Closed-Loop Supply Chain Design for Sustainable Procurement of Office Supplies at MIT

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ABSTRACT

Massachusetts Institute of Technology (MIT), home to almost 27,000 students and staff with almost 400 departments, labs and centers, has a largely decentralized procurement system and informal reverse logistics flow or cost rebate programs for office supplies. Building on the success of the centralized procurement process for personnel protective equipment (PPE) and cleaning supplies, this capstone explores the feasibility of a consolidated office supplies procurement process and options for take-back schemes in the form of reverse logistics in order to support the MIT Climate Action Plan of net zero carbon emission by 2026. In order to achieve these key objectives, initially we mapped out the entire demand driven delivery process and order fulfillment at MIT to identify opportunities. Next, using historical purchase data of top purchased products on campus we designed and proposed an office supply stockroom model that could be located at the distributed mail centers or other shared locations. These locations could also serve as a drop off point for used office supplies to be picked up for recycling. Qualitative data has been collected in the form of user surveys and interviews to gauge user perception, knowledge and readiness towards making sustainable choices. Finally, by linking the forward and reverse logistics flows, the project frames the circular supply chain that is enabled by the stockroom model to increase sustainable purchasing and reduce waste and cost for the institution.

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1 INTRODUCTION

In an effort to support the MIT Climate Action Plan, the MIT Office of Sustainability (MITOS), in partnership with the MIT Center for Transportation and Logistics (MIT CTL) is looking to expand the centralized personal protective equipment (PPE) procurement model to office supplies on campus to take a step toward making supplies procurement more sustainable. Reports such as the Gartner Supply Chain Top 25 for 2021: Insights on Leaders (Gartner, 2021) and the State of Supply Chain Sustainability Report of 2021 (MIT Center for Transportation and Logistics, 2021) indicate that most companies are making considerable efforts to be carbon neutral in the near future, with long-term plans of being carbon negative. Sustainability and being eco-friendly are playing a bigger role in driving a company's value, as customers increasingly favor companies that are working to achieve sustainability (Gartner, 2021). The MIT Climate Action Plan is one such effort: The institute has committed to a net-zero carbon emission by 2026 and a collective effort toward decarbonization in its operations, with a goal of eliminating direct emissions by 2050 (Massachusetts Institute of Technology, 2021).

1.1 Motivation

With 15,722 employees and 11,934 students (Massachusetts Institute of Technology, 2021) at more than 400 departments, labs, and centers (DLCs), MIT procures an enormous volume of office supplies. Previous surveys and studies of the purchasing and procurement model for various DLCs at MIT revealed that the system is largely decentralized and independent. Each DLC currently has one or more administrative staff members (strategic buyer, administrative officer, or finance officer) who are responsible for office supplies procurement. They currently use MIT's custom online ordering platform, known as the buy-to-pay (B2P) system, and an MIT-issued purchasing/procurement card to place their orders. A large volume of orders is currently being procured from Vendor 1 and Vendor 2; however, the buyers can choose to order commodities from local vendors or other vendors of their choice. Once the order is placed, the vendor arranges shipment and final delivery to the respective DLC locations within a promised delivery window.

In the current process, there are no minimum order quantities, and these orders are placed on a "need by" basis by respective DLCs; in other words when the administrative officer feels the DLC may need certain supplies he or she may be inclined to order it purely based on intuition with no prior planning. Although there is an "MIT preferred" sustainable or eco-friendly product offering available on B2P, buyers have full discretion to make the final product selection. As a result, the current procurement process does not encourage or enforce a more socially responsible, sustainable purchasing model. Additionally, with such a degree of autonomy, there is no clear coordination of procurement or take-back and re-use of office supplies.

The lack of a centralized order consolidation system or of coordination between DLCs has resulted in a large number of small orders being placed by individual DLCs purely on a need-by basis, with little to no demand planning. This situation has led to a number of problems, including high ordering frequency for small orders, over-ordering, a high number of last-mile deliveries, higher delivery costs, and frequent misdelivered orders. Other consequences include excess packaging material consumption and a lack of a model for suppliers to take back commodities such as toner cartridges, batteries, pallets, and other recyclable items.

1.2 Problem Statement

To address those issues, MITOS is looking for a procurement and fulfillment model for office supplies that would encourage more efficient, cost-effective purchasing and reduce waste while maintaining required service levels.

This project builds upon the success of the demand planning model developed for centralized ordering of Personal Protective Equipment (PPE) and cleaning supplies at MIT during COVID (Sorel and Gao, 2021). We propose a centralized, consolidated fulfillment and reverse logistics model that includes office supply stockrooms located at various locations on campus that could also serve as drop-off points for office supply recycling. This circular supply chain structure would not only help to make office supplies procurement and delivery more efficient, but would also make it eco-friendlier and more sustainable while ensuring the same level of service.

1.3 Approach

To achieve the above-mentioned objective, we carried out the following steps, which will be described in detail in Chapter 3 Data and Methodology and Chapter 4 Results and Analysis:

- Initially we mapped out the order fulfillment and the demand-driven delivery process at the DLCs to identify opportunities for efficiencies, and analyzed the DLCs' historical purchasing data to identify the most frequently purchased office supplies consumed on campus.
- In partnership with MIT Mailing Services, we conducted an analysis of viable locations on campus that could serve as stockrooms as well as intermediary drop-off points for office supplies recycling and for collecting other hard-to-recycle items. As part of the reverse logistics proposal, we researched take-back schemes offered by original equipment manufacturers of office supplies like toner cartridges and other printing supplies. This was done to identify the reverse flows of these commodities back to their source, create a scalable solution that can be deployed on campus, and identify any future opportunities for cost rebates.
- We conducted an approximation analysis of the office supplies consumption rate as well as of packaging specifications to propose a vendor managed vending machine at strategic locations on campus to act as a stockroom for frequently consumed SKUs.
- Additionally, we collected qualitative data through surveys and interviews with stakeholders involved in purchasing to first, gauge user perception, knowledge, and readiness to make sustainable choices, and second, to understand the buyers' perspective and decision-making process in order to characterize the limitations and the opportunities to improve the existing model. This included collaborating with the "Working Green Committee" at MIT, a sustainability-focused employee group, leveraging their expertise on making MIT's supply chain more circular and carbon-neutral.

Ultimately, by linking the forward and reverse logistics flows, the project frames the circular supply chain that is enabled by the stockroom model to increase sustainable purchasing and reduce waste and cost

for the institution. The results of the engagement survey indicate that the majority of stakeholders on campus are willing to make purchasing choices that align with MIT's climate action plan, even if it costs them more. However, some expressed concerns about potential efficiency, safety, and liability issues that could affect adoption.

The remainder of this paper includes a literature review that informed the development of the project's methodology; data collection and methodology; the results of applying the model; a discussion of the implications of those results; and concluding thoughts, including suggestions for future research.

2 LITERATURE REVIEW

As defined previously, this project seeks to develop ways of **driving sustainable purchasing efforts of office supplies and increase their take-back on the MIT campus.** In this chapter we have reviewed articles relevant to the following four domains:

1. Benefits of consolidated demand and supply
2. Demand planning for a stockroom model
3. Last mile delivery and distribution network
4. Establishing a circular supply chain

2.1 Benefits of consolidated demand and supply

As discussed in section 1.1 one of the key challenges with regards to sustainability is decentralized order placement and fulfillment processes. Combining purchases provides advantages in terms of increased reliability with the vendor (time taken by them to make a shipment), reduced lead times, and smaller safety stocks needed by the customer. (Buffa, 1988)**.** Our project has considered opportunities for designated order consolidation areas. One key concept is the "Hub and Spoke" model of supply chain design whereby flows from multiple suppliers will be consolidated in a particular point before the consolidated shipments are directed to manufacturing plants or end customers (Cheong et al., 2007). This concept shows great promise

not only in terms of reduced lead times and improvements in the customer's cycle service levels but in our case also creates an opportunity to reduce packaging material. The consolidation locations can also act as a "take-back" location for used supplies, thus consolidating the forward and reverse logistics of the office supplies' value chain.

2.2 Demand planning for a stockroom model

One important factor that may influence ordering frequency for the DLCs would be the availability of a demand planning tool. Equipped with an easy-to-use demand planning tool, DLCs will be able to understand how much they expect to consume for a given period of time and order accordingly depending on the storage capacity. Once an estimation of average consumption including the top consumed SKUs has been identified, we can leverage it into proposing the capacity and location of tentative storing areas, in other words potential stockrooms. These stockrooms can be considered to be supply closets where certain office supply commodities will be pre-stocked by the vendor and DLC representatives can simply come and pick up a necessary order. Depending on the availability of space, their needs and priorities, DLCs can adjust their order accordingly.

Statistical modeling coupled with informed judgment can help in making an accurate demand forecast. One common method is using a time series forecasting model, which uses the historical demand/consumption data for an item or group of items to construct a forecast for the future demand of that item (or group). Time series models can thus be quite effective depending on the parameters considered and the level of calibration. The forecasting periods may also vary depending on strategic planning decisions (long term; > 5 years), medium term (financial decisions, >1 year) or short-term operational forecasts (daily, weekly or monthly) (Cook, 2016). For the purposes of our project, we use simple time series models since office supplies SKUs tend to be high volume products with a long shelf life. The simplest time series model for forecasting short term individual items is the moving average, where the N-period moving average forecast for the next period is the average demand over the previous N periods.

(Silver et al., 2017). Considering the simplicity of the model and the fact that more recent historical purchase data would be accurate, Silver et al. (2017) also proposes simple exponential smoothing whereby the smoothing factor determines the extent to which the older data influences the forecast. Other variations of the simple exponential model include simple exponential model with level trend and even seasonality, which may be appropriate for our project due to seasonality in the demand pattern based on the academic periods.

Although big data coupled with machine learning can seem intriguing with the expectation that they would provide better quality forecasts, it can also lead to misleading information and increased complexity owing to the larger number of variables affecting the forecast (Boone et al., 2019). Machine Learning Algorithms tend to be complex and time consuming. Hence, considering the small number of SKUs characterized mostly by high-volume products with little or no variation in consumption trends, our model considers time series forecasting with seasonality using historical sales and cross validation to come up with short term monthly forecasts.

2.3 Last-mile delivery and distribution network

Last-mile delivery can be defined as the final piece of the puzzle in the forward supply chain whereby final delivery of the product is being made to the customer's doorstep. However, in spite of it being the final piece of the supply chain it is considered to be the most complex and expensive and least eco-friendly part (Gevaers et al., 2014). Crainic and Sgalambro (2014) defined a two-tier city logistics service network, where freight is moved from distribution centers on the outskirts of the city to satellite distribution centers (CDCs) located within the city and then distributed to customers by a different fleet of dedicated vehicles. Although the context of our project does not take into consideration freight consolidation and transportation to the MIT campus, we can adopt some of the principles of the second-tier urban delivery and scale it down for order delivery to the DLCs on campus. For the purposes of our project three different potential solutions are being compared and considered for the smooth conduct of the last

mile delivery. The existing literature has helped understand and propose innovative ways for order consolidation and the corresponding user feedback from such a proposal. The three potential solutions could be:

(i) Last mile delivery by Vendor 1' representative

(ii) Last mile delivery by Mail Services representative

(iii) Order pickup from stockroom/cross-docking location by the representative from individual DLCs.

In an attempt to reduce overall carbon footprint and expedite delivery (Giret et al., 2018) proposes the use of an Intelligent Transport System (ITS) and crowdsourcing, whereby people will be able to deliver packages during their regular movements, instead of having travel dedicated towards order delivery with a route optimization algorithm. The main aim of the ITS technology is to reduce time in transit as well as frequency and distance of last mile delivery. Hence it takes into account all forms of transportation and elements: vehicles, drivers, infrastructure, and also, the users—all of them interacting dynamically, which in turn, adds large complexity as a particular package may switch hands multiple times before delivery to the final customer. The concept of ITS helps us explore how order consolidation and clustering of buildings can help reduce last mile delivery distance if representatives of individual DLCs would be willing to carry multiple orders including those of their neighbors, leading to shared workload.

Looking into last mile parcel delivery by 25 vehicle rounds in crowded areas of London, Allen et al. (2018) found that 62% of the average time of 7.3 hours that a vehicle spent in the round was spent at the curbside unloading and delivering the packages. This not only entailed higher fuel costs and associated CO_2 emissions with regards to the vehicle left running but fines for blocking curbside infrastructure prioritized for public transportation (In New York city alone UPS accumulated fines worth $16M in 2016 while servicing clients; (Jensen, 2016). Considering the time and sustainability aspect (Allen et al., 2018) proposes the reinvention of the age-old "porter system" previously used in many European cities, whereby

goods offloaded at a docking station would be delivered on foot using trolleys or wheelbarrows. The paper goes on to propose two scenarios, in the first case the van stops at the curbside in the driver's preferred location, where a pre-notified porter is waiting to receive the parcels from the driver. The driver would still be making the same number of stops in the dedicated area of responsibility as before, with last mile delivery being made by the porter. Other than curbside time reduction, this model does not necessitate the requirement of a consolidation or storage location. For the second scenario, the driver would be making deliveries to a number of "order pooling" or consolidation points, from which the porters would be making multiple deliveries to the customers, depending on the volume of packages. The first scenario is akin to crowdsourcing and is more appropriate for densely populated areas. Considering that the volume of order is not very high, our project considers last mile delivery akin to the second scenario, whereby manual delivery would be made on foot to multiple DLCs.

2.4 Categorizing materials flow and establishing a circular supply chain

A circular economy can be considered as bidirectional, whereby materials and products flow back to the supplier for re-use or recycling. As Seitz (2004) pointed out, there is more pressure on producers in the manufacturing sector to participate in End-of-life product take-back as a producer is expected to take charge of the product even at the end of the product life cycle, in other words in the post-consumer stage. Our research project considers the importance of the implementation of a circular and more sustainable supply chain not only in raising awareness for purchasing eco-friendly products but also considering the possibility of order consolidation in reducing the number of trips, packaging materials and take backs by the vendor. One way to achieve a circular economy is by implementing the cycle of 3R's, in other words Recycle-Re-use-Refurbish (United States Environmental Protection Agency, 2020). Vadakkepatt et al., (2021) offers a framework which retailers can use to promote and enhance efforts towards sustainability using the 3 R's; a similar framework for office supplies will also be incorporated in our project.

More companies are pledging to reduce net carbon emission in line with reduction of GHG emissions as we see more than 1000 companies are already working with the Science Based Target Initiative. A sustainable and circular supply chain plays a key role in this regard as we find companies that have made it into Gartner's list of the top supply chains of 2021 have had a very high score on environmental, social and governance factors, by virtue of supply chain network optimization to reduce GHG emissions, using recyclable or compostable packaging materials or using take-back schemes (Gartner, 2021). According to a recent study of 19,000 consumers in 28 countries 80% responded that sustainable product sourcing is important to them, with nearly 60% willing to change their shopping habits to reduce environmental impact (Widlitz and Stacey, 2020). Another survey of 120 retail businesses in 13 countries show 94% respondents claiming customer demand for sustainable products has gone up over the past two years (Suston-EOG Survey, 2019). Building on these premises, considering office supplies a retail product, our project also strives to promote eco-friendlier and more sustainable product sourcing and order consolidation to minimize wastage.

Another key driver in moving towards a reduction of waste has been the significant contribution of indirect GHG gas in consumption and disposal of purchasing goods related to a technical university (including office supplies, chemicals, furniture and others). Using the concept of material flow analysis, defined as the "systematic assessment of the flows and stocks of materials within a system defined in space and time" (Brunner and Rechberger, 2004), quantifying the amount of emission produced during material consumption can help in understanding the role played by indirect GHG emissions. Although Material Flow Analysis is mainly conducted in a city or town level, (Perlman, 2020) has conducted a detailed study into the materials flow and waste create by the acquisition and use of various supplies by classifying the product types as outlined in Economy-wide Material Flow Accounts (EW-MFA) handbook (Eurostat, 2018) at MIT. The paper goes into detail in streamlining all the different product categories and their net GHG emissions using the US Environmental Protection Agency's WARM model, concluding that up to 28% of GHG emissions could be contributed by the Scope-3 (indirect) emissions for purchased goods at MIT. Our project

separates only the office supplies' entities included in the paper and works in depth on developing a more sustainable distribution system, while adopting some of the ideas and recommendations relevant to user behavior and preferences in making sustainable choices for the DLCs at MIT.

3 DATA AND METHODOLOGY

Our working methodology focused on both qualitative and quantitative data in proposing the new circular supply chain design. First, we conducted an extensive field visit in an effort to map out the current order generation and fulfillment process at MIT. Quantitative data obtained from the Vice President for Finance Office has been used to identify the top purchased commodities on campus. Equations for the tentative use rates for these supplies were hypothesized in designing a supply stockroom which would basically act as a centralized office supply closet akin to a vending machine. This coupled with qualitative data collected from the extensive surveys helped in defining the feasibility of a centralized stockroom which will act as a supply closet whereby representatives from DLCs would be able to swipe their purchase cards and pickup certain commodities, similar to a traditional vending machine with replenishments done at a set cadence by the vendor.

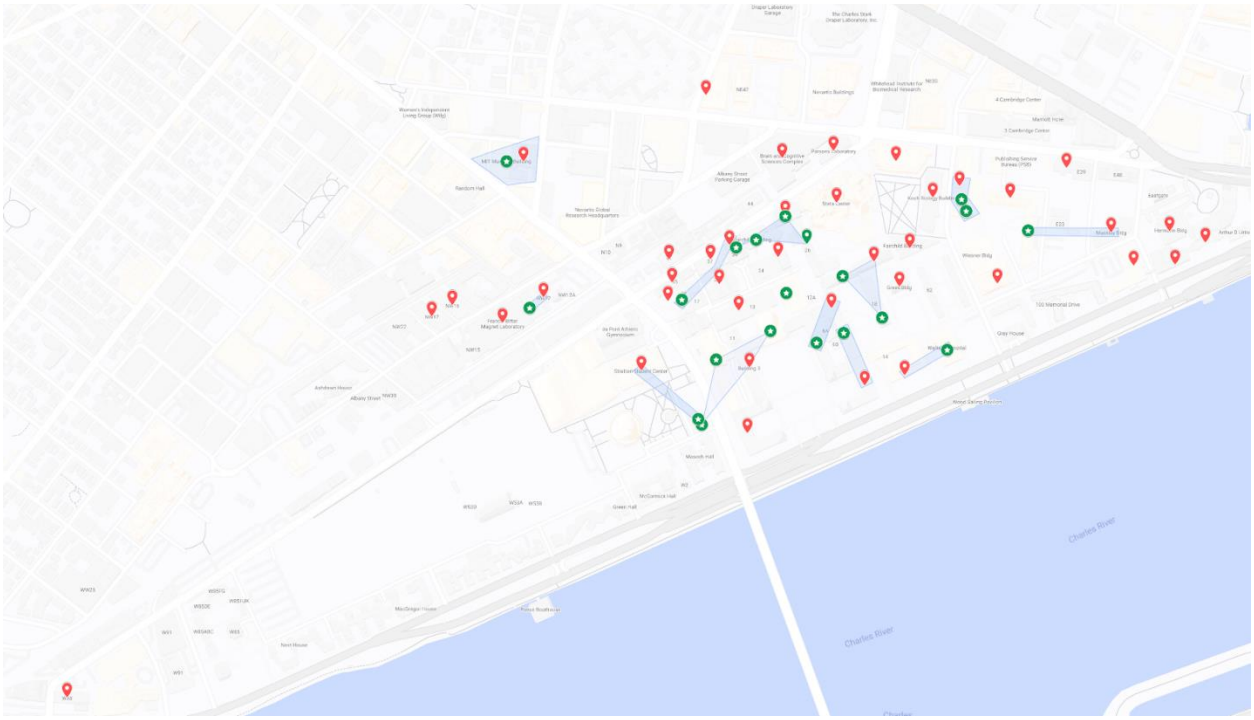
3.1 Development of the proposed stockroom model

The proposed stockroom locations will basically act as strategic consolidation points in the fulfillment process (referred to as Distributed Mail Centers) serving the dual purpose of being used as a supply closet location where DLC users can come and pick up their office supply orders or buying any new items on the spot from an office supply vending machine. This location would also serve as a dedicated office supply recycling station for collecting used toner cartridges, tech-waste (any discarded electronic items such as mice, keyboards, wires, CDs/DVDs, printers, monitors, copiers etc.), batteries and any packaging material that is hard to recycle/non-recyclable.

3.1.2 Potential location of the stockrooms and office supply take-back stations

We have identified 39 DMC locations at MIT where the stockroom model can be deployed. These 39 DMCs (location marker red in Figure 1) service all of MIT's departments, labs and centers. Locations marked in green in Figure 1, and the blue cluster markings denote the buildings in close-by proximity that are serviced by each DMC.

Figure 1: Map of Distributed Mail Center Locations at MIT



Below is a tabulated view of these DMCs and the respective serviced buildings categorized by zones. Zones have been defined based on the geographic proximity with a nearby DMC location and each DLC can be assigned to a particular zone for the purpose of office supplies pickup and recycling drop-off.

Table 1: Location of all the DMCs across MIT (as of March 1, 2022)

Zone	DMC Location (Building Num.)	Floor	Buildings Serviced
Zone 1	W98	Basement	W98
Zone 2	NW12	118	NW12, NW13
Zone 2	NW14	3106	NW14
Zone 2	NW16	279	NW16
Zone 2	NW17	277	NW17
Zone 2	W20	Basement	W20, W11
Zone 3	1	42	1
Zone 3	3	15	3,5,7,10,11
Zone 4	13	333	13
Zone 4	14N	752	14, 50
Zone 4	32	81	32
Zone 4	35	317	35
Zone 4	36	193	26, 36, 38, 39
Zone 4	37	264	37
Zone 4	41	2nd Flr	41
Zone 5	NE49	3rd Flr	NE49
Zone 5	N52	196	N51, N52
Zone 6	E14	194	E14

Zone 6	E19	116	E17, E18, E19
Zone 6	E25	175	E25, E23
Zone 6	E40	10	E40
Zone 6	E51	265	E51
Zone 6	E52	166	E52
Zone 6	E53	364	E53
Zone 6	E60	44	E60
Zone 6	E62	649	E62
Zone 7	24	31	12, 24
Zone 7	31	133A	31
Zone 7	46	1134	46
Zone 7	18	39	18, 48
Zone 7	54	815	54
Zone 7	56	15	56,16,18
Zone 7	2	26	2,6
Zone 7	66	17	66
Zone 7	68	102A	68
Zone 7	76	46	76
Zone 7	8	13	4,8
Zone 7	9	136	9,33

3.2 Data Collection

In this section, we have identified and described the mix of qualitative customer data and quantitative procurement data that has been used extensively in designing the proposed supply chain strategy.

3.2.1 Qualitative Data

Data was collected from the perspective of how that data would aid in answering our research question. We captured qualitative data from individual DLC's buyers, administrative officers and finance officers through an engagement survey (Appendix A). This survey was created with a set of questions that gathered inputs from recipients on what sustainability meant to them and how motivated they were to participate and co-create a solution in making office supplies procurement more sustainable. The survey also presented them with scenarios of a stockroom model where they would potentially walk to pick up their orders while dropping off any office supplies recyclable material and gauged their willingness to participate in such a solution. Upon completion of the survey, we conducted 30-minute interviews with participants who expressed interest in discussing this topic further with us and shared their inputs on existing processes, challenges and areas of improvement in the office supplies procurement process at MIT.

3.2.2 Quantitative data for "most purchased SKUs"

In order to better understand the existing consumption volume of office supplies at MIT, we received a list of high-volume SKUs and their 'eco-friendly' SKU alternatives from Vendor 1. This data allowed us to identify the top office supplies commodities (by volume) consumed at MIT, approximate their daily/monthly usage volume at MIT, quantify the volume of office supplies recyclable material that is currently not being recycled and subsequently quantify the potential cost saving opportunities if this material is shipped back to Vendor 1.

3.3 Current office supply procurement process at MIT:

3.3.1 Ordering and demand generation at DLCs

The Massachusetts Institute of Technology community, consisting of more than 27,000 students and staff is home to six degree granting schools: School of Architecture and Planning, School of Engineering, School of Humanities, Arts and Social Sciences, Sloan School of Management, School of Science and the MIT Schwarzman College of Computing.

Each of these schools is autonomous in its operations and each school is broken down into departments, labs, centers and institutes (DLCs) within each school. There are additional administrative bodies at MIT, operating independently and not affiliated with a particular School, which are also considered as a DLC within MIT. Over the course of the year, these DLCs consume various kinds of office supplies in their day-to-day operations. These include, but are not limited to, commodities such as writing and correction (pens, pencils, highlighters, whiteners), containers (binders, envelopes, boxes, crates, shelves, folders, desk organizers), writing material (notebooks and notepads), labels and adhesives ('sticky notes', nametags), printing paper, printer toner cartridges, mechanical fasteners (paper clips, binder clips, staplers), chemical fasteners (adhesive glue, scotch tape, duct tape), batteries, office food and bottled water. This list of common commodities has been determined based on the findings in our interviews with various buyers, administrative officers and finance officers at respective DLCs.

Currently the DLCs place orders on a 'need by' basis, where they evaluate their office supply needs in a sporadic manner. Their reordering patterns can be categorized into the following types - visual estimation of inventory to determine reorder levels, order collection from various stakeholders within the DLC at a fixed/need by cadence, reorders triggered from stock-outs or a fixed reordering frequency for certain office supply categories.

Once the supplier (primarily Vendor 1) receives these orders, it fulfills them in the order they are received. Consolidation of inbound shipments can provide avenues for cost reduction and make the overall supply chain more cost efficient. There is an increasing demand for just-in-time inventory of small orders at various DLCs, which has provided a huge opportunity to consolidate inbound orders from the supplier. These orders are usually in smaller lots, which when consolidated can result in significant reduction in packaging material and the number of shipments needed for last mile deliveries. (Buffa, 1988) also suggests that in order to implement a consolidated fulfillment system we need to study whether or not the system is demonstrating some key prerequisite attributes which have been aligned and identified for the case of MIT as follows:

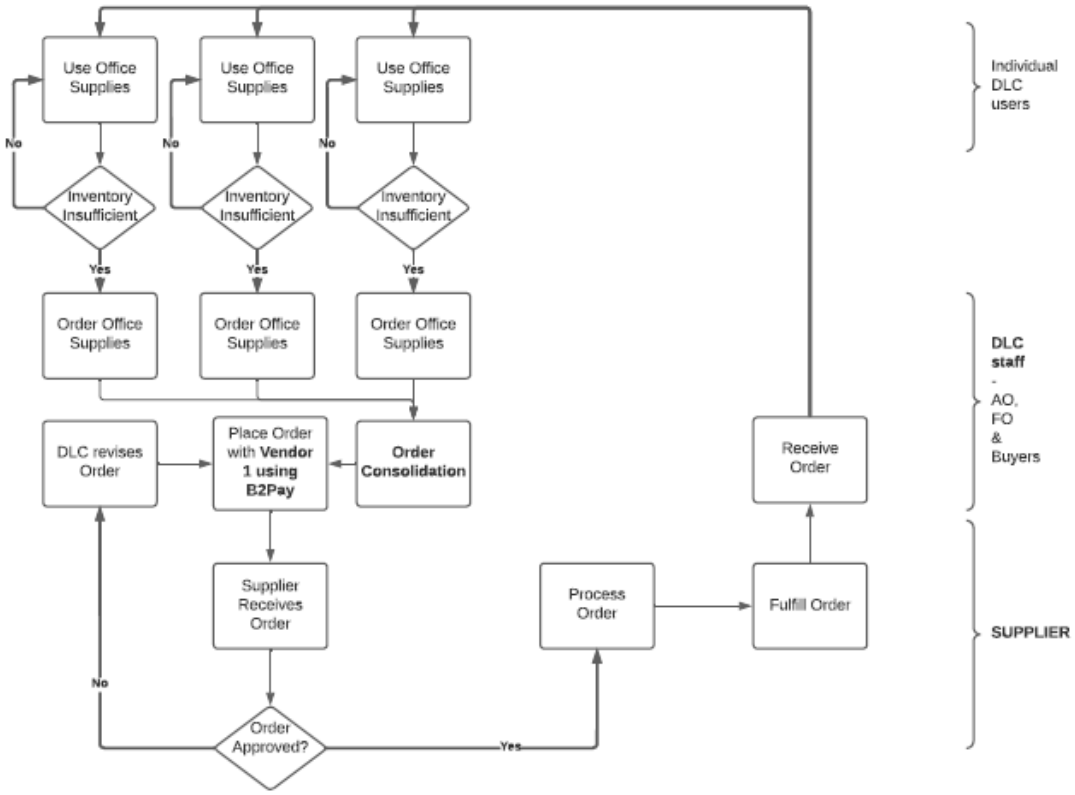
1. Multiple stakeholders are placing individual orders in the system with varying expectations of level of service with the same vendor. Some require the shipments to be delivered the next day (expedited shipping), whereas others prefer a standard shipping method.
2. The Vendor is able to consolidate orders at a cross-docking location. At MIT these locations are in E19 and STATA Center where on-site personnel are responsible for breaking down orders, sorting them by delivery addresses, developing a strategy for what order these shipments need to be delivered in, and lastly delivering them to respective DLCs on foot.
3. Some orders are delivered directly to the customer rather than consolidating shipments. There is a lost opportunity to reduce usage of packaging material on orders going to the same delivery location by consolidating them into bigger boxes/pallets that can be broken down at the end location for delivery to respective customers within a single geographic cluster.
4. The Vendor and the consignee share a formal business relationship where they share a strategic relationship and a standardized (bulk) pricing contract.

3.3.2 Order management and inbound shipment by the supplier

The DLCs have autonomy in their decision to place an office supplies order from their preferred vendor. This autonomy is crucial for their decision making since they need to choose vendors that serve them with preferred brands of product, an extensive product catalog, competitive pricing and, most importantly, meet their service level and delivery expectations. The vendors that service most of the office supplies at MIT include Vendor 1, Vendor 2 and Vendor 3.

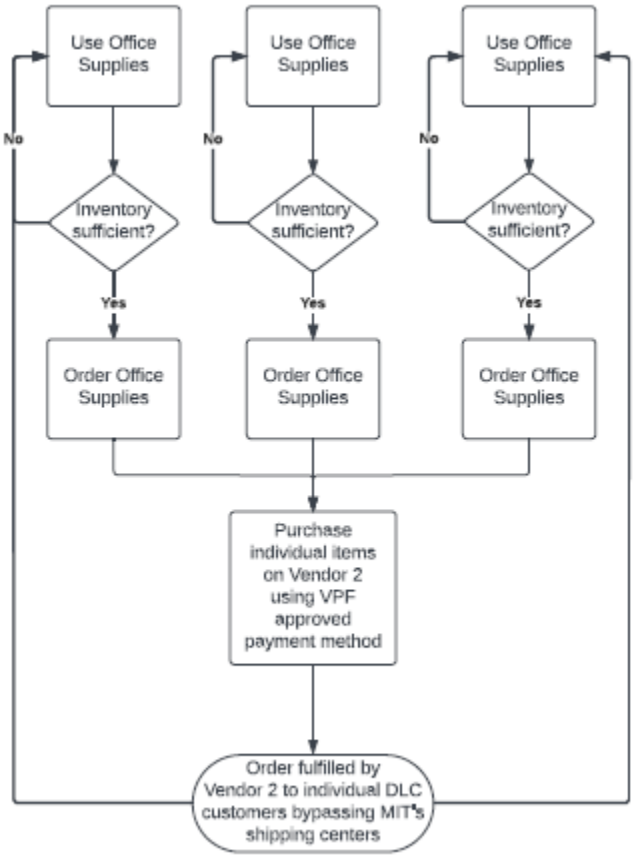
Vendor 1 is currently MIT's preferred vendor, has a stockroom location on campus, and has on-campus personnel who assist with the sorting of inbound shipments and delivery to the last mile DLC addresses. Vendor 1 primarily serves the MIT campus from its warehouse location in Framingham, MA, given the geographical proximity of this warehouse from the campus. Vendor 1 is triaging all incoming orders from MIT, packaging them based on the packing slip per delivery address, consolidating them in a pallet and using its own delivery trucks to deliver to MIT. They deliver these shipments to two primary shipping locations on the MIT campus. These locations are Building **E19** and Building 32 (**STATA Center**)'s shipping/receiving rooms (*MIT-Department of Facilities).* These two buildings divide the MIT Campus delivery map into two halves and depending on the volume of demand and the proximity of the buildings to each, packages are delivered to the DLCs from either of these two buildings. Vendors are currently shipping items directly to these two buildings, which are then sorted by the MIT Mailing Services by DLC addresses. Mailing services personnel then conduct the last mile delivery of individual shipments. Figure 2 illustrates the existing office supply procurement process at MIT for Vendor 1.

Figure 2: Existing Office Supply Procurement Process at MIT (Vendor 1)



The existing procurement process consists of consolidated office supplies order placement by administrative officers, finance officers and/or buyers at respective DLCs. In the current state of procurement, there is some level of order consolidation happening at the DLC level. Figure 3 illustrates the office supply procurement happening via Vendor 2 using the drop-shipping method.

Figure 3: Office Supply Procurement via Vendor 2



3.3.3 Role of MIT Mailing Services in the inbound shipment process at MIT

In existence for over 30 years, MIT Mailing Services has provided a variety of shipping, distribution and pickup solutions to a variety of stakeholders at MIT. They support all inbound and outbound shipment services on the MIT campus in Cambridge, MA. Their basic services include: mail delivery to MIT offices and dormitories; pickup at over 40 locations on the MIT campus, DMCs (Distributed Mail Centers) and Recycling stations; interoffice, U.S. and international mail processing; and receiving packages and freight at shipping docks. (Massachusetts Institute of Technology, 2022). They also offer detailed tracking services to the consignees with a "status" of their inbound/outbound shipment

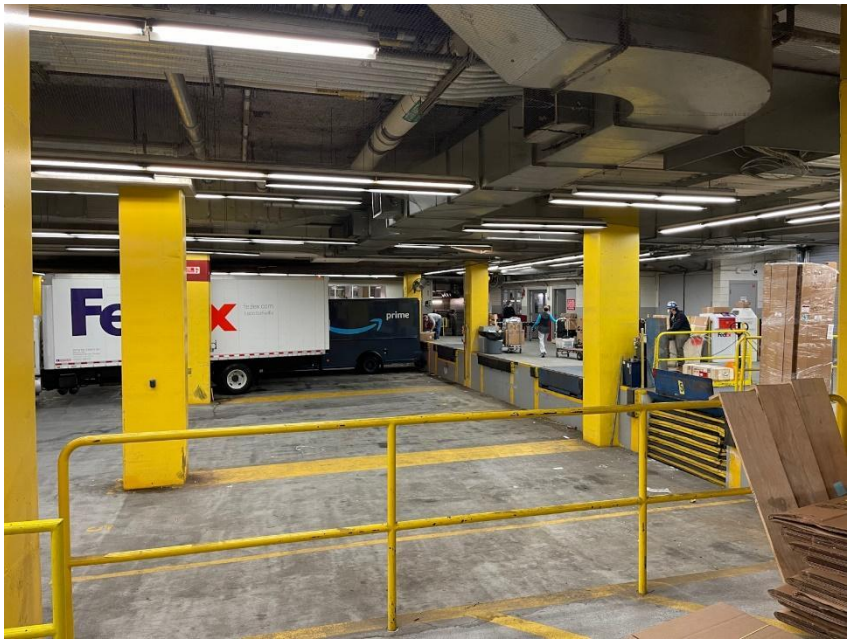
(Received, In-Transit, Attempted Delivery, Delivered). The following summarizes information gathered during an on-site visit of the MIT inbound shipment (small parcels), distribution and pickup operations architected by Martin O'Brien (Senior Manager of Campus Services) and supported by MIT Mailing Services.

The two primary shipping docks at MIT are located at the E19 (400 Main Street), and the STATA (32 Vassar Street) center. These two shipping docks are strategically located, dividing the campus into two serviceable areas. Any shipments to Buildings E14, E15, E17, E18, E19, E23, E25, E40, E51, E52, E53, E60, E62, and 68 are shipped to and received at the E19 location. And similarly, any shipments to Buildings 1, 2, 3, 4, 5, 6, 6C, 7, 8, 9, 10, 11, 13, 14N, 14S, 14E, 16, 18, 24, 26, 32, 33, 34, 35, 36, 37, 38, 39, 41, 42, 44, 46, 48, 54, 56, 66, and 76 are serviced by the STATA center shipping room (located in the basement). Any packages addressed to the building on the outer perimeter of the MIT campus (all NE, NW, W, N, and EE buildings) are delivered directly to those buildings by Vendor 1 direct delivery vans/drivers. The STATA center handles 2/3rd of the volume of inbound packages at MIT. MIT Mailing Services staffs both these locations and their primary roles and responsibilities include: shipment unloading, signing of bill of lading for the driver, breakdown any shipments that have been palletized and shrink wrapped, sort shipments based on building numbers, consolidate shipments based on their delivery tour strategy, load shipments on industrial hand trucks and deliver shipments on foot (to each individual floor/room of the building the package was addressed to). The main reason MIT Mailing Services is heavily involved in this process is the access restrictions of vendors to MIT buildings. This is also the reason the receiving of these small parcels needs to be done by them and they are responsible for the last mile delivery on campus via foot. There are rare exceptions, such as FedEx.

MIT Mailing Services currently tries to adhere to a service level agreement of delivering these small parcels, packages and mail within 48 hours of receiving them. Depending on the volume of shipments, the best effort is to deliver these shipments on the same day. However, if the volume is not manageable by the present staff, these deliveries may carry over into the 48–72-hour window. In extremely rare instances these shipments are delivered more than 72 hours of their unloading at the shipping locations.

3.1.3.1 Shipment unloading and receiving at MIT shipping centers

MIT Mailing Services tries to schedule delivery appointments during the first half of the day in an effort to meet the <24-hour delivery turnaround time. However, the delivery trucks may arrive later in the day or make multiple deliveries during the day. The end-to-end process of receiving, all the way to the delivery is repeated each time a truck is unloaded. There are currently five dock doors available at E19 and two at the STATA center shipping location.



STATA center Dock Door for shipment receipt

Once the shipment is unloaded from the truck, it is transferred to a shipment sorting room through a conveyor belt (roughly 20 feet in length). One MIT Mailing Services staff checks the package for address completeness and puts aside any packages that require further investigation.

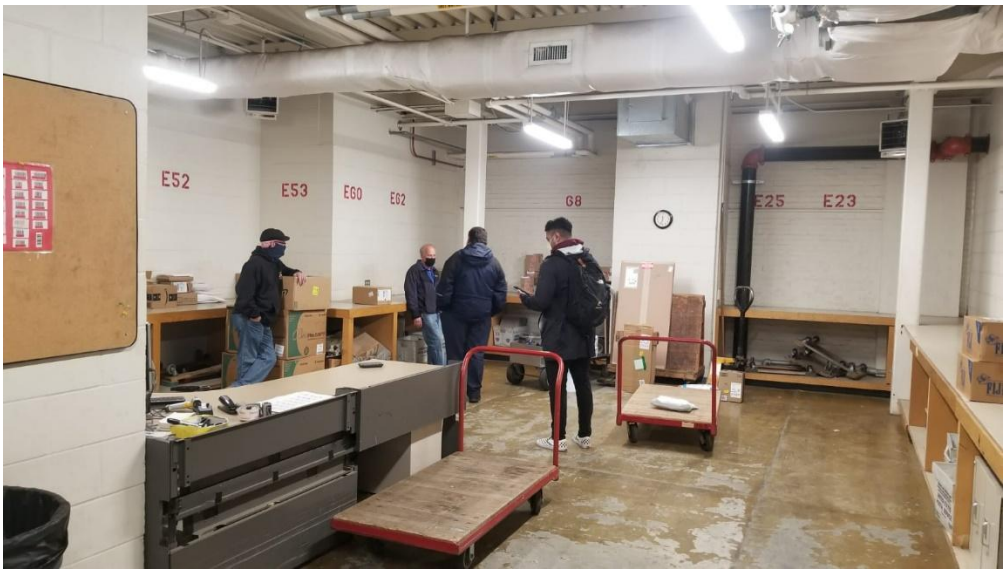
Shipments being unloaded at the STATA Center

Shipment unloaded and being transferred to the sorting room

After the packages arrive in the sorting room, the building number on them is identified and they are placed in their respective sections. The sorting room has a designated section for each of the buildings it is servicing.

Packages being placed under their respective building number

Building number sections in the sorting room



Sorting and Consolidation room at E19

After the packages have been put away to their respective location, the staff reviews the staffing plan for the day for their last mile delivery plan. The buildings are grouped into clusters based on their geographic proximity and the last mile delivery scheduling aims to ensure most packages are delivered on a single trip from the sorting center. These clusters for STATA sorting are as follows (in the order of buildings serviced) -

a. Cluster 1 - Building 2,4,6,8,9,10,11
b. Cluster 2 - Building 14,76,13
c. Cluster 3 - Building 16,56,66,54,18
d. Cluster 4 - Building 26,36,37,38,39,24,33,35
e. Cluster 5 – Building 46, 32,31,41,42,44,48

3.1.3.2 Package scans and ASN updates for DLCs

Once the 3PL contracted by the vendor drops the shipments at the shipping location, they are signed as received by an MIT Mailing Services staff member. The 3PL website then indicates the item as delivered. The last mile tracking of these shipments from the MIT shipping rooms to the respective consignee is facilitated by the MIT Mailing Services website - indicating the status of the shipments as “Received,” “In-Transit,” “Attempted Delivery,” “Delivered.” They use the same waybill/ASN number as the 3PL company/vendor.

3.1.3.3 VENDOR 1 Edge case

The only exception to the above case is all deliveries coming from Vendor 1. These deliveries are primarily office supplies being ordered by MIT DLCs (Departments, Labs and Centers). They are dropped at either E19 or the STATA center depending on the associated shipping room for the majority of packages' building numbers. For example, if on a given day most of the addressed shipments are being serviced by the STATA center, the Vendor 1 truck will deliver shipments there. Vendor 1 may make multiple deliveries in a day and may service either or both shipping rooms. Vendor 1 also has an on-ground, full-time staff member present at MIT who is responsible for unloading, sorting and doing the last mile delivery on foot to respective DLC buildings. Their process is very similar to that of the MIT Mailing Services - the only difference being that they have a separate drop-off zone (in the same basement) and consolidation area and the delivery routing and consolidation is based on their memory and past experience in understanding the best route to delivery packages on foot on the MIT campus. They too use hand trucks/trolleys to deliver these packages.

Office supplies ready to be delivered to DLCs

Packages are also loaded onto the trolley in order of their intended delivery sequence - following a 'First In First Out' methodology. Manual sorting and loading of packages may take from 30 minutes up to 2 hours (depending on the volume for the day). This process is repeated every time a Vendor 1 truck delivers shipments to MIT. This truck is currently not taking back any items with it meant for recycling or through a take-back program.

3.3.4 Distributed Mail Centers (DMC)

Each MIT office has a designated local Distributed Mail Center (DMC) which serves as the central delivery and pickup point for interdepartmental or US Mail (Source: MIT Department of Facilities Website). MIT Mailing Services delivers these items (such as mail, magazines, pamphlets) addressed to their respective addressed room number slots in a DMC.

Distributed Mail Center (DMC) at Building E36

Mail is currently received and sorted at the WW15 location, and from there delivered to their respective DMC location by MIT Mailing services via foot. A DMC may service one or more buildings. Although a DLC may not have access to a Distributed Mail Center in their same building, their assigned DMC will always be within walking distance and easily accessible.

3.3.5 Existing role of DMCs in recycling

DMCs also act as strategic collection points for tech-waste (such as toner cartridges, batteries, CDs and electronic items). The Mailing Services staff members, on their trip to a DMC to drop and pick up letters, also pick up these recycling items from their designated drop-off areas and bring them to the shipping rooms in E19 or STATA center. From here, they are picked up by contracted MIT recycling vendors on their weekly pickups from MIT.

Existing decentralized recycling collection at E36 DMC

3.4 Procurement Opportunities

This section explores the procurement opportunities which can be leveraged based on the purchase data in order to come up with an office supply commodity consolidation model.

3.4.1 Identification and classification of relevant SKUs

Based on purchase data from the Office of the Vice President for finance we identified the top 50 SKUs by volume purchased by MIT. From these 50 we identified and segregated 23 SKUs which fall within the scope of our project. The SKUs which have not been considered include kitchen supplies and food items, the demand for which is highly variable depending on the nature of the DLC and does not fall within the scope of office supplies. A complete list of all 50 SKUs has been provided in Appendix D. Considering the purchase data has been provided for FYs 2019 and 2020 we see a skewness towards the purchase of cleaning supplies and disinfectants in light of the COVID-19 pandemic. Adjustments for this trend of purchase in cleaning supplies may be required if usage significantly changes after the pandemic. For the 27 SKUs that we have considered within the scope of our project, Table 2 summarizes them bundled into categories with the number of SKUs falling under each category.

Table 2: Categories of "high-running" SKUs

Category	Number of SKUs
Copy Paper (8.5 x 11)	3
Hand sanitizer/soft soap	3
Napkins/Tissue	3
Disinfecting wipes	1
Notebook/Exam book	3
Tape	2
Battery (AA/AAA)	3
Pens/Markers	5

We have also identified the dimensions of each SKU from the product description available (similar SKUs have been bundled together). For the purposes of our project and to maintain referential integrity we have used generic names of the "office supplies" instead of actual names for the SKUs (Table 3).

Table 3: Dimension of "office supplies" SKUs

Category	SKU	Dimension (L x W x H) (in.)
Copy Paper (8.5 x 11)	Copy Paper (8.5" x 11") 1 RM	8.5 x 11 x 2.1
Hand sanitizer/soft soap	Hand sanitizer (8oz)	1.6 x 2.9 x 6
	Hand sanitizer (12oz)	2.25 x 2.75 x 6.53
	Soft soap (7.5 oz)	1.6 x 3 x 5.4
Napkins/Tissue	Napkins (400 pcs)	6 x 6 x 12
Tape	DUCT TAPE 48MMX55M	3.75 x 3.75 x 1.88
	Tape dispenser	6.41 x 2.56 x 2.71

Battery (AA/AAA)	Battery (AA x 24pcs)	1.99 x 0.55 x 0.55
	Battery (AAA x 24pcs)	6 x 5 x 4
Pens/Markers	Pen type A (12 pcs)	1.06 x 2.75 x 6
	Thick Pen type B (12 pcs)	1.31 x 2.88 x 5.75
	Dry Erase Marker	1.3 x 2.75 x 5
Disinfecting wipes	Disinfecting wipes (75 counts)	4.2 x 4.3 x 8.3
Notebook/Exam book	9 x 6 notebook (150 pgs.)	9 x 6 x 1
	Exam Book (8.5 x 7)	8.5 x 7 x 0.1
	Exam Book (8.5 x 11)	8.5 x 11 x 0.1

3.4.2 Methodology to calculate SKU consumption rates

In order to come up with the inventory level that needs to be held at each stockroom we calculate the use rate per person based on certain assumptions of user experience for a typical school and historical data. We have scaled up/down the daily, monthly or seasonal uses in an effort to calculate the weekly use per person (considering 5 working days in a week and 14 weeks in a semester). We have also calculated the use case from the perspective of a typical student irrespective of the department. The total number of students at MIT has been approximated to be 12,000 (considering both on and off campus), since the total student number has hovered between 11,300-11,900 since 2013 (Massachusetts Institute of Technology, 2021). Additionally, there are almost 12,000 faculty and staff on campus (Massachusetts Institute of Technology, 2022). However, for simplicity, our project focuses on the student perspective as illustrative of a process that could be adapted to account for the other user profiles that may vary more depending on administrative and research activities. Although this is a potential limitation, the variability in the use of office supplies is not expected to be high owing to the nature of the institution itself. For the high running SKUs that have been proposed to be stocked, we have formulated equations to come up with

approximations for the tentative inventory to be stocked; the resultant consumption table on a per student basis is given below.

For hand sanitizer, 3mL or 0.1oz of is recommended per use, (You Aren't Using Enough Hand Sanitizer, Berezow, 2017) with an average hourly use of once (Infection Prevention and Epidemiology, Michigan Medicine, University of Michigan).

Equation 1. Hand sanitizer use per person per day

= uses per hour × oz per hand sanitizer use × number of hours spent at DLC

= 1 × 0.1 × 8

= 0.8 oz.

Considering the similar recommended use of soft soap 3 times per day (without hand-washing after use of restroom, since soft soap for restrooms is supplied by the MIT custodial services)

Equation 2. Soft soap daily use per person per day

= uses per hour × oz per hand soft-soap use × number of use cases at DLC

= 1 × 0.1 × 3 = 0.3 oz.

From the same understanding we make an estimation for **a use rate for disinfecting wipes of 3/person/day**; summing up to 15 pcs being used by an average student in a given week.

MIT also has a quota of 3,000 pages per semester per student (Information Systems and Technology MIT, 2021), although it is estimated that only 10% of the students exceeds this quota (Srinivasan D., 2010). Considering an average student uses 70% of the print quota (including use for administrative purposes):

Equation 3. Average copy paper use per person per day

$= (\frac{Print\ quota\ in\ a\ semester}{Number\ of\ weeks\ in\ a\ semester} \times Fraction\ printed) \div Number\ of\ days\ in\ a\ week$

$= (\frac{3000}{14} \times 0.7) \div 5$

= 43 pages

Similarly using user experience data, assuming each student uses on average one 150-page notebook every 4 weeks, provided by MIT,

Equation 4. Notebook used per person per day

= no. used in n weeks ÷ (number of days in a week × n)

= 1÷ (5×4)

= 0.05 notebook/person/day

Exam blue books are used mostly during final/midterm exams. Considering an average full-term student takes 4-5 classes per semester with both a midterm and finals, equates to 10 exam books used per student per semester. Hence exam books have been recommended to be replenished every 6 weeks only if our stock room space permits.

For napkins we also make the recommendation from personal experience of a use rate of 5/person/day.

Duct-tape is used quite scarcely, specific to some DLCs and has been limited to use of 0.25 roll/person in an entire semester. On the contrary for tape dispensers, the use is more profound with an estimated use of 1 roll of tape dispenser per student per semester.

Equation 5. Black tape dispenser used per person per day

= used per semester ÷ (number of weeks per semester × number of days per week)

= 1 ÷ (14 × 5)

= 0.014

MIT has 162 classrooms managed by the Registrar's office (Source: https://student.mit.edu/roominv/roominv.cgi). Considering various and individual A/V systems housed at the DLC level we have made the estimation of 400 A/V systems. Considering a nominal use rate of 13 weeks for a pair of AAA batteries:

Equation 6. Total number of AAA batteries used by A/V systems

= *total number of A/V systems × number of batteries used per system × (number of weeks per year ÷ shelf life in weeks)*

= 400 × 2 × (52÷13)

= 3200

Due to the lack of sufficient data as to the other uses of batteries at the DLC levels, we have used the consumption rate for the A/V systems to benchmark our model. Batteries used in these systems are considered to comprise of 10% of the total AAA batteries used on a DLC level (DLCs have their own TV and multimedia systems in breakout rooms and libraries). The number of AA batteries acquisitioned is assumed to be approximately one-third of the AAA batteries. This is largely owing to the higher capacity of AA batteries (almost 3 times) and hence longer run time. (Borges, 2022)

Total number of AAA batteries purchased in a year = 36000

Total number of AA batteries purchased in a year = 12000

Average annual AAA battery consumption per student = 36000/12000 = 3

Average annual AA battery consumption per student = 12000/12000 = 1

For the sake of simplicity, we assume a linear use rate for stationary such as pens as 2/person/month (span of 4 weeks), evenly divided between the two types of pens available in the list of top 50 SKUs. For markers this number is set lower at 1/person/month (span of 4 weeks). Table 4 lists out the weekly consumption rate for the various commodities.

Table 4: Quantification of Weekly Consumption Rate

Category	**SKU**	**Weekly consumption**	**Unit**
Copy Paper (8.5 x 11)	Copy Paper (8.5" x 11") 1 RM (500 pages)	215	Pages/person
Hand sanitizer/soft soap	Hand sanitizer (8oz)	0.8 oz.	Oz./person
	Hand sanitizer (12oz)		
	Soft soap (7.5 oz)	0.15oz.	Oz./person
Napkins/Tissue	Napkins (400 pcs)	25	Pcs/person

Tape	DUCT TAPE 48MMX55M	0.018	Rolls/person
	Tape dispenser	0.07	Pcs/person
Battery (AA/AAA)	Battery (AA x 24pcs)	0.04	Pcs/person
	Battery (AAA x 24pcs)	0.013	Pcs/person
Pens/Markers	Pen type A (12 pcs)	0.25	Pcs/person
	Thick Pen type B (12 pcs)	0.25	Pcs/person
	Dry Erase Marker	0.25	Pcs/person
Disinfecting wipes	Disinfecting wipes (75 counts)	25	Pcs/person
Notebook/Exam book	9 x 6 notebook (150 pgs.)	0.25	no./person
	Exam Book (8.5 x 7)	5	/semester/person
	Exam Book (8.5 x 11)	5	/semester/person

3.4.3 Results for the stockroom model

Given the quantification of the weekly consumption rate, we are able to quantify how much each stockroom is expected to stock on average with key design considerations such as size and number of DLCs serviced. Table 5 quantifies the amount use rate and the potential number of weeks each SKU is expected to serve on a per-student basis.

Table 5: Number of Students Served by Each SKU on a Weekly Basis

Category	**SKU**	**Qty in one SKU**	**Number of weeks serving 1 student**
Copy Paper (8.5 x 11)	Copy Paper (8.5" x 11") 1 RM (500 pages)	500 pages	2.33

Hand sanitizer/soft soap	Hand sanitizer (8oz)	8 oz.	20
	Hand sanitizer (12oz)	12 oz.	30
	Soft soap (7.5 oz)	7.5 oz..	50
Napkins/Tissue	Napkins (400 pcs)	25	16
Tape	DUCT TAPE 48MMX55M	1	55.6
	Tape dispenser	1	14.3
Battery (AA/AAA)	Battery (AA x 24pcs)	24 pcs	416
	Battery (AAA x 24pcs)	24 pcs	139
Pens/Markers	Pen type A (12 pcs)	12 pcs	48
	Thick Pen type B (12 pcs)	12 pcs	48
	Dry Erase Marker	1 pcs	4
Disinfecting wipes	Disinfecting wipes 75 counts.	25	3
Notebook/Exam book	9 x 6 notebook (150 pgs.)	1 pc (150 pgs.)	4
	Exam Book (8.5 x 7)	5	14
	Exam Book (8.5 x 11)	5	14

From the table above, considering 52 weeks in a given year, we find that certain low demand SKUs may not need to be replenished on a weekly basis.

Key considerations for anomalous SKU's

For the purposes of our analysis and considering the anomalous nature of batteries and exam books, we make the assumption that the "stock-room" model allows buyers to purchase batteries in "pairs" instead of individual SKU of boxes containing 12 pairs. This would allow for better stocking up and purchase options since an entire box of batteries may not be feasible for purchase by an individual DLC.

As defined in section 3.1.4, MIT currently has more than 40 Distributed Mail Centers (DMCs).

From the mapping of the DMC location, we find that each DMC on average serves 1,2,4 or 5 buildings depending on the size of the DMC and the number of DLCs served. Considering the variation in the number of DLCs served, our proposed stockroom model has three variations catering to the need for 100, 200 and 400 students respectively.

Table 6 below analyses the total requirements of high-volume office supplies for a DLC catering to 100 students.

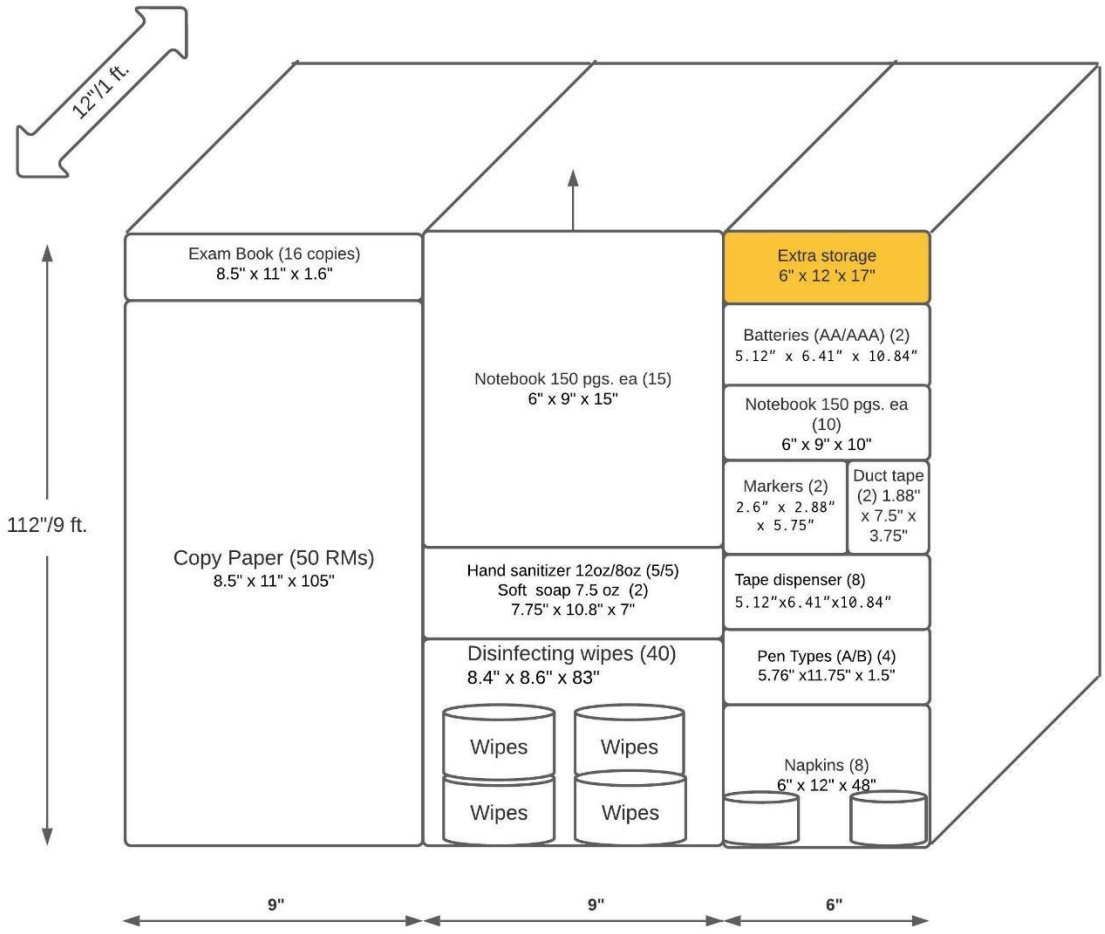
Table 6: Stockroom: Weekly Stocking Options for 100 Students

Category	**SKU**	**Qty in one SKU**	Number of SKUs needed to fulfill weekly demand for 100 students	Number of SKUs kept at the stockroom
Copy Paper (8.5 x 11)	Copy Paper (8.5" x 11") 1 RM (500 pages)	500 pages	42.92	50
Hand sanitizer/soft soap	Hand sanitizer (8oz)	8 oz.	5	5
	Hand sanitizer (12oz)	12 oz.	3.33	5
	Soft soap (7.5 oz)	7.5 oz.	2	2
Napkins/Tissue	Napkins (400 pcs)	25	6.25	8
Tape	DUCT TAPE 48MMX55M	1	1.8	2
	Tape dispenser	1	7	8
Battery (AA/AAA)	Battery (AA x 24pcs)	24 pcs	0.24	1
	Battery (AAA x 24pcs)	24 pcs	0.72	1
	Pen type A (12 pcs)	12 pcs	2.08	2

Pens/Markers	Thick Pen type B (12 pcs)	12 pcs	2.08	2
	Dry Erase Marker	1 pc	2.08	2
Disinfecting wipes	Disinfecting wipes 75 cts.	25	33.33	40
Notebook/Exam book	9 x 6 notebook (150 pgs.)	1 pc (150 pgs.)	25	25
	Exam Book (8.5 x 7)	5	7.14	8
	Exam Book (8.5 x 11)	5	7.14	8

Using the above numbers and optimizing for space and demand we designed a potential stockroom/supplies cabinet that could be installed in the DLCs and replenished at a monthly cadence. As we can see from the model below (Figure 4) there is some extra space at the bottom of the cabinet which can again be utilized to keep any of the high running SKUs (such as Napkins). Other high value items such as a couple of toner cartridges (average dimension 12 x 6.5 x 5.5 inches) can also be stocked for urgent/emergency needs by any of the DLCs; in other words, this extra space can be further utilized depending on the nature of the demand from the DLCs. Since Exam books only tend to be demanded every 6 weeks, the model also takes into consideration substituting the space allocated for exam books to store high running copy paper (and vice versa during the mid and final terms). The stockroom model can be scaled up by installing multiple such cabinets depending on space constraints and number of DLCs served.

Figure 4: Proposed Stock Room Containing Weekly Supplies for 100 Students



3.4.4 Comparison between the current order fulfillment and proposed order fulfillment

A push system in inventory planning and production can be defined as one where the production/stocking is initiated in anticipation of customer orders. Push systems are often based on forecasts and offer higher utilization of resources and a better ability to meet customer demand. On the downside, push processes are associated with higher inventory levels which impair the efficiency and the flexibility of the system. On the other hand, in pull systems, production is triggered by customer demand. Pull systems are constrained by

inventory and capacity decisions. Pull systems are more flexible and low inventory levels can be achieved, but often additional stock out cost and long customer lead times are created (Varlas et al., 2021).

Based on our review of the existing procurement process, we are going in with an assumption that orders can be fulfilled at any cadence from the individual DLCs but they are consolidated and triaged at Vendor 1 and subsequently shipped to MIT using their delivery trucks. These deliveries can range from once a week to multiple deliveries in a single day - depending on the volume of incoming orders

Our project proposes the movement from a purely pull inventory planning system whereby the vendor ships products only when an order is placed to a mix of the push-pull system. In this system the high-running SKUs will be stocked at the proposed stockroom location in order to fulfill anticipated demand (this can be either the DMC location, a location within a DLC itself or even a shared common space). This would not mean cost savings with regards to order fulfillment but shorter lead times enabling DLCs to stock less with just-in-time (JIT) on campus. Figure 5 illustrates the current order fulfillment process by Vendor 1 on campus while Figure 6 illustrates the proposed fulfillment using the “push-pull” model.

Figure 5: Current Order Fulfillment by Vendor 1 Using the "Pull" Inventory Fulfillment Method

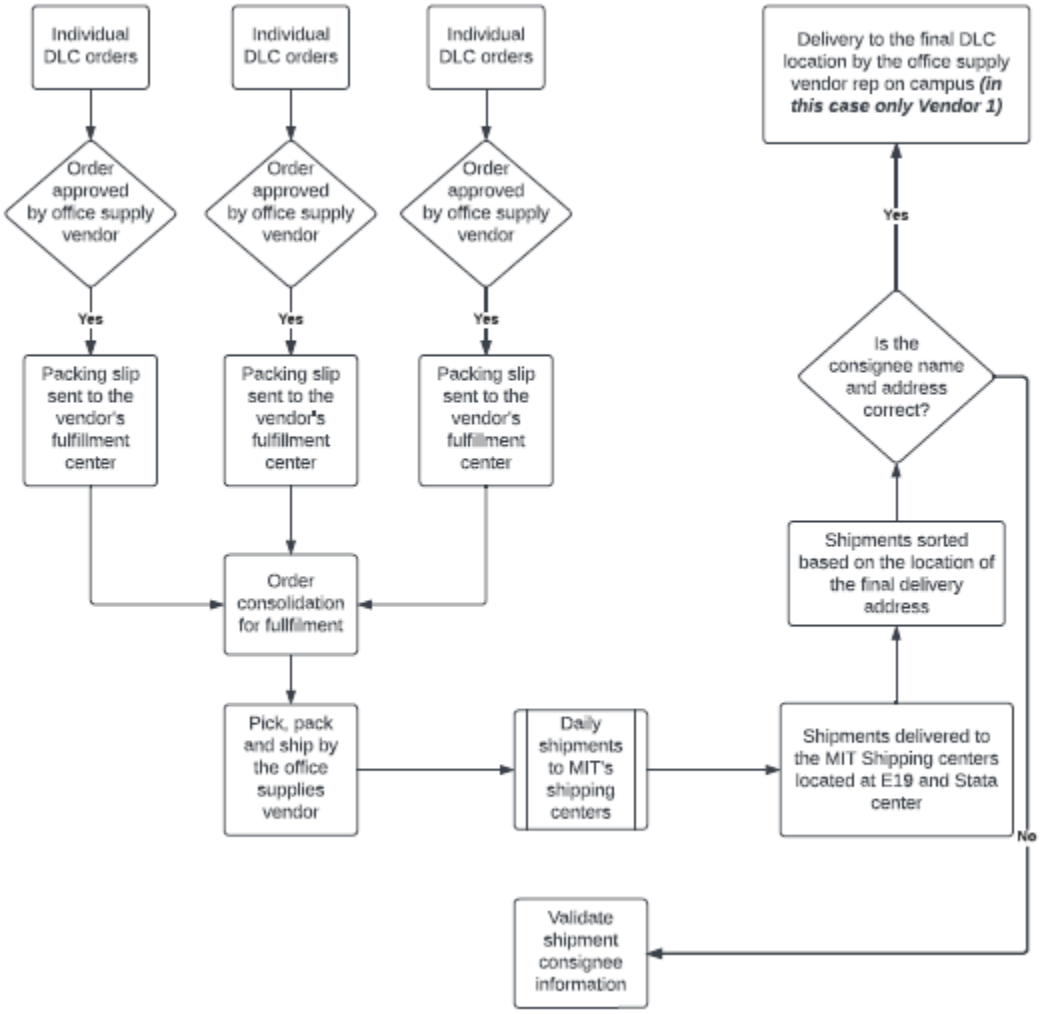
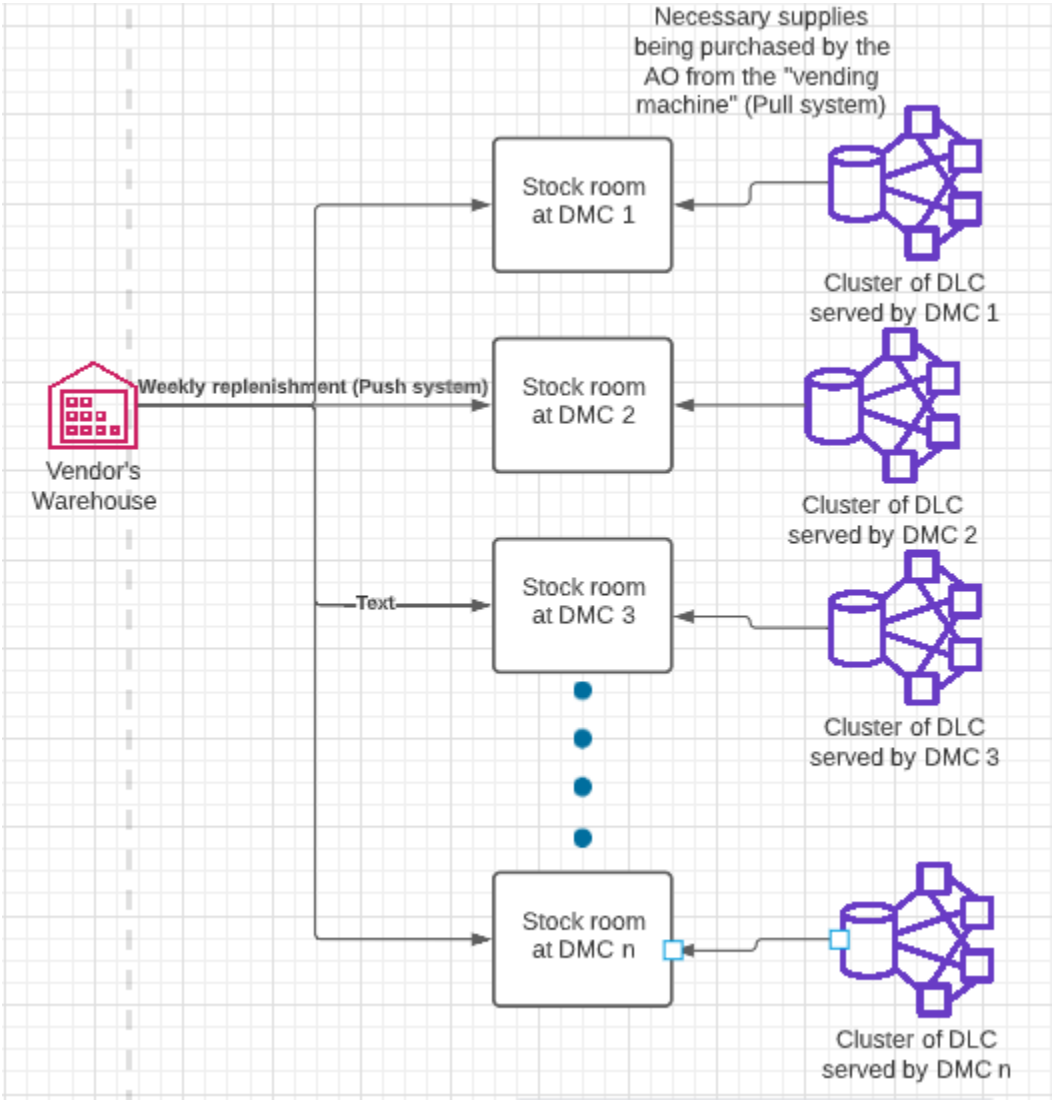


Figure 6: Proposed order fulfillment with the stockroom "push-pull" model (AO: abbreviation of administrative officer)



3.5 Recycling and take-back opportunities

As iterated previously the main aim of this project had been to promote sustainable practices at MIT and an integral part of this is encompassed in the reverse logistics which determines how best can used office supplies be recycled and re-used. This section elaborates the scaling up and utilizing the existing

DMC locations (mentioned in section 3.1.5) in implementing an office supplies take-back station along with the stockroom.

3.5.1 Quantifying recyclable materials savings

According to the data provided by the vendor (Vendor 1),

- Average packaging material per shipment per DLC = 0.77lbs
- Cardboard weight per shipment = 0.7623lbs
- Air pillows, plastic film and other packaging material = 0.0077lbs

Recyclable packaging material generated per month = 0.77 * Average shipments per month

As we can see from the quantification above there is enormous potential for cost savings and environmental benefits. For instance, even if we reduce the number of monthly shipments across approximately 400 DLCs by 1, we are looking at recyclable packaging material savings worth 308lbs in one month alone.

3.5.2 Potential opportunities for toner cartridge recycling

One of the key initiatives that is shaping the drive towards establishment of a sustainable economy (as discussed in the literature review is the establishment of the practice of 3R's) is the *Product Recycle - Re-use and Refurbish* initiative. Toner cartridges are one of the top 50 SKUs purchased at MIT. Our project further explored the various toner cartridge rebate programs and potential opportunities that may exist with the original equipment manufacturer (or O.E.M.) in regards to streamlining the returns process for empty toner cartridges.

Importance of toner cartridge recycling

According to a study by Riverside Technologies Incorporation (who manage the recycling operations on the MIT campus), recycling print cartridges reduces air and water pollution associated with landfilling, helps save energy, and conserves natural resources. Used cartridges that are not recycled are most commonly dumped into landfills. They may take up to 1000 years to fully decompose and, it is

expected, that for every 100,000 recycled print cartridges, we can save 9599 kilograms of aluminum; 40 tons of plastic; and 1,000,000 liters of oil (Riverside Technologies Inc., 2019). According to their 2020 Sustainability Report, HP has recycled 11,900 tons of Original HP Ink and Toner and Samsung Cartridges with another 19 tons of plastic saved in efficient packaging in printers alone. This goes to show the impact of an O.E.M. can have in making the toner cartridge supply chain more circular and sustainable.

An important aspect that influences sustainable toner cartridge sourcing is the amount of volatile organic compound (VOC gas) emissions that the cartridge emits upon its re-use, which can be an issue if there is no streamlined process for recycling, emphasizing the importance for recycling by the O.E.M themselves. This significantly impacts the indoor air quality and the overall health quality of the users subjected to this environment. According to a recent study by Fraunhofer Wilhelm-Klauditz-Institute, in contrast to OEM cartridges, almost 96% of cheap, counterfeit toner cartridges do not maintain Blue Angel standards of total VOC emissions. The Blue Angel standards is an industry-wide standard used to deem a product as being eco-friendly by the German government since 1978 (Gu, 2017). According to the US Environmental Protection Agency, high exposure to volatile organic compounds can pose significant health risks including damage to liver, kidney and the central nervous system (United States Environmental Protection Agency, 2021). Bolstering the efforts towards toner cartridge rebates may also help in reducing the practice of purchasing cheap, counterfeit toner cartridges, since the cost rebate will help reduce the burden of the overall price of purchase for the original.

Existing toner cartridge rebate program at MIT

As described previously, there does not currently exist any consolidated used toner cartridges' rebate program at MIT. Individual DLCs may choose to mail used toner cartridges to the vendor (Vendor 1); however, there are currently no means to incentivize the take-back process or make it user-friendly to incentivize more DLCs to participate in the program.

Available toner cartridge rebate programs

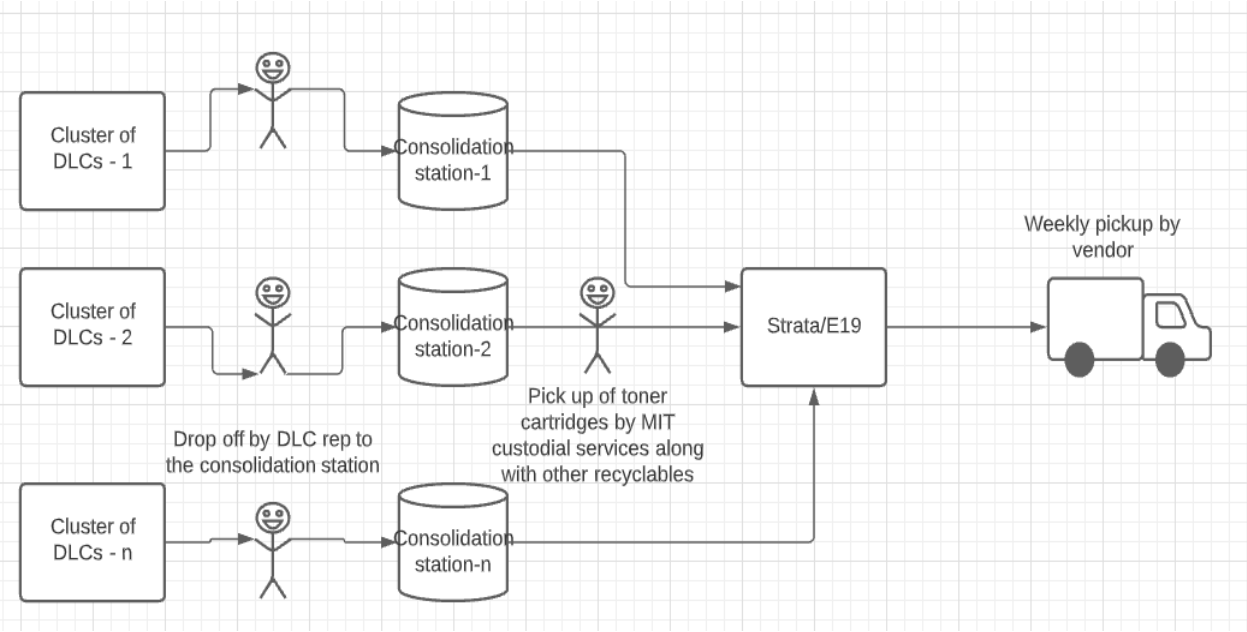
One of the major OEMs for printers and toner cartridges at MIT is Vendor 4. Currently they have three different schemes to facilitate the toner cartridge take back process for both original Vendor 4 and Vendor 5 manufactured toner cartridges. (Vendor 4 Planet Partners - Supplies recycling program)

1. Dropping off at partnered office supply stores: Vendors such as Vendor 1, Vendor 6 etc. accept used toner cartridges from individual owners. Vendor 1, for instance has a $2 refund policy for toner cartridges returned by individual customers (this policy does not apply to commercial customers like MIT).
2. Mailing it: After registering on the Vendor 4 website a customer can request a shipping label and drop off the used toner cartridge at the nearest UPS/FedEx location.
3. Requesting a pickup: For bulk return of over 1,000 Vendor 4 ink cartridges or more than 76 Vendor 4 or Samsung toner cartridges the user can select a time and location for getting the toner cartridges picked up.

Proposal for used cartridge consolidation

After careful consideration of the current purchasing behavior and the survey data analysis, our project proposes a more streamlined consolidation process for DLC-wide toner cartridges. Historical trends in toner cartridge sourcing suggest that toner cartridges are mostly originally manufactured Vendor 4 toner cartridges. Hence, considering the sheer volume of MIT wide used toner cartridges, it would be beneficial to consolidate all used cartridges for streamlined recycling. Leveraging the office-supplies take-back station, users could drop off their used toner cartridges, which would then be consolidated for a centralized pickup by the Vendor 4 representative from the inbound shipment consolidation locations at STATA or E19, depending on space constraints. As we can see from the process flow, this would not only streamline the process of toner cartridge consolidation but would also allow for significant financial benefits with regards to cost rebates from the vendor. Figure 7 illustrates the proposed take-back scheme of toner cartridges to the original equipment manufacturer.

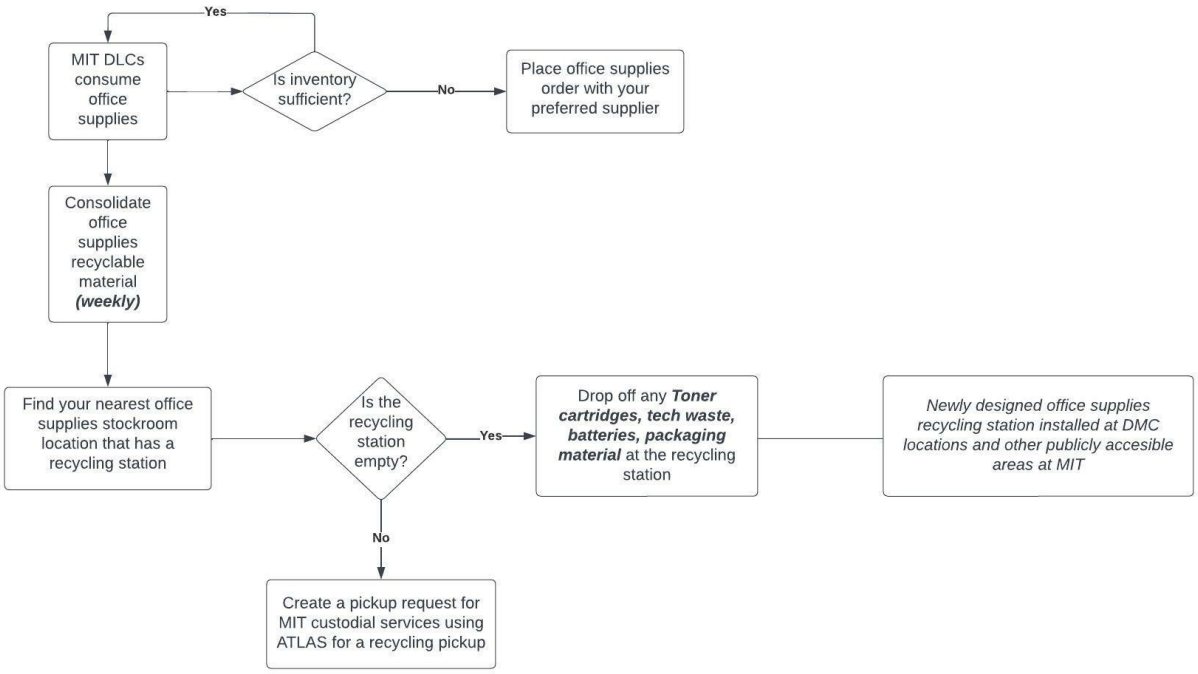
Figure 7: Flow Diagram for Proposed Take-Back Scheme of Toner Cartridges to the Original Equipment Manufacturer



3.5.3 Consolidated office supplies collection process

In a new process, our proposal is to design a consolidated office supplies recycling station which captures 4 different streams on recycling which either do not exist or currently are not advertised well enough for mass usage across the university. These include empty toner cartridges, batteries, tech-waste and packaging material including non-recyclable plastics. Engaging visual messaging will be used to educate users about the process of recycling office supplies and hard to recycle materials and what happens next once they drop off this material at these collection points. The entire process flow diagram for the consolidation of take-back supplies from the point of view of the DLCs is illustrated in Figure 8.

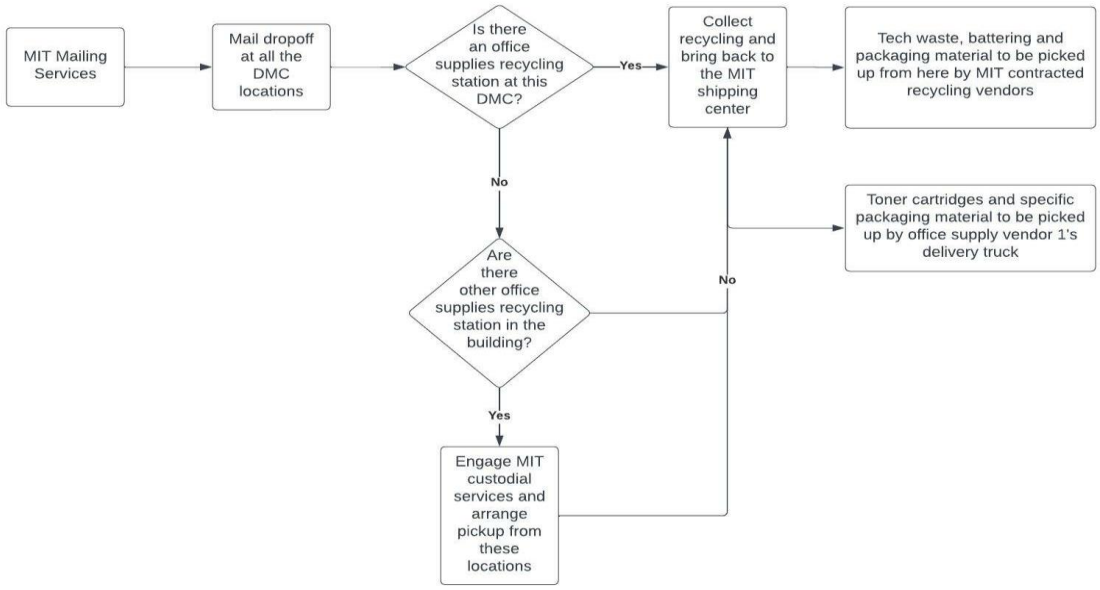
Figure 8: Consolidated Office Supply Drop-off by the DLC representative



In order to promote mass adoption across MIT, we are looking to position these office supplies collection station not only at each DMC location (where DLC members with access can use these stations on their way to collect their office mail/use the office supplies stockroom location) but also place one station per building which could be used publicly and not be limited to users with exclusive DMC access. However, these two separate locations of the stations would mean two separate workflows for the MIT Mailing services to arrange pickup from each station (demonstrated in Figure 9) -

A. MIT Mailing services staff (with access to the DMC location) can pick up office supplies recycling on their way to drop off mail at respective DMCs.
B. MIT custodial services staff can arrange pickup (at a weekly cadence and upon special request) from the publicly accessible locations since they do not have access to the DMCs.

Figure 9: Proposed Office Supply Recycling Process



4 ENGAGEMENT SURVEY WITH MIT STAKEHOLDERS

We conducted an engagement survey across MIT stakeholders to understand the current office supplies procurement process, how they would use the proposed stockroom model in this capstone and what actions where they willing to take to make their procurement process more efficient and sustainable. The key research questions that we were trying to answer through this survey are as follows:

- What does the current purchasing process look like at different labs, departments and centers at MIT?
- What are some of the key pain points of the associated stakeholders about the procurement process?
- What actions are DLC stakeholders willing to take to participate in the proposed stockroom model?
- What were some of the key pain points in the current procurement process for the DLC stakeholders and whether they saw any concerns with this proposed model?

These research questions allowed us to create a set of survey questions to help us better understand the priorities of a stakeholder doing office supplies procurement, what was influencing their decision making and inability to make more sustainable choices on campus and what actions were they willing to

take to support the model presented via this capstone. Through the answers to these questions, we are looking to gauge the interest in the proposed supply chain design, solicit their feedback to make the office supplies procurement more closed-looped and gather data that could prove the potential success of the stockroom model.

The final survey included 16 questions. We identified key points of contacts responsible for purchasing at 58 different DLCs and sent them a Qualtrics survey via email. Our primary demographic included the Administrative Officers and Administrative Assistants who are responsible for most of the office supplies procurement at DLCs. Out of the 58 DLCs we saw a participation of 28 DLCs which constitutes a response rate of 48%.

4.1 Key summary statistics about the participating DLCs

The engagement survey saw participation of a total of 37 individuals involved in the office supplies procurement process at different departments, labs and centers at MIT. They represented a total of 28 DLCs (refer to Appendix B for a complete list of the survey respondents). The majority of the people involved in this process had the job title of an 'Administrative Assistant'. Roughly 33% of the participating DLCs characterized themselves as 'Large' meaning that they either spanned across multiple buildings or had their population size greater than 50 members. (Small DLC can be categorized as less than 20 members, and a medium DLC can be categorized as 20-50 members). Roughly 41% of the participants reported that their DLC had specialty procurement needs since they were categorized as 'Wet' meaning that they procured chemicals for their respective operations. We also found that for 65% of the participants the subject of sustainability was 'very important' to them. Figure 10, 11, 12 and 13 gives a pictorial insight of the survey results. Appendix C also lists out some of the additional questions asked in the engagement survey but there were no significant results to report based on the survey responses

Figure 10: Size of the DLCs (as Defined by the User)

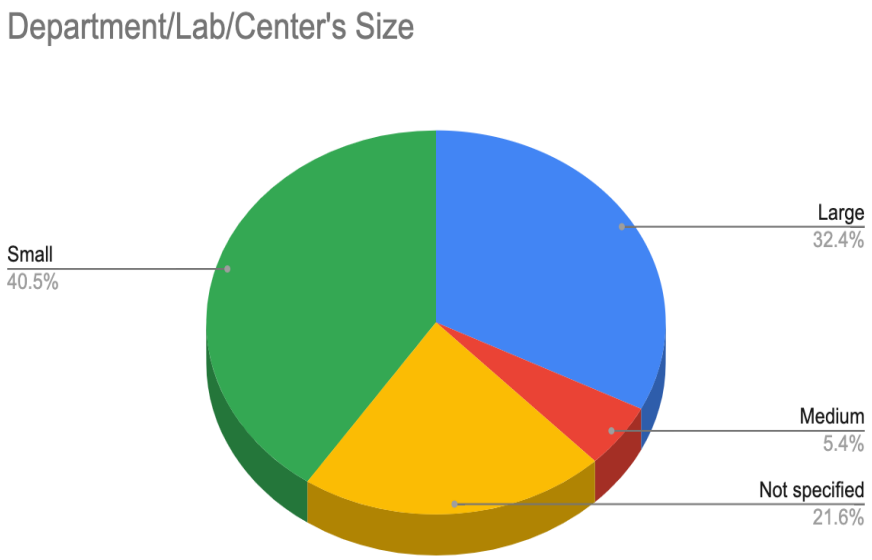


Figure 11: Decision-Making Ability of the Respondent

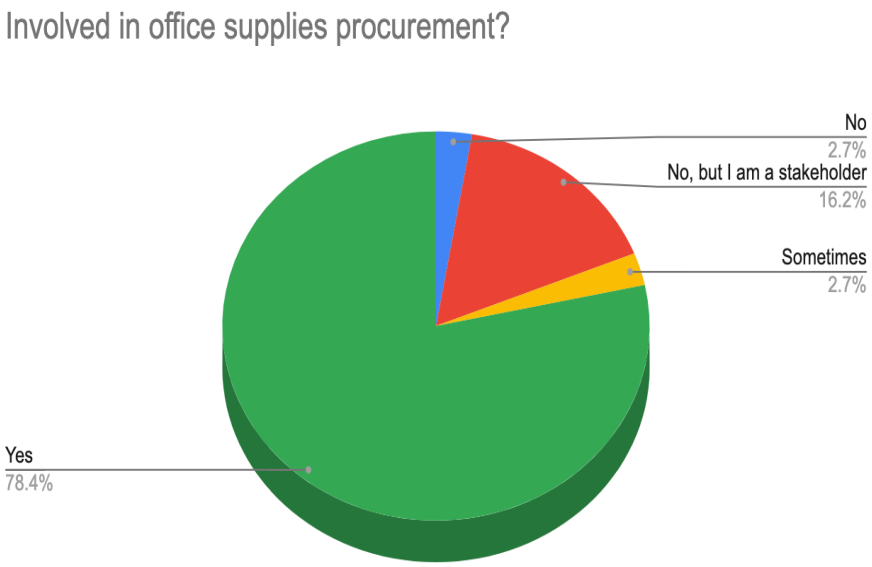


Figure 12: Type of Procurement by DLCs

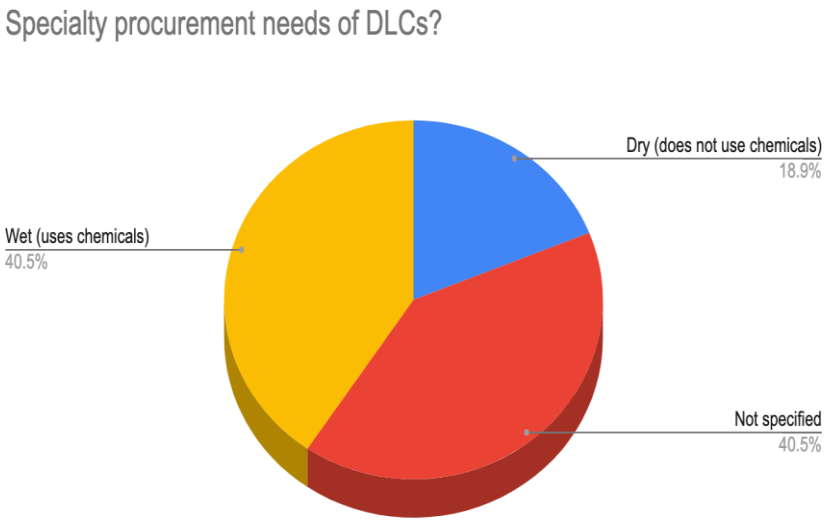
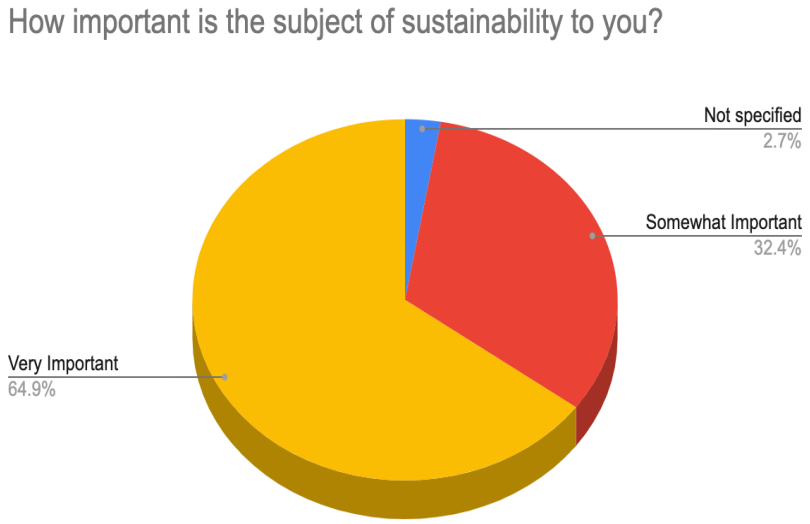


Figure 13: Importance of Sustainability



4.2 Key survey questions and their responses by our target audience

In this section we are highlighting all the questions that we presented to our target audience through the Qualtrics survey, along with a percentage breakdown of their response and the categories they identified themselves in.

Question 1 asked about the stakeholder's viewpoint on making sustainable choices at MIT and what makes it difficult. This question enabled multiple responses, and the percentage of respondents indicated the total cumulative participants that had this option as a part of their final selection. Through this question we wanted to get a sense on whether the audience was inclined to making sustainable choices in their procurement process, and if yes, what were some of the reasons why this was difficult (especially in the context of office supplies procurement). We observed that a strong majority of stakeholders (38%) were eager to participate in new ways to make their existing workflows more sustainable. But there was similar section of stakeholders (32%) that felt that there was not enough information available on on-going sustainability initiatives at MIT and there was a lack of collaboration among DLCs (27%) that would enable DLCs that would enable these initiatives to be successful.

Stakeholder's viewpoint on making sustainable choices and what makes it difficult?	**Percentage of respondents**
I'm confident in my ability to make sustainable choices, but always looking for new solutions.	38%
There isn't enough information available on MIT's sustainability initiatives	32%
Lack of a collaboration between different DLCs at MIT on sustainability initiatives	27%
Economic/Supply Chain uncertainty around COVID-19	16%
Limited sustainability programs offered by your employer	14%
As a buyer, I'm purchasing for other stakeholders and making sustainable choices is often out of my control. Quality of the product or their choices are often the priority.	3%

Making sustainable choices is expensive.	3%
Most employees are working remotely.	3%
Most purchases are urgent & time sensitive. People often don't have the time to research sustainable choices.	3%
Unnecessary plastic and paper in packaging makes it harder to be more sustainable.	3%

Question 2 asked “How is office supplies inventory currently tracked at DLCs, and what does the re-ordering process look like?” This question was also a multiple-response selection, and the percentage of respondents indicate the total cumulative participants that had this option as a part of their final selection.

Re-ordering process	**Percent of respondents**
Visual estimation of available inventory, and place orders for items we think are 'depleting'	49%
We order items only after we run out of inventory	30%
We consolidate all requirements of members of our DLC (via email, google form, slack message etc.) and place orders at once	14%
We order items on a need-by basis.	11%
We actively count the inventory on hand, and place orders for items below a certain threshold	5%
My department has a distributed purchasing system which optimizes office supplies procurement.	3%

Through this engagement survey, we were trying to gather data from people and gain perspective on co-creating a solution for sustainable office supplies procurement on MIT's campus. The model proposed was using the **'Distributed Mail Centers'** as a pickup location for office supplies orders.

Through the survey we shared with the audience that there was an opportunity to use these DMC locations to drop-off office supplies shipments for all departments and have them pick it up from here instead of getting it delivered to each of their respective buildings. A designated DMC location would be a very short walk from each of the DLC buildings, and would be accessible without any significant disruption to one's day to day work. It could also serve as a 'stockroom' for storing office supplies - where MIT partner vendors can stock certain popular items which can be purchased directly at these locations (though a vending machine-like setup).

The following are some of the key responses and findings from the survey about the above-mentioned model:

Question 3 asked, “How likely are you to collect your orders from such a pickup location on campus (instead of getting them delivered directly to your DLC location)?” Responses to this question allowed us to gauge the overall interest of people in a stockroom model for office supplies. A total of 32% of survey respondents constituted the demographic of people who would be interested in such a model and make trips to a nearby location to pick up their office supplies shipments/orders.

Response	**Percent of respondents**
Extremely unlikely	35%
Somewhat unlikely	19%
Neither likely or unlikely	14%
Somewhat likely	27%
Extremely likely	5%

Question 4 asked “This model also gives us an opportunity to create a collection point for "hard to recycle" items*. How likely are you to carry these “hard to recycle” items with you in your office supply pickup tour (& making operations at MIT more eco-friendly)?”

**Some of the office supply items like printer, toner, ink cartridge, tech waste (computer accessories), batteries etc. require specialty recycling collection bins and are considered "hard to recycle".*

However, when we shared this same stockroom model from a reverse flow perspective enabling the DLC stakeholders to recycle their 'hard to recycle' commodities, we saw a jump in the positive response rate to a total of 76% (somewhat likely and extremely likely). This shows that stockroom model fulfillment is ideally positioned as a complementary location where certain office supply commodities can be easily recycled. The added benefit enabling DLCs to accomplish multiple tasks in a single trip at such locations on campus could drive fulfillment volumes.

Response	**Percent of respondents**
Extremely unlikely	14%
Somewhat unlikely	5%
Neither likely or unlikely	5%
Somewhat likely	35%
Extremely likely	41%

Question 5 asked "If Vendor 1 provisioned a "vending machine" like set-up at these DMC locations, where you could purchase office supplies, how likely are you to use this method to purchase your supplies (instead of placing your orders online)?" This question allowed us to get into the minds of the DLC stakeholders regarding how they viewed an office supplies vending machine and whether will they procure items from them by walking a short distance on campus instead of placing an order online. A total of 38% of survey respondents constituted a positive response rate (combining the somewhat likely and extremely likely categories). This is a promising statistic since 41% of survey respondents had indicated that they would be willing to go to a central location for recycling 'hard to recycle' commodities. Having a vending machine at those locations would be a really helpful addition for these stakeholders since this will save them

significant time in the fulfilment of the office supplies but also make their procurement extremely eco-friendly.

Response	Percent of respondents
Extremely unlikely	8%
Somewhat unlikely	24%
Neither likely or unlikely	14%
Somewhat likely	22%
Extremely likely	16%
No response	16%

Question 6 asked “Are you willing to donate excess office supplies to a "Re-use/Repurpose" which could be used by other Departments, Labs or Centers? (Supplies will be donated at your collection point)”.

The responses to this question showed the overall enthusiasm of DLC stakeholders in a re-use and re-purposing program for office supplies. This is an indicator of them dealing with excess office supplies and 62% of the respondents were extremely likely to engage with other DLCs and collaborate with them for the re-use and repurposing of their excess inventory. Our inference is that this could result in a lot of cost savings for DLCs participating in the "Re-use/Repurpose" program and hence there is a very high likelihood of its adoption and implementation.

Response	Percent of respondents
Extremely unlikely	11%
Somewhat unlikely	5%
Neither likely or unlikely	8%
Somewhat likely	14%
Extremely likely	62%

Question 7 asked “Collaboration with other DLCs: How likely are you to collaborate with other DLCs on consolidating office supplies orders?”

Interestingly the response to this question were perfectly symmetric where 30% of the people were neither likely nor unlikely to collaborate with other DLCs.

Response	**Percent of respondents**
Extremely unlikely	16%
Somewhat unlikely	19%
Neither likely or unlikely	30%
Somewhat likely	19%
Extremely likely	16%

Question 8 asked “How likely are you to share a storage location with a few other DLC that are in your building?” The main purpose of asking this question was to see if DLCs were willing to collaborate with other DLCs to share a storage space which would result in lesser need for storage space on their office floor and potentially expand the stockroom model to these shared spaces. A strong percent (22% extremely likely and 24% somewhat likely) of respondents indicated that they would be interested in collaboration.

Response	**Percent of respondents**
Extremely unlikely	16%
Somewhat unlikely	14%
Neither likely or unlikely	8%
Somewhat likely	24%
Extremely likely	22%
No response	16%

Questions 9 & 10 were asked to better understand what actions the DLC stakeholders were willing to take to participate in a closed loop stockroom model for office supplies procurement. We wanted to understand

how far they were willing to walk to these pick-up/drop-off locations and how often were they willing to make these trips. The responses helped us understand the varied nature of the distance and frequency of travel that people were comfortable with making where a majority of the people reported that they were willing to walk up to 5 minutes to a nearby location to pick-up office supplies/drop-off recycling material and were willing to make such trips no more than once a week. This goes to show that if a stockroom model was located within a 5-minute radius of these DLCs and was replenished frequently to warrant a 'once a week' cadence of visit, we would be able to maximize the likelihood of adoption of a stockroom model.

Question 9: *How far are you willing to travel to make your collections?*

Response	**Percent of respondents**
I am willing to walk 5 minutes to a nearby stockroom location to pick up my order(s)	41%
Nothing further than going downstairs in my building to pick up my order	27%
I am willing to pick up orders for another DLC in my building if I can bring it back with me in a single trip	22%
I am willing to walk 10-15 minutes to a nearby stockroom location to pick up my order(s)	19%
I am willing to take a 'carry out' cart with me to pick up these orders. Something that I often do when I am bringing groceries back home.	11%
Not willing to travel at all.	5%
This is dependent on the weight of the items ordered.	3%

Question 10: *How often are you willing to travel to make your collections?*

Once every quarter	3%
Every month	11%
Every two weeks	16%
Once a week	35%
Multiple times a week (3-4)	19%
No response	5%
Not willing to travel at all	8%
On a need-by basis	3%

Question 11 asked "What does your current recycling process consist of?". A huge percent of respondents (92%) indicated that they were only limited to using MIT recycling bins in their offices or buildings which do not offer specialty recycling. This creates a very strong value proposition of a stockroom model if we are able to offer a specialty recycling option for hard to recycle commodities.

Current strategies	**Percent of respondents**
We use the MIT recycling bins in our office or building	92%
We have a separate process to recycle batteries	49%
We have a separate process to recycle toner cartridges	49%
We use MIT's special recycling locations for specialty items	49%
We currently have a DLC specific re-use & recycling strategy	8%

Question 12 asked "Do you currently use green shopping lists provided by your office supplier?" Through this question we wanted to get a sense whether people were actively purchasing products that were part of a sustainable, green, and eco-friendly office supplies product offering. The 22% of response of 'Yes' shows that a stockroom model with green product offerings could have an impact on the MIT campus. This question also shows that the people choosing not to purchase these sustainable, green, and eco-friendly

product offerings was not due to a lack of knowledge about them since only 5% of the respondents shared that they were unaware of these green lists.

Response	Percent of respondents
No	43%
Yes	22%
Not sure	16%
Sometimes	5%
These green lists do not meet our needs	5%
Unaware of the green lists	5%
Other	3%

Question 13 asked "Are you willing to spend more money on office supplies that are a part of this "preferred/green/eco-friendly" offering by a supplier? (If this meant that the products you now use have the smallest carbon footprint in the entire catalog)". This question helped us uncover an important finding that cost is not an issue for DLCs to purchase more sustainable product offerings – As seen in question 12 where only 22% of survey respondents said that they were actively using these "preferred/green/eco-friendly" offerings by the supplier. This was evident in the breakdown of responses for this question where 19% of survey respondents who were 'extremely likely' to spend more money on procuring these sustainable product offerings and another 54% of respondents said that they were 'somewhat likely' to do so. However additional research is needed to understand why 73% of the stakeholders have responded that cost is not an issue for them to make sustainable choices but only 22% of stakeholders are actually buying these green product offerings.

Response	Percent of respondents
Extremely unlikely	11%
Somewhat unlikely	0%
Neither likely or unlikely	16%

Somewhat likely	54%
Extremely likely	19%

Question 16: *Do you have any concerns with such a proposed model?*

Through this question we were trying to dig deeper into how the DLCs perceived the proposed closed-loop stockroom model. We wanted to make sure to provide them with a avenue where they could pro-actively raise concerns which could then be further analyzed and better improve the model. This question was left open-ended on purpose because we wanted to solicit any top of the mind concerns of the stakeholders and not silo them by asking feedback on any one aspect of the model.

While 48% of survey respondents shared that they did not have any particular concerns about the proposed model, there were a few important call-outs by the DLCs regarding the proposed process. The most important one being around liability concerns around carrying heavy items from the collection points by the DLC stakeholders.

According to one of the survey respondents "*Due to physical constraints and need for special accommodations, hauling office supplies is just not a feasible option. Liability concerns if someone gets injured while hauling back-office supplies."* The next biggest concern was around security and theft of high value electronics and other valuables that were dropped off at the collection points from the seller. This concern however would not be applicable to the scope of our project since this model is only being proposed for low-cost, high-volume office supplies.

A few survey respondents expressed concerns on how this model would cater to a DLC that spans across multiple buildings. This exact problem statement is the basis of section 3.4.4 '*Future scale-up opportunities at MIT (post-pilot)'* of this capstone where we have discussed the assignment of a designated DMC location to an MIT building which is within walking distance to any of the DLCs on campus.

One of the other survey participants expressed concerns on the future of such initiatives in a post-Covid work culture - *"This is a great initiative but it does not take into account our new hybrid/remote working*

system. Most of the department is hybrid/fully remote which makes it difficult to streamline a process for office supplies procurement."

A few survey respondents expressed concerns on their variable needs of office supplies and expressed concerns whether a 'one size fits all' would be the right solution for them - "*Some departments have very specific office supply needs, and it is unlikely that all of their needs can be accommodated in a vending machine model. Moreover, the SKU selection for the vending machine model is very important for its successful adoption. The heavier the items get; the less likely people are to use the vending machine for them."*

Over 30% of survey respondents expressed interest in speaking further with us (either in person or via zoom) to co-create a sustainable office supplies procurement process and engage further with the Center for Transportation & Logistics.

There were various comments left by the survey respondents that hinted towards their excitement for such an office supplies procurement design. One of the comments was "*While I'm sure a vending machine of office supplies won't carry everything that everyone wants, it could eliminate a measurable fraction of internet ordering and give immediate gratification of delivery/receipt. Also, amping up the 'hard to recycle' efforts at less well-attended DMCs will be very much appreciated."* Another survey respondents said "*I already visit 4 different DMCs on a weekly or fortnightly basis as my research groups sit in five different buildings. I'm sure that at least three of these rooms are large enough to support such a vending machine/'hard to recycle' center."* But one of the most notable recommendations made was regarding the creation of a donation/office supplies exchange marketplace which would increase re-use and repurposing on MIT campus "*We have so many unused supplies. How can we distribute them? And tons of paper that we won't need."*

4.3 Key take-aways from the engagement survey

Through these results of the engagement survey, we were able to collect insights into what people thought of the closed loop stockroom model for office supplies procurement and were able to gather key data point around certain operational parameter that would enable the stockroom model to success – such

as maximum distance of such a stockroom can be from any DLC and how frequently are people going to use it. The survey also gave the stakeholders an opportunity to voice concerns regarding such a model. The results of the survey form the basis of the discussion and conclusion section of this capstone.

5 DISCUSSION

One project goal was to find ways to link the forward flow and the reverse flow of office supplies on the MIT campus to encourage sustainable procurement and recycling actions. The research focused on a proposed stockroom model as a key enabler in making this link. We discuss the research results from engagement with the various campus stakeholders, study of various operational flows at MIT, and study of industry practices around consolidated fulfillment and vendor take-back strategies by describing the material, information and financial flows of the potential circular supply chain on campus. Seamless and standardized processes increase the likelihood of its adoption and reduce the need for exception handling.

5.1 Material Flow

The key stakeholders for the proposed stockroom model are suppliers like Vendor 1, campus customers (DLCs), and MIT Mailing Services as facilitator. The proposed model positions the MIT Mailing Services DMCs as office supply hubs by expanding their scope to include office supplies shipments, a 'hard to recycle' items collection point and an on-demand office supplies vending machine (subject to space constraints). These DMC locations are already being used for mail, magazines and small parcels. We are confident that the current network of active DMCs on campus (over 38 locations servicing all buildings on the MIT campus, see Section 3.4.4) will be able to service all MIT DLCs within a 5-minute walk from their building. Here is a view of the current state and future state of operations with respect to office supplies fulfillment on campus as illustrated in Figure 14 and Figure 15 respectively.

Figure 14: Current State of Office Supplies Fulfillment by Vendor 1 on Campus

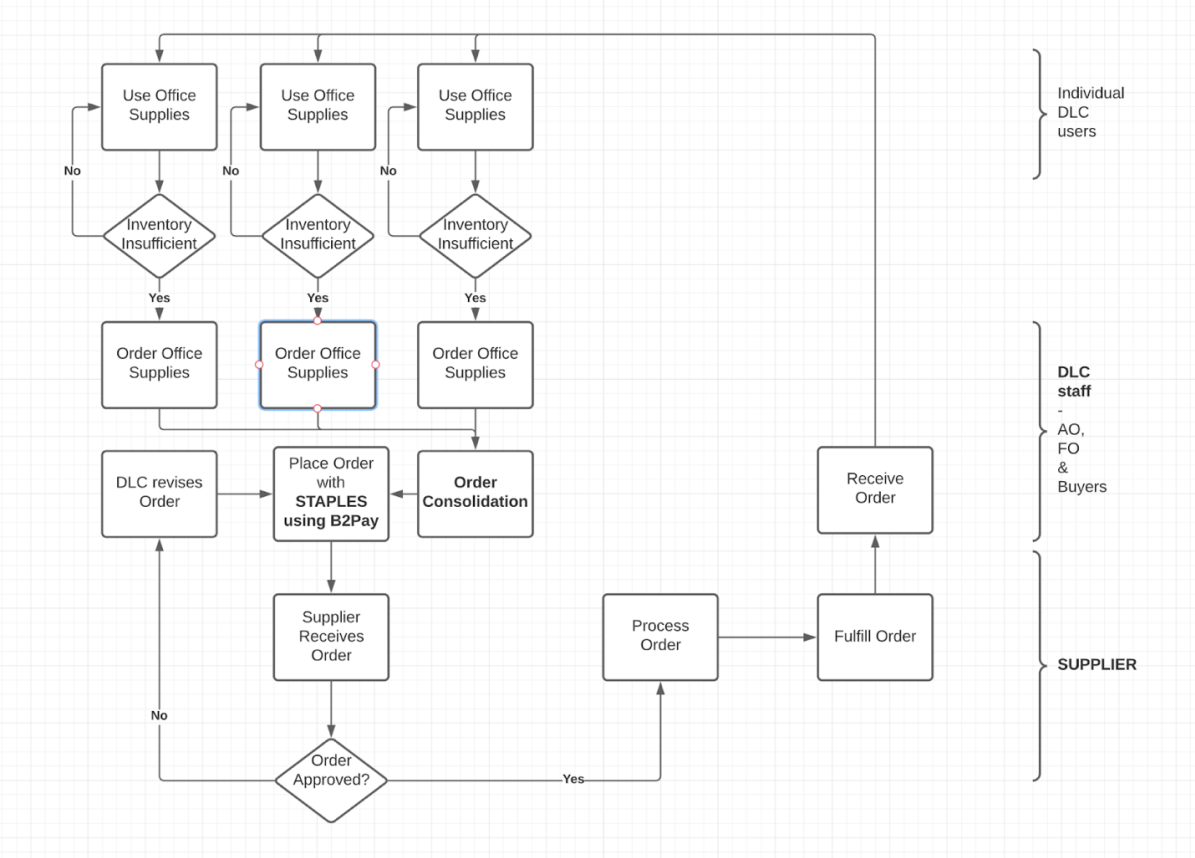
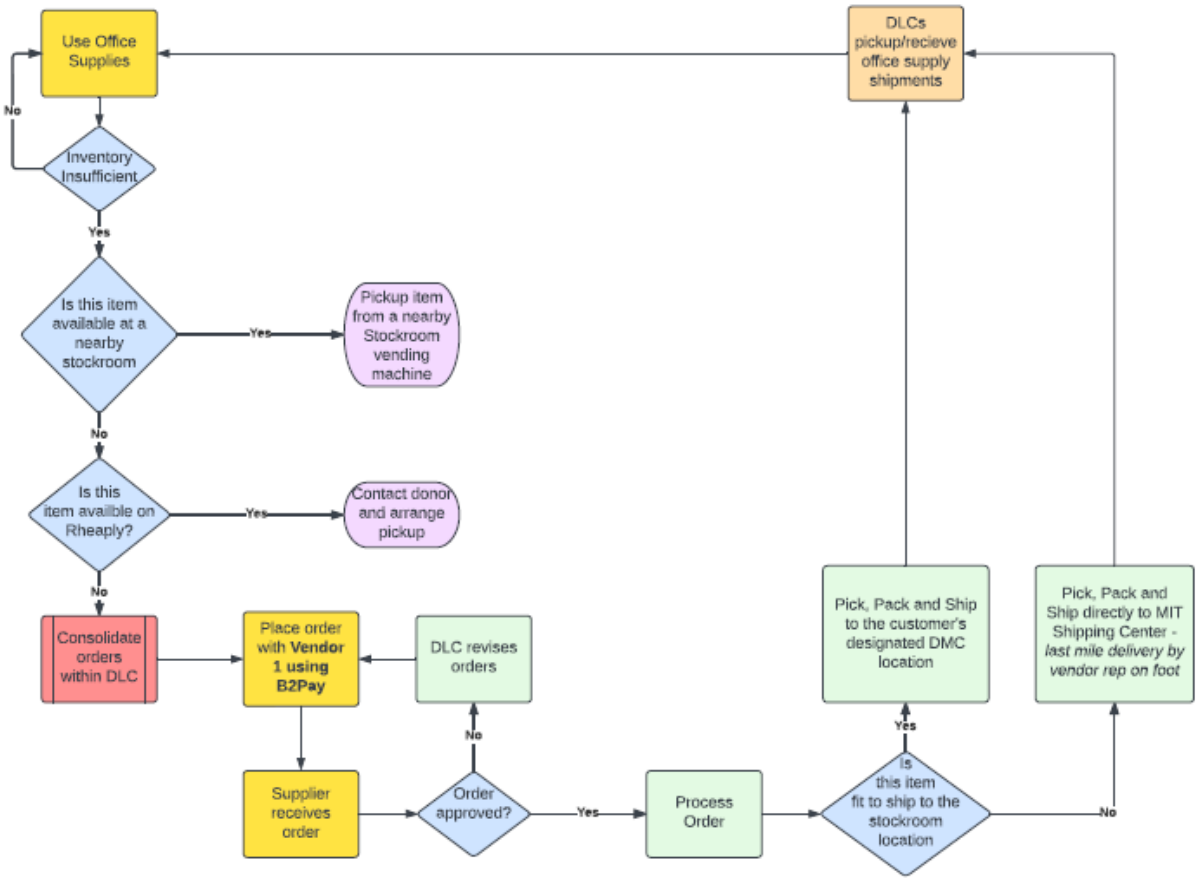


Figure 15: Future State of Office Supplies Fulfillment by Vendor 1 on Campus



This also aligns with the engagement survey results indicating over 41% of people are willing to walk up to 5 minutes to a pickup location to pick up office supply orders. Over 35% of survey respondents indicated that they are willing to pick up their orders once a week. In addition, over 41% of the respondents said that they were ‘Extremely Likely’ and 35% were ‘Somewhat likely’ to use DMC locations as a collection point for hard to recycle items.

The role of MIT Mailing Services is incredibly important because they are the strategic partners who have access to the DMC locations for inbound shipments and recycling vendors, which do not have similar access. MIT Mailing Services will need to establish a service level agreement with stakeholders in

regards to the cadence and frequency of office supplies shipment delivery. They will also need to create a service level agreement on how frequently they will collect items from the hard to recycle collection points in the DMC location. Mailing Services could coordinate with MIT custodial services to arrange pickups from open access, non-DMC locations while designating personnel and establishing a cadence to service restricted access DMC locations. We also found out via the survey and site visits that certain DMC locations already have a recycling bin for tech waste, toner cartridges and batteries but oftentimes they are overflowing and the DLC members are not sure of who to reach out to arrange a pickup. MIT Mailing Services can provide a service level agreement to the stand-alone service requests created via ATLAS to arrange pickups from these collection points.

Furthermore, section 3.3.5 dives deeper into the stockroom model, with a "vending machine" for certain office supplies, to be replenished at a weekly cadence, adapting the push inventory process for an "on demand" fulfillment option. Authorized personnel from the DLCs would be able to make payment (see financial flow section) and immediately pick-up their required supplies. The stockroom location (in this case it can be a DMC, a DLC or a shared space for multiple DLCs) with its hard-to recycling station will also act as a take-back consolidation point, where DLC representatives will be dropping off their recycling material. The goal is to have MIT Mailing Services, or a contracted service vendor, drop off office supplies shipments to the appropriate DMC location, collect take-back items for their return trip, restock the office supplies vending machine.

The engagement survey also indicated interest in a re-use and repurpose marketplace where DLCs could list excess office supply items for free use by another DLC member. MIT currently partners with Rheaply and has an asset exchange platform, which is a free-to-use marketplace and can be used to find takers of excess office supplies. (Massachusetts Institute of Technology, 2022). There can be challenges around scheduling and finding a meet up time for conducting these exchanges. The DMC locations could act as a drop off point for the intended customer as long as the shipment is clearly marked with the recipient's details. If established, the MIT Office of Sustainability and the Office of the Vice President for Finance

(VPF) would need to generate more awareness on campus about such services through brochures, information signage at strategic locations and website enhancements since survey respondents proposing the idea of a re-use platform seemed to be unaware of this resource.

One of the key decisions for the stockroom model is defining which SKUs to include in the model (for both shipment drop-off as well as the vending machine). In addition to DMC space constraints for shipments and potentially the vending machine, engagement survey respondents expressed concerns regarding liability and limitations in someone's ability to haul back heavy shipments dropped off at the stockroom location. The stockroom model needs to cater to SKUs that are easy to pick up and carry and are within the DMC space constraints.

There are also labor planning constraints that MIT Mailing Services must manage to support this initiative. They will need to schedule dedicated staff to collect and sort office supplies shipments meant for each stockroom location (these shipments will need to be addressed as such), walk to respective DMC locations to drop off these shipments, and haul back the recycling items to the shipping centers in the STATA and E19 buildings. They will also need to deal with space constraints in the two shipping centers since some hard to recycle items must be stored for their subsequent pickup by contracted recyclers, suppliers and original equipment manufacturers.

Lastly, MIT Mailing services will also need to revitalize their discussion and existing contracts with recycling vendors regarding the scope of items that can be collected and recycled. The current scope of ‘hard to recycle’ items include batteries, toner cartridges, tech waste, and excess packaging material. Mailing services will need to identify a list of designated recycling vendors who will be responsible to pick up each of those categories. In some cases, such as toner cartridges and packaging materials, the collection could be conducted by the original equipment manufacturer and the vendor/supplier respectively.

5.2 Information Flow

The flow of information in the critical path of this process as well as the stakeholders is very crucial for the process to work seamlessly. This information flow backbone would be associated with the fulfillment operations and the associated demand signals. One key requirement is a way to distinguish which items are meant for which stockroom location for MIT Mailing Services delivery and which are delivered directly to individual DLCs by the Vendor 1 personnel on premise via a hand truck. Vendor 1 and/or MIT Mailing Services must also inform the DLCs that their designated shipments are available at the DMC pickup location. They can do this via a delivery notification (email or SMS) or via an online tracking platform. This will allow the customers to plan their trip to collect these items.

The flow of information is required both on the fulfillment side as well as the take-back flow of material. On one hand the weekly consumption rate of the inventory in the stockroom needs to be monitored and relayed back to Vendor 1 and the MIT shipping centers. This can be done either via sensors to track the available inventory at given point of time or via a weekly cycle count of the available inventory on hand by MIT mailing services. This will allow both Vendor 1 and MIT Mailing Services to come up with a weekly replenishment schedule for all the material stocked in the vending machine. This will allow them to maintain a decent service level and reduce the instances when a customer walks to the DMC location to buy something from the vending machines only to find that the item is out of stock. Additionally, all OEMs supporting takeback schemes of toner cartridges have a specific set of specification on how to package the cartridges and documentation of information (printer registration, toner cartridge lot number) while preparing the shipment to be sent back to them. This information needs to accurately flow back and forth between the DLCs and the OEMs.

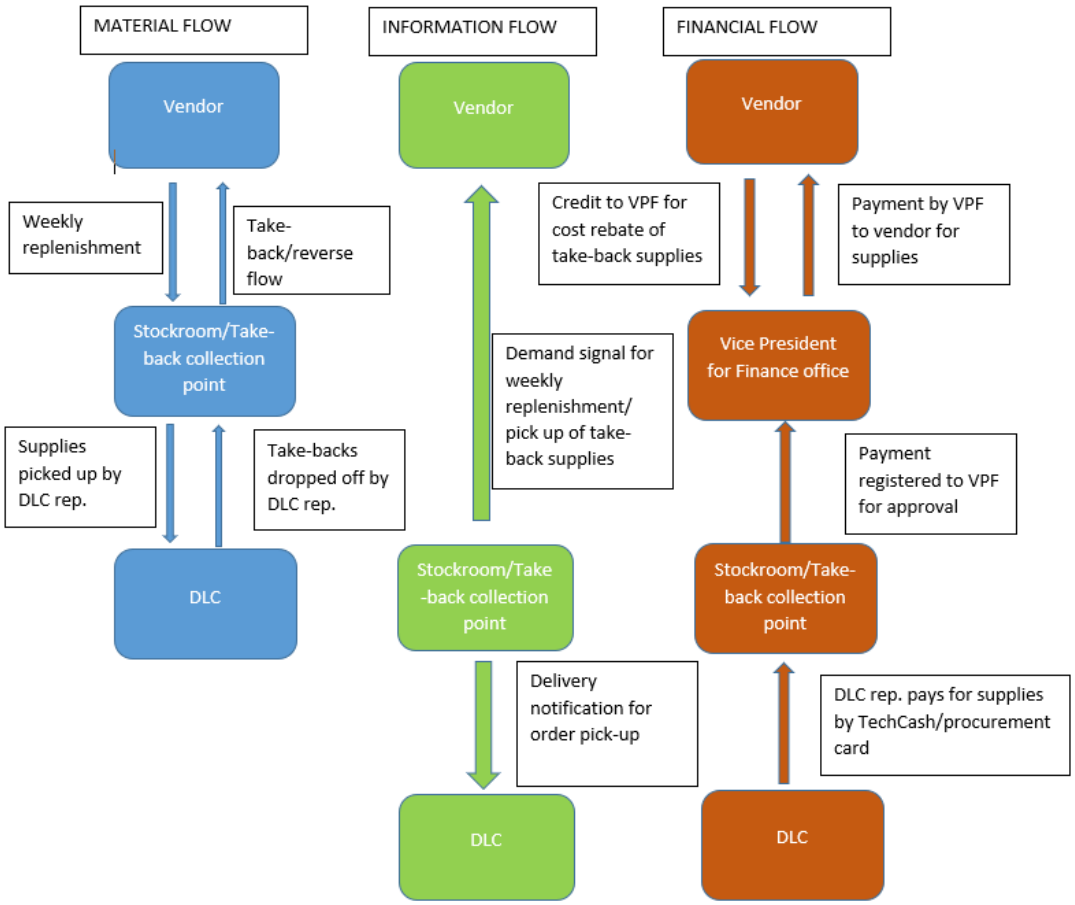
5.3 Financial Flow

The most crucial enabler for the office supply options is the financial flow between MIT DLCs and the respective vendors. For purchases online, there are no changes expected for DLC payment (e.g., through

the B2P system/Coupa). For any purchases made at the DMC vending machine, the DLC representative will be able to use MIT procurement cards or TechCASH to purchase the necessary office supplies.

MIT can also expect cost rebates from the original equipment manufacturers and office supplies vendors who offer to take-back toner cartridges and packaging material from campus. The VPF office can then negotiate the terms of this contract and request a future purchase credit or a one-time monthly/annual reimbursement. In the current scope of the project, we have not analyzed how this cost rebate can flow back to individual DLCs. But once the process is implemented, this topic can be explored to incentivize DLCs to actively recycle. Figure 16 highlights the various Material, Information and Financial flows for the proposed system.

Figure 166: Material, Information and Financial Flow for the Proposed System



6 CONCLUSIONS

Through this project we have made an attempt to co-create a solution with MIT stakeholders which would enable DLCs to procure office supplies in a more sustainable manner. MIT's new climate action plan has reiterated the focus on making meaningful contributions to decarbonizing the global economy by reducing MIT's own climate impact. It has shifted the focus on optimizing operational efforts to maximize impact in this initiative, foster collaboration and strive towards a speedy adoption which enhances the likelihood of success in this process.

The engagement survey conducted as a part of this project has clearly indicated the synergy between MIT's overall outlook on sustainability and the willingness of stakeholders on campus to make choices that aligns with this climate action plan. Over 65% of the people participating in the survey said that the subject of sustainability was 'very important' to them and another 33% shared that it was 'somewhat important'. 38% of the people were not only confident in their ability to make sustainable choices but also consistently looking for new ways to participate, collaborate and execute new sustainable solutions. What stood out the most to us that a 73% of the people were willing to spend more money on office supplies that were a part of this "preferred/green/eco-friendly" offering (and more expensive than a regular substitute). This number can be broken down into 54% as 'somewhat likely' to do so and another 19% as 'extremely likely'. These results clearly indicated that stakeholders from various departments, labs and centers at MIT deeply cared about the environment but also were willing to make changes to their existing processes and purchasing behaviors and make more sustainable choices. On the other hand certain DLC stakeholders expressed concerns around the liability issues of carrying bulky items across campus and the limited accessibility to people with varied abilities to participate in this process. This creates a lot of focus on the selective SKU that can be used as a part of the stockroom program which not only have a high consumption rate but also are small in size and easy to carry around.

In our proposed model through this capstone, we have attempted to repurpose existing infrastructure at MIT, expand its operational capabilities and leverage it to meet the climate action initiatives on campus. The climate action plan highlights the importance of "building greater resilience into all of our activities, infrastructure, and systems" and through this proposed model we are trying to maximize the existing capabilities of our infrastructure and make it serve the institute's broader climate mission. The proposed model also shows promise in terms of its likelihood of its adoption as demonstrated by the respondents in their survey responses. People are not only willing to make multiple trips to the stockroom location but also walk longer and make changes to their existing purchasing behavior. There are obvious challenges around the type of SKUs that can be fulfilled via the stockroom since heavy items will present

a challenge in one's ability to haul them back to their desks. But this solution could be a viable alternative to procure low weight, high volume SKUs that stakeholders are currently getting delivered to their individual desks. The proposed solution not only reduces the packaging waste around unitizing individual shipments but also consolidates packages for their last mile delivery.

The proposed model also presents a unique opportunity for MIT Mailing Services to start collecting data from their operational involvement in this process. During our research we found that although stakeholders on campus are participating in a variety of recycling processes (either through MIT or having their own recycling strategy), there was no available data around the total number of toner cartridges, batteries and pounds of tech waste and packaging material currently being recycled out of MIT. MIT Mailing services involvement in this process can not only consolidate the operational side of this activity but gives them the ability to identify the volume of each type of recycling material coming out of each collection point. There is also an opportunity to use sensors at the collection points that will enable the MIT Office of Sustainability to collect exact data on the volume of recycling happening at these stockroom locations. They can also identify reduction in the total number of individual deliveries made on campus per day by adopting the stockroom model and conduct a comparative analysis of service level tradeoffs between direct fulfillment and fulfillment via MIT stockrooms. They can further their data collection initiative with their strategic recycling partners on campus, to identify the total volume being hauled back by them from MIT monthly and use this as a strategic lever in future contract negotiations.

At the end of this capstone project, we would like to make recommendations to the MIT Center for Transportation and Logistics, Office of Sustainability and the Vice President's Office for Finance to make collective efforts towards piloting this initiative in the E38 building. During our project scoping we found this location to be ideal in terms of its size, location and serviceability to a diverse group of DLCs on MIT campus. In order to make this pilot successful it will be very important for MIT-OS and VPF to consolidate information on this initiative under the same umbrella as their other sustainability initiative and make the messaging consistent across all online and offline platforms. Creating detailed information signage on the

office supplies recycling station will also educate stakeholders on how to correctly recycle items and ensure that the streams do not contaminate.

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APPENDICES

Appendix A: Engagement Survey

Here is a link to the engagement survey that was sent out to the stakeholders at MIT affiliated with different departments, labs and centers - https://mit.co1.qualtrics.com/jfe/form/SV_a3jz9ddZMPZwxHU

A detailed breakdown of all questions and their responses can also be found in the Result and Analysis section of this capstone project.

Appendix B: List of survey respondents

Below is a list of the various administrative positions of stakeholders (involved in the office supplies procurement process) who responded to our MIT Office of Sustainability - Sustainable office supplies engagement survey: Table 7 and Table 8 presents an exhaustive list of the survey participants categorized by their job title the participating DLCs.

Table 7: List of Survey Respondents Job Title

Participating Stakeholder Job Title	**Number of survey participants**
Academic Administrator	2
Administrative Assistant	17
Administrative Officer	5
Assistant Director	1
Associate Director of Finance and Operations	1
Executive Director	1
Facilities Administrator	1
Finance Officer	1
Lab Manager	1
Manager	1
Manager, Finance and Administration	1
Operations Administrator	1
Program Coordinator	1
Research Support Associate	1
Senior Administrative Assistant	1
Sr. Staff Associate	1

Table 8: Departments/Schools/Labs or Centers that Participated in the Engagement Survey

Department/Lab/Center	Participants
Center for Environmental Health Sciences	1
Center for International Studies	1
Center for Transportation and Logistics	3
Department of Biological Engineering	2
Department of Chemistry	2
Department of Electrical Engineering and Computer Science	1
Department of Material Science and Engineering	1
Department of Mechanical Engineering	1
Department of Nuclear Science and Engineering	2
Institute for Soldier Nanotechnologies	1
Jameel Poverty Action Lab	1
Kavli Institute for Astrophysics and Space Research	2
Laboratory for Information and Decision Systems	1
McGovern Institute	2
Microsystems Technology Lab	1
MIT AeroAstro	1
MIT Chancellor's Office	1
MIT Comparative Media Studies/Writing	1
MIT Libraries	1
MIT Museum	1
MIT Office of Innovation	1
MIT Office of the First Year	1
MIT Sea Grant	1
Office of Sustainability	2
Picower Institute for Learning and Memory	1
Research Laboratory of Electronics	1
Resource Development/Development Planning and Initiative Office	1
Sloan School of Management - Master of Finance	1

Appendix C: Additional survey questions

Here are some of the additional questions asked in the engagement survey but there were no significant results to report based on the survey responses.

Question 14: *How likely are you to change vendors if they offered a more sustainable product offering, consolidated fulfillment, had a robust "take-back" strategy and made it easier for you to recycle?*

Response	**Percent of respondents**
Extremely unlikely	11%
Somewhat unlikely	0%
Neither likely or unlikely	16%
Somewhat likely	38%
Extremely likely	35%

Question 15: *Are you willing to pay a sustainability fee per month which would allow the hiring of temporary staff (who can deliver these office supplies from the stockroom to your DLC location for urgent needs) and further improve sustainability initiatives at MIT?*

Response	**Percent of respondents**
Yes	8%
No	16%
Maybe	24%
This decision is above my pay grade	51%

Appendix D: Top 50 SKUs procured at MIT for FYs 2019-2020

Vendor 1 Item #/SKU	Eco Attributes	Description
320863	N	PURELL ORGNL HD SNTZR8OZ
826830	Y	TISSUE FACIAL BOUTIQ 6/PK
492072	Y	30% REC COPY PAPER
713140	N	POLAND SPRNG WATER .5L 24/CASE
831882	N	BLUE BOOK
607942	N	PURELL ALOE HD SNTZR 12OZ
826277	N	BOOK EXAM 8.5X7 BLUE 1000/CART
831884	N	EXAMINATION BLUE BOOK
369657	N	CLOROX WIPES VALUE PK 3/35CT
122374	Y	COPYPLUS 8.5X11 COPY CS
752602	Y	KLEENEX ANTIVIRAL 3PK
701799	N	RECY EXAM BOOK 11X8.5 8CT 16PG
501890	N	CHALK ASST
478405	Y	CUP HOT PERFECT TOUCH 12OZ
346361	N	ELMER S SCHOOL GLUE 4OZ EACH
344887	N	MINIMOOS 1/2 AND 1/2 CREAMER
749565	Y	BAGASSE 9X6 NOTEBOOK
707196	N	KCUP GM BRKFST BLND 24CT
125328	Y	SHARPIE FINE PERM BLACK 12/DZ
479074	N	PROCELL AAA CELL BATTERY
324027	N	MORNING HARVEST OATMEAL W/TOP
479067	N	PROCELL AA CELL BATTERY
708552	N	BATTERY AA INDUSTRIAL
202648	N	SOFTSOAP HND SOAP ALOE 7.5OZ
468389	N	DUCT TAPE 48MMX55M
634797	N	DRY ERASE ERASER
616321	N	CLOROX DSNFCT WIPE 75CT LMNFRS
406231	Y	HAMMERMILL LASER CASE
163865	N	STPLS PAD PERF LTR WH 12PK
811662	N	HORIZONTAL NAME BADGE HLDR CLR
234377	Y	HAMMERMILL LASER PRINT 8.5X11
533786	Y	COPY PAPER 3 HOLE 20# 8.5X11
470743	N	COFFEEMATE CREAMER 50CT
420565	N	CHICKEN FLAVOR NOODLE SOUP
888937	N	CW LD 8MIC 30GAL WHT CT/500
700937	Y	DISH LIQUID FREE & CLEAR 25 OZ
135855	N	8.5X11 COPY RM

123372	N	BIC ROUND STIC MED BLK DZ
513096	Y	8.5X11 MULTIUSE 20/96 CS
429174	Y	PILOT G2 RET FINE BLACK 12
272153	N	EXPO ERASER EA
130674	N	BLACK TAPE DISPENSER
887844	Y	LUNCHEON NAPKINS 400SHTS WHITE
707198	N	KCUP GM DK MAGIC BOLD 24CT
470745	Y	KLEENEX FACIAL TISSUES
703594	N	CHALK
752287	Y	SCOTT M-FOLD TOWELS
564482	N	PALMOLIVE ORIG DETERGENT-28OZ
502054	Y	MARKER DRY ERASE CH EXPO 4/AST