constructed data base acquires and sorts all the input information by customer segmentation characteristics, specific type of products, pricing strategy, season of introduction, and even functionality. Consequently, when there is an utterly new product launched into market, the analogous forecasting system will essentially learn that product's distinctive properties as mentioned above which eventually create a procedure based on the mutual points with the past products. Since the nature of analogous forecasting feature, which keeping track of all the historical product data that assist the new product development, there must be also unsuccessful product remained and evaluated, it would cause a massive mistake that only successful ones are kept which uncertainly take place for the comparable new products, or even unmatch between types of products.

7 Sales and operation plannning

According to AMR research, nearly a quarter of companies in the US do not use the SOP although its well-proof establishment and the eventual payoffs retrieved for any company appropriately utilize it. Furthermore, the dramatic rise in the supply chain's complication results in a stricter and tough environment for making accurate forecasting and efficient planning, even a company have been using it for many years may possibly not well execute it and reap any benefits that essentially SOP obtains. (Harry Hawkes 2007, 2-5).

Sales and operation planning acts as a vital gateway in a company that every departments will be brought together. Every key communication related to products, costs, time and so forth will be determined in SOP, also, top management is able to efficiently receive as well as response to every crucial part of a company via SOP. In the most basic form of it, sales and operation planning dictates the most activities that encompasses sales, marketing, finance situation, operation, manufacturing planning, even research and development. Essentially, SOP allows a silo concern not only what other department's job but also attempting to integrate and optimize all the related crucial processes that consequently results in a better performance in strategies, proficient capabilities that altogether achieving the final mutual objectives.

Indeed, SOP is an important tool that assists top management making best decisions for the business, balancing level of service and inventory. SOP sets many criteria and policies that leading to mandatory procedures every silo ought follow, aligning companies in creating more efficient integration. It gives organizations the disciplines to concentrate on priorities, encourages the cross-functional team make binding crucial decisions in which individual legal rights, mutual visions are well determined and consented. A successful SOP system can be a momentum for top management inspire employees, smoothing the entire company which certainly leading to a united lucrative firm. (Martin Murray. 2018).

7.1 Sales and Operation planning fundamentals

There are four fundamentals in SOP: supply, demand, volume and mix. Firstly, the balancing between supply and demand will be examined. There is an example that used to illustrate extensively this importance: a company's sales department is able and willing to sell 180 units a month which is believed to dramatically increase the total revenue of a whole year 35% compare to the previous. However, a big challenge occurs that the manufacturing is only capable of producing 160 units at the highest productivity a month, which obviously insufficient to reach the sale's requirement. In reality, when demand exceeds supply, level of service will be negatively influenced which possibly result in permanently lost customers, total costs considerably increase because of over time or urgent temporary outsource, more importantly, products' quality will not be ensured since lead time is forced to be shorter, all of the mentioned possible consequences are definitely not beneficial for any business. Likewise, when supply is greater than demand, the outcomes are expected to be unfavorably similar. Costs will be significantly surged due to excessive inventory, worker dismissal would be put into consideration, which leading to production rate and capability dramatically decrease, more noticeably, revenue and profit margin would be significantly smaller since mandatory price cuts or promotional events such as discounting, customers incentives. Therefore, the vital role of SOP is to maintain an appropriate balancing rate between supply and demand, on time notify the top management as imbalance signal is about to take place that proper modifications and decisions will be pull out immediately.

The two remaining fundamentals are volume and mix. These are basically the same in term of concerning the manufacturing capacity, however, volume is more into big picture decisions that quantify and determine the total magnitude of a production or even dictate the manufacturing rate of a product family. On the other hands, mix duty is more detailed on how an individual item is produced. As a matter of fact, companies give a heavier concentration on mix, since it is concrete and real time requirement, unlikely, volume is considered once or twice a year since it should be fix and consent are made from all the department so that capability and facility will be prepared and established ahead. Brilliant companies attempt to proactively and cautiously forecast for the volume first, when it is done efficiently, the mix will be much easier to accomplish. Furthermore, being able to plot a relevant volume strategy will greatly diminish the risk of supply and demand imbalance, from which company can certainly enforce the mix schedule and production rate while simultaneously strengthen the supply capability. (Thomas Vollmann. 2011).

Essentially, Sales and operation planning ensures the big picture as volume is well designed first then moving narrower into individual that confidently manageable. Understanding the main role of SOP assist companies executing it more efficiently as well as maneuvering a company as whole moving toward the mutual goals, which is extremely important for any business.

7.2 Sales and Operation planning processes

As assisting companies to understand approaches to run an effective SOP, bunch of critical procedures has been developed which is considerably a significant hint helping top management in making better decisions for the business.

7.2.1 The monthly sales and operation planning process

SOP is a tool that allow top management capable of accessing clear visions to create better ideas and decisions for sales plan, manufacturing plan, inventory level of every product family. Nevertheless, SOP would be invalid unless a set of crucial information are reliable and accurate, which encompass basis of recent data, forecasting, management knowledge about current situation. Hence, a validated set of processes is created for a more effective accomplishment in SOP. These processes will be taken place in the end of every month so that new month’s resolution would be encountered.

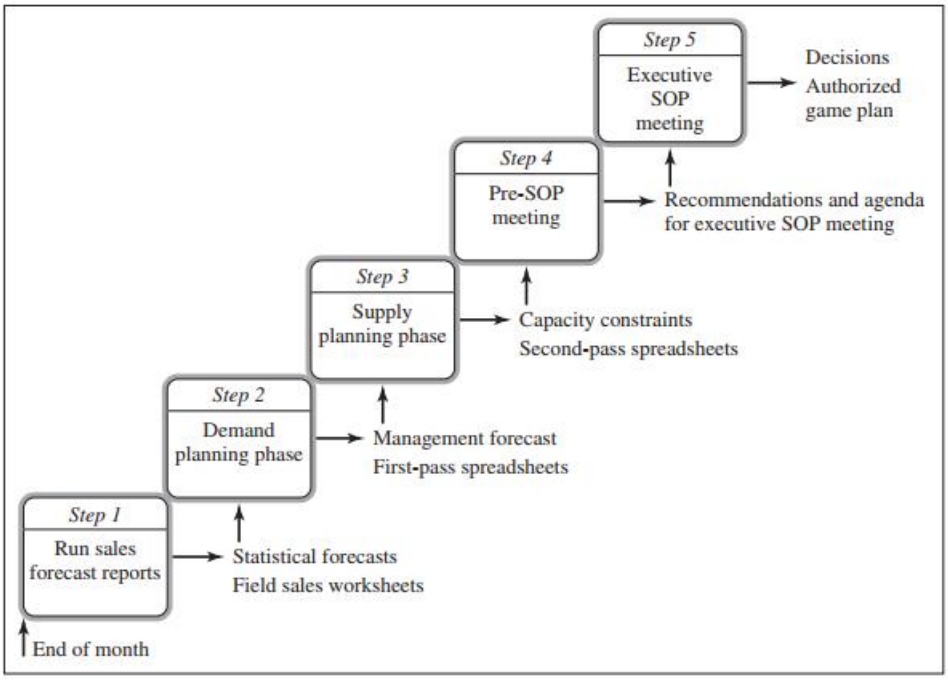


Figure 41: Crucial steps taken place in SOP (Thomas Vollman 2011, 123).

Having these steps effectively executed every month potentially obtain a massive advantage from a productive SOP system any company attempt to achieve.

Firstly, run the sales forecast reports will be taken place as soon as a month ends to summarize and update every related sales data such as actual demand, inventory, production and so forth, from such valuable information and report analysis that evaluations and examinations are executed, result in proper notifications will be announced. Next, the output of the first phase will be the critical input for the demand planning phase. Sales and marketing department will review all the analyzed historical data with the upcoming products to raise an inquiry that whether a new forecast be developed for the next 12 months, or the existing one already suitably useable for the current product line. A new forecast will be seriously considered since all the recording data regarding actual sales, production capability are available. Here, proper modifications will be made. In the third phase, the capacity planning will be elaborated. The manufacturing plan will be plotted out whether it has been used before or completely new, which dependent on any changes occurred in sales forecast, or inventory. The plan might possibly be modified due to, for instance, demand is believed to be higher in the next month that current capacity and workforce utilization cannot deliver with the current schedule's constraints. Importantly, if there is any such change occur in the manufacturing plan, top management is highly involved, also the middle management is allowed providing appropriate knowledge. Hence, these strict involvement and authorization result in the fourth phase, which is pre-SOP meeting. In this summit, representatives from different core departments will discuss about the decision on manufacturing plan and forecast so that the balance between supply and demand is specifically determined and maintained. Also, many opinions and knowledge given will be examined and resolved, in a situation if there is uncertainty, all the troubles and problems then will be handed to executive meeting. Besides the official overall volume plan for product family, many alternatives for unexpected cases will be developed, in addition, recommendations from middle and top management in term of resource planning, backup plans are attended proactively. Finally, the top-tier meeting will be held up involving many executives. The final decisions regarding mix planning for individual products will be called out, if there is such modification must take place, senior managers will discuss and disclose. Review repeatedly the detail manufacturing plan and compare it to the overall business plan, and most importantly, tracking and updating constantly the customer service and the performance according to the approved KPIs.

As a matter of fact, unanticipated events likely occur all the time, in such situation, re-planning will be necessary. When there is any information from demand management signal that the imbalance between supply and demand is far gone the acceptable limits, re-planning will certainly happen. Similarly, if conditions change in manufacturing environments, or new market opportunity emerges, re-planning will be taken into account. (Larry Lapide. 2004).

7.3 An innovative perspective to construct an advanced SOP system

As complexity in supply chain environment increasing unstoppably, the impact on forecasting accuracy and planning effectiveness is considerably massive. Hence, a fresh approach for SOP is mandatory. It goes beyond the regular intensive meeting between executives; instead, there is a bunch of critical techniques that companies should consider as endeavoring to overcome the sophisticated requirements from the demanding market.

7.3.1 Processes must match with the overal objectives

Given the challenging complication in the market that trigger companies to revamp their processes and examine it whether they are aligned with the business goals. In fact, even many companies have been using SOP do not totally understand its ultimate benefits. Essentially, companies should review it regularly whether the system is utilized efficiently or are there any alternatives could be developed for a better performance. Traditionally, SOP system always try to plan long horizon strategies, which always end up as a responsive system to react with the changings and fluctuations, managers then giving a significant effort to create resolutions to resolve problems in the meeting monthly. Instead, company should elaborate on the decisions that seriously account for the perspectives of strategic, tactical, operational and executional. (Harry Hawkers, Curt Mueller and Abhishek Malhotra. 2009).

Figure 42: Reviewing persepctives to match business objectives

7.3.2 Integration in value chain is an excellent alternative

In the fast changing and globalized circumstance, a smart company would like to have an advanced SOP system which is inclusive within a value chain encompassing many other involved parties. Besides, internal activities should be also integrated as cross-functional team should expand relevant activities horizontally, such as marketing and IT, which is alike consolidation. Beyond that, it is important to incorporate key suppliers and retail players to determine the actual situations more accurately with a broad spectrum of perspectives. Potentially, it will degrade the total cost to serve across the supply chain due to the merging, which also allow flexibility and a better level of service. (Harry Hawkers, Curt Mueller and Abhishek Malhotra. 2009).

7.3.3 Techonolgy is an opportuity

Historically, companies usually manage information of SOP processes using nothing more advanced than Excel spreadsheets. Essentially, the data accuracy is extremely important as it allows companies to analyze data as a deeper level of detail. The complexity of supply chain results in the growth of order levels as well as sophistication in data capturing and evaluating. Therefore, companies should be considering go beyond the traditional book keeping, improving their analytics capabilities by using technology with supply chain integration (VMI, real time tracking and analysis, integrated information system that connects supplier, manufacturer and retailer). (Harry Hawkers, Curt Mueller and Abhishek Malhotra. 2009).

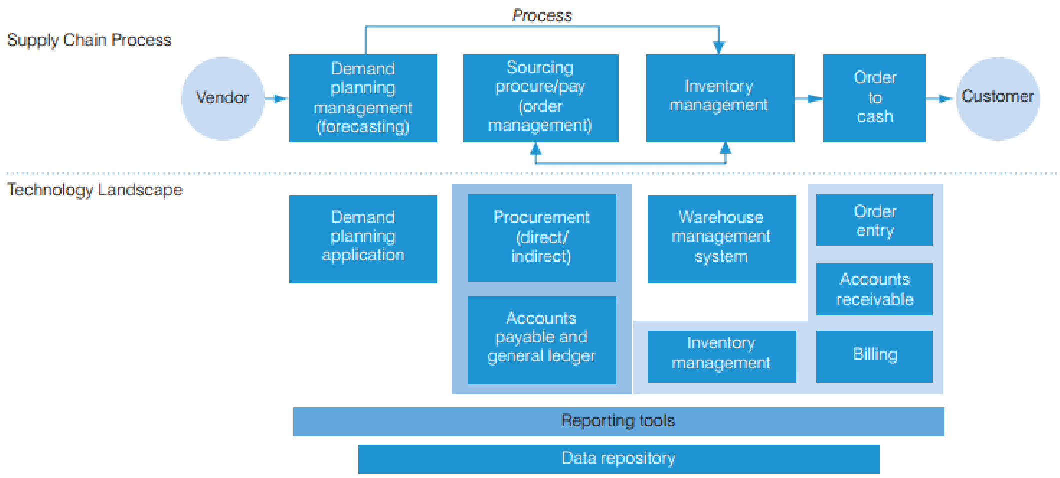


Figure 43: Technology boosting the supply chain effeciency

7.3.4 Being more proactive to future demand

Conventionally, SOP data is derived mostly from historical tracking, meaning the future demand will be dependent on the past sales in previous months, or manufacturer's transported shipments. However, there is a better idea when using a modern forecasting system which captures and studies many certain patterns such as trend, seasonality, or even variability driving factors, also, forecasting team must closely supervise the ongoing market that the combination of system's machine learning and human's accountability will result in a more efficient anticipation for the demand as well as a better proximity to customers. (Harry Hawkers, Curt Mueller and Abhishek Malhotra. 2009).

7.3.5 Compromise in KPIs

Typically, many different departments within a company will have a disparate set of metrics that measure the performance. In fact, it is significantly limited in inspiring every silo making decisions which result in the best for the business as a whole, instead of the ones that just solely advantage for their own. For example, the manufacturing department is encountering a decision that whether they should produce an item that extreme innovative required, but potentially bring a huge revenue for company, or producing an unchallenging item which take a very short time to engineer and accomplish but considerably less money coming back. Undoubtedly, most of the manufacturing department will vote for the easy one which obviously has a much higher success rate as well as achieve the KPIs. Apparently, this is no good in a perspective of optimum solution for any business. In fact, companies should attempt to align and look for indicators that could be consented and used for a variety of departments within a company. A metric that can be enclosed with a major strategic goal, following with rationale reasons and incentives, which possibly change the behaviors and thoughts of the dominant. Fortunately, there are a few of companies claiming that harmonized KPIs have been developed and deployed not only internally but also for multiple of companies within a same value chain. There is an example between a consumer-packaged goods (CPG) and its own retailer. The CPG believes itself that they have been doing a great job by achieving over 95% of on-time performance. However, the retailer does not think so when affirming that just only 80% goods are on time. As a controversy about to begin, they both realize that two completely different ways of measuring on time performance have been the reason for the misunderstanding. The CPG company measure the metric by number of trucks checked in the retailer’s distribution warehouse, dissimilarly, the retailer accounts the metric by the number of trucks are unloaded. As seeing throughout the difference in KPI which support both companies redefine and create a new reconciling metric which eventually help reducing the normal waiting time at the distribution warehouse. (Harry Hawkers, Curt Mueller and Abhishek Malhotra. 2009).

8 Production planning

Production planning can be easily understood as a design for information flow in the language of manufacture. When there is a product is being executed, it might require many sub-assemblies, which conventionally derived from different companies, or so-called suppliers. Moreover, these sub-assemblies might also consist of many different components. Hence, there must be tools that calculate all the crucial necessary parts that request to be manufactured by the company or placed orders for the suppliers that eventually a finished product is accomplished for customers. The following sections will be discussing about two most critical tools, which are Master Production Schedule and Material Requirement Planning.

8.1 Master Production Planning (MPS)

Fundamentally, MPS is a plan that used as a gateway to communicate the information between the sales, which represents for what a company wants to serve customers, and the manufacturing side, which accounted for the available producing capabilities. Importantly, MPS is a statement for the production, not demand. On other words, MPS is not a forecasting system but it consumes the forecasted demand as an input an translate it into the manufacturing plan in which the timing and quantity of a certain product will be carefully determined. There are two valid reasons why production and demand are completely different in the language of MPS. Firstly, demand has low and peak season which production hardly chase, hence, the products that forecasted for high season might be manufactured in advance. Secondly, low season in demand can result in relatively small requirements of a certain products, on the contrary, due to the economy and rationality, production must be executed in bigger batch size, meaning production expectedly lead or lag compare to the actual demand. In addition, thanks to the MPS, manufacturing can efficiently communicate and become more coordinated with the sale, exchanged information can be numerous, but the vital key is about the product available to promising date (ATP)

In fact, MPS might be similar on the big picture, still, there are some considerable differences when it comes down to manufacturing environments that a company is executing. In the engineer-to-order environment, when a customer's order received, meaning company is producing a distinctively unique item; not only customer has to wait for manufacturing, storing and delivering, but also the raw materials purchase and designing stage, which obviously result in an extensive interval of lead time. Next, make-to-order environment has no finished goods but there is already element has been purchased and stored in the inventory, which is the raw materials. Specifically, it is believed to be extremely challenging to predict the customer's exact demand, thus it always results in a very massive amount of raw materials, or feasible components configuration that can be physically combined. In term of assemble-to-order, it moves down a bit forward the downstream, when there are not only raw materials is determined but also work in progress (WIP) are stored in the inventory. Forecasting for the end items has been becoming super difficult which reflect on the numerous amounts of possible assembly from the available WIP, thus preparing the WIP is crucial but only producing the end item only when ultimate customer's order is determined. Lastly, make-to-stock environment's inventory will mostly be finished goods. At this point, MPS is the most complicated compare to other since it is a production statement for the entire end item in which many sub-components and parts are included.

As moving down from engineer-to-order to make-to stock environment, the lead time decreases dramatically, however, the demand is harder to forecast as moving from raw materials, then WIP, which are basically aggregated forecasting since these can be configured with many different combinations, to end item, which obviously is an individual.

8.1.1 Connections with other deparments within a firm

As the main objective of MPS is to answer the critical inquiry that is when to produce which item in how much quantity. Significantly, in order to come up with an optimal solution for such a vital situation, MPS requires a remarkably set of information derived from different departments which become an input of the MPS planning computation.

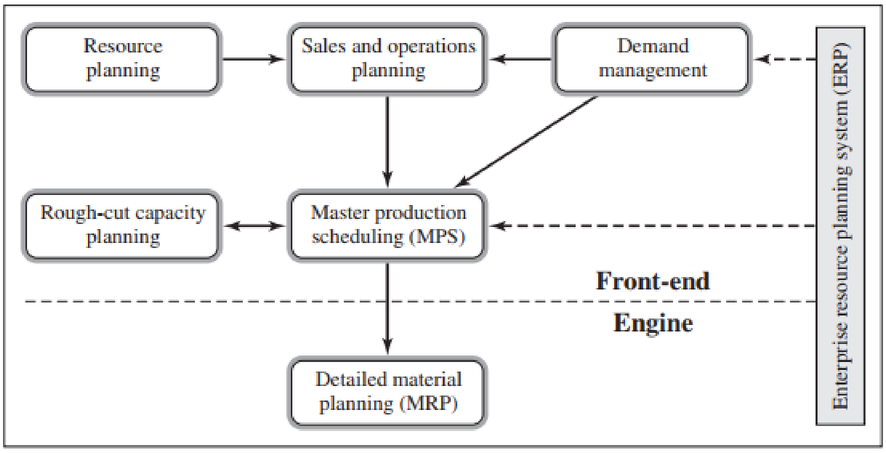


Figure 44 : Connections between MPS and others (Thomas Vollman 2011, 185-188).

As the picture shown above, Demand management will be responsible for collecting many data from all the possible related sources to create the current customer's orders, forecasting for future demand for both end item and spare part if needed, also the current inventory situation and even physical distribution approaches are determined. These reports and forecasts will be elaborated and transferred to SOP, in which all the information will be consolidated that eventually shaping into the sales and operation plan of the company. This plan is a statement which claiming the quantity and requested quality to meet the objectives. In some companies, this plan might be interpreted as the amount of money generated by sales, on the other hands, many companies will use the number of produced units as a demonstration, and this number will be a crucial input for MPS as the quantity that the manufacture must execute. As all the important input is specified, running MPS is not always as smooth as expectations, in fact, there are usually possible bottleneck that potentially slow down the entire manufacturing process, thus the rough-cut capacity planning is considerably significant for any company in which the analyses for MPS are constantly executed trying to eliminate all the existed faults in the system, especially the capacity issues. All the problems must be solved proactively for an efficient MPS.

8.1.2 Time-phased record

Essentially, time-phased record is a tool which brings all the related data into an integrated platform in which the forecasted demand, production plan and inventory available are specifically shown.

Time period	0	1	2	3	4
Forecasted demand		10	15	18	24
Production plan					
Projected available balance	30				

Visually, the record illustrates 3 extremely critical elements that reflects the efficiency in coordination and execution between sales department and operation planning part: forecasting, production plan and current inventory.

As the table shown above, the MPS starts with the beginning inventory on-hand is 30 with the forecasted demand values for the next 4 periods. There are several ways to come up with the production plan values which strictly depend on the chosen strategy that a company is running.

In addition, the projected available balance, or inventory on-hand, is calculated as previous available inventory plus production values minus forecasted value.

Time period	0	1	2	3	4
Forecasted demand		10	15	18	24
Production plan		5	5	10	20
Projected available balance	30	25	15	7	3

As the example demonstrated, the company has the initial inventory level of 30 items with all the forecasted demand available, they decide to manufacture 5 items in the first two weeks, then 10 and 20 items for week 3 and 4 respectively. The on-hand inventory (IOH) level for period 2 will be calculated as:

$$IOH_2 = IOH_1 + Production_2 - Demand_2 = 25 + 5 - 15 = 15\ items$$

As a matter of fact, everything takes place in the supply chain must be accounted for costs, and MPS is not an exception. When there is available data about forecasted demand retrieved from the Demand management department, SOP is required to create the figures in term of quantity of produced item which satisfy the demand as well as other factors such as desired level of inventory, labor constraints and so forth. Manufacturing and stocking items are costly, thus SOP must construct optimal solutions on which the total cost for production are kept as economical as possible whilst consumer's orders are still efficiently fulfilled and maintained.

8.2 Study case applied for MPS in practical use

There is a bicycle company which received an annual order of 2000 bikes from its key customers whose specific monthly demands are shown as below:

Month	Demand
1	200
2	150
3	100
4	50
5	50
6	100
7	150
8	200
9	200
10	250
11	300
12	250
Total	2000

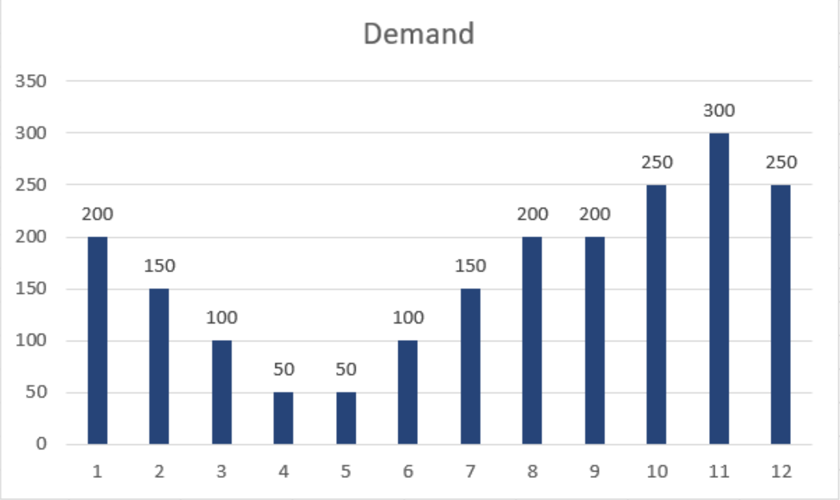


Figure 45: Bike shop example

Obviously, this is a fruitful 1-year contract in which receiving all 2000 bikes at once is not a case the customer desire to deal, instead, the bike delivery period will be spread out in the most economical way as the company has to try to figure out the suitable interval.

In fact, constructing a manufacturing plan request costs, there are two main costs that will be given:

Set up cost for one production run: 500€/run

Holding cost: 1€/item/month

Objective of the case is to find the optimal solution in which the total costs will be lowest so that specific appropriate periods for delivery will be determined.

8.2.1 Wagner-Whitin method

Essentially, Wanger-Whitin method assists the planner to create a manufacturing schedule in which the combination of set up costs for each production and inventory costs to be the possibly smallest. This method relies on two critical elements. The first one is believed it is conventionally fine to have zero inventory. On other words, purchasing orders possibly be placed as there is no sufficient inventory on-hand to fulfill the very next future demand. The second method stating that it is rather irrelevant to make products in advance whereas the holding cost is even greater than the set-up cost.

The procedure of this model is fairly straightforward:

1. Begin with time t = 1
2. Look for the cost to produce the exact required amount of demand
3. Look backward entire previous order (until t=1) to find the sufficient production to fulfill the demand in the current period by adding onto the existing previous order t-1
4. Pick the possible lowest options
5. At the last period, rolling backward until t = 1 to find and pick the lowest solution.

Indeed, procedures are relatively difficult to capture, as to illustrate the method, the mentioned bike shop example is brought into use.

Month	Demand
1	200
2	150
3	100
4	50
5	50
6	100
7	150
8	200
9	200
10	250
11	300
12	250
Total	2000

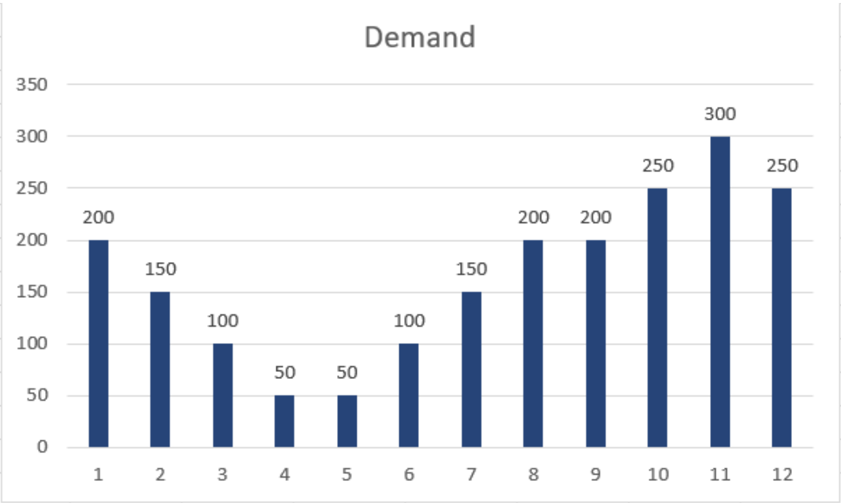


Figure 46: Bike shop example

Period t	Procedures	Decisions
1	Option 1: make 200 items for D(1) Total cost = 500€	There is no other option

		since this is the first period
2	Option 1: produce enough for both D(1 and 2) Total cost = 500 + (1)*150 = 650€ Option 2: do the best in period 1 plan and start producing in period 2 Total cost = 500+500= 1000€	Obviously, the option 1 absolutely outplay option 2.
3	Option 1: produce enough for D(1,2,3) Total cost=500+(1)*150+(2)*100=850€ Option 2: do the best in period 1 plan, start producing enough for D(2,3) Total cost= 500+500+(1)*100=1100€ Option 3: do the best in period 2 plan, start producing in period 3 Total cost=650+500=1150€	Option 1 is undoubtedly the best option.

As keep computing forward with the same procedures, the following is the final solutions

Period	1	2	3	4	5	6	7	8	9	10	11	12
Demand	200	150	100	50	50	100	150	200	200	250	300	250
order 1	500	650	850	1000	1200	1700	2600	4000	5600	7850	10850	13600
order 2		1000	110	1200	1350	1750	2500	3700	5100	7100	9800	12300
order 3			1150	1300	1300	1600	2200	3200	4400	6150	8550	10800
order 4				1350	1400	1600	2050	2850	3850	5350	7450	9450
order 5					1500	1600	1900	2500	3300	4550	6350	8100
order 6						1700	2850	2250	2850	2850	5350	6850
order 7							2100	2300	2700	3450	4650	5900
order 8								2350	2550	3050	3950	4950
order 9									2750	3000	3600	4350
order 10										3050	3350	3850
order 11											3500	3750
order 12												3850

Figure 47: Wagner-Whitin calcualtion in spreadsheet

As approaching the step 5 in the procedure, looking at the last period which is month 12, the least amount of money to fulfill 2000 bikes for the customer is 3750€, and the solution says that to come up with this value, the order of month 12 has to be produced at month 11 combined, the production for month 10 has to be made in advance in month 9, and so forth (yellow box indicates the best solution for planner to know when to produce for what month).

As more detail, the production for the first 5 weeks will be integrated and produced in month 1, which costs 1200€, month 6 will be responsible for all the demanded bikes in the next three months (6,7,8) since it just costs 1050€ to manufacture and storing, month 9 and 10 will be combined and cost 750€, and the last run for production will be held in month 11, with the total cost of producing 2000 bikes is 3750 euros, which is the optimal solution.

8.2.2 Mixed Interger Linear Programming method

Another method will be introduced by using the mixed integer linear programming in Excel spreadsheet. On a deeper understanding, this method is nothing else but optimization which consists of the optimal objective, constraints and variables.

Obviously, the ultimate objective of the problem is attempting to reduce the total costs which encompass setup cost and holding cost

$$\text{Min: TC} = \sum_t c * R_t + \sum_t h * I_t$$

Where: c: setup cost for each production run

R_t = 1 if the production line is open, otherwise 0

h: holding cost (€/item/period)

I_t: inventory in the end of time t

Next, constraints will be elaborated. Importantly, inventory flow has to be balance, on other words, the remaining inventory on-hand will be equivalent with subtraction between the sum of production and previous IOH minus the current demand.

$$P_t + I_{t-1} - D_t = I_t$$

Where: P_t: Production in time t

D_t: Demand in time t

In addition, there are some critical constraints that ensuring the optimization model executes correctly

$$P_t \leq Capacity_t$$

$$P_t, Q_t \geq 0$$

$$R_t = \{0,1\}$$

$$\text{M}*R_t - P_t \geq 0$$

In the last constraint, with M is a very large number that guarantees the R_t will not be 0 if there is any item produced in time t, which is apparently impossible when running the model.

setup cost	€ 500.00	per run
holding cost	€ 1.00	per item per month
M	9999	
Capacity	99999	items per month

total setup cost	€ 2,000.00
total holding cost	€ 1,750.00
total cost	**€ 3,750.00**

-Objective: Minimize TC
-Constraints input :
1. R(t) is binary
2. M*R - Production plan > 0
3. Production plan < capacity
4. Ending IOH, Production plan > 0

Period	1	2	3	4	5	6	7	8	9	10	11	12		
Demand	200	150	100	50	50	100	150	200	200	250	300	250		
Beginning IOH	0	350	200	100	50	0	350	200	0	250	0	250		
Production plan	550	0	0	0	0	450	0	0	450	0	550	0		
R_t	1	0	0	0	0	1	0	0	1	0	1	0	4	runs
Capacity	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999	99999		
Ending IOH	350	200	100	50	0	350	200	0	250	0	250	0	1750	items IOH in total
M*R	9999	0	0	0	0	9999	0	0	9999	0	9999	0		

Figure 48: Using MILP to optimize

8.3 Available-to-promise (ATP)

Essentially, available-to-promise is a vital communication tool between manufacturing and sales department in which the available remaining inventory that possibly fulfill the further orders from customers after all the committed demand is established. On other words, ATP determines the number of feasible products that can be certainly promised to customers, which is obviously spare inventory, or even safety stock. Importantly, sales department strictly require a reliable data on ATP since it gives the sales and distribution department the guidance as well as visibility about available products to sell to customer, from which proper decisions will be manipulated.

There are two main components in ATP, which are discrete and cumulative. Respectively, discrete is believed to have an un-carried over inventory, meaning remaining IOH in the previous cycle cannot be brought into next ones. On the other hand, cumulative allows all the IOH to be integrated and flow throughout the schedule computation dependently.

There is a quick example on how the ATP is calculated, given the information as below

Time period	0	1	2	3	4	5	6
Forecast		15	10	12	20	15	5
Customer orders		5	8	13	15	10	5
IOH	20						
Production plan		35			35		
ATP Discrete							
ATP Cumulative							

Figure 49: Example with given demand for ATP calculation

Running the mentioned method which result in the optimal solution for MPS production planning in which 35 items will be manufactured in period 1 and 4, plus having the existing IOH is 20, the ATP results will be computed as:

Time period	0	1	2	3	4	5	6
Forecast		15	10	12	20	15	5
Customer orders		5	8	13	15	10	5
IOH	20	40	30	17	32	17	12
Production plan		35			35		
ATP Discrete		29			5		
ATP Cumulative		29			34		

Figure 50: ATP calculation

Basically, ATP will be calculated as a cycle where production plan is setup, meaning there are 2 cycles in this example, from t=1 to t=3, and from t=4 to t=6.

Looking at the data, customer orders represents for committed orders that the company must deliver, which is not included in the remaining available inventory, or ATP.

IOH formula will be:

$$IOH_t = IOH_{t-1} + Production_t - MAX[forecast, customer\ orders]$$

Sometimes, company has an over-committed product delivery, thus MAX function would be more appropriate to calculate the actual remaining IOH in the end of every period.

As discrete characteristic does not allow inventory to be transferred to other cycle, the ATP will be computed as:

$ATP_{discrete\ in\ 1st\ cycle}$ = IOH + MPS – committed customer orders = 20+35-5-8-13=29

$ATP_{discrete\ in\ 2nd\ cycle}$ = MPS – committed customer orders = 35-15-10-5 = 5

On the contrary, cumulative is much generous when IOH can be compensated for the other time:

$$ATP_{cumulative\ in\ 1st\ cycle} = \text{IOH+MPS - committed orders} = 20+35-5-8-13=29$$

$$ATP_{cumulative\ in\ 2nd\ cycle} = ATP_{remain} + \text{MPS} - \text{committed orders} = 29+35-15-10-5=34$$

As accomplishing the customer committed orders in period 1, there are new orders coming to the company, at this particular moment, ATP will thankfully assist the sales department in the decision that whether or not the promise for products as well as delivery date are made for customers.

additional order	period request from customer
5	2
2	3
10	4
3	5

Time period	1	2	3	4	5	6
Forecast		10	12	20	15	5
Customer orders		13	15	25	13	5
IOH	34	21	6	16	1	-4
Production plan				35		
ATP Discrete		6			-43	
ATP Cumulative		6			-37	

Figure 51: Additional demand in ATP

Obviously, the additional orders cause a considerable trouble for the company if the current MPS production plan is maintained, which results in negativity in ATP. Essentially, with the insufficient ATP, it is unlikely for the company to accept the new orders since it will significantly affect the entire manufacturing plan, or even worse, a new MPS plan can be developed to flexibly fulfill the unexpected orders from customers, which obviously a strain that any company wants to avoid. Hence, there is a concept so-called Time Fencing which is commonly known and applied as a solid protection from any possible vulnerability derived from unexpected demand. The Time

Fencing will be determined independently as different companies have different strategies and approaches with customers, some will have 3 months, others might go up to 6 months. With t is the time customer orders received by the company, this rule is claiming:

If t < Demand Time Fencing, then fully only committed to the current MPS (aka Frozen)

If Demand Time Fencing < t < Planning Time Fencing, slight modification is acceptable (aka Slush)

If t > Planning Time Fencing, considerable modifications in MPS allowed (aka Water)

To have an easier understanding about this concept, when the customer order arrival is too close to the current period, then company should deny it, when it is a bit far from the current period, then some of orders can be considered, and when the orders are way to far ahead, then a new MPS can be developed to meet the customers' needs. In fact, the concept of time fencing incredibly help many companies stabilize the MPS planning which also assist in a predictable and controllable MRP later on.

8.4 MPS in the special environment – Assemble-to-order

Conventionally, assemble-to-order company is recognized by numerous numbers of end product possibility since the limitless configuration of components and spare parts. For example, a Chevrolet automaker probably carry billions of WIP which can be all the feasible options that customers request. This means the MPS in this environment is considerably complicated since it cannot fully rely on the end item planning.

In fact, MPS used in assemble-to-order case has recipe in which all the details about components, subassemblies, or even raw materials will be listed. It acts as a guidance in term of required ingredients to construct an entire end item that wanted from customers; the recipe is called planning bill of materials. Essentially, there are two different ways to plan for a manufacturing process to produce the end items for customers. The first is building entire process from nothing, meaning after the desired end item is known from customers, the manufacturer will make an MPS based on that end item, and more noticeably, start building that item from assembling the components, then constructing it into modules, then finally all the modules will be combined into ultimate end products. As a matter of fact, the mentioned procedure is completely fine and reliable except one deadly crucial element, lead time, which is definitely extensive and customers are not certainly willing to wait. The other approach is designing a system in which two parallel synchronized lines will run simultaneously. The first line is responsible for assembling the components and modules, the second one is in charge for final combinations. Significantly, this system is incredibly shorter than the first one in term of customer respond time. However, it is also challenging to maintain such kind of procedures which strictly require a tightly integrated and constantly efficient communication so that components are made available whenever desired end item is ordered. This system is known as two-level MPS.

Two-level MPS uses a special type of planning bill of materials, known as super bill. The super bill describes all the possible options and modules that construct an average end item. Average item meaning an average notebook can have 4gb of ram, 0,8 full HD panel (80% of notebook will have full HD screen), 0,65 cell phone connectivity (there is a censor which is accessible with cell phone in 65% of notebook). It is obviously impossible to build such kind of notebook, however, this piece of information about average item is extremely valuable for a laptop maker in which the average possible component usage included.

Considering a brief example of a car industry. There is an automaker that running on the assemble-to-order strategy that offering its customers multiple options to choose for their car. The options include 3 modes of horse power (100,200 and 300), two modes of shifting gear (automatic and manual), and colors (Red, Blue and Green). Apparently, there are 18 possibilities of the final cars which is extremely difficult for the company to forecast as well as maintaining the inventory. Meaning constructing an MPS from the end item is impossible to be successful.

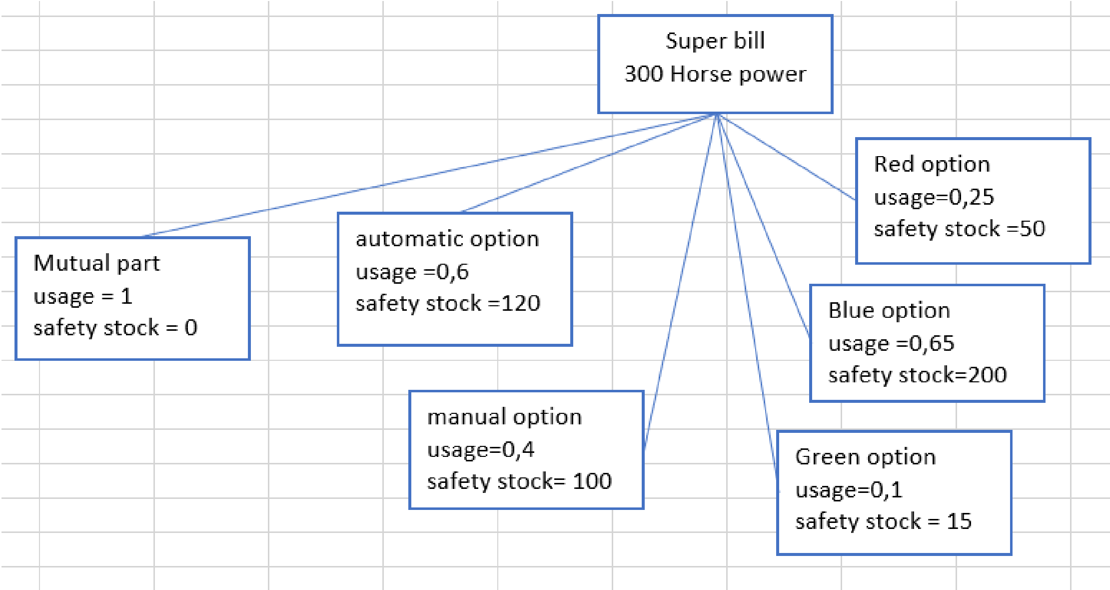


Figure 52: BOM¨for the 300 horse power

The graph above illustrates all the possible configurations in the 300-horsepower option. Significantly, there are many options with the components and subassemblies in term of colors and shifting modes, however, it is just required to have only one forecasting model for the 300 horse-power, the final customization will be relied on the usage proportion. For example, forecasting 100 orders will be taken place for 300-horsepower model next month, then there will be 60 options with automatic, 40 with manual, 25 options for red and so forth. In addition, with the safety stock available, the company is fully control and aware of available items from which a proper ATP will be informed to customers.

8.4.1 Two-level MPS

When the overall picture derived from super bill is clarified, the final assembly schedule (FAS) will be constructed in which the details about final assembly orders, planning quantity for critical components, and other finishing processes will be taken care in depth.

The FAS will be mostly executed mostly on the two-level MPS technique, which is believed to assist a lot of assemble-to-order companies to control the flow of components and subassemblies that must be ensured available before an order is promised to customers.

For a deeper understanding in two-level MPS, the mentioned car example will be exploited more. As 100 orders are believed to happen for 300-horsepower car, the MPS will be:

period	0	1	2	3	4	5	6
forecast		100	100	100	100	100	100
customer orders		72	88	80	78	94	95
IOH	0	0	0	0	0	0	0
MPS production plan		100	100	100	100	100	100
ATP (discrete)		28	12	20	22	6	5

Figure 53: MPS for 300-horsepower car

There are different amounts of actual committed orders took place as the picture shown above, hence the MPS production plan is set to run a lot size with 100 items, IOH and ATP will be calculated as mentioned earlier.

As 100 orders are forecasted for the 300-horsepower car, the automatic shifting option is believed to possess 60%:

period	0	1	2	3	4	5	6
forecast		60	60	60	60	60	60
customer orders		55	60	58	62	61	50
IOH	0	70	10	70	8	70	9
MPS production plan		130		130		130	
ATP discrete		15		10		19	

Figure 54: MPS for automatic option

And manual shifting option to be 40% of all 300-horsepwer demand:

period	0	1	2	3	4	5	6
forecast		40	40	40	40	40	40
customer orders		42	35	38	40	30	41
IOH	0	48	8	50	10	50	9
MPS production plan		90		90		90	
ATP discrete		13		12		19	

Figure 55: MPS for manual option

Overall, the two-level MPS assist organizations in term of designing a proper approach to its vast offered options of end items in which final customizations from customers have been a challenge to deal with. The method aligns all the production planning as the way products are sold, instead of the way they are manufactured. (Thomas Vollmann, 2011, 200-203).

8.5 Materials requirement planning (MRP)

As Master Production Schedule will be developed based on the customers' orders derived from SOP, which are mostly end items, such as how many bikes, cars, computer will be in need for the next month. However, as a matter of fact, these end items are constructed from bunch of sub-assemblies and components, like 4 wheels for a car, 1 monitor for a computer and so forth. These components play an extremely significant role in planning to manufacture the end products; MRP is the tool that fully in charge to take care all the materials needed for an end item production. Especially, for companies that manufacturing complex products, such as cars, phones, laptops and so forth, which probably consist of thousands or even millions of components, MRP is a core of the manufacturing planning.

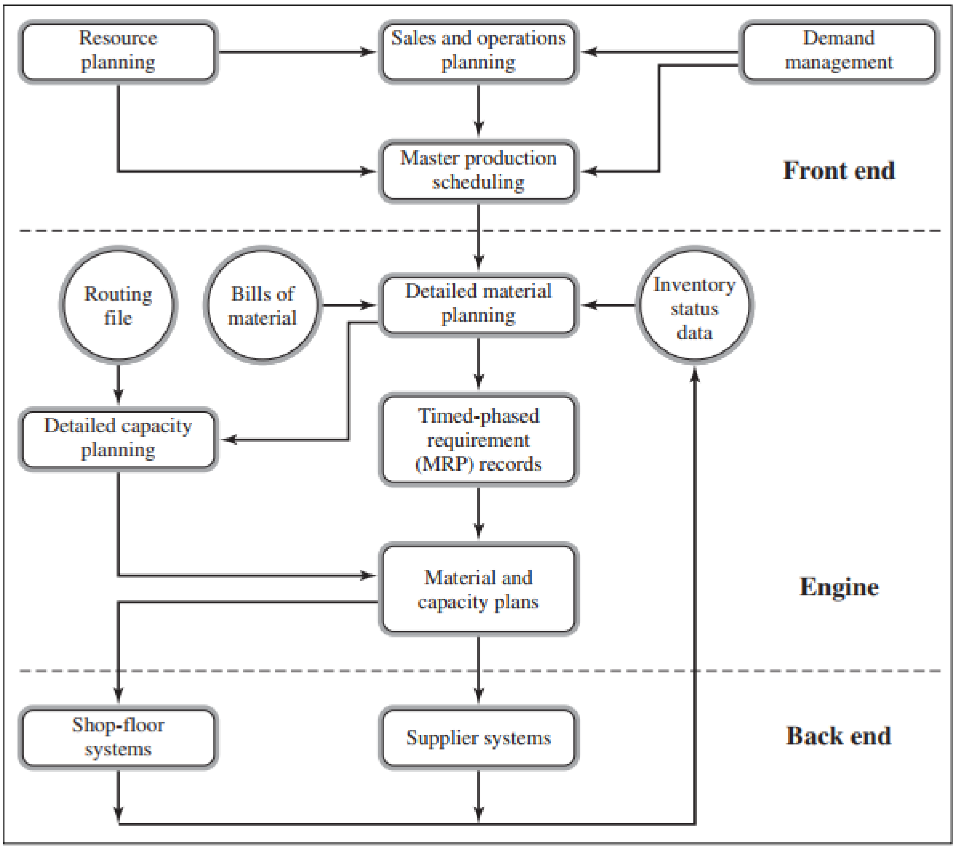


Figure 56: MRP in the MPC environment (Thomas Vollman 2011, 214-218).

As a more concrete picture demonstrates the MPC processes, front end will be responsible for the MPS outcomes, which require lots of information from SOP and demand management so that end items' demand will be determined and evaluated. All the elaboration computed in the MPS then will be shifted down to MRP to construct a more specific plan via an incredibly vital gate – detailed material planning. In this phase, all the requirements calculated from MPS will be translated into the equivalent MRP language in term of components and raw materials, using time-phased record (such as MPS needs 10 bikes for the next month demand, detailed material planning will then transform such kind of information down to MRP, which means there are 20 wheels needed in next month); in order to do so, MRP necessitates two critical effects. The first one is Bill of material (BOM), which acts as a recipe to make a product. BOM consists of every component necessary for every sub-assembly (such as 10 bikes need 20 wheels, 1 wheel needs 5 bolts). The second effect is inventory status, meaning whether the initial or previous stock for a certain component is remained or empty. These two elements assist the detailed material planning an easier and smoother way when translating from MPS into MPR requirements, also, the accuracy and other computations (such as ATP) will be considerably more reliable.

An MRP system plays as a backbone role in any manufacturing planning phase. It helps a company a clearer vision on detailed steps to transform many small steps from many component assemblies into a final accomplished product. For an ordinary understanding, MPS serves the customers' demand, and MRP fulfill the MPS's requirements.

8.5.1 Conventional approach

There is a quick example will be illustrated for a deeper understanding the MRP procedures. There are two different organizations, one is only assembling finished bikes, and the other is OEM, or components manufacturer. The BOM for the upcoming bike is simple which consists of 2 wheels needed.

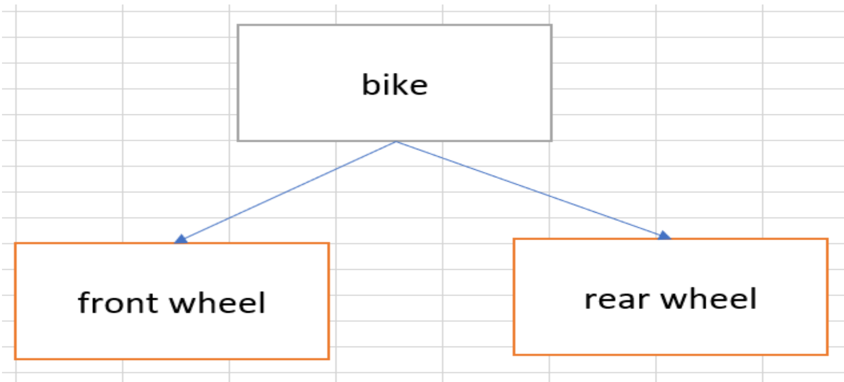


Figure 57: Simple BOM for a bike

And the future demand for the upcoming months are given as following:

Period	1	2	3	4	5	6	7	8	9	10	11	12
Gross req	0	0	0	0	0	30	50	80	100	90	120	100

Figure 58: Given demand for bikes¨

And the results for all the factors in MPS will be demonstrated in spreadsheet:

lead time	2	period	total setup cost	7000
setup cost	1000	euro per run	total holding cost	0
holding cost	5	/unit/month	total cost	7000
M	90000			

Period	1	2	3	4	5	6	7	8	9	10	11	12		
Gross req	0	0	0	0	0	30	50	80	100	90	120	100		
Beginning Inv	0	0	0	0	0	0	0	0	0	0	0	0		
Due in/Net Req	0	0	0	0	0	30	50	80	100	90	120	100		
End Inv	0	0	0	0	0	0	0	0	0	0	0	0	0	totoal IOH
Planned order release	0	0	0	30	50	80	100	90	120	100	0	0		
R(t)	0	0	0	0	0	1	1	1	1	1	1	1	7	runs
M*R	0	0	0	0	0	90000	90000	90000	90000	90000	90000	90000		

Figure 59: MPS for the given demand

With the given lead time and all the related costs, the other factors are calculated based on the Gross requirement (total forecast in demand) for the bike in certain months. Noticeably, there is an element called Planned order release, meaning the order/production has to be made before the Due in within the interval equivalent with lead time. For example, there are 30 bikes forecasted in June, meaning that 30 bikes have to be ordered/manufactured 2 months before, which is the lead time of this company. As the gross requirement is forecasted and Planned order release is identified, MRP then can be measured:

lead time	1	period	total setup cost	3500
setup cost	500	euro per run	total holding cost	0
holding cost	1	/unit/month	total cost	3500
capcity	9999			

Period	1	2	3	4	5	6	7	8	9	10	11	12		
Gross req	0	0	0	60	100	160	200	180	240	200	0	0		
Beginning Inv	0	0	0	0	0	0	0	0	0	0	0	0		
Due in/Net Req	0	0	0	60	100	160	200	180	240	200	0	0		
End Inv	0	0	0	0	0	0	0	0	0	0	0	0	0	total IOH
Planned order release	0	0	60	100	160	200	180	240	200	0	0	0		
R(t)	0	0	0	1	1	1	1	1	1	1	0	0	7	runs
M*R	0	0	0	90000	90000	90000	90000	90000	90000	90000	0	0		

Figure 60: MRP accroding to the MPS plan

The gross requirement for MRP is not forecasted in this case but strictly dependent on the Planned order release information derived from MPS. On other words, MPS needs 30 bikes in period 4 which used for the demand in period 6, that there will be 60 wheels (1 bike includes 2 wheels) are in need in period 4 as data transferred down.

Obviously, the method used to create the plan that already satisfy the customers' demand. However, that definitely is not a desirable result for any manufacturer and related parties in the supply chain since the total cost is extremely considerable. (almost 10500 euros to satisfy the forecasted demand). Indeed, there must be an optimal approach to come up with the better formula by which the costs are kept as minimum as possible while demands are still contented

8.5.2 Optimal approach

By using the same MILP method which was done previously in MPS section, the results for an integrated optimization both for the bike company and the OEM manufacturer are calculated.

lead time	2	period			total setup cost	3000							
setup cost	1000	euro per run			total holding cost	2150							
holding cost	5	/unit/month			total cost	5150							
M	90000												
Period	1	2	3	4	5	6	7	8	9	10	11	12	
Gross req	0	0	0	0	0	30	50	80	100	90	120	100	
Beginning Inv	0	0	0	0	0	0	50	0	190	90	0	100	
Due in/Net Req	0	0	0	0	0	80	0	270	0	0.00E+00	220	0	
End Inv	0	0	0	0	0	50	0	190	90	0	100	0	430
Planned order release	0	0	0	80	0	270	0	0	220	0	0	0	
R(t)	0	0	0	0	0	1	0	1	0	0	1	0	3
M*R	0	0	0	0	0	90000	0	90000	0	0	90000	0	

Figure 61: Optimized MPS plan for bikes

lead time	1	period	total setup cost	1500
setup cost	500	euro per run	total holding cost	0
holding cost	1	/unit/month	total cost	1500
capcity	9999			

Period	1	2	3	4	5	6	7	8	9	10	11	12	
Gross req	0	0	0	160	0	540	0	0	440	0	0	0	
Beginning Inv	0	0	0	0	0	0	0	0	0	0	0	0	
Due in/Net Req	0	0	0	160	0	540	0	0	440	0	0	0	
End Inv	0	0	0	0	0	0	0	0	0	0	0	0	0
Planned order release	0	0	160	0	540	0	0	440	0	0	0	0	
R(t)	0	0	0	1	0	1	0	0	1	0	0	0	3
M*R	0	0	0	90000	0	90000	0	0	90000	0	0	0	

Figure 62: Optimized for MRP plan for wheels according to MPS

With the same demand but different strategies in manufacturing planning that optimally executed for both firms, the total cost is now less than over 33% compare to the conventional approach (6650 euros for the total cost).

8.6 MRP in Manufacturing and Controlling Planning system

As ensuring a smoothing MRP running that there are some critical key points required to be concerned and elaborated.

8.6.1 The system planner

Undoubtedly, human resource always plays the most important role in any activity. Indeed, the MRP planners, who can be a purchaser, production planner, or inventory controller, are the ones that get most deeply involved in the system. They are the ones who have the rights and discretion to make proper decisions which keep everything, including materials and personnel, circulate smoothly within the firm. In the modern environment, MRP data are computerized, thus the BOM can be extremely numerous. To take care of such kind of massive volume, planners are responsible to review any records that need to be in action. In addition, analyzing the system is strictly required so that possible errors and bottlenecks are quickly identified. Eliminating faults whilst maintaining and finding more factors that could help increasing the system's performance are the jobs that only the planners are trained and aimed to accomplish. (Thomas Vollman. 2011. 235-238).

8.6.2 Allocation

Allocation is the procedure in which the order launching process and components availability will be carefully concerned. To assemble 20 bikes, there are 40 wheels needed, if there are insufficient amount of wheel inventory, that order for 20 bikes might not be launched. When there is enough components for an order to be finished, then MRP will allocates the exact amount of components needed, thus, physical inventory may be greater than projected available balance, the buffer between these two is the allocated stock which have not been removed from the inventory yet. Planners are required to be fully aware of this knowledge since it has a massive impact on the ending inventory as well as ATP calculation. Proper corrections will be taken place if there are unidentified buffer in inventory, possible roots might come from data inaccuracy and un-update. (Thomas Vollman. 2011. 235-238).

8.6.3 Bottom-up replanning (BURP)

As a matter of fact, material shortage in supply chain environment is unavoidable. BURP uses pegging data to solve such kind of problems. This process is executed by the planners who analyze and evaluate all the feasible resolutions that can tackle the shortage with the possible lowest cost while maintaining the customer trust. All the solutions can save such kind of situation can be lead time compression by negotiation for letting people working earlier. Furthermore, changing the master schedule is also considered. Sometimes, it is a bitter truth that all the problems are not solved by lead times and production changing. Customers will be informed about the situation as soon as possible and delayed delivery date is notified in advance so that customers can make their following proper actions. (Thomas Vollman. 2011. 238-240).

8.6.4 Exception code

Exception code are used to ‘’separate vital few from trivial many’’. Meaning that if the system is functioning as expected, there are no need to review and evaluate all the parts and components which costs lots of resources to execute. In fact, there are only few, from 5 to 20 percent, that significantly important require the planners to check every production cycle. There are two main categories for the exception codes. The first one is data accuracy checking. The planners are expected to inspect all the entry processes for a certain amount of materials which consist of date, quantity, nonvalidity existence checking and so forth. The second type of exception code is messaging the planners which parts/components are needed the most the upcoming period. Also, there are bunch of diagnostics for existing work orders and purchasing order delivery. Those diagnostics will be opened in the system in purposes that orders need to be either schedule further or sooner, even removed is necessary, which results in due dates are revised to be more suitable for the manufacturing plan. (Thomas Vollman. 2011. 240-245).

9 Coordination of processes in MPC

As a matter of fact, all the mentioned departments are strictly related within the MPC. Demand management will ensure all the information are consolidated and fulfill for the other silos. Forecasting then will follow the analyses and customers' derivations from demand management that create accordance values for the future needs, which can be relatively understood as gross requirement, a very important input for MPS. In MPS, the Planned order release will be calculated which will be consumed later by MRP as a demand input for the sub-assemblies and components planning. Obviously, one step happens to be unconcise in the chain will have a massive interruption for others. Demand management creates an irrelevant perspective on the market and products probably result in a bias forecasting, which then leading to an imprecise manufacturing plan for both MPS and MRP. In fact, to enhance the overall performance of the chain as well as the company, regular meeting between C-suite from all the critical departments are held. According to John C. Chamber, 1971, a successful forecasting constantly requires a reliable information from demand management, which might encompass marketing research or customers interests analyses, and more importantly, a strong connection and collaboration between managers and forecasters is the core to detect the company' issues and objectives, by which proper forecasting methods will be picked, furthermore, once the goals as well as problems of company are determined and evaluated, the chosen forecasting system is likely to be more appropriate, truly reflect the products onto the aimed market. Once forecasting system is capable of creating the reliable set of future expected information, MPS then consumes it as the gross requirement (GM), also, the Inventory on hand, or projected available balance is checked following which the manufacturing plan for items are calculated, and planned order release will be made based on the plan combined with the concept of lead time. Once the planned order release is known, then that data will be transferred down as an input for MRP, which ingests it as a gross requirement role in MPS case. Following by the same terms such as projected available balance plus schedule receipt, the production plan for components and raw materials will be constructed. All the chain is integrated which every individual stage must try to enhance the capability so that the overall performance of MPC within a firm can be positively increased. (John C. Chambers, Satinder K. Mullick and Donald D. Smith. July 1971).

10 Demand varying with normal distribution and system nervousness

Essentially, MPS is extremely crucial in term of maintaining the satisfied customer service level as well circulating a stable flow of information which will be fed down to MRP. As mentioned before, Gross Requirement in MPS will be derived from demand forecast function. In fact, there are always errors in forecast, or known as demand uncertainty, which results in a poor level of service in MPS and unfavorable inventory valuation. Indeed, demand practically cannot be deterministic, but fluctuating in a calculated pattern; it is normally distributed conventionally.

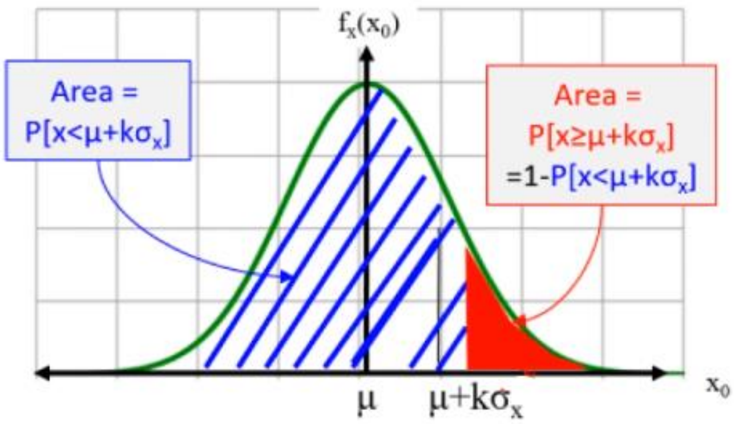


Figure 63: Normal Distribution

On other words, demand that probably happen X% will be vary around the mean in a standard deviation interval, the X% can be calculated in Excel spreadsheet as:

Cumulative normal distribution, or cdf: =Norm.Dist (X,μ,σ,1)

A given exact point probability, or pdf: =Norm.Dist (X,μ,σ,0).

As the demand is varying, it greatly influences on the reliability of input data on the detailed planning for components and raw materials. Regular adjustments on both MPS and MRP in term of gross requirements due to the fluctuation can generate a considerable amount of costs, such as production costs, inventory costs and so forth. A nervous system is obviously not an ideal situation any company desires to pursuit, in fact, there are many ways have been developed to tackle down this strain; there is one dominant solution that outplays others – freezing MPS methodology.

10.1 Freezing the Master Production Schedule

As the planning horizon of the MPS is rolling, the actual sales will be constantly updated, meaning it is valid to re-plan the MPS according to the new updated information. However, as doing so that will undoubtedly generate a massive cost. According to Blackburn (1986,1987), there are several strategies have been investigated, and MPS freezing is the most effective way. (Kadipasaoglu and Sridharan, 1995). Its functionality is to freeze a portion of a determined planning horizon, so-called frozen interval.

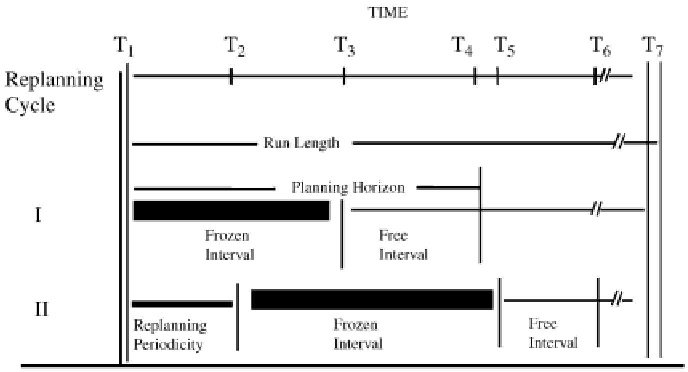


Figure 64: Freezing MPS strategy. (Jinxing Xie, Xiande Zhao. 2002. 70-75)

In fact, an effective frozen strategy must come along with appropriate choices of parameters. There are 3 main freezing parameters that considerably trigger differences in MPS planning: planning horizon (PH), freezing proportion (FP) and re-planning periodic (RP). These parameters have a huge impact on the decision for frozen intervals as well as related costs. PH is represented for the number of intervals on which the production schedule is developed until the next re-planning cycle. In addition, frozen interval is the amount of time in which the production will be executed according to the original strategy, free interval is contrary in which adjustments are allowed to happen. FP is referred to the ration between frozen interval and PH, meaning the higher FP is, the more stable the system will be, since there will be few adjustments made, however, loss of sales and total cost increasing due to possible excessive inventory might be matter. RP is understood as the number of periods between successive re-planning. (Ou Tang. Planning and re-planning the MPS under demand uncertainty. August 2000).

10.1.1 Impact of PH

According to an experiment executed by Jinxing Xie and Xiande Zhao, a longer planning horizon will reduce the total cost and increase the level of service, however, the system nervousness will be significantly greater. Consequently, the managers must to make decisions on the crucial trade-offs between instability and combination of costs and level of service. Also, according to Zhao (2001), the longer PH under capacity constraint will reduce the total cost compare to the one without capacity constraint. The reason is capacity constraint will allow the system to make proper modifications in production to best utilize the available capacity. (Jinxing Xie, Xiande Zhao. Freezing the MPS under single source of constraint and demand uncertainty. 2002.)

10.1.2 Impact of FP

In the same experiment, when FP is equal 0, the total cost will be the lowest and level of service will be the highest. Since when the FP is zero, only the order in first period is frozen, meaning there is no trade-off between production setup cost and holding cost, as such in the experiment, the produced orders are always greater than expected demand in first period. Therefore, loss of sales will not going to happen. Furthermore, since every other period are free, excessive capacity in one period can be used for another. When FP is non-zero, the lower it is, the higher the total cost will be, the lower the service level also. The fact that excessive stock can be compensated within periods, which results in the longer horizon planning attain the better level of service. (Jinxing Xie, Xiande Zhao. Freezing the MPS under single source of constraint and demand uncertainty. 2002.)

10.1.3 Impact of RP

The experiment suggests that the higher RP (less frequent in schedule revision) will result in lower total cost and better service level. In addition, the system will achieve the peak performance as the fraction between frozen interval and RP is 1, on other words, revision take place as soon as the frozen intervals finish is the most optimal solution. The interpretation for that statement could be explained as the more frequent the schedule is revised and updated, the more adjustments will be executed on MPS. (Jinxing Xie, Xiande Zhao. Freezing the MPS under single source of constraint and demand uncertainty. 2002.)

11 Study case

There is an SME bicycle company that has been struggling with all the historical sales data and barely construct any ideas for the future planning in term of the upcoming demand as well as manufacturing plan. I was hired as an SOP planner to help the team with all the planning as well as calculations in both forecasting and manufacturing planning, in 2 years horizon in 2019 and 2020, to come up with the relative figures to which company can according and create a better proposition as well as make finer decisions on their own bike production field.

As intending the Holt-Winter forecasting model as the main tool, also, using MILP optimization for the Master Production Planning plus Materials Requirement Planning, there is obviously no fully transparent data that I can use to evaluate, however, when looking at some reports and analyze historical data, there are few critical points that helps a lot for my duty fortunately.

Firstly, the company sees a year in 4 periods, meaning 4 quarters. The first quarter (from January to March) has 40% of the average demand, the second quarter has 160% of average demand, following by the third and the fourth with 140% and 60% respectively.

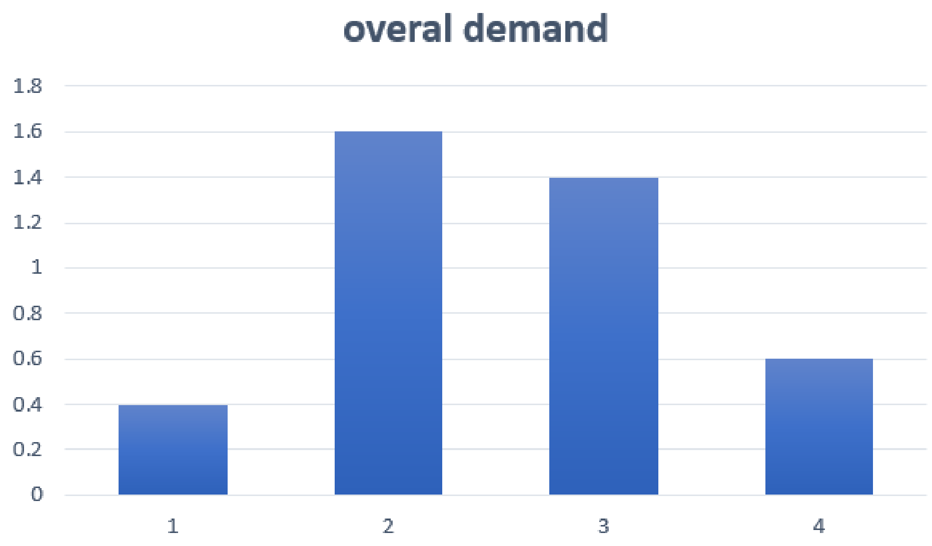


Figure 65: Demand vaties in a year

Also, looking back the most current periods, there are critical data that can be collected:

$$\hat{a}_{2018Q3} = 1023\ ;\ \hat{b}_{2018Q3} = 42.6$$

From this piece of information, the first Holt-Winter forecasting can be calculated as:

$$\hat{x}_{2018Q3,2018Q4} = \left(\hat{a}_{2018Q3} + \hat{b}_{2018Q3}\right) * F = (1023 + 42.6) * 0.6 = 640 \text{ bikes}$$

In fact, there were 595 bikes were sold in 2018Q4, also, the values for level and trend were estimated:

$$\hat{a}_{2018Q4} = 1015\ ;\ \hat{b}_{2018Q4} = 40.8$$

From this piece of information, the value of α and β can be computed as:

$$\hat{a}_{2018Q4} = \alpha\left(\frac{x_{2018Q4}}{F_4}\right) + (1-\alpha)\left(\hat{a}_{2018Q3} + \hat{b}_{2018Q3}\right)$$

$$\rightarrow\ \alpha = 0.68$$

$$\hat{b}_{2018Q4} = \beta\left(\hat{a}_{2018Q4} - \hat{a}_{2018Q3}\right) + (1-\beta) * \hat{b}_{2018Q3}$$

$$\rightarrow\ \beta = 0.035$$

Then, all the future quarter until 2020 can be calculated as:

$$\hat{x}_{t,t+\tau} = \left(\hat{a}_t + \tau\hat{b}_t\right) * \hat{F}_{t+\tau-P}$$

The results are calculated in Excel spreadsheet and shown as below:

	x(t)	a^(t)	b^(t)	F(t)	x^(t,t+1)
2018Q3		1023	42.6	1.4	639.36
2018Q4	595	1015.325	40.84039	0.6	423
2019Q1				0.4	1756
2019Q2				1.6	1593
2019Q3				1.4	708
2019Q4				0.6	488
2020Q1				0.4	2017
2020Q2				1.6	1822
2020Q3				1.4	806
2020Q4				0.6	

Figure 66: Forecasting values for 2019 and 2020

As the forecasting values have been calculated, the results will be the very important input for dependent processes, which are MPS and MRP.

At this stage, the integrated for both MPS and MRP will be executed. As a matter of fact, this is fairly a challenge for big companies to accomplish since integrate MPS and MRP simultaneously require certain sacrifices in term of cost (if a company has an OEM partner to manufacture components for them). However, the bike company still has a compatible factory which can facilitate to make some critical parts themselves.

Part	Quantity	Make/Buy decision
Frame	1	Make
Wheel	2	Make
Handle Bar	1	Buy
Saddle	1	Buy
Chain	1	Buy
Pedal	2	Buy
Brake	2	Buy
Screw	25	Buy

Figure 67: BOM and M/B decisions

As information provided above, an MPS outcomes for a finished bike will create another input that transferred down to calculate two main dependent parts which are Frame and Wheel. Furthermore, the following information is given by the shop owner:

finished bike		frame		wheel	
setup cost	8200	setup cost	5000	setup cost	4000
holding cost	1.5	holding cost	0.5	holding cost	0.25
M	99999	M	99999	M	99999
capacity	3000	capacity	5000	capacity	10000

Figure 68: Production information

As a matter of fact, forecasting is always lagging, hence, a simple simulation on varying demand is executed.

Seasonal coefficient	Varying Demand (bikes)
0.4	420-490
1.6	1700-2100
1.4	1600-1850
0.6	700-800

Figure 69: Simulated demand values according to seasonal factor

As each quarter has a specific seasonal factor, that a range which includes upper limit and lower limit is set as the expected demand will vary within the interval.

After 4 simulation runs on the demand for the next 2 years, the following are the results as well as detailed stochastic optimizations for MPS and MRP for Frame and Wheels. To be more specific, each demand row in the stochastic optimization below will contain the formula RANDBETWEEN(420,490) in the 2019Q1 and 2020Q1, for example. In other words, the demand will be determined based on constant available seasonal coefficient but randomly variable projecting values.

First run result:

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	424	1848	1753	709	462	1949	1710	700				
Beg IOH	0	1848	0	1171	462	0	0	700				
MPS plan	2272	0	2924	0	0	1949	2410	0				
R(t)	1	0	1	0	0	1	1	0	4	runs	TC1	39071.5
Capcity	3000	3000	3000	3000	3000	3000	3000	3000				
Ending IOH	1848	0	1171	462	0	0	700	0	4181	total IOH		
M*R	99999	0	99999	0	0	99999	99999	0				
planned order release	2272	0	2924	0	0	1949	2410	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	2272	0	2924	0	0	1949	2410	0				
Beg IOH	0	0	0	0	0	0	2410	0				
MRP plan	2272	0	2924	0	0	4359	0	0				
R(t)	1	0	1	0	0	1	0	0	3	runs	TC2	16205
Capcity	5000	5000	5000	5000	5000	5000	5000	5000				
Ending IOH	0	0	0	0	0	2410	0	0	2410	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	2272	0	2924	0	0	4359	0	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	4544	0	5848	0	0	3898	4820	0			TC3	13205
Beg IOH	0	0	0	0	0	0	4820	0				
MRP plan	4544	0	5848	0	0	8718	0	0				
R(t)	1	0	1	0	0	1	0	0	3	runs		
Capcity	10000	10000	10000	10000	10000	10000	10000	10000				
Ending IOH	0	0	0	0	0	4820	0	0	4820	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	4544	0	0	0	0	8718	0	0				

Figure 70: Stochastic optimization 1

Second run result:

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	468	2082	1611	768	430	2090	1705	758				
Beg IOH	0	2082	0	1198	430	0	0	758				
MPS plan	2550	0	2809	0	1.14E-13	2090	2463	0				
R(t)	1	0	1	0	0	1	1	0	4	runs	TC1	39502
Capcity	3000	3000	3000	3000	3000	3000	3000	3000				
Ending IOH	2082	0	1198	430	0	0	758	0	4468	total IOH		
M*R	99999	0	99999	0	0	99999	99999	0				
planned order release	2550	0	2809	0	1.14E-13	2090	2463	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	2550	0	2809	0	1.14E-13	2090	2463	0				
Beg IOH	0	0	0	0	0	0	2463	0				
MRP plan	2550	0	2809	0	1.14E-13	4553	2.27E-13	0				
R(t)	1	0	1	0	0	1	0	0	3	runs	TC2	16231.5
Capcity	5000	5000	5000	5000	5000	5000	5000	5000				
Ending IOH	0	0	0	0	0	2463	0	0	2463	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	2550	0	2809	0	1.14E-13	4553	2.27E-13	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	5100	0	5618	0	2.27E-13	4180	4926	0			TC3	13231.5
Beg IOH	0	0	0	0	0	0	4926	0				
MRP plan	5100	0	5618	0	2.27E-13	9106	4.55E-13	0				
R(t)	1	0	1	0	0	1	0	0	3	runs		
Capcity	10000	10000	10000	10000	10000	10000	10000	10000				
Ending IOH	0	0	0	0	0	4926	0	0	4926	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	5100	0	0	0	2.27E-13	9106	4.55E-13	0				

Figure 71: Stochastic optimization 2

Third run result:

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	457	1980	1666	780	443	2044	1780	772				
Beg IOH	0	1980	0	1223	443	0	0	772				
MPS plan	2437	0	2889	0	0	2044	2552	0				
R(t)	1	0	1	0	0	1	1	0	4	runs	TC1	39427
Capcity	3000	3000	3000	3000	3000	3000	3000	3000				
Ending IOH	1980	0	1223	443	0	0	772	0	4418	total IOH		
M*R	99999	0	99999	0	0	99999	99999	0				
planned order release	2437	0	2889	0	0	2044	2552	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	2437	0	2889	0	0	2044	2552	0				
Beg IOH	0	0	0	0	0	0	2552	0				
MRP plan	2437	0	2889	0	0	4596	4.55E-13	0				
R(t)	1	0	1	0	0	1	0	0	3	runs	TC2	16276
Capcity	5000	5000	5000	5000	5000	5000	5000	5000				
Ending IOH	0	0	0	0	0	2552	0	0	2552	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	2437	0	2889	0	0	4596	4.55E-13	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	4874	0	5778	0	0	4088	5104	0			TC3	13276
Beg IOH	0	0	0	0	0	0	5104	0				
MRP plan	4874	0	5778	0	0	9192	9.09E-13	0				
R(t)	1	0	1	0	0	1	0	0	3	runs		
Capcity	10000	10000	10000	10000	10000	10000	10000	10000				
Ending IOH	0	0	0	0	0	5104	0	0	5104	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	4874	0	0	0	0	9192	9.09E-13	0				

Figure 72: Stochastic optimization 3

Forth run result:

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	451	1723	1677	754	420	1768	1707	777				
Beg IOH	0	1723	0	1174	420	0	0	777				
MPS plan	2174	0	2851	0	2.27E-13	1768	2484	0				
R(t)	1	0	1	0	0	1	1	0	4	runs	TC1	38941
Capcity	3000	3000	3000	3000	3000	3000	3000	3000				
Ending IOH	1723	0	1174	420	0	0	777	0	4094	total IOH		
M*R	99999	0	99999	0	0	99999	99999	0				
planned order release	2174	0	2851	0	2.27E-13	1768	2484	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	2174	0	2851	0	2.27E-13	1768	2484	0				
Beg IOH	0	0	0	0	0	0	2484	0				
MRP plan	2174	0	2851	0	2.27E-13	4252	2.27E-13	0				
R(t)	1	0	1	0	0	1	0	0	3	runs	TC2	16242
Capcity	5000	5000	5000	5000	5000	5000	5000	5000				
Ending IOH	0	0	0	0	0	2484	0	0	2484	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	2174	0	2851	0	2.27E-13	4252	2.27E-13	0				

Period	2019Q1	2019Q2	2019Q3	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4				
Demand	4348	0	5702	0	4.55E-13	3536	4968	0			TC3	13242
Beg IOH	0	0	0	0	0	0	4968	0				
MRP plan	4348	0	5702	0	4.55E-13	8504	4.55E-13	0				
R(t)	1	0	1	0	0	1	0	0	3	runs		
Capcity	10000	10000	10000	10000	10000	10000	10000	10000				
Ending IOH	0	0	0	0	0	4968	0	0	4968	total IOH		
M*R	99999	0	99999	0	0	99999	0	0				
planned order release	4348	0	0	0	4.55E-13	8504	4.55E-13	0				

Figure 73: Stocahstic optimization 4

Essentially, these stochastic optimizations are contructed based on the ouputs of simulation runs, and the input elements which are shown as below:

Objective	minimize the Total cost (TC = TC1+TC2+TC3)
Variables	MPS plan, 2 MRP plans and 3 R(t)
Constraints	R(t) is binary
	Plans in MPS and MRP > 0
	Ending IOH > 0
	M*R(t) > MPS, MRP plans
	MPS, MRP plans < own capacity

Figure 74: Optimization model inputs

12 Conclusion

12.1 For companies in general

Primarily, manufacturing and planning control consists of many crucial functions within supply chain. In fact, an efficient MPC system require much effort, coordination and transparency in any company. Demand management must be capable of acquiring reliable information about potential customers' interests as well as maintaining current customers so that demand data will be estimated. Forecast must come alongside with demand management since all the data will be directly shifted down as an indispensable input for the forecasting system. Here, the forecast department must be able to choose the most appropriate method used for the computation throughout experiment and evaluation. As mentioned in the thesis, there are many forecasting methods that have been utilizing by different companies and manufacturing environments, still, understanding the targeted market and company's essence are the strict requirements in this function. Furthermore, decisions on many related coefficients used for the projecting models are not easy; in real life, there is no given data that the responsible team for the forecast must come up with many factors by elaborating historical data, testing and implementing. Using the descriptive analysis or regression is recommended. In fact, demand is varying instantly by many factors, but still, the variance can be estimated by determining the root of causes, one of which was mentioned in the thesis, normal distribution. Next, MPS consumes the outputs from forecast department to create the manufacturing plan for the end products. the most challenging part in this step is to come up with an optimized plan so that customers' demands are satisfied, and in a business perspective, costs must be ensured to be the possible lowest. Using the MILP method or Wagner-Within as a consulting tool to develop the plan is suggested. Information about finished items demand then will be transferred down from MPS to MRP. At this stage, manufacturing plan for components and raw materials executed. Similar methods as MPS are utilized, however, components manufacturers, known as OEM, are usually outsourced by companies, hence integration in term of reducing costs for both firms is barely efficient. Still, optimization throughout the plan is implemented by involved parties to ensure components and products are manufactured and fulfilled to end customers.

12.2 Self-reflection

The project time has been a bit long since the scope of topic about sales and operation planning is limitless. Still, this area is my most concerning in the world of supply chain and logistics. Personally, I incredibly value the optimizing approaches that help the supply chain become more efficient and critical in any business. Practically, I believe I was able to describe the picture of many crucial connected processes occurring the supply chain, also, I was able to point out the optimized methods in every aspects and activities, including specific illustrations. The thesis has been very informative and compelling. I did lots of readings from which many interesting new knowledges were attained, especially in the executions for MPS and MRP. I also find myself more credited in such field. However, there are many certain difficulties during the time. Comparing the same content in many different sources to come up with the final thoughts is challenging, also, many formulas require particular factors and elements which I could not access since the data for study case were constructed myself, not from any real company, still, I did overcome it. Furthermore, trying to think about proper approaches in the choices between optimization, which require more sophisticated factors, and simulation, which is easier to implement. At the simulation step, it was rather difficult since the bike company case has a seasonal factor for each quarter of a year, hence ranges of variance were constructed and run. Nevertheless, it was a wonderful time spent to research about such my favorite subject, and I am totally grateful for that.

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