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AN APPROACH TO INVENTORY MANAGEMENT IN MASS CUSTOMIZED PRINTING PRODUCTION ENVIRONMENT

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BY

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ABSTRACT:

In the competitive industrial setting of present times, it is hard for the manufacturing sector of developed economies to compete with those of developing countries because of the considerably high costs associated with Labor, Material and Transportation in addition to strict Environmental Sanctions, fierce competition from Sinking industries and the ever-shifting global economic patterns. For a manufacturing industry to survive in such conditions, it must be willing to change, should be technologically superior, access multiple markets, be responsive and adapt quickly.

New manufacturing concepts and Business strategies are proposed and introduced frequently. One such business/manufacturing strategy that has proved to be successful is Mass Customization. The advantage of MC companies over traditional manufacturing comes with its fair share of challenges. This thesis identifies some important challenges faced by the printing industry, which has adapted MC, and solves one of these challenging problems.

DEDICATION

I would like to dedicate my work to my parents who made this possible, putting up with me through tough times, encouraging me, supporting me throughout and for their wise words “We will support your studies no matter what…study as much as you want…it is and will be your only asset”

AKNOWLEDGEMENTS

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LIST OF ACRONYMS

B2B	Business to Business
B2C	Business to Consumer
CAPP	Computer Aided Process Planning
CI	Continuous Improvement
CIJ	Continuous Ink Jet
CT	Cycle Time
DOD	Drop on Demand
DOE	Design of Experiment
GT	Group Technology
HVP	High Volume Production
KP	Knapsack Problem
LSS	Lean Six Sigma
MC	Mass Customization
MDKP	Multi-Dimensional knapsack Problem
OEE	Overall Equipment Efficiency
OR	Operational Research
R&D	Research and Development
SME	Small and Medium Size enterprises

SOP	Standard Operating Procedure
TPS	Toyota Production System
USPTO	Unites States Patent and Trademark Office
W2P	Web to Print
WIP	Work in Progress

I. INTRODUCTION

1.1. HISTORY OF PRINTING:

The history of printing can be traced back to 3000 B.C., to the Mesopotamian civilization when seals were used to print on clay tablets. The printed artifacts are the most ancient surviving printed material in all of history.

Different civilizations around the world historically specialized in different forms of printing and were printing on different materials. China and Egypt used stamps as seals before printing on large blocks. China, India and Europe specialized in printing on clothing before printing on papyrus (paper).

1.1.1. WOOD BLOCK PRINTING:

It was a type of printing text, images and patterns, widely used in East Asia. It was used to print on textiles and later on paper. The earliest use of dates back to about 220. Block books were produced during the 15th century.

Buddhism was hugely responsible for the use and propagation of printed texts.

1.1.2. STENCILS:

Stencils might have been used to colour clothes for a long time. The technique probably reached the peak of finesse during the Katazome and Edo periods in Japan. In Europe, at around 1450, stencils were used to colour black and white prints on old master prints.

1.2. PRINTING TECHNOLOGY:

1.2.1. MOVABLE TYPE:

Movable type is a system that dates back to around 1900. It used movable plates/ pieces of metals on which matrices struck by letterheads were mounted. The world's first movable time system was made in China by Bi Sheng using porcelain. Wang Zhen started using more durable wooden block by 1298 C.E. Wang also developed a complex system of revolving tables and numbers in Chinese making a wood based movable system more efficient. Wood block printing continued to still be predominantly used.

1.2.2. THE PRINTING PRESS

Gutenberg collaborated with Dritzehen, who was a gem cutter and the owner of a paper mill making the movable type printing more efficient and durable compared to Woodblock printing. The printed material were cheaper to make and the low price of Gutenberg's bible (1455) established that the movable printing press was superior and apt for printing western languages.

Gutenberg's innovation to the movable printing press is considered the most important innovation of the second millennium and the printing technology that initiated the paradigm change from mass manufacturing to mass customization technology.

1.2.3. ROTARY PRITING PRESS

Invented by Richard March Hoe in 1843, rotary printing press uses a cylinder with impressions, which are inked and rolled continuously on consecutive papers to print. William Bullock improved on the rotary printing press later.

1.3. CONVENTIONAL PRINTING TECHNOLOGY

In printing, there are two areas that dictate the output:

- Image/Letters – Printing area
- Non-Printing areas

There are four types of processes in conventional printing:

- Planographics – In this type, the printing and non – printing areas are in the same plane and the separation is maintained by chemical or physical properties. Examples of Planographics based printing include offset lithography, collotype and screen less printing.
- Relief – In relief type printing, the printing and non-printing areas are on different planes. The printing areas are on a plane face and the non – printing areas are on a lower plane. Flexography and Letterpresses use relief type process to print.
- Intaglio – In a plane, the printing areas are engraved below the plane while the non – printing area is on the plane. Steel die engraving and gravure printing use this technique.
- Porous – The printing area is covered by a mesh that ink can penetrate and the non – printing areas are covered with stencil to repel and block ink spill. Screen printing and Stencil duplicator use this technique.

1.3.1. LETTER PRESS

It is a type of relief printing. It uses a movable type plate that is placed inside the press, which is then inked and pressed against paper.

It was widely used from mid 15th century to the end of the 20th century, until the inventorion of offset printing.

1.3.2. OFFSET PRINTING

In offset printing the image is transferred from the plate to the rubber blanket which is then used to perform the printing. A flat (planographic) image carrier is used when the system is coupled with a lithographic process (which uses a process of oil and water repulsion). Lithography and offset printing are the most commonly used printing techniques used to print books and newspapers.

1.3.3. GRAVURE PRINTING

It is a type of intaglio printing. The image to be printed is engraved on a surface at a level below the surface of the plate. The engraving depressions are filled with ink and the spill is scraped off the surface using a blade. A cylinder made of copper plated with steel and wrapped with rubber, which is then rolled over the plate.

1.3.4. FLEXOGRAPHY

Flexography is a type of relief printing. It is called the modern version of letterpress.

1.3.5. DYE – TRANSFER PROCESS

It is continuous – tone colour photographic printing process. It was used to make film based movies.

1.3.6. INKJET PRINTING

It is used to print on paper, plastic and other substrates. Inkjet as the name suggests, print images and letters by spraying ink droplets.

Two technologies are used in Inkjet printing – CIJ (Continuous Ink Jet) and DOD (Drop on Demand).

1.3.7. LASER PRINTING

Laser printing is an electrostatic digital printing process. It produces high quality prints, both text and images. Laser printer uses a negatively charged cylindrical drum which attracts electronically charged powder ink selectively, based on the print image/letter, and the image is transferred to paper and the paper and the paper is heated to dry the ink.

1.3.8. SCREEN PRINTING

Screen printing uses porous printing technique. It is widely used to print on T-Shirts and on slippery surfaces including tiles, plastics, stickers, vinyl, wood etc.

A mesh coating is coated with ink as required for the image by moving a squeeze right across the mesh while the reverse stroke touches the ink to the surface of the material to be printed on.

Other types of printing include:

- Pad Printing
- Thermal Printing

1.4. TIMELINE – EVOLUTION OF PRINTING

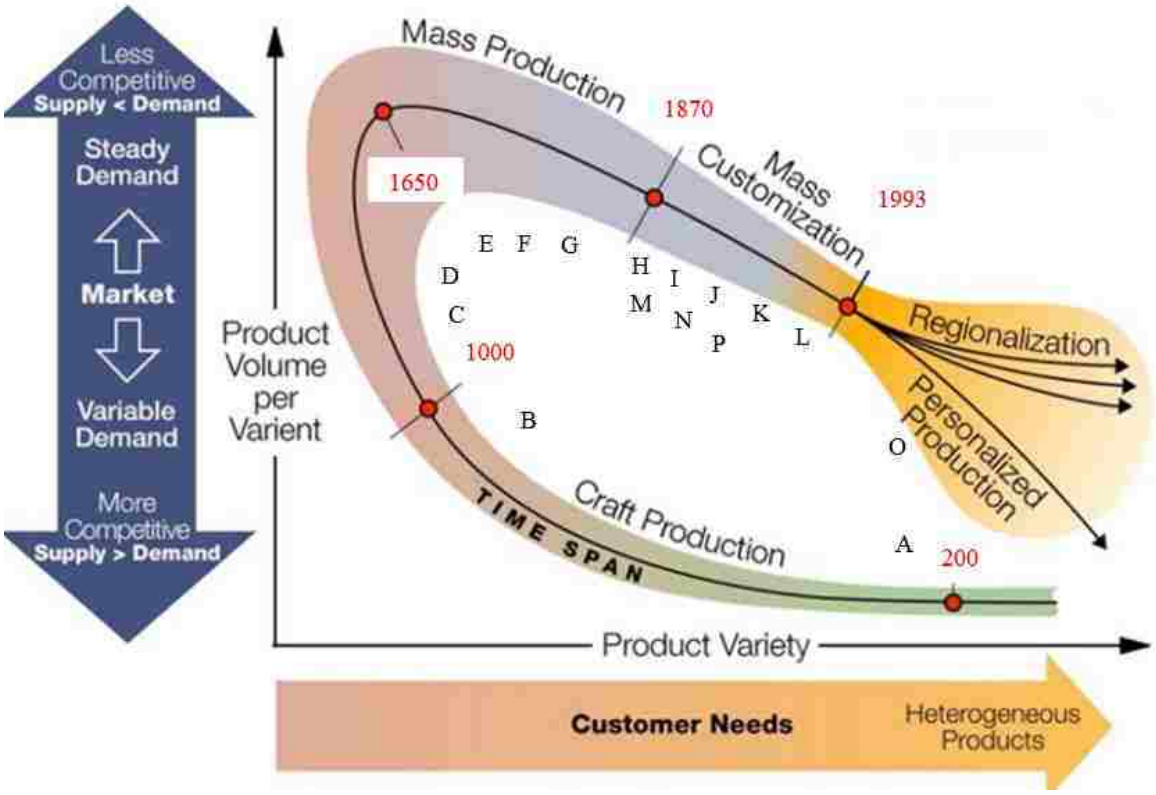


Fig 1: Shift in Manufacturing Paradigms and Associated Printing Technologies (Yoram Korean, 2010)

Table 1: Key – Figure 1

Printing Technology	**Year**	**Key**
Woodblock printing	200	A
Movable type	1040	B
Printing Press	1440	C
Etching	1515	D
Mezzotint	1642	E
Aquatint	1772	F
Rotary press	1843	G
Offset Printing	1875	H
Xerography	1938	I
Inkjet printing	1951	J
Dye-Sublimation	1957	K
Dot Matrix printing	1968	L
Laser printing	1969	M
Thermal printing	1972	N
3D printing	1984	O
Digital printing	1993	P

In the early ages of the printing technology's evolution, technologies were trying to reciprocate copying methods. Most of the technologies were created to reproduce art. The very first printing technologies can be traced back to Chinese civilizations and the Chinese letters were complicated to reproduce and were similar to art. Thus, the main focus of the printing technologies were reliable reproduction and not on printing scale. Thus, the first generation for printing technology including Woodblock printing and Movable Printing technology were considered as craft production technologies.

As the technology reached Europe and the first bible was reproduced using printing technology, Gutenberg realized the potential to improve on the printing technology to mass produce and invented the Gutenberg's printing press in 1440, changing the way printing technology was viewed. Gutenberg's printing press led to the paradigm shift from craft production to mass production for the printing industry. Gutenberg's printing press was followed by several other innovations to the printing technology including Etching, Mezzotint, Aquatint and Rotary press. Each printing technology progressively increased in reliability and number of prints that they could produce, thereby decreasing unit costs with the innovation of each technology.

The concept of mass customization came into printing around the 1990's, however several technologies that were developed before that were enablers of MC. The mass customization enabling printing technology started being innovated around the 1870's. The first printing technology that enabled mass customization was Offset Printing technology. Offset printing helped with printing multiple orders simultaneously at mass production efficiencies. Offset Printing technology was followed by Xerography, Inkjet, Dye – Sublimation, Dot Matrix, Laser, Thermal and digital printing. Although, till the beginning

of 1990's these printing technologies were used to mass produce, the potential for these printing technologies to be used to mass customize signifies that offset printing shifted the printing industry's paradigm from mass manufacturing to mass customization.

3D printing technology was first developed in in 1984. The first few generations of 3D printing were unreliable and it was not considered a reliable technology to produce sellable quantities. However, after mass customization being around for two decades now in the printing industry, 3D printing is being viewed as the enabler of the next paradigm shift in the printing industry, from mass customization to complete personalization.

These paradigms shifts with the associated technologies and timelines are shown in fig 1.

Note: In Fig 1, the timeline is split into three main manufacturing paradigms (Craft Production, Mass Production and Mass Customization). The keys "A to P" represent the printing technologies mentioned above and are placed corresponding to the manufacturing paradigms they enable.

Mass Customizing W2P companies are coming up with creative ways to use old technology, pairing the old mass production and craft production technologies with custom interfaces to produce mass customized products.

For Example: Screen printing, which was considered a craft production technology, can traditionally print only one T-Shirt or cloth based substrates at a time. However, using multiple screen printing machines and using different designs for printing, the end product line output can be customized product in a mass scale.

II. PRINTING INDUSTRY

The Printing industry has a long and strong background. Since Gutenberg invented the movable type printing press (around 1450's), printing has been considered the technology that started the modern civilization. Printing gave people the ability to document history efficiently and also distribute information reliably which was previously thought impossible. The Printing industry has come a long way since its inception.

Printing accessibility to the masses started after the Second World War, after which there were some significant advancements made to printing technology. Frenchman Rene Higonnet and Loius Moyround applied for the patent for a phototypesetter called the "Lumitype". Rene and Loius used the patent to produce the Photon 100 and consecutively the Photon 200, which were considered a significant advancement in mass printing technology. In parallel, traditional printing machines started seeing technological transformations from using hot metal composition to photo-matrices. This was the second generation of the mass printing technology. The third generation featured photographic storage. The fourth generation was the laser-output technology through Raster Image Processor (Kipphan, 2001).

Further developments in associated technologies, including the development of the computer and the word document helped expand the spectrum and opened the printing industry to new efficiencies, which were previously thought to be impossible to achieve.

Successful creation of the printing business as a huge industry of its own is attributed to the Germans.

2.1. MASS CUSTOMIZATION

The goal of Mass Customization is to provide enough variety so that the wants of the customers are satisfied, whereas the goal of mass production is to produce at sufficiently low costs so that everyone could have one (Michael T. Fralix, 2001). The practice of Mass Customization did not start in the automotive industry but rather in the apparel industry. There are several papers that support this fact including the one by Michael T. Fralix, a professor from MC State University who points out the shift in the expectations of the customers and how developed countries (especially the US) is losing to the developing countries when it comes to producing customizable products in a large scale. Most of the developing countries, which were making customizable products, were actually doing so without realizing that they were starting and using the next phase in manufacturing that is mass customization (Fralix, 2001).

High labour costs was and is the main reason for the industries in the developed countries to stick to the more convenient and cost effective mass production, while the world around them was changing. This along with several other factors lead to the slump in the manufacturing industry, the slump that still exists in almost every sector, be it manufacturing, service or hospitality. It is important to mention that industries in some countries like Germany did find a way to customize and mass-produce at the same time by investing heavily on Research and coming up with technology and supply chain sturdity to counterbalance the cost of work force.

Mass Customization is approached differently by each industry that uses MC as a competitive advantage. In automotive industry, it is customizing the looks (both interior

and exterior), offering different engine/power varieties, customizable paints, alloys etc., to meet the customer wants. In the apparel industry, it might be manufacturing clothes that meet the size of the majority of the population within certain age groups, or letting the customers choose colours, fabric and styling of their clothes.

Most of the industries adapt and use mass customization as a tool to attract customers and satisfy their preferences while keeping the available product variety under control. It is a choice and companies either adapt or do not. But one industry has evolved completely banking on this concept – the printing industry. There used to be a time when there existed small printing shops that specialized in only one kind of printing. Some shops printed just business cards while others printed posters and others textile. However, the present situation is entirely different. This will be discussed in the following section.

2.2. EMERGENCE OF MASS CUSTOMIZED PRINTING

Over the past decade or so, the way the printing business functions has changed tremendously. Earlier, before the dot com revolution, all the commercial printing was essentially by piece production. i.e., individual orders were taken, processed, orders for raw materials were placed, procured, printed on and then delivered. Traditional Printing process took almost a month to complete and lead times for raw material procurement added the most time to the overall process. As orders at traditional print shops were fluctuating and seasonal, raw material inventory was not held (to eliminate holding costs). However, after the dot com revolution, things changed. E-commerce became a predominant force in order procurement. Orders were consolidated and the concept of Mass customization came into the printing industry.

W2P companies dominate the printing business whose market share is growing tremendously mainly by the cannibalization of regular Printing Businesses. The reason for such success is the ever decreasing cost of production achieved by consolidation of orders, standardization of processes to decrease make ready and the enquiry, design and order processing being done by the customers, thereby reducing the cost of small orders dramatically.

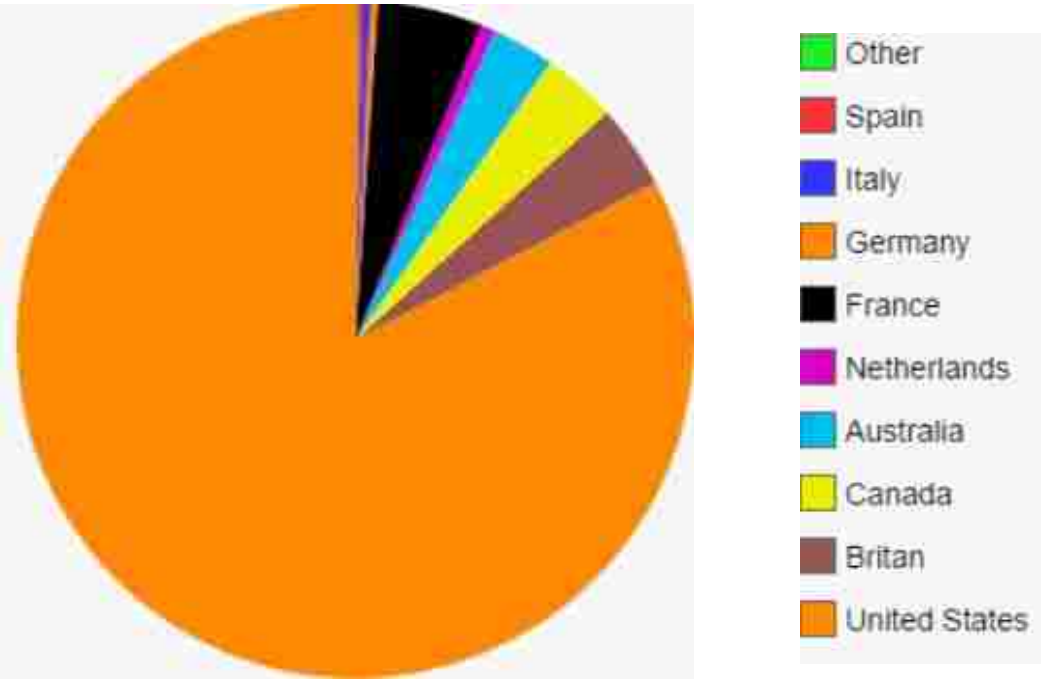


Fig 2: Vistaprint's printing market share – 2014

Vistaprint prints 81.37% of the total product printing done in the whole of the United States. This represents the total domination of the printing industry in the U.S. by Vistaprint (a Mass Customizing W2P company). [11] In each country mentioned, other MC W2P companies show a similar domination.

Examples of companies that mass customized and have been successful include: VistaPrint, Saxoprint, Laserline etc. It is necessary to evaluate and study their value added chain and production techniques to understand what makes them successful. The market is highly competitive due to the high cost of entry. The only way to penetrate the printing market is the original strategy that successful companies like Vistaprint followed, i.e. to find and exploit another market gap like Vistaprint and Saxoprint initially did (identifying the potential to step into the printing industry by catering to the printing needs of small businesses). The difference between the W2P mass customized printing industry and the traditional industry, from a customer's point of view, is that MC W2P companies are easy to order from, the delivery is quick and reliable, the quality is good with respect to the order size and of course, the choice to order small volume at mass production costs.

Infact, the W2P printing industry is so successful that even regular printing companies have moved on to provide just marketing advice and design inputs and outsource the printing to MC W2P companies. Traditional Printing companies now provide just customer end services like design and marketing assistance. This has led W2P companies to expand from just serving B2C to B2B as well.

The expansion of MC W2P printing company's market from just individual customers and small businesses to the B2B market was an unexpected twist that the CEO's of these business themselves did not expect. Mass Customizing W2P company's main aim was to serve small businesses at low costs but provide good quality product in low volumes. Most of the founders and CEO's of MC W2P companies began as 'Movers', acting as brokers bringing together printers and customers before realizing the market gap they could exploit. These men realized the presence of small businesses that needed printing services but could

not afford the very high consulting costs and individual printing cost that traditional printing companies commended, because of the small business's low budgets.

Robert Keane, the President and CEO of Vistaprint, the No. 1 Web-to-Print industry was the very first 'Mover' who talked about the existence of the market that could potentially serve small businesses as his business plan during his MBA in France. Vistaprint has a turnover of about 1.3 Billion USD and has been growing at an average of 14% since 2002. Robert developed his marketing catalogue and went into business in 1995, starting in Paris.

A similar example was the story of Thorsten Fischer, the founder of Flyeralarm, a German W2P printing company (No. 3 in all W2P companies). Fischer started as a mover in Wurzburg, Germany. He realized the market gap mentioned earlier when he started designing and printing advertisements for small local entrepreneurs and subsequently after publishing his own marketing magazine in the city, realized the time and the cost difference between traditional printing and his venture. He quit and started Flyeralarm in 2002.

Both Vistaprint and Flyeralarm started small like Amazon did (Amazon started by selling rare books) and all three companies started before the dot com revolution and therefore did not use the internet to support their products nor market it. Vistaprint, Flyeralarm nor Amazon had even realized the potential for growth that would come with the inclusion of internet in their business's promotion and interfacing.

E-Commerce was the innovation that the printing industry was waiting for. DRUPA (2000) was the initiative that made it all happen. DRUPA used the dot come revolution to interface customers with printing companies using the internet as the interface. The DRUPA initiative brought together 20 start-up companies into a single hall, developing an E-

Procurement interface that brought together customers and printing companies. The DRUPA companies worked on a commission basis, collecting and consolidating customer orders based on volume, style and time requirements. The business idea eventually failed, but the first set of tools for internet based procurement and online configuration was already in the market.

Vistaprint entered the E-commerce based procurement business in 2000 followed by Flyeralarm in 2002. E-commerce had been around for a long time before, but the necessary tools for E-Procurement and interfacing did not come into being until the fall of DRUPA. Amazon and W2P companies have grown rapidly since (Fralix, 2001).

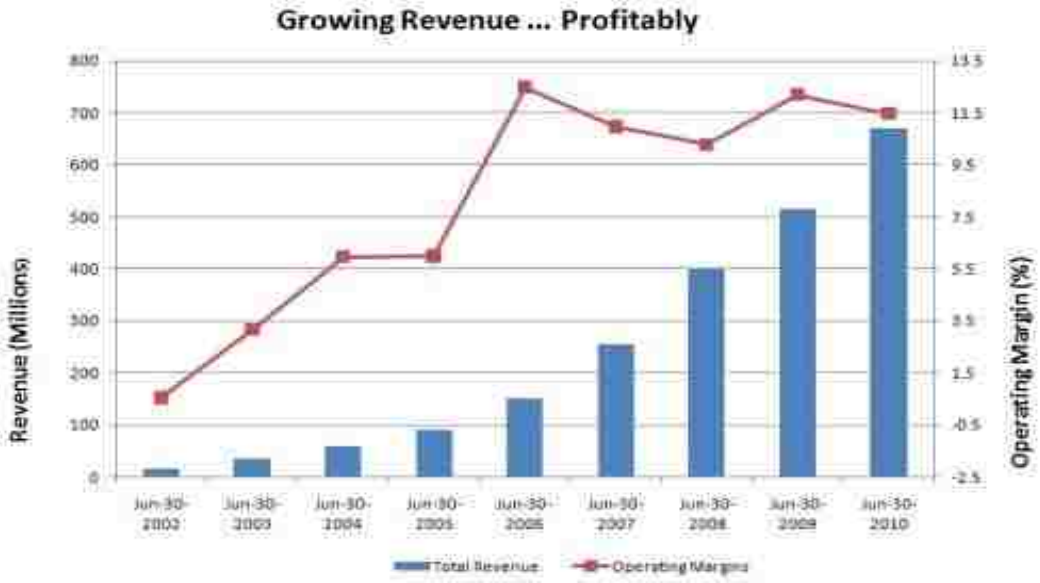


Fig 3: Revenue – Vistaprint – 2002 to 2010 [5]

2.3. ABOUT THE COMPANY – VISTAPRINT

Vistaprint (Currently Cimpress) is a W2P mass customizing company, headquartered in Paris. Vistaprint has printing facilities in Deer Park, Australia, Windsor, Canada and Venlo,

Netherlands. As of 2007, Vistaprint was the 4th fastest growing printing company in North America. [8]

Started by its president and CEO Robert Keane in 1995, its first product was business cards. It has expanded to print on other material. The product list of Vistaprint includes: [9]

Table 2: Product/Services offered by Vistaprint

CATEGORY	**EXAMPLE PRODUCTS/SERVICES**
BUSINESS CARDS	Standard Business Cards, Signature Business Cards, Brilliant Finish Business Cards, Raised Print Business Cards and Spot Gloss Business Cards
BUSINESS SERVICES	Logo Design, Mailing Lists, Toll Free 800 Number, Credit Card Processing, Incorporate Today, Partner Marketplace and Postage Meters
CALENDARS	Wall Calendars, Desk Calendars, Magnetic Calendars, Pocket Calendars and Poster Calendars
CHECKS	Checks, Credit Card Processing and Gift Certificates
CORPORATE GIFTS	Promotional Products, Personalized Mugs, Pens, Bottle Openers and USB Flash Drives
CUSTOM CLOTHING	Men's T-Shirts, Women's T-Shirts, Kids T-Shirts, Polo Shirts, Men's Polo Shirts, Women's Polo Shirts, Hats, Hoodies, Tote Bags, Promotional Products and Design Services

DIGITAL MARKETING	Websites, Website Design Services, Domain Names, Social Media Marketing and Email Marketing
HOLIDAY PRODUCTS	Holiday Cards, Christmas Address Labels and Gift Tags
INVITATIONS & ANNOUNCEMENTS	Wedding Invitations, Save the Dates, Birthday Invitations, Birth Announcements and Baby Shower Invitations
LABELS & STICKERS	Address Labels, Return Address Labels, Mailing Labels, Stickers & Decals and Custom Stickers
MAGNETS	Car Door Magnets, Magnetic Business Cards, Postcard Magnets, Magnetic Calendars and Photo Magnets
MARKETING MATERIALS	Postcards, Flyers, Postcard Mailing Services, Brochures and Rack Cards
PHONE CASES	Samsung Galaxy Cases and iPhone Cases
PHOTO GIFTS	Personalized Mugs, Phone Cases, Canvas Prints, Wall Calendars and Desk Calendars
SIGNS & POSTERS	Banners, Lawn Signs, Lawn Signs, Political Signs and Construction Signs
STAMPS & INK	Self-Inking Stamps, Pre-Inked Stamps, Signature Stamps, Date Stamps and Pocket Stamps
STATIONERY	Address Labels, Return Address Labels, Mailing Labels, Pens and Letterhead

After Vistaprint reached the saturation of its market growth in terms of customized printed product, it went on to takeover other established and upcoming printing and digital

companies all over Europe and the United States and changed the parent company's name from Vistaprint to Cimpress, while its north American brand retained its name as Vistaprint.

Through the use of patented technology which range from business strategies, printing technology and order aggregation to web interfaces, Vistaprint is able to aggregate large number of customized orders based on product grouping – product grouping is done on the basis of raw material type, size, ink substrate, capacity, delivery time constraints etc. A preliminary search for patents by Vistaprint on the US patent office website turns up 125 patents registered under the company's name [13].

Vistaprint uses Computer Integrated automated manufacturing techniques to minimize human intervention and improve overall efficiency. Orders that were traditionally produced at 60 labour minutes are done at around 60 seconds through the use of a combination of aggregation of orders and automated processes. Vistaprint has been able to utilize the principles of mass production to print short-run commercial printing at mass production efficiencies.

2.4. MARKET – COMPETITION IN MASS CUSTOMIZED PRINTING INDUSTRY

Every market can be segregated using the 80/20 rule. Robert Keane, the president and CEO of vistaprint identified a market gap that existed during his time. Traditional printing shops could not satisfy the tail end of the 80/20 customer base.

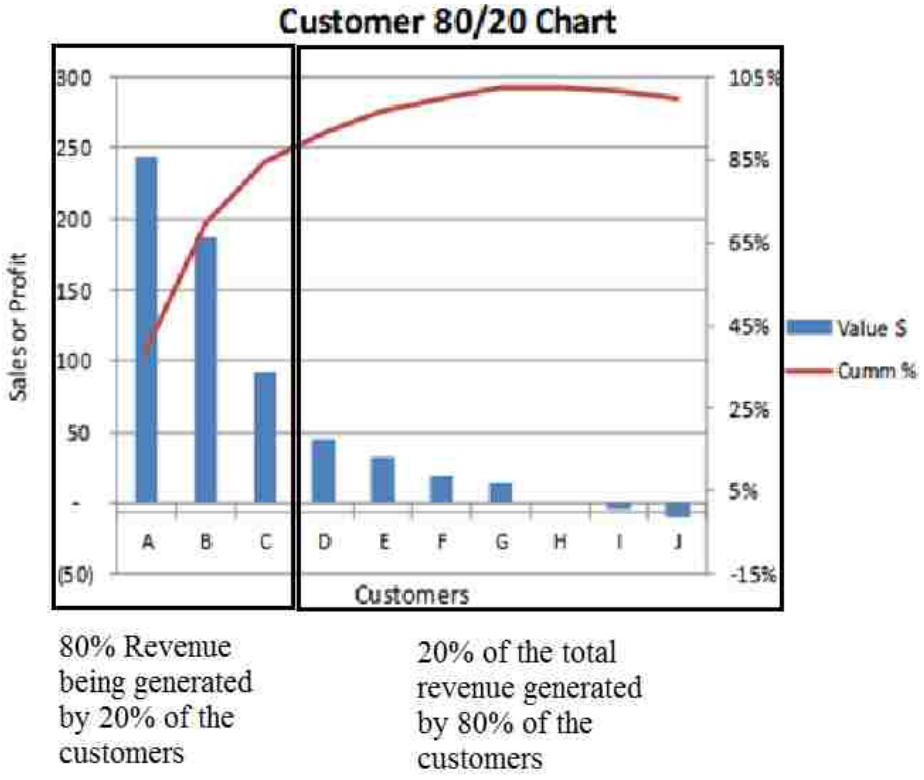


Fig 4: Customer 80/20 chart (Konig, 2013)

The 20 % of the customers that generated 80 % of the profit in the whole of the printing industry were the ones that the traditional printing shops were competing over. Their business model was based around their technology restrictions and cost effectiveness requirements. The traditional printing process followed by traditional printing shops were quite simple (Fig 5). The customers come in and consult with the printing shop's designers about the type of product they wanted to print. The designers designed the layout of the product based on the customers wants, with the details about the type of substrate to be used, quality of substrate, size layout etc. and an expert in the shop's available technology would analyze the design and fix a minimum order number that had to be placed. Then the customer was consulted and prices were decided.

Fig 5: Traditional Printing Process – Process Flow (Konig, 2013)

As traditional printing shops took care of one customer at a time, their minimum number print requirements were huge. After the order was placed, the shops contacted their supplier and ordered the ink, plates in some cases and paper type according to requirements. The suppliers would then send the raw materials which would arrive at the print shop at different times and as the order sizes were considerably small and scattered, these print shops had to pay premium costs to acquire them. The materials arrived, printing presses were run, printing was done and delivered. This process took a lot of time and money. Thus, the required minimum volume of production was justifiably big and so were the costs. As a result, only big businesses could afford to market their products through printed material. Small businesses could not afford to print their marketing material and relied on word of mouth and local newsletters to promote their businesses.

MC W2P companies have to invest heavily on technology to counterbalance and achieve low unit cost requirements. Vistaprint invests about 10% of its revenues on its technology alone, to stay competitive. Vistaprint invested $176 Million in 2014 alone to improve its technology. Since Vistaprint's inception, investments on technology, development and capital is estimated to be around $1.3 Billion. [12].

After making heavy investments in technology and development of sound business strategies MC W2P companies started taking in orders from customers that required just

small volumes of marketing material, consolidated and printed them keeping the overall cots the same as other printing shops, but making the individual costs considerably low. During the early years of production, MC W2P companies realized the potential to decrease costs even further. They started using a base set of product variety offerings using product variety management techniques. For example: The business cards that Vistaprint prints are offered on a controlled number of base substrate paper material types like gloss, premium gloss and Smooth Matte. The raw material paper stock is maintained in their warehouse and the customers can choose only from these paper types but can customize the text, style and design on the card they print. Because of controlling the base substrate type offered, Vistaprint could decrease delivery time, decrease raw material costs as they were ordered and stocked up on (low unit cost because of placing bulk orders with the suppliers) and consolidate orders as they come in, the individual costs decreased even further.

Eventually MC W2P companies started streamlining their processes and decreasing the production costs. And the individual unit costs were decreased even further by cutting out the design and selection support out of their process and making the customers design and make the choices themselves. Because of MC W2P company's low aggregate costs, they started thinking about other product lines they could expand into. MC W2P companies like Vistprint then moved into printing postcards, letterheads, posters, flexes, signboards, envelopes, mugs, bottles, pens, invitation cards, greetings, textiles etc. Their market share increased with their product lines. MC W2P companies eventually started cannibalizing the local print shops and after the revolution in global logistics and through successful collaboration with global logistics companies, they started expanding into markets all over the world from their base country. As their businesses grew, W2P companies started

expanding their manufacturing facilities into countries with high local and geographic demand. Most successful W2P companies have facilities all over Europe, North America and certain key countries in Asia. The growth has been drastic and the market saturated a decade ago. Companies started moving from just B2C to B2B. Printing businesses that were pushed out of business and other retail shops started outsourcing their printing to W2P companies.

Successful MC W2P companies like Vistaprint have expanded into other businesses outside just printing on products. Vistaprint now does advertising consultation and prints promotional material custom-made to the client's requirements, extending from manufacturing into business services. The printing market has saturated and in order to expand their businesses, there is a need for W2P companies to step into other streams of printing related businesses and acquisitions like Vistaprint has successfully done.

2.5. CHALLENGES FACED BY MASS CUSTOMIZING INDUSTRIES

Mass customization is offering customers the ability to customize their product while achieving mass production efficiencies in their manufacturing. Achieving such efficiency is not an easy task and companies have tried and failed. The failure roots from the inability of the manufacturing setting to cope with the challenges of mass customization.

The problems faced by MC W2P company's industrial setting is similar to the problems faced by traditional mass manufacturing companies, i.e. the seven wastes identified by TPS – Transportation, Inventory, Motion, Waiting, Over – Processing, Over Production and Defects. However, the constraints that surround the problems are more complicated than in mass manufacturing.

Some of the common problems faced by mass customized industrial settings include: (Amit, Rahul, 2007)[7]

- Elicitation costs – Requirement of heavy investment on Information Technology
- Higher capital investments on Flexible Manufacturing Systems
- High Inventory storage costs to feed the flexible systems
- Increased setup costs and need to update equipment on a regular basis
- Unpredictable Economy of scale might drive costs up
- Requirement to cross train workers and hire specialists adds cost
- Customer relation and marketing centres are important – adding more cost burden
- Work force performance tracking is difficult as the required work might vary drastically
- Unpredictable/ Unforeseeable production challenges
- Increased downtimes compared to traditional settings
- Reduced efficiencies because of small batch sizes (each unit might be different)
- Sequencing challenges
- Unpredictable demand
- High sourcing complexity as demand cannot be forecasted properly
- Requirement to be responsive to market trends as they tend to change frequently and abruptly – might be seasonal but unpredictable
- Logistics infrastructure might cost more than manufacturing
- Risk of failure is high, as each new product added does not usually have a proven track record to draw from
- The need to learn as you go

A preliminary review of the challenges sheds light on the fact that the most common and important challenge faced by MC W2P companies is excessive inventory. It is extremely difficult to calculate inventory to be maintained (both warehouse and on-floor) because of the extremely fluctuating demand patterns which are difficult to forecast accurately. The difference between Forecasted demands and actual demands may vary significantly. These constraints form the base of the problem studied in this thesis.

To understand the severity of the inventory control problem, it is important to understand the production system and the related supply chain in W2P companies. A case study was done using Vistaprint's manufacturing facility in Windosr, Canada to understand the inventory control challenge in detail. After a preliminary study was done on the entire production facility's inventory control, a detailed study was done on the Windsor facility's textile printing section.

2.6. PRODUCTION SYSTEM AND THE RELATED SUPPLY CHAIN - VISTAPRINT

Vistaprint collects orders through their web interface. The design collection and documentation process is completely automated and helps reduce costs because of the elimination of administrative staff and design staff.

Vistaprint's document model architecture and technology uses web-based data architecture. The model defines, processes and stores designs. Compared to bitmap and pdf, Vistaprint's model provides significant advantage in terms of storing and modifying designs. The interface allows products to be customized while staying within the boundary of Vistaprint's manufacturing ability.

Based on keywords typed in by the customer, Vistaprint's auto-matching software generates algorithms to pull up previous design outlines and templates that can be customized according to the customer's requirement.

Vistaprint's Vista Studio software is a downloadable software that a customer can download and use to design the product according to their requirement. Vistaprint has an internet-based, remote application that customers can use to contact Vistaprint's customer support through, over the web voice assistance.

Once the order is received over the net, DrawDocs software of Vistparint automatically converts the image into high-resolution image, converting pre-press files from the customer document into high definition print-ready images that can be printed.

Cost effectiveness, which is the advantage mass customizing W2P companies have over traditional print shops is achieved by a variety of strategies. One of the factors which contribute to cost effectiveness, and arguably the most important contributing factor, is the ability of W2P companies to aggregate orders. Vistaprint's VistaBridge technology helps Vistaprint aggregate orders based on a set of constraints – combination to achieve the lowest production cost, similarity of print parameters, multiple order aggregation (when the same customer order more than one product), delivery times etc. VistBridge's main parameter is to achieve the lowest overall cost for the whole process by using a set of complex algorithms, developed by Vistaprint's R&D department based in Switzerland. VistaBridge automates aggregated workflow to Vistaprint's high volume production printers – offset or digital, achieving the lowest possible overall cost. Other parameters under consideration include material quality, type, shipping location, colour vs black &

white and Single or double sided printing. VistaBridge aggregates orders from different customers, continuously calculating and adjusting print jobs during the shift, i.e. the operators nor the personal know what the next print job would be. [11]

Example for aggregation by VistBridge for Business Cards: VistaBridge aggregates a maximum of 143 business cards onto a single sheet of paper substrate. The substrate stack size is typically 250, 500 or 1000 units (plus the ones for quality checks). If there are a considerable amount of customers who ordered 250 business cards, VistaBridge aggregates the orders and prints say 143*250 business cards in a single job. If there are several customers that order 1000 units, then a stack of 100 units plus the ones for quality checks are printed in a single job. However, if there are more orders of 250 business card units and just a few 1000 unit orders, VistaBridge aggregates the order in such a way that 4 of the images on the sheet are the same, thereby achieving an overall print of 1000 units even when only 250 sheets are printed.

The orders, after being acquired, run through Vistaprint's Viper software, which distributes orders to the production facilities based on shipping locations, production capabilities/capacity and inventory levels. Viper's output is the input for VistaBridge.

Both Viper and VistaBridge update their output continuously, recalculating order schedules and order aggregation even during the shift. Herein lies the basic problem. Because of VistaBridge and Viper's continuous updating and demand fluctuations, inventory levels are hard to calculate.

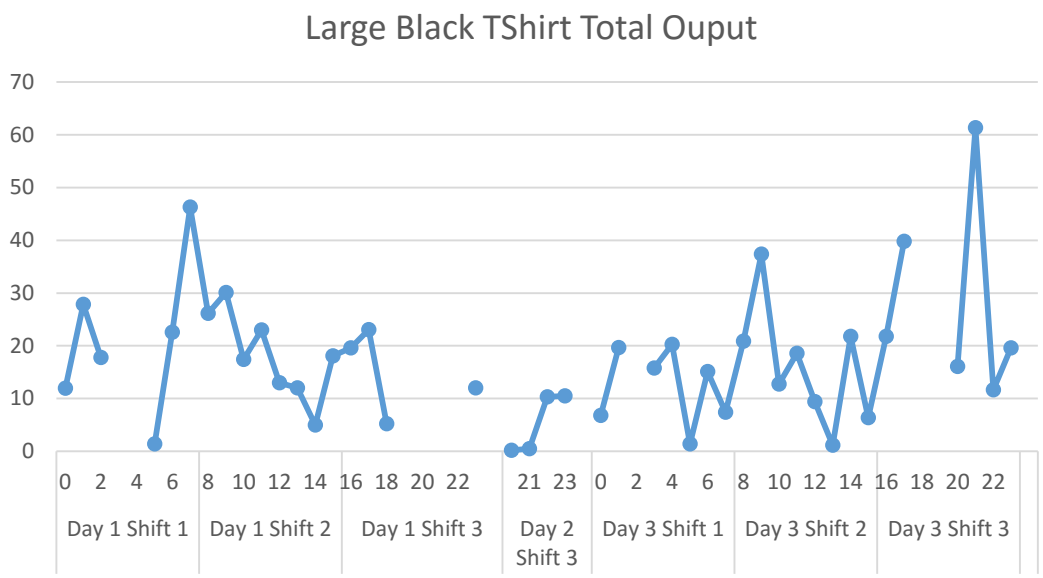


Fig 6: Time Series – Hourly output

The production facility runs 7 day, three 8 hour shifts. It is a continuous and HVP setting. The on floor inventory is placed on racks right next to the printing machines and at the boundaries of the textile section.

At the beginning of each shift, the supervisor receives a count of the total number of dark shirts, light shirt, tote bags and hats to be printed in the shift to calculate the workforce requirement for the shift. The personal (supervisor, workers and material handlers) do not get the count of individual product outputs required (i.e. type, colour and size are unknown) and the orders might be updated during the course of the shift as well. Because of these constraints, it is almost impossible to maintain a controlled amount of on floor inventory. In addition, the fluctuations in demand add even more strain to the inventory level calculations. The result of such a situation is the stacking of excessive inventory, whose levels have not been properly documented and without any proper replenishment cycles.

The textile layout alone holds 24,152 units of raw material inventory.

This data reflects the huge on-floor inventory levels in MC W2P settings. Because of the fluctuating and unpredictable demand, companies prefer maintaining excessive inventory as opposed to maintain less than required. However, because of the inexistence of effective inventory calculation methods tailored to MC settings, it is almost impossible to compute exactly how much excess on floor inventory is present.

2.7. PROBLEM STATEMENT

As explained in the previous section the demand fluctuations in MC W2P companies are erratic. The cycle times are as low as 15 seconds and the production is High Volume. The production planning continuously updates orders till the very last possible moment and the personal on the floor do not know the shifts nor the hourly individual raw material unit requirements. This uncertainty is counterbalanced by maintaining excessive inventory in the warehouse with high safety stock and reorder points. A similar mentality and approach is employed in setting on floor inventory levels as well. Most MC W2P companies stock their production floor with excessive inventory for fear of running out of raw material before the replenishment cycle occurs. Most Inventory control models deal with calculating and optimizing warehouse inventory, considering the costs associated with them (ordering cost, transport cost, space cost etc.). However, it is important to note that the same costs apply for maintaining on floor inventory as well. The associated costs with holding on floor inventory is actually higher than that of maintaining warehouse inventory. Inventory associated costs like space costs are actually higher on floor. Warehouses are typically constructed to house maximum inventory and their design facilitates optimized inventory

storage. However, when it comes to on floor inventory, the inventory cannot be stored as they are in warehouses, i.e., they have to be accessible, placed strategically etc., thereby occupying more space on floor than they did in the warehouses. Similarly, the other inventory associated costs like the potential for alternative investments (higher potential to invest in production machines rather than on the warehouse) is higher in the case of On Floor Inventory.

The problem of On Floor inventory calculation and subsequent optimization is an area that has been rarely researched in depth, especially for highly varying demand setting such as in MC W2P companies. This thesis works on bridging that gap by analyzing the effectiveness of current on-floor inventory calculation/optimization methods for MP settings on MC settings using data obtained from the case study conducted at Vistaprint and if required, modify the existing inventory control methods in accordance with the constraints of MC W2P's production settings.

The calculated inventory levels are validated using the simulation software – Flexsim.

III. APPROACH

The problem at hand is approached in the following way:

- Data is collected from Vistaprint's Textile layout
- A literature review and background research has been done to analyze and document the present available methods of Inventory Control for MC environments and other production settings with fluctuating demands

- The available data is analyzed using available operational research methods for inventory control and inventory levels are calculated

- The calculated inventory levels is compared to previous year's output data from Vistaprint and Vistaprint's textile forecast for 2015

- The model used is adjusted or modified based on outliers

- The calculated inventory levels are verified using the simulation software – Flexsim

Space is expensive especially in developed countries.

A total of 1031 square feet is covered by the local inventory at the textile printing section alone. This is in addition to the huge warehouse space that is stocked at high safety levels.

There are several traditional inventory control methods that are used in the industry to calculate optimum inventory levels. The problem is however, the fact that the assumptions made for these calculations do not enclose the constraints surrounding those in mass customizing W2P companies. A list of the traditional inventory calculation methods and their incompetence to meet the needs to solve this particular problem is mentioned below:

- **SIMPLE EOQ (Economic Order Quantity) MODEL**

  Assumptions made:

  Demand is fixed units per unit time – This is not the case for MC W2P companies. The demand fluctuations are extremely hard to forecast, especially to the hourly rates to calculate on floor inventory requirements based on forecasts.

  Because of the basic difference in the assumption for EOQ, other variants of EOQ including

- Finite Production rate
- EOQ with backorders (apart from demand uncertainty, EOQ with backorders assumes that shortage can be met after replenishments, which is not the case at MC W2P companies as even small stoppages result in huge revenue losses)
- Quantity Discount Models

Cannot be used to solve this problem.

- **NEWSVENDOR MODEL**

Assumptions made:

Demand is not known. However, the demand characteristics like mean, standard deviation and the demand distribution is known. The demand distribution is attempted to be traced.

The hourly output of small black T Shirt (sorted demand frequency) for the month of January of 2014:

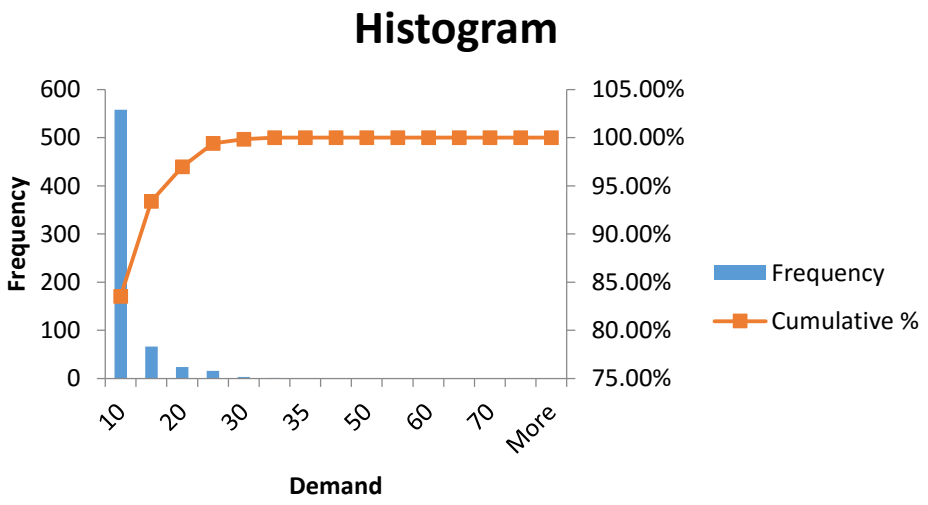


Fig 7: Frequency Distribution of hourly output of Small Black T-Shirt– January 2014

For the February of 2014 the hourly output traces the following pattern:

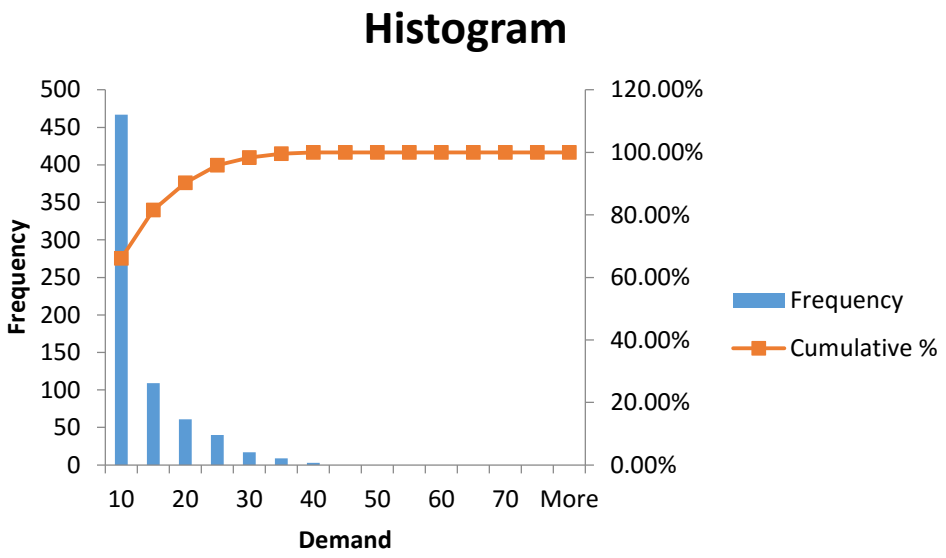


Fig 8: Frequency Distribution of hourly output of Small Black T-Shirt– February 2014

The demand pattern varies considerably from one month to the next and the frequency pattern does not fall under neither normal nor uniform distribution, which are the basic requirements to use the news vendor model. Calculations can be done considering the pattern to be normally distributed with highly positive skewness. However, the resulting calculations will be inaccurate.

In addition to these inaccuracy problems, Newsboy models are basically used for calculating required inventory for products with short lifetime.

- **LOT SIZE REORDER POINTS** is an extension of EOQ and therefore cannot be considered to solve the problem at hand.

Similarly, other traditional inventory calculation models are not effective because of the conflicting assumptions made by each model.

(Song & Zipkin, 1991) proposed an inventory model which takes into account the variations in demand due to external factors including product life cycle, economic conditions etc.

- **JUST-IN-TIME**

Traditional Lean approaches try to get rid of inventory completely. An ideal Lean setting has zero inventory, both raw material and WIP inventory. It is challenging to employ JIT in traditional manufacturing settings itself. It is even more difficult to employ JIT in MC W2P production environment. MC W2P production settings are high volume production settings with individual product manufacturing/cycles as low as 20 seconds and product variety is high. It is extremely difficult to employ just JIT in such settings. However a mixture of minimal local inventory and JIT might be a possible solution.

Demand forecast is inaccurate, but can be used as a base for managing expected inventory. The forecast data is based on seasonal demand histories.

It is clear that none of the inventory control models can be used to calculate On Floor inventory levels for MC W2P companies accurately. However, this is expected because of the unforeseeable demand fluctuations. One of these inventory control methods have to be considered and explored to set base inventory, which although might not be the optimal solution, can form the base to find strategic combinations (like traditional inventory models + JIT).

IV. LITERATURE REVIEW

The literature review is divided into three segments based on the topics covered in this thesis.

- Mass Customization
- Operational Research and
- Simulation based verification

4.1. IDEA MAP

Paper Title, Author and Year of Publishing	Mass Customization	Inventory Control	Simulation	Printing Industry
(P.Zipkin, 2001) The Limits of Mass Customization. MIT Sloan Management Review	✓			
(Chan, Jie, Kamaruddin & Azid, 2014). Implementing the Lean Six Sigma Framework in a Small Medium Enterprise (SME) – A Case Study in a Printing Company, 387–396Fproblem statement	✓			
(Rose, A.M.N., Deros, B.Md., Rahman, M.N.Ab. & N.Nordin, 2011) Lean manufacturing best practices in SMEs. International Conference on Industrial Engineering and Operation Management, 1(1), 872–877	✓			
(A.König, 2012) Mass Customization of Print Products The emergence of Online Printers – small business as a gap in the market	✓			✓
(Salvador, Holan, De & Piller, 2009) Cracking the Code of Mass Customization - MIT Sloan Management Review. MIT Sloan Management Review	✓			✓
(Fralix, 2001)U.S. Apparel Employment U.S. Textile and Apparel Trade. Journal of Textile and Apparel, Technology and Management, 1(2), 1–7	✓			✓
(Feitzinger & Lee, 1997). Mass Customization at Hewlett-Packard: The Power of Postponement. Harvard Business Review, 75(1), 116–121	✓			✓
(Bhatia & Asai, 2012) Mass Customization in Apparel & Footwear Industry – Today's Strategy, Future's Necessity. Wipro, 1–16	✓			✓
(Zhang, Chen & Tseng, 2003) Process Planning for Mass Customization, 1–15	✓	✓		✓
(Yao & Liu, 2009). Optimization analysis of supply chain scheduling in mass customization. International Journal of Production Economics, 117(1), 197–211	✓	✓		

Aigbedo, H. (2007). An assessment of the effect of mass customization on suppliers' inventory levels in a JIT supply chain. European Journal of Operational Research, 181(2), 704–715	✓	✓		
(Yang, Teng & Chern, 2001). Deterministic inventory lot-size models under inflation with shortages and deterioration for fluctuating demand. Naval Research Logistics, 48(2), 144–158	✓	✓		
(Song & Zipkin, 1993). Inventory Control in a Fluctuating Demand Environment. Operations Research	✓	✓		
(Khurma, Bacioiu & Pasek, 2008). Simulation-based verification of lean improvement for emergency room process. In Proceedings - Winter Simulation Conference, 1490–1499			✓	
(Yao & Zhu, 2010). Visual simulation framework of iron and steel production scheduling based on Flexsim. Bio-Inspired Computing: Theories and Applications			✓	
(Kleijnen, 1995) Verification and validation of simulation models. European Journal of Operational Research, 82(1), 145–162			✓	
(Fujimoto, 1989). Parallel discrete event simulation. Proceedings of the 21st Conference on Winter Simulation, 19–28			✓	
(Carson, 2002). Model Verification and Validation. Proceedings of the 2002 Winter Simulation Conference, 52–58			✓	

Part 1: Mass customization – gives a brief outline of the literature on mass customization as a business strategy in the printing industry

Part 2: Operational Research – Gives a brief review of the research done on inventory control in Mass customizing industries

Part 3: Cites publications that use simulation software as validations for improvements in both manufacturing and service industries.

4.2. MASS CUSTOMIZATION:

(Fralix, 2001) talks about how there has been a tangible change in the way manufacturing is done all over the world and how the United States has been lagging behind. Fralix's paper title "From Mass Production to Mass Customization" talks about the apparel industry being the first to adopt Mass Customization as a competitive strategy well before any other industry. The paper sites examples of the employment numbers of the apparel industry over the last 20 years. The apparel industry employed around 1.4 Million workers during its peak to 800,000 after its decline. Fralix talks about the competitive nature of the industry, the developing countries having an upper hand in terms of their ability to manufacture high volumes and low costs and that the developing countries should look to other ways to compete. Fralix says that Mass Customization is the solution for balancing this competition out. Michael's paper goes on to talk about how body scanning and digital printing can support mass customization in the apparel industry.

(Salvador, Holan & Piller, 2009) publication on MIT's Sloan Management review, looks at Mass Customization from the view of a business strategy than a manufacturing strategy.

The paper “Cracking the code of Mass Customization” explains the current mind set of the industry management, which could mass customize. Because of the failures companies of Levi Strauss Co’s (Custom Jeans), the executives of think of Mass Customization as the ideal solution that is impossible to practice nor achieve. Mass Customization is not an ideal strategy that the industry must strive to reach but a strategic mechanism that companies can use to align their organization with needs of the customers. This paper goes on to describe three fundamental capabilities that an organization has to develop in order to align itself with the needs of the customers and evolve – Solution Space Development, Robust Design Process and Choice Navigation. Developing these capabilities will help an existing organization move from a Mass Manufacturing Paradigm to a Mass Customizing Paradigm.

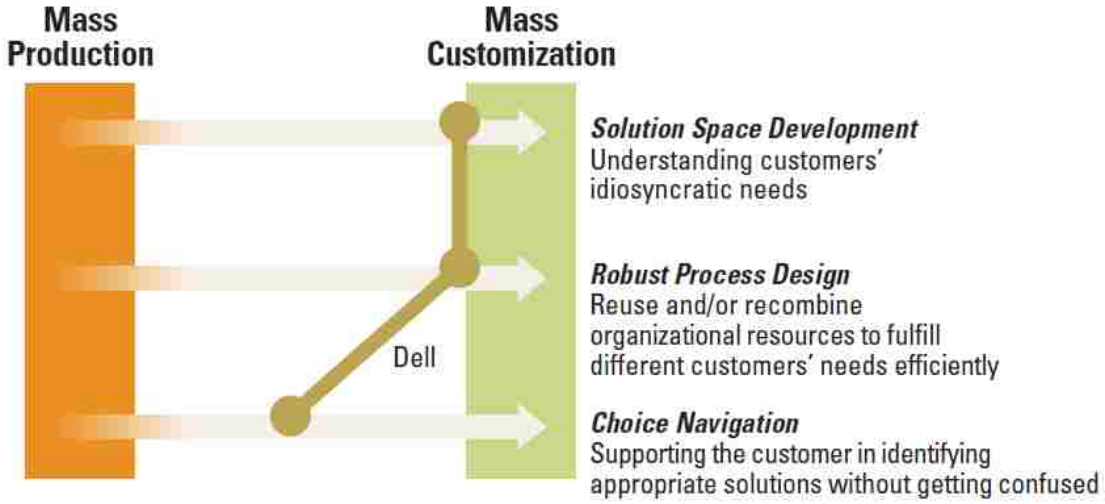


Fig 9: Mass Production to Mass Customization (Zipkin, 2001)

(Konig, 2013) paper titled “Mass Customization of Print Products” gives a detailed insight into the evolution of the printing industry, from small print shops that catered to a certain

group of businesses that could afford the high cost to the emergence of the W2P industry. The paper explains how W2P companies use mass Customization as a strategy to achieve low costs and thereby satisfy both high and low end customers. Konig's paper gives insight into how the three most successful W2P companies (Vistaprint, Flyeralarm and Saxoprint) were started, explaining the market gap that the these company's founders identified and exploited. This paper explains how the dot com revolution and the DRUPA initiative introduced Web Based interfaces as a solution to reduce costs by cutting down on administrative hierarchies – Deign and Order procurement. The paper goes on to explain the competition between the MC W2P companies from 2007 to 2013, citing product prices as a base for comparison of competitiveness. The product compare was a marketing folder of A4 size with 6 pages and 1500 copies of each.

Table 3: Cost comparison from 2007 to 2013

			Data Collection Month/Year			
Row	Company Name	URL	11/2007	9/2008	9/2010	5/2013
1	Flyeralarm	www.flyeralarm.de	83,78 €	83,07 €	83,07 €	73,39 €
2	unitedprint.com	www.print24.de	123,64 €	118,64 €	76,88 €	65,71 €
3	Saxoprint	www.meindruckportal.de	77,07 €	75,14 €	67,62 €	72,00 €
4	Onlineprinters	www.diedruckerei.de	89,00 €	89,90 €	81,80 €	73,72 €
5	Price difference min - max		60 %	58 %	23 %	12 %
6	Average price between companies		93,37 €	91,69 €	77,34 €	71,20 €
7	Changes from 11/2007 to 5/2013					- 24 %
8	Cost Estimation with data from [14] [15]					244,10 €
9	Difference Cost Estimation / Online Printers					- 71 %

A paper published in the Harvard Business Review titles "Mass Customization at HP: Power of postponement" gives an insight into how HP has leveraged MC to counter the competition from rival companies. Different companies approach and leverage MC from different perspectives. HP leveraged MC by postponing the differentiating component

assembly till the very last possible moment. Postponement is achieved by using Modular Product Design, Modular Process Design and Agile Supply networks. Other strategies to postpone the customizing components till the very last moment include the use of local warehouses to assemble the customizing components decreasing the overall cost. (Feitzinger & Lee, 1997).

The transition to MC is complicated. The paper title "The Limits of Mass Customization" elaborates on this topic and compares Mass Customization with traditional mass manufacturing setting (Zipkin, 2001). This paper talks about the three main elements of Mass Customization as being Elicitation (mechanism for interacting with the customer to obtain product specifications), Process Flexibility and flexible and responsive logistics setup. The limitations for MC include

- People are not ready to get every single configuration customized – decisions on which characteristics of a product is to be customized is a difficult and the trends change frequently
- Requires highly flexible production technology
- Requires to develop an effective way to elicit customer requirements – high development costs
- Requires highly responsive and strong direct to customer logistics system and

4.3. OPERATIONS RESEARCH

Most of the research done on OR related to MC has been on process planning and variety management. There exists a serious gap with respect to inventory control in MC settings.

(Zhang, Chen & Tseng, 2003) explains in depth the complications of process planning in MC industries. Process planning connects product designs to the production floor. Process planning is usually done for individual products. When it comes to MC settings, the combinations of customizable products is high, thereby making process planning for individual products extremely difficult. Most MC industries face process planning complications. The paper titled "Process Planning for Mass Customization" outlines the cause for process planning complication in MC settings and provides solutions for keeping the process planning and the process as a whole under control. Product variety management is the proposed solution for controlling the diversity the available products thereby making process planning less complicated.

The paper explains in detail a case study conducted for the product variety management and subsequent process planning for a customizable high power washer. There are five ways to approach process planning:

- The traditional Approach – Done from memory and codebooks
- Workbook Approach – Done by deriving from a workbook of previously stored process plans
- Variant Approach – Based on Group Technology (GT)
- Generic Approach – Similar to Workbook approach, but is done in a systematic manner
- Generic and

- Semi Generic Approach

The paper goes on to talk about creating BOM's for the high – pressure washer, grouping similar parts and creating diverging modules for customizable parts based on product family and comes up with a master process plan for making customizable high pressure washer manufactural without having huge economic impacts that MC industries face.

(Yao & Liu, 2009) explains how to deal with scale production effect and customized demand in MC setting. Responsive supply chain and operation characteristics are required to provide ideal conditions to solve the supply chain complications in MC setting. This paper talks about the complications in operations scheduling in MC settings. The paper derives from previous work, proposing a dynamic and multi – objective model and the appropriate solving algorithm to compensate these contradicting problems.

(Wang, Fan, Li & Xiaoxia, 2007) talks about Mass Customization being the front-runner for competitive edge in this century. The paper analyses the characteristics of the supply chain of mass customized settings and gives insight into ways to harmonize and optimize he supply chain of mass customizing industry.

(Yang, Teng, Chern & Sheng, 2001) explains the shortfalls of EOQ for certain products whose value decreases with time. EOQ traditionally assumes a constant demand and a fixed unit cost. The literature modifies the classical EOQ model that includes fluctuating demand function and reducing purchase costs as constraints. The paper also proposes an algorithm to calculate optimal replenishment cycles and schedules. The literature claims that the proposed model decreases inventory costs by 32.4%.

(Aigbebo, 2003) assess the effect of MC on supplier's inventory when the automotive OEM the suppliers supply to uses MC as a competitive advantage whilst adopting JIT. The literature discusses the effect of MC on JIT adopted supply chain. When an automotive OEM adopts MC after adopting JIT, stress is applied on the supply chain, which is directly transferred to the supplier's inventory levels to prevent stockouts at the OEM the supplier supplies to. The literature proposes the use of min – sum and min – max formulations proposed by Kubiak et al. (1997).

(Song & Zipkin, 1993) proposes an inventory model that considers demand rate fluctuations. The variables that affect demand include economic fluctuations, stages in a products life cycle etc. Optimal policies are derived and algorithms have been developed to compute them.

4.4. SIMULATION BASED VERIFICATION

(Khurma, Bacioiu & Pasek, 2008) outlines the key challenges faced by Emergency Departments in Canadian Hospitals, their adverse effects on patients. The wastes that causes these challenges are identified using lean tools and improved. The emergency departments are high stress, highly sensitive environment and as a result the proposed improvement cannot be validated by performing experiments in the hospital and simulation is used to verify the proposed improvements. This paper validates simulation as a viable tool for verification in service settings. Because the production settings in MC W2P companies are high volume and highly sensitive, verification of inventory levels can be done using simulation tools.

(Yao & Zhu, 2010) explains the process scheduling done for steel making. Flexsim is used to validate the scheduling. Actual data obtained from analyzing already available data is entered in the simulation software and the output is compared to the proposed output, thus proving the effectiveness of FlexSim as a simulation validation tool.

(Kleijnen, 1995) analyzes the effectiveness of simulation models for the verification of operational research discussing

- Effective programming techniques
- Statistical Analysis of simulation outputs

Validation is done through

- Comparing outputs with real world data
- Comparing outputs against real data using graphical, Schruben and t tests
- Correlation between simulation outputs and real response means
- Sensitivity analysis using DOE and regression analysis
- White vs black box simulation models

(Fujimoto, 1989) published a paper under the topic “Parallel Discrete Event Simulation”. The literature gives a brief look at the literature available in the discrete event simulation. The paper discusses asynchronous simulation (a limited number of events occur at a single point in the simulated time) in detail, highlighting the requirement to run multiple simulations concurrently to observe and analyze events. The literature discusses the challenges of concurrent simulation and discusses the strategies proposed to approach complex concurrent simulation problems.

(Carson, 2002) outlines the guidelines and techniques that can be used to validate simulation models. The paper explains why it is important to validate and verify the simulated models closeness to the real world setting being simulated. The goal of a simulation is to predict the behaviour of a system under different situations. It is necessary for the simulation to be close/similar to real world system to help predict the behaviour of the real world system based on the simulated model. This paper emphasized on the validation of the accuracy of a simulated model, providing examples of situations where inaccurate assumptions can be made and offers a detailed guideline for the verification and validation of simulated models.

The problem at hand is one that is common to most of the mass customizing W2P companies. To find a structured solution for the problem, the approach to finding the right solution is enclosed in the DMAIC framework.

V. DMAIC FRAMEWORK, IDENTIFICATION AND ANALYSIS OF MODEL

DMAIC stands for Define, Measure, Analyse, Improve and Control. DMAIC forms the core of Six Sigma. Six Sigma is usually performed to control process variation. However, the DMAIC framework is a tool that can be used to solve any problem in a structured approach.

In MC W2P companies, the strategies (both business and manufacturing) are ever changing and evolve rapidly. New products are launched and taken out of production constantly. This rapid change gives relatively short time windows to understand and optimize production processes. Typically, MC W2P companies try just to achieve continuous production runs and do not analyze individual process in detail. This leads to an

unstandardized work setting (except for the production process). In such settings, the noise is high and it is easy to deviate from the core problem.

To avoid deviating from the problem, a structured approach like the DMAIC framework comes in handy. In the following section, the thesis addresses the on-floor inventory control problem and finds a solution by following the DMAIC framework. In the course of following the DMAIC framework, we define the problem in detail, measure the characteristics and constraints surrounding the on floor inventory control problem (Current Inventory Levels, Space covered, Cycle Times etc.), Analyse the possible Inventory control solution and check its compatibility and Apply the inventory control solution thereby improving the excess inventory scenario and proposing control measures to sustain the solution.

5.1. DEFINE PHASE:

MC W2P companies rely on one key strategy that gives them an edge over other traditional printing companies i.e., MC W2P companies rely on postponement and consecutive aggregation of orders to achieve printing at low unit costs. In terms of final product costs, postponement and aggregation has been able to reduce the unit price of individual products to very low prices compared to traditional printing. The order aggregation is completely automated and performed by the W2P companies production planning software. The orders are planned and aggregated at the printing facilities continuously, i.e. orders are updated as the customers place orders through the MC W2P company's web interfaces. This leads to effective cost reduction.

For example: When an order for business cards are placed by a person to a mass customizing W2P company (like Vistaprint) from a location in the U.S, the company's order procurement software updates the central server as soon as the payment is received. The received order of business cards is then analyzed using a set of predefined algorithms and transferred to one of the print facilities, say to the one in Windsor, Ontario, Canada. The local production planning software receives the order and processes the request. If the order is for, say 1000 units of business cards on substrate type smooth matte, the local production planning software continuously weighs the trade-off between shipping costs and manufacturing costs of individual orders. If the customer had asked for regular shipping (three-day shipping), the production planning software waits till the production can be initiated after aggregation of orders. If at the end of the first day (3 shifts), there are not enough orders that can be printed on smooth matte, the production planning software holds the printing off the production floor till the next day, while weighing the cost of shipping to the cost of production. The next day, say if there are enough orders to run a gang of 250 sheet stacks of smooth matte, then the production planning software prints the same business card in four different locations on the sheet. Thus, the end product is 1000 business cards that the customer ordered which is then expedited to the customer. The production of products is achieved at the lowest possible unit cost.

The postponement and aggregation of orders leads to shocks in the supply chain. The personnel on the floor and the logistics division do not know the orders they are to print during the shift. The short cycle times, frequent inventory turns and demand fluctuations add further stress to the already stressed supply chain.

This unpredictable demand and material requirement cannot be forecasted beyond a certain range of accuracy. The logistics division of MC W2P companies, which is responsible for raw material procurement and in house distribution, copes with this unpredictability by maintaining excessive inventory in their warehouses with high reorder points and safety stock. The warehouse sizes and scale is increased frequently to cope with demand fluctuations. The cost of floor space is an extremely high investment, which is the reason that most automotive companies tend to keep their suppliers nearby and get the raw materials delivered Just – In – Time. However, JIT alone is not an option for MC W2P companies.

The mentality of MC W2P companies to maintain high inventory in their warehouses is transferred to the floor as well. As demand is unpredictable and printing cycle times are as low as 15 seconds, MC W2P companies stock their floors with excessive inventory. Most MC W2P companies do not understand the direct and in direct cost of such a practice. The fear of running out of inventory on – floor, prevents the MC W2P companies from attempting to scale down the on – floor inventory. This thesis tries to find a solution to the on – floor excessive inventory stocking problem and validates it using simulation.

The on – floor inventory control has been studied on the textile layout of Vistaprint.

5.2. MEASURE PHASE:

In a mass customized environment, the product variety is extremely high. This is because, based on the degree of customization the number of possible combinations leads to exponential increase in product variety. However, the number of base variations can be controlled. In textile printing, the product variety available may be numerous, but the

number of sizes available typically forms the base of products and of course, the quality and type of Shirt used.

In this study, the company prints on exactly 8 types of T-Shirts and each type of T – Shirt has 5 sizes. That is a total combination of 40 types. Hats, Tote Bags and Mouse Pads are printed on the textile section as well and will be a part of the textile section studied. This adds another 5 types of products to the line, making the number of products that the textile layout is responsible for a total of 45 types.

The digital layout was used to identify the areas where the inventory was placed on the floor.

- Racks

- Dryer

- Packer

- Printers

- Embroidery Line

Fig 10: Textile Floor Layout

There was inventory present in unspecified, unmarked locations as well. The inventory is in boxes, and each box contains 72 units, except for Tote Bags which contain 120 units in the small size's box and 50 units in both Large Half Bleached and Two Tone Half Bleached boxes.

So, in future, the reference to boxes of inventory means the corresponding number of individual items inside the box.

Next, the total inventory on floor is carefully documented. The total amount of inventory could not just be mentioned in number of boxes as there were units in loose present around the work floor.

The results were tabulated.

Table 4: Total On-Floor Inventory on Textile Floor Layout

S. No	Product Type	Size	Total Number of Boxes	Capacity of one box	Number of Product in Totes	Total Inventory in Workspace
1	White Men's T-Shirt	Small	27	72	0	1944
		Medium	31	72	0	2232
		Large	36	72	0	2592
		X-Large	19	72	0	1368
		2XL	19	72	0	1368
2	Black Men's T-Shirt	Small	9	72	12	660
		Medium	11	72	12	804
		Large	14	72	12	1020
		X-Large	6	72	12	444
		2XL	8	72	12	588
3	Ash Men's-Tshirt	Small	3	72	0	216
		Medium	4	72	0	288
		Large	4	72	0	288
		X-Large	4	72	0	288
		2XL	4	72	0	288
4	Premium Men's T-Shirt	Small	4	72	0	288
		Medium	4	72	0	288
		Large	6	72	0	432
		X-Large	3	72	0	216
		2XL	6	72	0	432
5	White Long Sleeve T-shirt	Small	3	72	12	228
		Medium	3	72	12	228
		Large	3	72	12	228
		X-Large	3	72	12	228
		2XL	3	72	12	228
6	Black Long Sleeve T-Shirts	Small	3	72	0	216
		Medium	3	72	0	216
		Large	3	72	0	216
		X-Large	3	72	0	216
		2XL	3	72	0	216
7	Ladies T-shirt	Small	5	72	0	360
		Medium	5	72	0	360
		Large	5	72	0	360
		X-Large	5	72	0	360
		2XL	3	72	0	216
8	Youth T-Shirts	Small	6	72	0	432
		Medium	6	72	0	432
		Large	6	72	0	432
		X-Large	6	72	0	432
		XS	6	72	0	432
9	Hats	White	6	72	0	432
		Wheat	5	72	0	360
10	Tote Bags	Small Half Bleached	4	120	0	480
		Large Half Bleached	8	50	0	400
		Large Two -tone Half Bleached	8	50	0	400

The number of T- Shirts, Tote Bags and Hats alone total to 24,152 units.

Next, the space covered by this Inventory is measured and tabulated as well.

The inventory is placed on multi – level racks, most being 4 levels high. It is possible to add more inventory in the same space by adding more levels of racks, however, as most of the workers in the Textile Printing section are woman, it might not be ergonomically advisable because of height issues.

Some other interesting and noteworthy observations were made during this study, which will be discussed later on.

Table 5: On – Floor Inventory Space Coverage – Textile Layout

S.No.	Length (in cm)	Width (in cm)	Surface Area covered (cm^2)	Surface Area covered (m^2)	In sqft.
1	170	157	26690	2.669	28.7288491
2	178	209.5	37291	3.7291	40.13965949
3	70.5	228	16074	1.6074	17.30189286
4	77	233	17941	1.7941	19.31151299
5	70	306	21420	2.142	23.0562738
6	55	222	12210	1.221	13.1427219
7	76	235	17860	1.786	19.2243254
8	70	309	21630	2.163	23.2823157
9	56	229	12824	1.2824	13.80362536
10	55	229	12595	1.2595	13.55713205
11	290.5	140	40670	4.067	43.7767813
12	55	228.5	12567.5	1.25675	13.52753133
13	171	699	119529	11.9529	128.6598203
14	73	310.5	22666.5	2.26665	24.39799394
15	57	226	12882	1.2882	13.86605598
16	51	174	8874	0.8874	9.55188486
17	60	226.5	13590	1.359	14.6281401
18	56.5	330.5	18673.25	1.867325	20.09969957
19	56	232	12992	1.2992	13.98445888
20	71	230	16330	1.633	17.5774487
21	71	310	22010	2.201	23.6913439
22	61	123	7503	0.7503	8.07615417
Dropped off Inventory on Skids					
23	163	619	100897	10.0897	108.6045218
Total Surface Area Occupied			605719.25	60.571925	**651.9901435**
Embroidery					
	182.5	1856	338720	33.872	**364.5948208**
Mouse pads					
	63.5	200	12700	1.27	**13.670153**

The total space covered by on floor inventory is 1030.255 square feet. The inventory is mounted on racks as mentioned and are mostly placed right next to the printing machines to help with easy access and the skids with replenishment inventory are dropped off at the marked location on the layout. There are no specific replenishment times and the supervisor fills out the required inventory and the material handler picks up the list and replenishes the required quantity of the required product.

The inventory on the skids dropped off for replenishment was not added to the inventory documented. It adds another 108.604 square feet to the space covered, increasing the total to 1138.86 square feet.

The machines/equipment involved in the process are printers, dryers and packers. The textile to be printed on is removed from its package from the box, printed on the printing machine, then dried using dryers and packed using packer machine. The machine cycle times were documented as well.

Table 6: Machine Cycle Times – Printing Layout

Description	Unit	Print Type	CT (s)
Textiles Dark Shirt Printing	Side	Full	42.75
Textiles Dark Shirt Printing	Side	Pocket	28.200
Textiles Embroidery	Stich		0.07
Textiles Embroidery- hat	Unit		153.10
Textiles Embroidery- shirt	Unit		129.80
Textiles Fold/Bag/Pack- Binned Items	Pack		7.80
Textiles Fold/Bag/Pack- DS Items	Pack		30.70
Textiles Light Hat Printing	Side		28.05
Textiles Light Shirt Printing	Side	Full	28.45
Textiles Light Shirt Printing	Side	Pocket	21.72
Textiles Mouse Pad Pack	Unit		17.15
Textiles Tote Bag	Side		27.74
Textiles Youth Shirt Printing	Side		26.86

The mouse pads had a local inventory of 16 boxes in total with the 3mm box having 1440 units in each of them and the 6mm mouse pad's inventory had 90 units in each box.

The total was 2160 units in the boxes and the total number of units (Boxes plus individual units) in the textile segment was 26,312 units.

5.3. ANALYSE & IMPROVE PHASES:

The MC W2P industry is ever changing. Unpredictability is the main reason for the inventory problems in MC W2P companies. Traditional inventory models for calculating inventory levels require predictable demand levels, at least with respect to the distribution of demand data. However, in the case of MC W2P companies' demand patterns do not follow the traditional distribution patterns.

An example is the demand pattern of the small black t – shirt demand on the first week of January 2014.

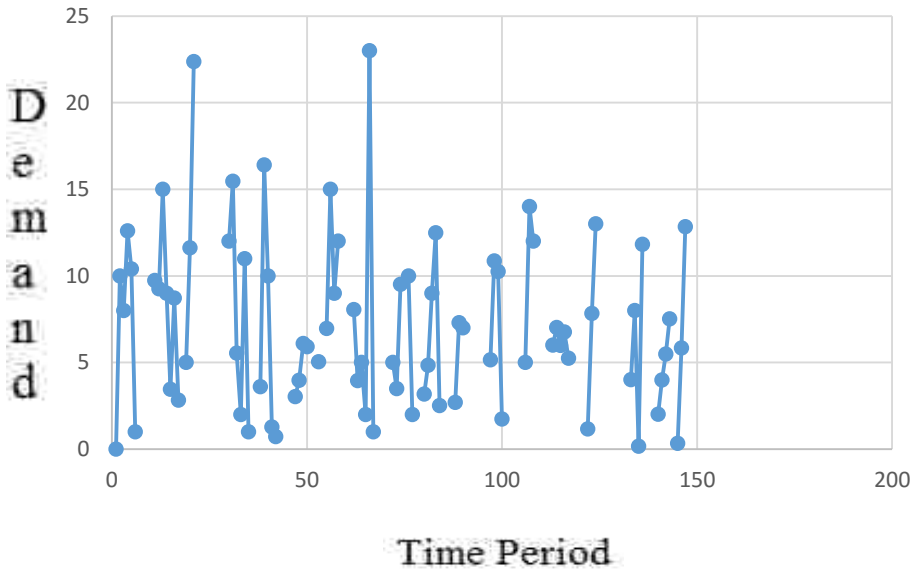


Fig 11: Hourly demand of Small Black T – Shirt – Jan 2014

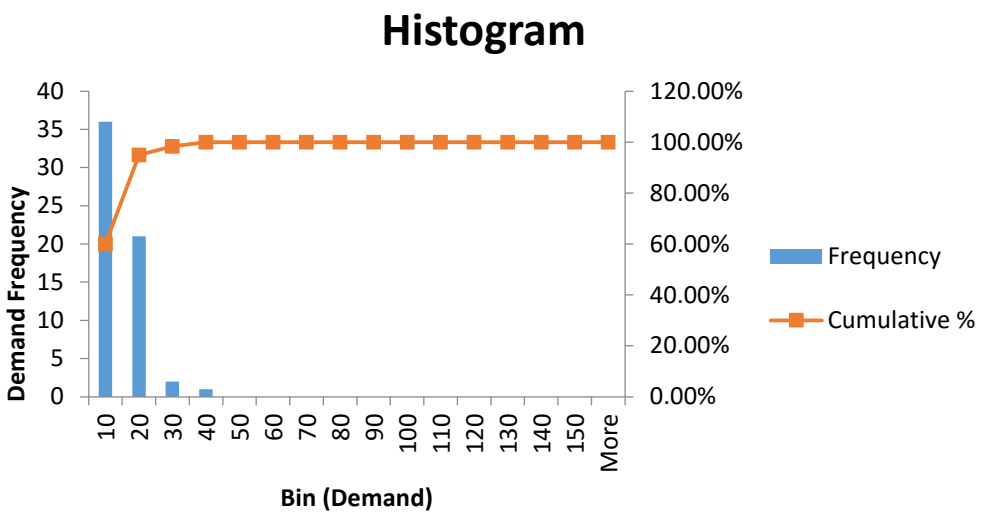


Fig 12: Hourly demand distribution

The on – floor inventory control problem in MC W2P company is a complicated problem. There is absolutely no way that the demand can be smoothed out. Traditional automotive plants have changed from push to pull based system entirely because of their ability to smooth out production. Lead times for cars to be delivered is long enough to help automotive assembly plants to plan and assemble cars at a smooth pace. Takt time can be calculated and achieved in traditional automotive assembly plants. However, in MC W2P industry settings none of this is possible. Takt time varies tremendously and the products variety is high adding further stress to the system.

MC W2P market is extremely competitive and cost cutting is a technique most MC W2P companies use to push out competition. Along with this, new product lines, new packages deals at low costs and increasing freedom for customers to customize their products are strategies MC W2P companies use to gain their competitive edge. These changes are frequent and hence the production/printing lines have to be flexible enough to adapt to

these changes to compliment the business strategies. New equipment procurement is done frequently, workers are trained to enable new product printing etc. and changes are extremely frequent. MC W2P companies have to adjust to even slight changes in the market and continuously change to fulfill the customer's expectation to keep their business competitive. In comparison, traditional automotive companies change existing car designs and introduce new modes typically once every year. This low frequency of the requirement to change in the automotive industry makes it relatively easy for automobile companies to have standardized process flows and thereby optimize their inventory levels. But, MC W2P companies have to change and adapt frequently and hence their inventory problem is complicated.

Unlike traditional manufacturing industries, MC W2P companies cannot adopt JIT completely to satisfy their production floor's needs. An ideal setup would be a combination of maintaining on-floor inventory and use JIT to reduce on floor inventory levels without stopping the line due to inventory exhaustion.

Traditional Inventory control models are mainly dedicated to calculate warehouse inventory and the costs considered relate to the same. Most inventory control models consider costs like ordering costs, volume based discount rates, transportation costs, carry over costs etc. However, these costs are not entirely applicable to on floor inventory calculation. The costs related to holding on floor inventory, although being the same as that of housing warehouse inventory, is higher that holding inventory warehouse. For eg: Warehouses are specifically designed to hold inventory, with high ceilings, and inventory being stacked up on top of each other and the layout planned to maximize storage efficiency. However, when the same inventory is transferred on floor, the setup is not

designed to maximize inventory storage, therefore the space related costs is actually higher while storing inventory on floor rather than in the warehouse. The main costs associated with on floor inventory are space related costs, labor costs and potential for alternative investment. Labor costs are the cost of hiring and paying material handlers. This can be curbed in the long run, however it is important to maintain enough material handlers as decreasing on floor inventory levels may increase the requirement to distribute inventory frequently. Thus, labor costs cannot be considered and similarly, the potential cost for alternative investment cannot be considered either. The inventory is still held in the warehouse and so, the investment on inventory is still the same. Space cost is the cost that has to be considered while calculating on floor inventory.

The ideal inventory control model should consider this cost and the system has to be a periodic review model that has to be simple enough to use but already a proven practice. It is already known that the any model that is considered will not be accurate because of the unpredictable demand pattern, which does not have a predictable distribution pattern. However, there needs to be a base set for calculating on floor inventory levels in MC W2P companies.

After much consideration and because of the fact that MC W2P company's industry setting is highly competitive, News Vendor model was considered to calculate inventory levels. Traditionally News Vendor model is used to calculate inventory levels for perishable products. This has made the output from this model extremely stringent. The model can be used to consider space coverage costs as well. The sensitivity of the model has been analyzed for varying periods.

The NewsVendor Model can be used to find a tradeoff percentage between the revenue from maintaining a certain amount of inventory to the associated costs with maintaining that amount of inventory. The News Vendor model's output gives that percentage of inventory to be maintained so that, if the demand falls below the prefixed level of inventory the profit from holding only the calculated amount of inventory would be the ideal amount to overcome the cost lost due to unused inventory (in this case inventory level vs space cost).

The industry average for space coverage costs is 3%.

The industry average is the cost for the space coverage in warehouses. Warehouses are specialized to hold huge amounts of inventory, with high ceilings and specialized multilevel racks that can be used to stack up inventory, one on top of the other. However, when it comes to on floor inventory, the inventory has to be accessible and only a certain amount of inventory can be held. Thus, the inventory holding costs for on floor inventory is higher. However, for this problem we will consider the average warehouse inventory cost as the average space coverage cost for on floor inventory as well.

A preliminary review of the demand characteristics shows that even though the demand spikes are unpredictable, it is noticeable that there are signals that point to the increase in demand consecutively.

For example: Just before Christmas, families start planning early for the holidays and start ordering 'thank you' notes and custom Christmas cards before the holiday season starts. The early spike is enabled by preseason advertisement campaigns as well. These increases in demand early in the time line can be used to calculate the inventory levels required for

the consecutive term. Similar to the way Forecasting works, inventory models can be used to setup inventory levels by analyzing demand trends from previous timeline to setup inventory levels for the next time line. A logical scale of data that could yield dependable results would be monthly demand, i.e., using one month's demand to set the inventory level for the next(on – floor) inventory. However, as MC W2P companies demand changes in short notice, there is a necessity to consider smaller windows of demand, say bi monthly and weekly. The effectiveness of the use of monthly, bi monthly and weekly demand to set on floor inventory levels for the consecutive timeline has been analyzed in the first study.

For this study, a total of three variants of T Shirts namely Black half sleeve, Black long sleeve and white half sleeve T Shirts were used were chosen and used. The choice was based on their varying demand spectrum – Low, Medium and High. For both the black T Shirt types mentioned, all five sizes were analyzed, i.e. small, medium, large, XL and XXL. For the white T Shirt however, the small and medium sizes were analyzed. The types for T Shirts considered for the study show varying levels of demand uncertainty. The News Vendor model was used to analyze the demand pattern from the January of 2014 to the January of 2015 and compared to a simple forecasting method (simple moving average), to check their effectiveness in comparison to forecasting techniques.

5.3.1. NEWS VENDOR MODEL FORMULA AND NOTATIONS [14]:

D = Demand

C_o = Overage Cost (Loss of Excess Supply)

C_u = Underage Cost (Loss of profits for under supply)

Q^* = Order Quantity (Inventory Level)

C_o = Purchase Price – Salvage Value

C_u = Selling Price – Purchase Price

$C_f = C_u / (C_o + C_u)$

The average cost price of plain T Shirt is 3 Cad.

The average selling price of printed T Shirt is 15 Cad.

Thus, the space coverage cost of holding 1 piece of inventory on floor for 1 year is approximately 10 cents. This can be added to the cost price of the T Shirt to include the space coverage cost when finding the trade-off inventory level.

Calculation of C_f:

Cost = 3.10 Cad (3+.010 - space cost – modification)

Salvage Value = 0 Cad (can be carried over to next time period)

Selling Price = 15 Cad

C_o = 3.1 Cad

C_u = 11.9 Cad

C_f = 79.3 %

What the value of C_f means is that while analyzing the demand characteristics, setting an inventory level that satisfies 79.3 % of the demand would be the ideal level to minimize space related costs while satisfying the un - forecastable demand.

The data analysis is done in two parts. As mentioned earlier, one part is to identify and compare the effectiveness of month to month inventory setting with Bi monthly and week to week inventory setting and comparing it with simple moving average to identify the effectiveness of the chosen inventory control model to forecasting techniques.

After identifying which degree of inventory control based inventory setting is effective (monthly, bi monthly or weekly) a recent demand data has been analyzed to set the inventory for the consecutive time period.

The bin size considered is 5 units, because the average time taken for a material handler to move from the local warehouse to the textile floor layout is approximately 1.5 minutes, which is approximately equal to the cycle time to print on 5 units of textile.

Table 7: News Vendor Model – Month to Month, Bi Monthly and Weekly – Comparison with Simple Moving Average

S. No.	T-Shirt Type			Q*												Min. Qty.												Simple Moving Avg.											
				J	F	M	A	M	J	Ju	Au	S	O	N	D	J	F	M	A	M	J	Ju	Au	S	O	N	D	J	F	M	A	M	J	Ju	Au	S	O	N	D
1	Small Black T Shirt	Monthly		15	20	20	20	15	10	10	15	15	15	15	20	72	72	72	72	72	72	72	72	72	72	72	72	9	12	13	13	9	7	6	7	7	8	9	10
		Bi Monthly	1st Half to 2nd Half	15	20	20	25	15	15	15	10	10	15	20	20	72	72	72	72	72	72	72	72	72	72	72	72	8	12	13	13	10	7	7	7	8	7	9	10
			2nd Half to the 1st Half on Next Month	15	20	20	20	15	10	10	15	10	20	15	20	72	72	72	72	72	72	72	72	72	72	72	72	10	12	13	13	8	6	6	7	7	9	8	10
		Weekly	1st week to 2nd week	15	20	25	20	20	15	10	10	15	15	20	20	72	72	72	72	72	72	72	72	72	72	72	72	9	12	13	13	11	8	7	6	9	6	10	10
			2nd week to 3rd week	15	20	20	25	15	10	10	15	15	15	15	20	72	72	72	72	72	72	72	72	72	72	72	72	8	13	13	13	8	6	7	7	7	8	8	11
			3rd week to 4th week	15	20	20	20	15	10	10	15	10	15	15	20	72	72	72	72	72	72	72	72	72	72	72	72	10	12	13	13	8	6	6	7	7	9	8	10
			4th week to 1st week of next month	20	20	20	25	20	10	10	15	15	20	15	20	72	72	72	72	72	72	72	72	72	72	72	72	12	13	12	14	7	6	6	7	7	11	7	11
2	Medium Black T Shirt	Monthly		20	25	25	25	20	15	15	15	15	20	25	30	72	72	72	72	72	72	72	72	72	72	72	72	11	16	16	17	12	9	9	8	9	13	14	16
		Bi Monthly	1st Half to 2nd Half	20	25	25	25	20	15	15	15	20	15	25	30	72	72	72	72	72	72	72	72	72	72	72	72	12	16	16	17	13	9	9	8	10	10	15	17
			2nd Half to the 1st Half on Next Month	20	25	25	30	20	15	15	15	15	25	20	30	72	72	72	72	72	72	72	72	72	72	72	72	11	15	16	17	12	9	8	9	8	15	12	15
		Weekly	1st week to 2nd week	20	25	25	25	25	15	15	15	20	15	30	30	72	72	72	72	72	72	72	72	72	72	72	72	13	16	16	16	14	9	9	8	11	8	18	15
			2nd week to 3rd week	20	25	25	30	20	15	15	15	15	20	20	30	72	72	72	72	72	72	72	72	72	72	72	72	11	16	17	17	12	9	9	9	10	13	13	18
			3rd week to 4th week	15	25	25	25	25	15	15	15	15	20	20	25	72	72	72	72	72	72	72	72	72	72	72	72	11	15	16	17	12	9	8	9	8	15	12	15
			4th week to 1st week of next month	25	25	25	30	15	15	15	15	15	30	30	30	72	72	72	72	72	72	72	72	72	72	72	72	13	16	16	17	9	9	8	9	9	18	12	17
3	Large Black T Shirt	Monthly		25	35	35	40	30	20	20	20	25	30	25	30	72	72	72	72	72	72	72	72	72	72	72	72	15	23	23	25	17	12	12	11	13	15	15	17
		Bi Monthly	1st Half to 2nd Half	25	35	35	40	35	20	20	20	25	25	30	35	72	72	72	72	72	72	72	72	72	72	72	72	15	23	23	25	19	13	12	11	15	12	17	17
			2nd Half to the 1st Half on Next Month	25	35	35	40	25	20	20	20	20	30	25	30	72	72	72	72	72	72	72	72	72	72	72	72	15	23	23	25	15	12	11	11	12	18	12	17
		Weekly	1st week to 2nd week	25	35	40	35	35	20	20	20	25	20	30	30	72	72	72	72	72	72	72	72	72	72	72	72	17	23	24	24	22	14	12	11	15	10	19	15
			2nd week to 3rd week	25	35	35	40	25	20	20	20	25	30	25	35	72	72	72	72	72	72	72	72	72	72	72	72	14	23	23	25	16	13	12	11	14	15	13	20
			3rd week to 4th week	20	35	40	40	30	20	20	20	20	25	25	30	72	72	72	72	72	72	72	72	72	72	72	72	15	23	23	25	15	12	11	11	12	18	12	17
			4th week to 1st week of next month	30	35	35	35	20	25	20	20	20	35	25	30	72	72	72	72	72	72	72	72	72	72	72	72	19	23	22	25	12	13	11	12	12	20	12	18
4	XL Black T Shirt	Monthly		30	40	30	40	30	20	20	20	20	30	30	40	72	72	72	72	72	72	72	72	72	72	72	72	14	20	20	21	15	11	11	10	11	17	16	19
		Bi Monthly	1st Half to 2nd Half	30	40	30	40	30	20	20	20	20	30	40	40	72	72	72	72	72	72	72	72	72	72	72	72	13	20	20	21	16	12	12	10	13	14	18	18
			2nd Half to the 1st Half on Next Month	30	40	30	30	30	20	20	20	20	40	30	40	72	72	72	72	72	72	72	72	72	72	72	72	14	21	20	21	14	11	11	11	10	19	15	19
		Weekly	1st week to 2nd week	30	30	40	30	30	20	20	20	20	20	40	30	72	72	72	72	72	72	72	72	72	72	72	72	14	19	21	21	18	13	11	10	13	11	19	16
			2nd week to 3rd week	30	40	30	40	30	20	20	20	20	40	30	40	72	72	72	72	72	72	72	72	72	72	72	72	13	21	20	21	15	11	12	10	12	17	16	20
			3rd week to 4th week	20	40	30	40	30	20	20	20	20	30	30	40	72	72	72	72	72	72	72	72	72	72	72	72	14	21	20	21	14	11	10	11	10	19	15	19
			4th week to 1st week of next month	30	30	30	30	20	20	20	20	20	40	30	40	72	72	72	72	72	72	72	72	72	72	72	72	16	21	21	21	11	11	10	11	11	22	14	19

5	XXL Black T Shirt	Monthly		20	25	25	25	20	15	15	15	15	20	20	25	72	72	72	72	72	72	72	72	72	72	72	72	10	14	14	15	11	9	8	8	8	11	11	13
		Bi Monthly	1st Half to 2nd Half	20	20	25	25	20	15	15	15	15	15	20	25	72	72	72	72	72	72	72	72	72	72	72	72	10	14	14	14	12	9	9	8	9	10	11	12
			2nd Half to the 1st Half on Next Month	20	25	25	25	15	15	15	15	15	20	15	20	72	72	72	72	72	72	72	72	72	72	72	72	10	14	15	16	10	8	8	7	8	12	10	13
		Weekly	1st week to 2nd week	20	25	25	20	25	15	15	15	15	15	25	20	72	72	72	72	72	72	72	72	72	72	72	72	11	13	14	14	13	9	9	9	9	8	12	11
			2nd week to 3rd week	20	25	25	25	20	15	15	15	15	15	15	25	72	72	72	72	72	72	72	72	72	72	72	72	9	15	14	15	11	8	10	8	9	11	10	14
			3rd week to 4th week	20	25	25	25	20	15	15	15	15	20	20	20	72	72	72	72	72	72	72	72	72	72	72	72	10	14	15	16	10	8	8	7	8	12	10	13
			4th week to 1st week of next month	20	25	25	25	15	15	15	10	15	20	15	25	72	72	72	72	72	72	72	72	72	72	72	72	12	15	15	15	8	8	8	7	8	13	9	14
6	Small Black Long Sleeve T Shirt	Monthly		10	10	10	5	5	5	5	5	10	10	10	5	72	72	72	72	72	72	72	72	72	72	72	72	4	5	4	3	2	2	2	3	4	4	4	3
		Bi Monthly	1st Half to 2nd Half	10	10	10	5	5	5	5	5	10	10	10	5	72	72	72	72	72	72	72	72	72	72	72	72	4	5	4	3	2	2	2	3	4	3	4	3
			2nd Half to the 1st Half on Next Month	10	10	10	5	5	5	5	5	5	10	5	5	72	72	72	72	72	72	72	72	72	72	72	72	4	5	3	2	3	2	2	3	3	4	3	3
		Weekly	1st week to 2nd week	10	10	15	5	5	5	5	5	10	5	10	5	72	72	72	72	72	72	72	72	72	72	72	72	5	5	5	3	2	2	2	2	4	3	5	3
			2nd week to 3rd week	10	15	10	5	5	5	5	5	5	10	10	10	72	72	72	72	72	72	72	72	72	72	72	72	4	5	4	3	3	2	2	3	5	3	4	3
			3rd week to 4th week	5	10	10	5	5	5	5	5	5	10	10	5	72	72	72	72	72	72	72	72	72	72	72	72	4	5	3	2	3	2	2	3	3	4	3	3
			4th week to 1st week of next month	10	10	5	5	5	5	5	5	10	10	5	10	72	72	72	72	72	72	72	72	72	72	72	72	4	4	3	2	3	2	3	4	3	5	3	4
7	Medium Black Long Sleeve T Shirt	Monthly		15	15	10	10	5	5	5	10	10	15	15	15	72	72	72	72	72	72	72	72	72	72	72	72	6	7	6	5	3	3	3	5	5	7	7	6
		Bi Monthly	1st Half to 2nd Half	10	15	10	10	5	5	5	10	10	10	15	15	72	72	72	72	72	72	72	72	72	72	72	72	6	7	6	5	3	3	3	4	6	6	9	7
			2nd Half to the 1st Half on Next Month	15	15	10	10	10	10	5	10	10	15	10	15	72	72	72	72	72	72	72	72	72	72	72	72	7	8	5	4	4	3	3	4	5	8	5	6
		Weekly	1st week to 2nd week	15	15	10	10	5	5	5	10	10	10	20	10	72	72	72	72	72	72	72	72	72	72	72	72	7	7	6	6	3	3	2	3	6	6	12	4
			2nd week to 3rd week	10	15	10	10	5	5	10	10	10	10	15	15	72	72	72	72	72	72	72	72	72	72	72	72	5	6	6	5	3	4	3	5	6	6	7	9
			3rd week to 4th week	10	15	10	10	5	5	5	10	10	15	15	15	72	72	72	72	72	72	72	72	72	72	72	72	7	8	5	4	4	3	3	5	5	8	5	6
			4th week to 1st week of next month	15	15	10	5	10	10	5	10	10	15	10	10	72	72	72	72	72	72	72	72	72	72	72	72	7	8	5	4	4	4	3	4	5	9	4	6
8	Large Black Long Sleeve T Shirt	Monthly		15	15	15	15	10	10	10	10	10	20	15	15	72	72	72	72	72	72	72	72	72	72	72	72	7	9	8	7	4	4	4	6	7	9	8	8
		Bi Monthly	1st Half to 2nd Half	15	15	15	15	10	5	10	10	15	15	20	15	72	72	72	72	72	72	72	72	72	72	72	72	8	10	7	7	4	4	4	5	7	8	10	9
			2nd Half to the 1st Half on Next Month	15	15	15	15	10	10	10	10	10	20	15	15	72	72	72	72	72	72	72	72	72	72	72	72	7	8	8	7	4	5	4	6	6	10	7	7
		Weekly	1st week to 2nd week	15	15	15	15	10	5	5	10	10	15	20	15	72	72	72	72	72	72	72	72	72	72	72	72	8	10	8	6	4	4	3	4	6	7	11	8
			2nd week to 3rd week	15	15	15	15	10	5	10	15	15	20	20	20	72	72	72	72	72	72	72	72	72	72	72	72	7	10	7	7	4	3	4	6	8	9	8	9
			3rd week to 4th week	15	15	15	15	10	5	5	10	15	15	15	15	72	72	72	72	72	72	72	72	72	72	72	72	7	8	8	7	4	5	4	6	6	10	6	7
			4th week to 1st week of next month	15	15	15	10	10	10	10	15	10	20	10	15	72	72	72	72	72	72	72	72	72	72	72	72	9	8	8	6	4	6	4	6	6	11	5	6

9	XL Black Long Sleeve T Shirt	Monthly		15	15	15	10	10	5	10	10	10	15	15	15	72	72	72	72	72	72	72	72	72	72	72	72	6	8	7	5	3	3	4	5	6	9	9	7
		Bi Monthly	1st Half to 2nd Half	15	15	10	10	10	5	10	10	15	15	20	15	72	72	72	72	72	72	72	72	72	72	72	72	6	9	6	6	4	3	4	5	7	7	10	8
			2nd Half to the 1st Half on Next Month	15	15	15	10	10	10	10	10	10	20	15	15	72	72	72	72	72	72	72	72	72	72	72	72	6	7	6	4	4	3	4	5	6	10	7	7
		Weekly	1st week to 2nd week	15	15	15	10	10	5	5	10	15	15	20	10	72	72	72	72	72	72	72	72	72	72	72	72	6	8	7	6	4	2	3	5	6	6	10	6
			2nd week to 3rd week	20	15	10	10	10	5	10	10	15	20	15	15	72	72	72	72	72	72	72	72	72	72	72	72	7	9	6	6	3	3	4	5	7	9	9	19
			3rd week to 4th week	10	10	15	10	10	5	10	10	10	15	15	15	72	72	72	72	72	72	72	72	72	72	72	72	6	7	6	4	4	3	4	5	6	10	7	7
			4th week to 1st week of next month	15	15	15	10	5	10	10	10	10	20	10	10	72	72	72	72	72	72	72	72	72	72	72	72	7	8	6	5	3	4	4	5	6	12	5	6
10	XXL Black Long Sleeve T Shirt	Monthly		10	10	10	10	5	5	5	10	10	15	10	10	72	72	72	72	72	72	72	72	72	72	72	72	5	6	5	4	2	2	2	4	5	7	5	5
		Bi Monthly	1st Half to 2nd Half	10	15	10	10	5	5	5	10	10	10	15	15	72	72	72	72	72	72	72	72	72	72	72	72	4	7	5	4	2	3	2	4	5	6	6	6
			2nd Half to the 1st Half on Next Month	10	10	10	5	5	5	5	10	10	15	5	10	72	72	72	72	72	72	72	72	72	72	72	72	6	5	5	4	3	2	3	4	5	8	4	5
		Weekly	1st week to 2nd week	10	15	10	10	5	5	5	55	55	10	15	10	72	72	72	72	72	72	72	72	72	72	72	72	4	7	5	5	3	2	2	3	4	5	7	6
			2nd week to 3rd week	10	15	10	5	5	5	5	10	10	10	10	15	72	72	72	72	72	72	72	72	72	72	72	72	5	7	5	3	2	3	2	5	5	6	5	7
			3rd week to 4th week	10	10	10	10	5	5	5	10	10	15	10	10	72	72	72	72	72	72	72	72	72	72	72	72	6	5	5	4	3	2	3	4	4	8	4	5
			4th week to 1st week of next month	10	10	10	5	5	5	5	5	10	15	5	10	72	72	72	72	72	72	72	72	72	72	72	72	7	5	5	3	2	2	3	3	4	9	3	5
11	Small White T Shirt	Monthly		45	75	75	90	75	90	75	75	60	45	45	45	72	144	144	144	144	144	144	144	72	72	72	72	27	41	43	46	41	44	38	37	34	25	23	24
		Bi Monthly	1st Half to 2nd Half	45	75	75	75	75	90	90	75	75	45	45	60	72	144	144	144	144	144	144	144	144	72	72	72	27	40	44	46	42	46	44	41	39	26	25	28
			2nd Half to the 1st Half on Next Month	45	75	75	90	75	90	60	60	60	45	45	45	72	144	144	144	144	144	72	72	72	72	72	72	27	40	42	46	41	43	33	33	29	25	22	22
		Weekly	1st week to 2nd week	60	75	75	75	75	75	90	75	75	60	60	45	72	144	144	144	144	144	144	144	144	72	72	72	28	37	43	43	45	42	47	42	38	24	28	25
			2nd week to 3rd week	45	75	75	75	60	90	75	75	75	45	45	60	72	144	144	144	72	72	144	144	144	72	72	72	25	44	45	48	38	49	41	40	39	28	21	30
			3rd week to 4th week	60	75	75	90	75	75	60	60	60	60	45	45	72	144	144	144	144	144	72	72	72	72	72	72	27	42	42	46	41	43	33	33	29	25	22	22
			4th week to 1st week of next month	45	60	75	90	75	90	60	60	60	45	45	45	72	72	144	144	144	144	72	72	72	72	72	72	28	41	40	46	39	49	30	32	27	26	20	25
12	Medium White T shirt	Monthly		75	100	100	125	100	100	100	100	75	75	75	75	144	144	144	144	100	144	144	144	144	144	144	144	35	55	58	66	61	62	57	52	46	40	37	37
		Bi Monthly	1st Half to 2nd Half	75	100	100	125	100	100	125	100	##	75	75	75	144	144	144	144	100	144	144	144	144	144	144	144	36	54	58	64	61	61	63	55	52	41	43	36
			2nd Half to the 1st Half on Next Month	75	100	100	125	100	100	100	100	75	75	75	75	144	144	144	144	100	144	144	144	144	144	144	144	33	55	58	68	61	62	52	48	41	40	31	38
		Weekly	1st week to 2nd week	75	100	100	100	100	100	125	100	##	75	75	75	144	144	144	144	100	144	144	144	144	144	144	144	36	51	61	55	60	57	66	54	58	40	45	33
			2nd week to 3rd week	75	100	100	125	125	125	125	100	##	75	75	75	144	144	144	144	125	144	144	144	144	144	144	144	36	58	56	74	63	65	59	56	47	41	42	39
			3rd week to 4th week	75	100	100	125	100	100	100	100	75	75	75	75	144	144	144	144	100	144	144	144	144	144	144	144	33	55	58	68	61	62	52	48	41	40	31	38
			4th week to 1st week of next month	75	100	100	125	100	125	100	75	75	75	75	75	144	144	144	144	100	144	144	144	144	144	144	144	35	53	53	69	61	69	49	44	42	48	28	42

Output Comparison:

Key:

Small Black T Shirt

Histograms:
X Axis: Demand Quantity
Y Axis: Deamnd Frequency

Deamnd Vs Inventory Chart
X Axis : Hours
Y Axis: Demand

Min Qty
News Vendor based Q*
Simple Moving Avg.

Jan to Feb

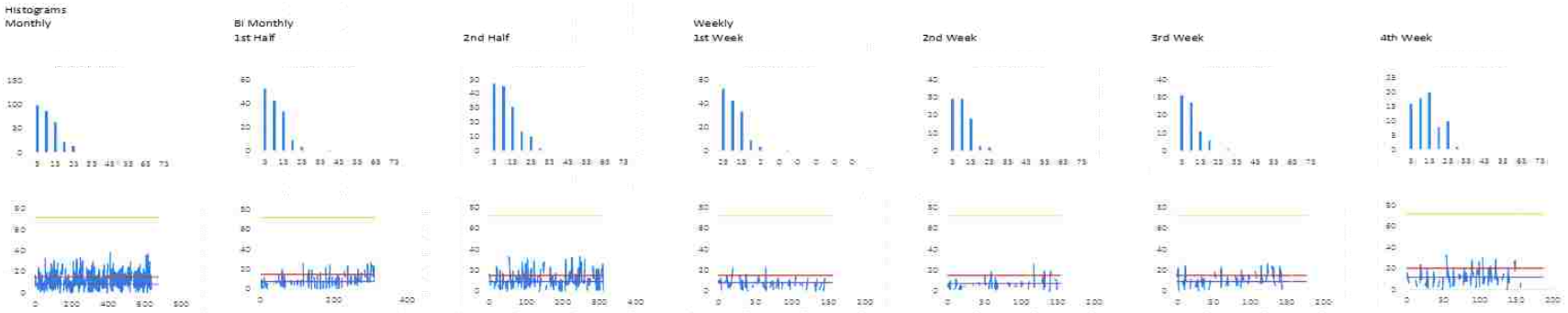


Figure Set 13 : Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Figure Set 13 shows the comparison charts between Demand vs Set Inventory levels along with histograms of the demand distribution (see Appendix B).

The comparison charts (Fig set 13, see Appendix B) show clearly the competence of the selected model to be used to set on floor inventory levels. As expected the sensitivity of the model increases as we move from month to month to bi-monthly to week to week i.e., the adaptiveness of the inventory control model's output to the demand increases as the period of review decreases. Weekly Demand analysis for setting inventory helps in tracking shifts in demand more accurately and spikes in demand in immediate time periods can be included in the analysis thereby making the inventory calculation more satisfying than month to month and bi monthly demand analysis based inventory setting. Because of the rapidly changing demand in MC W2P companies, the periodic review system with weekly review period would be an ideal solution.

As expected when raw materials are considered in loose quantities there are outliers i.e., demand does lie outside the set levels of inventory. This is however impossible to avoid as demand uncertainty is the major cause of the inventory problem in the first place. However, an upwards of 80% of the demand is satisfied in most cases. On the other hand, MC W2P companies prefer moving inventory in boxes (1 box = 72 units), from the warehouse to on – floor, as it is easier to track and more economical to do so. When, inventory is considered in boxes, the inventory quantities go in multiples of single box quantities, i.e., 72, 144, 216 etc. Unlike the automotive sector, individual item's volume is small and the overall tracking and transport of loose items are hard. Hence, MC W2P companies prefer moving inventory in boxes rather than individual units. If inventory bin size is considered in terms of boxes, there will be no necessity for maintaining safety inventory.

For the 2nd part of the data analysis, a more recent demand data set is considered to set the inventory levels for Vistaprint and compare it with the period the inventory has been set for. As already proven, because of the effectiveness of week to week inventory level setting, weekly inventory calculation is experimented on the December demand. We consider and analyze the demand for the month of December for all T Shirt Types and the results are tabulated as follows:

Table 8: December – Weekly Textile Inventory Level Setting – News Vendor

S. No.	T-Shirt Type	Time Period		Q*	Min. Qty.
				D	D
1	Small Black T Shirt	Weekly	1st week to 2nd week	20	72
			2nd week to 3rd week	20	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	20	72
2	Medium Black T Shirt	Weekly	1st week to 2nd week	30	72
			2nd week to 3rd week	30	72
			3rd week to 4th week	25	72
			4th week to 1st week of next month	30	72
3	Large Black T Shirt	Weekly	1st week to 2nd week	30	72
			2nd week to 3rd week	35	72
			3rd week to 4th week	30	72
			4th week to 1st week of next month	30	72
4	XL Black T Shirt	Weekly	1st week to 2nd week	30	72
			2nd week to 3rd week	40	72
			3rd week to 4th week	40	72
			4th week to 1st week of next month	40	72
5	XXL Black T Shirt	Weekly	1st week to 2nd week	20	72
			2nd week to 3rd week	25	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	25	72
6	Small Black Long Sleeve T Shirt	Weekly	1st week to 2nd week	5	72
			2nd week to 3rd week	10	72
			3rd week to 4th week	5	72
			4th week to 1st week of next month	10	72
7	Medium Black Long Sleeve T Shirt	Weekly	1st week to 2nd week	10	72
			2nd week to 3rd week	15	72
			3rd week to 4th week	15	72
			4th week to 1st week of next month	10	72
8	Large Black Long Sleeve T Shirt	Weekly	1st week to 2nd week	15	72
			2nd week to 3rd week	20	72
			3rd week to 4th week	15	72
			4th week to 1st week of next month	15	72
9	XL Black Long Sleeve T Shirt	Weekly	1st week to 2nd week	10	72
			2nd week to 3rd week	15	72
			3rd week to 4th week	15	72
			4th week to 1st week of next month	10	72
10	XXL Black Long Sleeve T Shirt	Weekly	1st week to 2nd week	10	72
			2nd week to 3rd week	15	72
			3rd week to 4th week	10	72
			4th week to 1st week of next month	10	72

Table 8: Continued

11	Small White T Shirt	Weekly	1st week to 2nd week	45	72
			2nd week to 3rd week	60	72
			3rd week to 4th week	45	72
			4th week to 1st week of next month	45	72
12	Medium White T shirt	Weekly	1st week to 2nd week	75	144
			2nd week to 3rd week	75	144
			3rd week to 4th week	75	144
			4th week to 1st week of next month	75	144
13	Large White T Shirt	Weekly	1st week to 2nd week	55	72
			2nd week to 3rd week	55	72
			3rd week to 4th week	50	72
			4th week to 1st week of next month	50	72
14	XL White T Shirt	Weekly	1st week to 2nd week	50	72
			2nd week to 3rd week	50	72
			3rd week to 4th week	55	72
			4th week to 1st week of next month	55	72
15	XXL White T Shirt	Weekly	1st week to 2nd week	40	72
			2nd week to 3rd week	35	72
			3rd week to 4th week	35	72
			4th week to 1st week of next month	45	72
16	Small Ash T Shirt	Weekly	1st week to 2nd week	10	72
			2nd week to 3rd week	15	72
			3rd week to 4th week	10	72
			4th week to 1st week of next month	15	72
17	Medium Ash T Shirt	Weekly	1st week to 2nd week	20	72
			2nd week to 3rd week	30	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	25	72
18	Large Ash T Shirt	Weekly	1st week to 2nd week	35	72
			2nd week to 3rd week	40	72
			3rd week to 4th week	35	72
			4th week to 1st week of next month	45	72
19	XL Ash T Shirt	Weekly	1st week to 2nd week	30	72
			2nd week to 3rd week	35	72
			3rd week to 4th week	30	72
			4th week to 1st week of next month	40	72
20	XXL Ash T Shirt	Weekly	1st week to 2nd week	20	72
			2nd week to 3rd week	20	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	25	72

Table 8: Continued

21	Small White Long Sleeve T Shirt	Weekly	1st week to 2nd week	10	72
			2nd week to 3rd week	15	72
			3rd week to 4th week	10	72
			4th week to 1st week of next month	15	72
22	Medium White Long Sleeve T Shirt	Weekly	1st week to 2nd week	20	72
			2nd week to 3rd week	30	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	20	72
23	Large White Long Sleeve T Shirt	Weekly	1st week to 2nd week	30	72
			2nd week to 3rd week	30	72
			3rd week to 4th week	30	72
			4th week to 1st week of next month	35	72
24	XL White Long Sleeve T Shirt	Weekly	1st week to 2nd week	25	72
			2nd week to 3rd week	30	72
			3rd week to 4th week	25	72
			4th week to 1st week of next month	25	72
25	XXL White Long Sleeve T Shirt	Weekly	1st week to 2nd week	15	72
			2nd week to 3rd week	20	72
			3rd week to 4th week	10	72
			4th week to 1st week of next month	15	72
26	Small White Womens T Shirt	Weekly	1st week to 2nd week	30	72
			2nd week to 3rd week	45	72
			3rd week to 4th week	25	72
			4th week to 1st week of next month	35	72
27	Medium White Womens T Shirt	Weekly	1st week to 2nd week	35	72
			2nd week to 3rd week	45	72
			3rd week to 4th week	30	72
			4th week to 1st week of next month	40	72
28	Large White Womens T Shirt	Weekly	1st week to 2nd week	35	72
			2nd week to 3rd week	40	72
			3rd week to 4th week	35	72
			4th week to 1st week of next month	40	72
29	XL White Womens T Shirt	Weekly	1st week to 2nd week	25	72
			2nd week to 3rd week	30	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	30	72
30	XXL White Womens T Shirt	Weekly	1st week to 2nd week	15	72
			2nd week to 3rd week	25	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	20	72

Table 8: Continued

31	Small White Premium T Shirt	Weekly	1st week to 2nd week	10	72
			2nd week to 3rd week	15	72
			3rd week to 4th week	10	72
			4th week to 1st week of next month	15	72
32	Medium White Premium T Shirt	Weekly	1st week to 2nd week	25	72
			2nd week to 3rd week	35	72
			3rd week to 4th week	35	72
			4th week to 1st week of next month	30	72
33	Large White Premium T Shirt	Weekly	1st week to 2nd week	35	72
			2nd week to 3rd week	55	72
			3rd week to 4th week	40	72
			4th week to 1st week of next month	40	72
34	XL White Premium T Shirt	Weekly	1st week to 2nd week	35	72
			2nd week to 3rd week	45	72
			3rd week to 4th week	35	72
			4th week to 1st week of next month	40	72
35	XXL White Premium T Shirt	Weekly	1st week to 2nd week	20	72
			2nd week to 3rd week	25	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	25	72
36	Youth XS T Shirt	Weekly	1st week to 2nd week	20	72
			2nd week to 3rd week	25	72
			3rd week to 4th week	20	72
			4th week to 1st week of next month	25	72
37	Youth Small T Shirt	Weekly	1st week to 2nd week	25	72
			2nd week to 3rd week	25	72
			3rd week to 4th week	25	72
			4th week to 1st week of next month	25	72
38	Youth Medium T Shirt	Weekly	1st week to 2nd week	25	72
			2nd week to 3rd week	30	72
			3rd week to 4th week	25	72
			4th week to 1st week of next month	30	72
39	Youth Large T Shirt	Weekly	1st week to 2nd week	25	72
			2nd week to 3rd week	25	72
			3rd week to 4th week	25	72
			4th week to 1st week of next month	25	72
40	Youth XL T Shirt	Weekly	1st week to 2nd week	15	72
			2nd week to 3rd week	20	72
			3rd week to 4th week	15	72
			4th week to 1st week of next month	15	72

Dec to Jan

Small Black T Shirt

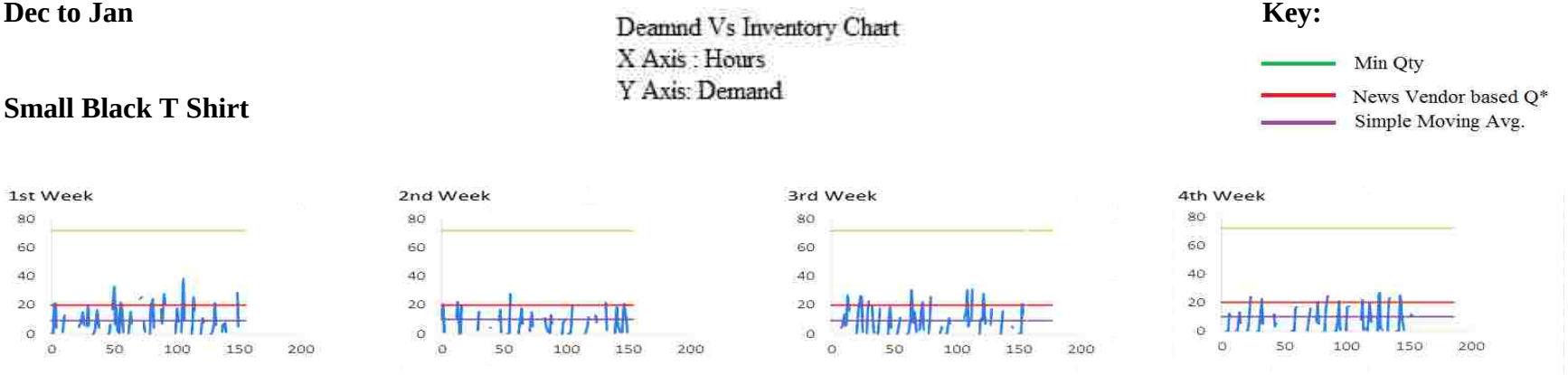


Fig Set 14: Output Comparison - Demand vs Inventory

(Fig Set 14) depicts demand vs inventory (see Appendix C). The charts are conclusive evidence for the potential of the News Vendor model to be used to set inventory levels in MC W2P companies. Periodic (weekly) demand can be analyzed to set the base inventory for the consecutive week. However, the output of News Vendor model cannot be used alone. A combination of News Vendor based inventory level setting and Kanban based JIT is an ideal solution to satisfy demand in highly fluctuating Mass Customizing W2P companies.

As mentioned earlier, MC W2P companies maintain and transfer inventory in boxes and not loose products. As shown in the demand and inventory comparison, when boxes of inventory is used as inventory setting, the demand is completely satisfied. The number of hourly demand not being satisfied is rare and an emergency Kanban system can be put in place to satisfy those outliers as well. To plan for inconsistencies in demand, as is common in MC W2P Company's production settings, a controlled level of safety stock can and should be maintained. This is future work in the field that will not be touched upon in this thesis.

5.4. CONTROL PHASE:

Mass Customizing W2P company's production and inventory setting is more complicated than Mass Production setting mainly because of the erratic demand fluctuations. The typical solution that most settings follow is overstocking for the fear of stopping the line because of running out of inventory stock. Even after implementing the proposed inventory control method, there is a potential for the production setting to fall back to the original practice of overstocking. In order to maintain the calculated levels of inventory and to keep

the production running smoothly, a Kanban based replenishment coupled with emergency JIT system is an ideal solution.

As MC W2P settings are high volume production settings, the replenishment should be smooth and instantaneous. As the warehouse is in house, the replenishment time is relatively low. Considering the current inventory turn of one hour, it is necessary to implement a scanning system that is linked to the central production control software's database. This system is already in place in most MC W2P companies to track shipments after printing. A similar system can be used to scan and update the central database for tracking on floor inventory levels. A separate in house database can be used to link the production floor to the material handling department in the logistics section of the facility. As each box of inventory is opened and each T Shirt is pulled from it to print, the database can be updated by the workers on the floor. Most MC W2P production floors house state of the art machinery with computer based interfaces, thus making the updating part simple. As the box of inventory that is opened on floor is scanned, the material handler at the warehouse can pull the replenishment from the warehouse and stack it on the material handlers transport vehicle. As the materials are pulled on floor, the material handler can do the same at the warehouse. When there is an unexpected spike in demand and a certain type of raw material is running low even before the inventory turn, the material can be replaced with ease as well. At the facility under study, a simple Kanban system is used in the embroidery section of the Textile printing area. The embroidery section is comparatively slowly paced when compared to other printing areas of the Textile Section and thus just traditional card based Kanban system is sufficient. However, as the printing section of the Textile layout is extremely fast paced with cycle times as low as 15 seconds, an electronic

Kanban system would be more ideal. It is important to resist the impulse to overstock when certain inventory calculation does not suffice due to an unexpected surge in demand. When such a situation arises, the inventory calculation can be updated by using a more recent demand data over a small range of time.

Thus, a periodic review of inventory using News Vendor Model has been proved to be an effective solution to calculating inventory levels in fluctuating demand in MC W2P companies.

Before implementing the proposed inventory control based calculation on – floor, there is a necessity to prove its competence to satisfy the proposed hourly inventory turn. Performing experiments on floor is not possible as performing experiments on MC W2P company's production floors are a daunting task and might potentially lead to huge losses because of the short cycle times. Simulation is an effective tool that comes in handy in such situations. To validate the proposed inventory calculation simulation software FlexSim was used. The aim of the simulation's outcome is to prove that the proposed inventory level is enough to satisfy the pre-set inventory turn of 1 hour.

VI. VALIDATION BY SIMULATION:

6.1. BUILDING THE MODEL:

The initial simulation model built was an exact replica of the production floor (fig. 10). This was done using the layout shown in the measure phase. However, as the calculated inventory levels are lower than the present levels of inventory, the number of racks were reduced to hold only the calculated amount of inventory.

Human factors were not considered in this simulation. The whole process is almost completely automated. Workers just pick and place the T Shirt onto the printing machine, remove and place it on the dryer after printing and after the T Shirt's print is dried, pick and place them on the packing machine. Although this adds time to the overall process, the comparative time is negligible and therefore were not considered to keep the simulation model simple. The cycle times considered are mentioned in the measure phase as well. The boxes in the simulation however, represent individual units to reduce the complexity of the simulation model.

Note: The cycle times mentioned include human intervention to a certain degree increasing the reliability of the simulation model.

6.2. ASSUMPTIONS & LIMITATIONS:

- As the purpose of the simulation is to prove that the inventory levels are enough to sustain the proposed inventory turn of 1 hour, the human factors and the transportation times (in layout) were not considered to verify the inventory level's sustainability under optimal efficiency conditions (no human intervention).
- As it has already been proven that the proposed individual inventory levels are enough to satisfy individual demand requirements (Fig set 1 and 2 – Minimum Quantity – Boxes), except for a few hours, the simulation considers inventory in 3 sets – Dark T Shirts, Light T Shirts and Youth T Shirts and not the individual products as such.

- The simulation model cannot be used to study the effect of demand variation on individual products as such, but on T shirt groups as a whole – Light, Dark and Youth T shirts.
- The queues are introduced in between printing and drying machines and in between the drying machine and the packing machine to observe the accumulation (if present) of un-finished raw materials insider the layout due to bottle necks. The Queues are virtual and do not exist on the floor.
- The model can be used in the future to study the potential of minimal inventory and JIT combination after implementation of loose item inventory instead of boxes.
- As a single source is considered, demand fluctuation based responsiveness cannot be studied using the model.

6.3.VALIDATION:

To test the authenticity of the model and to verify it, a basic simulation was run.

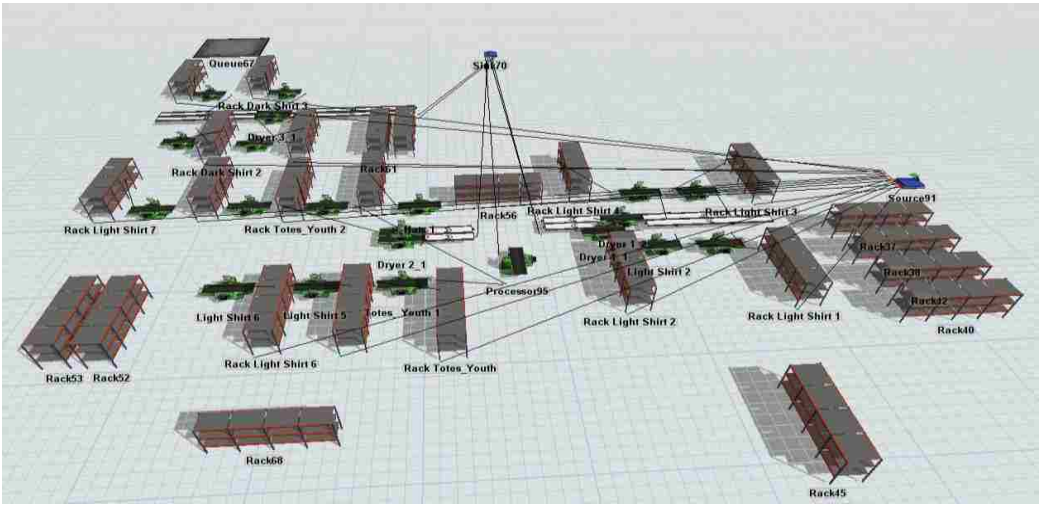


Fig 15: Initial Simulation layout

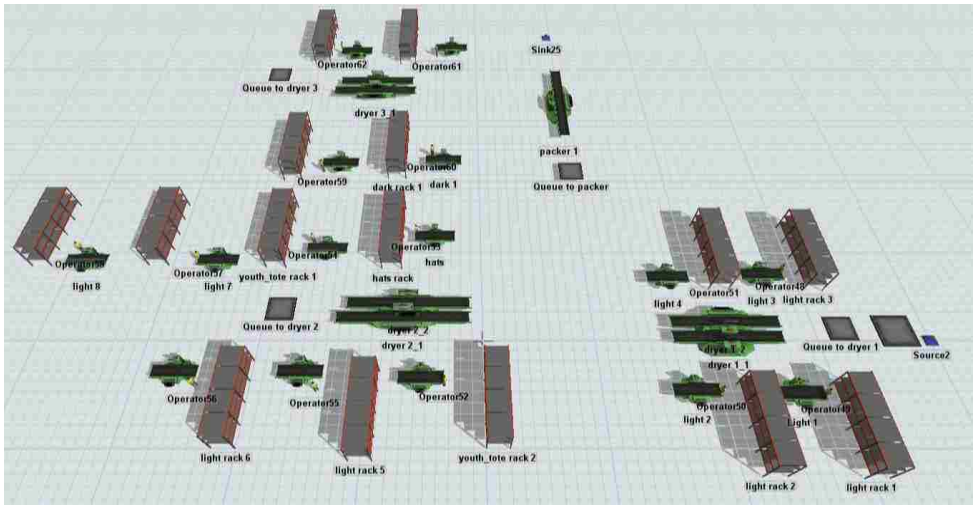


Fig 16: Revised simulation layout

The data for the maximum capacity of the individual printing machines is shown below.

Table 9: Maximum hourly output – Printing Machines

T Shirt Type	Size	Max Output
White Men's T-Shirt	Small	18.42
	Medium	18.42
	Large	18.42
	X-Large	18.42
	2XL	18.42
Black Men's T-Shirt	Small	17.45
	Medium	17.45
	Large	17.45
	X-Large	17.45
	2XL	17.45
Ash Men's-Tshirt	Small	18.42
	Medium	18.42
	Large	18.42
	X-Large	18.42
	2XL	18.42
Premium Men's T-Shirt	Small	18.42
	Medium	18.42
	Large	18.42
	X-Large	18.42
	2XL	18.42
White Long Sleeve T-shirt	Small	18.42
	Medium	18.42
	Large	18.42
	X-Large	18.42
	2XL	18.42
Black Long Sleeve T-Shirts	Small	7.09
	Medium	7.09
	Large	7.09
	X-Large	7.09
	2XL	7.09
Ladies T-shirt	Small	6.96
	Medium	6.96
	Large	6.96
	X-Large	6.96
	2XL	6.96
Youth T-Shirts	Small	3.72
	Medium	3.72
	Large	3.72
	X-Large	3.72
	XS	3.72

Running the simulation model for a periods of 1 hour show the following results with respect to the output of the printing machines.

Table 10(a): Maximum output from running simulation

stats_contentmax	stats_contentavg	stats_input	stats_output	stats_staytimemin	stats_staytimemax	stats_staytimeavg	state_current	state_since
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
1	1	135	134	26.860001	26.860001	26.860001	2	3600.076
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
0	0	0	0	0	0	0	1	3600.076
1	1	135	134	26.860001	26.860001	26.860001	2	3600.076
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
1	1	166	165	21.719999	21.719999	21.719999	2	3600.076
1	1	128	127	28.200001	28.200001	28.200001	2	3600.076
1	1	128	127	28.200001	28.200001	28.200001	2	3600.076
1	1	128	127	28.200001	28.200001	28.200001	2	3600.076
1	1	128	127	28.200001	28.200001	28.200001	2	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	6	3600.076
0	0	0	0	0	0	0	6	3600.076
0	0	0	0	0	0	0	6	3600.076
0	0	0	0	0	0	0	6	3600.076
0	0	0	0	0	0	0	6	3600.076
0	0	0	0	0	0	0	6	3600.076
0	0	0	0	0	0	0	1	3600.076
1	1	0	2110	0	21.719999	1.705801	4	3600.076
1	0	2096	0	0	0	0	7	3600.076
0	0	0	0	0	0	0	1	3600.076
0	0	0	0	0	0	0	1	3600.076

Table 10(b): Condensed Output

T Shirt Types	Units	In Number of Boxes
Light Shirt	1328	18.44
Dark Shirt	512	7.11
Hats/Totes/ Youth	270	3.75

The output of the simulation is comparable to the calculated maximum output, thereby validating the comparability of the model to the production setting.

Next the maximum demand for Light T Shirts, Dark T Shirts and Youth T Shirts was extracted from the available data.

Table 11: Maximum Hourly Output – Jan 2014 to Jan 2015

Max Outputs	Dark T Shirt	Light T Shirt	Youth T Shirt
Units	276	933	141
In Boxes	3.83	12.96	1.96
Output - Hourly	Dark T Shirt	Light T Shirt	Youth T Shirt

Here, the maximum demand is the end result of Printing and Drying. From the cycle time data (Table 6), it is clear that the dryers are potential bottlenecks in the process. Therefore, the maximum output from the line is expected to be lower than the maximum potential output from the printing machine and the data reflects that assumption.

Next, the simulation model was run for an hour and the following data was collected as the output from the dryers in the Textile Layout

Table 12(a): Hourly Output from Dryers

Object	Class	stats_ content	stats_ contentmin	stats_ contentmax	stats_ contentavg	stats_ input	stats_ output	stats_ staytimemin	stats_ staytimemax	stats_ staytimeavg	state_ current	state_ since
dryer 1_1	Processor	1	0	1	0.992304	150	149	23.690001	23.690001	23.690001	2	3557
dryer 1_2	Processor	1	0	1	0.992176	150	149	23.690001	23.690001	23.690001	2	3558
dryer 2_2	Processor	1	0	1	0.9109	649	648	5	5	5	2	3557
dryer 2_1	Processor	0	0	1	0.95651	153	153	22.24	22.24	22.24	1	3557
dryer 3_2	Processor	1	0	1	0.990925	142	141	25	25	25	2	3557
dryer 3_1	Processor	1	0	1	0.990602	142	141	25	25	25	2	3558

Table 12(b): Condensed Output

Units	284	949	130
In Boxes	3.94	13.18	1.81
Percentage Difference	2.90	1.71	-7.80

The percentage difference of the actual maximum output and the simulation output is 2.8%, 1.7% and 7.8% for Dark, Light and Youth T Shirts respectively. The higher difference between the actual and simulation value of the Youth T Shirt is because of the fact that at the layout, the youth T Shirt is run on both Dark and Light T Shirt dryers (based on availability). However, in the simulation the Youth T Shirt is run on the Dark T Shirt dryer. The dark T Shirt dryer's cycle time is lower than that of the Light T Shirt dryer. Thus, the simulated model produces lesser output of Youth T Shirts when compared to the actual system, owing to the negative difference.

The average difference of 2% is owed to the in layout transportation time.

Thus, the simulation model has been validated.

6.4. SIMULATION – HOURLY MAXIMUM CAPACITY BASED OUTPUT

Now, the validated simulation model is run to check if the proposed level of inventory is capable of satisfying the proposed inventory turn of 1 hour.

The inventory levels for the dark, light and youth T Shirt are set (rack capacity) and the input from the source (drop off at the beginning of each inventory turn) is set and the simulation is run.

We obtain the following results of hourly output.

Table 13: Hourly Simulation Output

Object	Class	stats_ content	stats_ content min	stats_ content max	stats_ content avg	stats_ input	stats_ output	stats_ staytime min	stats_ staytime max	stats_ staytime avg	state_ current	state_ since
Source2	Source	0	0	0	0	0	1	0	0	0	5	0
Light 1	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
light 2	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
light 3	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
light 4	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
dryer 1_1	Processor	1	0	1	0.994	152	151	23.69	23.69	23.69	2	3599
dryer 1_2	Processor	1	0	1	0.994	152	151	23.69	23.69	23.69	2	3599
youth_tote 2	Processor	1	0	1	1	134	133	26.86	26.86	26.86	2	3572
light 5	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
light 6	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
hats	Processor	1	0	1	1	129	128	28.05	28.05	28.05	2	3590
youth_tote 1	Processor	1	0	1	1	134	133	26.86	26.86	26.86	2	3572
light 7	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
light 8	Processor	1	0	1	1	166	165	21.72	21.72	21.72	2	3584
dryer 2_2	Processor	1	0	1	0.994	716	715	5	5	5	2	3597
dryer 2_1	Processor	1	0	1	0.9939	161	160	22.24	22.24	22.24	2	3580
dark 1	Processor	1	0	1	1	128	127	28.2	28.2	28.2	2	3581
dark 2	Processor	1	0	1	1	128	127	28.2	28.2	28.2	2	3581
dark 3	Processor	1	0	1	1	128	127	28.2	28.2	28.2	2	3581
dark 4	Processor	1	0	1	1	128	127	28.2	28.2	28.2	2	3581
dryer 3_2	Processor	1	0	1	0.9921	26	25	141.68	141.68	141.68	2	3570
dryer 3_1	Processor	1	0	1	0.9921	26	25	141.68	141.68	141.68	2	3570
Sink25	Sink	1	1	1	0	357	0	0	0	0	7	0
light rack 1	Rack	69	1	234	152	235	166	0	3583.8	1791.9	1	3584
light rack 3	Rack	69	1	234	152	235	166	0	3583.8	1791.9	1	3584
light rack 2	Rack	69	1	234	152	235	166	0	3583.8	1791.9	1	3584
light rack 4	Rack	69	1	234	152	235	166	0	3583.8	1791.9	1	3584
dark rack 4	Rack	53	1	180	117	181	128	0	3581.4	1790.7	1	3581
dark rack 3	Rack	53	1	180	117	181	128	0	3581.4	1790.7	1	3581
dark rack 1	Rack	53	1	180	117	181	128	0	3581.4	1790.7	1	3581
dark rack 2	Rack	53	1	180	117	181	128	0	3581.4	1790.7	1	3581
hats rack	Rack	16	1	144	80.5	145	129	0	3590.4	1795.2	1	3590
youth_tote rack 1	Rack	47	1	180	114	181	134	0	3572.38	1786.19	1	3572
light rack 7	Rack	69	1	234	152	235	166	0	3583.8	1791.9	1	3584
light rack 8	Rack	69	1	234	152	235	166	0	3583.8	1791.9	1	3584
light rack 6	Rack	55	1	220	138	221	166	0	3583.8	1791.9	1	3584
light rack 5	Rack	69	1	234	152	235	166	0	3583.8	1791.9	1	3584
youth_tote rack 2	Rack	47	1	180	114	181	134	0	3572.38	1786.19	1	3572
Queue_ Distribution	Queue	0	0	2347	0	3097	3097	0	0	0	6	0
Queue to packer	Queue	869	0	869	429.84	1227	358	0	2529.72	1259.99	8	3599
packer 1	Processor	1	0	1	0.9926	358	357	10	10	10	2	3597
Queue to dryer 2	Queue	177	0	179	89.489	1054	877	0	610.26	305.679	8	3590
Queue to dryer 3	Queue	456	0	456	226.12	508	52	0	3203.6	1601.8	8	3581
Queue to dryer 1	Queue	356	0	358	178.31	660	304	0	1948.19	974.095	8	3584

In the table above, the racks house a considerable amount of inventory at the end of the hourly inventory turn, thereby proving the effectiveness of the set inventory levels. Furthermore, it is observed that the bottle necks downstream lead to the accumulation of inventory in the layout, which have to be worked on next to make the entire process streamlined, as half-finished raw material or WIP have storage costs as well.

6.5. LIMITATIONS

- The simulation model does not take into account the in-layout transport time and human factors (time).
- The simulation considers uniform distribution of demand with mean as the individual cycle times and no standard deviation.
- The simulation is to validate the potential of the calculated inventory levels to satisfy a hour's demand and nothing else.

VII. CONCLUSIONS:

Thus, an approach to solving the on floor inventory control problem in Mass Customized W2P company was developed and a case study was conducted in a local MC W2P company to prove the ability of the proposed approach to satisfy the demand variations in their production facility.

In the process, the following improvements were achieved in the local MC W2P company's textile production floor:

- When loose items are considered, the potential improvement is 87.77% reduction in inventory.

- When minimum box quantities are considered, the potential improvement is 82.65% reduction in inventory.

These improvements lead to an overall improvement in the control of the production setting.

The set inventory level's potential to satisfy the proposed inventory turn of 1 hour was validated using the simulation model.

VIII. FUTURE WORK:

The proposed use of the News Vendor Model to set On Floor Inventory Levels in MC W2P companies is solely based on the demand data acquired from Vistaprint. The proposed Inventory control method may or may not satisfy the demand fluctuations in another MC W2P company. This work can be used to test the proposed approach's potential to form a global On Floor Inventory setting standard for MC W2P companies.

As an immediate extension of this work, and as individual units based inventory settings require a combination of JIT, a potential approach to calculating safety stock for such varying demand scenarios can be developed and tested on the available data and as an extension of the inventory level output from the proposed model.

The main reason for the inventory control problem is the demand fluctuation and in MC W2P companies, demand fluctuation is extremely erratic. Strategic approaches can be developed to keep the demand fluctuation under check and study the proposed model's compatibility to the revised demand settings.

MC W2P companies inventory problem (both On floor and Warehouse) is a problem that is relatively new and not much research work has been done in the field. This thesis is a small step in this area and has the potential to form the base to further research into the field.

APPENDIX A

History of Printing

Introduction to printing	The history of printing goes back to the duplication of images by means of stamps in very early times. The use of round seals for rolling an impression into clay tablets goes back to early Mesopotamian civilization before 3000 BCE, where they are the most common works of art to survive, and feature complex and beautiful images. In both China and Egypt, the use of small stamps for seals preceded the use of larger blocks. In China, India and Europe, the printing of cloth certainly preceded the printing of paper or papyrus. The process is essentially the same - in Europe special presentation impressions of prints were often printed on silk until the seventeenth century. The development of printing has made it possible for books, newspapers, magazines, and other reading materials to be produced in great numbers, and it plays an important role in promoting literacy among the masses.
Geography based history	**Woodblock Printing** Block printing is a technique for printing text, images or patterns used widely throughout East Asia both as a method of printing on textiles and later, under the influence of Buddhism, on paper. As a method of printing on cloth, the earliest surviving examples fromChina date to about 220.Ukiyo-e is the best known type of Japanese woodblock art print. Most European uses of the technique on paper are covered by the art term woodcut, except for theblock-books produced mainly in the fifteenth century. **In China** The world's earliest printer printed fragments to survive are from China and are of silk printed with flowers in three colours from the Han Dynasty (before AD 220). The technology of printing on cloth in China was adapted to paper under the influence of Buddhism which mandated the circulation of standard translations over a wide area, as well as the production of multiple copies of key texts for religious reasons. It reached Europe, via the Islamic world, and by around 1400 was being used on paper for old master prints and playing cards. The oldest wood-block printed book is the Diamond Sutra. It carries a date on 'the 13th day of the fourth moon of the ninth year of the Xiantong era' (i.e. 11 May 868). A number printed dhāraṇī-s, however, predate the Diamond Sūtra by about two hundred years **In India** In Buddhism, great merit is thought to accrue from copying and preserving texts. The fourth-century master listed the copying of scripture as the first of ten essential religious practices. The importance of perpetuating texts is set out with special force in the longer Sukhāvatīvyūha Sūtra which not only urges the devout to hear, learn, remember and study the text but to obtain a good copy and to preserve it. This ‘cult of the book’ led to techniques for reproducing texts in great numbers, especially the short prayers or charms known as dhāraṇī-s. Stamps were carved for printing these prayers on clay tablets from at least the seventh century, the date of the oldest surviving examples. Especially popular was the Pratītyasamutpāda Gāthā, a short verse text summing up Nāgārjuna's philosophy of causal genesis or dependent origination. Nagarjuna lived in the early centuries of the current era and the Buddhist Creed, as the Gāthā is frequently called, was printed on clay tablets in huge numbers from the sixth century. This tradition was transmitted to China and Tibet with Buddhism.

	Printing text from woodblocks does not, however, seem to have been developed in India. **In Europe** Block printing was practised in Christian Europe as a method for printing on cloth, where it was common by 1300. Images printed on cloth for religious purposes could be quite large and elaborate, and when paper became relatively easily available, around 1400, the medium transferred very quickly to small woodcut religious images and playing cards printed on paper. These prints were produced in very large numbers from about 1425 onwards. Around the mid-century, block-books, woodcut books with both text and images, usually carved in the same block, emerged as a cheaper alternative to manuscripts and books printed with movable type. These were all short heavily illustrated works, the bestsellers of the day, repeated in many different block-book versions: the Arsmoriendi and the Biblia pauperum were the most common. There is still some controversy among scholars as to whether their introduction preceded or, the majority view, followed the introduction of movable type, with the range of estimated dates being between about 1440–1460.
Stencil printing	Stencils may have been used to color cloth for a very long time; the technique probably reached its peak of sophistication inKatazome and other techniques used on silks for clothes during the Edo period in Japan. In Europe, from about 1450 they were very commonly used to colour old master prints printed in black and white, usually woodcuts. This was especially the case with playing-cards, which continued to be coloured by stencil long after most other subjects for prints were left in black and white. Stenciling back in the 27th century BC was different. They used color from plants and flowers such as indigo (which extracts blue). Stencils were used for mass publications, as the type didn't have to be hand-written.
Movable Type	Movable type is the system of printing and typography using movable pieces of metal type, made by casting from matrices struck by letter punches. Around 1040, the world's first known movable type system was created in China by Bi Sheng out of porcelain. He also developed wooden movable type, but it was abandoned in favour of clay movable types due to the presence of wood grains and the unevenness of the wooden type after being soaked in ink. Neither movable type system was widely used, one reason being the enormous Chinese character set. Metal movable type began to be used in Korea during the Goryeo Dynasty (around 1230). Jikji was printed during the Goryeo Dynasty in 1377, it is the world's oldest extant book printed with movable metal type. This form of metal movable type was described by the French scholar Henri-Jean Martin as "extremely similar to Gutenberg's". East metal movable type may have spread to Europe between late 14th century and early 15th century. It is traditionally summarized that Johannes Gutenberg, of the German city of Mainz, developed European movable type printing technology with the printing press around 1439 and in just over a decade, the European age of printing began. However, the details show a more complex evolutionary process spread over multiple locations. Also, Johann Fust and Peter Schöffer experimented with Gutenberg in Mainz. Compared to woodblock printing, movable type page-setting was quicker and more durable. The metal type pieces were more durable and the lettering was more uniform, leading to typography and fonts. The high quality and relatively low price of the

	Gutenberg Bible (1455) established the superiority of movable type, and printing presses rapidly spread across Europe, leading up to the Renaissance, and later all around the world. Today, practically all movable type printing ultimately derives from Gutenberg's movable type printing, which is often regarded as the most important invention of the second millennium. Gutenberg is also credited with the introduction of an oil-based ink which was more durable than previously used water-based inks. Having worked as a professional goldsmith, Gutenberg made skillful use of the knowledge of metals he had learned as a craftsman. Gutenberg was also the first to make his type from an alloy of lead, tin, and antimony, known as type metal, printer's lead, or printer's metal, which was critical for producing durable type that produced high-quality printed books, and proved to be more suitable for printing than the clay, wooden or bronze types used in East Asia. To create these lead types, Gutenberg used what some considered his most ingenious invention, a special matrix where with the moulding of new movable types with an unprecedented precision at short notice became feasible. Within a year of printing the Gutenberg Bible, Gutenberg also published the first coloured prints. The invention of the printing press revolutionized communication and book production leading to the spread of knowledge. Rapidly, printing spread from Germany by emigrating German printers, but also by foreign apprentices returning home. A printing press was built in Venice in 1469, and by 1500 the city had 417 printers. In 1470 Johann Heynlin set up a printing press in Paris. In 1473Kasper Straube published the Almanach cracoviense ad annum 1474 in Kraków. Dirk Martens set up a printing press in Aalst(Flanders) in 1473. He printed a book about the two lovers of Enea Piccolomini who became Pope Pius II. In 1476 a printing press was set up in England by William Caxton. Belarusian Francysk Skaryna printed the first book in Slavic language on August 6, 1517. The Italian Juan Pablos set up an imported press in Mexico City in 1539. The first printing press in Southeast Asia was set up in the Philippines by the Spanish in 1593. The Rev. Jose Glover intended to bring the first printing press to England's American colonies in 1638, but died on the voyage, so his widow, Elizabeth Harris Glover, established the printing house, which was run by Stephen Day and became The Cambridge Press. The Gutenberg press was much more efficient than manual copying and still was largely unchanged in the eras of John Baskerville and Giambattista Bodoni, over 300 years later. By 1800, Lord Stanhope had constructed a press completely from cast iron, reducing the force required by 90% while doubling the size of the printed area. While Stanhope's "mechanical theory" had improved the efficiency of the press, it still was only capable of 250 sheets per hour. German printer Friedrich Koenig would be the first to design a non-manpowered machine—using steam. Having moved to London in 1804, Koenig met Thomas Bensley and secured financial support for his project in 1807. With a patent in 1810, Koenig designed a steam press "much like a hand press connected to a steam engine." The first production trial of this model occurred in April 1811.
GutenBerg's Printing Press	A printing press is a mechanical device for applying pressure to an inked surface resting upon a medium (such as paper or cloth), thereby transferring an image. The systems involved were first assembled in Germany by the goldsmith Johannes Gutenberg in the mid-15th century. Printing methods based on Gutenberg's printing press spread rapidly throughout first Europe and then the rest of the world, replacing

	most block printing and making it the sole progenitor of modern movable type printing. As a method of creating reproductions for mass consumption, The printing press has been superseded by the advent of offset printing. Johannes Gutenberg's work in the printing press began in approximately 1436 when he partnered with Andreas Dritzehen—a man he had previously instructed in gem-cutting—and Andreas Heilmann, owner of a paper mill. It was not until a 1439 lawsuit against Gutenberg that official record exists; witnesses testimony discussed type, an inventory of metals (including lead) and his type mold. Others in Europe were developing movable type at this time, including goldsmith Procopius Waldfoghel of France and Laurens Janszoon Coster of the Netherlands. They are not known to have contributed specific advances to the printing press. While the Encyclopædia Britannica Eleventh Edition had attributed the invention of the printing press to Coster, the company now states that is incorrect.
Rotary Printing Press	A rotary printing press is a printing press in which the impressions are carved around a cylinder so that the printing can be done on long continuous rolls of paper, cardboard, plastic, or a large number of other substrates. Rotary drum printing was invented by Richard March Hoe in 1843 and patented in 1847, and then significantly improved by William Bullock in 1863.
Conventional Printing Technology	All printing process are concerned with two kinds of areas on the final output: Image of printing areas, Non-image or non-printing areas After the information has been prepared for production (the prepress step), each printing process has definitive means of separating the image from the non-image areas. Conventional printing has four types of process: Planographics, in which the printing and non-printing areas are on the same plane surface and the difference between them is maintained chemically or by physical properties, the examples are: offset lithography, collotype, and screenless printing. Relief, in which the printing areas are on a plane surface and the non printing areas are below the surface, examples: flexography and letterpress. Intaglio, in which the non-printing areas are on a plane surface and the printing area are etched or engraved below the surface, examples: steel die engraving, gravure Porous, in which the printing areas are on fine mesh screens through which ink can penetrate, and the non-printing areas are a stencil over the screen to block the flow of ink in those areas, examples: screen printing, stencil duplicator.
Letter Press	Letterpress printing is a technique of relief printing. A worker composes and locks movable type into the bed of a press, inks it, and presses paper against it to transfer the ink from the type which creates an impression on the paper. Letterpress printing was the normal form of printing text from its invention by Johannes Gutenberg in the mid-15th century and remained in wide use for books and other uses until the second half of the 20th century, when offset printing was developed. More recently, letterpress printing has seen a revival in an artisanal form.
Offset Printing	Offset printing is a widely used printing technique. Offset printing is where the inked image is transferred (or "offset") from a plate to a rubber blanket. An offset transfer moves the image to the printing surface. When used in combination with the lithographic process, a process based on the repulsion of oil and water; the offset technique employs a flat (planographic) image carrier. So, the image to be printed

	obtains ink from ink rollers, while the non-printing area attracts a film of water, keeping the non-printing areas ink-free. Currently, most books and newspapers are printed using the technique of offset lithography.
Gravure Printing	Gravure printing is an intaglio printing technique, where the image being printed is made up of small depressions in the surface of the printing plate. The cells are filled with ink, and the excess is scraped off the surface with a doctor blade. Then a rubber-covered roller presses paper onto the surface of the plate and into contact with the ink in the cells. The printing cylinders are usually made from copper plated steel, which is subsequently chromed, and may be produced by diamond engraving; etching, orlaser ablation. Gravure printing is used for long, high-quality print runs such as magazines, mail-order catalogues, packaging and printing onto fabric and wallpaper. It is also used for printing postage stamps and decorative plastic laminates, such as kitchen worktops.
Flexography	Flexography (often abbreviated to flexo) is a form of printing process which utilizes a flexible relief plate. It is essentially a modern version of letterpress which can be used for printing on almost any type of substrate, including plastic, metallic films, cellophane, and paper. It is widely used for printing on the non-porous substrates required for various types of food packaging (it is also well suited for printing large areas of solid colour).
Dye Transfer Printing	Dye transfer is a continuous-tone color photographic printing process. Technicolor introduced dye transfer in its Process 3, introduced in the feature film The Viking (1928), which was produced by the Technicolor Corporation and released by Metro-Goldwyn-Mayer. Technicolor's two previous systems were an additive color process and a poorly received subtractive color process, the latter requiring two prints cemented together back-to-back. Process 3 used an imbibition process borrowed from the earlier Handschiegl color process, originally created in 1916 for Cecil B. DeMille's feature film Joan the Woman (1917). Technicolor further refined the imbibition dye transfer process in its Process 4, introduced in 1932, which employed three simultaneously filmed negatives. In the 1940s, this process was popularized by Eastman Kodak for general-purpose graphic arts work, but not for motion picture work, which remained exclusive to Technicolor (and for which Eastman Kodak was manufacturing Technicolor's light-sensitive camera and printing films, including the "blank receiver" film, on an exclusive basis, but not Technicolor's dyes), and is sometimes referred to by such generic names as "wash-off relief printing" and "dye imbibition" printing. The process requires making three printing matrices (one for each subtractive primary color) which absorb dye in proportion to the density of a gelatin relief image. Successive placement of the dyed film matrices, one at a time, "transfers" each primary dye by physical contact from the matrix to a mordanted, gelatin-coated paper.
Inkjet Printing	**Inkjet printing** is a type of computer printing that recreates a digital imageby propelling droplets of ink onto paper, plastic, or other substrates. Inkjet printers are the most commonly used type of printer, and range from small inexpensive consumer models to expensive professional machines The concept of inkjet printing originated in the 19th century, and the technology was first extensively developed in the early 1950s. Starting in the late 1970s inkjet printers

	that could reproduce digital images generated by computers were developed, mainly by Epson,Hewlett-Packard (HP), and Canon. In the worldwide consumer market, four manufacturers account for the majority of inkjet printer sales: Canon, HP, Epson, and Lexmark, a 1991 spin-off fromI BM. The emerging ink jet material deposition market also uses inkjet technologies, typically print heads using piezoelectric crystals, to deposit materials directly on substrates. There are two main technologies in use in contemporary inkjet printers: continuous (CIJ) and Drop-on-demand (DOD). Another emerging printing technology is pyro electro hydrodynamics by which liquids can be printed at nanoscale volumes.
Laser Printing	Laser printing is an electrostatic digital printing process. It produces high-quality text and graphics (and moderate-quality photographs) by repeatedly passing a laser beam back and forth over a negatively charged cylindrical drum to define a differentially-charged image. The drum then selectively collects electrically charged powdered ink (toner), and transfers the image to paper, which is then heated in order to permanently fuse the text and/or imagery. As with digital photocopiers and multifunction/all-in-one inkjet printers, laser printers employ axerographic printing process. However, laser printing differs from analog photocopiers in that the image is produced by the direct scanning of the medium across the printer's photoreceptor. This enables laser printing to copy images more quickly than most photocopiers.
Screen Printing	Screen printing is a printing technique whereby a mesh is used to transfer ink onto a substrate, except in areas made impermeable to the ink by a blocking stencil. A blade or squeegee is moved across the screen to fill the open mesh apertures with ink, and a reverse stroke then causes the screen to touch the substrate momentarily along a line of contact. This causes the ink to wet the substrate and be pulled out of the mesh apertures as the screen springs back after the blade has passed. Basically, it is the process of using a mesh-based stencil to apply ink onto a substrate, whether it be T-shirts, posters, stickers, vinyl, wood, or other material. Screen printing is also a stencil method of print making in which a design is imposed on a screen of polyester or other fine mesh, with blank areas coated with an impermeable substance. Ink is forced into the mesh openings by the fill blade or squeegee and by wetting the substrate, transferred onto the printing surface during the squeegee stroke. As the screen rebounds away from the substrate the ink remains on the substrate. It is also known as silk-screen, screen, serigraphy, and serigraph printing. One color is printed at a time, so several screens can be used to produce a multi coloured image or design.

APPENDIX B

Output Comparison:

Key:

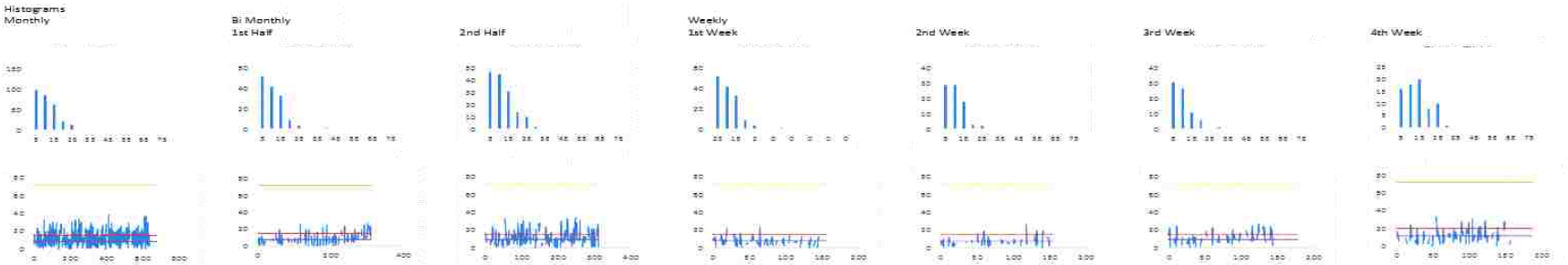
Small Black T Shirt

Histograms:
X Axis: Demand Quantity
Y Axis: Deamnd Frequency

Deamnd Vs Inventory Chart
X Axis : Hours
Y Axis: Demand

Min Qty
News Vendor based Q*
Simple Moving Avg.

Jan to Feb



Feb to March

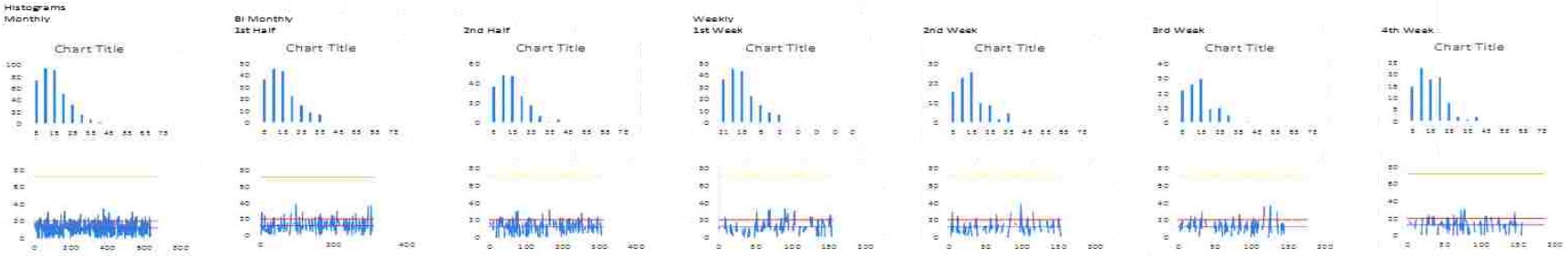
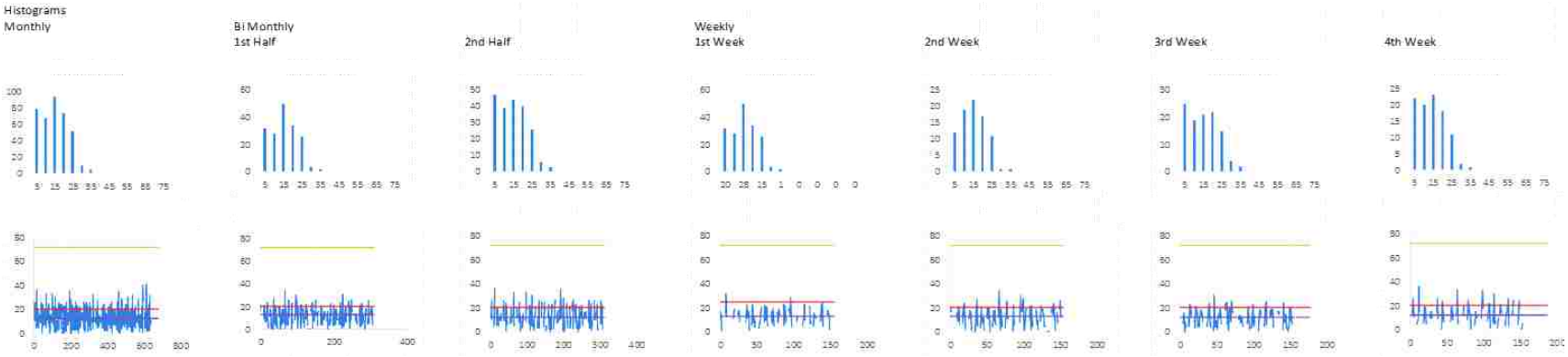


Fig Set 13 Output Comparison – Demand Histogram & Demand VS Inventory Comparison

March to April



April to May

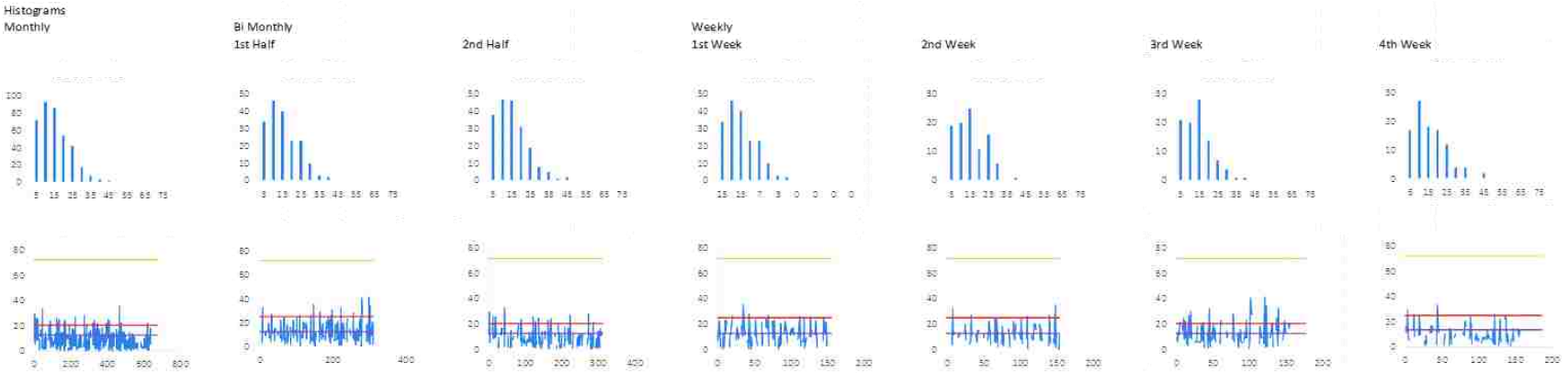
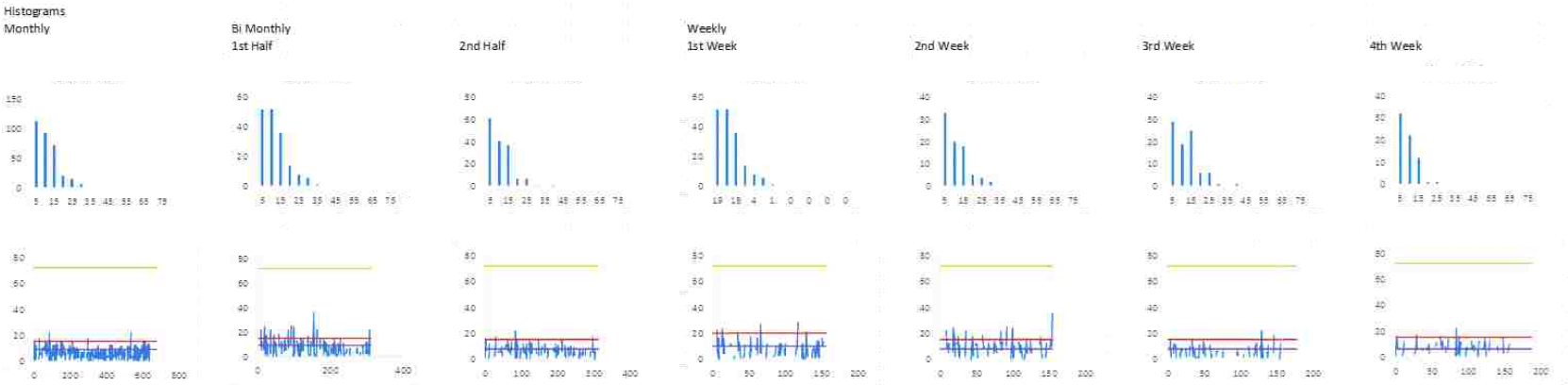


Fig Set 13 : Output Comparison – Demand Histogram & Demand VS Inventory Comparison

May to June



June to July

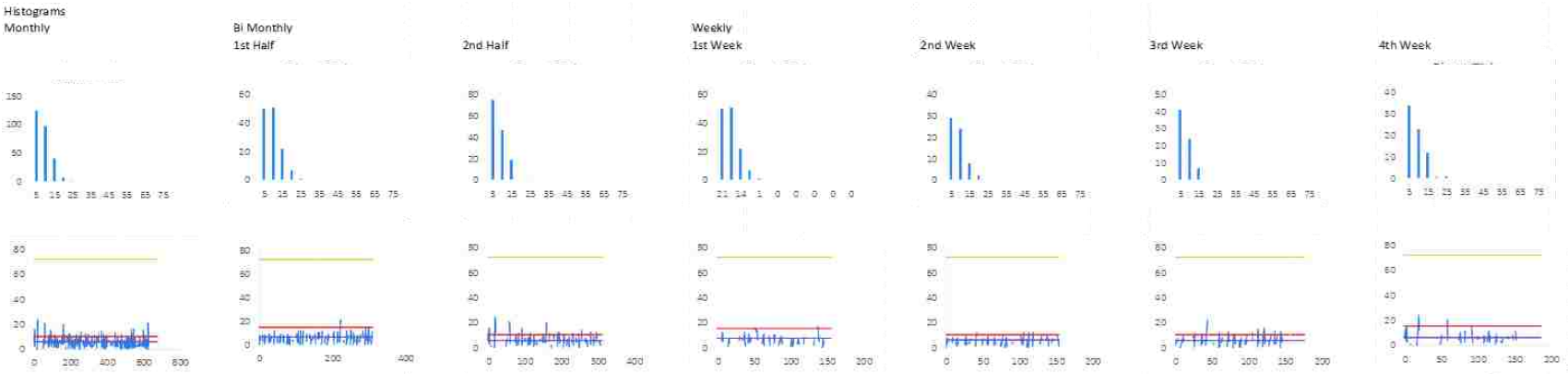
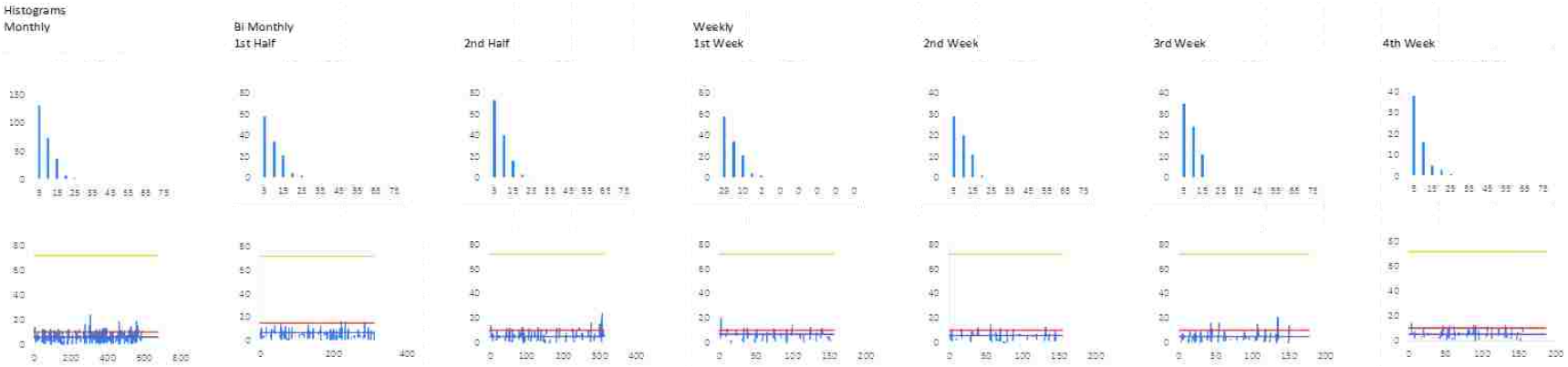


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

July to Aug



Aug to Sept

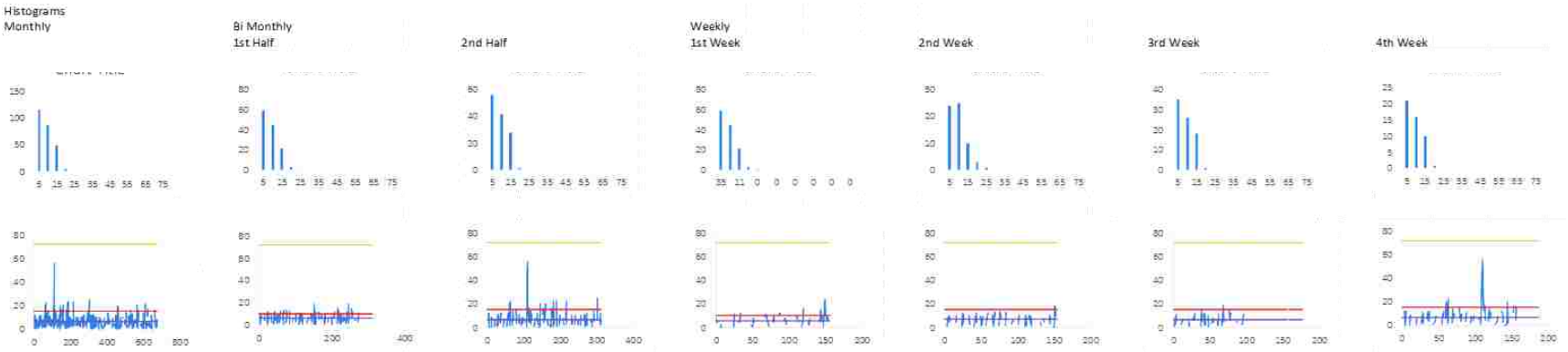
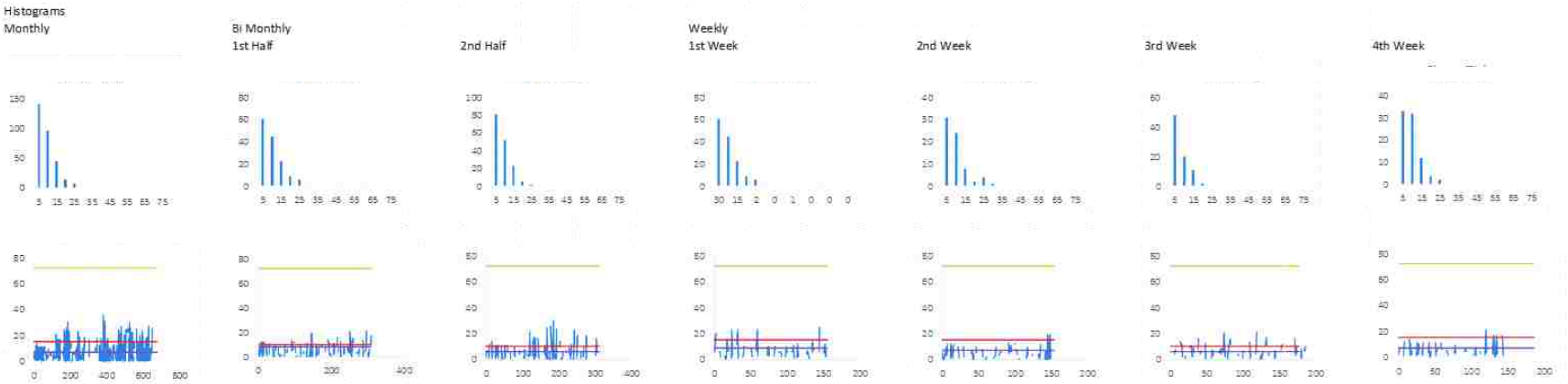


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Sept to Oct



Oct to Nov

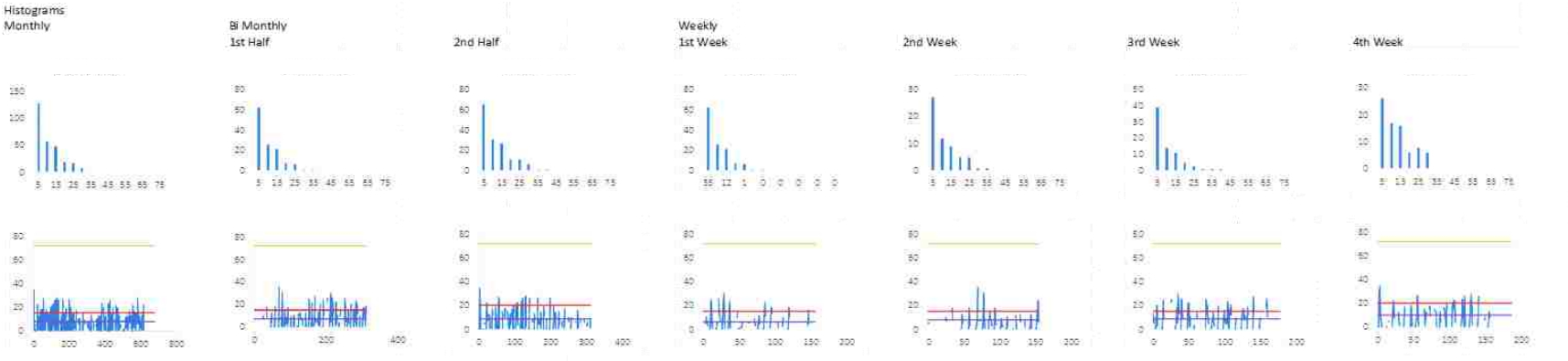
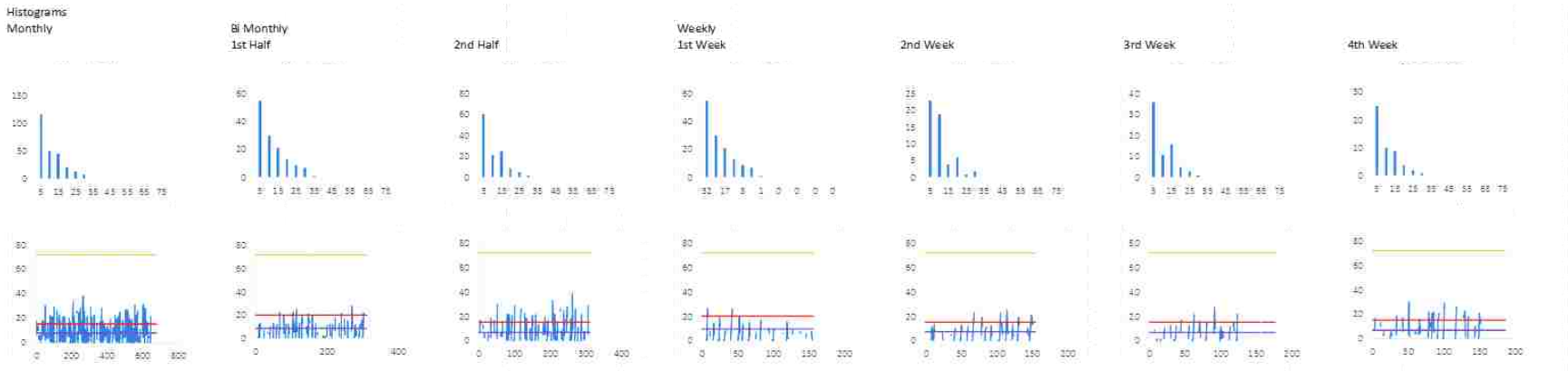


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Nov to Dec



Dec to Jan 2015

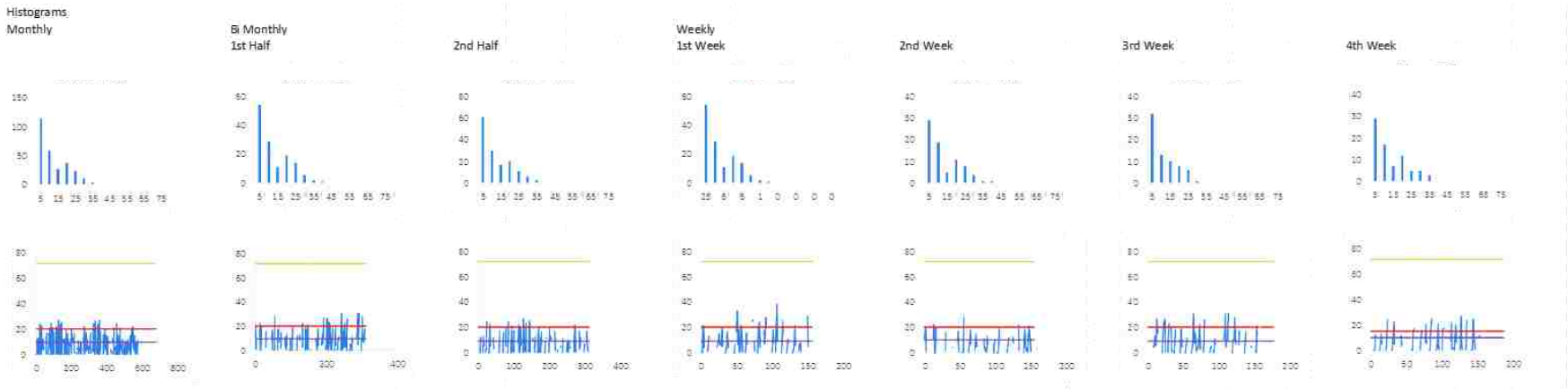


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Med Black T shirt

Jan to Feb

Feb to Mar

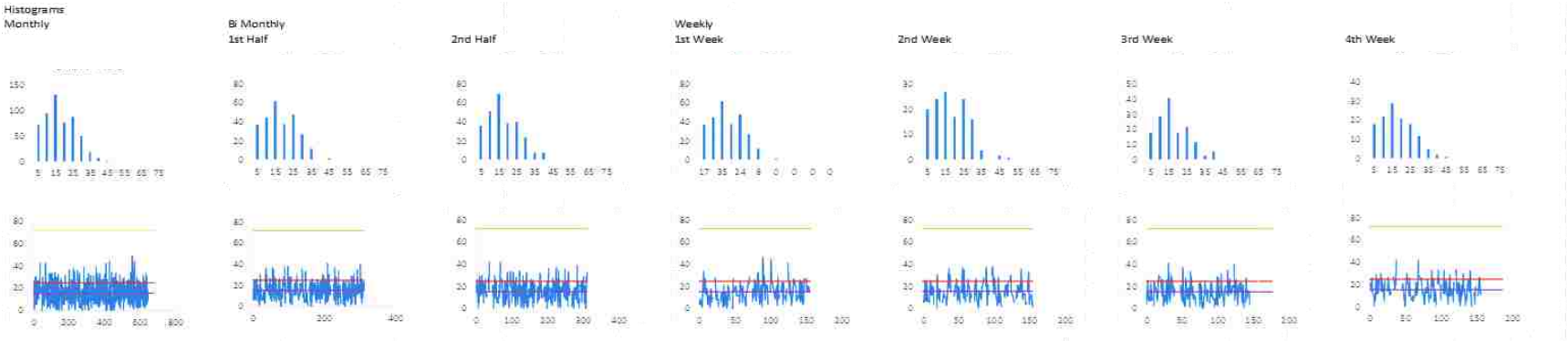
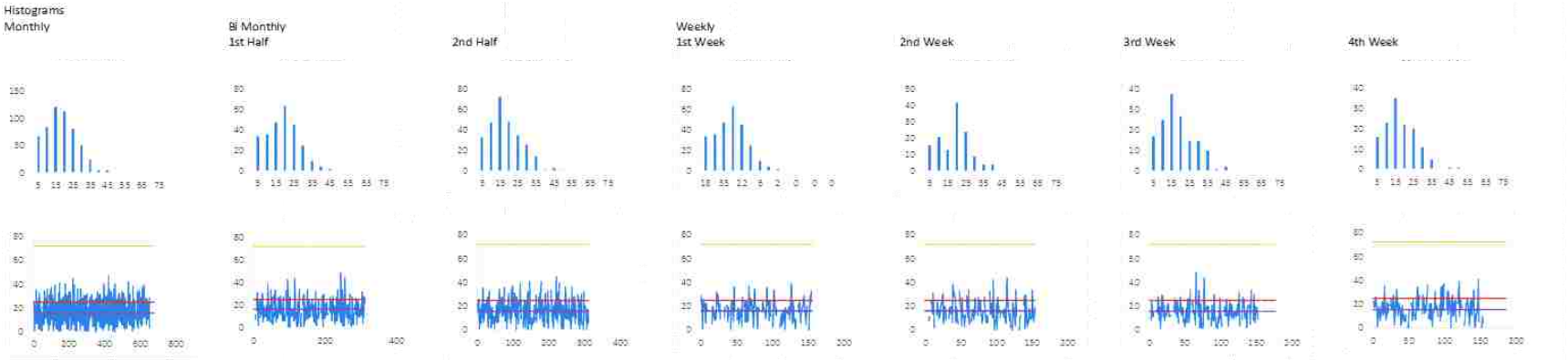


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Mar to April



Apr to May

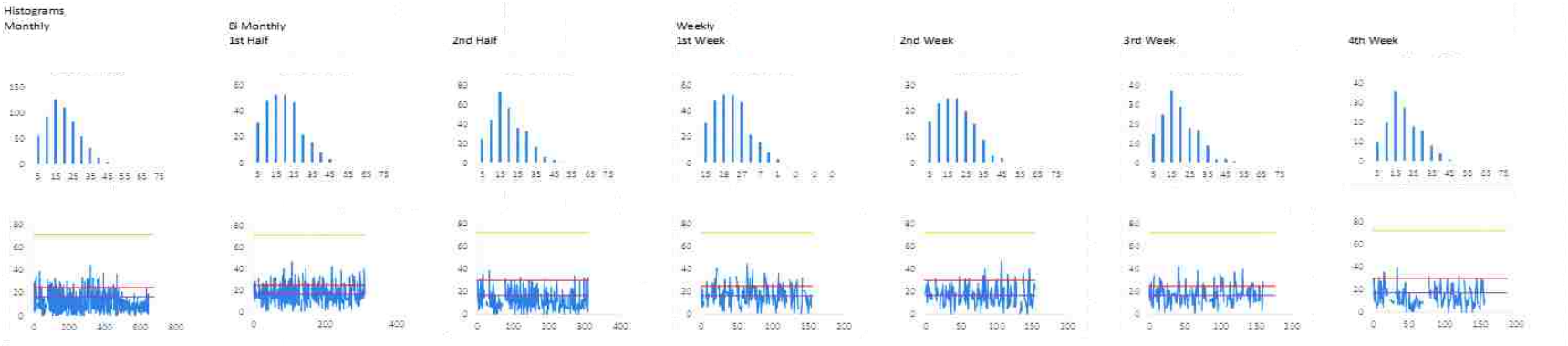
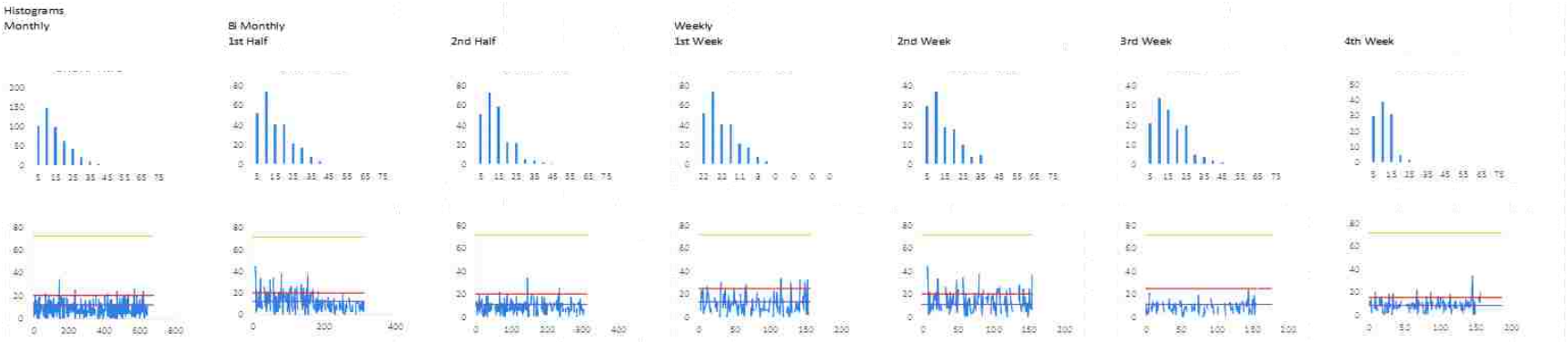


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

May to June



June to July

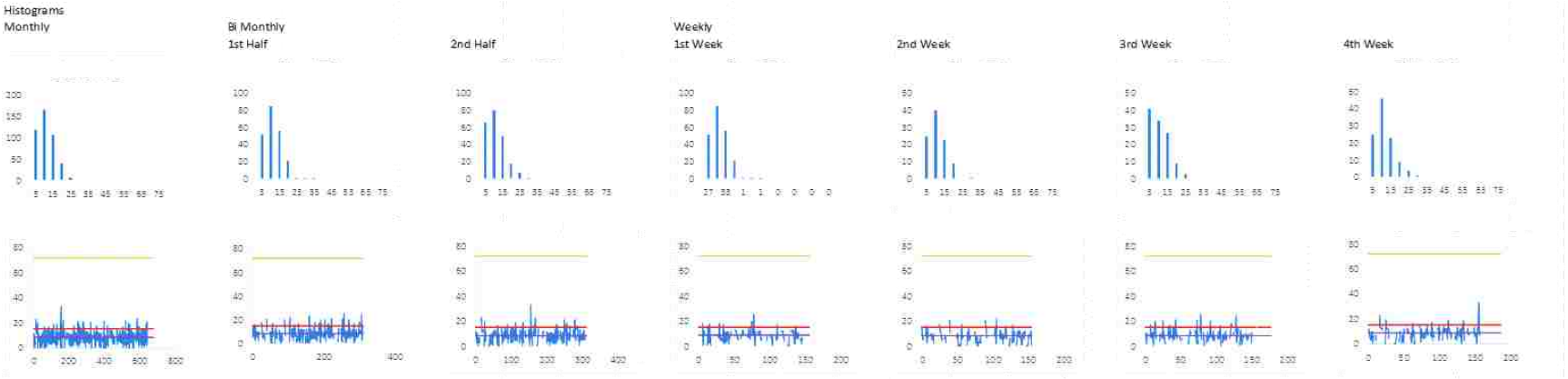
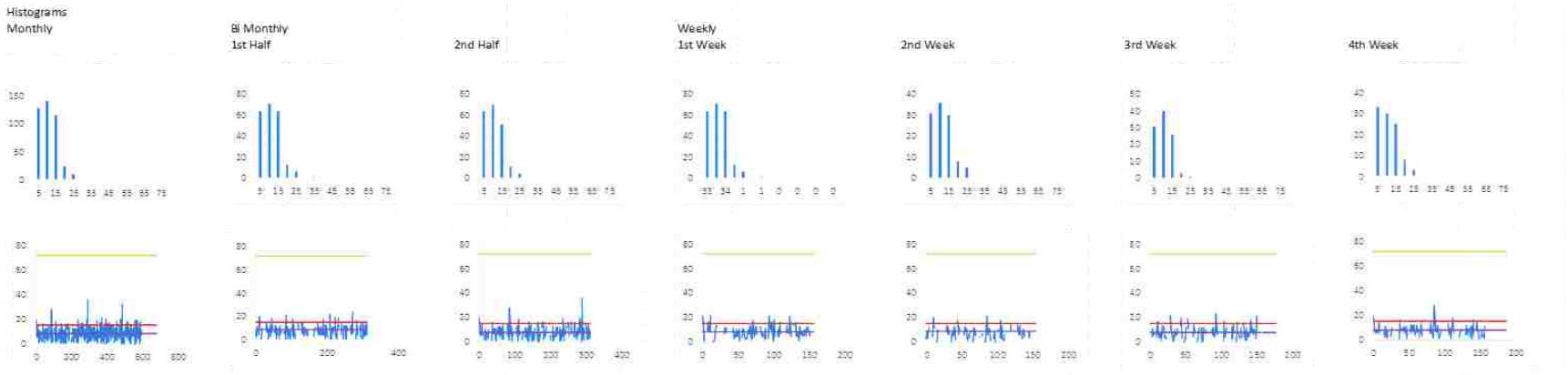


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

July to Aug



Aug to Sept

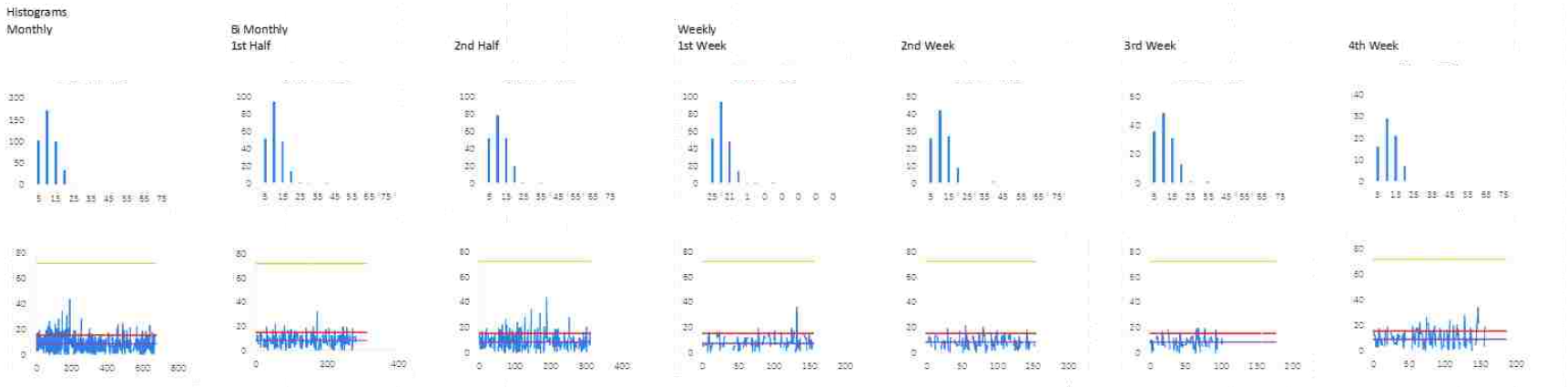
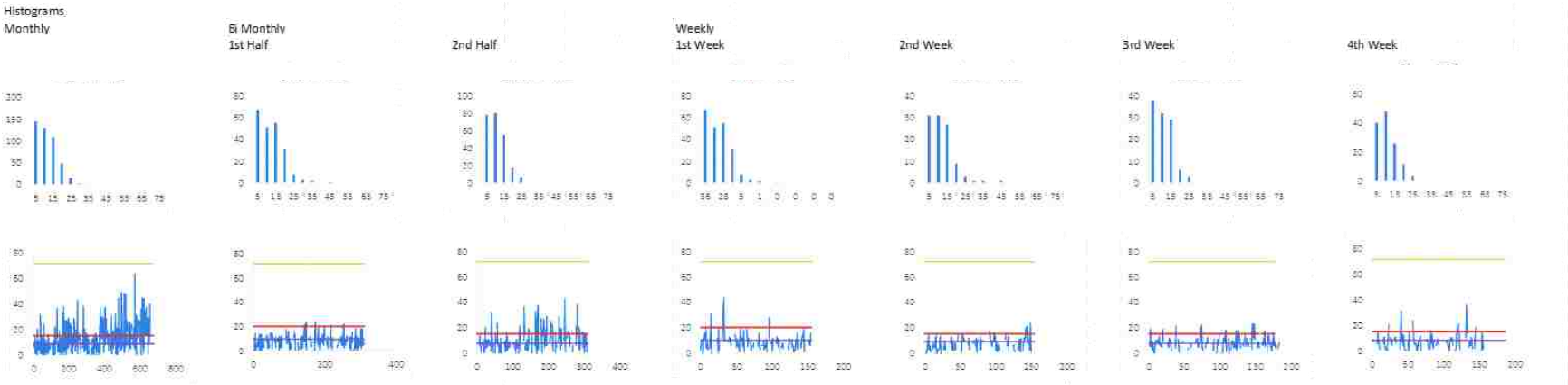


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Sept to Oct



Oct to Nov

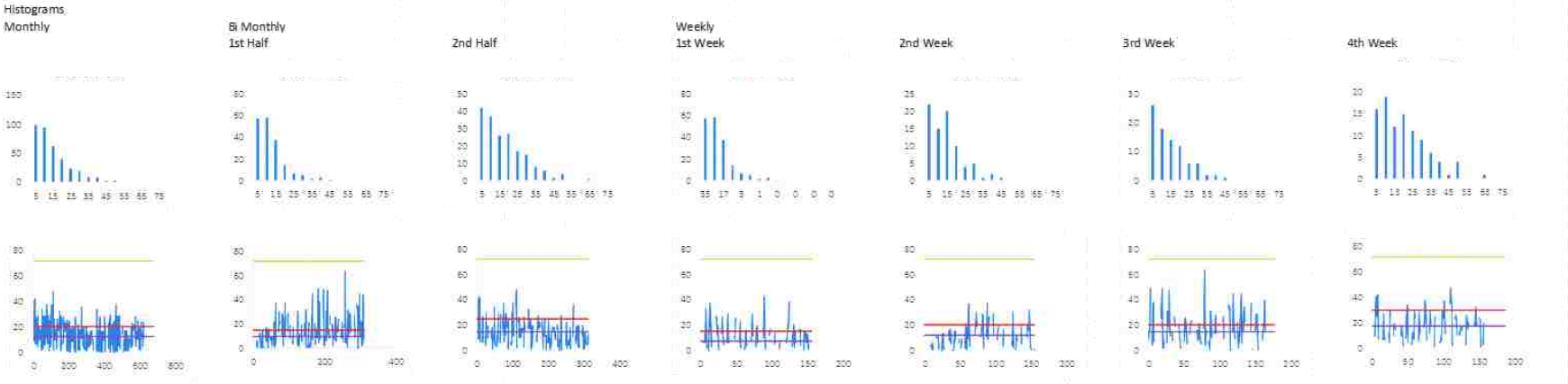
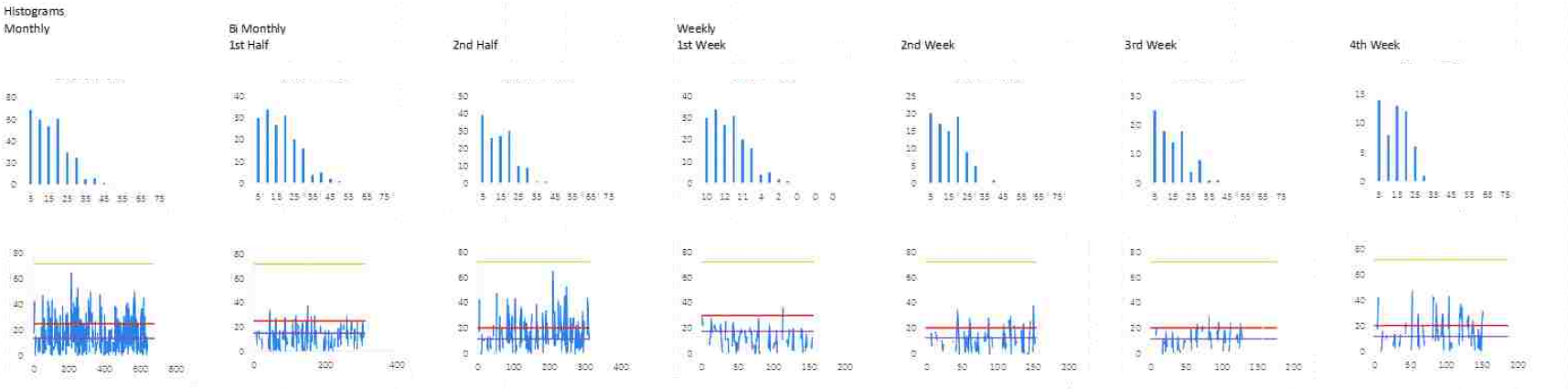


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Nov to Dec



Dec to Jan

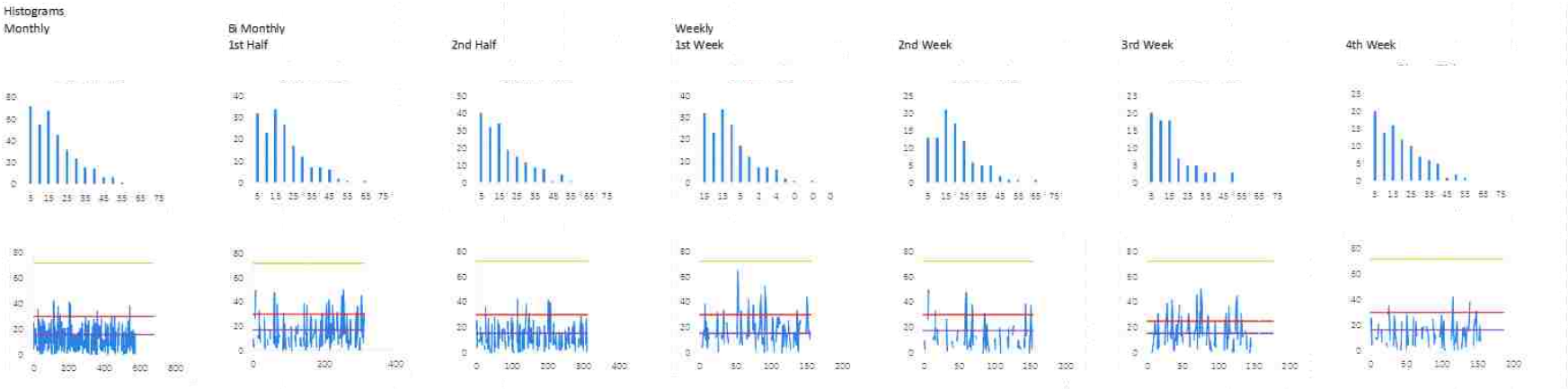
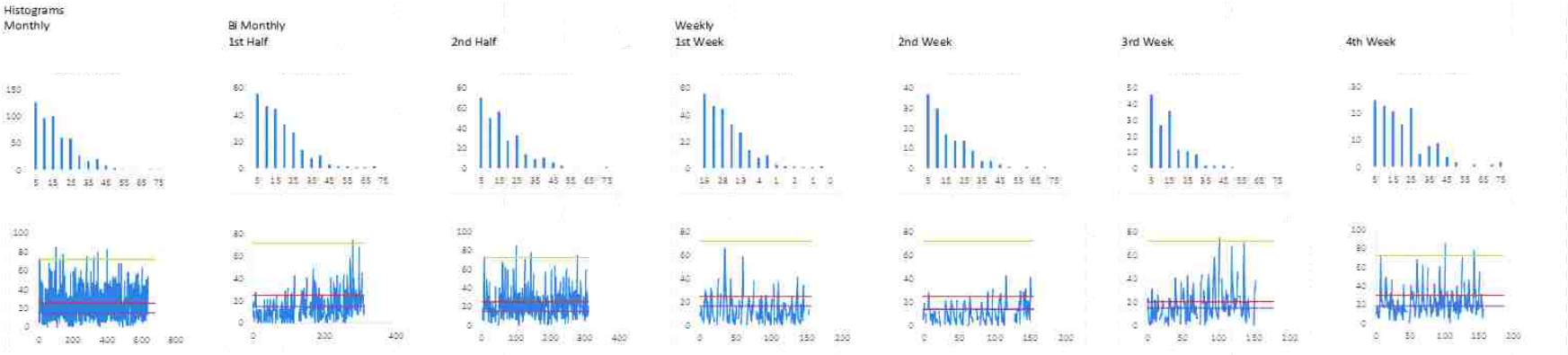


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Large Black T Shirt

Jan to Feb



Feb to March

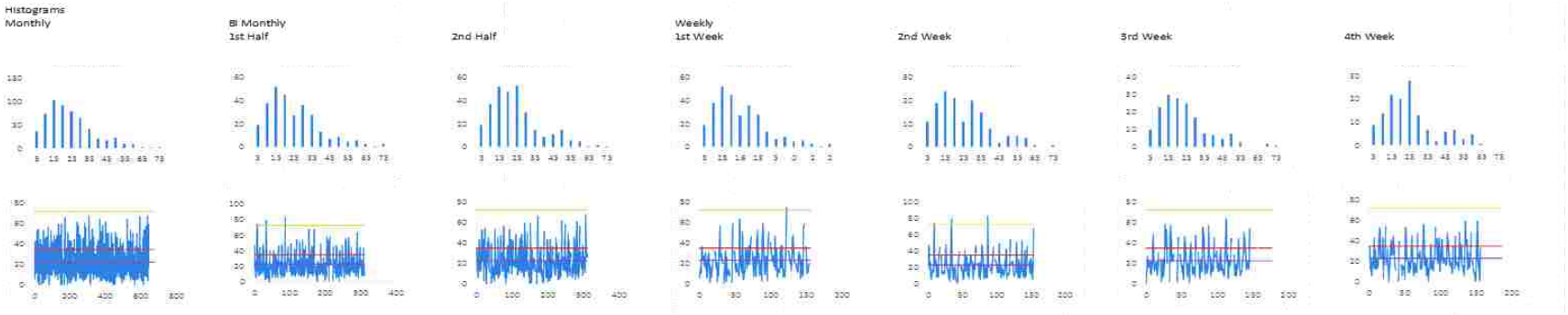
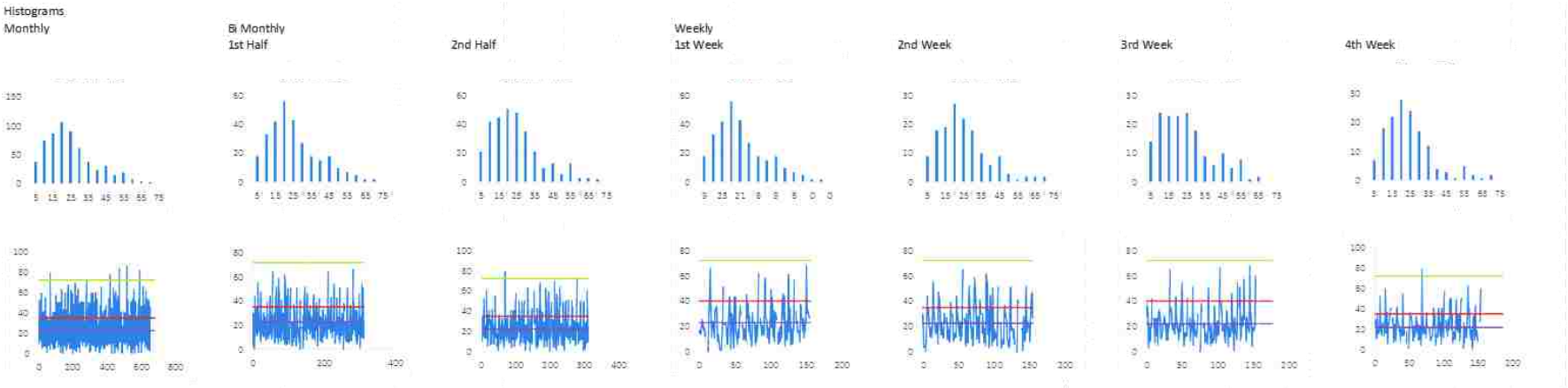


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

March to Apr



April to May

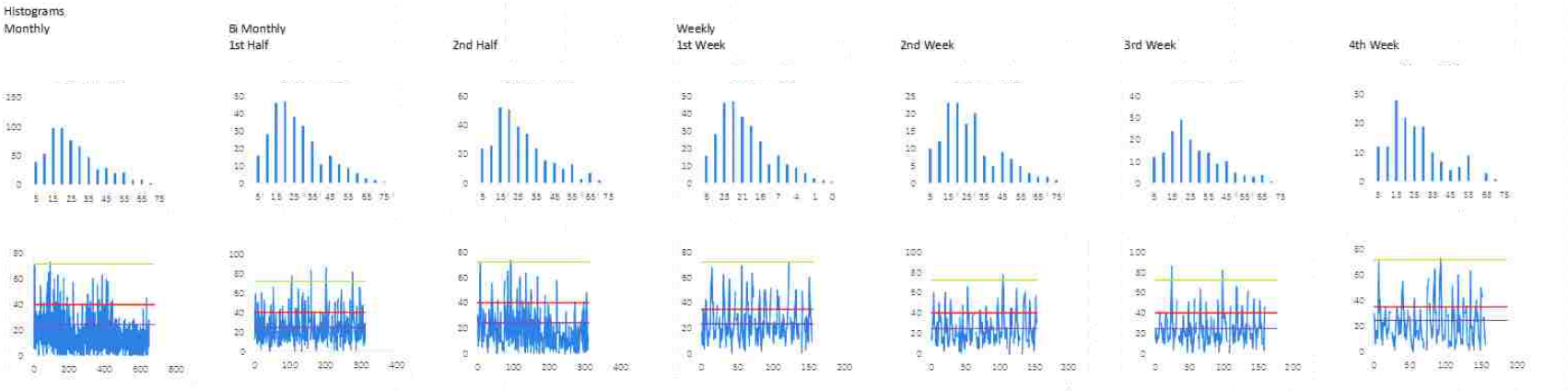
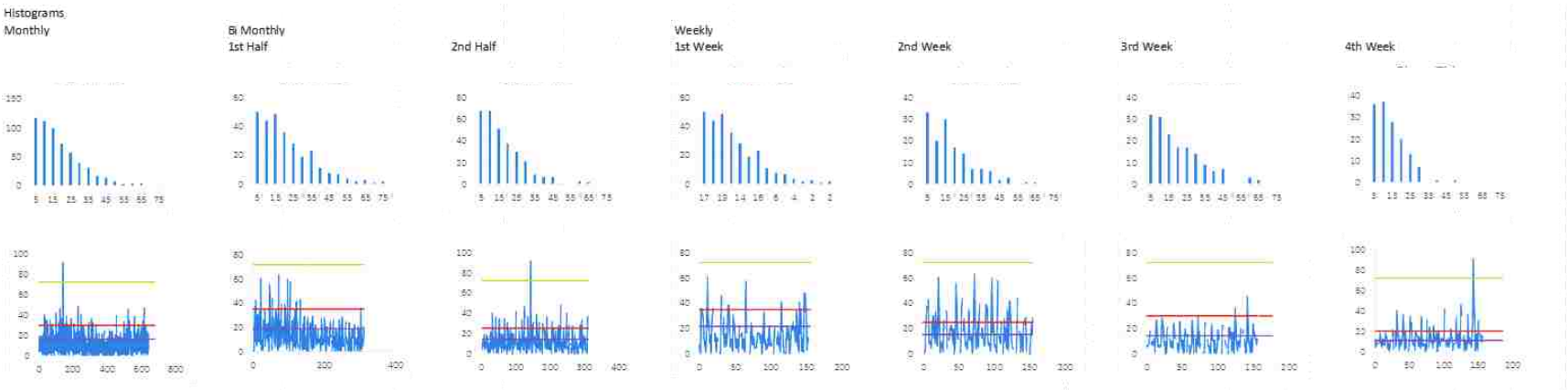


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

May to June



June to July

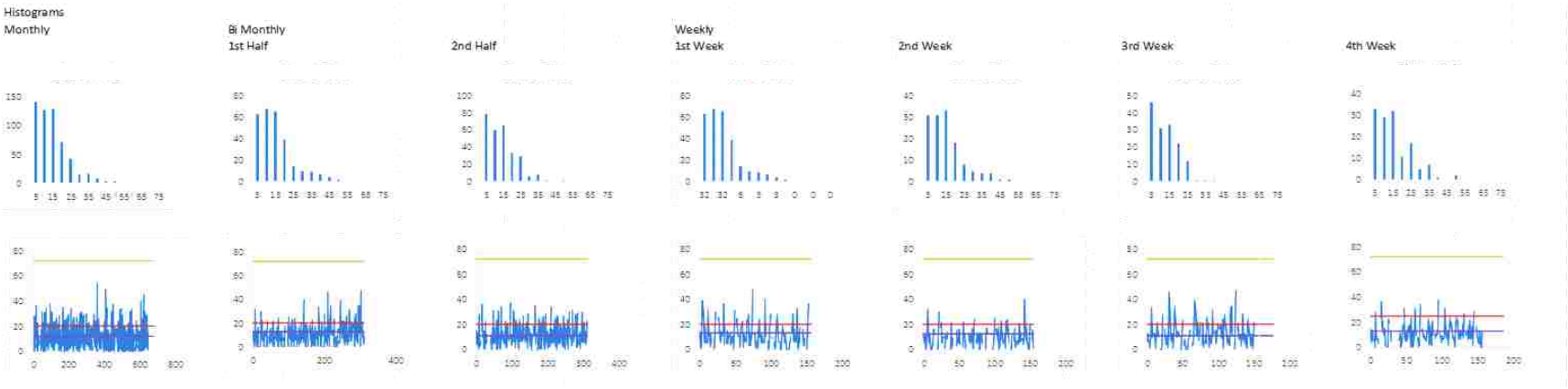
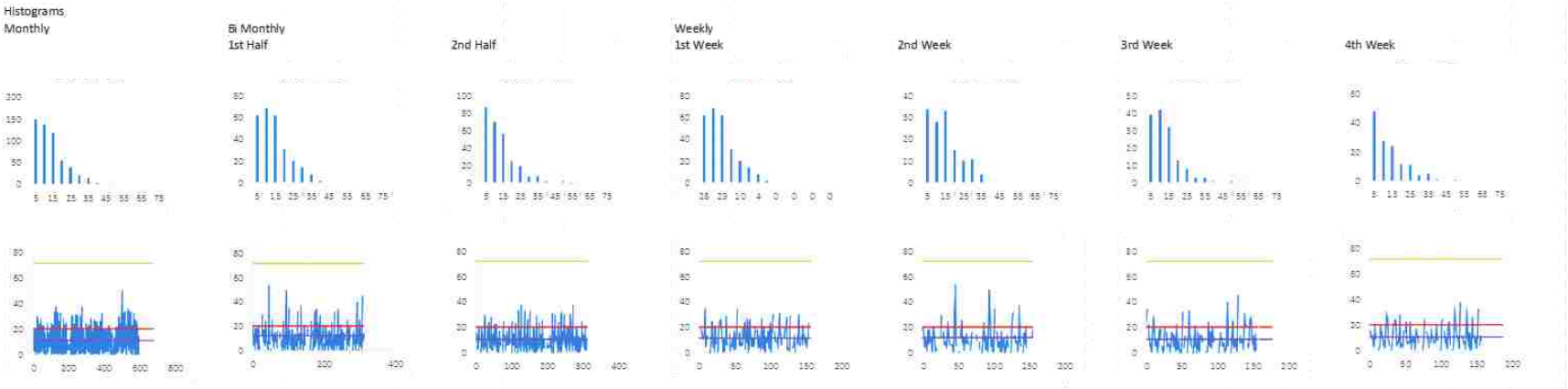


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

July to Aug



Aug to September

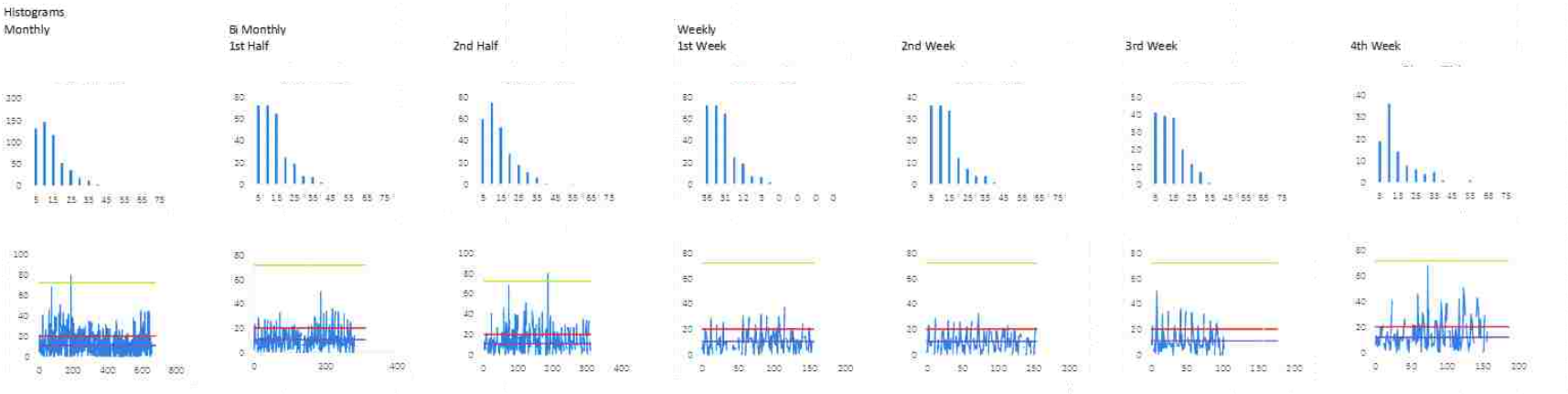
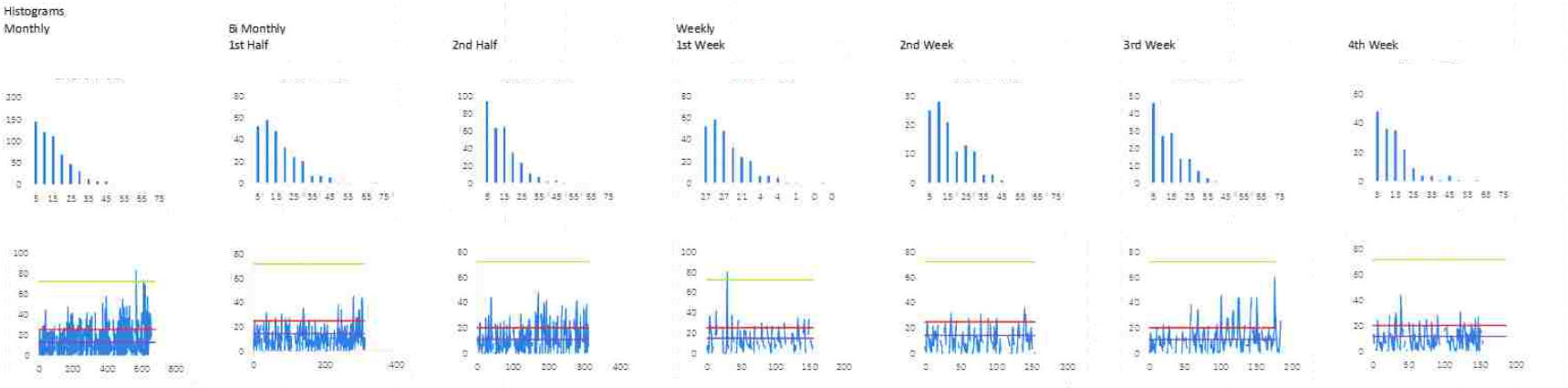


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Sept to Oct



Oct to Nov

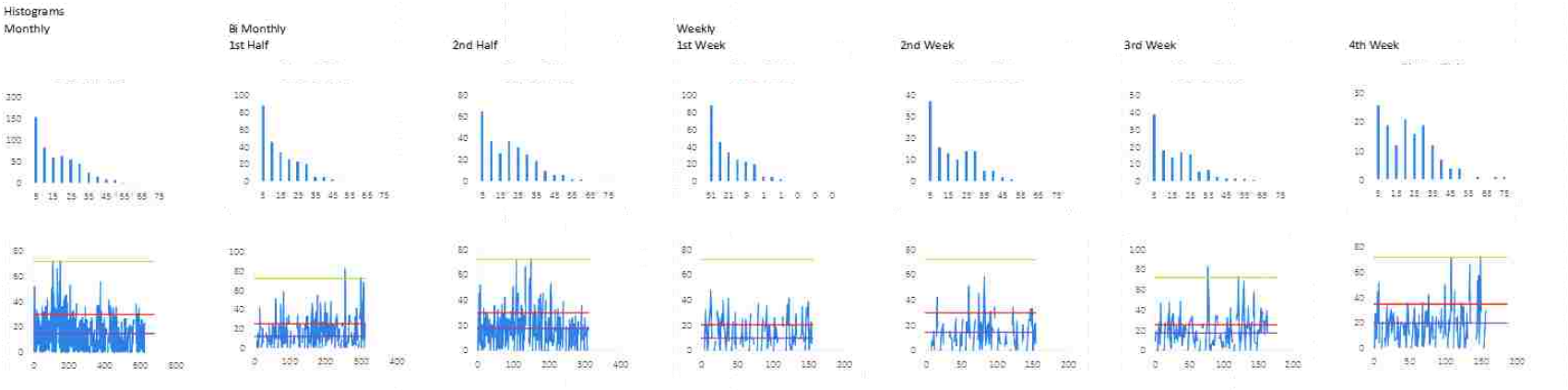
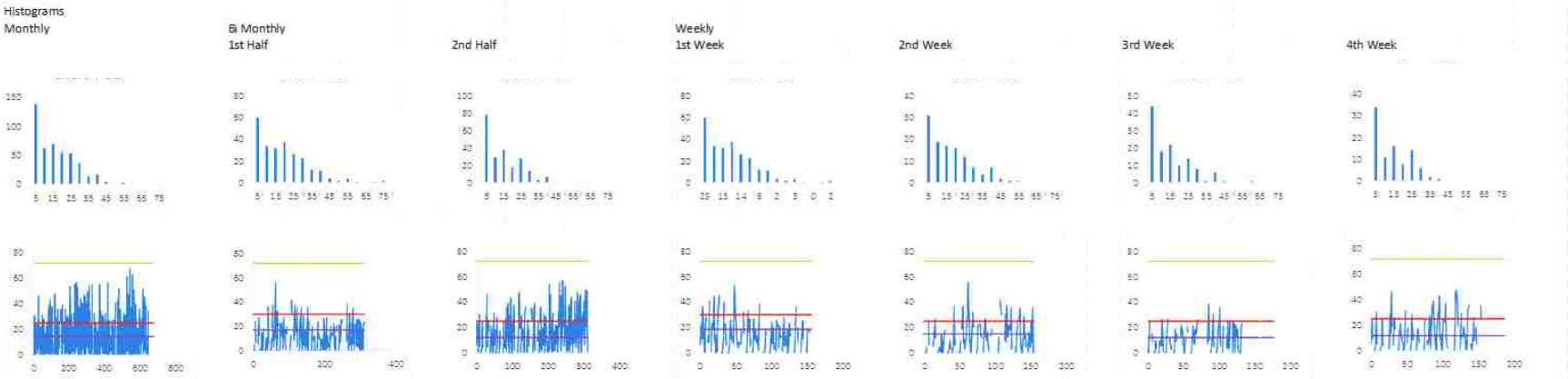


Fig Set 13 : Output Comparison – Demand Histogram & Demand VS Inventory Comparison

Nov to Dec



Dec to Jan

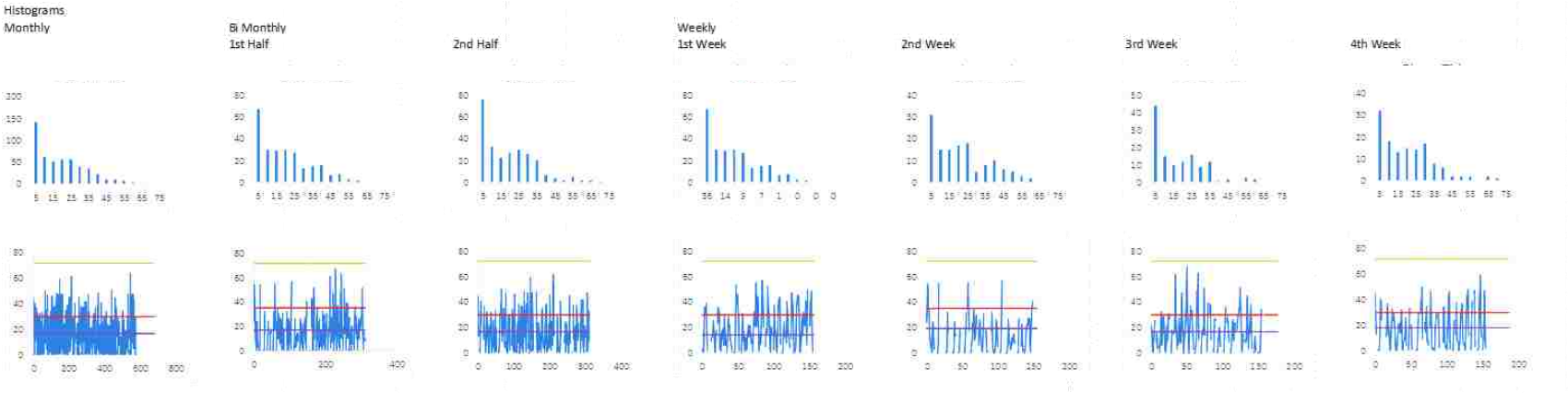
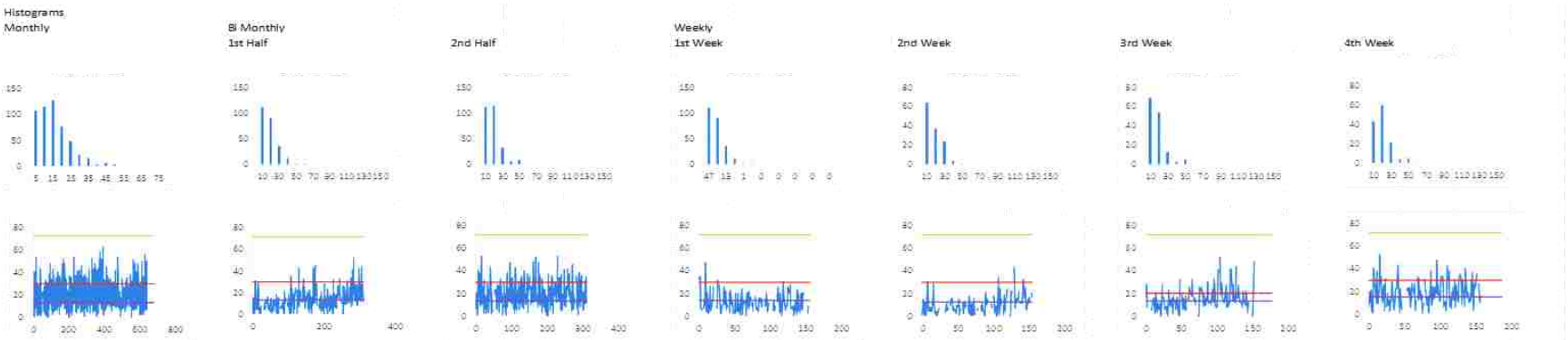


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

XL Black T Shirt

Jan to Feb



Feb to March

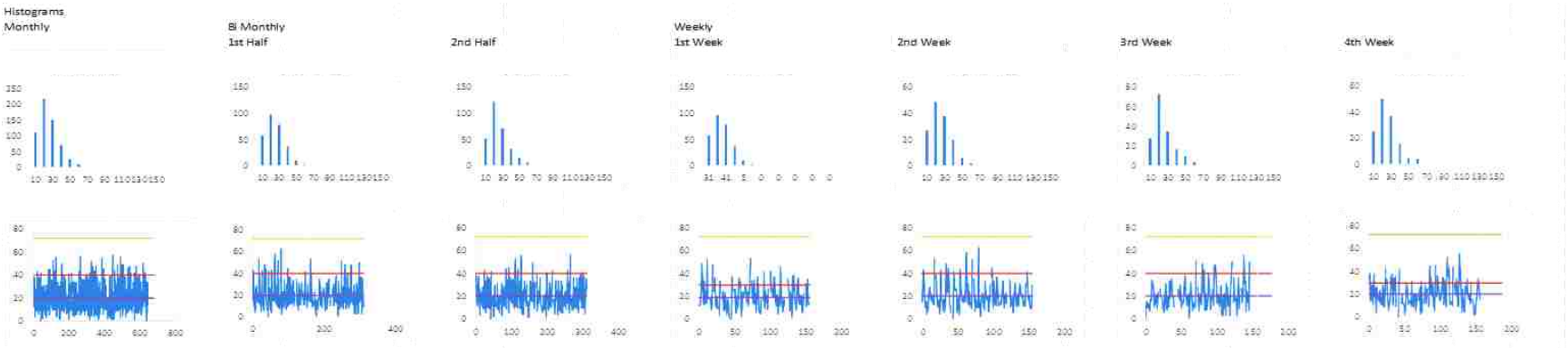
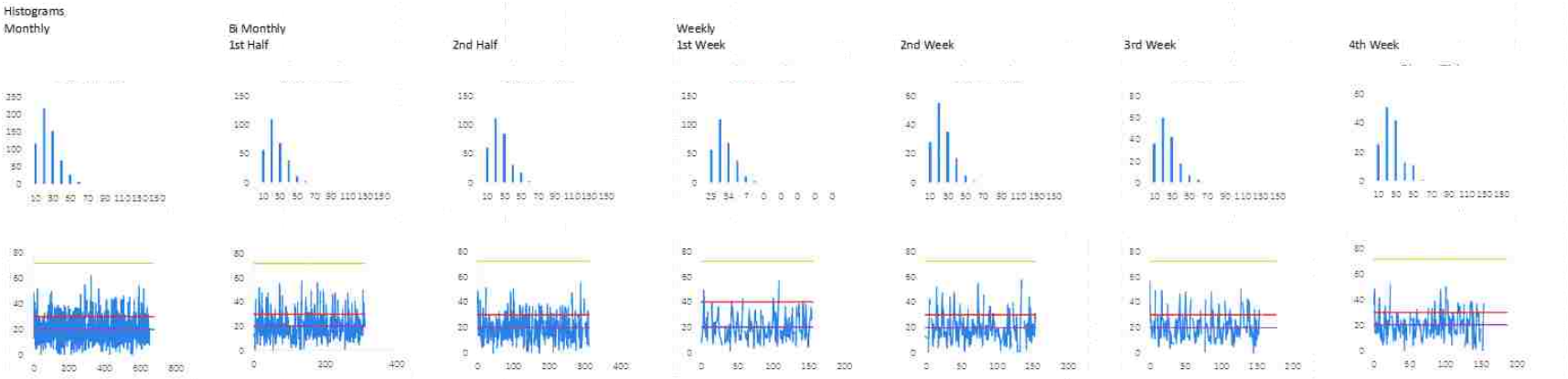


Fig Set 13: Output Comparison – Demand Histogram & Demand VS Inventory Comparison

March to April



April to May

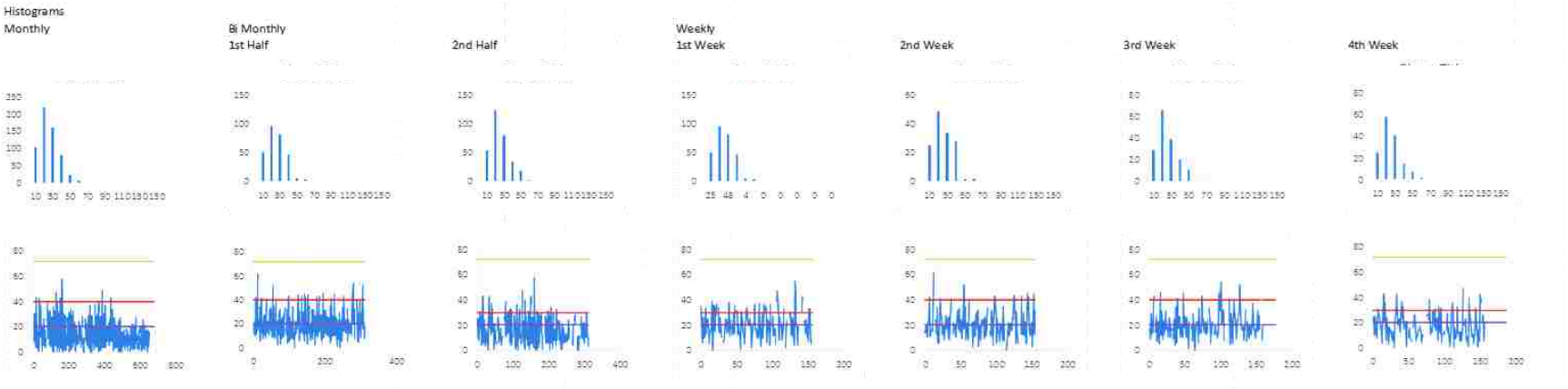
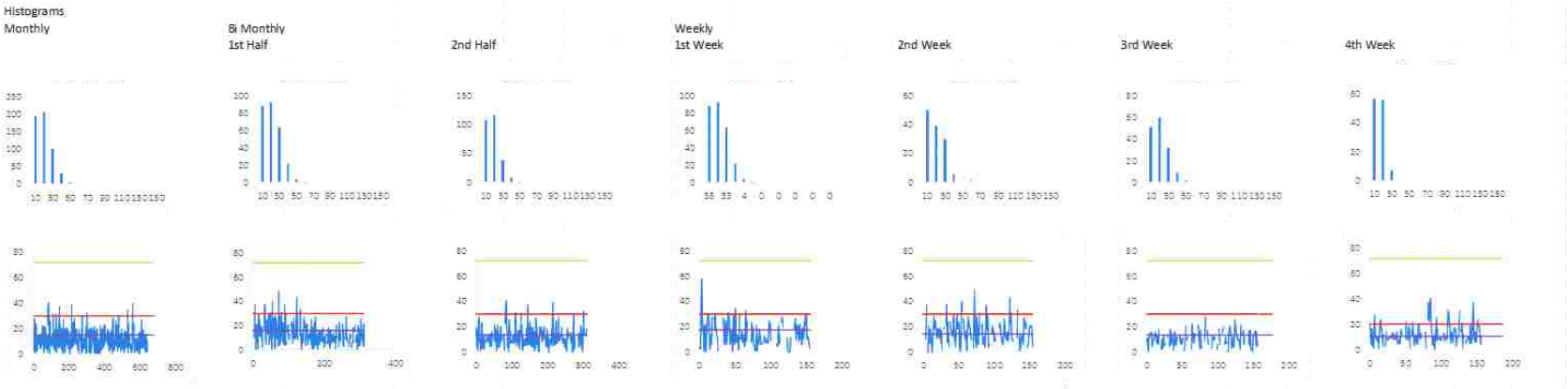


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

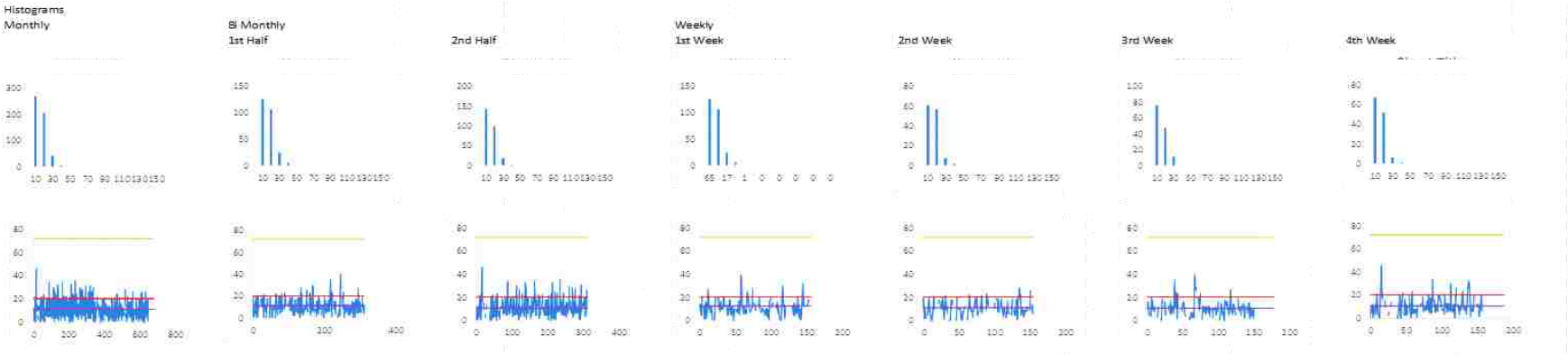
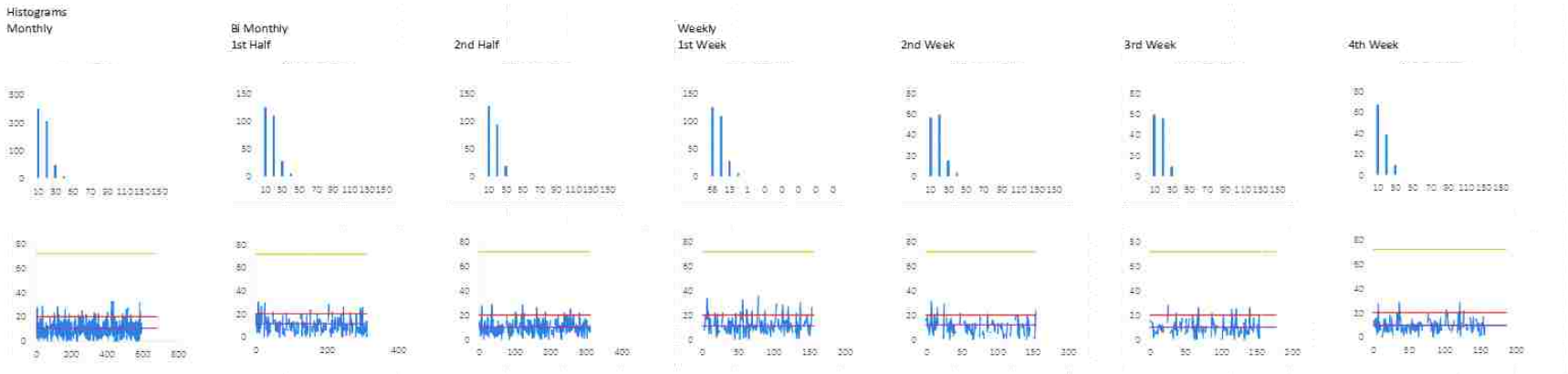


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug



Aug to September

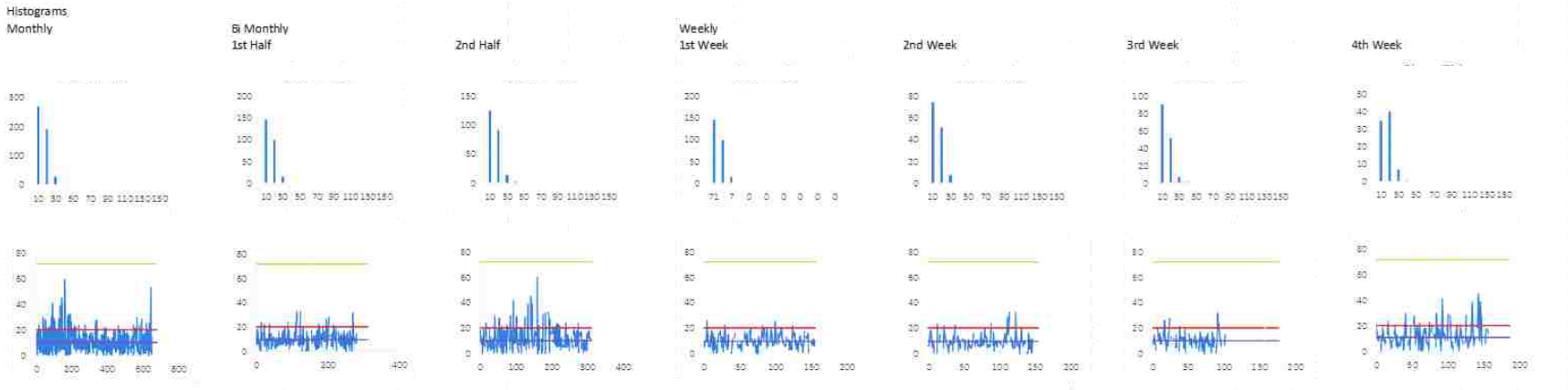
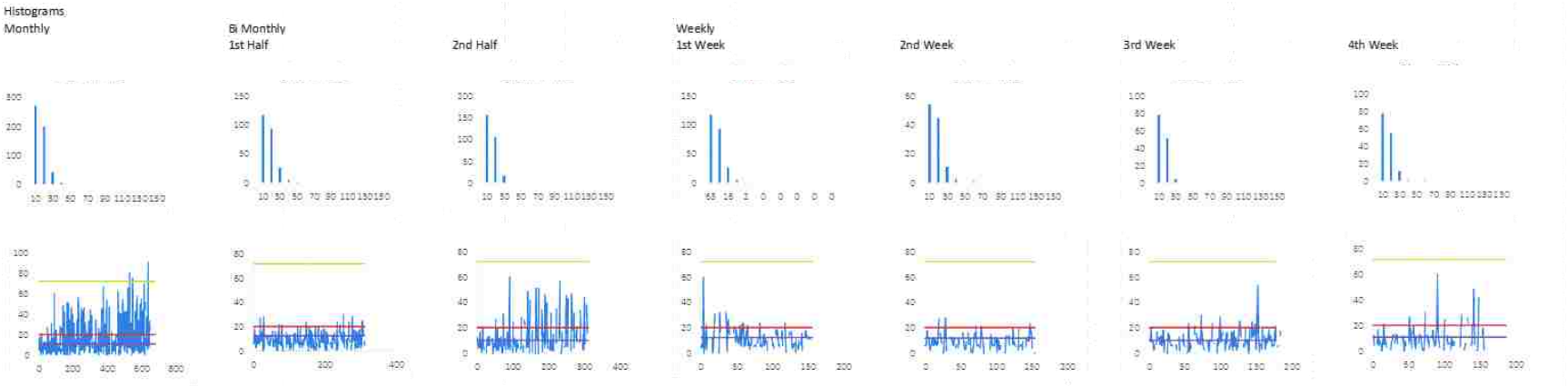


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

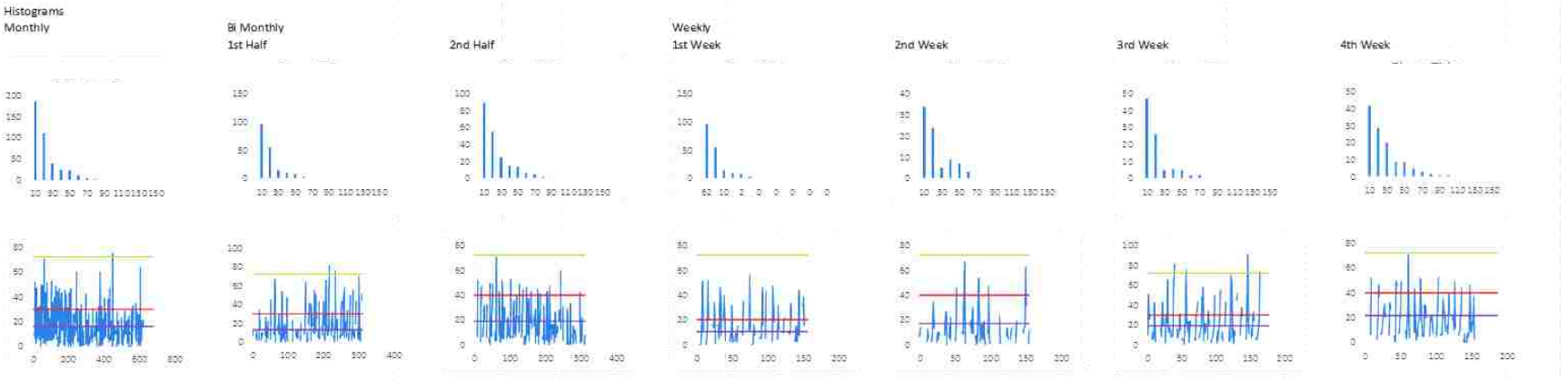
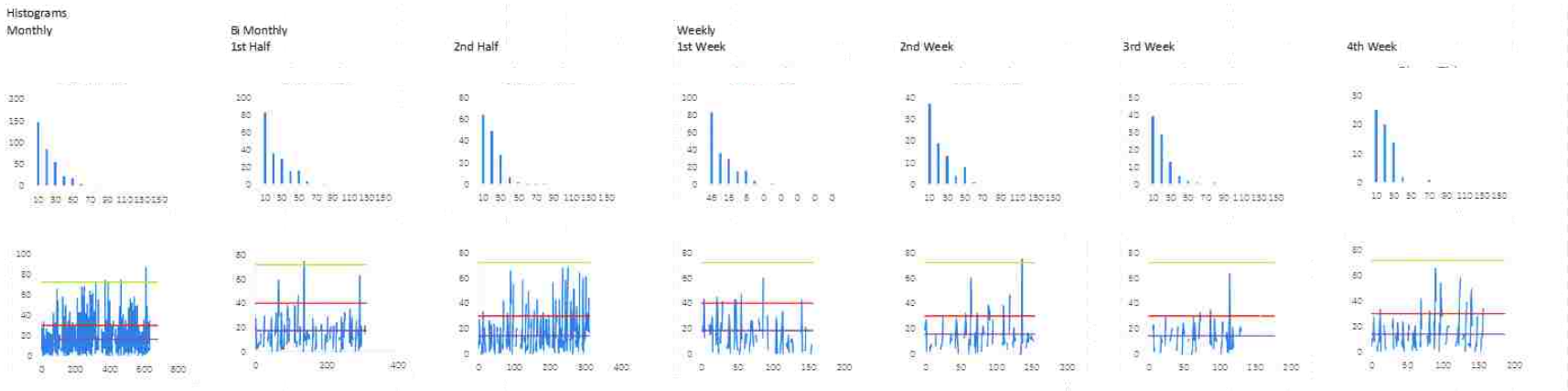


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

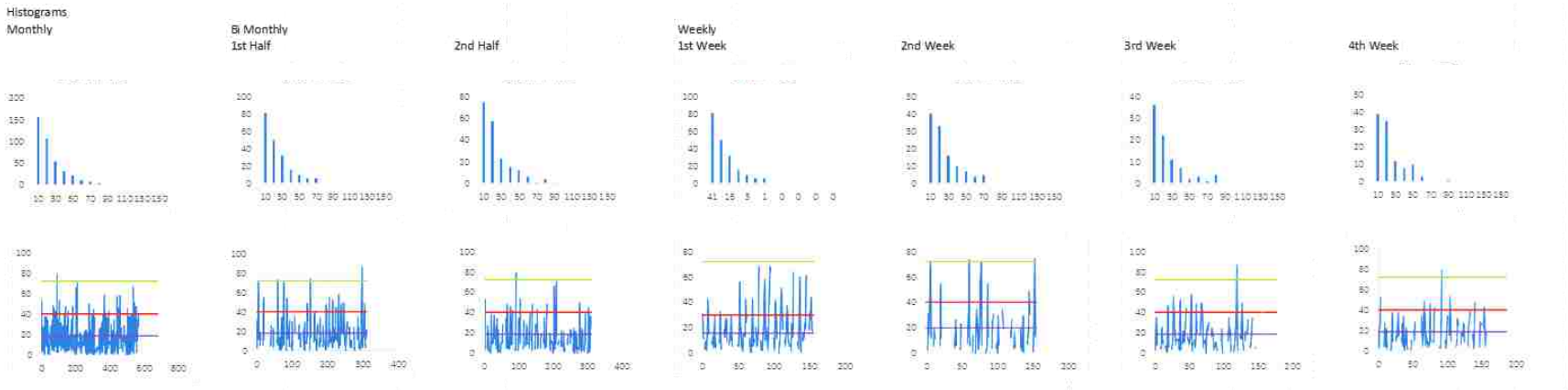
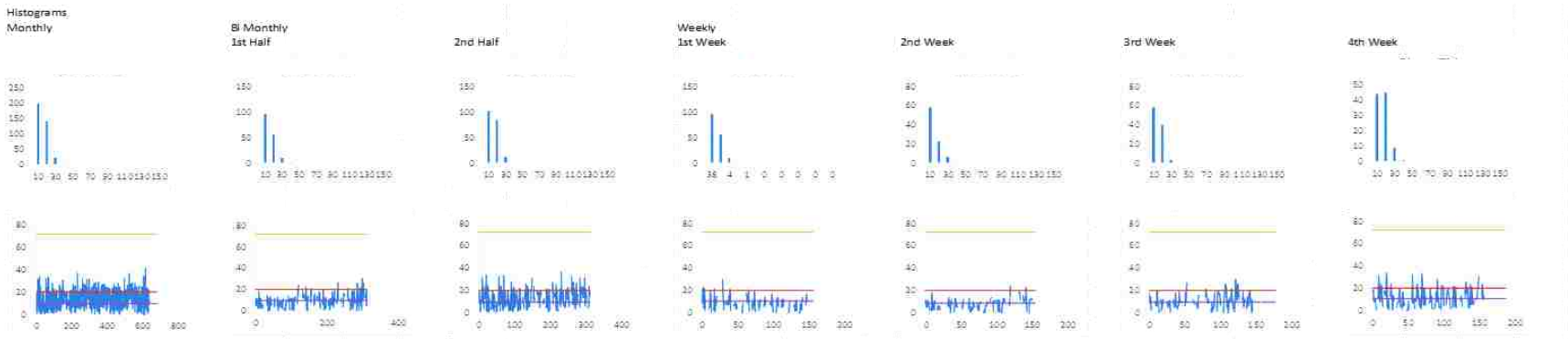


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

XXL Black T Shirt

Jan to Feb



Feb to March

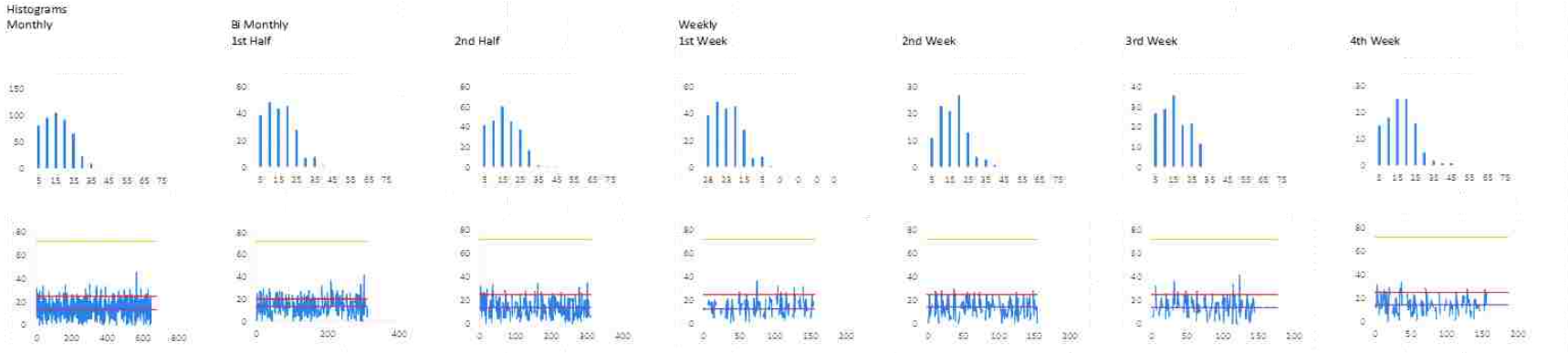
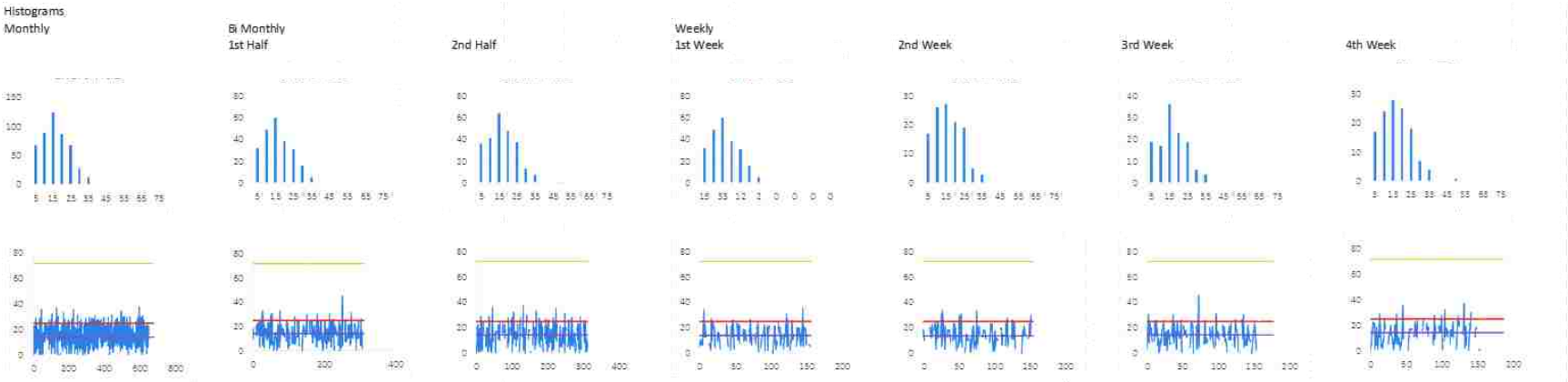


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

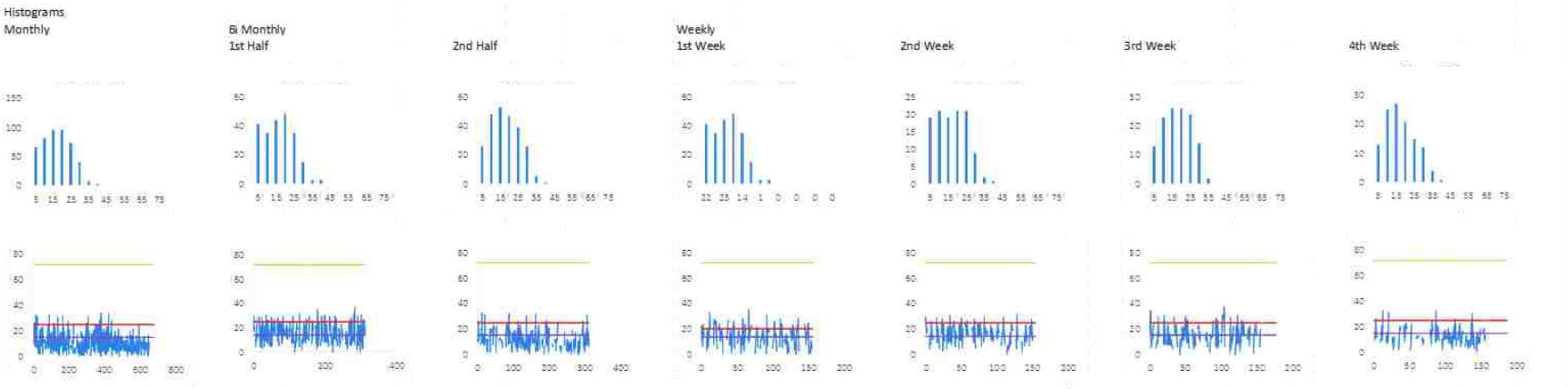
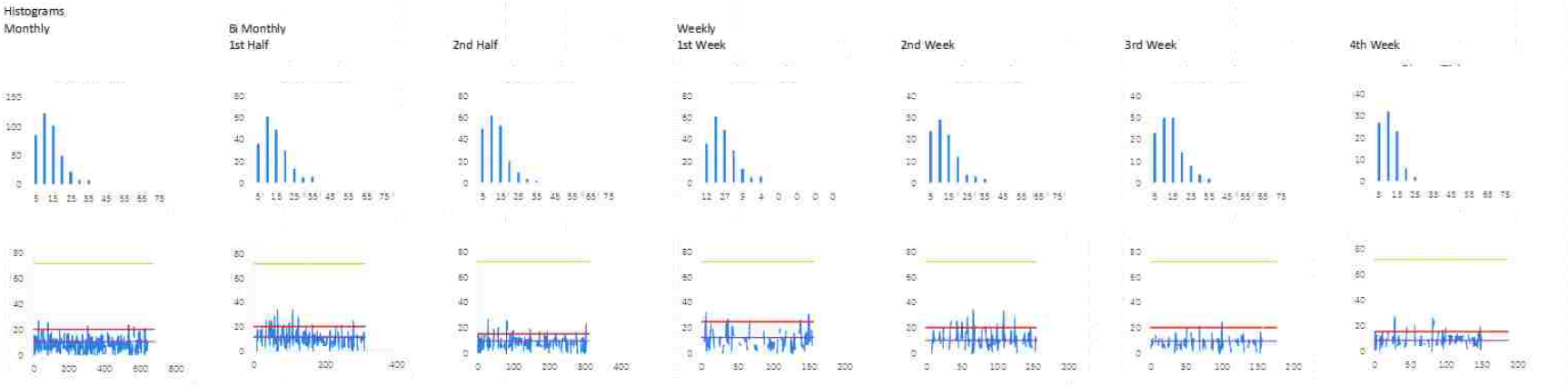


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

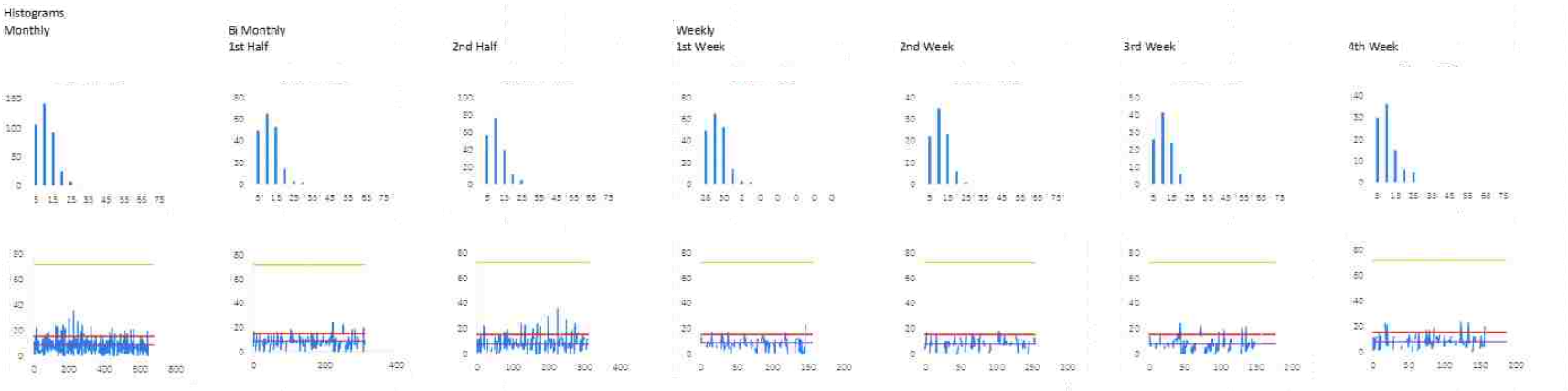
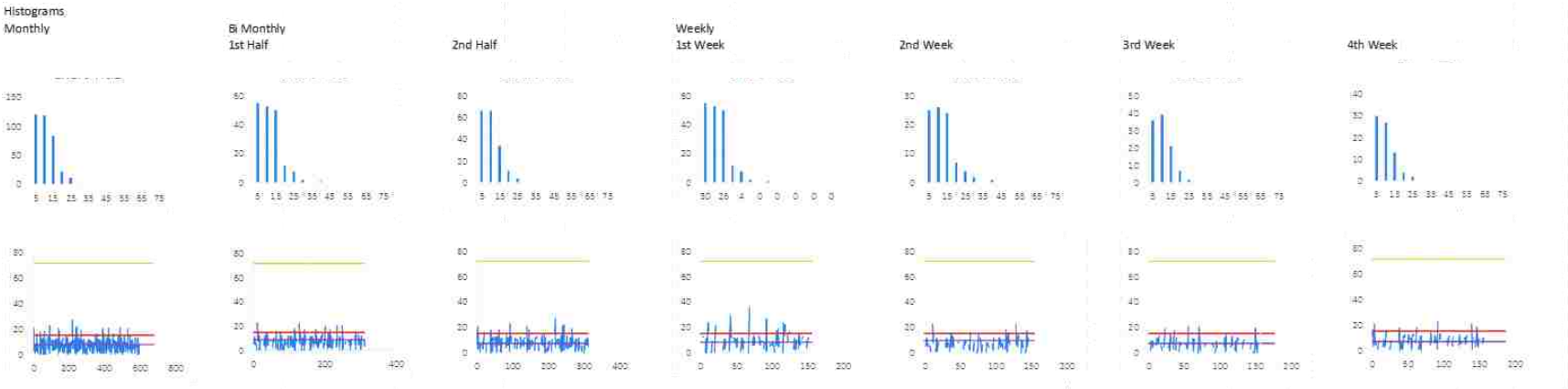


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug



Aug to Sept

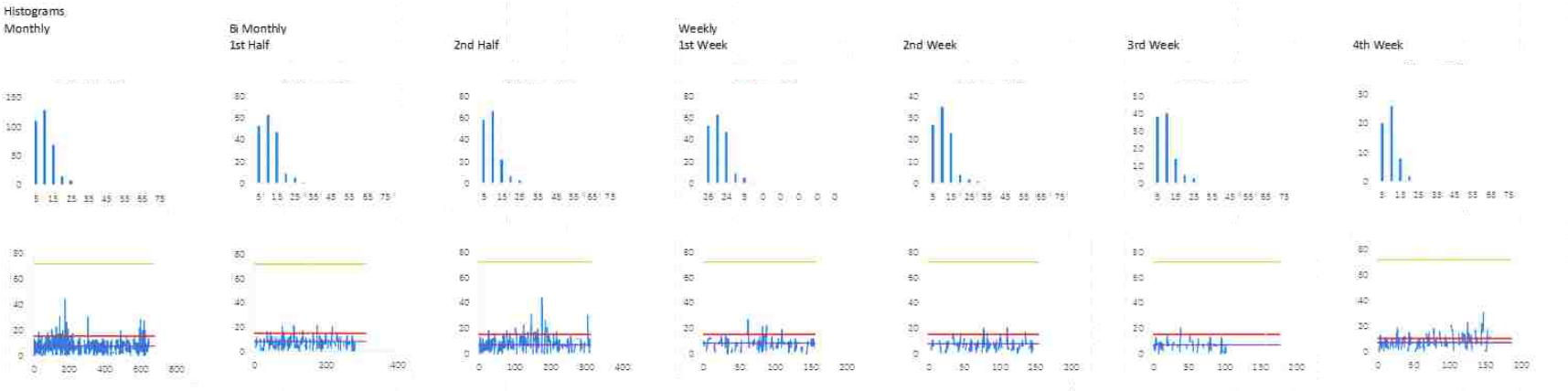
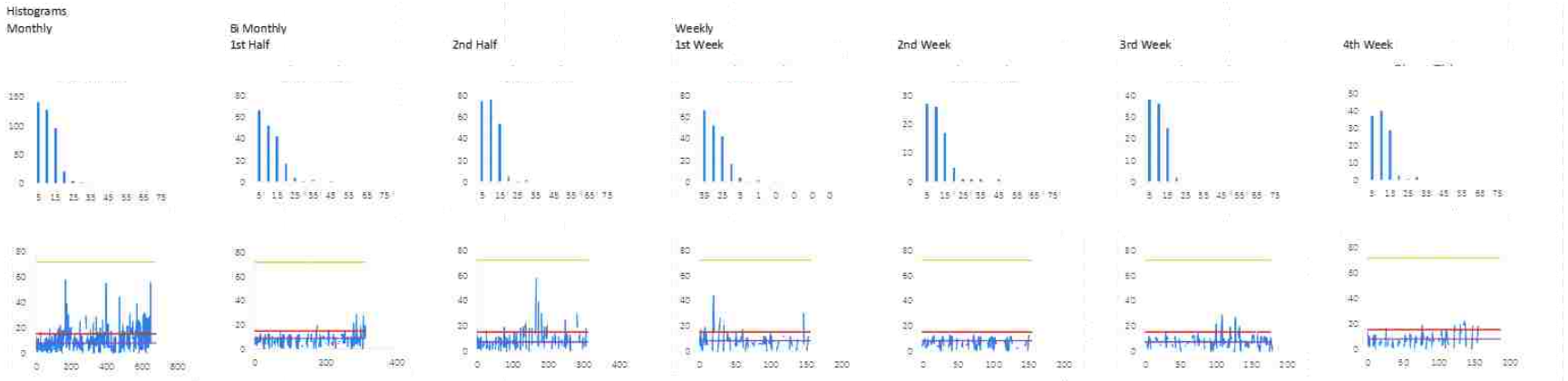


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

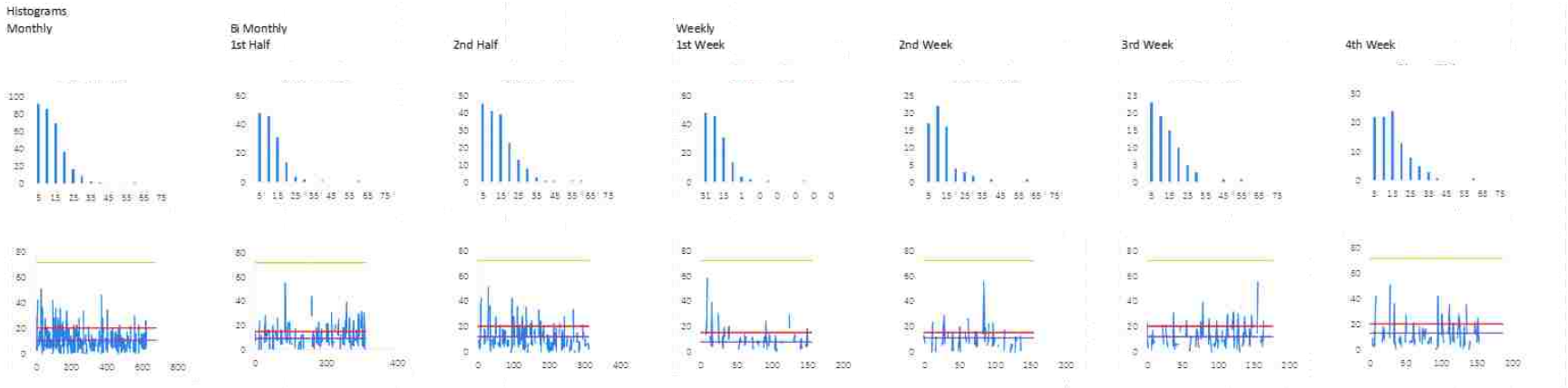
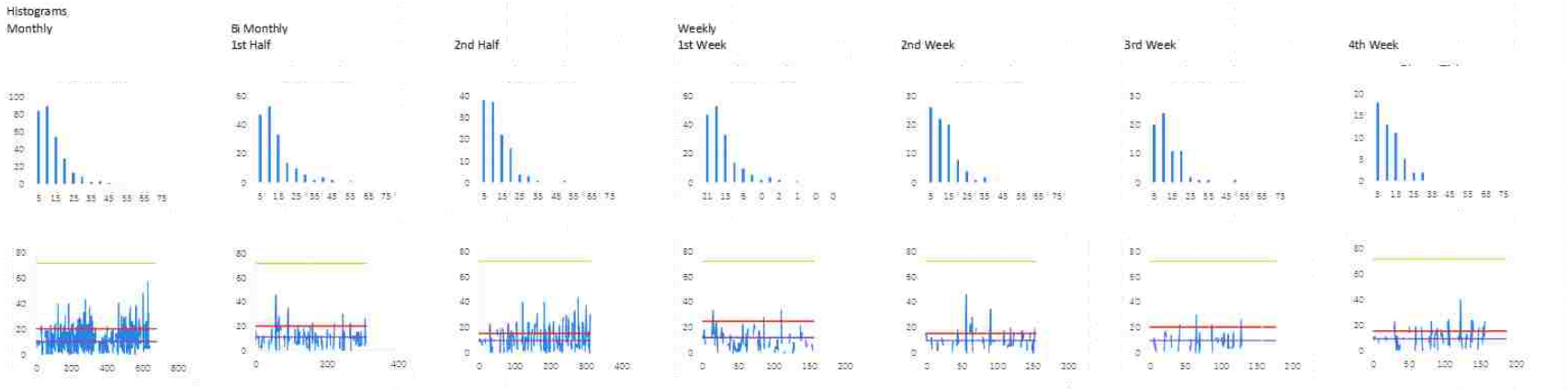


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

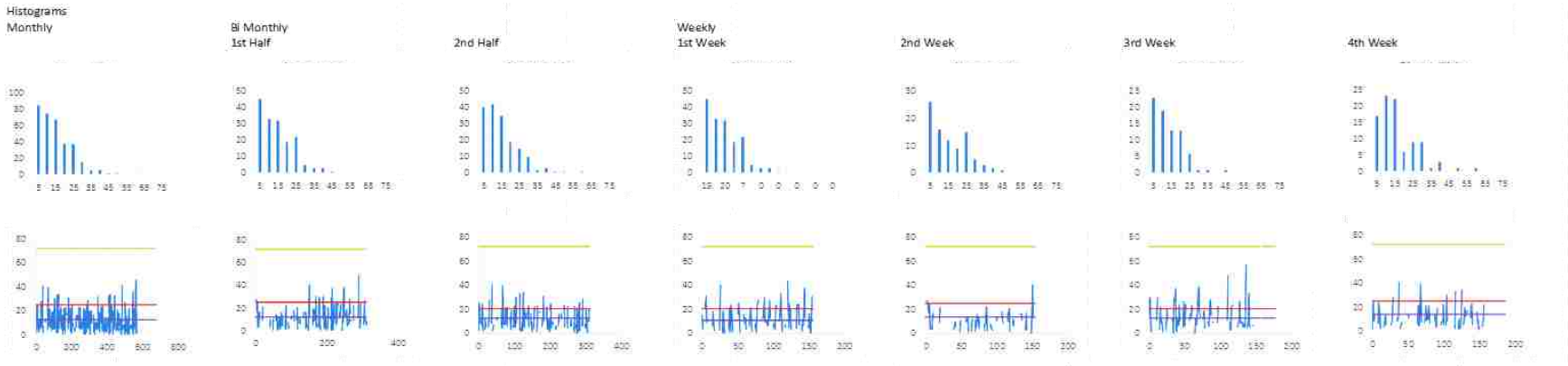
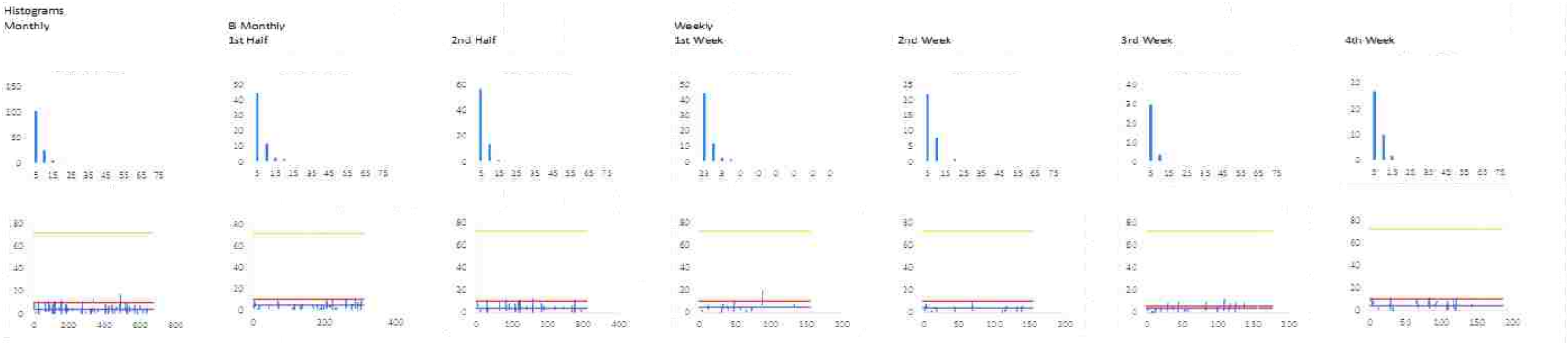


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Small Black Long Sleeve T Shirt

Jan to Feb



Feb to March

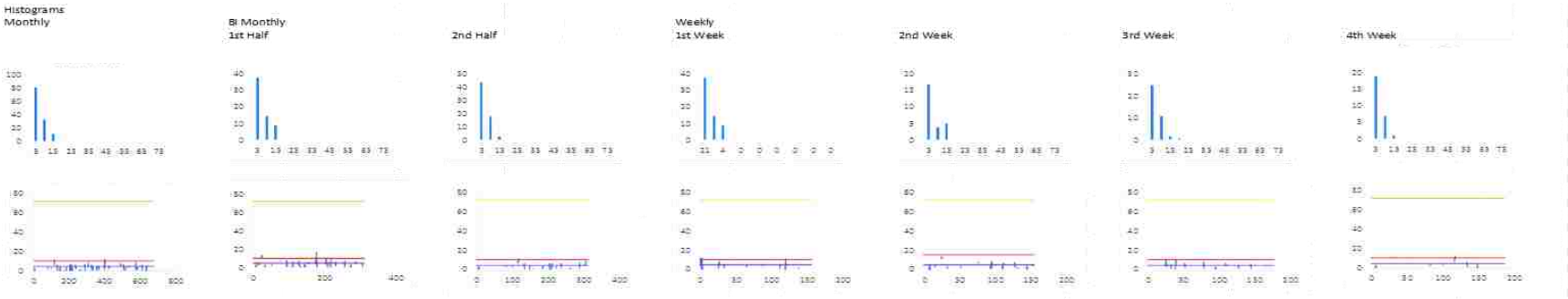
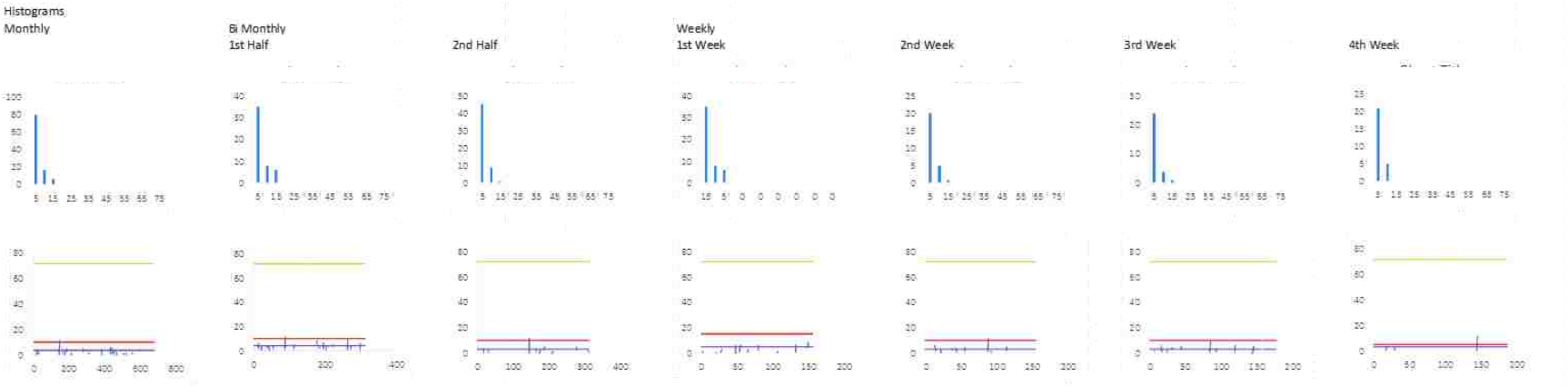


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

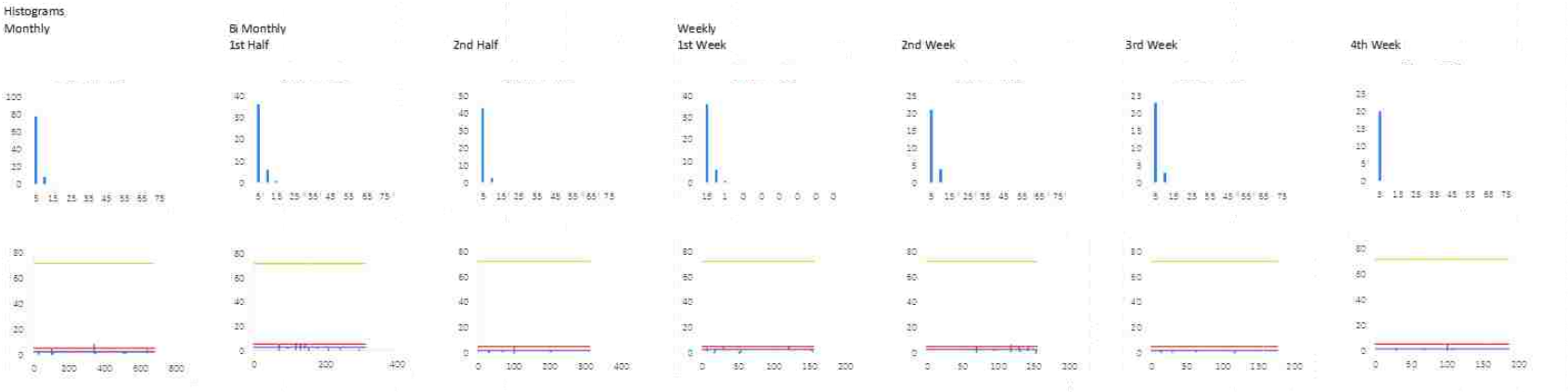
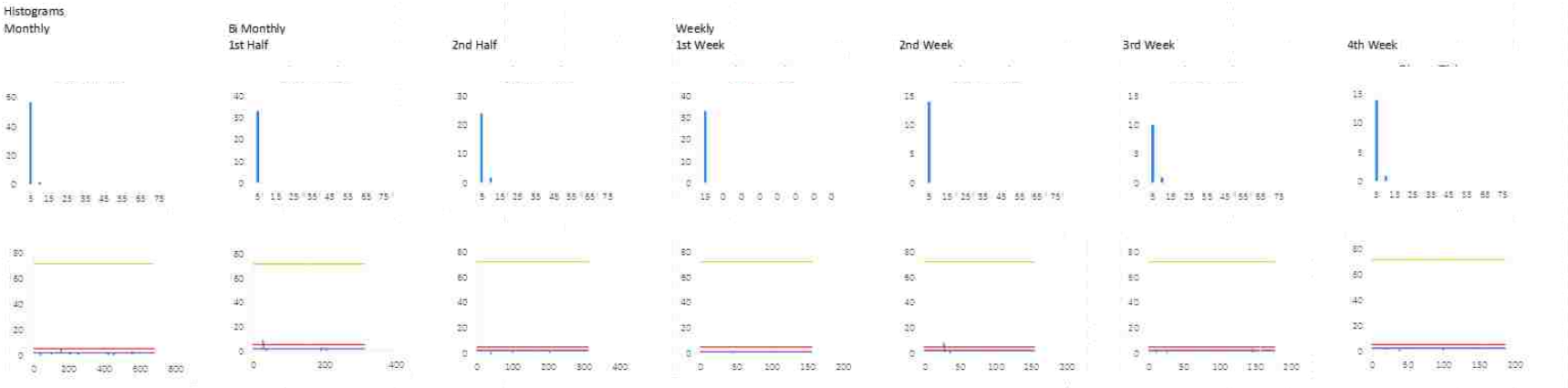


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

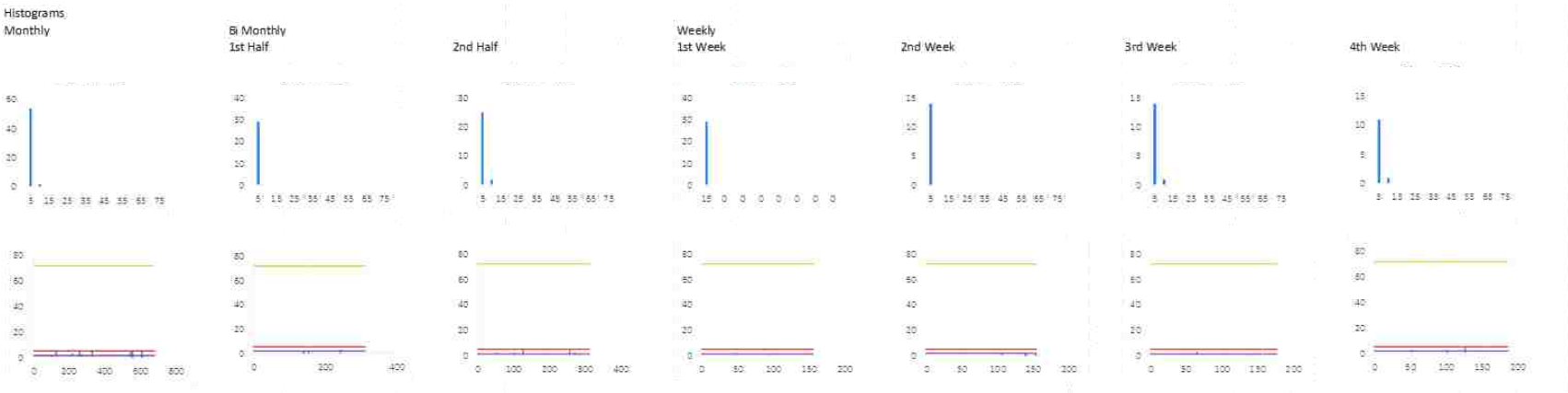
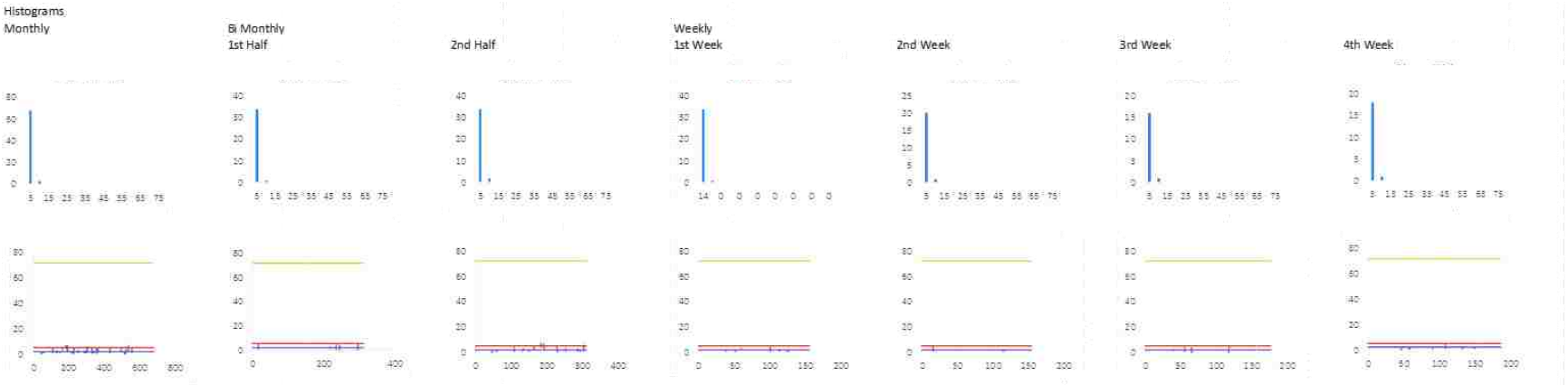


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug



Aug to Sept

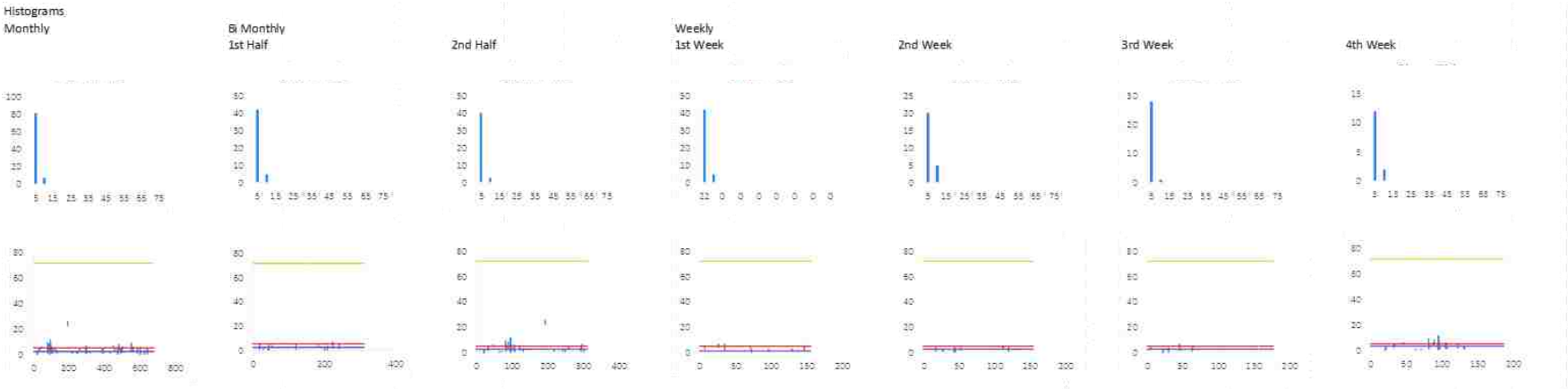
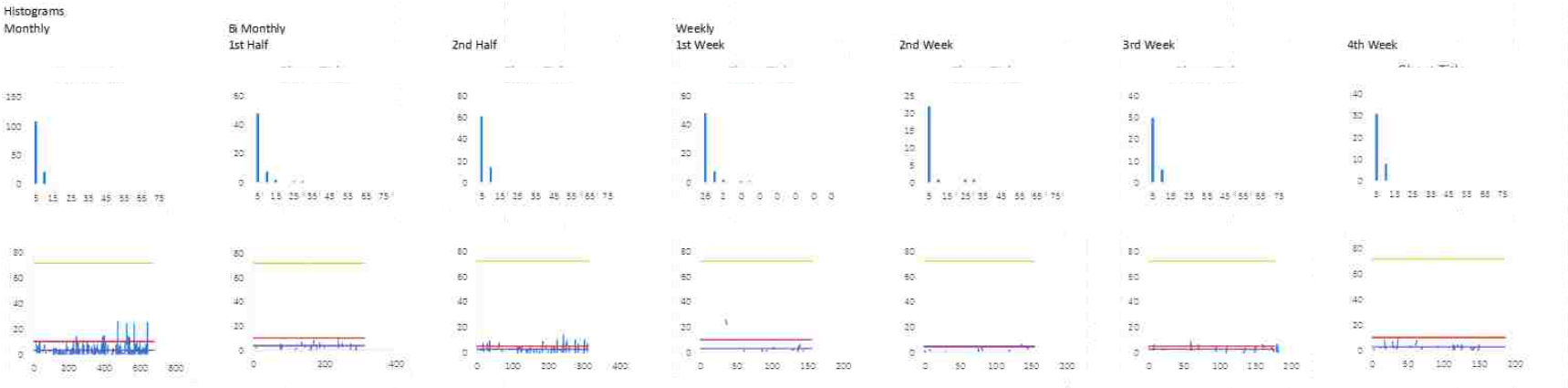


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

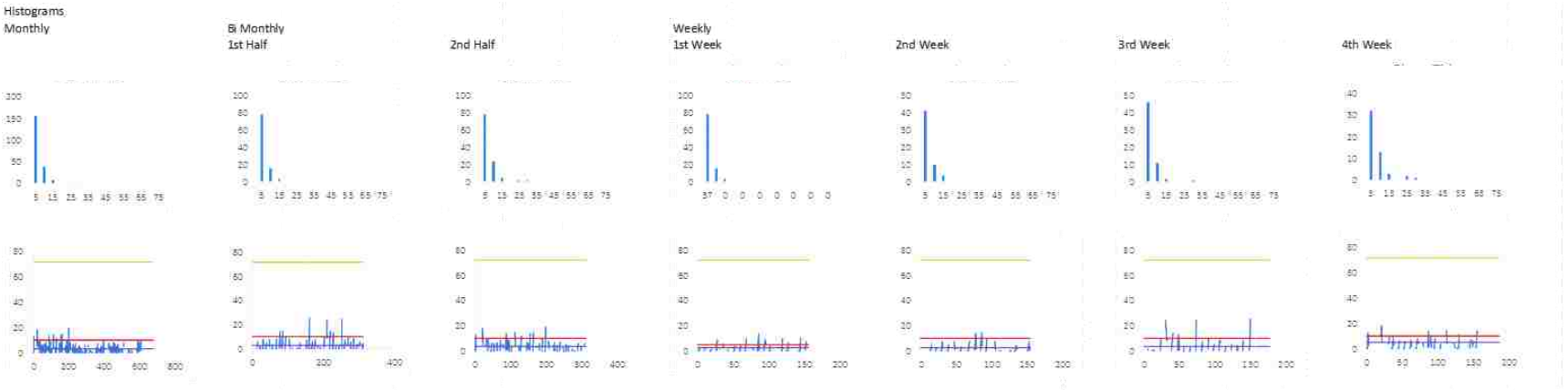
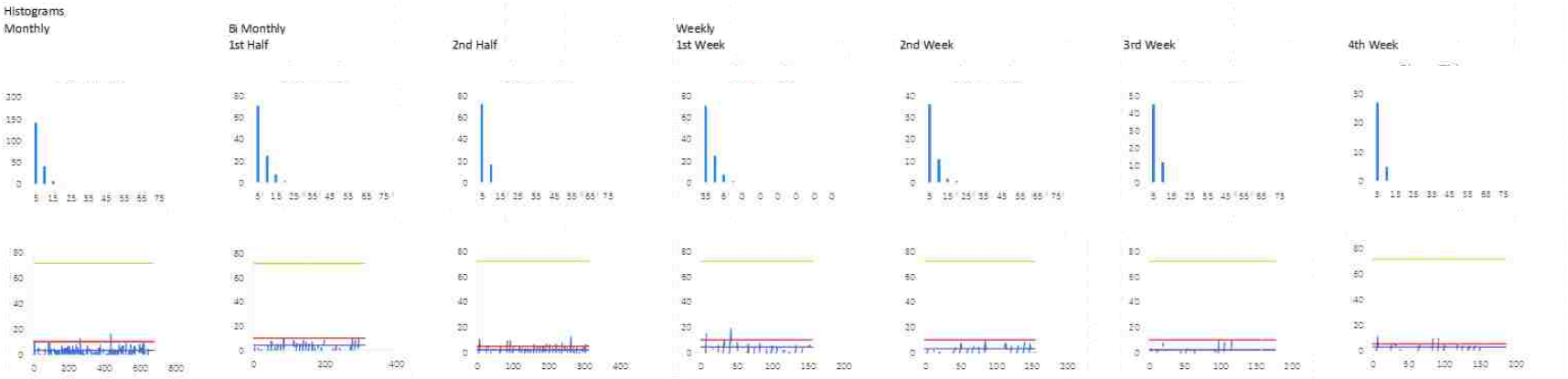


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

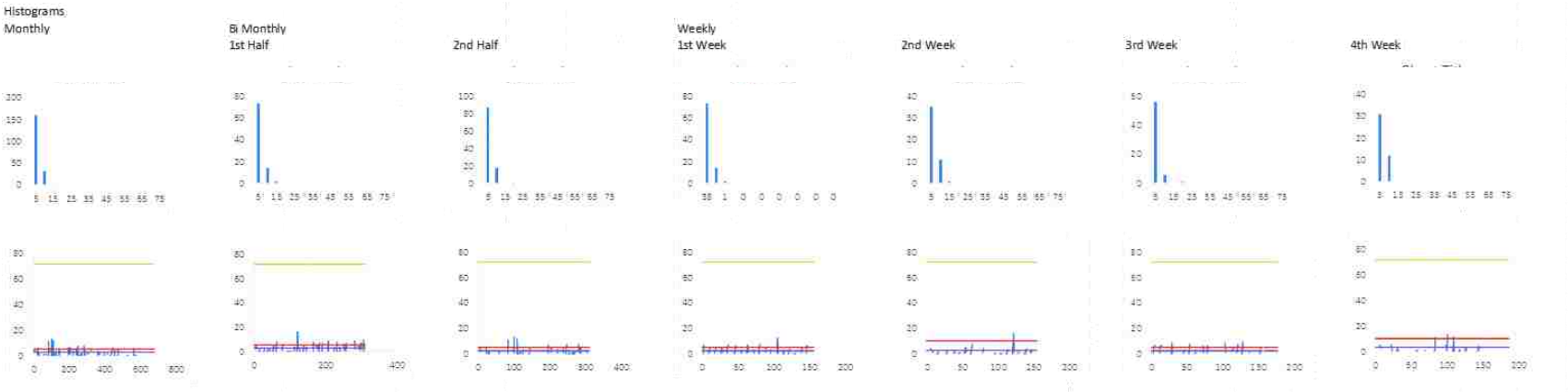
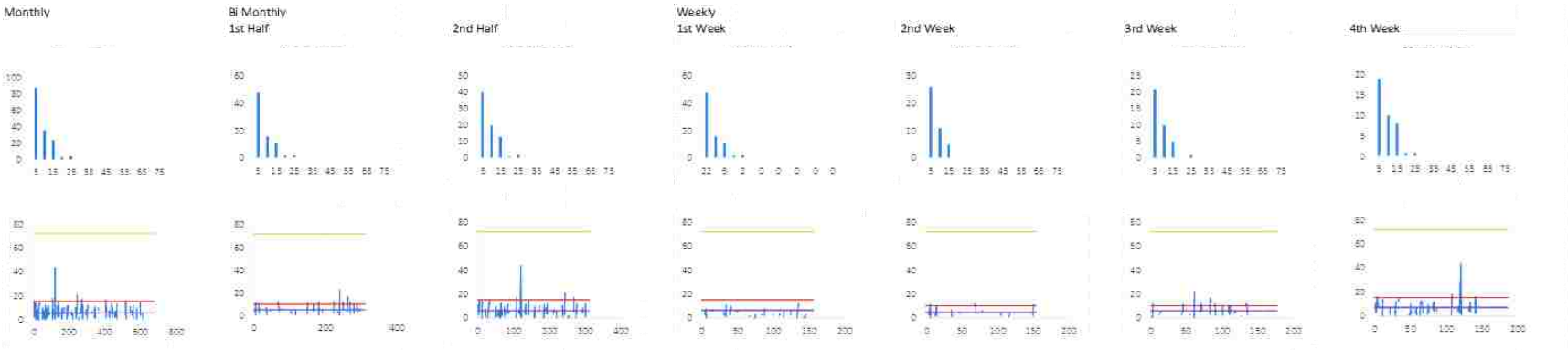


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Medium Black Long Sleeve T shirt

Jan to Feb



Feb to March

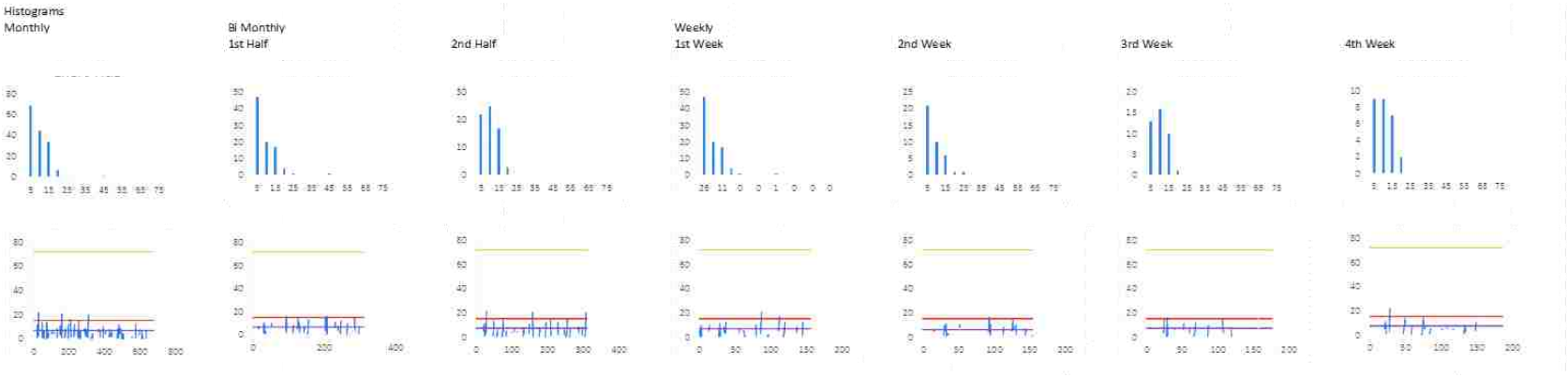
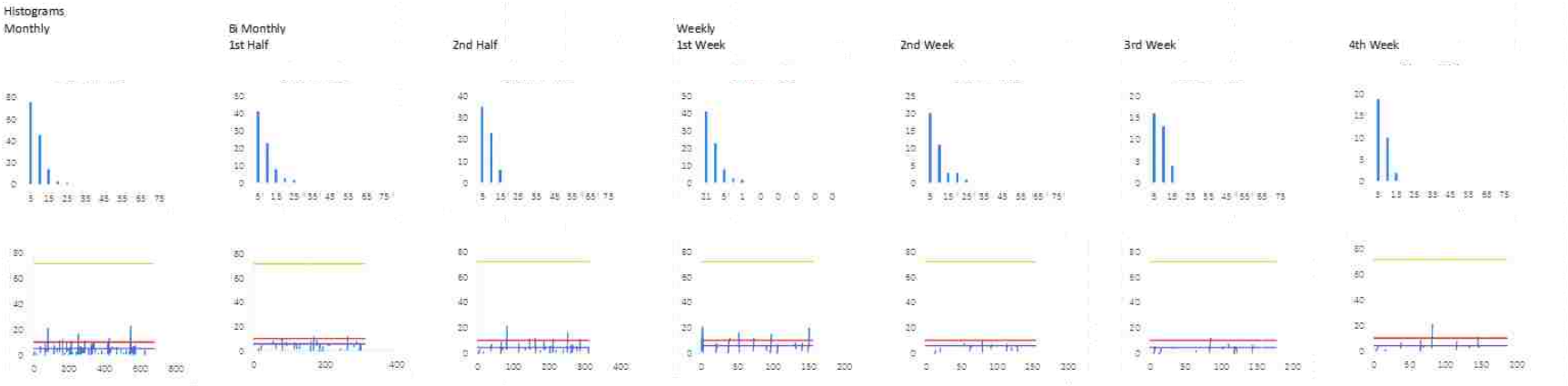


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

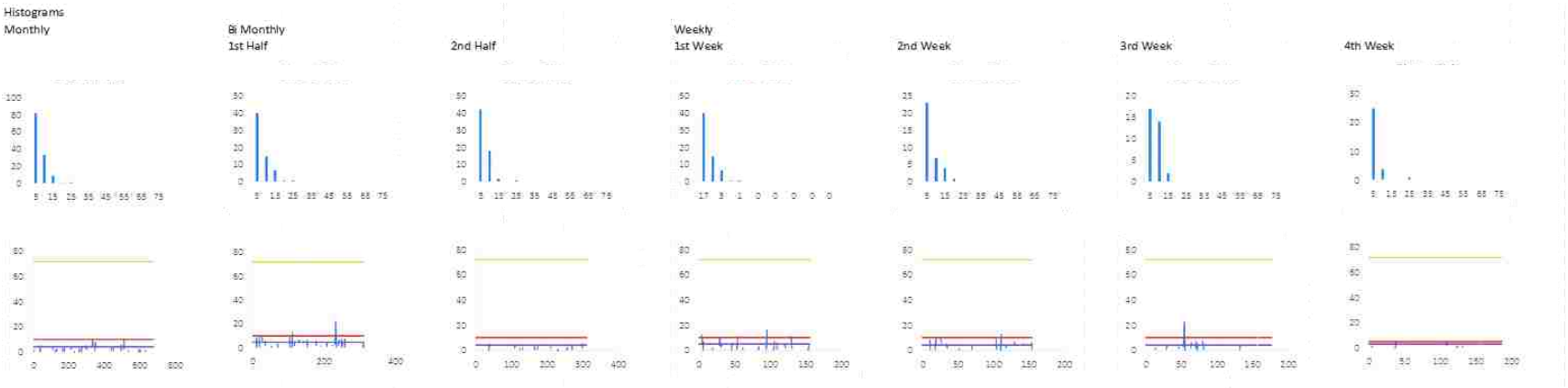


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June

June to July

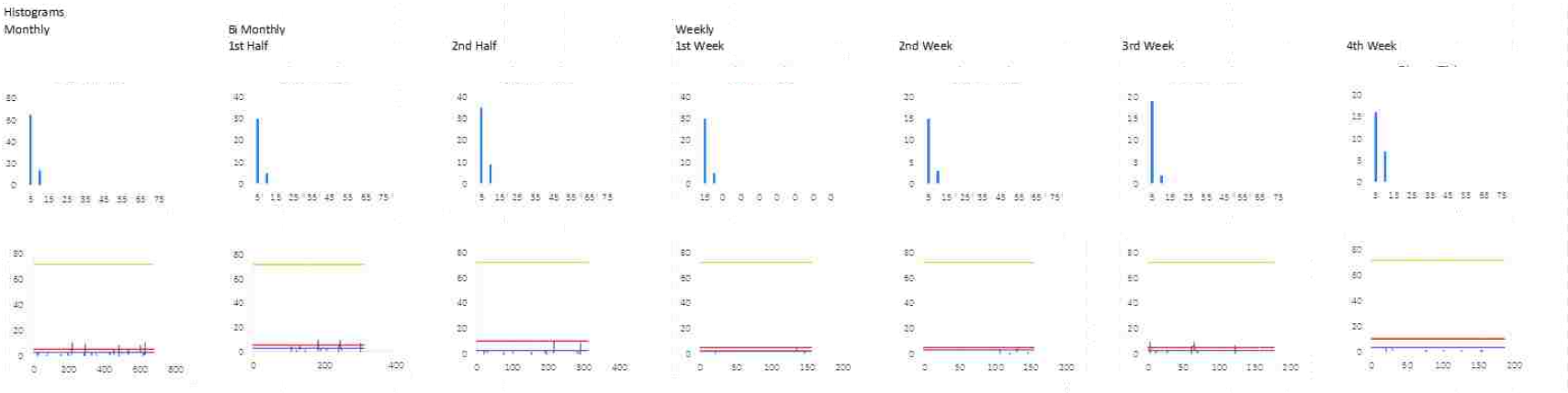
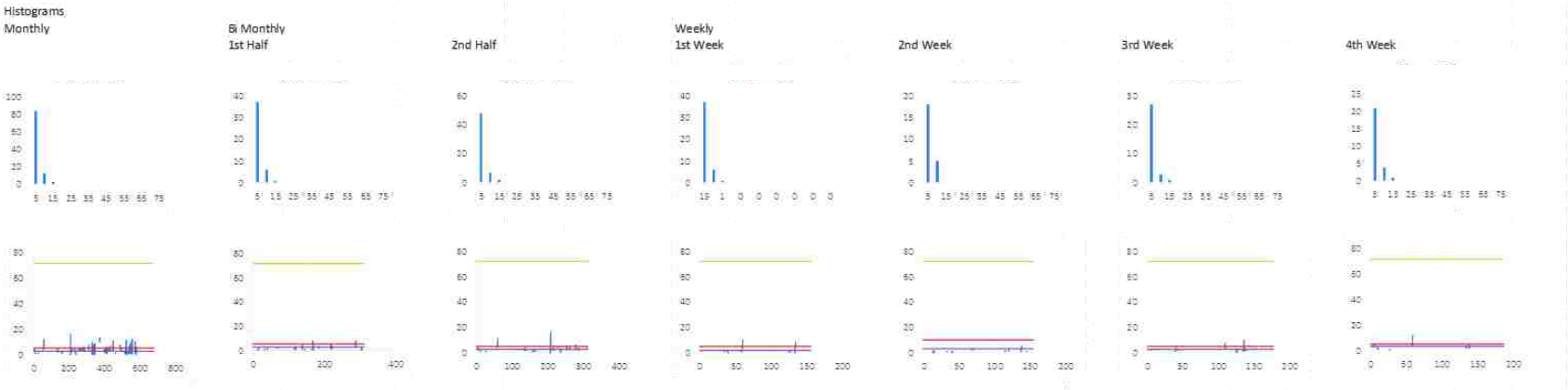


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug



Aug to September

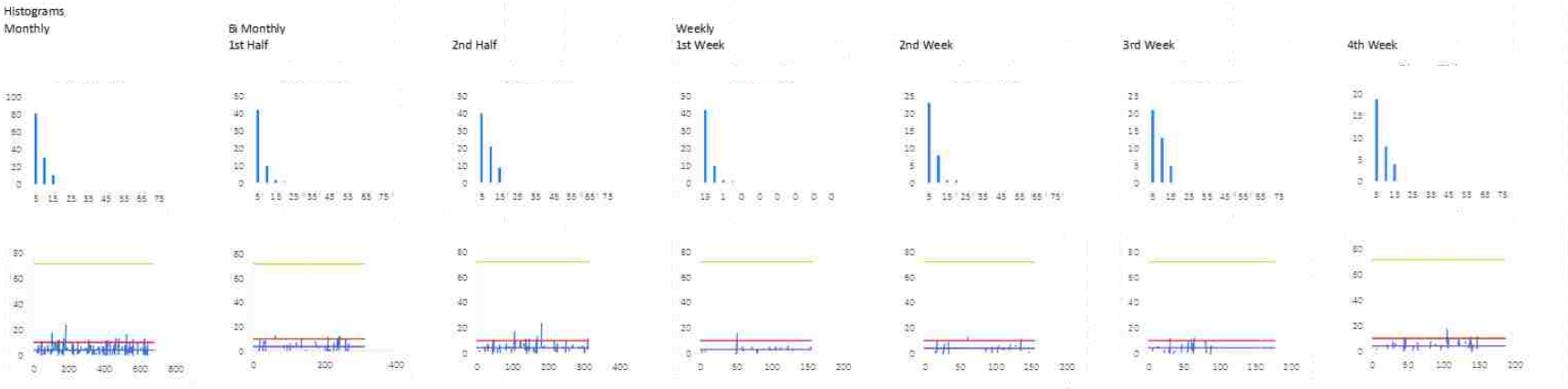
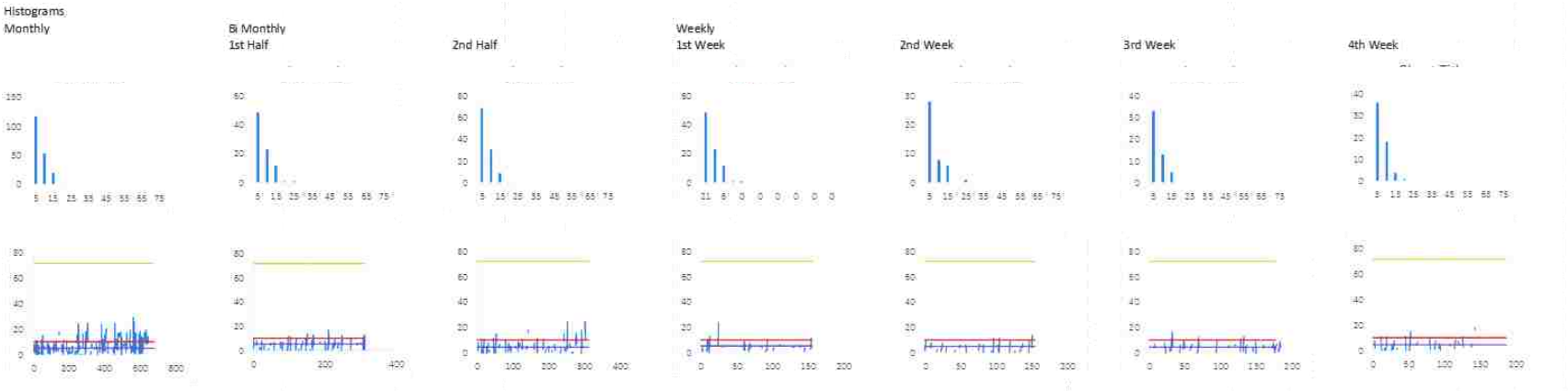


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

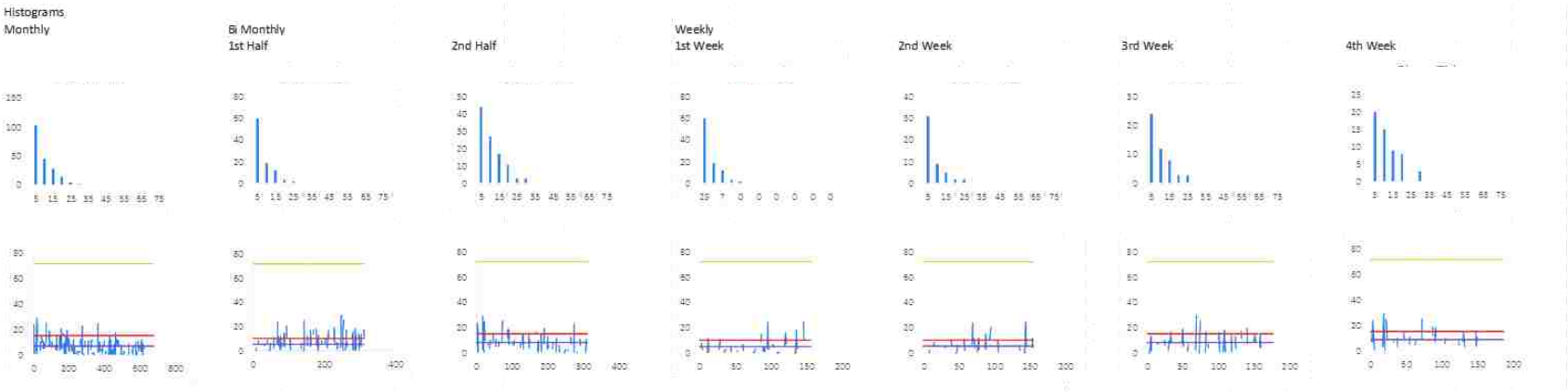
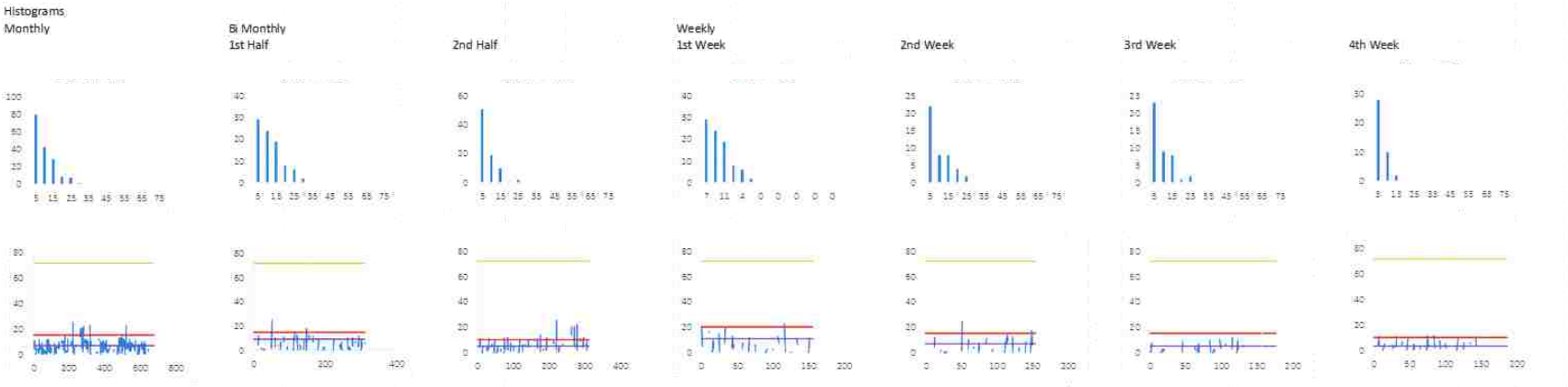


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

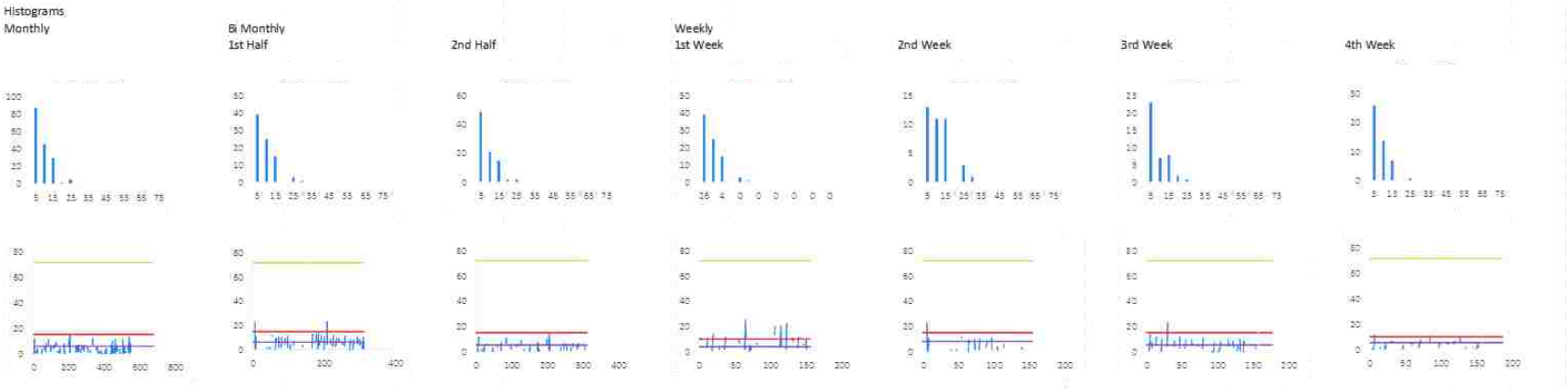
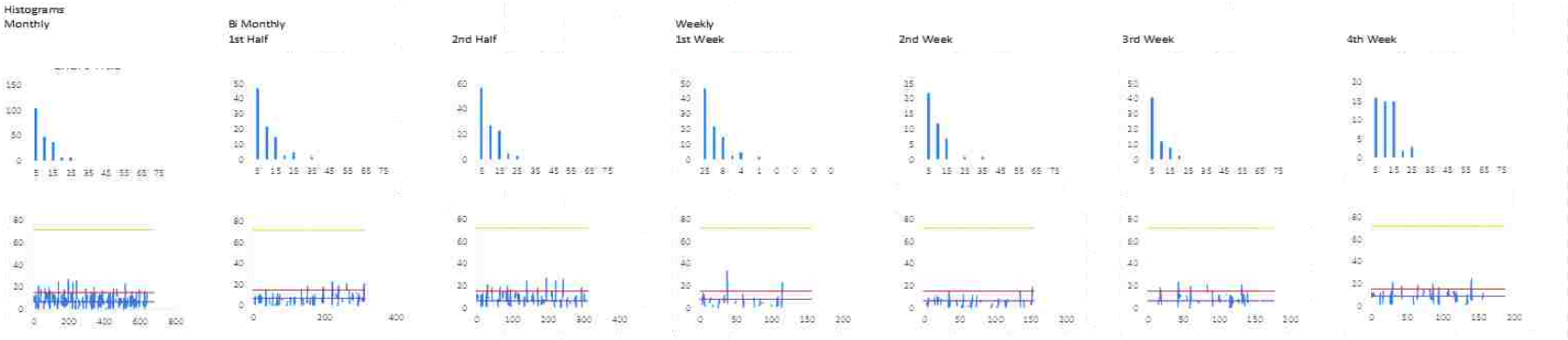


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Large Black Long Sleeve T Shirt

Jan to Feb



Feb to March

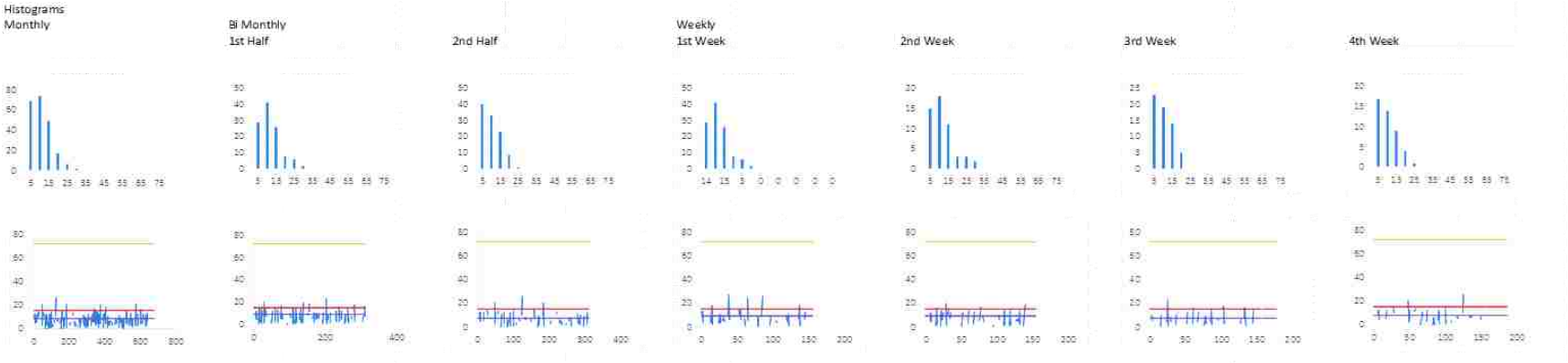
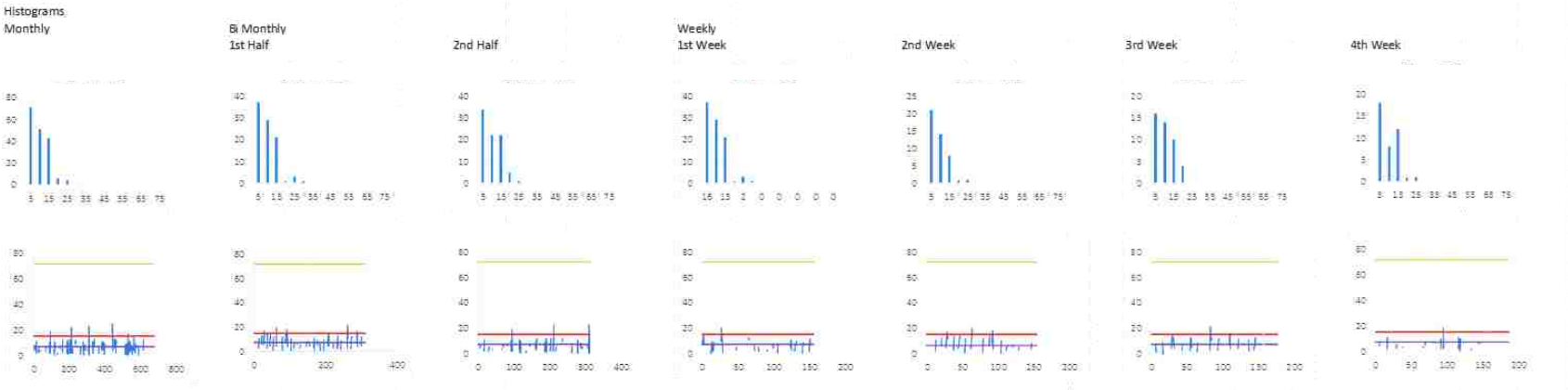


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

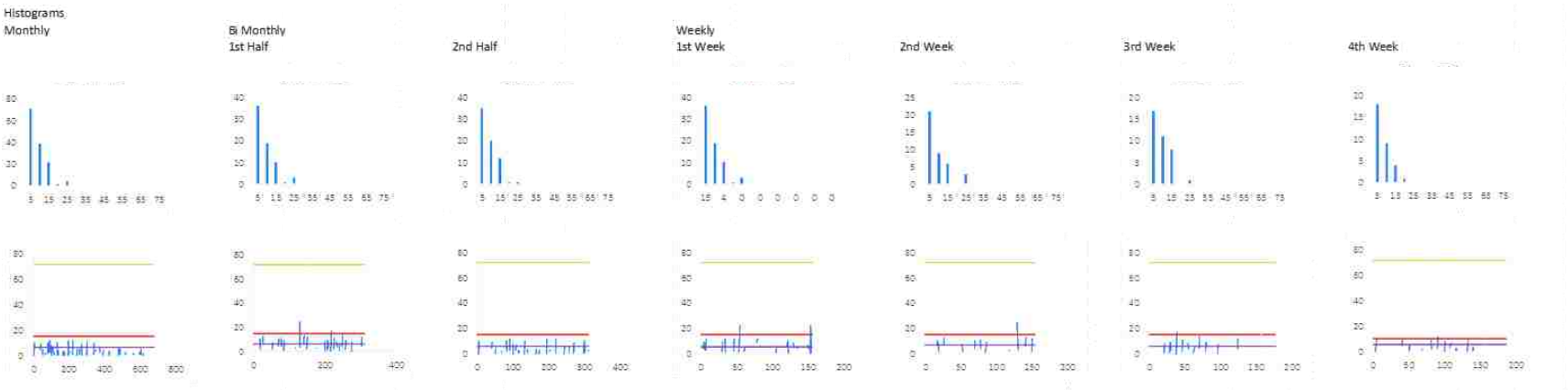
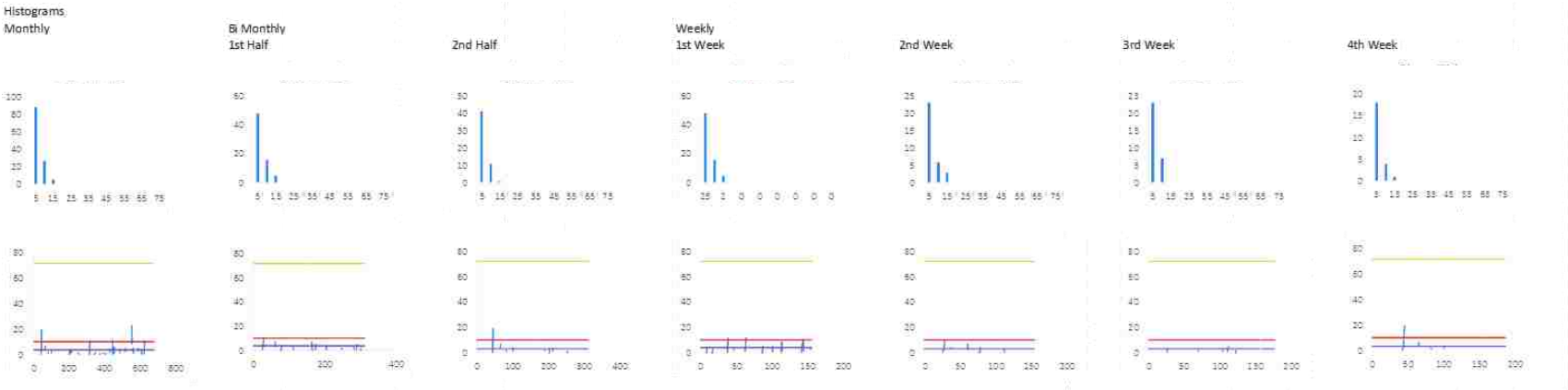


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

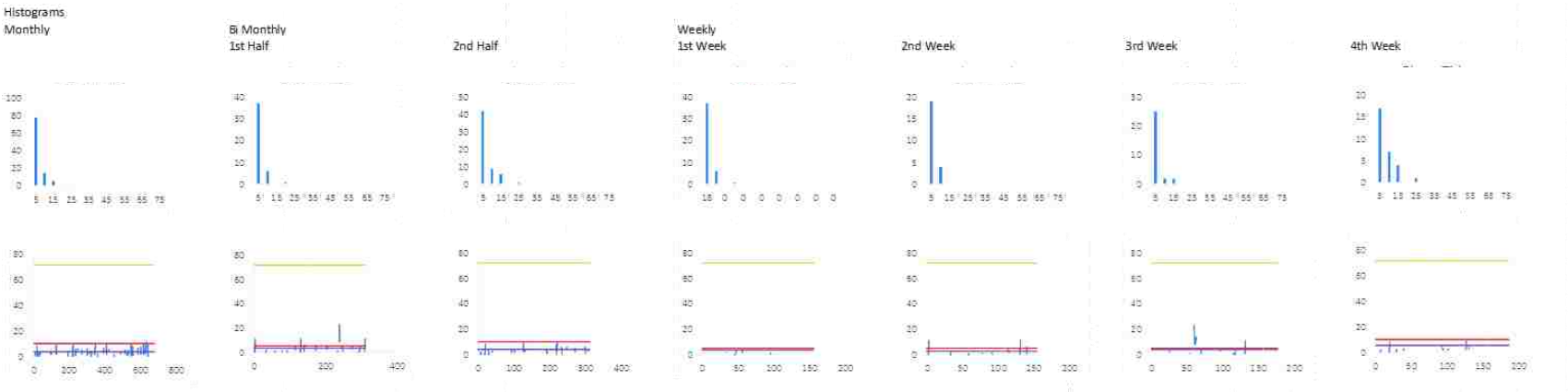
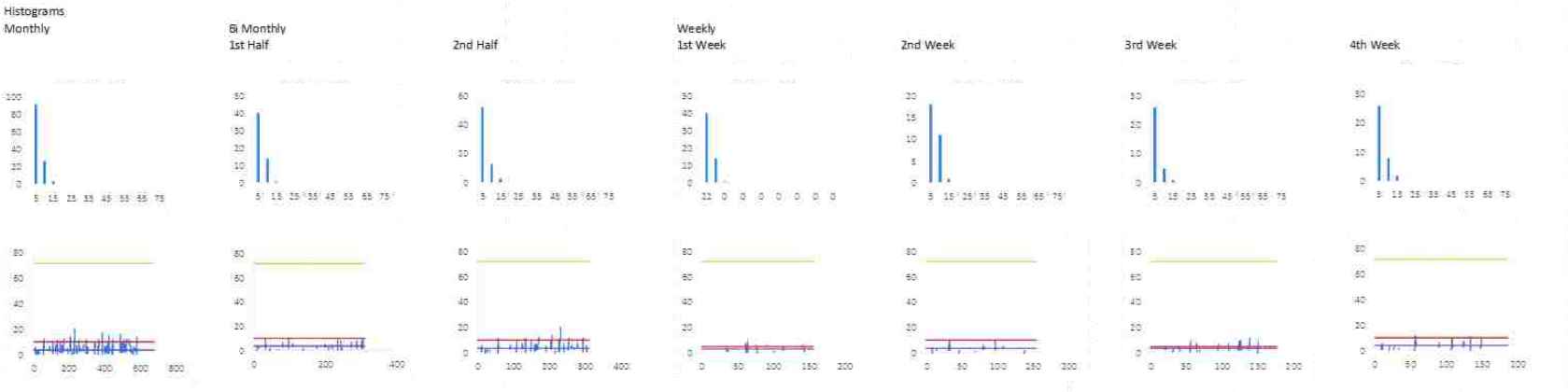


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug



Aug to September

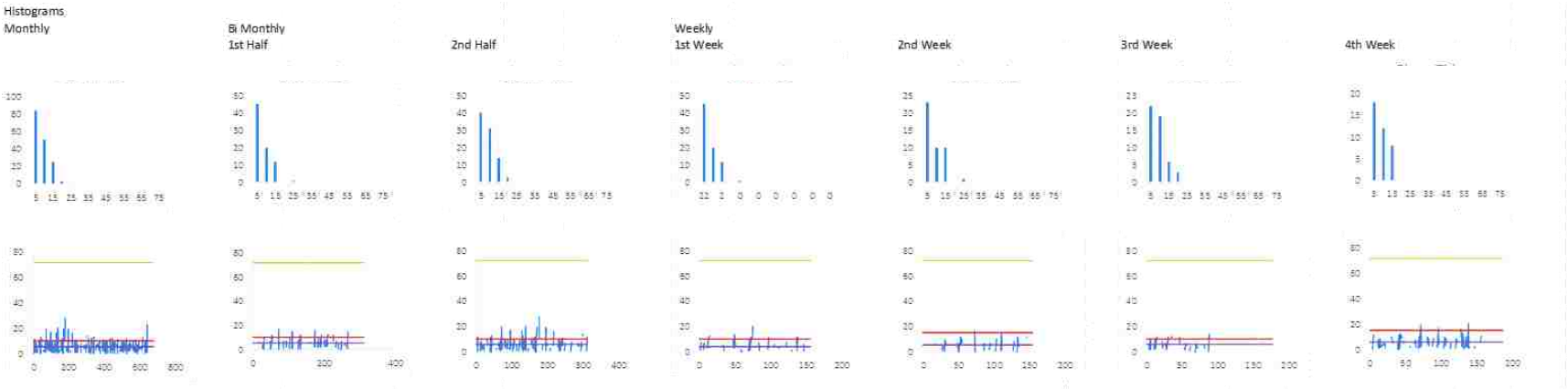
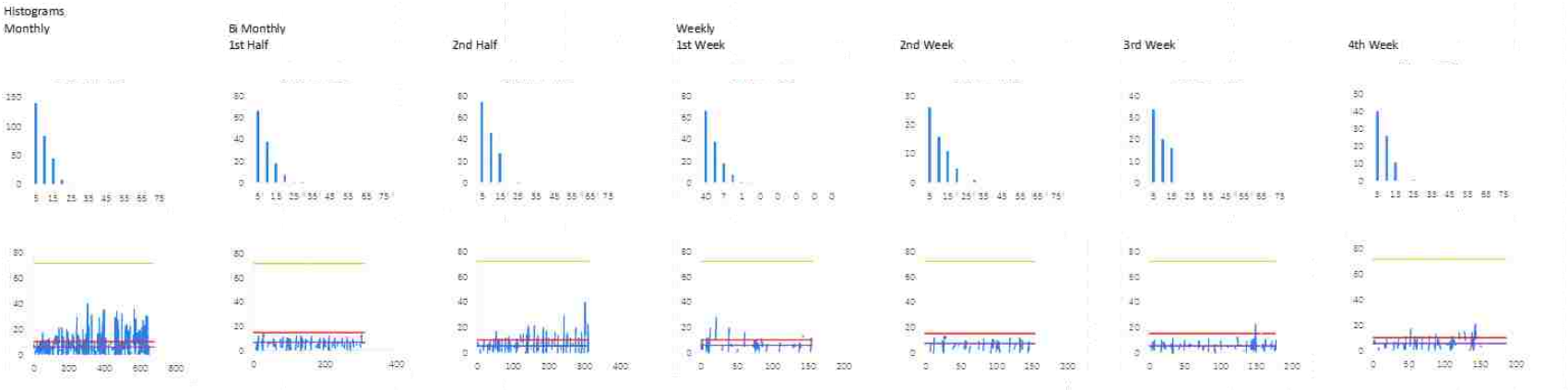


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

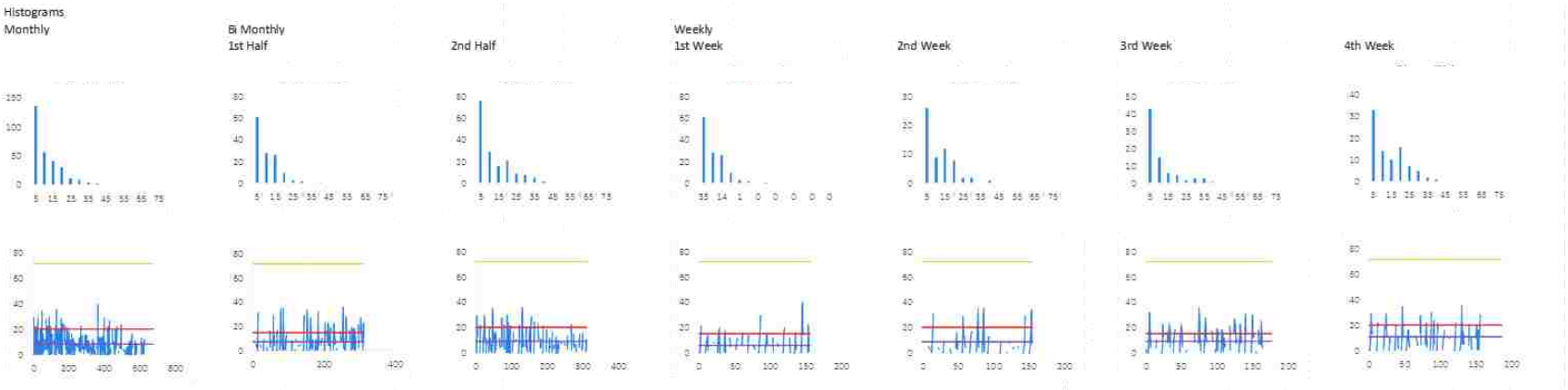
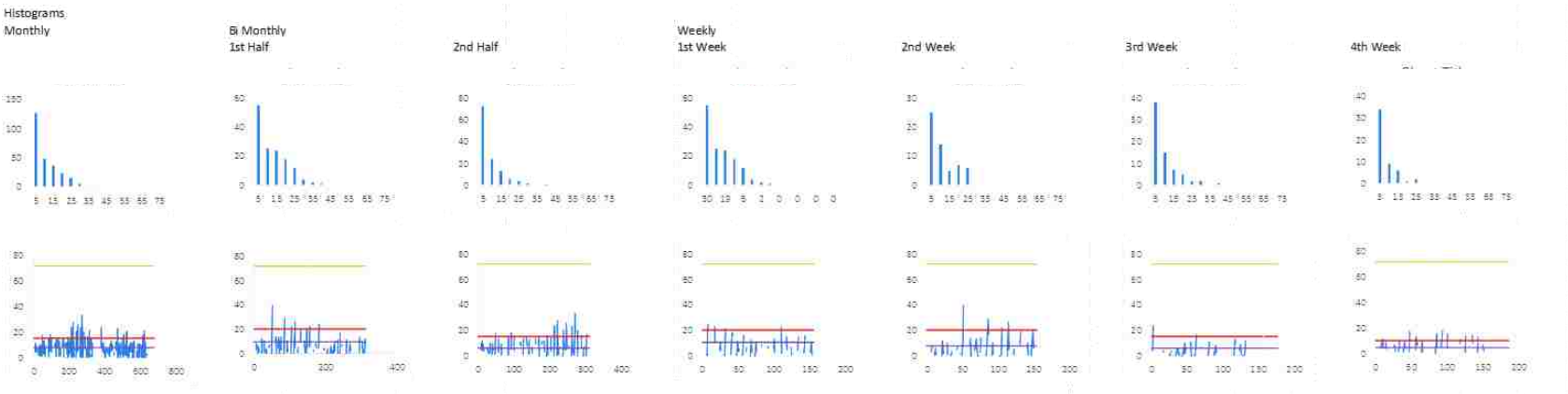


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

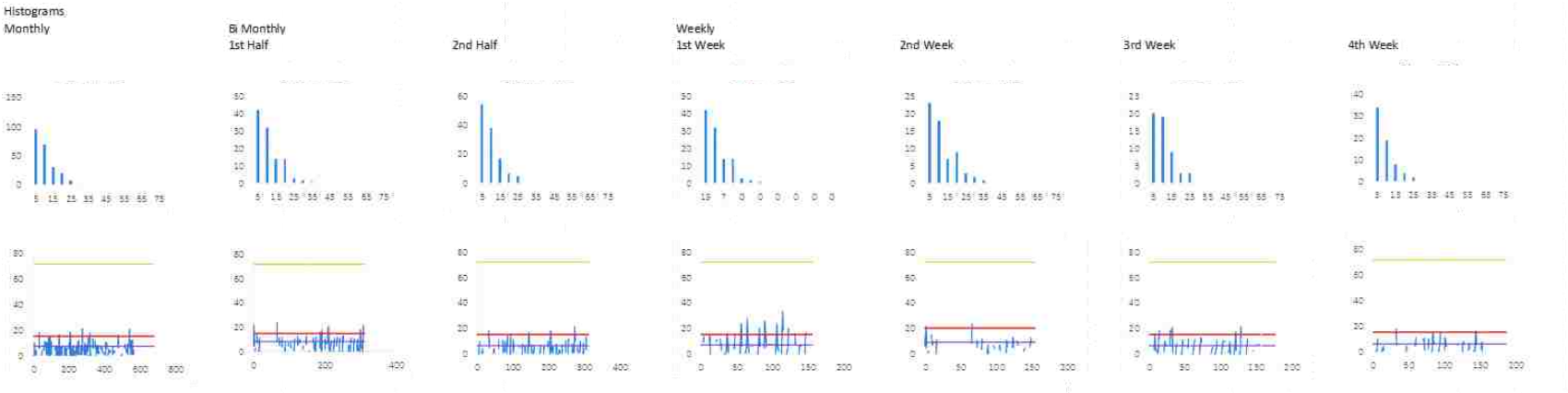
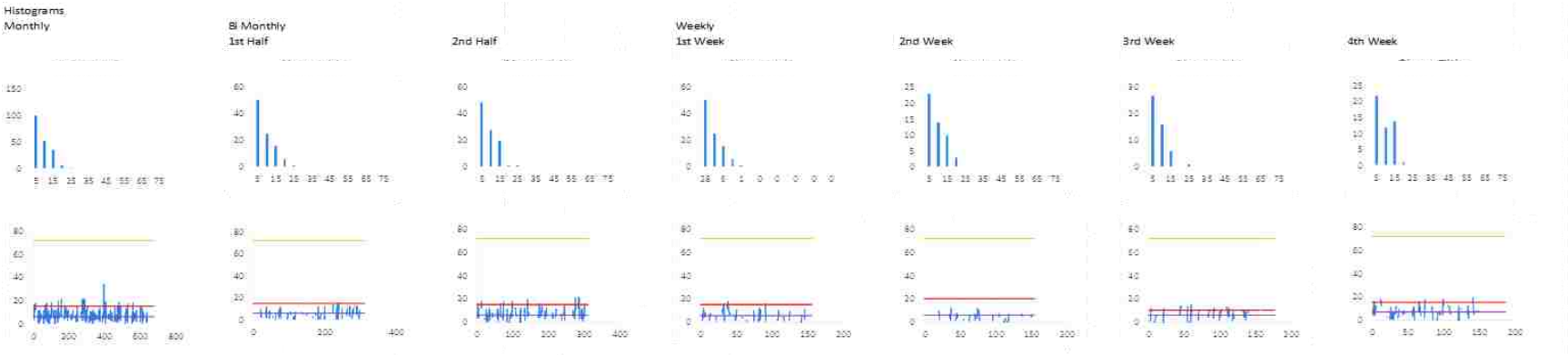


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

XL Long Sleeve T Shirt Black

Jan to Feb



Feb to March

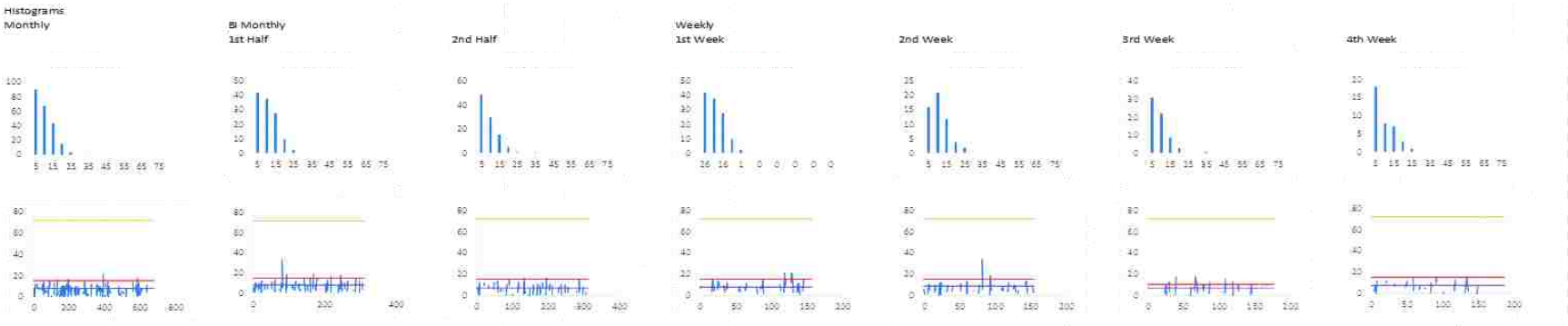
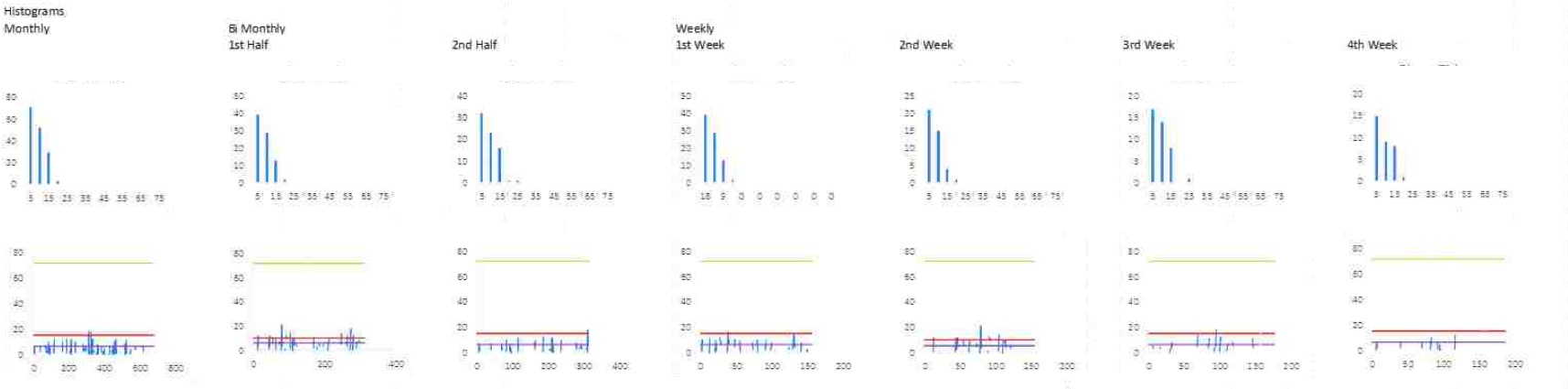


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

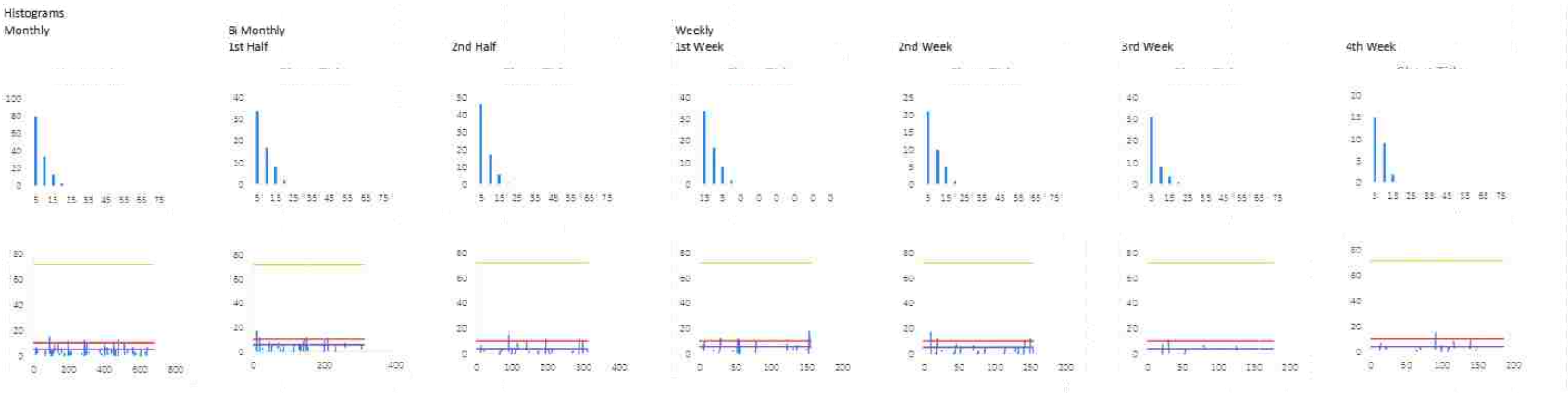
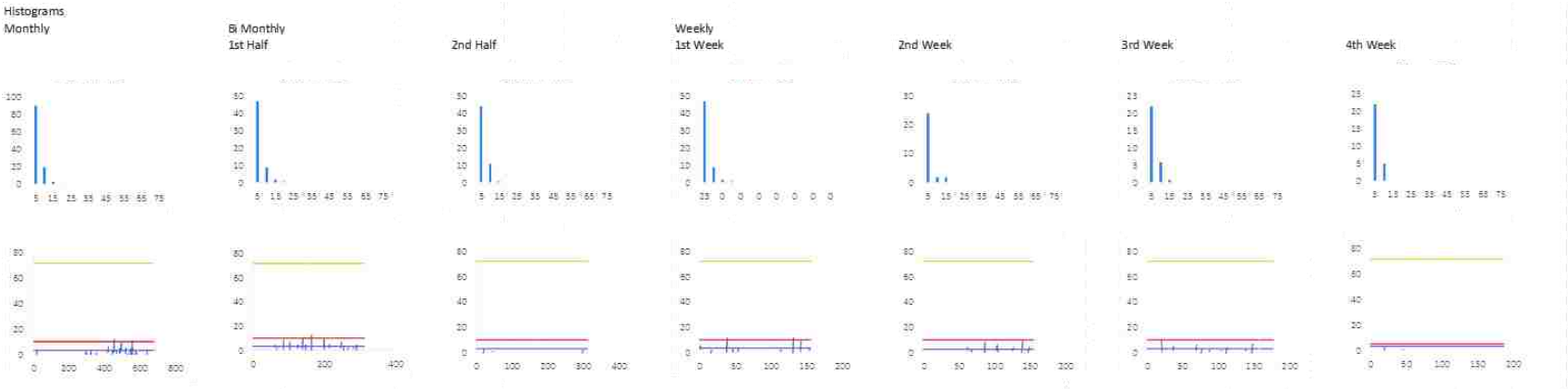


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

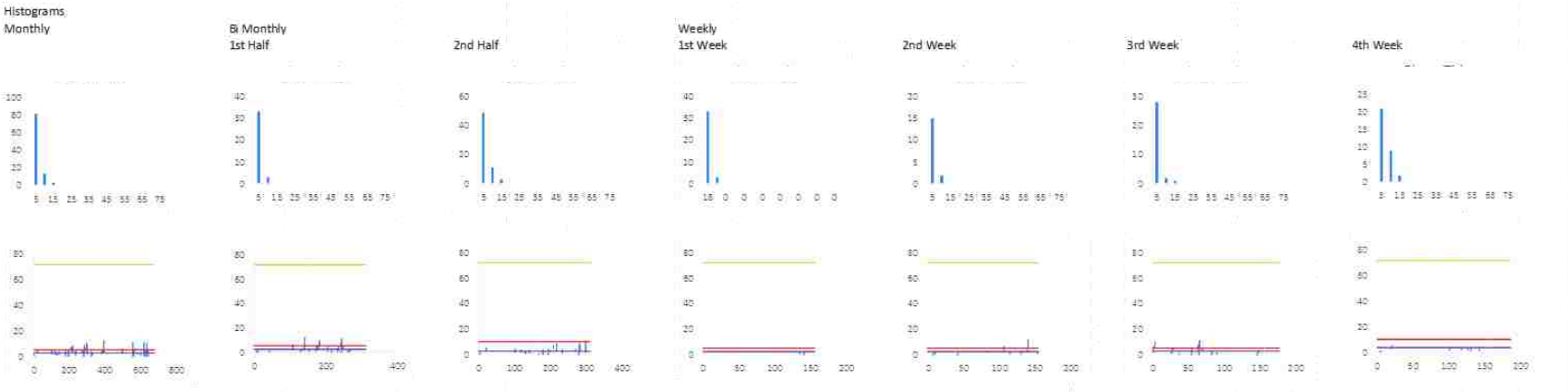
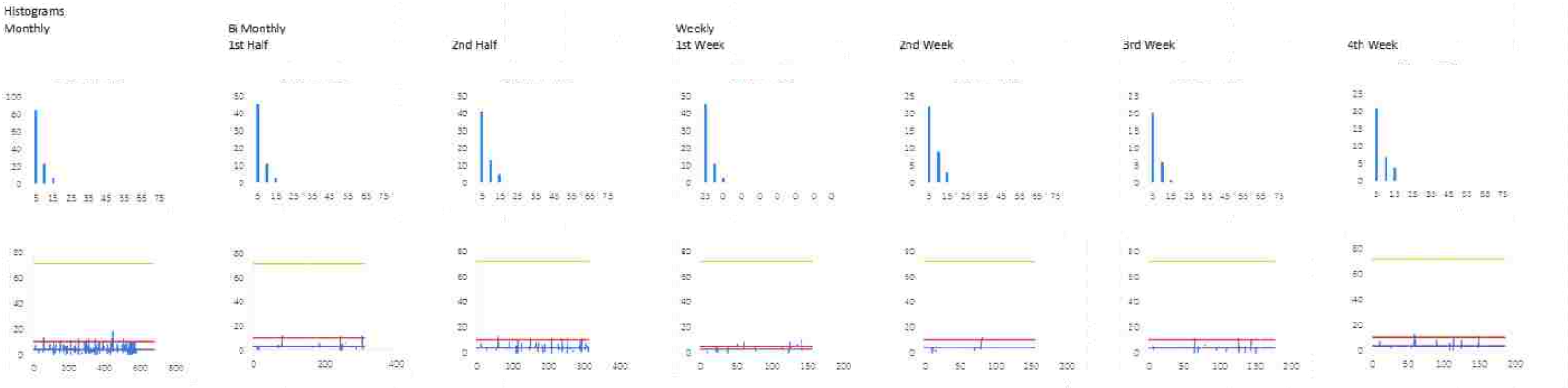


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug



Aug to September

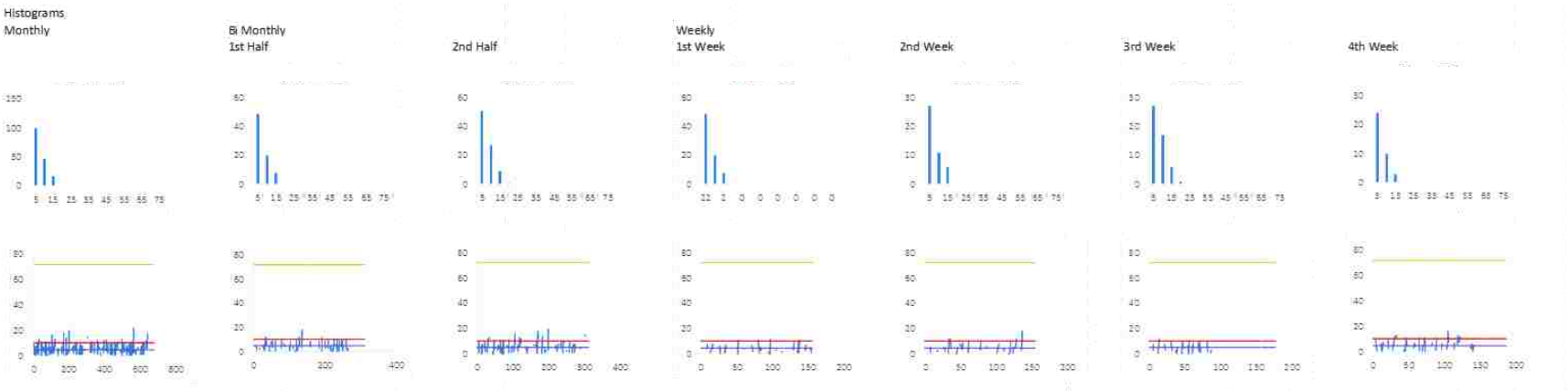
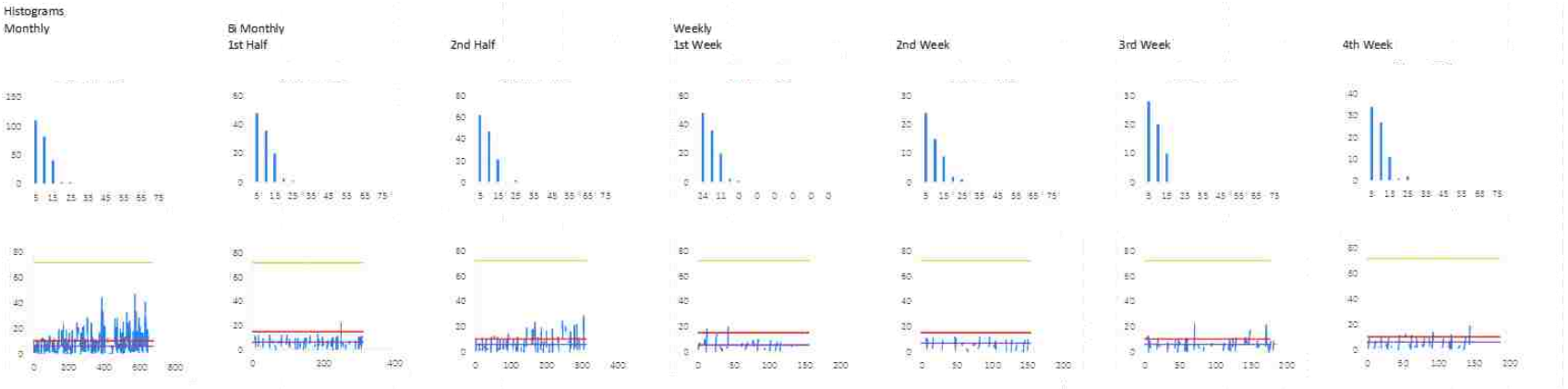


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

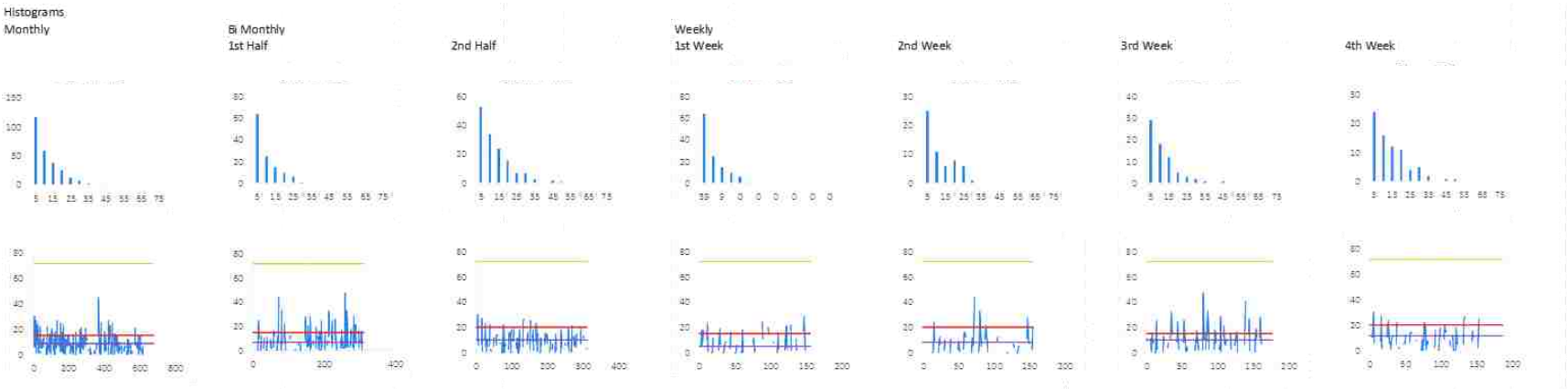
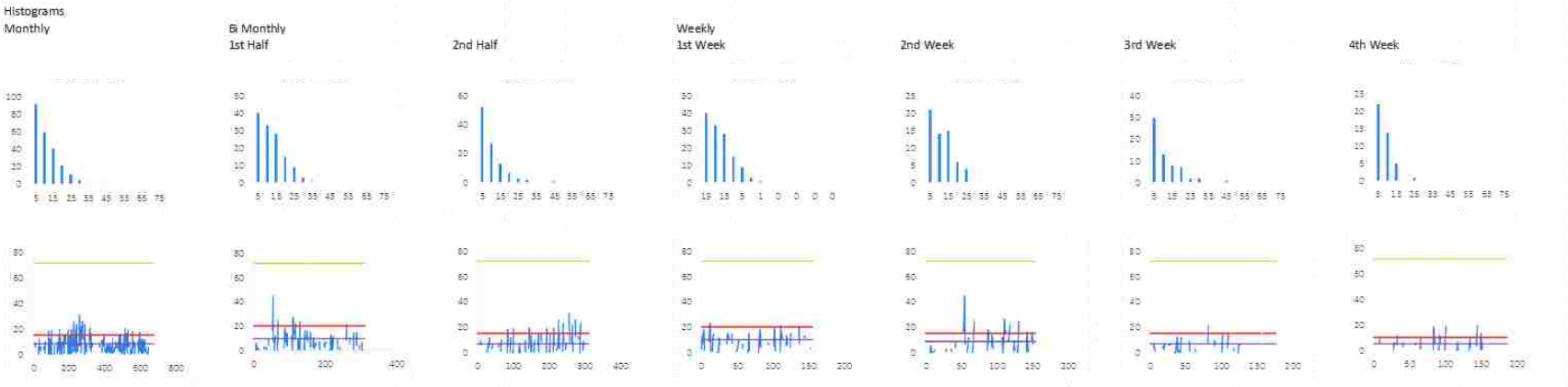


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

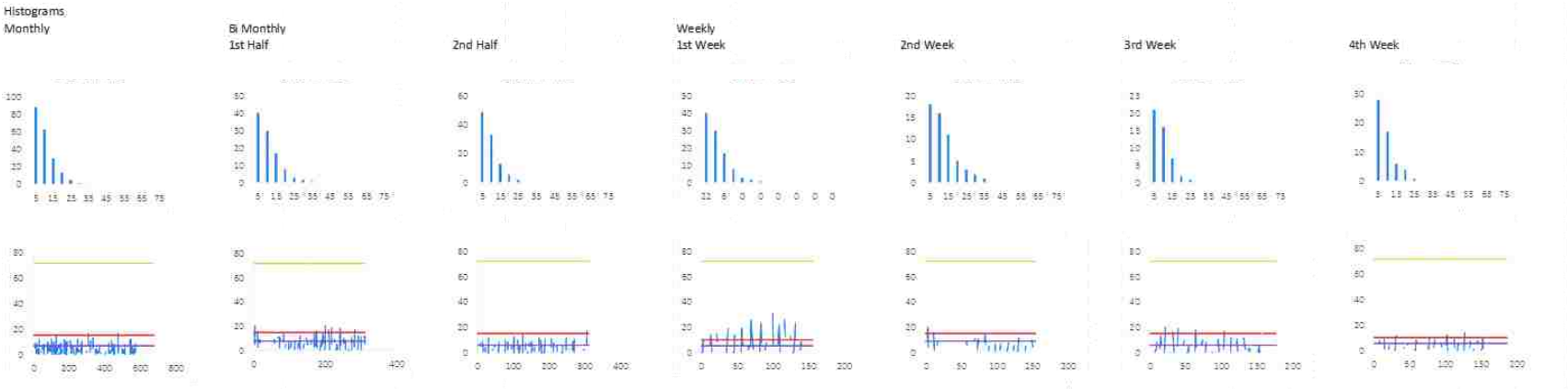


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

XXL Long Sleeve t-shirt black

Jan to Feb

Feb to March

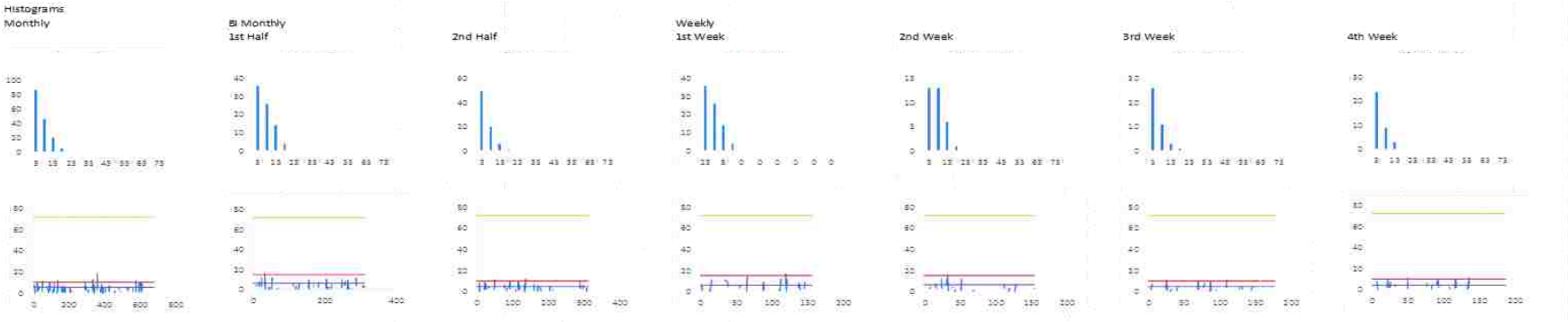
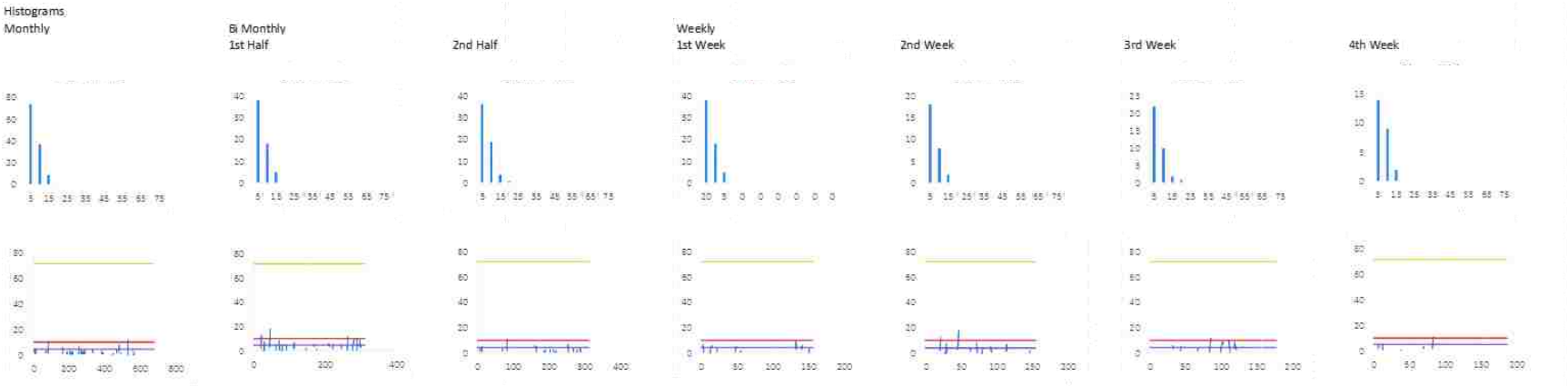


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

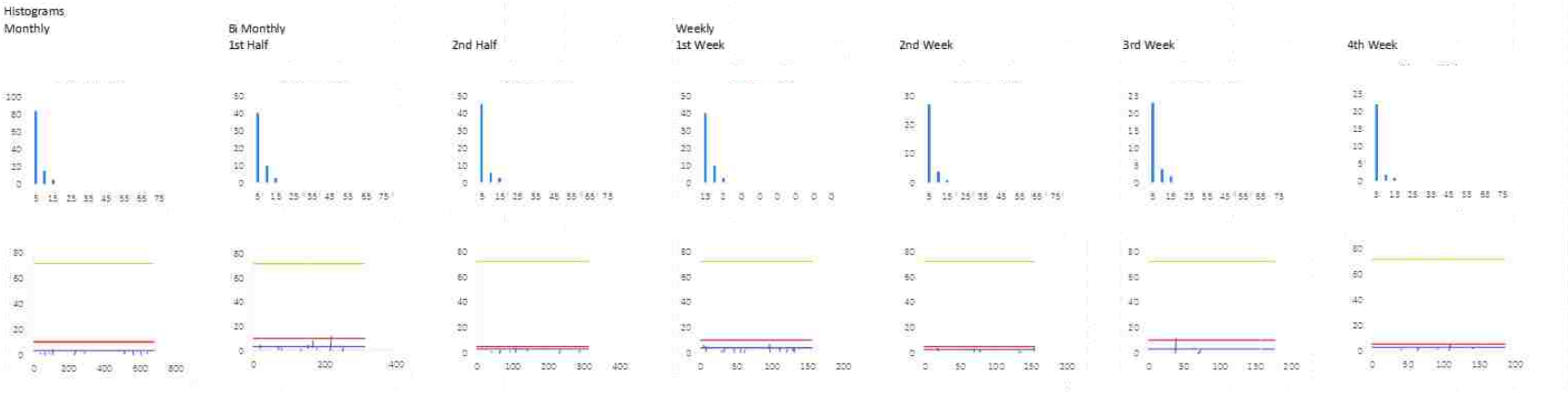
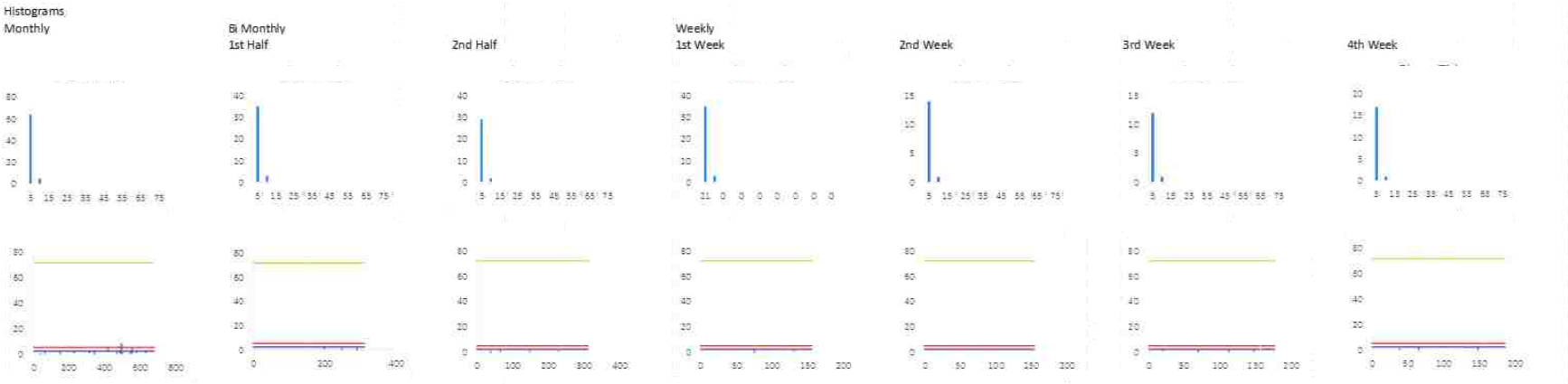


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

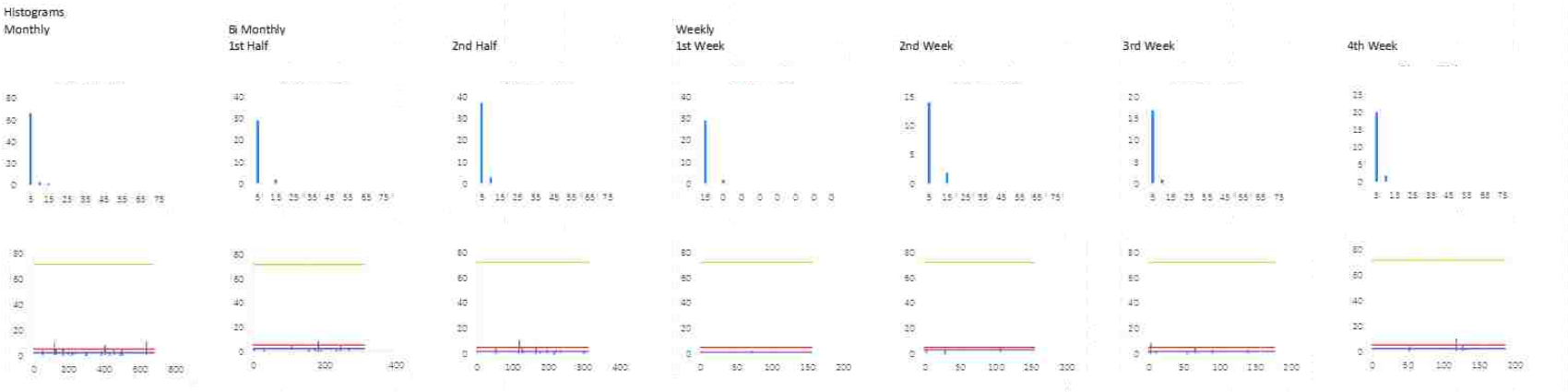


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug

Aug to Sept

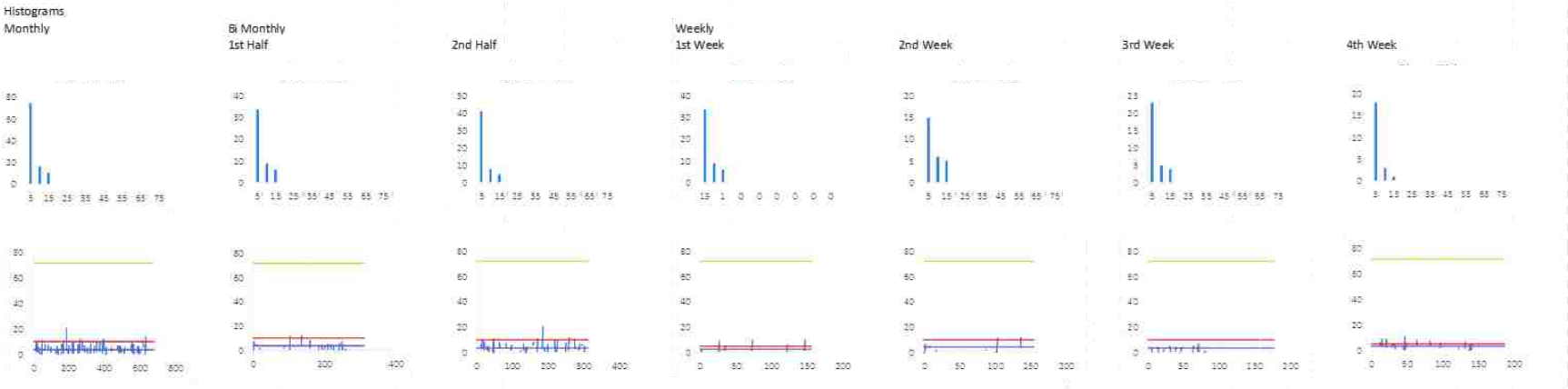
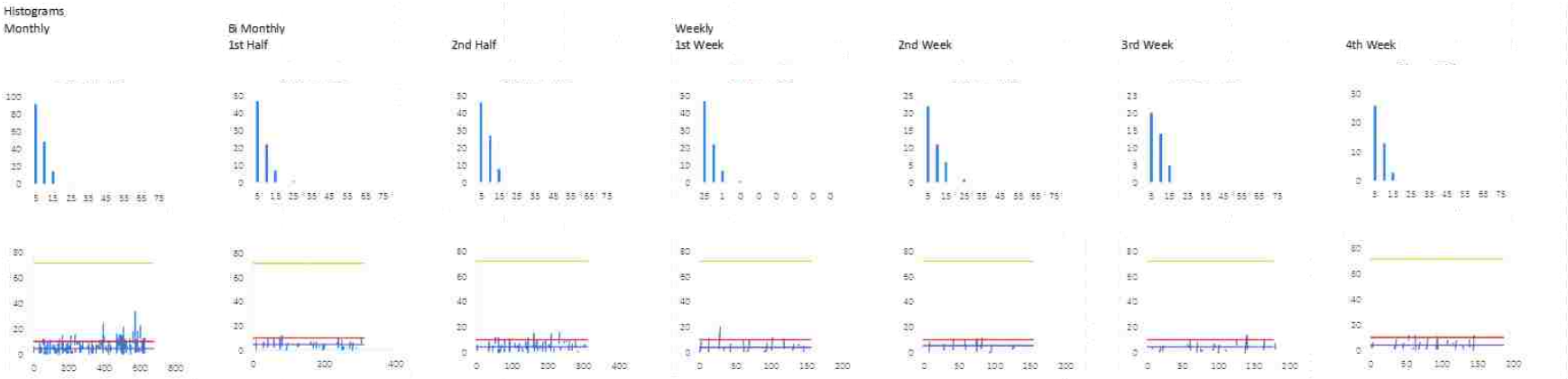


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

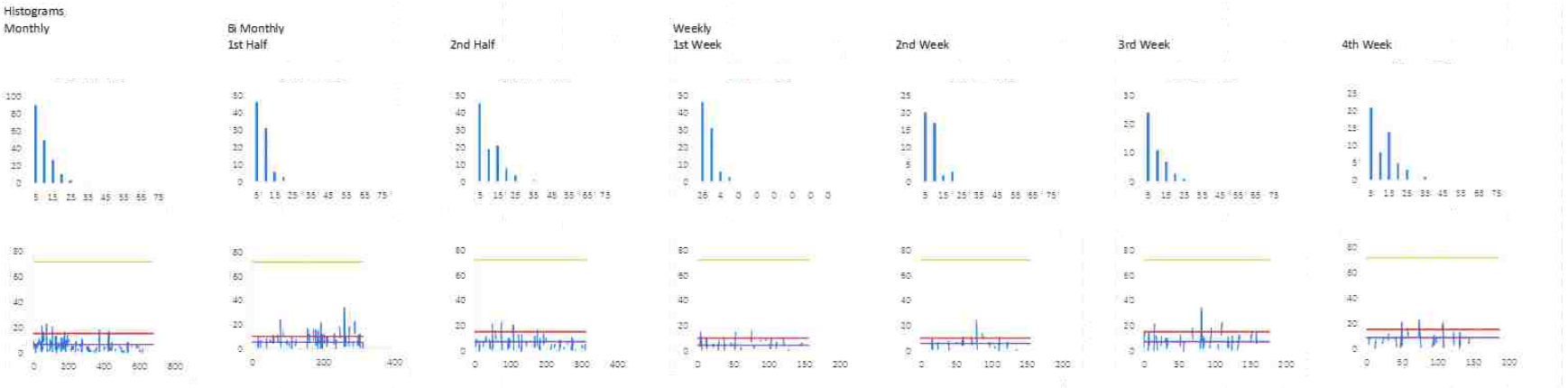
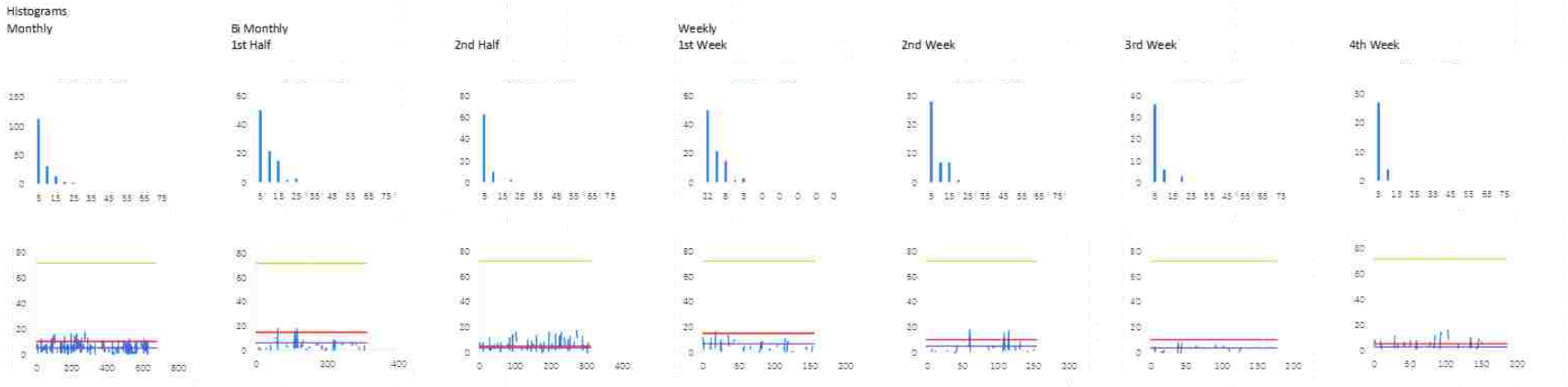


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

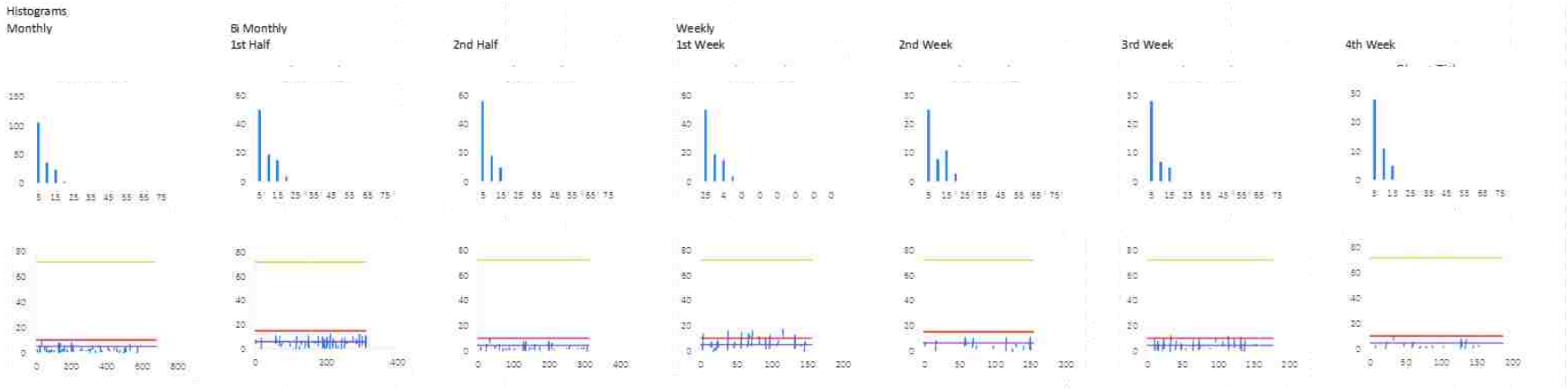
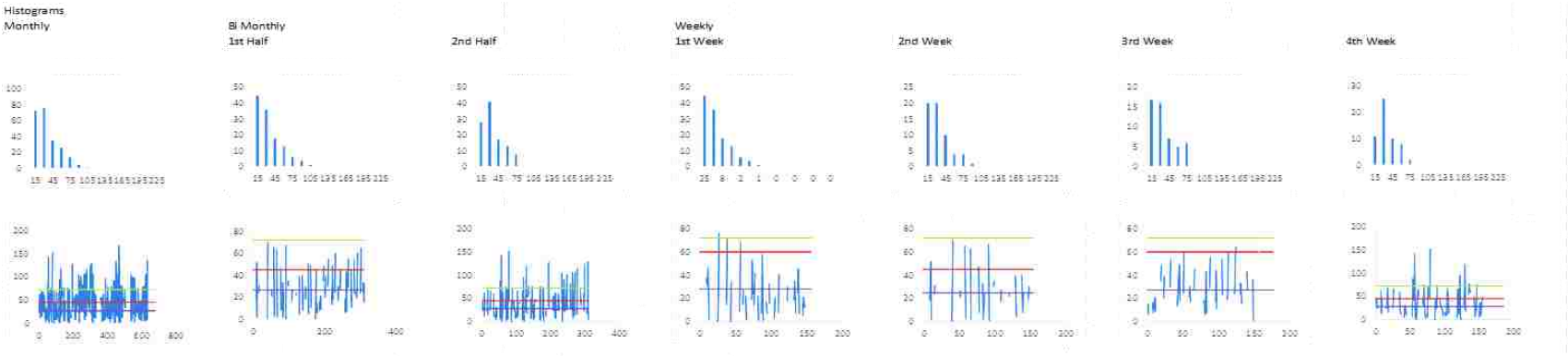


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Small White T Shirt Total

Jan to Feb



Feb to March

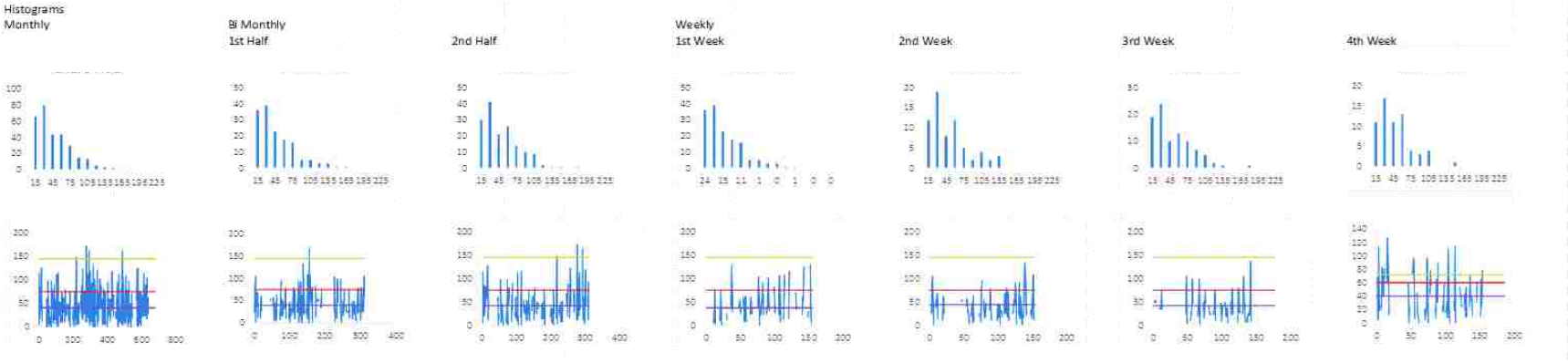
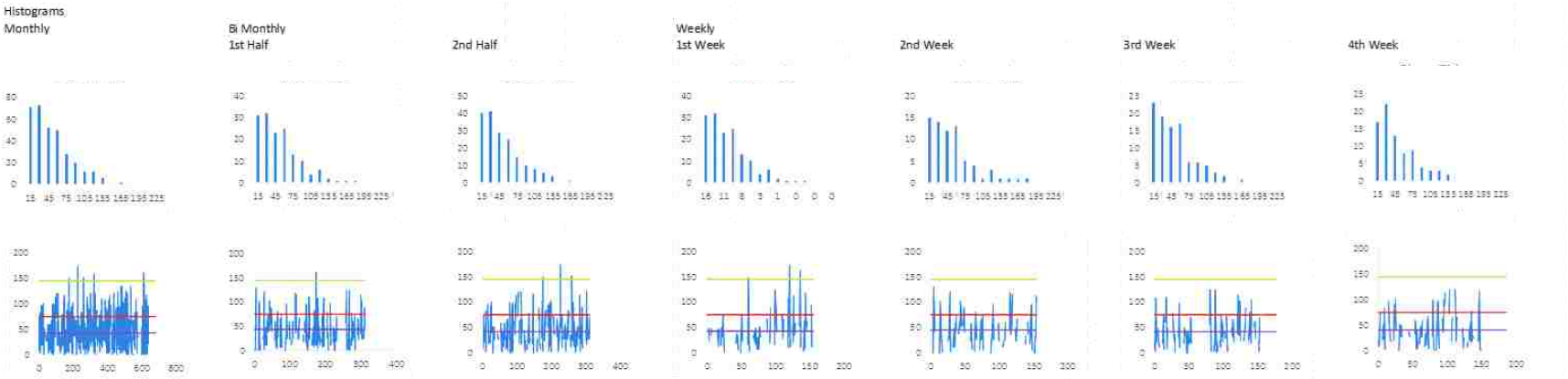


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

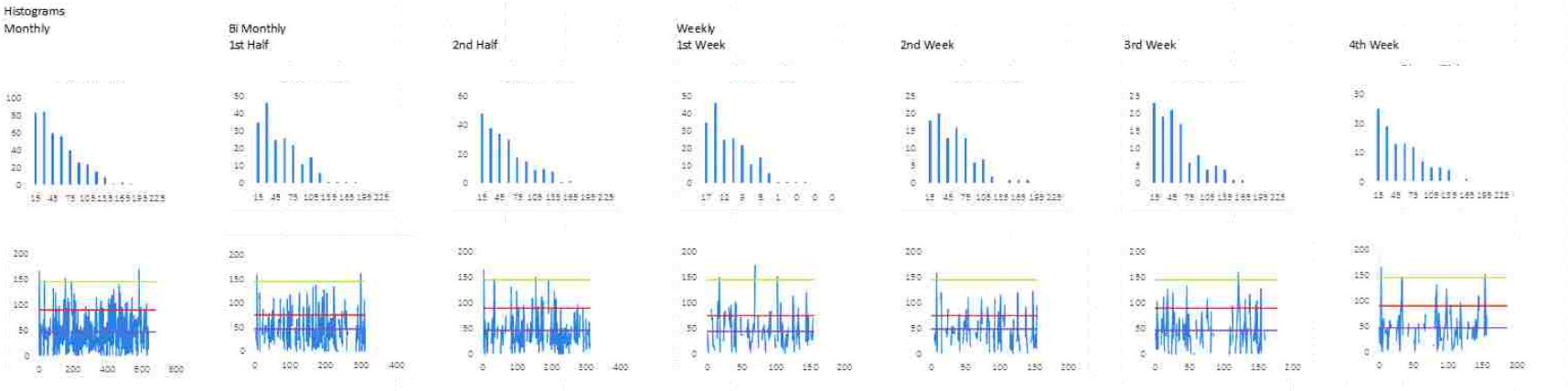
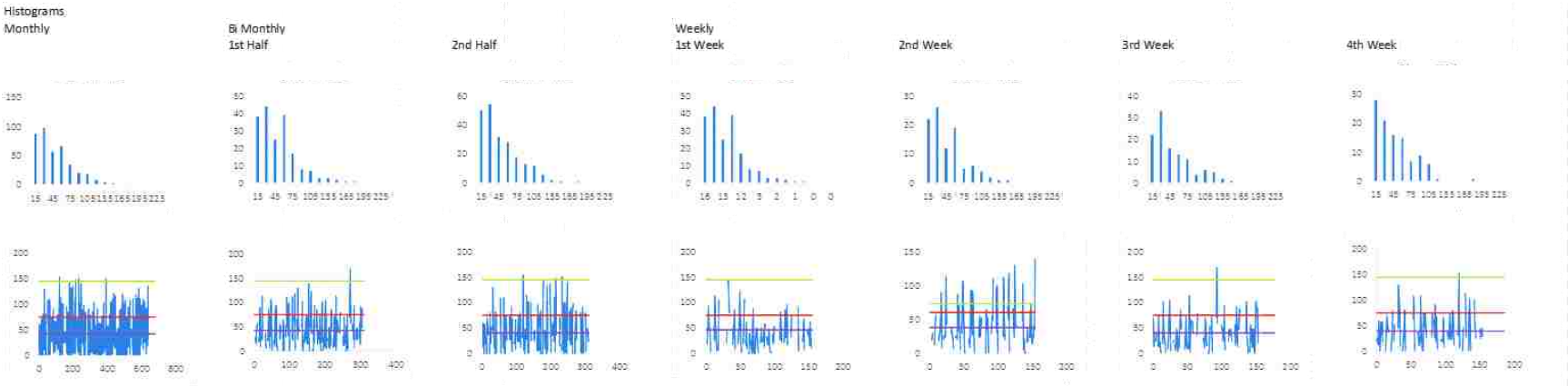


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

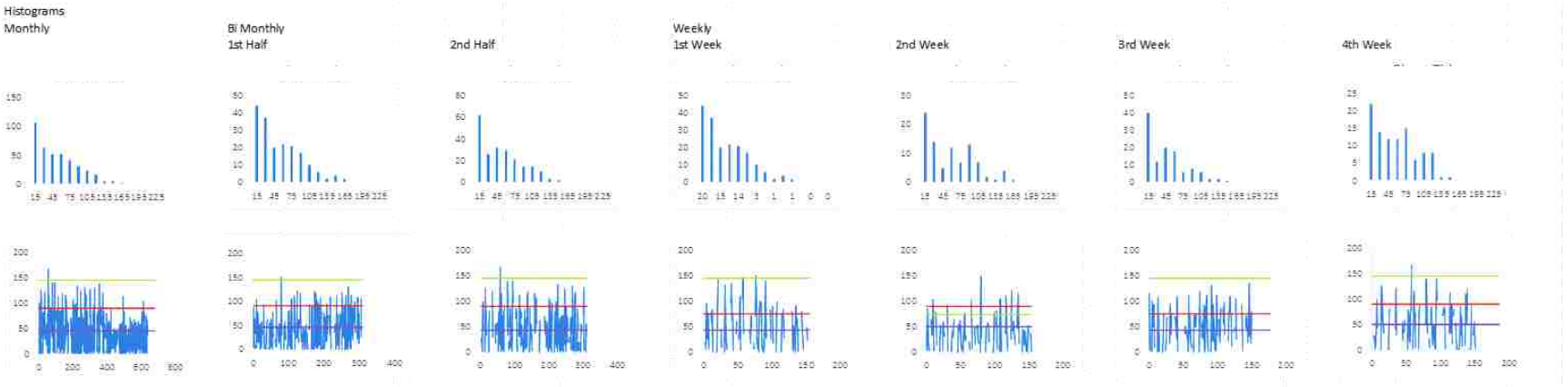
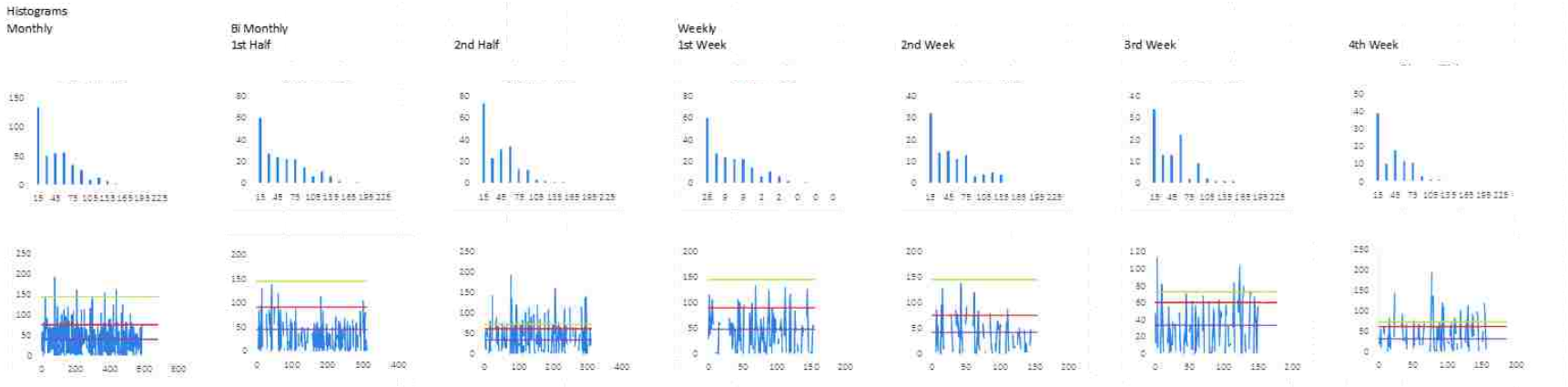


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to Aug



Aug to September

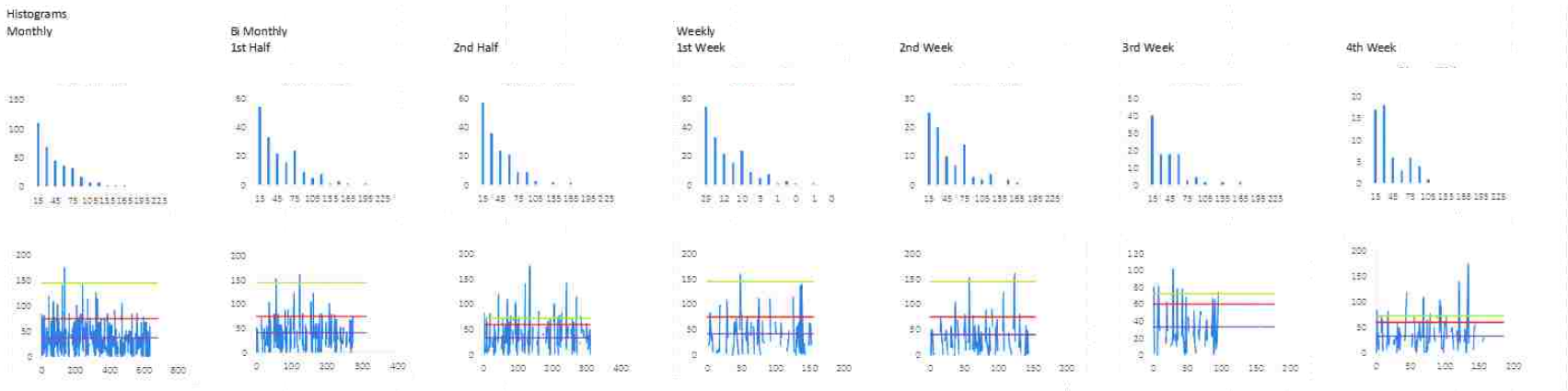
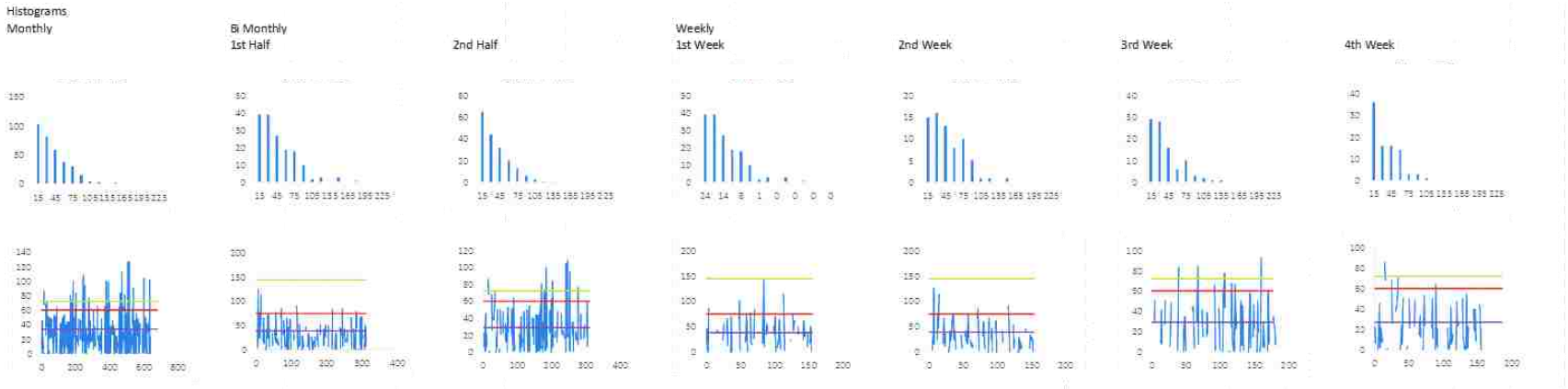


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

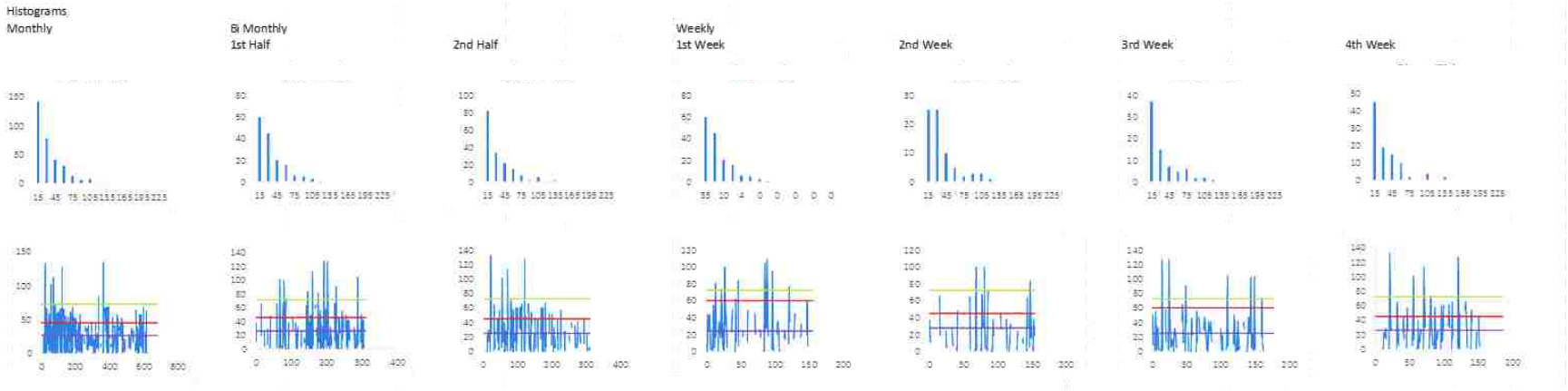
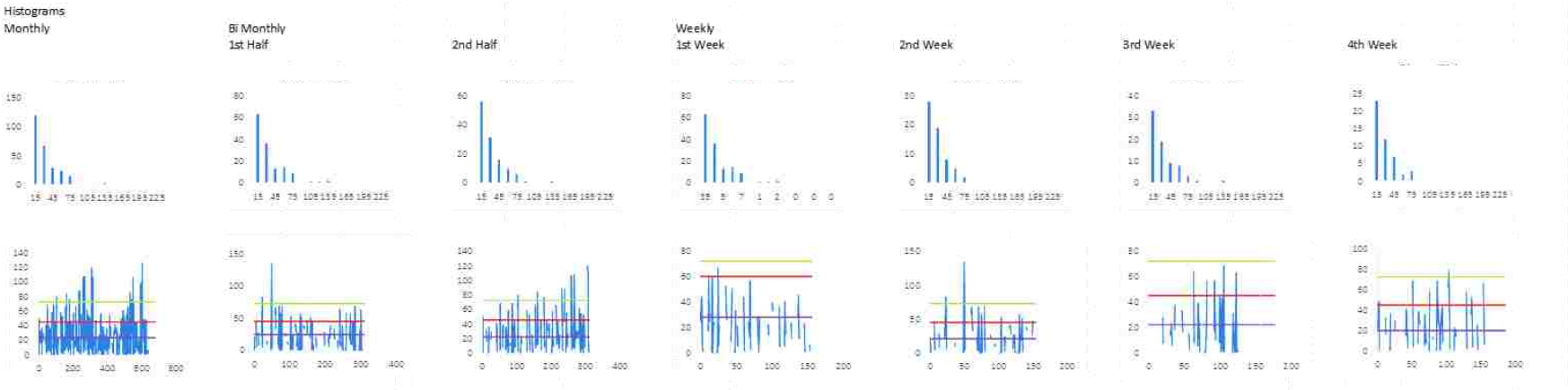


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

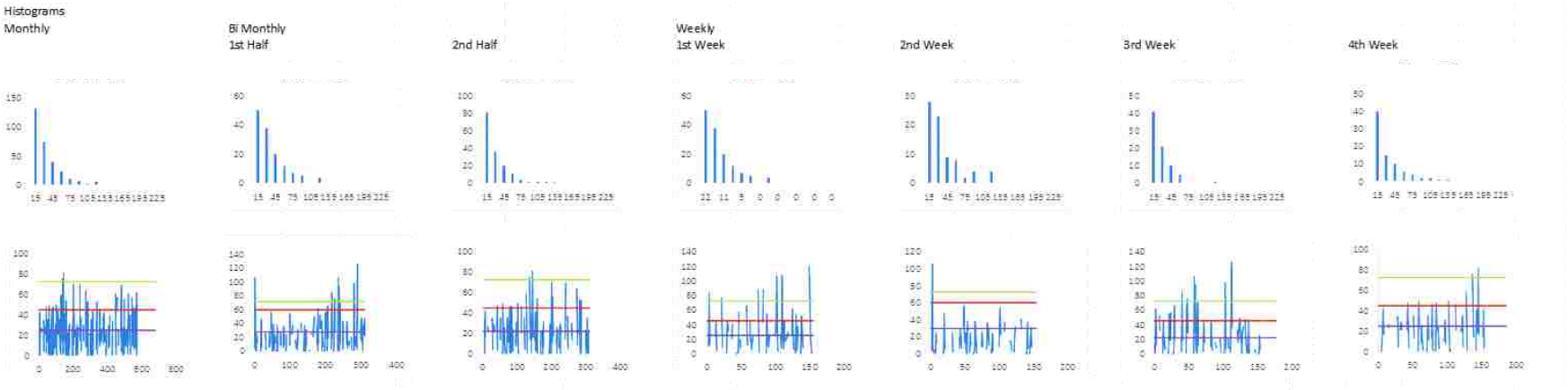
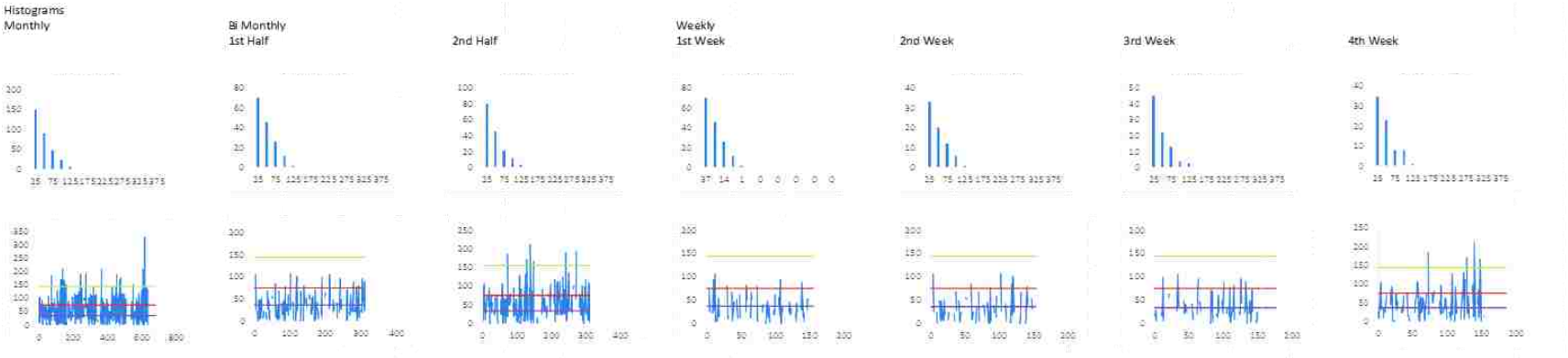


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Medium White T Shirt

Jan to Feb



Feb to March

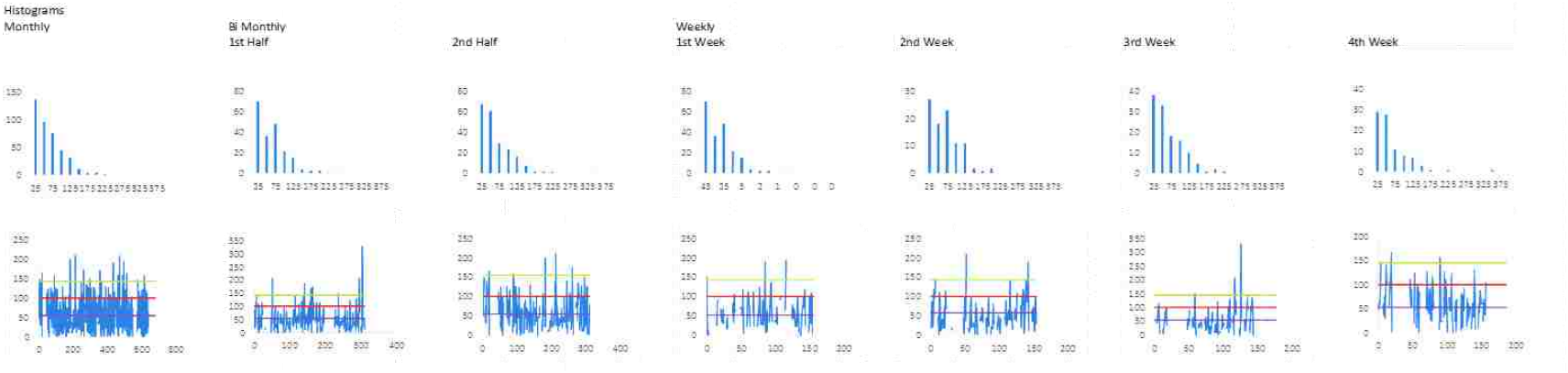
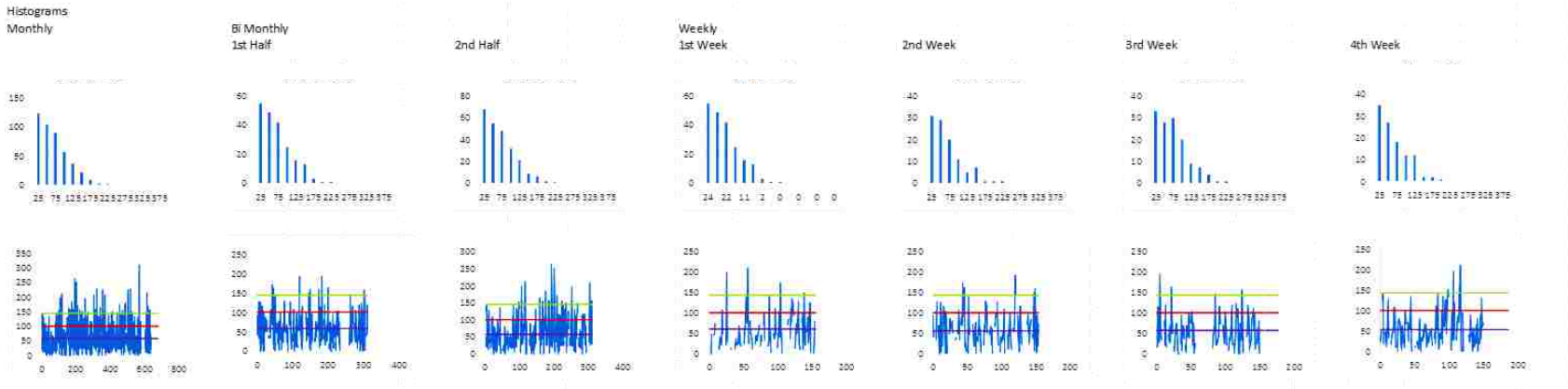


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

March to April



April to May

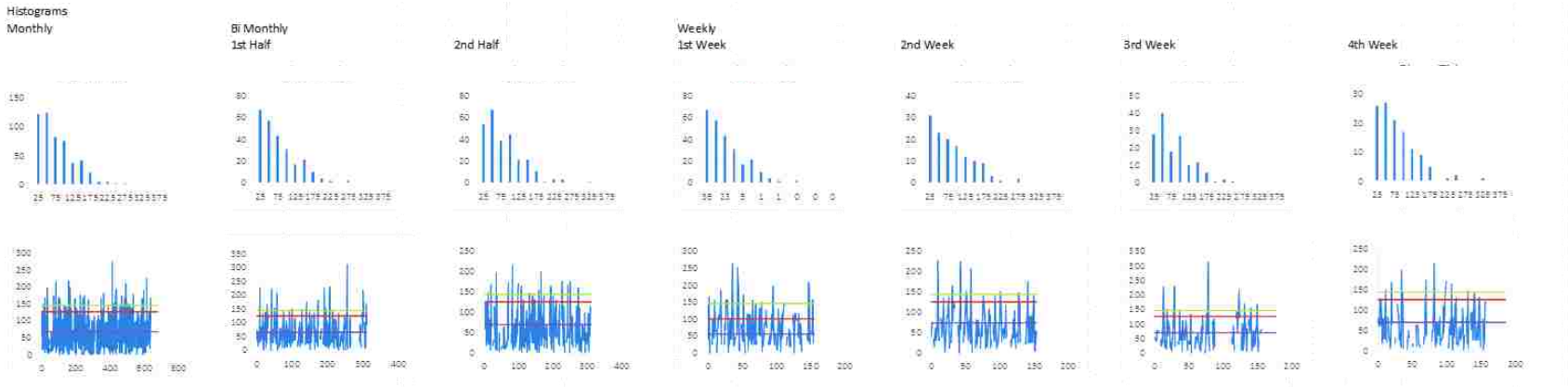
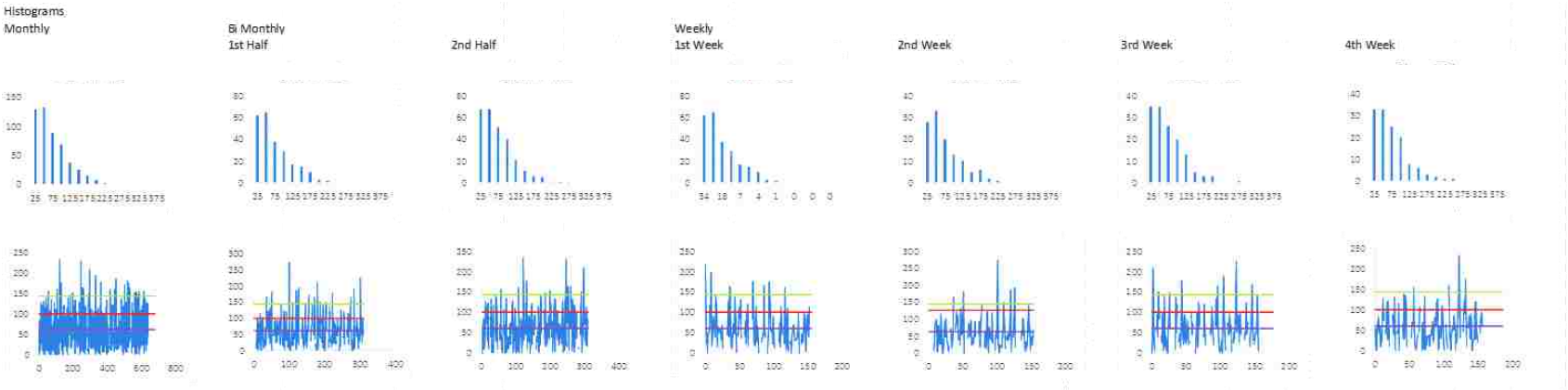


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

May to June



June to July

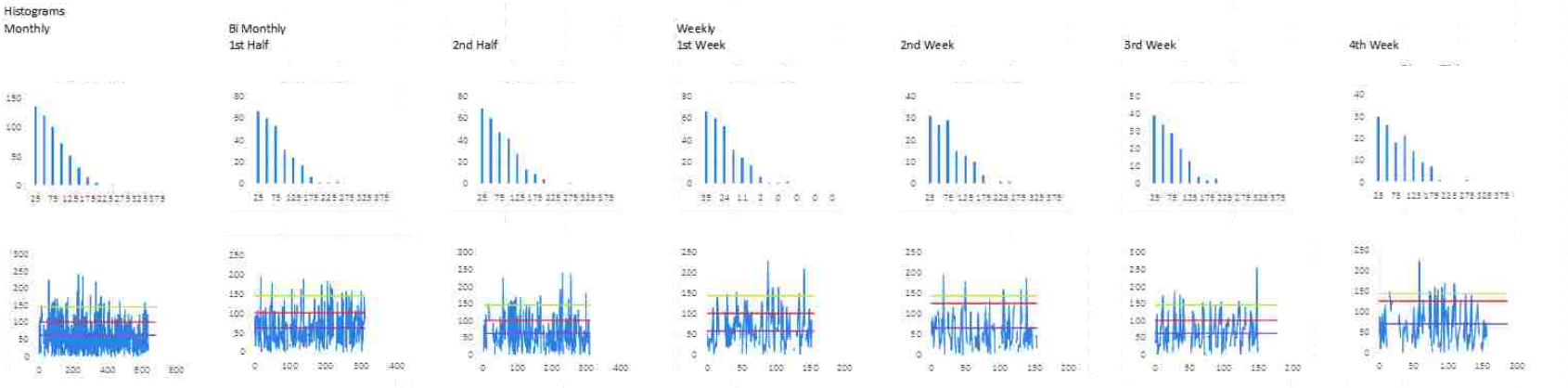
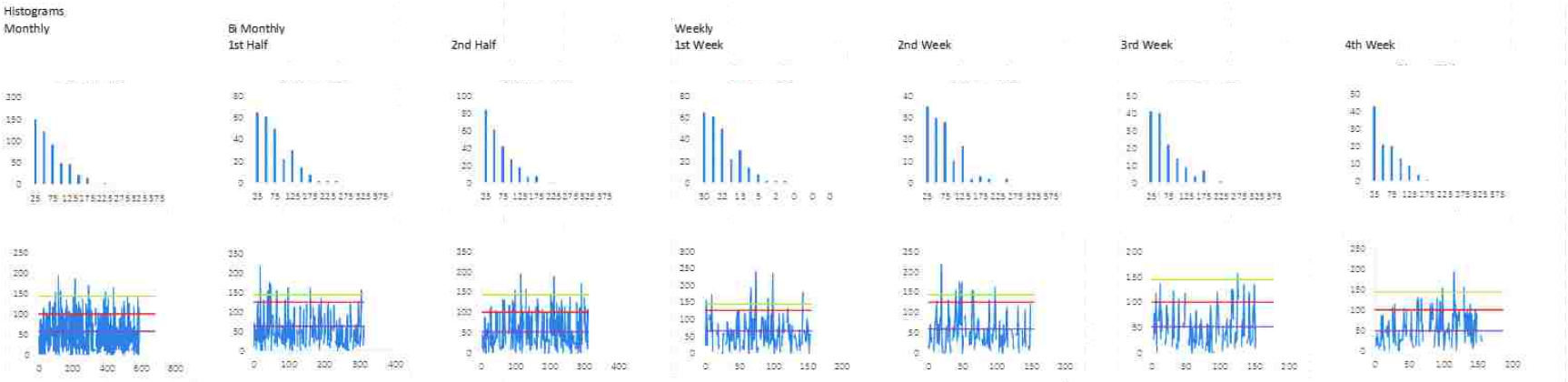


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

July to August



August to September

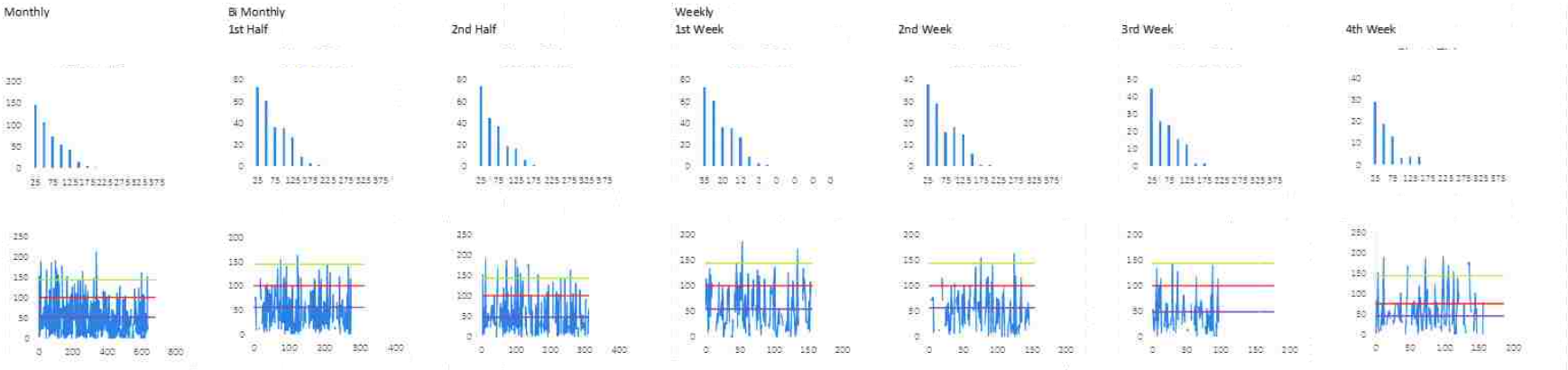
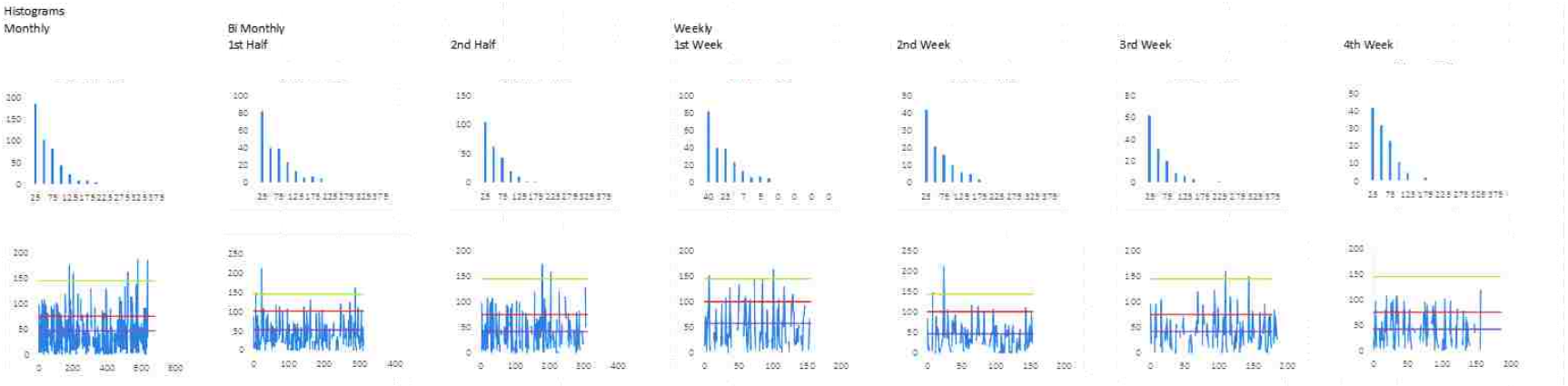


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Sept to Oct



Oct to Nov

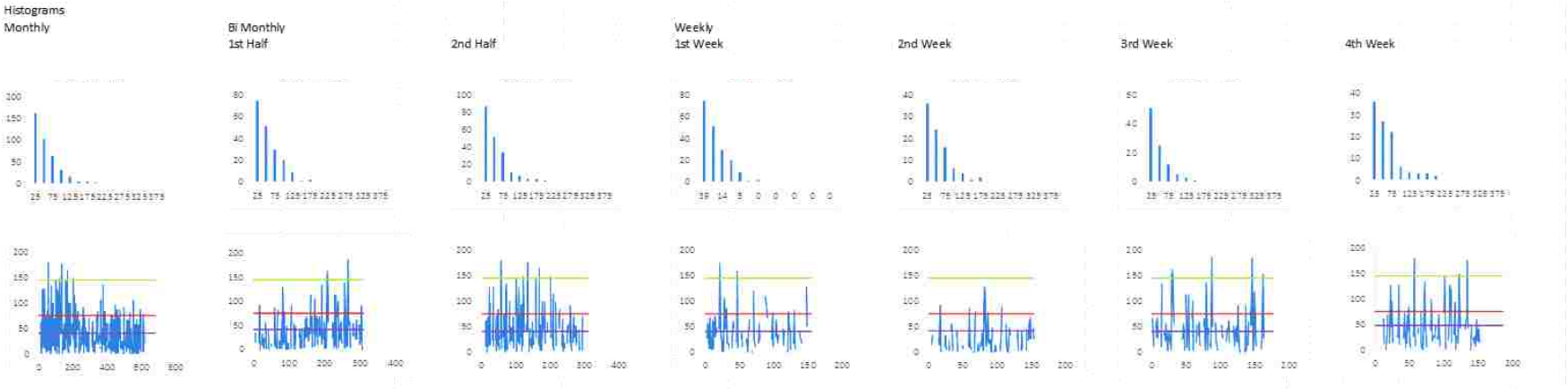
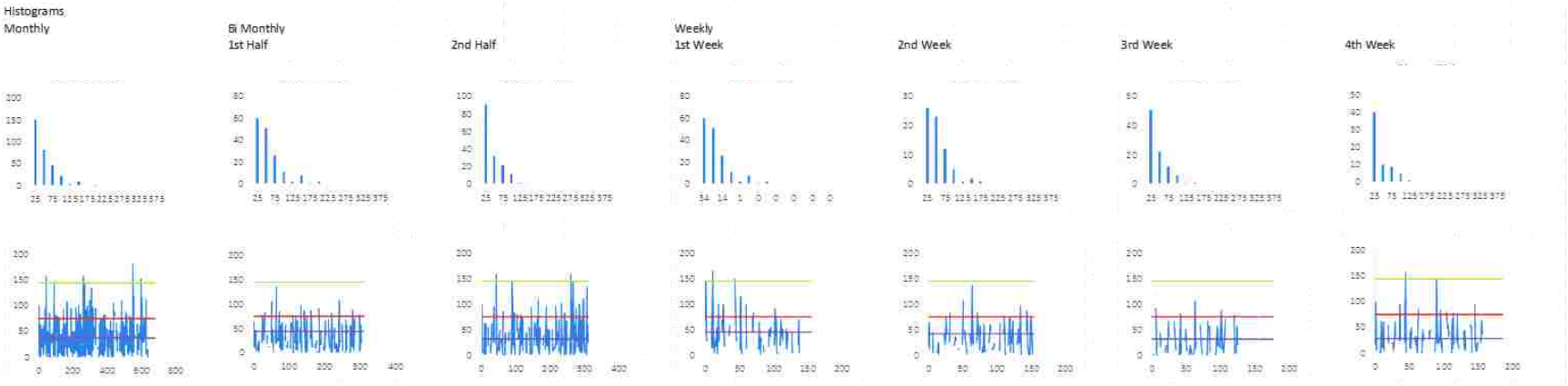


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

Nov to Dec



Dec to Jan

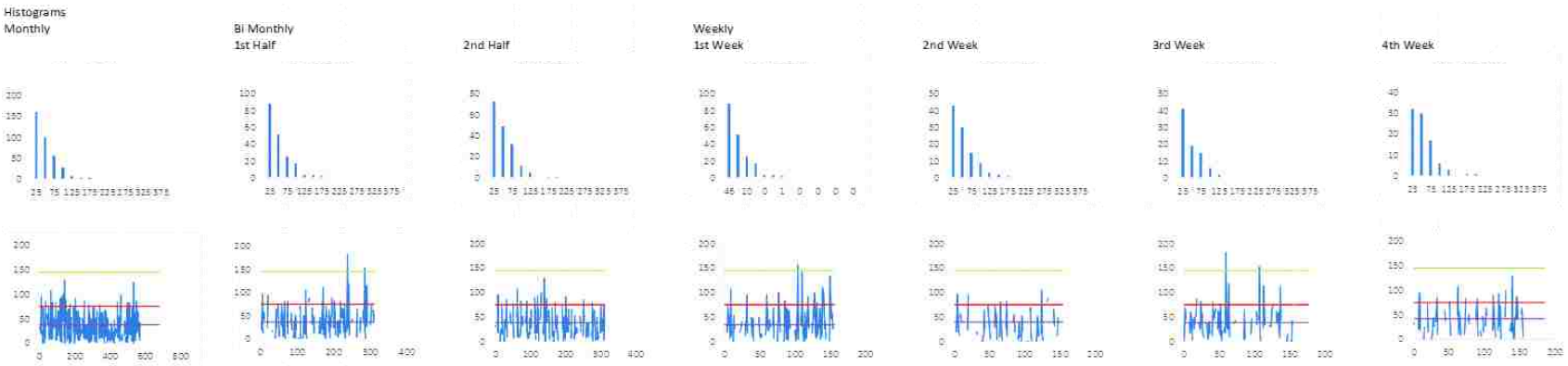


Fig Set 13: output Comparison - Demand Histogram & Demand Vs Inventory Comaprison

APPENDIX C

Dec to Jan

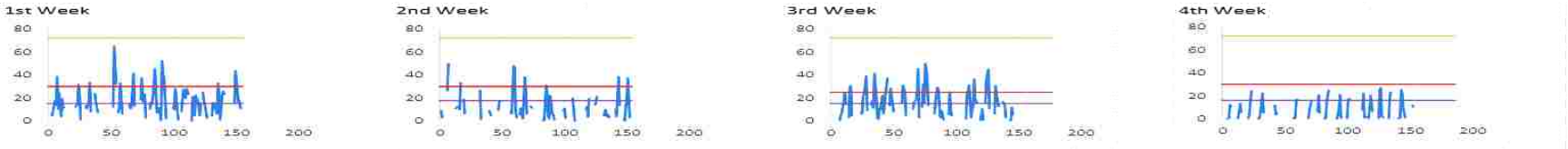
Deamnd Vs Inventory Chart
X Axis : Hours
Y Axis: Demand

Key:

Min Qty
News Vendor based Q*
Simple Moving Avg.

Small Black T Shirt

Medium Black T Shirt



Large Black T Shirt

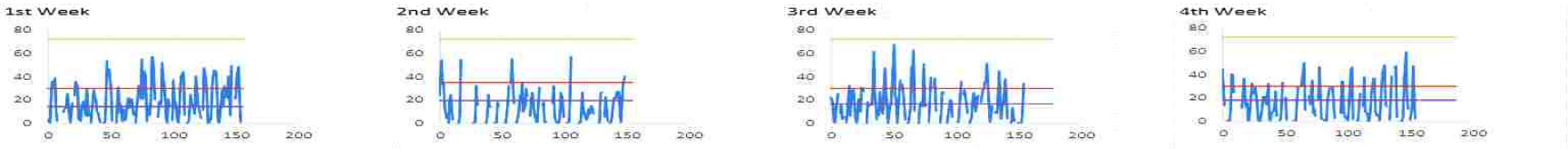
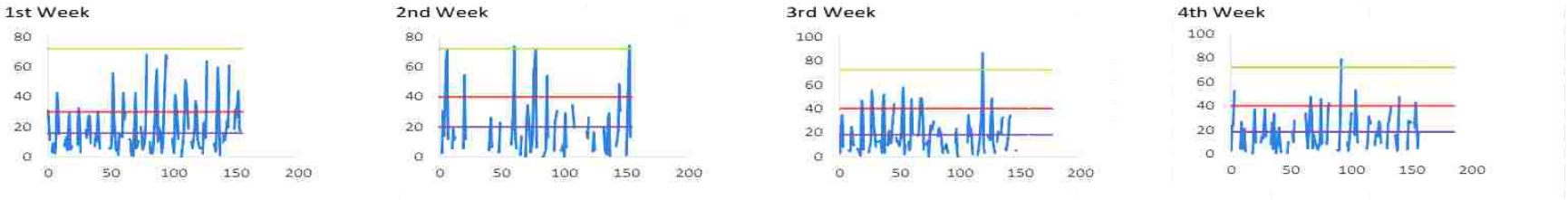
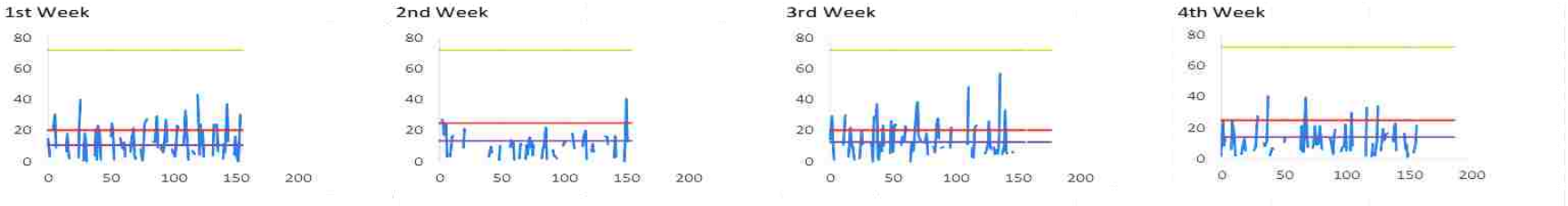


Fig Set 14: Output Comparison - Demand Vs Inventory

XL Black T Shirt



XXL Black T Shirt



Small Black long Sleeve T Shirt

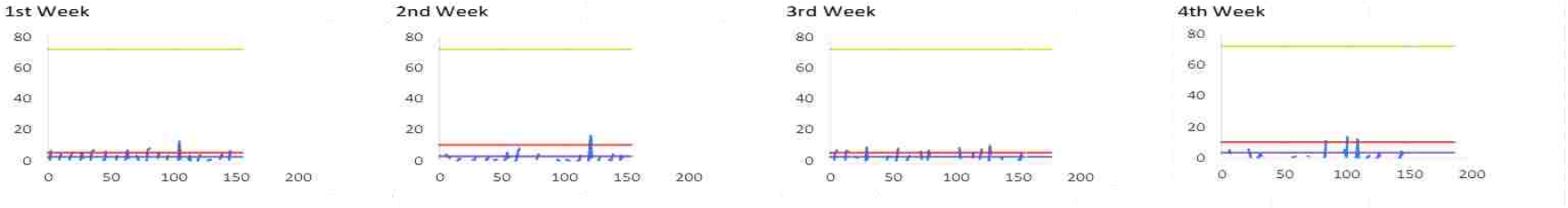
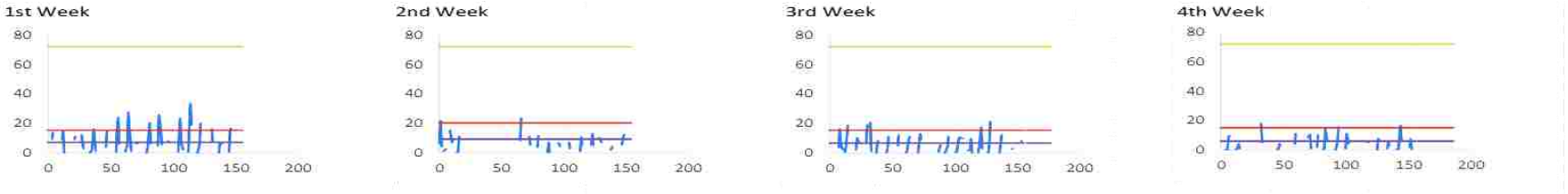


Fig Set 14: Output Comparison - Demand Vs Inventory

Medium Black Long Sleeve T Shirt

Large Black Long Sleeve T Shirt



XL Black Long Sleeve T Shirt

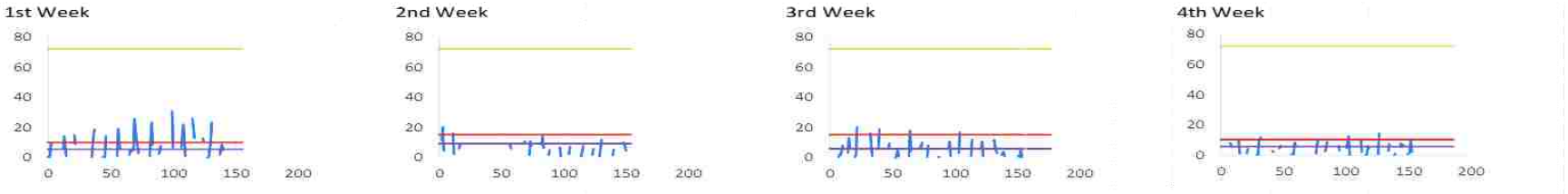
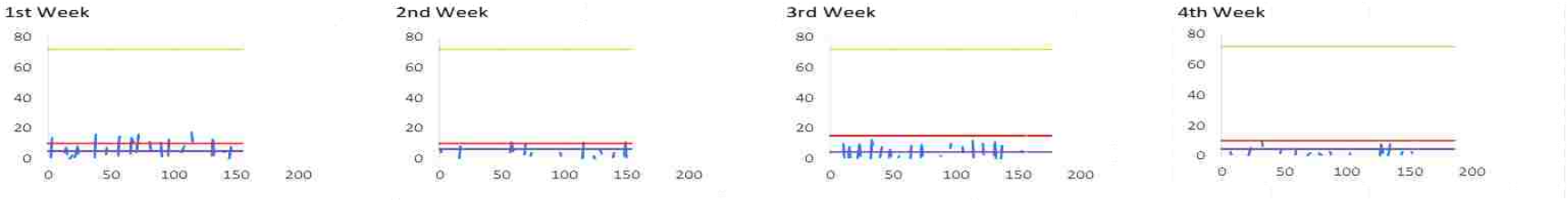
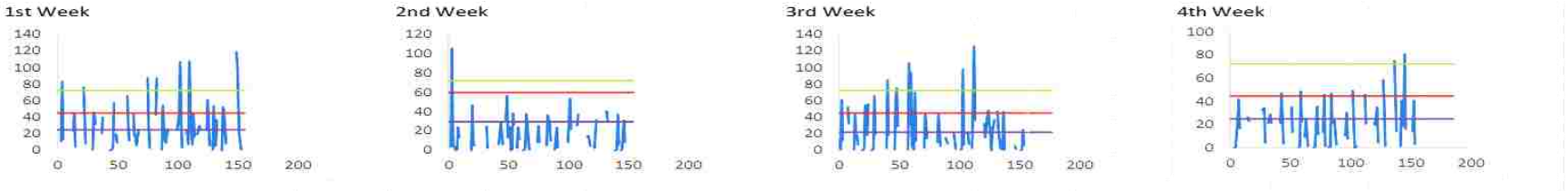


Fig Set 14: Output Comparison - Demand Vs Inventory

XXL Black Long Sleeve T Shirt



Small White T Shirt



Medium White T Shirt

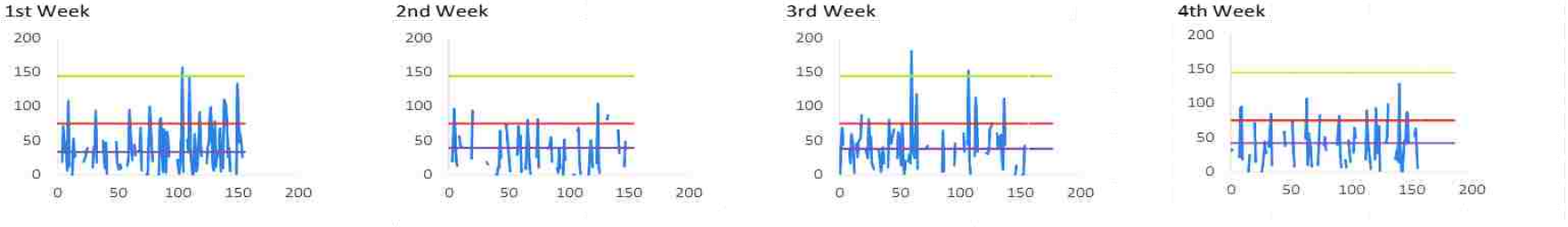
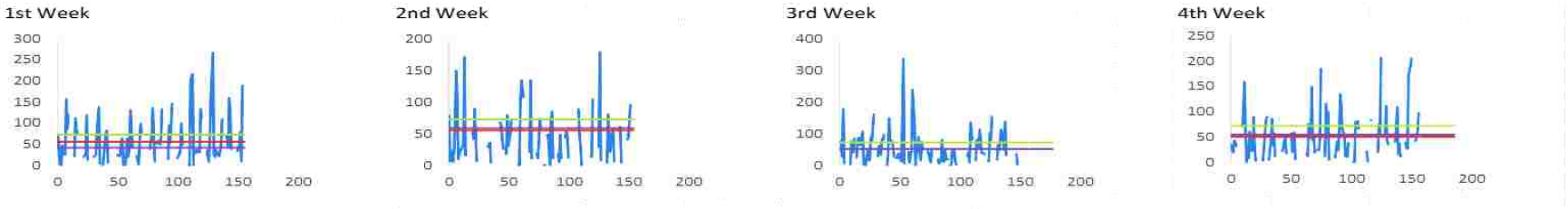
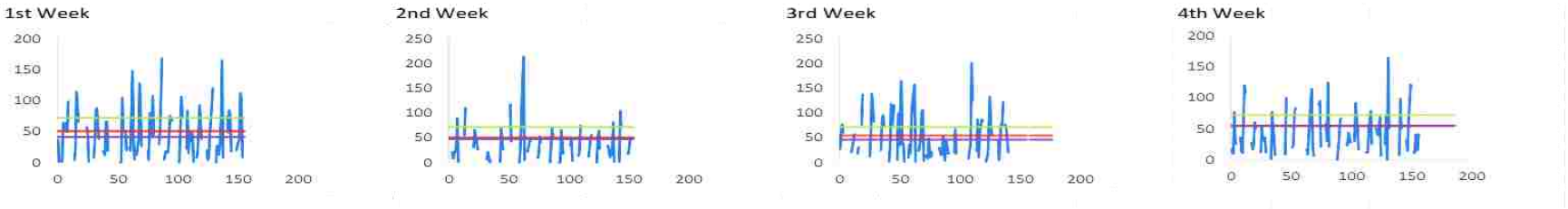


Fig Set 14: Output Comparison - Demand Vs Inventory

Large White T Shirt



XL White T Shirt



XXL White T Shirt

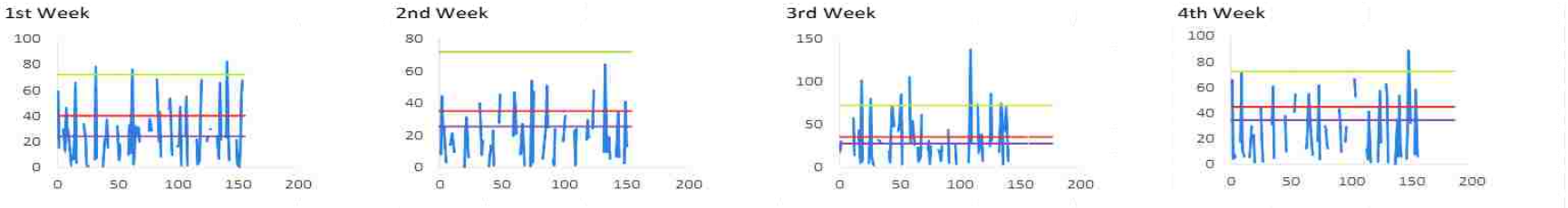
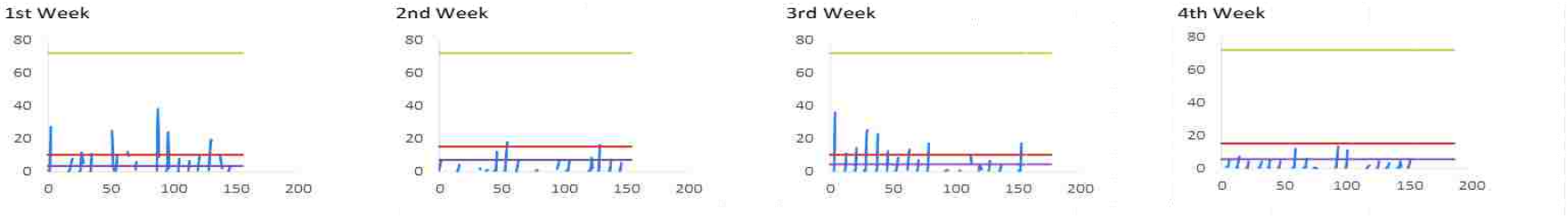
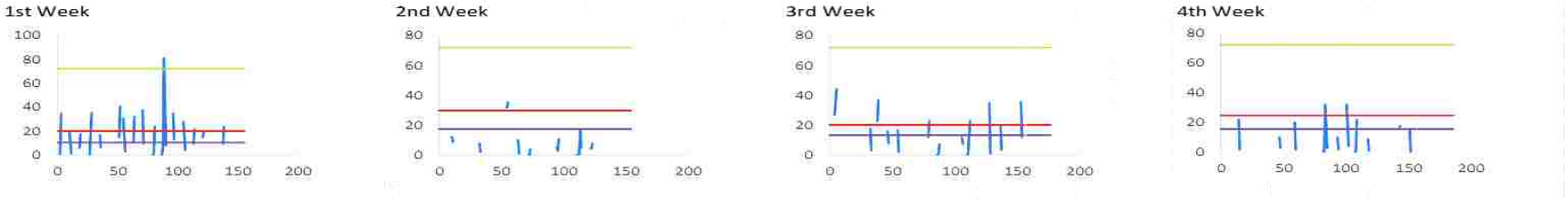


Fig Set 14: Output Comparison - Demand Vs Inventory

Small Ash T Shirt



Medium Ash T Shirt



Large White T Shirt

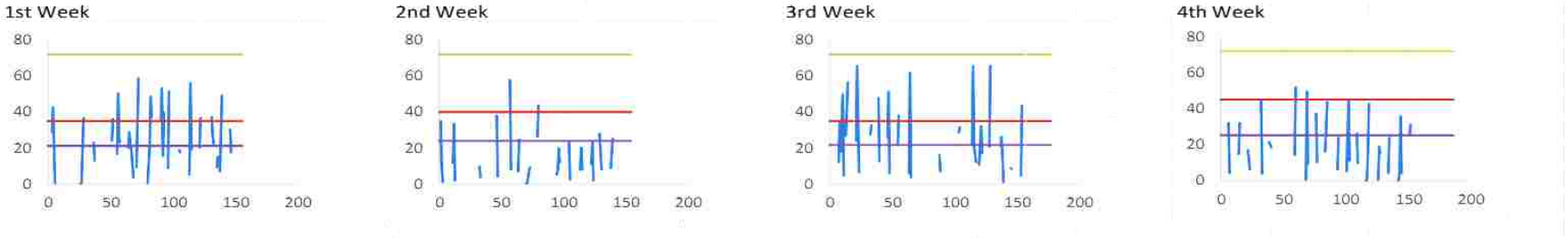
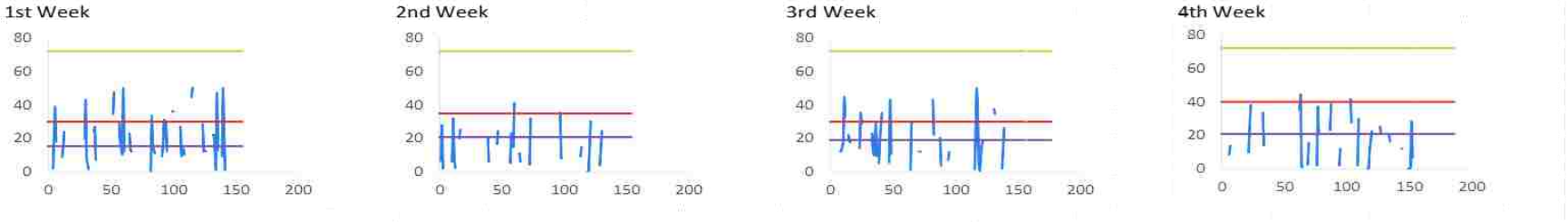
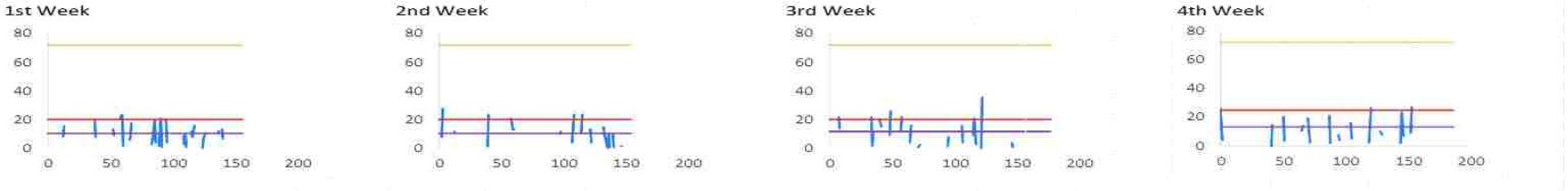


Fig Set 14: Output Comparison - Demand Vs Inventory

XL White T Shirt



XXL White T Shirt



Small White Long Sleeve T Shirt

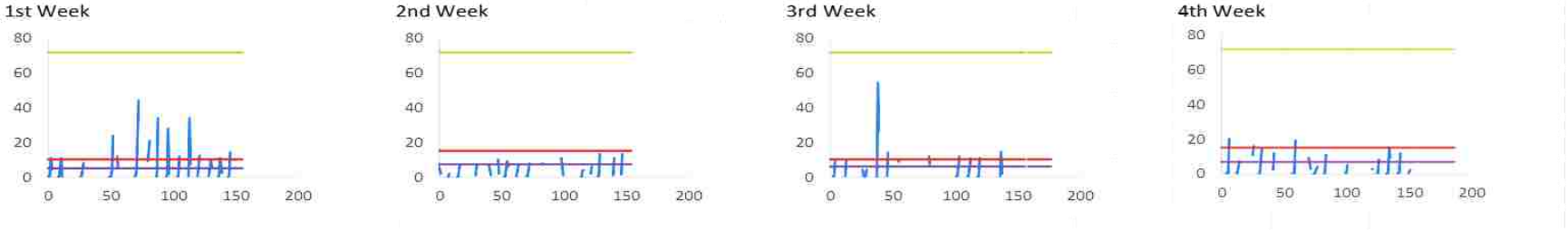
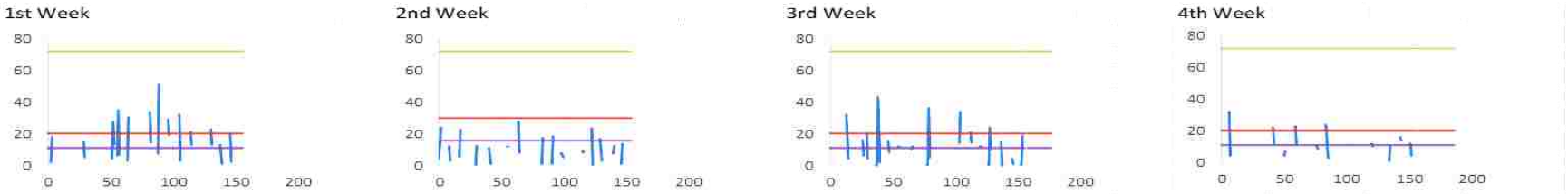
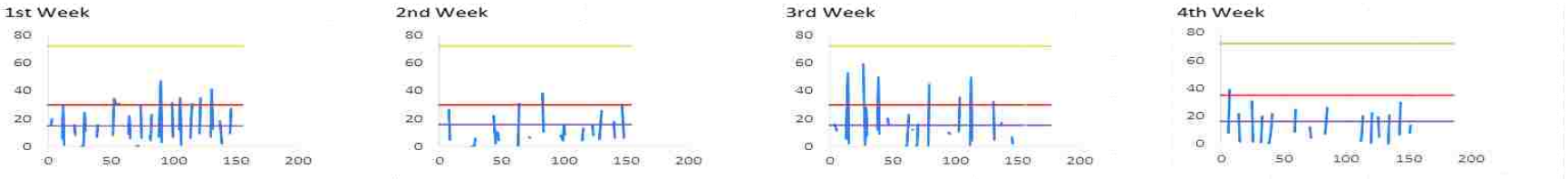


Fig Set 14: Output Comparison - Demand Vs Inventory

Medium White Long Sleeve T Shirt



Large White Long Sleeve T Shirt



XL White Long Sleeve T Shirt

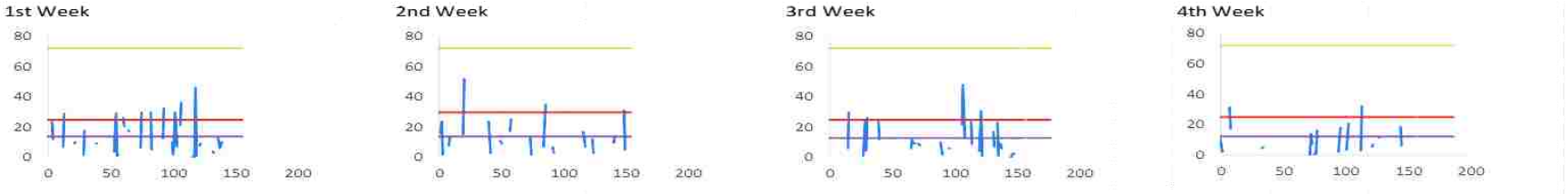
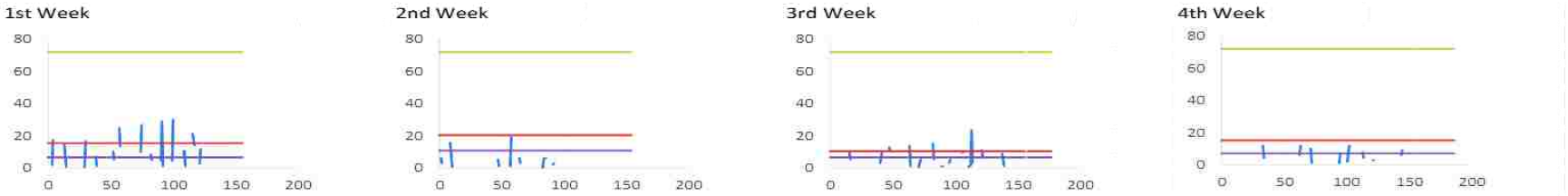


Fig Set 14: Output Comparison - Demand Vs Inventory

XXL White Long Sleeve T Shirt



Small White Women's T Shirt

Medium White Women's T Shirt

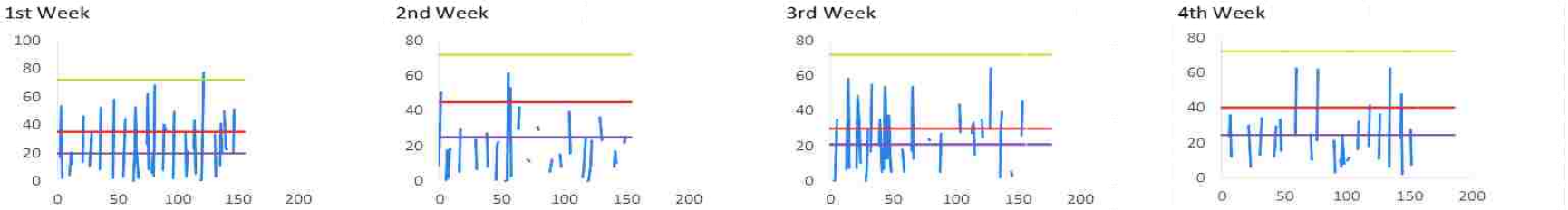
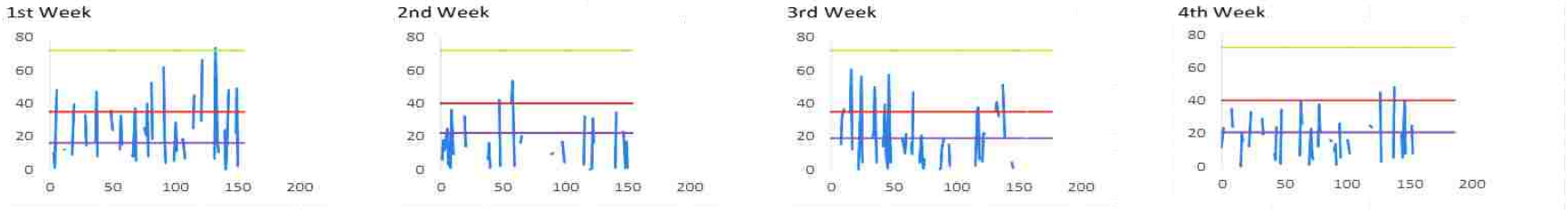
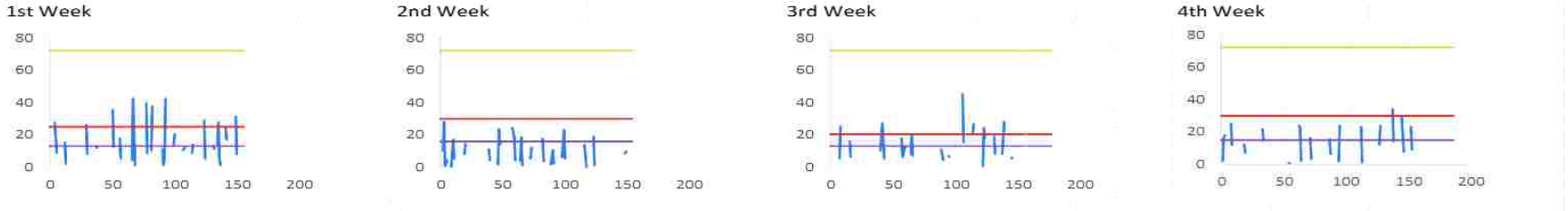


Fig Set 14: Output Comparison - Demand Vs Inventory

Large White Women's T Shirt



XL White Women's T Shirt



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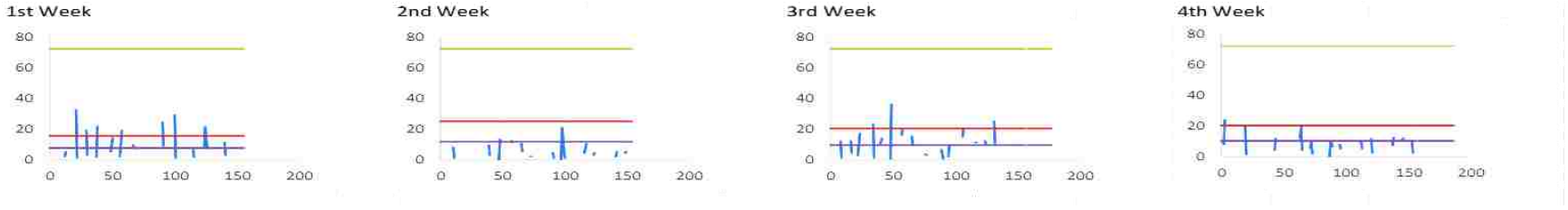
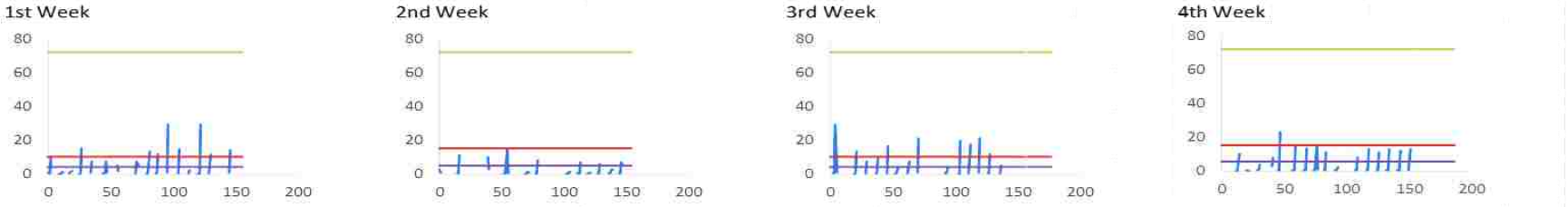
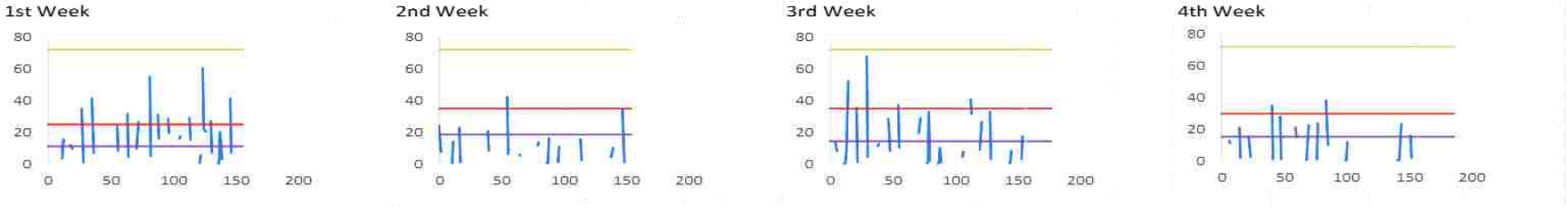


Fig Set 14: Output Comparison - Demand Vs Inventory

Small White Premium T Shirt



Medium White Premium T Shirt



Large White Premium T Shirt

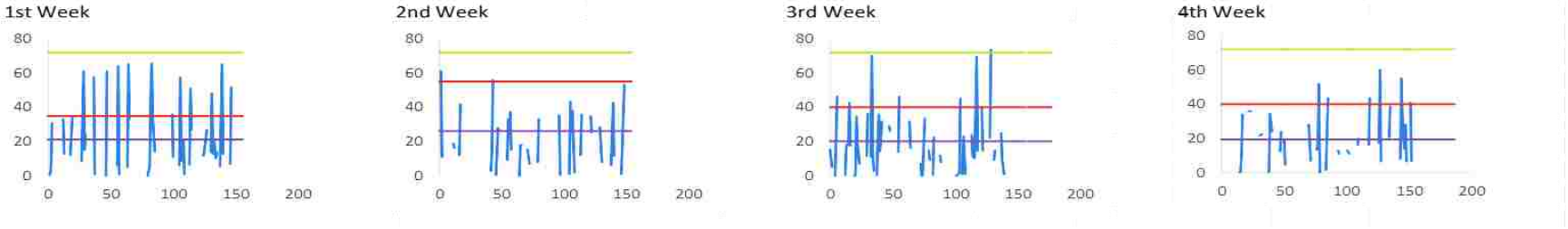
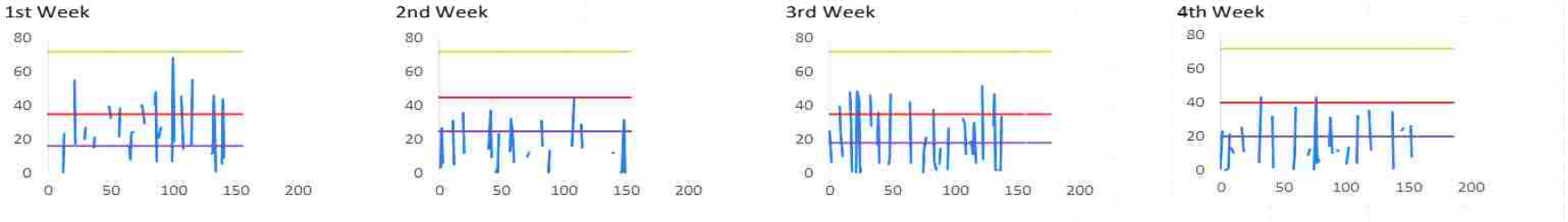
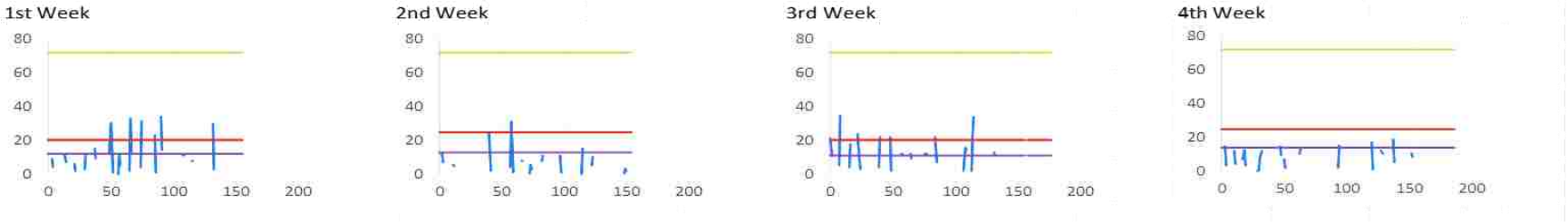


Fig Set 14: Output Comparison - Demand Vs Inventory

XL White Premium T Shirt



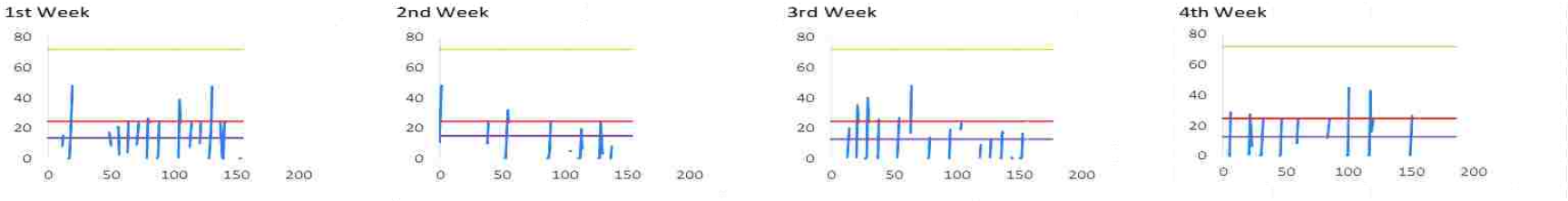
XXL White Premium T Shirt



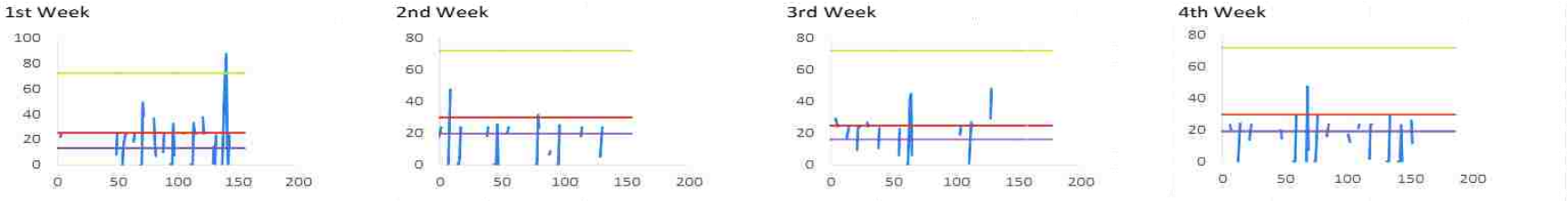
XS Youth T Shirt

Fig Set 14: Output Comparison - Demand Vs Inventory

Small Youth T Shirt



Medium Youth T Shirt



Large Youth T Shirt

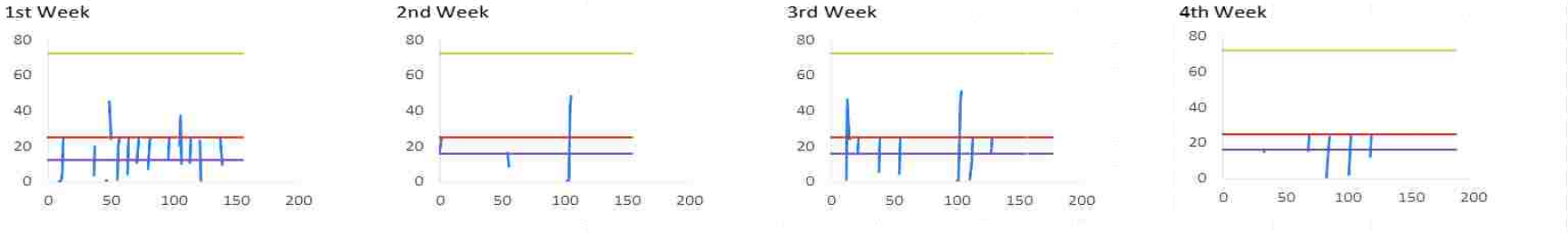


Fig Set 14: Output Comparison - Demand Vs Inventory

XL Youth T Shirt

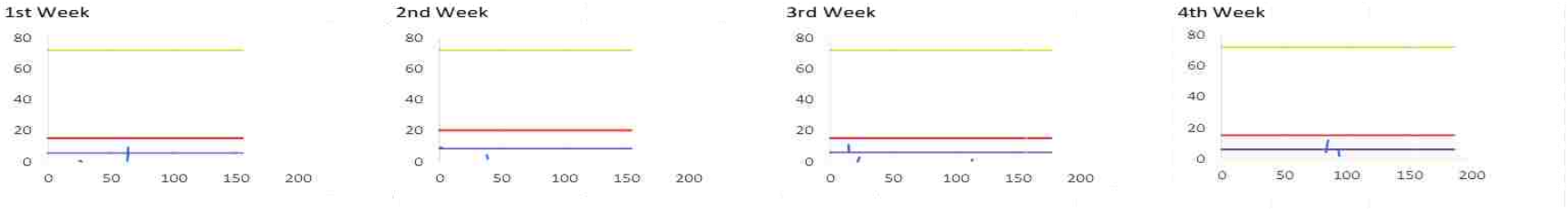


Fig Set 14: Output Comparison - Demand Vs Inventory

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tahtml%2FPTO%2Fsearch-bool.html&r=0&f=S&l=50&TERM1=Vistaprint&
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