Supply Chain Lessons from the Great Toilet Paper Shortage of 2020

The first six months of 2020 presented many challenges to businesses due to COVID-19 (also referred to as the Coronavirus). Public locations like restaurants and offices closed, and travel decreased dramatically as in-person interactions were severely discouraged to reduce the spread of the virus. Due to these changes and closures, global and regional supply chains were greatly affected. Many companies had to redesign their supply chains and discover new ways to manage extreme increases in the variability of both supply and demand in their markets.

To better understand how unpredictable supply and demand was during this time-period, please join us for a thought experiment. Imagine yourself living in the U.S. back at the end of February 2020. What we now know as the COVID-19 pandemic was mostly viewed as a problem that other countries were facing, being first identified in the Wuhan region of China in December 2019. The cases have started appearing in the U.S., and people are becoming more aware due to some of the horrific stories of the overextended healthcare systems in countries such as China, Italy, and Spain. You have read of shortages of some supplies in these countries, particularly medical supplies and personal protection equipment. Thus, you decide to go to your local store and purchase some precautionary supplies. Under this setting, which of the following items would you expect to start see shortages of in March 2020?

- Face masks
- Cleaning disinfectant
- Hand sanitizer
- Toilet paper

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1 This case was written by Dr. Mark Ferguson (Darla Moore School of Business, University of South Carolina) and Dr. Matthew Drake (Palumbo-Donahue School of Business, Duquesne University).
If you are honest with your answers, you probably would not choose toilet paper from this list. Assuming that the pandemic would hit the U.S. in a major way and assuming that the U.S. would follow the disease mitigation strategies that were currently being employed in China, Italy and Spain, you would expect to see a significant increase in demand for the first three items. You may also expect (and you would be correct) that the pandemic would not cause a major change in the overall usage of a common household products such as toilet paper. Yet, toilet paper started disappearing from store shelves by early March, and inventory stocks had still not recovered by the middle of June 2020. The toilet paper supply chain suddenly became a topic of everyday conversation as many retail-store locations experienced stock-outs and news article titles like “Wiped out of toilet paper? Here’s why” (ABC News) and “Is There Really a Toilet Paper Shortage” (The New York Times) started to appear, triggering stockpiling behaviors from consumer. The sudden spike in demand for toilet paper (as shown in Figure 1) wiped out retail-stores’ safety stocks of the product, leading to frequent stockouts (as shown in Figure 2).

**Figure 1:** Year over year dollar percent change in toilet paper sales (January to April 2020). Adapted from Geller and Baertlein (2020).
Such a surprising shortage raises the question in many people’s minds of “Why toilet paper?” In this article we explore the toilet paper supply chain to explain its unexpected supply
chain failures during the COVID-19 pandemic through the lens of some key concepts from operations and supply chain management.

**The Toilet Paper Supply Chain**

The top toilet paper manufacturers for the U.S. market are Procter & Gamble (P&G), Kimberly Clark, and Georgia-Pacific, who collectively own the consumer brands Charmin, Scott, Cottonelle, Angel Soft, and Quilted Northern. These brands offer a wide variety of commercial and consumer toilet paper roll types, ply counts, and package sizes. Combined, there are about 21 consumer toilet paper types not including the variety of packaging sizes (as depicted in Figure 3).

**Figure 3:** Consumer toilet paper types, not including package sizes

The consumer toilet paper supply chain (see Figure 4) starts with raw inputs that are manufactured into final products that are distributed via full truckloads to retail distribution centers. There the full truckload is redistributed into mixed-product truckloads, which are sent
to restock the physical stores. The final link in the supply chain is the end-use consumer who purchases from the retailer.

The first link in the supply chain is the raw material. Toilet paper in the U.S. is made from hard or softwood chips, water, chemicals that break the wood chips down to fibers, and bleaches to color the paper white (Anonymous, 2020). Most of these raw materials are sourced locally from North America, with a smaller percentage coming from Latin America. The second link is the manufacturing plant that turns the raw material into the finished product. Toilet paper manufacturers are typically domestic companies with manufacturing plants located across the United States.

**Figure 4:** Consumer market toilet paper supply chain

![Toilet paper supply chain diagram](image)

Paper mills that produce toilet paper are typically large and automated, consisting of paper making machines that costs around $300 million (Wieczner, 2020). Most of these manufacturing plants also produce other paper products such as paper towels, napkins, and
diapers. Due to the large fixed costs of the paper making machines combined with the low variability in the demand for these products, the plants are typically run at an average 92% - 95% capacity utilization (Wieczner, 2020). After manufacturing is complete, the finished product is then transported through a network of manufacturer and retail distribution centers before reaching the retail stores for consumers. Retail distribution centers (the third link of the supply chain) are located throughout the United States and are an average of approximately 200 miles from any given retail store (DeShields, 2016).

Because the U.S. market for toilet paper is a low growth, low margin business, toilet paper is promoted less than other consumer goods products. One reason for this is that a temporary price discount will not make people want to use more toilet paper but instead may incentivize them to stockpile during the promotional period and cut back on their purchasing during the periods when the product returns to the regular price. Since the latter behavior only reduces the profits for the manufacturer and increases the variability in the demand, toilet paper is rarely promoted through price discounts. Furthermore, when there is a sudden increase in demand, it often triggers inventory systems to raise safety stock levels and order quantities. As this trend flows back upstream, it creates larger and larger inefficiencies, commonly known as the bullwhip effect². Instead of utilizing promotions, manufacturers have primarily focused on making their supply chains more efficient by increasing the utilization of their manufacturing plants and by incorporating lean methodologies to reduce inventory levels throughout the supply chain.

To summarize, the supply chains for toilet paper have the following characteristics:

² See the following video for a brief introduction to the bullwhip effect: https://www.youtube.com/watch?v=tNUmEw2EJPs.
• Low growth market with relatively stable demand
• High fixed cost for equipment

What Happened to the U.S. Toilet Paper Supply Chain in 2020?

The overarching goal of the supply chain is to create the right number of products or services to meet demand on time and within the correct quality specifications. Each part of the supply chain has a great influence on the others. For the toilet paper industry, manufacturers (paper mills) and retail stores (distribution centers and stores) sit in the middle of the supply chain, making them vulnerable for inefficiencies especially during the COVID-19 pandemic. This portion of the toilet paper supply chain is influenced by the behaviors and outcomes of the suppliers (of raw inputs) and consumers. During the pandemic, both supplier availability and consumer demand were extremely variable and unpredictable, which led to stockouts and other inefficiencies.

We will first explore the demand side diving deeper into the reasoning behind consumer behavior. Then we will look at the limitations of the supply side and discuss why the supply chain was unable to react quickly. We will conclude by evaluating the short-term solutions of the manufacturers and retail stores along with detailing long-term solutions designed to build more resilient supply chains.

Demand Side: Consumer Buying Behavior Given Higher Uncertainty of Stocking Levels

Before the pandemic, commercial sales constituted 40% of total sales in the toilet paper market, whereas consumer sales made up 60%. However, with the public space closures, the use and orders for commercial toilet paper decreased greatly. On the other hand, with more people staying home, manufacturers predicted that the average household in the U.S. would increase its
usage of toilet paper by 40% (Georgia-Pacific, 2020). The demand shift from commercial to consumer products actually resulted in a 66% increase. In many industries such as food and cleaning supplies, commercial sales and inventories were sold to consumers to minimize a dramatic spike in demand and mitigate the bullwhip effect. However, the same solution cannot be replicated for the toilet paper industry since commercial toilet paper is typically made from different materials (normally recycled pulp instead of virgin pulp), is often a lower quality, and is oversized compared to consumers’ roll size specifications.

**Why was increased consumer buying overall not irrational?**

There are many considerations that a consumer analyzes when making home purchasing decisions such as available storage space, how fast an item is used, how long it takes to buy and receive the product, and the amount left that triggers replenishment. Viewing consumers as supply chain managers, these considerations translate to warehousing limitations, demand rate per period, lead time, and reorder point for a household, respectively. A reorder point is set so that an order is placed when there is enough inventory to satisfy the expected needs until the next replenishment delivery.

Consumers will weigh the various considerations above and the costs associated with them when deciding how much to purchase and when to place an order to manage their household inventory. They use the same rationale that businesses employ when determining their order quantity and reorder point. The order quantity is often determined by the Economic Order Quantity (EOQ) formula, which balances the cost of placing orders and the cost of carrying inventory to minimize total costs overall. When there is no demand uncertainty, the reorder point is computed as follows (see Figure 5).
Reorder Point = Demand Rate per Period \times Replenishment Lead Time

Figure 5: Graph of reorder point and EOQ with no uncertainty in demand or lead time

As the Coronavirus spread, obtaining toilet paper became more of a challenge. Stores would only allow a small number of customers to shop at time to meet social distancing regulations, and customers shopped less frequently due to health concerns. The additional wait time and health concerns increased the ordering costs for the consumer. This subsequently motivated consumers to decrease the number of trips made and increase their quantity purchased per trip (as determined by the EOQ formula). Furthermore, as stockouts became more frequent, toilet paper supply became more uncertain for consumers at their first-choice stores, forcing consumers to travel to other locations. This means that lead time for the replenishment was variable. When demand and lead time are variable, the reorder point equation changes to the following (see Figure 6).

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Reorder Point = Demand Rate per Period \times Lead Time + Safety Stock
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Figure 6: Graph of reorder point and EOQ with uncertain demand rate and/or lead time
The noticeable difference between this equation and the one discussed prior is the addition of safety stock, which can be used to mitigate uncertainty in the demand rate or the supply lead time. For households, additional safety stock became necessary as toilet paper is essential for everyday comfort. Therefore, consumers typically over-bought toilet paper each time they shopped throughout the pandemic.

The following list summarizes the impacts and characteristics of the demand side of the toilet paper supply chain.

- Toilet paper demand is normally split between commercial and consumer but most demand shifted to consumer.
- Consumers make their personal stocking decisions based on the cost of going to a store and the uncertainty in an item being available.
- If the consumer perceives that it is more dangerous to go to the store, then they buy more on each trip.
• If the consumer starts to observe out-of-stocks, then they buy more and hold more safety stock.

Supply Side: Why Were Manufacturers and Retail Stores Not Able to React Quickly?

In this section we discuss the challenges that different levels of the toilet paper supply chain faced in providing enough product to meet the demand due to COVID-19.

Suppliers – Raw Inputs

The main input for toilet paper is wood chips which are a byproduct of lumber being cut for larger wood products such as construction materials. When the Coronavirus hit, construction slowed dramatically, limiting the supply of wood chips for toilet paper manufacturers. Furthermore, some lumber mills were closed due to workers contracting the Coronavirus or because they were considered non-essential businesses. With the dramatic rise in demand and the simultaneous drop in supply, paper mills saw a disruption in the supply of their primary raw material.

Manufacturers – Paper Mills

Recall that before the pandemic, paper mills were already at a high capacity utilization (92% - 95%), producing a large variety and maintaining very small safety stocks since demand was primarily fixed. As a result, the paper mills were underprepared for a large spike in demand when the COVID-19 pandemic occurred. When the stockouts began, many people suggested that manufacturers just add capacity by running machines non-stop and/or buying a new machine all together. There are a couple of reasons why those solutions were not viable. It is important to note that the vast majority of paper mills also produce other essential paper products such as paper towels and diapers in the same mills where toilet paper is produced. When making a
different product, the machines must be temporarily shut down to change the settings and fixtures needed to make the new product, creating set-up times that result in a loss of utilization. Although this utilization loss can be minimized by producing less of the non-toilet paper products, it cannot be completely eradicated as the other products produced were simultaneously considered essential products; they also were at low availability across the United States.

Additionally, if manufacturers were to add capacity by purchasing a new machine, that would result in an additional fixed cost of $300 million per machine. The Newsvendor Model is an appropriate model when considering a manufacturer’s decision of adding capacity by purchasing a new paper making machine. The Newsvendor Model balances the cost of stocking out (known as “underage cost”) and the cost of having leftover inventory (known as “overwrite cost”) to find a quantity that minimizes the total costs. In this scenario, the underage cost equates to the lost profits due to unfulfilled demand if new capacity was not added. The overwrite cost includes the fixed cost of adding too much capacity, potentially by purchasing a new machine that does not generate any new additional sales. The machine would cost $300 million, so the overwrite would be that $300 million minus the amount expected to be received in exchange for the paper making machine at the end of its useful life (known as the “salvage value”). Since there is a very small market for used paper making machines, we can assume that the salvage value is practically zero for paper mills. Using the Newsvendor Model, it can be concluded that a very high profit margin for the product along with a very high probability of permanent lost sales would be required to justify the addition of so much capacity. With toilet paper already having a low marginal profit, it was not economically feasible for manufacturers to purchase machinery that would have most likely only been used until supply caught back up with demand. Thus,
adding capacity through building new paper mills or purchasing new machinery was not a good economic option for the manufacturers.

Retailers – Distribution Centers

Recall that distribution centers for larger retail store chains in the U.S. market span the entire country and are located an average of 200 miles from any given store. Although there is a large distribution network, distribution centers do not hold as much inventory as is typically imagined. Normally, retailers use these spaces as cross-docking\(^3\) terminals where manufacturers hand off their products which are then sorted and almost immediately transferred to retail store trucks. Inventory typically does not sit in a distribution center for more than one day. This just-in-time\(^4\) strategy allows retailers to reduce holding costs; this is especially true for the toilet paper industry. Toilet paper is a bulky product to store, so minimal inventory and safety stock is ideal. Therefore, when the shortages began, there was minimal to no additional stock stored anywhere to meet the new high demand.

The following list summarizes the impacts and characteristics of the demand side of the toilet paper supply chain.

- The supply of raw wood chips was disrupted due to low timber demand.
- Toilet paper factories use expensive equipment and were already operating at high utilization.
- Toilet paper is bulky and low margin, so there was very little/e extra stock in the supply chain, especially with most retailers using cross docking in their distribution networks.

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\(^3\)Cross-docking Explanation: [https://www.creativesafetysupply.com/articles/understanding-cross-docking/](https://www.creativesafetysupply.com/articles/understanding-cross-docking/)

\(^4\)Just-in-time Explanation: [https://www.investopedia.com/terms/j/jit.asp](https://www.investopedia.com/terms/j/jit.asp)
So How Did the Toilet Paper Supply Chain React to This Demand and Supply Shock?

In this section we discuss both short-term and long-term solutions that firms in the toilet paper supply chain developed to respond to the COVID-19-induced shocks to the demand and supply of toilet paper.

**Short-term Solutions**

Manufacturers and retailers took action to get toilet paper to consumers as fast as possible while using their current systems and technologies. Although these solutions, along with increased customer communication, provided some additional supply and more control over demand, it was not enough to completely resolve the stockouts at retailers across the United States. We further break down these actions taken by manufacturers and retailers.

**Manufacturers**

To increase capacity, toilet paper manufacturers decreased the variety of toilet paper options to just produce their most popular brand type and package size. The concept behind this strategy is similar to the operations management topic of delayed differentiation, in which products are initially produced in their most common form and then differentiated later in the supply chain to meet local tastes. In this scenario, toilet paper was produced in its most common type and package size, and the differentiation never took place since the retailers were happy to get their resupply in any form. This action reduced set-up times and allowed for capacity utilization to increase from 92% to 99%, increasing production by 8% or around 700,000 tons in the month of March alone (Wieczner, 2020). Manufacturers also reduced lead time by delivering directly to retail stores, bypassing the retail distribution centers. When demand spikes, it is more efficient to reduce lead times than variability (Chopra, Reinhardt, & Dada, 2004).
Retailers

The retailers’ main response was to try to control the demand to satisfy as many customers as possible, even if only partially. Many stores implemented policies restricting customers to only purchase a certain amount of toilet paper and other short-supply products. Retailers also limited or discontinued their e-commerce options to focus their total supply to in-store or pick-up deliveries only. These actions helped to re-ensure consumers’ confidence that supply would eventually become available, reducing their stress levels and panic buying.

The following list summarizes the short-term solutions that members of the toilet paper supply chain to react to the COVID-19 pandemic.

- Manufacturers reduced their demand variability and raised their factory utilization by eliminating some product variety. They also reduced the lead times to retailers through bypassing the distribution centers and delivering directly to the stores.
- Retailers limited consumer accessibility to scarce products by instituting maximum purchase quantity policies and eliminating online orders.

Resiliency Considerations and Longer-term Adjustments

During the COVID-19 pandemic, members of the toilet paper supply chain began to consider strategies to avoid another wide-spread shortage. One major toilet paper manufacturer, Kimberly Clark, stated that it will focus on agility by investing in the right levels of capacity to better manage system shocks, updating technologies so reporting is more comprehensive and accurate, and reevaluating their portfolio of different products to better balance cost, service, and
inventory turnover (Harrison, 2020). These ideas can also be applied to industries beyond the
toilet paper industry. The supply chain disruptions during the COVID-19 pandemic have forced
supply chain leaders of many different industries to reconsider their strategies on resiliency.

Additionally, Deloitte suggests that to build better resiliency and adaptability in supply
chains, companies should rethink the traditional linear supply chain structure (like Figure 4) and
instead consider a Digital Supply Network (DSN). In a DSN the barriers between supply chain
functions within an organization (such as forecasting, procurement, manufacturing planning,
transportation, warehousing, etc.) are eliminated. Instead these functions are connected to the full
supply chain network to facilitate end-to-end visibility, collaboration, responsiveness, and
agility. This allows each portion of the supply chain to better understand the vulnerable links in
the network and improve communication through all parties involved in the supply of the
product or service. A DSN allows supply chain participants to anticipate disruptions earlier due
to the enhanced visibility to the entire channel and communication between the parties. Once a
disruption is foreseen, the supply chain can adapt to mitigate the impact through executing agile
strategies such as establishing supply chain “war rooms” or “command centers” with
representatives from key supply chain participants to make collaborative decisions to resolve
issues related to the disruption, tapping into strategic inventory reserves secured from alternative
suppliers, rerouting production to other locations if one production facility must be temporarily
closed, and altering production schedules to reflect current inventory availability. Recent
advances in communication and information sharing technologies allow for DSNs to form and
improve visibility of the network without needing additional human and/or resource capital
(Kilpatrick and Barter, 2020).
Although building efficiencies within a supply chain is important, it is equally as important to build supply chains that can adapt quickly to unpredictable disruptions. The shortage of toilet paper in the United States during the COVID-19 pandemic revealed many weaknesses of an overly lean supply chain. However, consistent and transparent communication, adjustments for longer lead times, more dual and/or domestic sourcing, and a focus on preventative maintenance measures became more important than ever and should continue to be considered. Overall, by creating a supply chain network that is both resilient and adaptable, businesses will be more prepared for future disruptions.

The following list summarizes the longer-term solutions that members of the toilet paper supply chain are considering to increase resilience and agility in light of the COVID-19 pandemic.

- Firms are focusing on establishing agility and adaptability through better technologies.
- Firms are considering a shift in focus from linear supply chains to Digital Supply Networks.

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