Inventory Management for Small Businesses

February 2017

Abstract

Creatron, located on College St. west of the University of Toronto, sells electronics and electronic components suitable for students, hobbyists, and other interested parties. Creatron stocks many products that cannot be found in other nearby brick-and-mortar stores and thus provides a valuable service for those who need electronics components quickly and cannot spare the extra time or money to order online [1]. Creatron uses a point-of-sales system combined with perpetual inventory to track purchases and anticipate what time frame is necessary for reordering to keep product in stock [2].

This document describes an opportunity surrounding the tracking, analysis, and prediction of inventory data related to Creatron. Despite their use of the inventory management technologies outlined above, Creatron is vulnerable to out-of-stocks when confronted with an unexpected volume of individual customers and/or event organizers that purchase in bulk. This sometimes causes them to lose potential customers to competitors when the requested time frame for purchases falls short of the time needed to reorder from manufacturers[3]. Improving the physical, software, or procedural techniques involved in their inventory management system could benefit Creatron by reducing the number of out-of-stock incidents and thereby eliminating loss of profits due to these incidents [4].

A design that addresses this opportunity should allow Creatron to have increased awareness of their potential bulk purchase sources, enable Creatron to predict trends in individual purchases, increase Creatron's profit, and improve their reputation.

Some attempts at a solution already exist, and a broad overview of such attempts may be helpful in framing the issue. Point-of-sales software tracks inventory by keeping track of sales, but such software does not specifically track or predict bulk purchases [4]. Perpetual inventory software tracks inventory levels and reorders when they fall below a certain level, but is less than 50% accurate [4]. RFID tagging is accurate but infeasible for small companies [4]. Manual auditing and purchase calendars are accurate but difficult to manage and time consuming [4]. Partnerships with frequent bulk buyers track some bulk purchases but not all [2]. All the above attempts address portions of the opportunity, but none address all of it. A successful design should satisfy Creatron's need for an improved inventory management system.

References:

1. Creatron website. [Online] Available: creatroninc.com

2. J. Fung. Personal interview. Feb. 16 2017.

3. J. Chan. Personal interview. Jan. 26 2017.

4. Corsten, Daniel and Thomas W. Gruen. (2007). *A Comprehensive Guide To Retail Out-of-Stock Reduction In the Fast-Moving Consumer Goods Industry* [Online]. Available `http://www.nacds.org/pdfs/membership/out_of_stock.pdf`

Contents

1 *Introduction*

This opportunity involves improving the inventory management and preparation for Creatron, an electronics component supplier based in Toronto. The current system was deemed inadequate due to its incapability to address sudden high demand, such as those caused by events that require bulk purchases of product. These events include hackathons and major school projects.

2 *Background*

2.1 Community

Creatron is an electronics component supplier that supplies products for various events, such as school projects and hackathons, and to individual buyers. It sells a wide range of products, from basic components such as wires and resistors, to more complex parts such as arduinos and miniature oscilloscopes, to products that are shipped from outside Canada, such as Raspberry Pis, which are otherwise difficult to obtain in-store [1]. However, in the case of school projects and last minute bulk purchases for events, there is unexpectedly high demand for certain products. On several occasions, such demand is enough to deplete Creatron's stock of these items [2]. Thus, other consumers are unable to acquire the products they need which leaves them unsatisfied. Furthermore, due to the deadlines associated with these events, Creatron may not be able to restock in time. This is detrimental to both Creatron and the buyer, as the buyer is unable to acquire enough product, and Creatron loses out on potential profit and customers.

Creatron has two locations, a downtown location located near College and Spadina as well as a Scarborough location [2]. For customers who live in the GTA, Creatron is nearby and imports many items that are otherwise only available online and thus, subject to long shipping times at high cost. Creatron also produces special student kits in a partnership with a few professors from University of Toronto, Ryerson University, and OCAD University, allowing students to easily and conveniently acquire all their electronics needs in a single package. However, Creatron does not have a similar partnership with high schools [2]. It also doesn't currently partner with all possible other events such as hackathons, which sometimes put in orders on very short notice [3].

Currently, event organizers either email or call Creatron to order in bulk or come directly to the store. The communication channels are too flexible, as customers may not state all the necessary information effectively without a form to remind them of what they should include,. If the organizers choose to visit the store to purchase the items without ordering them beforehand, Creatron may or may not be able to supply the necessary items (see section 2.2 for bulk purchase case study [4]).

Creatron is currently using a point of sales system provided by Moneris to manage their inventory [3]. When the stock of a certain item hits the lowest allowable value (which differs from item to item), the store will place an order for refills. This lowest allowable value is determined by the typical sales trends tracked by the point of sales system, which analyzes information based on purchase data. They order an item once the POS system identifies that the item's stock is at a certain threshold, for example 30% of the item's original supply. However, this system still leaves Creatron vulnerable to the unexpected bulk purchases mentioned

above, and Creatron does not currently track out of stock incidents or take any measures to minimize them [3].

According to an employee at Creatron, there are currently no physical constraints restricting the sizes of restocking orders [3]. Financial constraints were not specified, but it was mentioned that they are directly proportional to the amount of sales, although there is much flexibility. Shipping times are different for each product which makes the inventory process more difficult. There is no carrying cost for products in store since most of the items are very small in size and all items are held at or behind the counter.

2.2 Case Studies

One inventory management system failure occurred during the winter of 2015-2016 when Creatron was depleted of its stock of strain gauges, devices that use resistance to measure force. This was due to the unexpected demand caused by a school project at Marc Garneau Collegiate Institute (MGCI). One of the students affected by this incident was interviewed for details regarding the situation [5]. Due to an AP Physics project that involved measuring forces, most of the students decided to purchase strain gauges from Creatron, since it was the most convenient location in Toronto for this product. Due to the tight deadlines, the students were unable to purchase the product from online retailers due to the shipping time. This unexpected demand caused Creatron to run out, and the next shipment of product was unable to arrive in time to meet the project deadline.

The different stakeholders and factors that affected the OOS are displayed in the flowchart of events below, Figure 1:

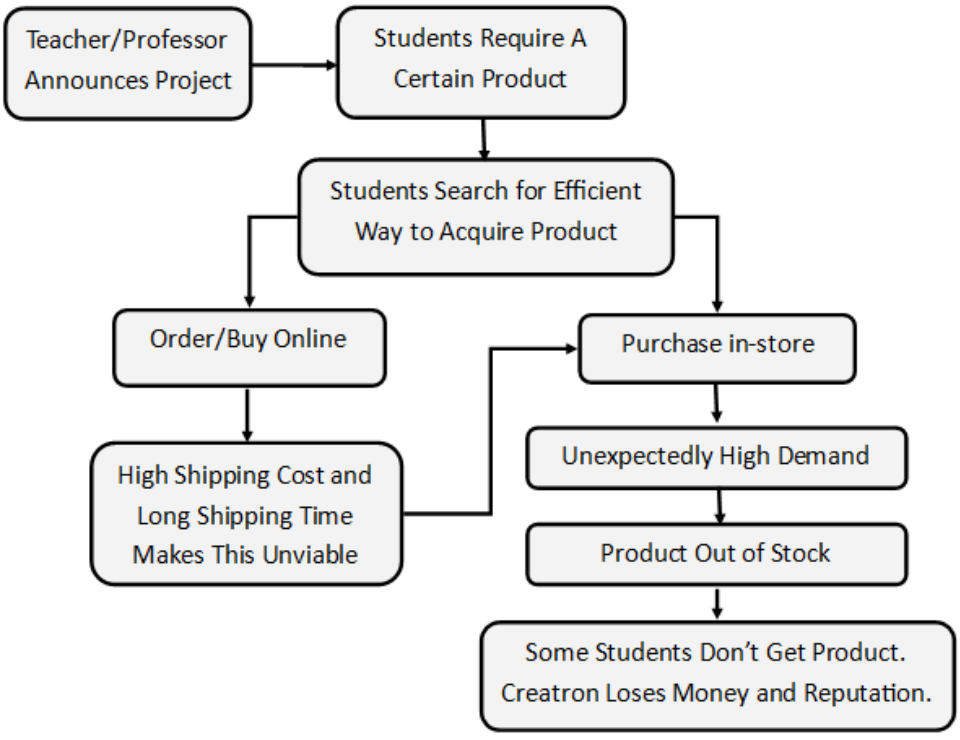


Figure 1: Causes, Stakeholders, and Consequences involved in Out-of-Stocks

Another case study involves a customer making a bulk purchase from Creatron. The customer was a

contest organizer for an IEEE Hackathon and required a total of 100 breadboards for the event [4]. With the hackathon on Saturday, February 19th, the organizer emailed beforehand and went to the Creatron store on Thursday. Originally, the Creatron staff told him that the earliest they could prepare the supplies would be Monday, two days after the hackathon takes place. In order to satisfy their customer and profit from the interaction, Creatron needed to make an extra shipment, and provided the supplies to the customer on Friday, the day before the hackathon.

According to this bulk purchaser, the event recurs annually. If Creatron kept track of recurring bulk purchases such as this one, they could benefit by being better prepared.

2.3 Opportunity

The Moneris point of sales system that Creatron is currently using leaves room for improvement, as there have been multiple instances of products running out of stock as stated above [3]. By developing a new inventory management or planning system, the quantities of various products can be known in greater detail, thus reducing the chance of an out-of-stock occurring and minimizing consequences to the business. Creatron should also ideally have a better way to communicate or partner with bulk buyers, such as organizers of hackathons, in order to better anticipate a bulk purchase. Improving communication with customers to anticipate extraordinarily high demand and refining the inventory management system would minimize out-of-stocks, which in turn, would improve Creatron's profits and customer service.

2.4 Importance of Reducing Out-of-Stocks

An out-of-stock (OOS) is an event that occurs when demand exceeds the current supply and the available inventory of a product is depleted. Generally, this can negatively affect a business like Creatron in the following ways:

- 44% of customers encountering an OOS would do without or buy from a competitor rather than buy another brand [6]
- "Revenue losses due to out-of-stock situations can far outweigh the stock losses themselves" [7]. In other words, a single OOS can cause long-term losses due to the inventory system inaccuracies that remain.

The causes of some OOS are seen below:

- Store errors caused 60% of OOS [6]
- Improper store ordering and demand forecasting systems caused 47% of OOS (Figure 2)

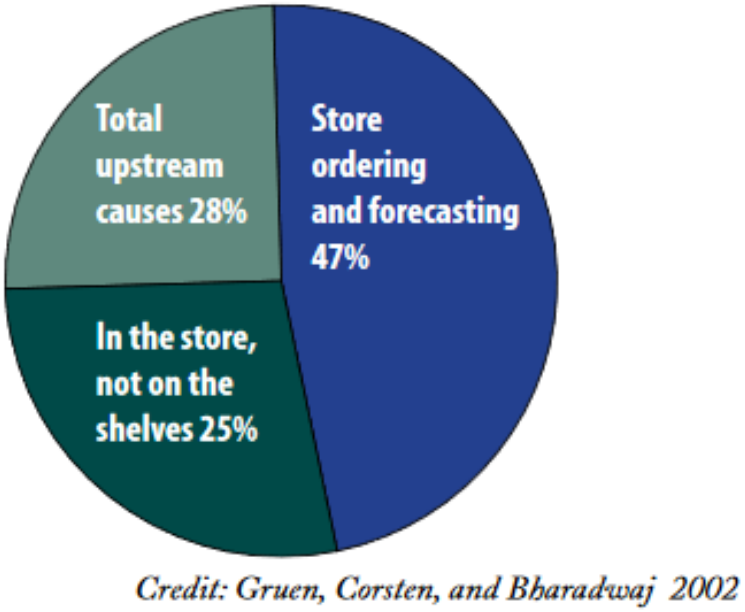


Figure 2: Root Causes of Out-of-Stocks [8]

Procter and Gamble showed that three of the root causes of OOS stemmed from flawed inventory management systems [8] (Figure 3):

Cause 1: inaccurate product data

- Inability to manage inventory data or account for product
  - Creatron uses software to conduct inventory management which is a more accurate method of tracking data than other alternatives, such as paper and pen [3].

Cause 2: poor ordering systems

- Overestimate supply or do not update information
  - Creatron does not track their OOS, which may interfere with their demand forecasting process [3]

Cause 3: demand forecasting inaccuracy

- Underestimates demand due to incomplete information
  - Creatron does not have a well defined method of communicating with event organizers/ schools [3]. This lack of information allows for these events, which often involve high demand for certain products, to often clear Creatron's entire inventory of certain items, which can leave other consumers unsatisfied.
- Does not account for replenishment issues like delivery timing
  - Creatron orders some items internationally. Sometimes, shipments are held at customs for unexpected amounts of time [3].

TYPE	ROOT CAUSE AREA	ISSUE DESCRIPTION	Usable Solution
Store Based Out of Stocks "Ordering"	Data Accuracy	Product data is inaccurate; perpetual inventory is inaccurate; POS data is inaccurate.	• Fix product data through data synch • Improve PI accuracy • Review POS scanning practices
	Forecast and Order Accuracy	Sales forecast is understated where OOS are unknown/not adjusted for in sales history. It is overstated where SKUs in history benefited from switching due to OOS from other SKUs. Demand forecast starts with the errors unknown from the sales forecast and attempts to estimate true demand based on unscientific judgment.	Add back measure of lost sales • Due to OOS in the estimate • Due to poor execution • Due to Data Synch errors
	Order Quantity	Demand forecast adjusted by inventory quantity which is frequently inaccurate.	• Enhance PI accuracy • Follow CAO recommendation for safety stocks level • Don't hide product • Use RFID to track cases and pallets
	Replenishment	Delivery cycle is too infrequent to match demand for fast moving items; quantity is different from order; delivery arrives late	• Adjust delivery cycle to meet most "stressed" items • Monitor delivery frequency and timing

Figure 3: Issues surrounding Out-of-stocks and Inventory Software
[8]

From the discussion with various Creatron employees, it appears that the greatest cause of OOS out of these three would be cause 3, as the largest contributor to out-of-stocks appeared to be unexpected bulk purchases.

2.5 Stakeholders

The main stakeholders involved in this community are listed below, along with how they are involved (Figure 4). Their ranking determines how much they affect or are affected by the current situation, with 1 being the most affected.

This ranking was determined through analysis of the stakeholders' power (level of authority), influence (active involvement), interest (level of concern) and impact (ability to affect project execution) according to the Project Management Body of Knowledge [11] (Figure 5).

Figure 4: Stakeholder Registry

Stakeholder	Stake	Rank
Creatron	• Sales are directly proportional to profit. • Sales affected by whether store supply is able to keep up with demand well.	1
Bulk Buyers (e.g. Schools and Event Organizers)	• Require large quantities of certain products, and are affected by whether or not the local store is not able to provide these products. • If demand is too high or if the store is out-of-stock, the students or participants may not be able to easily acquire the necessary parts. Examples include: hackathons, robotics tournaments.	2
Individual Purchasers	• Affect demand based on purchasing trends. The accuracy of Creatron's demand forecasting system determines whether the individual purchaser is able to acquire the necessary products. • Although individually these customers do not have a great impact on demand, there are many of them, causing them to have a large collective effect on demand.	3
Manufacturers/ Suppliers	• Produces and supplies Creatron with parts based on what Creatron predicts the demand will be. If predicted demand is high, Creatron will stockpile more in anticipation. The converse is true if demand is predicted to be low. • Manufacturers'/ Suppliers' profits are directly proportional to the orders Creatron places.	4
Competitors	• If Creatron is unable to attract enough interest through advertising, prices, etc. or supply enough to satisfy demand, other retailers will be able to take advantage. • Notable competitors include Sayal Electronics [9] and Digi-Key Electronics [10]	5

Figure 5: Stakeholder Ranking Process Chart

Stakeholder	Power	Interest	Impact	Influence
Creatron	High *(make purchasing decisions)*	High *(stand to profit from changes)*	High *(make all final decisions)*	High *(must implement all changes)*
Bulk Buyers	Medium *(have purchasing power)*	High *(large purchases may be affected)*	High *(purchasing habits may greatly alter system)*	Medium *(project may involve increased communication)*
Individual Purchasers	Medium *(have purchasing power)*	Medium *(small purchases may be affected)*	Medium *(purchasing habits may alter system)*	Low *(purchasing habits may only slightly change)*
Manufacturers/ Suppliers	Low *(simply a means of supply)*	Medium *(Creatron's purchasing decisions affect profit)*	Medium *(stock shipping and availability may impact system)*	Low *(only respond to orders)*
Competitors	Low *(only affect Creatron by comparison)*	Medium *(may lose business to Creatron)*	Low *(not involved in project execution)*	Low *(not involved in Creatron decisions)*

The above stakeholder analysis demonstrated that Creatron is the top stakeholder due to their high power, impact, influence, and interest. They are closely followed by bulk buyers, with high interest and impact, and then individual purchasers with medium power, interest, and impact. The least critical stakeholders are manufacturers/suppliers with medium interest and impact, and then competitors with medium impact.

Stakeholders were also classified according to the Project Management Body of Knowledge by engagement level, ranging from unaware to leading roles in the project [11] (Figure 6).

Figure 6: Engagement Level of Stakeholders

Stakeholder	Unaware	Resistant	Neutral	Supportive	Leading
Creatron					
Bulk Buyers					
Individual Purchasers					
Manufacturers/ Suppliers					
Competitors					

Note that most stakeholders are currently unaware of the project and its ramifications, but that Creatron are supportive of the endeavour.

3 *Requirements*

3.1 High Level Objectives (HLO)

1. Allow Creatron to have increased awareness of their potential bulk purchase sources.
    - This would allow Creatron to be better prepared for unexpected demand, thus reducing the number of out-of-stocks. By having better awareness, they can order from manufacturers in advance so that their supply would be able to meet the oncoming demand.
    - Stakeholders directly affected:
        i Creatron; items purchased from Creatron
        ii Manufacturers; items ordered by Creatron from manufacturers
        iii Bulk Buyers; buy from Creatron
2. Enable Creatron to predict trends in individual purchases.

- There are often trends for different products based on demands of individual customers, and this affects which products are in high demand. Individual customers, despite not purchasing vast quantities of materials, are much more frequent than bulk buyers. Therefore, the buying trends of collective individual purchasers affect general demand .
- Stakeholders directly affected:
  i Creatron; analyzes trends to determine which items are in demand
  ii Manufacturers; Creatron orders necessary items from manufacturers
  iii Individual purchasers; buy from Creatron, set trends in product demand

3. Increase Creatron's profit.
   - Creatron requires profit in order to pay its employees and stay in business. To do that, Creatron can increase the revenue it earns through sales, or reduce the costs of operation, which include number of employees, the cost of the systems used to manage the store and its inventory, and costs associated with maintaining the store.
   - Stakeholders affected:
     i Creatron; must profit from sales to stay in business
     ii Manufacturers; the greater Creatron's revenue, the more it can order from manufacturers.
4. Improve Creatron's reputation.
   - If customers are dissatisfied, they would frequent the business less and would also spread their negative impression of Creatron (through online reviews, or word of mouth). Similarly, if they are satisfied or impressed, they would be more inclined to recommend the business to others.
   - Stakeholders affected:
     i Creatron; the better the reputation of the company, the more customers it attracts, thus the more profitable it is
     ii Competitors; the market share of competitors is directly related to the market share of Creatron - the more customers Creatron has, the less its competitors have and vice versa.

3.2 Detailed Objectives (DO)

1. Enable Creatron to record and compile a list of their recurring bulk buyers.
   - Allows more accurate prediction of the sources of bulk purchases, which would lower the amount of out-of-stocks caused by these buyers as Creatron would be prepared in advance.
   - High Level Objectives Affected:
     i Increased awareness of upcoming bulk purchases
2. Develop a method to effectively track current demand for all products.
   - By knowing more about trends in the current demand, Creatron would be able to adjust their orders from the warehouse accordingly to meet the demand.
   - High Level Objectives Affected:
     i Prediction of trends in demand
3. Provide a channel for business-to-customer and customer-to-business communication.

- Communication between the business and customer would allow Creatron to prepare and provide for their customers.
- High Level Objectives Affected:
  i. Improved customer satisfaction
  ii. Prediction of trends in demand
  iii. Increased awareness of upcoming bulk purchases

4. Enable store managers to identify and forecast future demand for their products.
   - With information of future bulk orders, Creatron can account for the demand by, for example, stocking accordingly to prevent items from going out of stock.
   - High Level Objectives Affected:
     i. Prediction of trends in demand
     ii. Increased profit
     iii. Increased awareness of upcoming bulk orders
5. Develop a restocking strategy to maintain appropriate levels of stock as per expected demand.
   - Help Creatron maintain or improve customer satisfaction by keeping their store in stock while reducing costs of shipping by preventing the need for expedited delivery.
   - High Level Objectives Affected:
     i. Increased profit
6. Maintain or improve the current customer service level to increase customer satisfaction.
   - Improving the customer service would increase customer satisfaction levels, thus improving Creatron's reputation and increasing profit [12], and increasing the number of positive reviews.
   - High Level Objectives Affected:
     i. Improved reputation
7. Minimize cost of inventory management system.
   - If the cost of the system itself is too high, it might negate any potential benefits it would make, as Creatron would still be losing profit. Lower cost would increase profit.
   - High Level Objectives Affected:
     i. Increased profit
8. Resolve out-of-stock cases as quickly as possible
   - This would allow Creatron to reduce the effect that an out-of-stock has on profit and reputation, as fewer customers would be inconvenienced if stocks are quickly replenished.
   - High Level Objectives Affected:
     i. Increased profit
     ii. Improved reputation

3.3 Metrics

1. Number of unanticipated bulk buyers
    - The fewer the number of unanticipated bulk buyers, the more equipped Creatron is to supply the demand
2. Number of out-of-stocks
3. Number of years of data used to forecast demand for trends
    - As years pass, trends become more apparent, allowing demand to be predicted more effectively
4. Quality of data "tracked" measured in amount of information stored from the following:
    - Demographic of customer in need of item
    - Cost of item
    - Item identification
    - Discount on item
    - Number of items in stock
    - Whether item is out-of-stock or in-stock
5. Time it takes for business to respond to customer request for communication online/by phone
6. Effectiveness of method of communication, measured in time needed to record all necessary information as specified:
    - List of items needed
    - Amount of each item needed
    - Time by which items are needed
    - Identification information of customer
7. Cost to implement new system (in Canadian dollars)
8. Average time to check out an item
    - Since POS is used to track inventory at checkout, change in inventory tracking system affects checkout time
9. Ratio of positive to negative responses, where a negative response indicates that an OOS affects the customer's ability to purchase a product at Creatron
    - Any response type may be used to calculate ratio (for example, online reviews or customer surveys)
10. Average time taken per item to restock after an out-of-stock case
11. Change in projected revenue from purchases after implementing system (in Canadian dollars)

The following flowchart graphically shows the relationship between the above requirements (Figure 7).

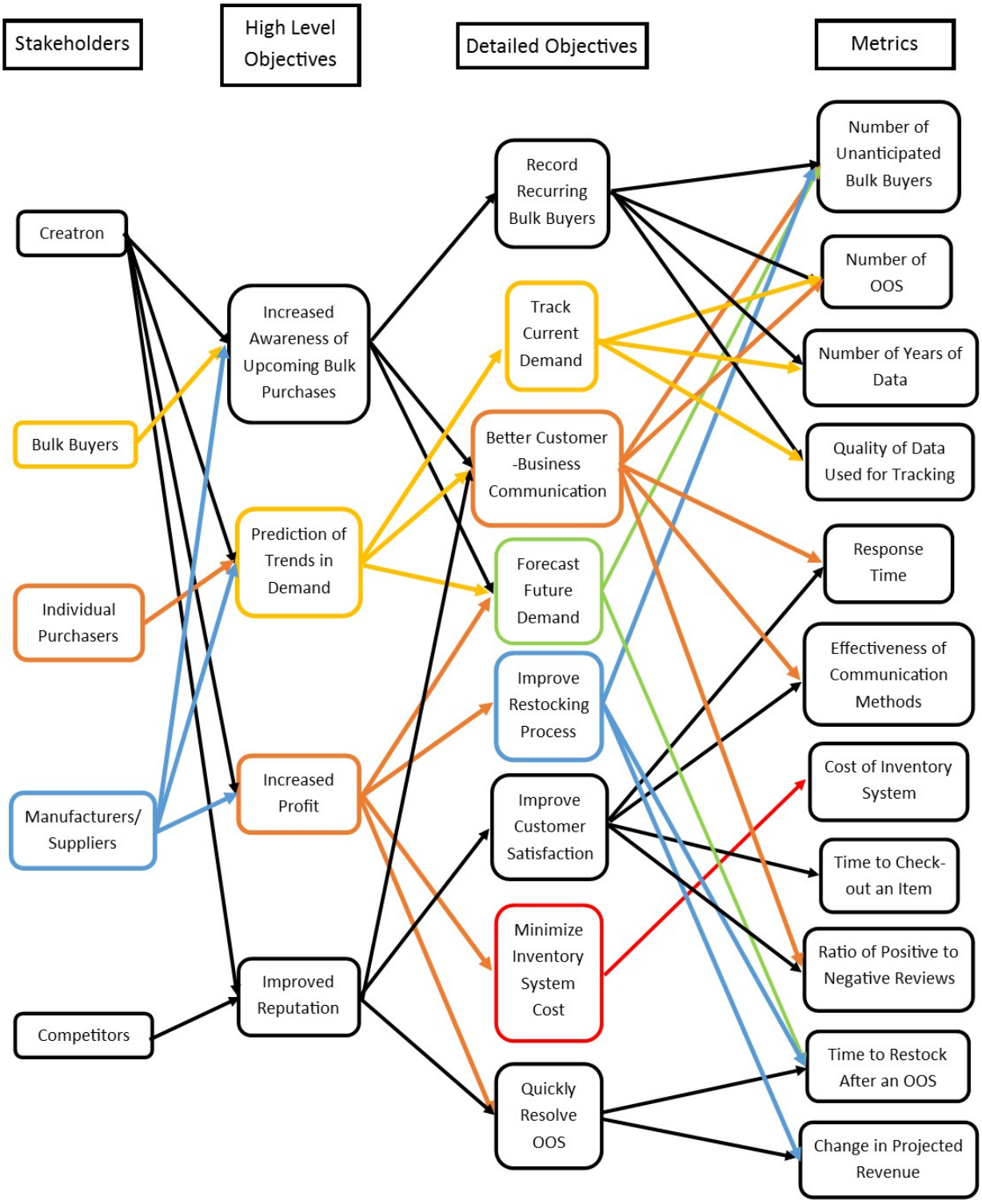


Figure 7: Relationships between Stakeholders and Requirements

3.4 Constraints

1. Number of out-of-stocks must be equal to or less than the current amount
    - The number of out-of-stocks is a critical issue with the current method, and reducing it is one of the main foci of this opportunity.
2. Cost to implement system must be within Creatron's operating budget.
    - If Creatron is unable to afford the solution, it will not be implemented
3. Average time to check out an item must be equal to or less than the current amount
    - This would ensure that customer satisfaction levels during checkout are at least maintained, and that the day-to-day operations of Creatron in the store itself are not adversely affected.

3.5 Criteria

1. Fewer unexpected bulk buyers are preferred
    - This reduces the number of times where unexpected demand can affect stocks.
2. Fewer out-of-stocks preferred
    - This would improve customer satisfaction, and reduce the negative impact that out-of-stocks have on the business.
3. Data that spans a longer period of time is preferred
4. Higher quality data preferred, i.e., accounts for greatest possible portion of Metric 4
    - Higher quality data would improve analysis of past and current trends
5. Faster response to customer requests via phone/online preferred
    - This would improve the communication system between business and customers, potentially leading to new partnerships which can improve business relations and enable the company to be more aware of incoming purchases.
6. Less time required to record necessary information preferred
    - More effective communication would improve the amount of information that can be received, and reduce the chance of misunderstanding or lacking information
7. Lower cost to implement system is preferred
    - Lower cost results in more profit for Creatron and its employees
8. Faster customer checkouts are preferred
    - Improves customer satisfaction and maximizes employee time efficiency
9. Higher positive to negative ratio of reviews is preferred

- Improves Creatron's reputation, potentially leading to more customers

10. Faster resolution to out-of-stock cases is preferred
    - Lessens the negative effects of an out-of-stock case
11. Increased revenue is preferred
    - Creatron would have greater profit margins and may be able to expand.

The relationship between metrics, criteria, and constraints is summarized in the metric flowchart (Figure 8).

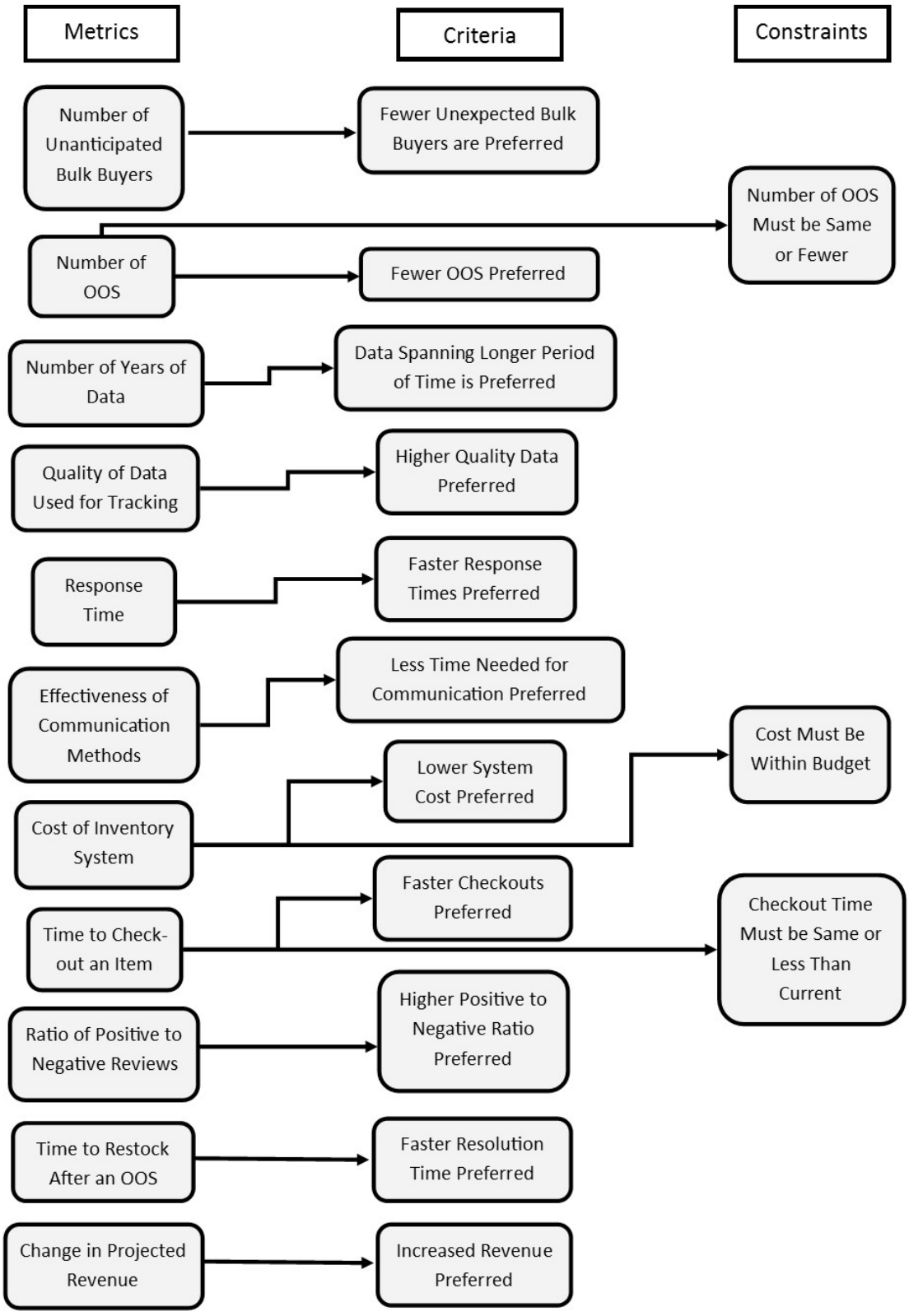


Figure 8: Analysis of Metrics and Relations to Criteria and Constraints

4 *Approaches*

This opportunity has multiple facets that can be dealt with in order to satisfy all the requirements. These include:

- Software components: integrating software to keep track of inventory and sales, communicating with consumers, predicting demand etc.
- Physical devices: using a calendar or organized shelf in order to better communicate what has been bought, sold, and is still available.
- Processes: altering inventory keeping/employee training process to improve availability of products. This includes training, checklists, and changing how people currently manage the inventory, without changing the physical storage system or software itself.

A solution may take into account only one of these aspects but may also take into account multiple approaches in order to develop a hybrid solution. Keep in mind that even though most of the reference designs may be software based, potential solutions do not have to be.

5 *Reference Designs*

There are several designs currently available that are able to meet some but not all of the aforementioned objectives. Each have their own positives and negatives, and will be compared in the table below (Figure 11).

5.1 Point-of-Sales

The current design that is employed by Creatron is a point-of-sales (POS) system designed by Moneris [3]. A POS system analyzes what customers buy when they make a purchase, to see which products are popular and track the rate at which inventory is exhausted [13]. Due to the current sophisticated software, most companies choose this option for its 85% accuracy ratio and its ability to analyze sales patterns [8]. However, such a software is difficult to adjust for those with poor computing skills, and 85% accuracy still leaves room for improvement. Furthermore, it lacks the capability to deal with sudden demands, which cause most of Creatron's out-of-stocks, and does not analyze details regarding delivery and quantity.

5.2 Perpetual Inventory

Perpetual inventory systems attempt to prevent OOS by setting a given limit for inventory, denoted R, below which the stock should not be allowed to drop [14] (Figure 9). This limit is set after a given period of analysis and aims to prevent ordering new stock until the last minute, so that the new shipment of Q items arrives exactly when the product runs out. Perpetual inventory on its own is less than 50% accurate and is

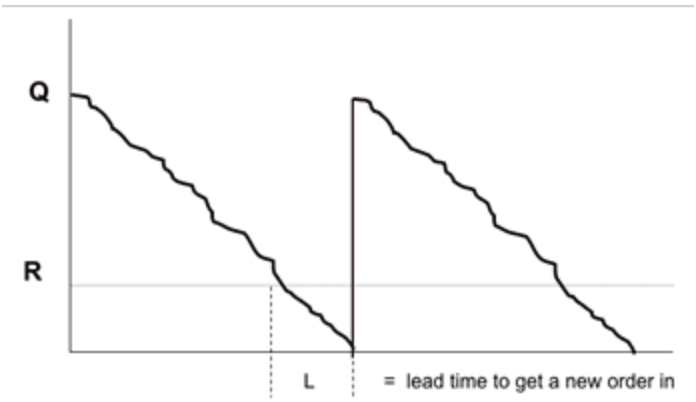


Figure 9: Perpetual Inventory system, where a shipment of Q items is ordered when current inventory drops to R, L time before predicted OOS [14]

normally combined with a POS system, as in the case of Creatron, to increase its effectiveness [8]. However, this system is also unable to account for sudden bulk purchases or delivery delays.

5.3 Manual Auditing

Completely manual auditing is another alternative. With careful workers, this method can achieve very high accuracy; however, it is difficult to scale, and would be taxing to implement for every product in Creatron [8]. It is also expensive, as extra workers need to be hired to solely manage the inventory. Both of these factors make it difficult to sustain in the long-term, making this an unviable option.

5.4 RFID Tags

The Radio Frequency Identification tagging system is another method used in industry. One example is Wal-Mart, which uses this method to reduce out-of-stocks by up to 16% [15]. The method works by planting small devices into cases, packaging, or the products themselves that either emit radio waves, or respond to radio waves. In either case, it allows for the sale of a product to be easily documented as the counting process is done electronically and, unlike a barcode, does not require a large surface that is scanned directly [8] (Figure 10). The amount of sales is then compared to the amount of stock, and resupplies are issued accordingly. This method has been proven to be quite effective for Wal-Mart, however, it is also extremely expensive, making them unviable for smaller businesses. In the case of Creatron, this method would be ineffective, since RFID tags are usually used to mark pallets of equipment and track when these pallets are emptied, and Creatron is so small that they are not likely to have multiple pallets of equipment [15]. This method is better suited to a store that has enough equipment that a large-scale analysis technique is necessary, but at Creatron most products appear to be present in relatively small quantities.

5.5 Inventory Calendar

A carefully maintained inventory calendar is another method that can be used to track sales and events. The store can track daily sales and incoming shipments in order to visualize and organize the information better. As well, future events can be plotted on the calendar in order to plan ahead for future bulk purchases.

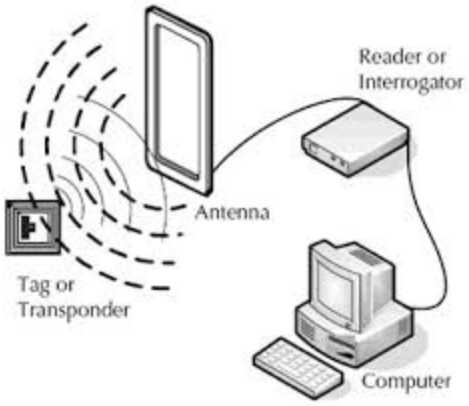


Figure 10: Process for RFID Tag System [16]

Once a year's worth of information is gathered, some trends and annual events would be known, allowing Creatron to prepare more effectively in the years to come. This calendar would be continuously updated every month or year. However, there are some downsides to this method: it is rather ineffective in the first year to plan for future bulk purchases, and it does not improve predictions for non-repeating or inconsistently repeating events.

5.6 University Partnerships

Partnerships with universities are also part of Creatron's current system of inventory management. Creatron currently partners with some professors in institutions such as the University of Toronto, Ryerson University, and the Ontario College of Art and Design (OCAD) in order to produce starter kits for some of the students [2]. Since Creatron and the professors can communicate directly, Creatron can prepare an exact amount of kits in advance for students, which means they will not understock or overstock the kits. However, this requires fast, direct communication with customers, a guarantee that the products will be sold, and many customers to make the kit building process profitable for Creatron. As well, Creatron currently does not partner with other sources of bulk purchases such as hackathons in order to produce kits due to the fact that hackathons may not request items far enough in advance, potentially leading to out-of-stocks, and due to the difficulty of scoping a communications process across all potential bulk buyers in the GTA [3].

5.7 Reference Design Comparison

Figure 11: Advantages and Disadvantages of Various Reference Designs

Reference Design	Advantage	Disadvantage
Point-of-sales	• Fairly accurate • Can be purchased straight from vendor	• Must be combined with other software to track inventory intake • Cannot account for future demand from bulk purchases
Perpetual Inventory	• Can be integrated with POS • Sets dates to reorder product	• Inaccurate • Does not account for sales spikes
Manual Auditing	• Fairly accurate • Highly customizable	• Time consuming and expensive • Laborious • Workers may lack ability to manually analyze trends
RFID Tagging	• Tailored to individual products • Works well with other software	• Tags usually go on pallets not individual products • Unable to tag some products such as wires • Expensive
Calendar	• Can double as store planning strategy • Highly customizable • Inexpensive	• Time consuming • Difficult to spot trends • Does not improve planning for non-repeating events, or events that repeat inconsistently
University Partnerships	• Tailored to each bulk buyer's needs, increasing customer satisfaction • Knows demand in advance, thus reducing out of stocks	• Currently only with some university professors • Not profitable for small purchases • Requires consistent and accurate direct communication with consumers

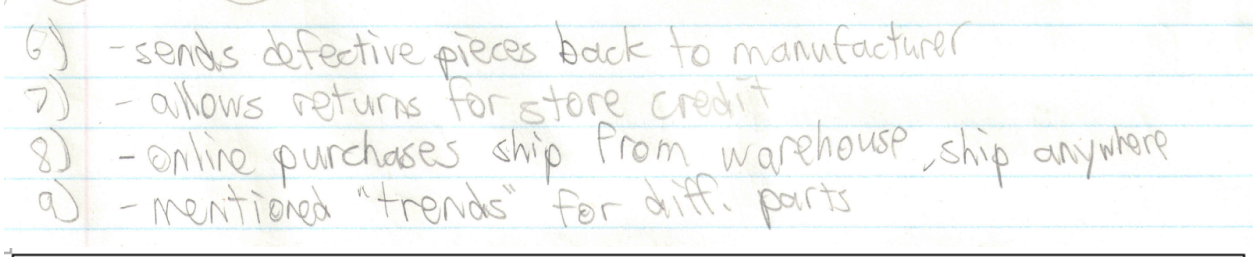
6 *Next Steps*

The currently available designs generally do not satisfy all of the objectives. Respondents to this RFP should aim to implement a design that will create a low-cost, accurate, and time-efficient inventory system. This can be done by changing software, physical, or procedural aspects of the current system. A design must enact significant improvements with respect to profit, reputation, awareness of bulk purchases, and recognition of demand trends before it can be considered to have sufficiently addressed the opportunity.

Bibliography

[1] "Creatron website." [Online] Available: `https://www.creatroninc.com`.

[2] J. Chan. In-Person Interview with Creatron Employee, Jan. 2017.



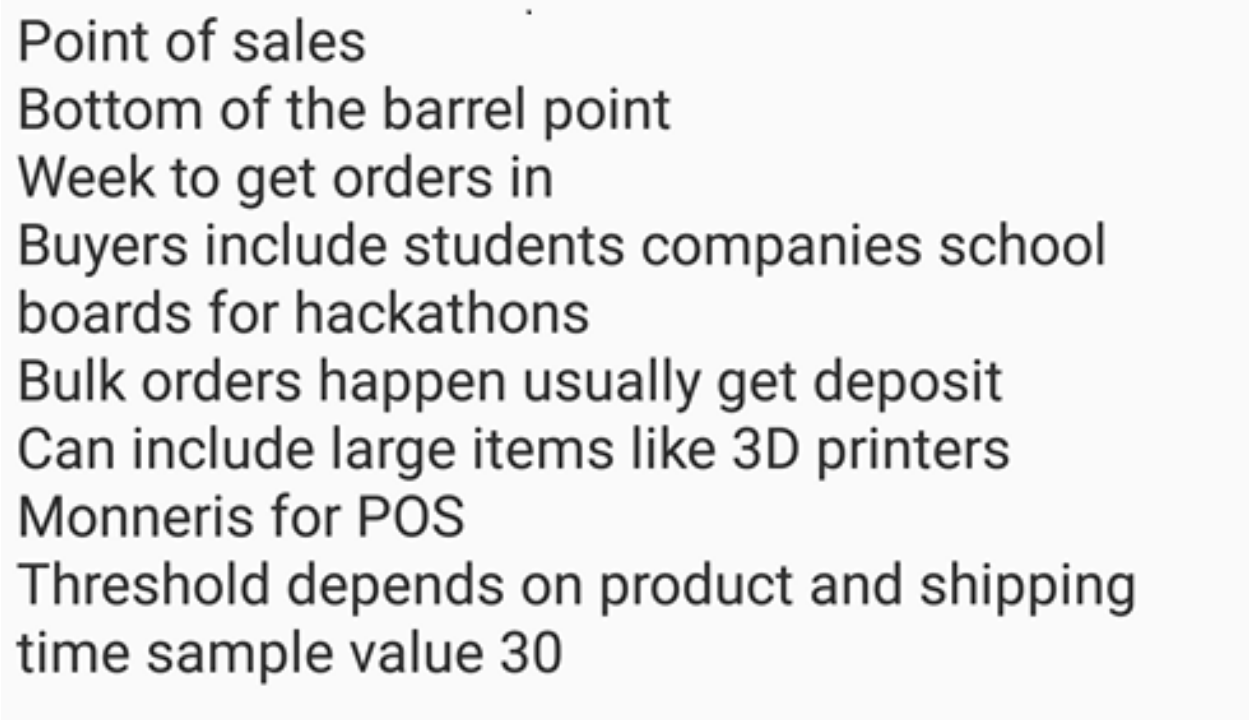
Customers:
students in university and high school
- University of Toronto
- Ryerson University
- OCAD

Communication with customers:
Starter kit for universities
- Know about the components needed for University projects
- Group required component as a kit to be sold as a package

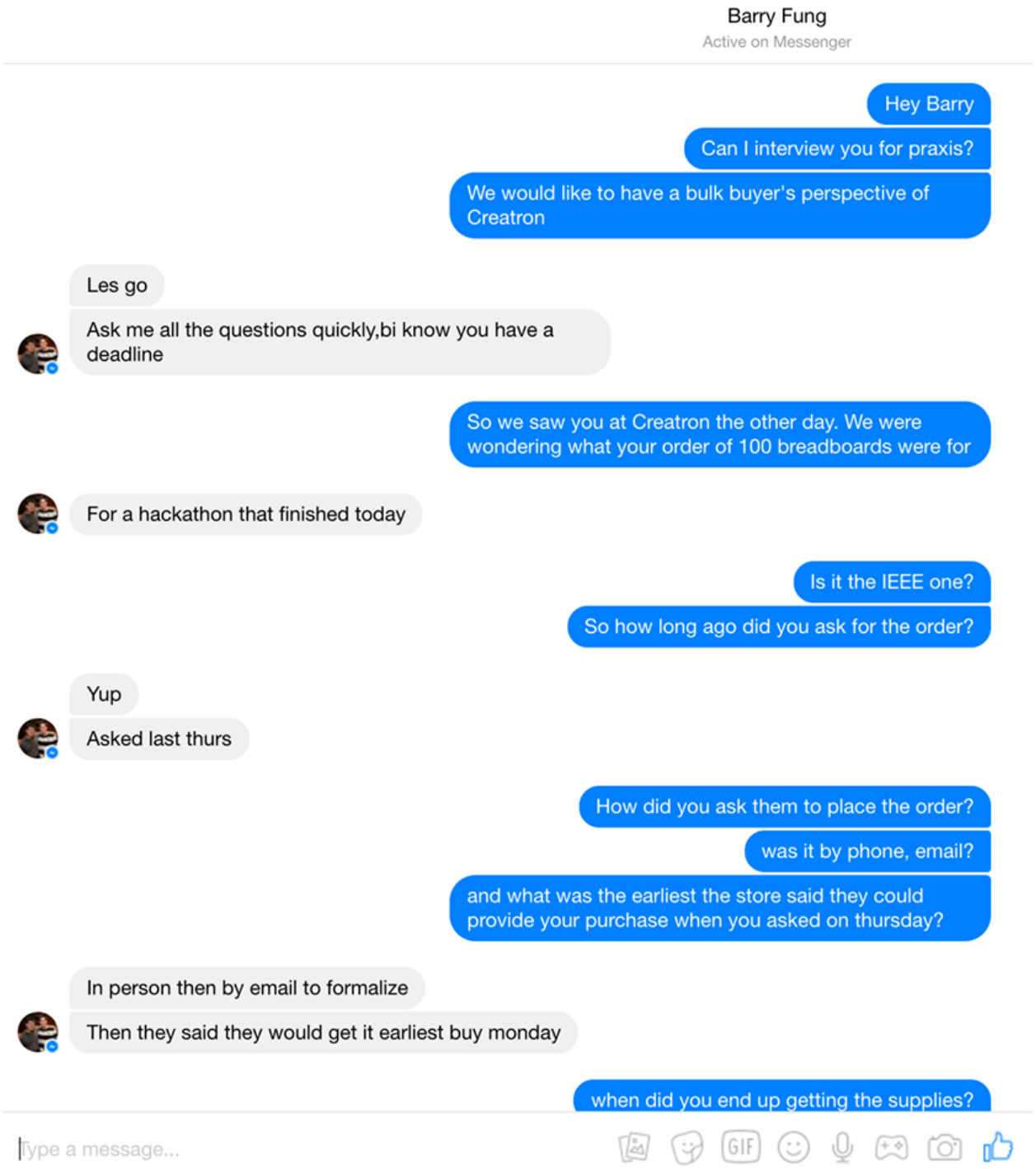
Does not have starter kits for students in high schools
Because:
- Too many high schools
- High school curriculum relatively unknown because it changes year to year

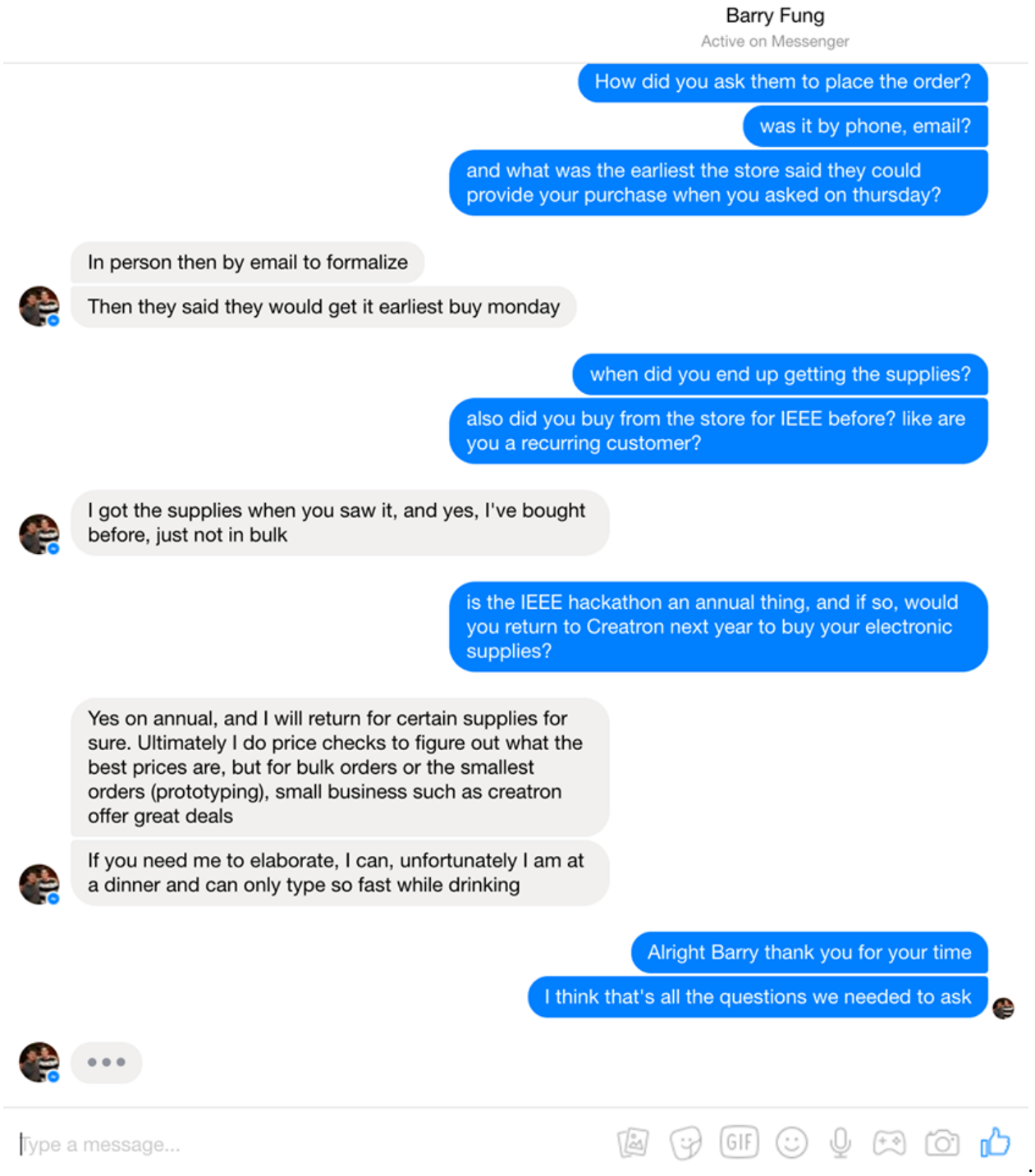
An incident from last year:
Students from Marc Garneau CI bought out all strain gauges from all Creatron branches in Toronto

[3] J. Fung. In-Person Interview with Creatron Employee, Feb. 2017.



[4] B. Fung. Facebook Messenger Interview with Event Organizer, Feb. 2017.


Barry Fung
Active on Messenger
Hey Barry
Can I interview you for praxis?
We would like to have a bulk buyer's perspective of Creatron
Les go
Ask me all the questions quickly,bi know you have a deadline
So we saw you at Creatron the other day. We were wondering what your order of 100 breadboards were for
For a hackathon that finished today
Is it the IEEE one?
So how long ago did you ask for the order?
Yup
Asked last thurs
How did you ask them to place the order?
was it by phone, email?
and what was the earliest the store said they could provide your purchase when you asked on thursday?
In person then by email to formalize
Then they said they would get it earliest buy monday
when did you end up getting the supplies?
Type a message...
GIF



[5] B. Esanu. In-Person Interview with Former Student, Feb. 2017.

By signing this document, I agree to have provided information pertaining to the purchase of goods from Creatron, as well as my experience with this company as a customer.

Name: BIANCA ESAN

Date: Feb 5th, 2017

Signature: Bianca Esan

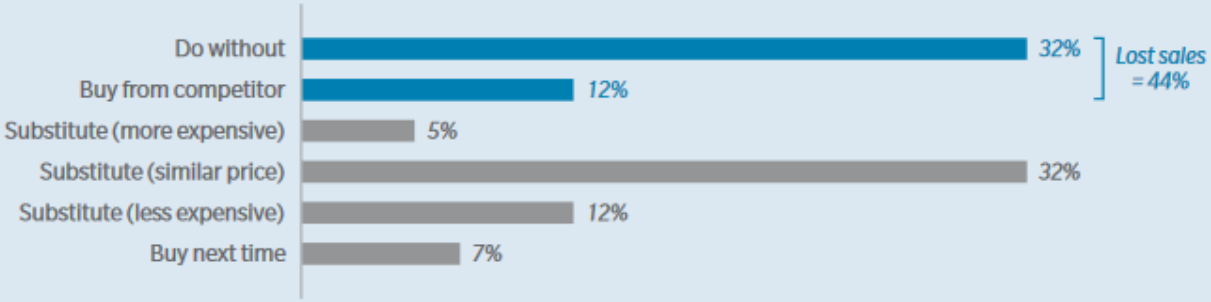
Discipline: ECE

[6] O. Wyman Oct. 2015. [Online] Available: http://www.oliverwyman.com/content/dam/oliver-wyman/global/en/2015/oct/OW_Optimising_Store_Operations.pdf

Poor on-shelf availability 	Out-of-stocks are often caused because automatic or semi-automatic ordering systems are too complex and ordering tools for staff are not helpful; hence sales may not be backed by sufficient supplies.	Screen most common reasons for out-of-stocks and check forecasting systems and inventory tools for weaknesses – if possible adjust system parameters and simplify tools. See Case Study 3.

Exhibit 6: How customers respond to out-of-stocks

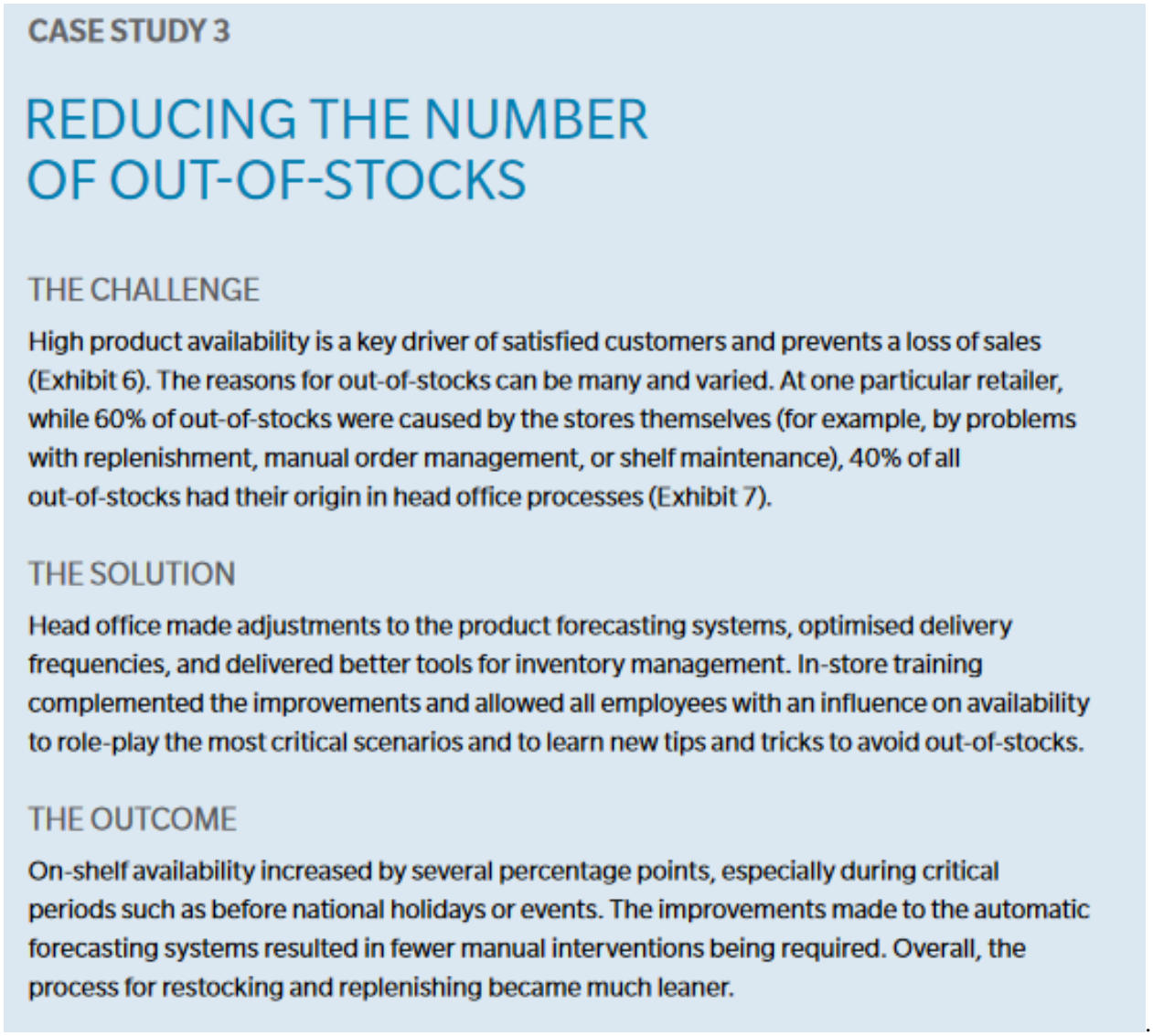
SHARE OF TOTAL



Source: Oliver Wyman analysis

Exhibit 7: Why do products go out of stock?

Source: Oliver Wyman analysis



CASE STUDY 3

REDUCING THE NUMBER OF OUT-OF-STOCKS

THE CHALLENGE

High product availability is a key driver of satisfied customers and prevents a loss of sales (Exhibit 6). The reasons for out-of-stocks can be many and varied. At one particular retailer, while 60% of out-of-stocks were caused by the stores themselves (for example, by problems with replenishment, manual order management, or shelf maintenance), 40% of all out-of-stocks had their origin in head office processes (Exhibit 7).

THE SOLUTION

Head office made adjustments to the product forecasting systems, optimised delivery frequencies, and delivered better tools for inventory management. In-store training complemented the improvements and allowed all employees with an influence on availability to role-play the most critical scenarios and to learn new tips and tricks to avoid out-of-stocks.

THE OUTCOME

On-shelf availability increased by several percentage points, especially during critical periods such as before national holidays or events. The improvements made to the automatic forecasting systems resulted in fewer manual interventions being required. Overall, the process for restocking and replenishing became much leaner.

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[7] Y. Kang and S. B. Gershwin, "Information inaccuracy in inventory systems: stock loss and stockout," *IIE Transactions*, vol. 37, pp. 843–859, Sept. 2005. [Online] Available: http://resolver.scholarsportal.info.myaccess.library.utoronto.ca/resolve/0740817x/v37i0009/843_iiisslas.xml

Many companies have automated their inventory management processes and now rely on information systems when making critical decisions. However, if the information is inaccurate, the ability of the system to provide a high availability of products at the minimal operating cost can be compromised. In this paper, analytical and simulation modelling demonstrate that even a small rate of stock loss undetected by the information system can lead to inventory inaccuracy that disrupts the replenishment process and creates severe out-of-stock situations. In fact, revenue losses due to out-of-stock situations can far outweigh the stock losses themselves. This sensitivity of the performance to the inventory inaccuracy becomes even greater in systems operating in lean environments. Motivated by an automatic product identification technology under development at the Auto-ID Center at MIT, various methods of compensating for the inventory inaccuracy are presented and evaluated. Comparisons of the methods reveal that the inventory inaccuracy problem can be effectively treated even without automatic product identification technologies in some situations.

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[8] D. Corsten and T. W. Gruen, "A comprehensive guide to retail out-of-stock reduction in the fast-moving consumer goods industry," 2007. [Online] Available:http://www.nacds.org/pdfs/membership/out_of_stock.pdf

Measurement Must Point to the Root Cause

Regardless of the measurement system used to track OOS— manual audit, POS data estimation, or perpetual inventory—it must be sustained, and it must point towards root causes. Due to their high expense and difficulty to scale, manual audits are usually not sustainable, and they do not provide a measure of sales loss. However, they can be effective when targeted at the most crucial products (either high velocity items or strategically important items such as "never outs" or preferred private brands), and when a second level of analysis is incorporated that links each OOS event to its likely root cause. A systematic means of assigning each identified OOS event to a set of pre-determined root causes can be implemented at a relatively low initial cost. However, it is costly to scale to a large number of items.

The use of point of sale (POS) data is a viable measurement method for many store formats. There are a number of companies that have developed algorithms to estimate OOS from POS data, and some retailers have developed their own in-house systems. POS measurement systems can be sustained, scaled and are able to deliver sales loss and duration measures. The accuracy of estimating OOS using POS data is 85 percent or greater, which is equivalent or greater to the accuracy of manual audits (where human error is present). One recent development of using POS data calculation is the ability to discern visible patterns in out of stocks and thereby point directly at possible root causes

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A third approach to measurement, perpetual inventory (PI) measurement systems can also be sustained, scaled and deliver sales loss and duration measures. However, PI systems suffer from the lack of on-hand accuracy necessary to make them consistently good measures. Algorithmic

Root Causes and Solutions

Moving from left to right across the trapezoids shown in Exhibit A, we researched seven key, different root causes and solution areas.

1. **Product Item Data Accuracy**. Product data inaccuracy creates an unstable foundation for ordering and forecasting. Commonly referred to as "data synch," there are clear impacts on out of stocks when product data issues are excessive. The primary recommendation focuses on collaborative synchronization of data between suppliers and retailers using a third party vendor. We also show how the use of a parent-child product relationship system can enhance product data accuracy.
2. **Ordering and Inventory Accuracy**. We identified a variety of store issues that create PI system inaccuracy (especially on hands). The level of PI inaccuracy was stunning, as PI accuracy (where the PI exactly matched the on-hands) ranged from 32 percent to 45 percent in the four studies we conducted or examined. Exhibit D shows the distribution of PI accuracy for the best case we encountered. Phantom inventory (when PI system on-hand is greater than true physical product on-hand) is a major cause of OOS, particularly store OOS, because the reorder system does not recognize how low store inventory levels are. For the retailer shown in Exhibit D, items with correct on-hands had OOS event rates of 4.1 percent and had a rate of 8.9 percent where on-hands were not accurate.

3. **Demand Forecasting Accuracy.** Ideally a demand forecast should be the same as a sales forecast, however they invariably differ, largely because of the impact of sales variances caused by OOS. Whenever a shopper does not buy or shifts their buying pattern due to an OOS, it adjusts the demand history away from the sales history and no one can see the true demand history. Merging POS lost sales history with the sales history can more closely represent true demand and lead to better demand forecasts. When we further examined the impact of individual store managers adjusting merchandising quantities from suggested computer assisted ordering (CAO) quantities, we found that store personnel underperform even imperfect CAO demand forecasts.
4. **Store and Shelf Replenishment.** Using the POS measurements we were able to identify patterns that showed when store replenishment (from the distribution center or by DSD vendors) was too infrequent. We also found a positive relationship between backroom inventory and OOS, and thus recommend matching delivery schedules to meet the demand on the shelf, rather than maintaining backstock (except for promotional and other specific items).

RFID Technology and Shelf Out of Stocks

Due to technological and financial reasons, most radio frequency identification (RFID) applications have been limited to tags on pallets and cases and have not descended to the individual item level, where RFID shows great promise to address shelf OOS. However, at the case and pallet level, RFID applications can track when the cases are delivered to the store's backroom, and when they move from the backroom to the store floor and vice versa. As a result, RFID has been shown to reduce shelf OOS for high velocity items that require that the store hold large levels of backstock. RFID applications can enhance sorting of cases coming off a delivery truck. Items that are known OOS get identified quickly for immediate stocking, while items that are still available to the shopper but have room on the shelf for a full case get secondary attention. Cases that are back-stock remain in the backroom, rather than being taken to the sales floor and returned. RFID requires disciplined shelf stocking practices. A case that cannot be completely stocked on the shelf becomes a problem when returned partially full because the RFID does not recognize a partial case in the backroom. In addition, RFID is being effectively applied to recognize shrink at the case level, where the impact of unrecognized shrink can have a large effect on OOS due to its large impact on inventory inaccuracy.

In sum, there are a variety of reasons, but we have identified the primary reasons:

- Demand forecasts are made with incomplete information, and thus often under-estimate demand;
- Inaccurate data from inventory systems provide incorrect ordering information;
- Traditional retail practices such as using only case-pack size to determine shelf allocation (86 percent of the dollar inventory on the shelf represents more than 7 days of supply) prevail, choking shelf space from the relative few fast movers, without consideration of time of supply;
- Item/SKU (stock keeping unit) proliferation—suppliers battle for shelf space by introducing "me-too" items, and are constantly changing UPC / GTIN (universal product code / global trade identification number) information and thereby contribute to inventory database inaccuracy;
- Promotional proliferation, generally at the urging of suppliers;
- Consolidation among retailers that bridge information systems containing inaccurate legacy data;
- Pressure to reduce personnel cost resulting in inadequate labor supply.

A. How accurate is inventory information?

Inventory record inaccuracy is a substantial problem for retailers using automated inventory management systems. Overall we found in our research that inventory records match actual inventory on-hand at a surprisingly low rate. In spite of large investments by retailers in perpetual inventory (PI) systems that link to POS systems, physical audits consistently show that PI data are typically accurate for less than half of the items in the store.

Accuracy can work two ways, with the actual on-hand inventory exceeding the recorded inventory level, or the actual on-hand inventory lower than the recorded inventory level. The physical audits show that about half of the time the PI shows more inventory to be in the store than is actually on-hand (referred to as "phantom" inventory), and that about half of the time the PI shows less inventory to be in the store than is actually on-hand (referred to as "hidden" inventory). Thus inventory accuracy is typically recorded as +- 1, +-2, +-3, and so on, reflecting the presence of both phantom and hidden inventory. There are several sources for inventory

[9] "Sayal electronics website," Feb. 2017. [Online] Available: `http://sayal.com/zinc/index.asp`.

[10] "Digi-key electronics website." [Online] Available: `http://www.digikey.com/`.

[11] *Project Stakeholder Management*, ch. 13. Project Management Institute, 5 ed., 2013. [Online] Available: `http://app.knovel.com/hotlink/toc/id:kpGPMBKPM1/guide-project-management/guide-project-management`

13.1.2.1 Stakeholder Analysis

Stakeholder analysis is a technique of systematically gathering and analyzing quantitative and qualitative information to determine whose interests should be taken into account throughout the project. It identifies the interests, expectations, and influence of the stakeholders and relates them to the purpose of the project. It also helps to identify stakeholder relationships (with the project and with other stakeholders) that can be leveraged to build coalitions and potential partnerships to enhance the project's chance of success, along with stakeholder relationships that need to be influenced differently at different stages of the project or phase.

Stakeholder analysis generally follows the steps described below:

- Identify all potential project stakeholders and relevant information, such as their roles, departments, interests, knowledge, expectations, and influence levels. Key stakeholders are usually easy to identify. They include anyone in a decision-making or management role who is impacted by the project outcome, such as the sponsor, the project manager, and the primary customer. Identifying other stakeholders is usually done by interviewing identified stakeholders and expanding the list until all potential stakeholders are included.
- Analyze the potential impact or support each stakeholder could generate, and classify them so as to define an approach strategy. In large stakeholder communities, it is important to prioritize the stakeholders to ensure the efficient use of effort to communicate and manage their expectations.
- Assess how key stakeholders are likely to react or respond in various situations, in order to plan how to influence them to enhance their support and mitigate potential negative impacts.

There are multiple classification models used for stakeholders analysis, such as:

- *Power/interest grid*, grouping the stakeholders based on their level of authority ("power") and their level or concern ("interest") regarding the project outcomes;
- *Power/influence grid*, grouping the stakeholders based on their level of authority ("power") and their active involvement ("influence") in the project;
- *Influence/impact grid*, grouping the stakeholders based on their active involvement ("influence") in the project and their ability to effect changes to the project's planning or execution ("impact"); and
- *Salience model*, describing classes of stakeholders based on their power (ability to impose their will), urgency (need for immediate attention), and legitimacy (their involvement is appropriate).

13.1.3.1 Stakeholder Register

The main output of the Identify Stakeholders process is the stakeholder register. This contains all details related to the identified stakeholders including, but not limited to:

- **Identification information.** Name, organizational position, location, role in the project, contact information;
- **Assessment information.** Major requirements, main expectations, potential influence in the project, phase in the life cycle with the most interest; and
- **Stakeholder classification.** Internal/external, supporter/neutral/resistor, etc.

The stakeholder register should be consulted and updated on a regular basis, as stakeholders may change—or new ones identified—throughout the life cycle of the project.

13.2.2.3 Analytical Techniques

The current engagement level of all stakeholders needs to be compared to the planned engagement levels required for successful project completion. Stakeholder engagement throughout the life cycle of the project is critical to project success.

The engagement level of the stakeholders can be classified as follows:

- **Unaware.** Unaware of project and potential impacts.
- **Resistant.** Aware of project and potential impacts and resistant to change.
- **Neutral.** Aware of project yet neither supportive nor resistant.
- **Supportive.** Aware of project and potential impacts and supportive to change.
- **Leading.** Aware of project and potential impacts and actively engaged in ensuring the project is a success.

The current engagement can be documented using Stakeholders Engagement Assessment Matrix, as shown in Figure 13-7, where C indicates the current engagement, and D indicates the desired engagement. The project team needs to identify the desired engagement level for the current phase of the project, based on available information.

Stakeholder	Unaware	Resistant	Neutral	Supportive	Leading
Stakeholder 1	C			D	
Stakeholder 2			C	D	
Stakeholder 3				D C	

Figure 13-7. Stakeholders Engagement Assessment Matrix

[12] E. W. Anderson, C. Fornell, and R. T. Rust, "Customer satisfaction, productivity, and profitability: Differences between goods and services," *Marketing Science*, vol. 16, no. 2, pp. 130–131, 1997. [Online] Available: http://bear.warrington.ufl.edu/centers/mks/articles/customersatisfaction.pdf

A variety of studies find that higher levels of customer satisfaction lead to greater customer loyalty (Anderson and Sullivan 1993, Bearden and Teel 1983, Bolton and Drew 1991, Boulding et al. 1993, Fornell 1992, LaBarbera and Mazursky 1983, Oliver 1980, Oliver and Swan 1989, Yi 1991). Through increasing loyalty, it is argued, customer satisfaction helps to secure future revenues (Fornell 1992, Rust et al. 1994, 1995), reduce the costs of future transactions (Reichheld and Sasser 1990), decrease price elasticities

(Anderson 1996), and minimize the likelihood customers will defect if quality falters (Anderson and Sullivan 1993). Internally, improving quality and customer satisfaction reduces costs associated with defective goods and services, such as warranty costs, field service, reworking/replacing defective goods, and handling/managing complaints (Crosby 1979, Fornell and Wernerfelt 1988, Garvin 1988, Gilly and Gelb 1982, TARP 1979, 1981). Word-of-mouth from satisfied customers lowers the cost of attracting new customers and enhances the firm's overall reputation, while that of dissatisfied customers naturally has the opposite effect (Anderson 1994, Fornell 1992). Finally, empirical work suggests that firms providing superior quality enjoy higher economic returns (Aaker and Jacobson 1994, Anderson et al. 1994, Capon et al. 1990, Nelson et al. 1992).

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[13] "Point of sale (pos) statement of needs," Apr. 2013. [Online] Available: http://www.se.rit.edu/~se361/Activities/POS-StatementOfNeeds.htm

Point of Sale (POS) Statement of Needs

Overview

A Point of Sale (POS) system is commonly found today at most retail store registers. Store merchandise, identified by a price code (UPC), is checked out by a cashier who then accepts payment for the item(s). A UPC is either read by a bar code scanner or manually entered by the cashier. At the completion of a sale, a receipt is created for the customer and sales information is collected for the generation of reports at a later time. The system also provides for processing the return of purchased items and reimbursement to the customer. While many POS systems support multiple terminals that are networked together and interface with external systems (such as inventory control) the primary goal of this system is to develop a self-contained sales terminal application that supports the purchase and return of store merchandise.

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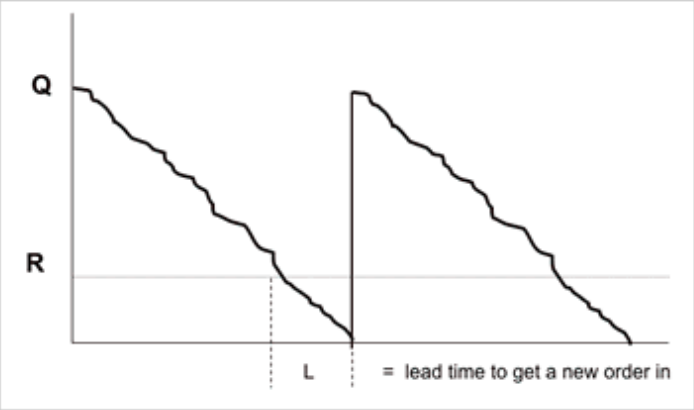
[14] C. Bozarth, "Perpetual system: Inventory management models: A tutorial," Jan. 2011. [Online] Available: https://scm.ncsu.edu/scm-articles/

article/perpetual-system-inventory-management-models-a-tutorial#1

h2. What is a Perpetual System?

Inventory level is constantly monitored and a new order place when a pre-established reorder point R is met



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[15] M. Roberti, "Epc reduces out-of-stocks at walmart," *RFID Journal*, Oct. 2005. [Online] Available: http://www.rfidjournal.com/articles/view?1927/

The RFID-enabled stores receive SKUs tagged at the case and pallet level from either Wal-Mart's own distribution centers or directly from suppliers. The improvement in out-of-stocks comes from using RFID to monitor how many cases have arrived at the store and how many have been brought out to the shelves, then comparing that information with how many items from those cases have been sold (Wal-Mart uses conventional point-of-sale data to determine sales).

For example, if each case of Pantene shampoo holds 24 bottles and the shelf can hold 48 bottles, Wal-Mart can determine that a shelf is close to being out of stock when 40 bottles or so have been sold. Pantene shampoo is then automatically added to a list of SKUs that must be picked from the back room and brought out to the shelves, or "merchandised." (The processes involved in detail in a case study published in the March/April 2005 issue of RFID Journal magazine, which is available online to premium content subscribers. See Wal-Mart Tackles Out-of-Stocks.)

The study found that automatically creating these pick lists, rather than having associates walk around and add items whenever they found an empty shelf, resulted in SKUs tagged at the case level being replenished three times more often than untagged SKUs. Moreover, it reduced in-store inventory by reducing the number of times an associate placed an order for more cases when cases were already somewhere in the back room.

"With the RFID-enabled stores, we alert them to the fact that there is product in the back room, and that they should merchandise that first before ordering more product,"

[16] "Choosing the right rfid technology." [Online] [image source only] Available: https://www.barcodesinc.com/info/buying-guides/rfid.htm.