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Technical Association of the Graphic Arts

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Toronto is in the ‘Dish With One Spoon Territory’. The Dish With One Spoon is a treaty between the Anishinaabe, Mississaugas and Haudenosaunee that bound them to share the territory and protect the land. Subsequent Indigenous Nations and peoples, Europeans and all newcomers have been invited into this treaty in the spirit of peace, friendship and respect.

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"He that plants trees, loves others besides himself."

- Collected by Thomas Fuller, 1732

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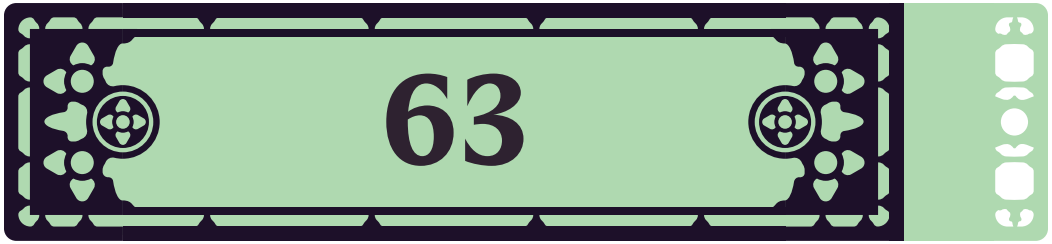
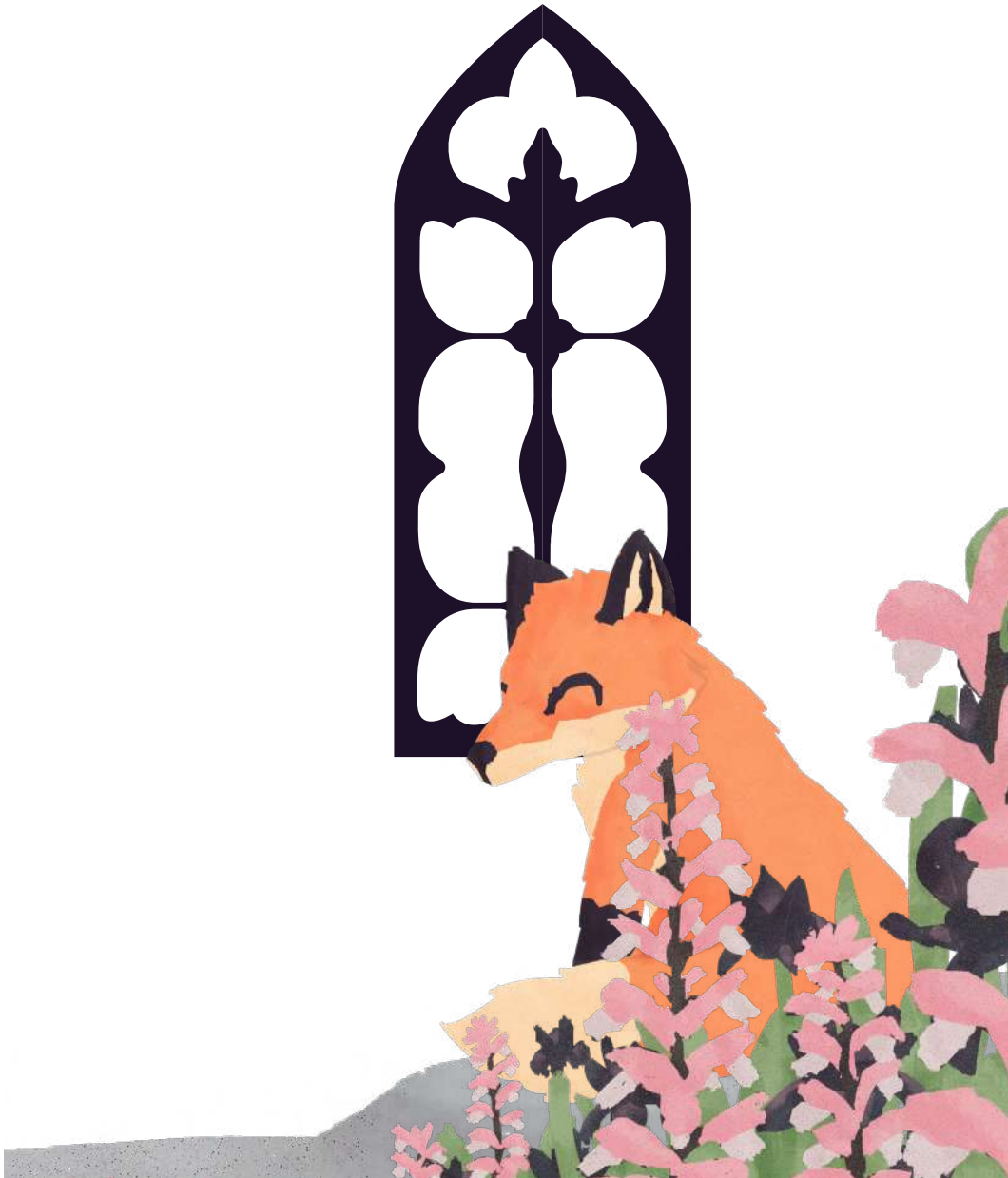
THESIS PAPERS





A LETTER FROM
Our Faculty Advisors

Dr. Krzysztof Krystosiak
(He/Him)

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Dr. Krzysztof (Kris) Krystosiak
Professor
Advisor of TMUTAGA

A LETTER FROM
Our President

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Aliyah Jaffer
(She/Her)

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Aliyah Jaffer
President of TMUTAGA

OUR INSPIRATION

An Introduction to the Theme

TMUTAGA as a student group has traditionally focused on the future, however in a day and age where human creation is more valuable than ever, we decided this year to look to the past. Specifically, we focused on when book arts and design was blossoming during the initial industrial revolutions.

The student papers this year all have a common theme: human creation and technology to make our lives, and the earth as a whole a more personable, sustainable, and kind experience. The future of print is not about technological advancement for 'progress,' rather the technological advancement to serve and unite people in order to help each other grow together—to cultivate a garden of knowledge.

This year's theme is nicknamed "Solarpunk," after a speculative earth of entirely green energy and renewable resources. Our interpretation looks to the past, to the days where natural wonder was seen as a gift above all else, and technology is there to support it.

***Sarib Nazir** | He/Him*

Sarib Nazir is a graphic designer based in Whitby, ON. He holds a degree in Graphic Communications Management from TMU with a minor in Communication Design and specialization in Digital Graphic Output. Currently, he is pursuing a role as a graphic designer for Oliver's Labels, a Toronto-based vinyl label company. He has worked on label and decal products for established intellectual properties such as the NHL and NBA, giving him further insight into the importance of colour management and placement of typographic elements. Sarib is excited to grow as an inclusive designer and further incorporate his passions into his day job and personal work.

ENHANCING PERSONALIZATION IN WIDE FORMAT PRINTING THROUGH AUTOMATED WORKFLOWS:

A COMPARATIVE ANALYSIS OF STICKER BUILDER AND ADOBE ACTIONS

ACKNOWLEDGEMENTS

I would like to extend my appreciation towards the advisor of this thesis, Dr. Abhay Sharma, for both his support and the demonstration of the Sticker Builder software at GCM Awards Night 2024, which inspired me to tackle this research topic. I would also like to thank Dr. Krzysztof (Kris) Krystosiak, who guided my peers and myself towards the completion of this capstone course. Additionally, the support of Darsan Sivanantharajah, the client support technician at GCM, was greatly appreciated in order to utilize the wide format printer located in Heidelberg Centre. Lastly, I want to deeply thank my friends and family for their endless support and encouragement throughout not only this semester but for my entire undergraduate career.

ABSTRACT

The printing industry has seen a shift in increasing personalized print with workflow automation software working in tandem with printers to support mass personalization and customization. Die-cut stickers, labels, and decals benefit from this change, delivering cost-effective marketing for businesses. This research examines the automated workflow presented by Sticker Builder, a print customizer tool allowing users to upload any given raster or vector file to produce a sticker sheet, and how that contrasts with a workflow made using the actions panel in Adobe Photoshop and Illustrator producing the same products. Through rigorous comparison, the research aims to answer how automated workflows catered towards wide format printers enhance the personalization of vinyl prints. Five raster images were selected to test the efficacy of both approaches, with the results being evaluated using three metrics: the efficacy of the dieline generated, background removal of the original raster, and size of the individual sticker within the sheets. Smoother dielines, higher-resolution artwork, and more sheet optimization were discovered in the Sticker Builder generated sheets compared to Adobe's outputs. For some rasters, the

latter provided more pleasing results, showcasing the limitations of Sticker Builder. Still, this research finds a positive impact on the personalization of vinyl prints gained through the use of this print customizer tool.

INTRODUCTION

Print and personalization have been intertwined for the better part of the last decade. With the convergence of variable-data printing, printers can support mass personalization for various clients without the caveat of individually designing and producing one's printed piece. This is exacerbated by a growing demand for flexible solutions which cater towards high and low volume personalized print runs creating further growth opportunities for commercial printers (Houch, 2024). Labels, die-cut stickers, and decals benefit from this due to their importance in reinforcing brand recognition for businesses (Kwik Kopy Australia Pty Ltd, 2023). Among sustainable efforts, the latest trend in wide format printing points towards increasing usage of workflow automation solutions to fasten production times and reduce human error (Print ePS, 2025). Figure 1 shows the manual workflow for preparing, printing, and cutting vinyl prints for wide format printing, a human-intensive process that accounts for a large amount of overhead costs for fulfilment departments (Joshi, 2006).

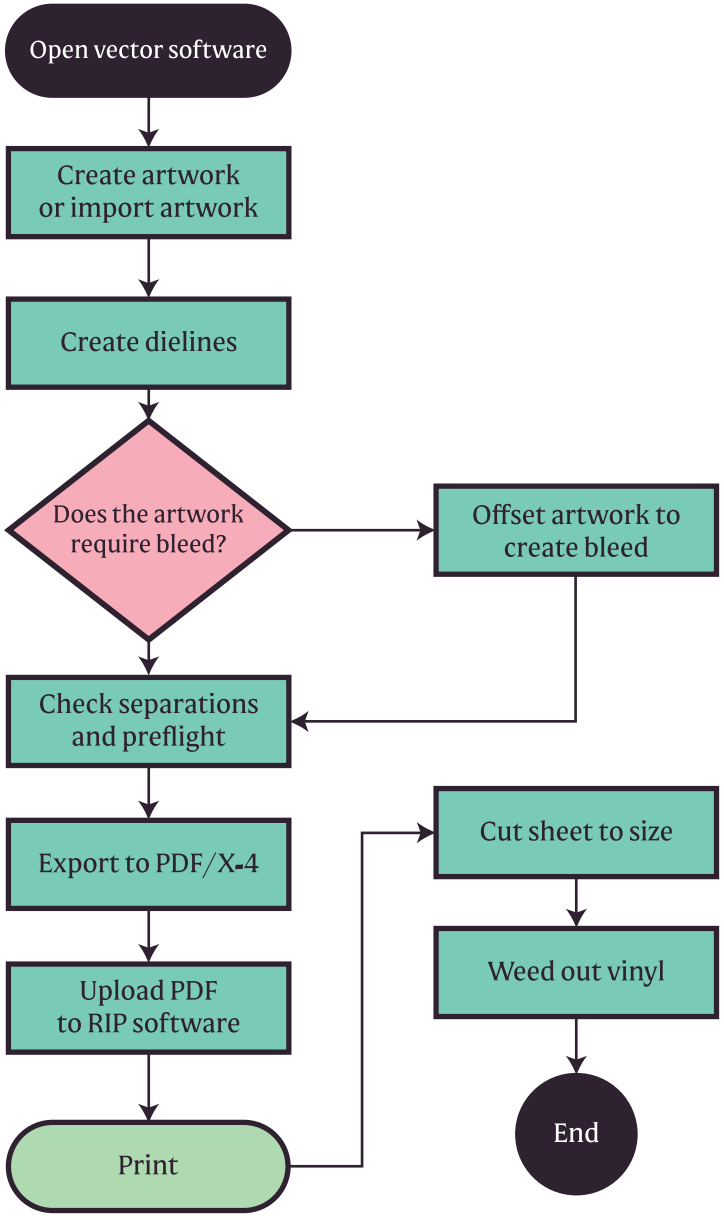

Figure 1: Current Prepress and Production Workflow for Vinyl Printing on a Wide Format Printer

Using the Actions panel in Adobe Creative Suite can help expedite this process without the use of workflow automation software. This panel allows the user to play a series of tasks including but not limited to–menu commands, panel options, and tool actions–on a single file or batch of files (Adobe, 2023). For example, an Adobe Photoshop action can be played to resize an image, apply a vignette effect, and save the file in the desired format. Actions can be edited, recorded, and customized willingly to suit the user's end goal. This thesis will examine a workflow created for producing vinyl prints using the actions panel and how it juxtaposes a fully automated workflow accomplishing the same tasks. Through the use of Sticker Builder by Antigro Designer, this research will focus on how automated workflows catered toward wide format printers can enhance the personalization of vinyl prints. Die-cut stickers and decals contain varying cut lines which Sticker Builder can recognize and apply a dieline without manual intervention. The efficacy of this dieline generation alongside automated background removal will be evaluated to determine how personalization for end users is impacted.

LITERATURE REVIEW

Wide Format Printing: Opportunities for Growth

Customization of vinyl prints lends itself incredibly well to wide format printers due to the ganging and nesting of multiple jobs on the large width of the roll substrate. The maximized nature of imposition on wide format printing results in shorter runs and faster turnaround times (Marx, 2015). As the prepress workflow is still undergoing change and optimization, Wide-Format Report (2012) proposes the wide format printer of the future will not only deliver products faster, but update customers where the product is in its production cycle. Many products printed on wide format inkjet have become commodities, which means margins are not as high. However, a template-driven storefront approach is ideal as customers perform the minimal amount of prepress and preflighting needed for their files. The rest should flow smoothly since the templates are optimized for the equipment and workflow (Romano, 2015). Wide format printing is celebrated for how many substrates it can support and although the purpose of this review is focused on vinyl, it is important to discuss how beneficial this versatility is for commercial printing. Window graphics are an important medium which wide format printers can take advantage of and draw viewers into a store with an eye-catching design. This is tied to the further development and trend of personalized print products, with wide format being touted as the tool to meet this growing demand and offer higher-margin and unique one-off offerings (McQuilken, 2022).

Job Definition Format (JDF), Integration, and In-Picture Personalization

Harvey (2014) explores how the introduction of JDF 1.5 has been significant for wide format printing. Previously, JDF supported ganging but was limited to a single job or iterations of jobs from one customer. The new process takes in the press-ready PDF, customer information, job identification, substrate information and provides intermediate stripping information to the print management information system (MIS) regarding costs and billing. Its limited integration with web-to-print is problematic for the purposes of this review, as JDF process data is very detailed to pass through web-to-print systems effectively. Daming (2003) provides a solution for improving efficiency for the production of digitally printed labels. By combining digital inkjet and laser finishing, companies can satisfy the needs of label converters and remove their existing investment in off-line technology. The lack of specificity towards wide format is a hindrance but the notion of being able to print and cut vinyl substrates in a single pass automatically is indicative of growth within the market. De Schamphelaere (n.d)'s article covers in-picture personalization, which is a photorealistic implementation of personalized elements within an image in a digital printing workflow. The benefit presented is increased attention received from the viewer by the printed material. Having the correct personalization further amplifies the emotional link between piece and person. This article confirms how important personalization is for customers and businesses alike in a printed piece, however the lack of specificity to wide format printing limits its usage for further research. In contrast, From Ideas to Adhesives' (2024) article goes beyond the emotional

link benefit and specifies how personalized vinyl stickers can be used to advertise one's brand. Unconventional shapes attract more viewers and the durability of the adhesive vinyl material ensures they last longer than other promotional materials such as flyers and direct mail.

Defining Web-to-Print and Evaluating its Efficacy

Web-to-print/Web-2-print is e-commerce for print, allowing customers to upload artwork onto an online storefront and have printers preflight, produce, and ship orders straight to their doorstep. If implemented successfully, it improves efficiency for printing and order processing on the customer end. Marx (2022) praises the efficacy of web-to-print as an automation tool as "it's [only] a click and it's off [the customers'] desk". By handling preflighting, quality control, and imposition, the web-to-print model has eliminated many touch points and builds an increasingly important partnership with clientele. The customer is not just purchasing a print, they are delegating the management of their visual assets to the printer. Adwiya (2022) covers a scenario where adopting web-to-print can result in discrepancies for order placement. There is often a difference between the order data and the amount of financial statements needed to track and organize said data, because of the high traffic imposed onto the web-to-print model. From Hsieh & Lin (2011)'s study, the most successful web-to-print providers such as VistaPrint and Kodak Gallery necessitate the importance of online personal photo/graphic editing software as a service to customers and then allow them to place an order immediately after editing is finished. The data sent to VistaPrint or Kodak will take in the

customer's artwork, apply cutlines and impose it to their desired needs. Coupled with a user-friendly interface and simplified transaction processing, market acceptance has grown exponentially into its current state. Smith (2011) states how every facet of VistaPrint's workflow is automated, removing the need for any tangible human interaction between the customer and company. Hsu & Rancourt (2020) outline VistaPrint's model (Figure 2) where online orders are aggregated through a system which automatically sorts and plans production based on similar design attributes.

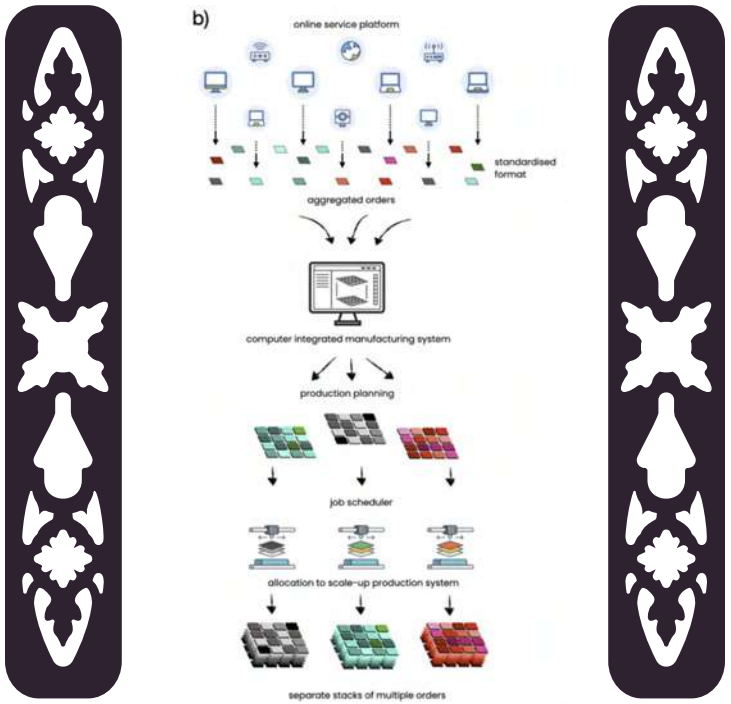

Figure 2: VistaPrint aggregate model for production

This works in favour of VistaPrint because they deal with products such as business cards and decals with simple personalization options such as typography and background colour choice. Ironically, the limitation of personalization and choice to customers is what has benefited VistaPrint's current model.

Challenges of Standardization for Web-to-Print

Gehman (2008) discusses how the challenge for most web-to-print applications is job submission. As customers can submit a multitude of jobs for production, many applications have trouble efficiently handling a variety of file formats, standardizing them and bringing them into the production workflow. Dewitz (2007) breaks down how web-to-print applications can be standardized by offering three levels of services to customers; order catalogued products with templatized customization, order catalogued products with design/content customization, and order catalogued products with complete customization. These levels are iterative, with the last offering no constraints for design or content to the customer. Both literature help explain how web-to-print models can facilitate personalization despite the issues that may take place. To remedy this, narrowing accepted file formats for online storefronts is beneficial. As this review pertains to vinyl prints such as labels, stickers, and decals, limiting file formats to SVG and PDF submissions could greatly increase the efficiency of these models. Singhal et al. (2020) proposed a cloud-based workflow solution titled "PrettyPrint" to achieve greater standardization for web-to-print models and reduce costly business operations for small and large scale print providers alike. In this workflow, the small scale print provider completes

prepress operations and uploads the job to a portal or online storefront, wherein it will be automatically tagged to a large scale print provider. The selection of the tag will be based on the shortest time to complete the job. Although this model leverages automation to optimize resource utilization and promote greater connection between smaller print shops, the lack of discussion on how it will impact personalization for customers leaves a gap that needs to be addressed for further research.

Industry 4.0 and Mass Customization

Despite its trending nature, mass customization is prone to limitations such as customers not entirely participating in the design process, combinations being predetermined by the designers, and the inability to provide personalized goods and services. Industry 4.0 is an all-encompassing term relevant to all manufacturing industries. It will enable companies to increasingly produce customized products with shorter run-times and lower costs than those associated with standardization and mass personalization (Wang et al., 2017). This is not specific to the printing industry, but the potential Industry 4.0 serves is tangential to the adoption of web-to-print workflows used by many commercial printers, where customer agency and choice are prioritized to deliver an enhanced and personalized product. König (2013) covers how mass customization and web-to-print models work in tandem with each other. Gang run printing nests various customers' jobs on a single roll or press sheet and requires standardization. This is easier to achieve in a web-to-print environment as it is not organized for piece production like a traditional printer is. Figure 3 shows the differences

in each respective workflow and how time-consuming the "job shop production" process is compared to a web-to-print online infrastructure.

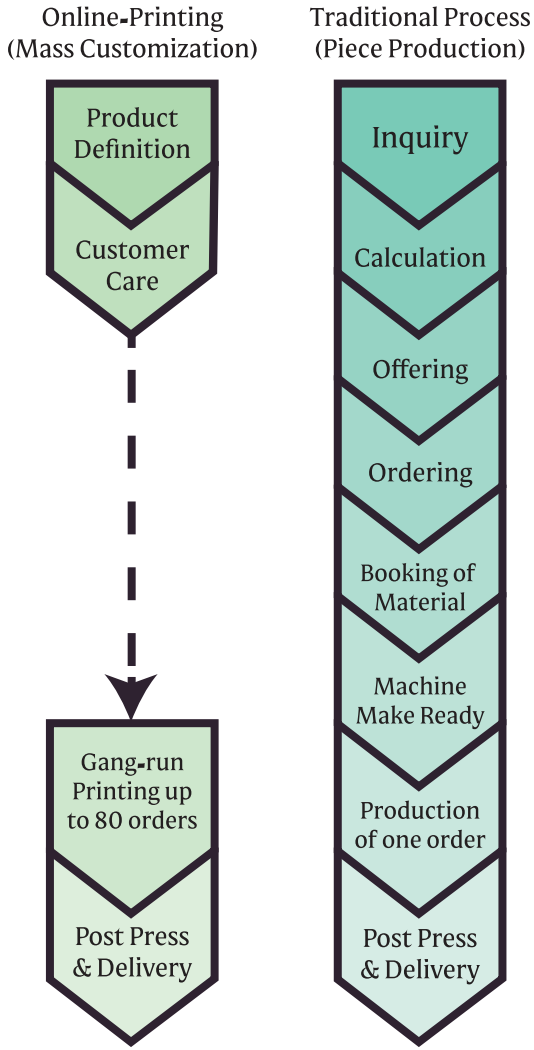

Figure 3: Job Shop Production vs. Online-Printing

Mejtoft (2011)'s study discusses the benefit gained from customized print products for customer relationships for a business to consumer (B2C) commercial printer. The paper demonstrates how to utilize information in customized printing via data mining of customer data, use of pre-stored data in customization depending on a customer's order and user input of data in the production. A gap found within this article is how businesses can possibly adopt this data for an automated workflow catered towards on-demand printing.

METHODOLOGY

Research will be conducted using a qualitative method approach. This was chosen because the research question necessitates further understanding of the phenomena between automated workflows for wide format printing and personalization. The main method of data collection will be done through a comparative analysis between Adobe Creative Suite and Sticker Builder. The same rasters will be used across Sticker Builder and Adobe Creative Suite to generate a 6-up sticker sheet, wherein they will be evaluated through parameters that will be later specified.

Apparatus for Data Collection

The Roland TrueVIS VG3-540 will be utilized to print on white adhesive vinyl roll. This wide format printer supports a portion of the expanded gamut with orange and green, and has an intuitive touch screen interface to track job progress. Roland VersaWorks raster image processor (RIP) software will be where final adjustments to the job are made such as print quality, colour management, and cutting options. Adobe Creative Suite will be used to

prepare job-ready PDFs, with Adobe Photoshop being the primary tool for generating artwork, Adobe Illustrator for imposition and dieline placement, and Adobe Acrobat to verify process and spot colour separations. These applications will work in tandem with each other to create a semi-automated workflow to prepare sticker sheets for printing. Sticker Builder by Antigro Designer will be vital for the gathering of primary data. This is a print customizer tool to support and enhance the creation of every product demanding intricate cut-outs through its automatic outline and dieline generation (Antigro Designer, n.d). The sticker sheets generated by this software will be ganged and nested alongside the Adobe Actions generated sheets to print on the Roland TrueVIS.

Sticker Builder Workflow

Users are able to upload a raster or vector under 50 megabytes of their choice, select how much of the background they want removed and the amount of offset for the dieline around the artwork - the software contains three options; tight, medium, and loose (see Figure 5a for comparison).

Optionally, the user can select the background colour of the offset as seen in Figure 5b, adjust the brightness, contrast, and saturation to their liking, adjust the dimensions, rotate, and mirror the image. Preset hue filters can also be applied to the artwork. After the user is satisfied with their personalized sticker, they can submit the design and the tool will proceed with background removal, dieline generation using the specified preset, and any other visual alterations explained previously. It is then imposed 6-up on a 9 x 4.35" sheet with a perforated box (measuring 8.64 x 4.24") around the stickers and the user's name right-aligned. The print-ready PDF

appears as seen in Figure 6, and is received in Dr. Sharma's Dropbox. Then, it is placed in a hot folder which automatically adds it to one of the queues in VersaWorks, where the user can modify any settings needed before printing. Access to the Dropbox folder and Sticker Builder will be granted to evaluate the efficacy of the software as an automated workflow for printing on vinyl substrates.

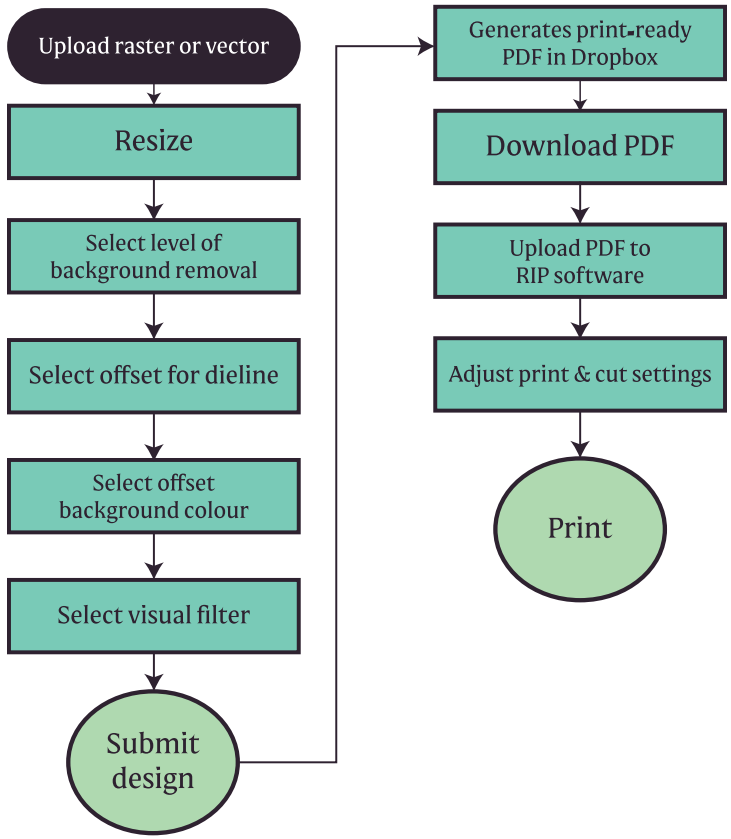

Figure 4: Sticker Builder Workflow

Figure 5a) Tight vs. medium vs. loose cutline precision

Figure 5b) White (#FFFFFF) vs. Pink (#FFCCCC) offset background and yellow hue filter

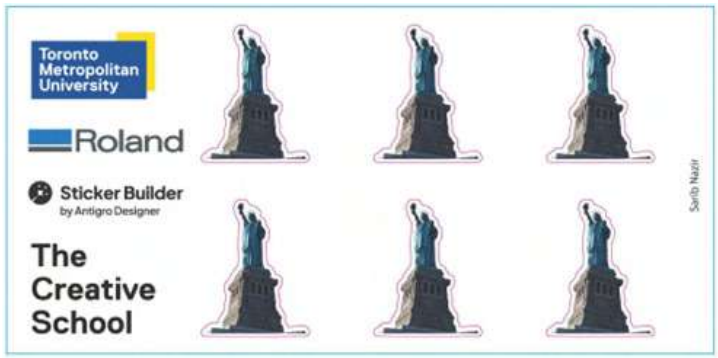

Figure 6: 6-up 1 piece sticker sheet generated by Sticker Builder

Figure 6 only accounts for a single design, but Sticker Builder allows for users to submit two or three designs. Many steps within this workflow stay the same as the one-piece variation, but the order of imposition differs for the two-piece and three-design imposition seen in Figure 7. For the purposes of this research, only the single design imposition will be used.

Figure 7: Two-piece imposition vs. three-piece imposition sticker sheet generated by Sticker Builder

Semi-Automation: Using Adobe Actions in Photoshop and Illustrator

By using the Actions panel in both Adobe Photoshop and Illustrator, an output similar to Figure 6 can be achieved through scripts and manual intervention. In the former application, the raster file is opened, and an action is played to remove the background, export it as a PNG, create a hue/saturation adjustment layer where lightness is turned down to -100, and re-export as a PNG, naming it "onecolour". To gain the most accurate background removal result in Photoshop, adjusting the image processing settings to use Adobe's cloud computing will be necessary. The default settings uses the user's own device and although the turnaround time is faster, the results are not as accurate, as seen in Figure 8.

Figure 8: Original raster vs. a.) Photoshop "device" background removal vs. b) Photoshop "cloud" background removal

Both exported PNGs from Photoshop will be placed and embedded onto an 9 x 4.35" Illustrator file named "StickerImposition". Then, they will be resized to match the dimensions of the artwork

on the Sticker Builder generated PDF - height is 1.599" and the width proportional. From there, dieline generation will occur as a fully manual process seeing as successful automated dieline generation using the Actions panel is problematic. The proposed method is to use image trace to trace, expand, and offset the "onecolour" PNG. Image trace contains multiple presets with "Silhouettes" providing the most consistent results for dieline generation. However, the Actions panel in Illustrator does not record specificity regarding which tracing preset is used, and will always default to the standard image trace preset. The results when the traced image is expanded and offset seen in Figure 9 vary widely. Unfortunately, the standard preset produces convoluted and overlapping dielines not suitable for print and cut operations on the Roland TrueVIS.

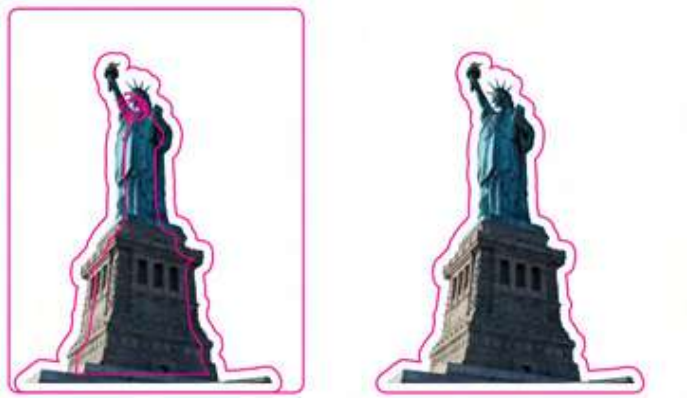

Figure 9: Expanding and offsetting a) default image trace preset vs. b) silhouettes image trace preset

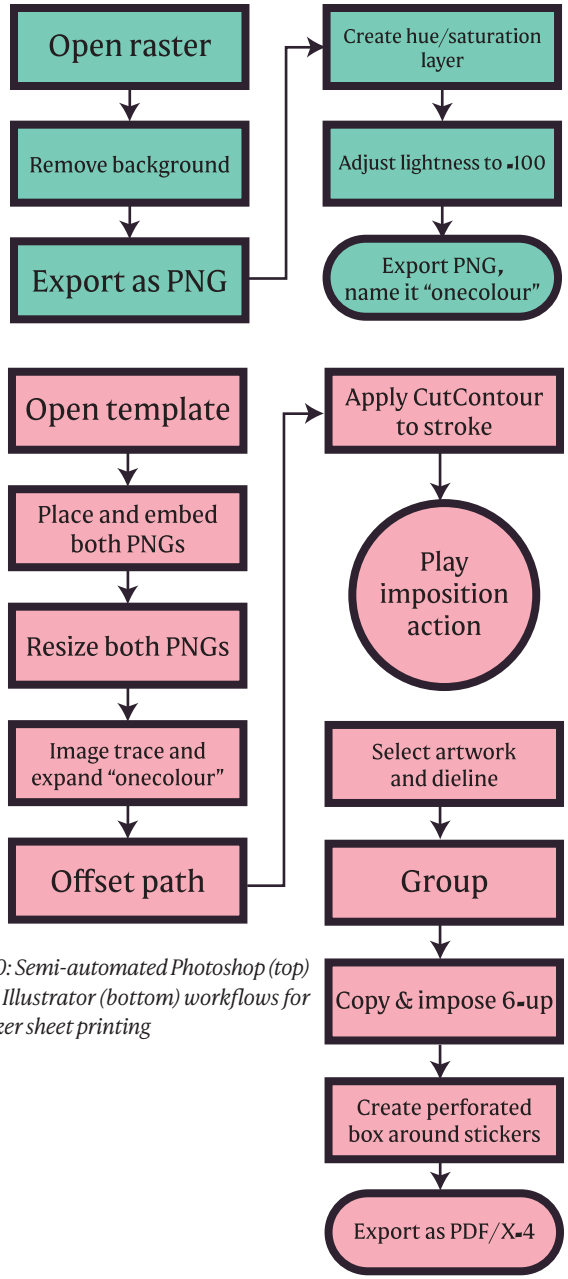

Figure 10: Semi-automated Photoshop (top) and Illustrator (bottom) workflows for sticker sheet printing

Imposition for the stickers can be automated once the dieline is generated. Both artwork and dieline will be selected and copied to impose 6 stickers. Then, a perforated rectangle measuring 8.64 x 4.24" around the stickers using a PerfCutContour spot colour will be created. The job is ready to be exported as a PDF/X-4 and placed into VersaWorks for further configuration. Figure 10 succinctly describes the workflows for both Adobe applications.

Evaluation Criteria & Parameters for Evaluation

The sticker sheet PDFs generated from both Sticker Builder and Adobe Illustrator will be evaluated using three metrics; the efficacy of the background removal, dieline generated, and the size of the individual sticker within each 6-up sheet. For the purposes of this analysis, Sticker Builder settings will be configured to use the following options:

- Advanced background removal
- Tight cutline precision
- White (#FFFFFF) offset background colour
- No adjustments made to brightness, contrast, and saturation
- No hue filter added

On Adobe Illustrator, the following options will be used to generate the dieline for the given raster. These values provide the closest results to the appearance of the dielines in Sticker Builder using the aforementioned configurations:

- 0.04" offset
- Round join
- Miter limit = 4
- 0.25pt stroke thickness

Once the perforated sheets have been punched out and the vinyl weeded after printing on the Roland TrueVIS, a sticker from each sheet will be placed against a piece of black construction

$$\% \text{ Change} = \frac{\text{Width/height of sticker in Adobe Illustrator PDF - Width/height of sticker in Sticker Builder PDF}}{\text{Width/height of sticker in Sticker Builder PDF}}$$

paper to assess the construction of the dieline. It is imperative that the outlines of the physical stickers are evaluated as that is the final output the user will receive on their end. This observational assessment will also be done on Illustrator to find exact values for dimensions and anchor point placements for dielines. For any sizing discrepancies, a chart following Table 1's format below will be used to record the dimensions, alongside the percentage change from Sticker Builder to Illustrator. The formula used will be as follows:

Sticker Builder		Adobe Illustrator	% change
W	width of sticker	width of sticker	
H	height of sticker	height of sticker	

Table 1: Sample chart for recording sizing differences

Selected Rasters for Evaluation

Five rasters have been chosen that each demonstrate a different variable that is proposed to have an impact on background removal and dieline generation for both Sticker Builder and Adobe Creative Suite.

Raster #1: Statue of Liberty, photographed by author

This raster's efficacy has been demonstrated throughout this thesis as seen previously. It was chosen to examine due to the verticality of the statue and how that would behave against the resizing algorithm of Sticker Builder. The colour contrast between the statue and background should result in no removal errors for both approaches. The background being a clear, sky blue should correspond to successful background removal as well.

Raster #2: Author's Birthday Celebration, photographed by author's sister

This builds upon the attributes of the Statue of Liberty image. Again, it is a vertically-oriented image but both foreground and background have more elements compared to the former. Since this image deals with hair, it is possible both background removal and dieline generation for that portion of the raster is compromised. For successful background removal, feathering must be utilized by Sticker Builder and Photoshop to soften the hard or jagged edges to match the background (Adobe, n.d).

Raster #3: Tabby Cat, provided by Unsplash

By building upon the inclusion of hair in raster #2, this image will further test how accurate and visually pleasing the background removal will appear for Sticker Builder and Photoshop. There were many images of furry animals to select but this was purposefully chosen due to the black background and contrast between it and the cat. The solid colour of the background will hopefully mitigate any interference from that variable of the raster so examination is only limited towards the subject itself. What is most imperative about this raster is how the generated dieline will appear. Although the tabby cat's fur contains soft edges, the distance between the many whiskers is miniscule. Due to this, the generated dieline may contain cuts that are too thin for the Roland TrueVIS to cut successfully.

Raster #4: Beef Brisket Curry and Rice, photographed by author

This raster contains two primary subjects; the curry and the rice. This variance in which element should be kept and removed is why this image was chosen. Similar to raster #2, the foreground and background contain more elements which could be detrimental to the removal process. Additionally, this image emphasizes width more than height which should provide key information on how Sticker Builder will resize it to fit 6-up. Depending on the result of the background removal in Photoshop, it is possible the generated dieline may contain overlaps.

Raster #5: Cliff in Northern Ontario, photographed by author

Juxtaposing raster #1, #2, and building upon raster #4, this image greatly accentuates width more than height. The dimensions are reminiscent of a web leaderboard ad, so it will be interesting to see how Sticker Builder resizes the image to fit 6-up. In Adobe Illustrator, when the height of this raster is 1.599” and the width is proportional to it - 3.486” - it is impossible for the sticker to be imposed 6-up as only two can fit within the perforated path. So, Sticker Builder will have to adjust the height to be smaller compared to the other rasters. This is also the most complicated foreground compared to the other selected images. It can be surmised that both Sticker Builder and Photoshop will have trouble determining which elements need to be removed. Dieline generation may prove to be problematic as well, since the jagged edges of the cliff and trees may result in overlapping and thin cuts.

RESULTS

Figure 11: Adobe Actions generated sticker sheet (top) vs. Sticker Builder generated sheet (bottom) for raster #1

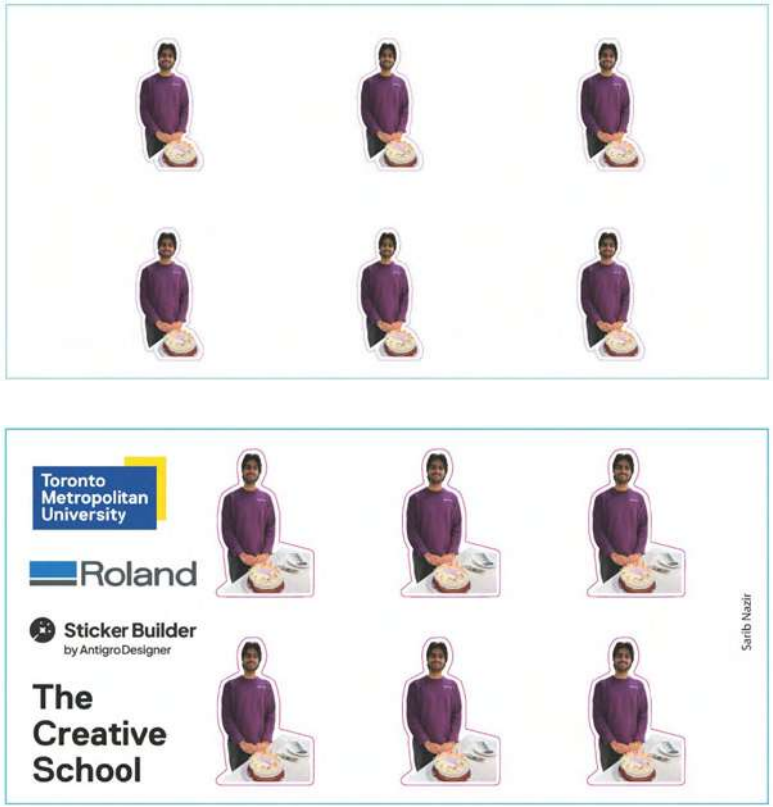

Figure 12: Adobe Actions generated sticker sheet (top) vs. Sticker Builder generated sheet (bottom) for raster #2

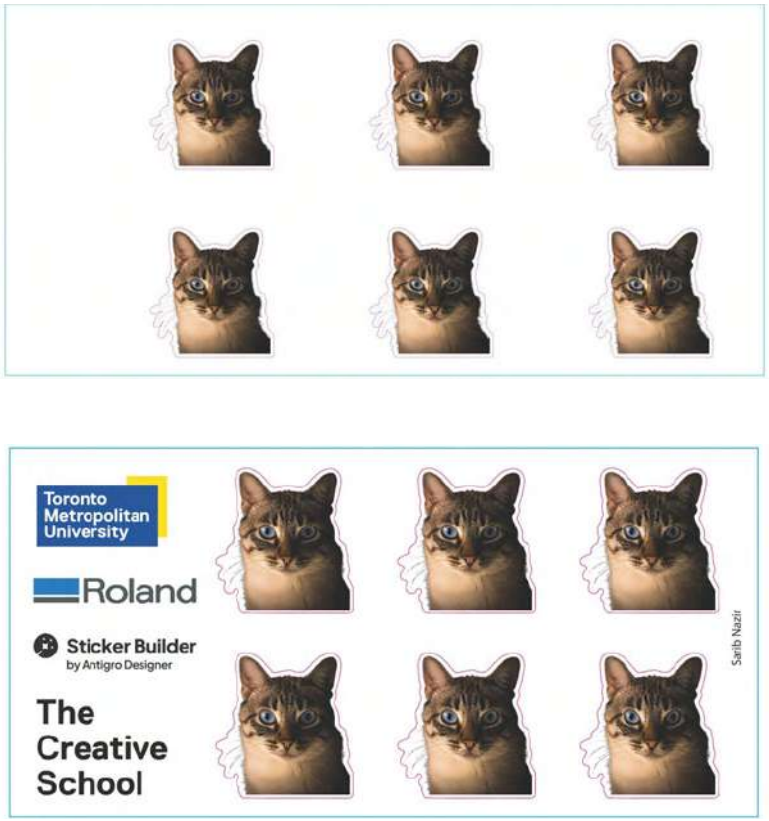

Figure 13: Adobe Actions generated sticker sheet (top) vs. Sticker Builder generated sheet (bottom) for raster #3

Figure 14: Adobe Actions generated sticker sheet (top) vs. Sticker Builder generated sheet (bottom) for raster #4

Figure 15: Adobe Actions generated sticker sheet (top) vs. Sticker Builder generated sheet (bottom) for raster #5

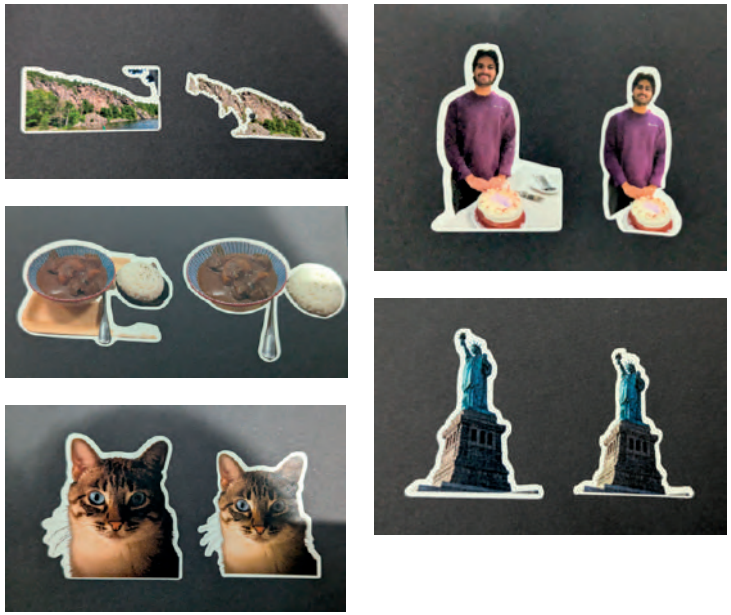

Figure 16: Physical comparison of stickers of all selected rasters between Sticker Builder (left stickers) and Adobe Actions (right stickers)

DISCUSSION
& Comparative Analysis

General Observations

The physical comparison shows the Actions generated stickers having a tighter cutline compared to Sticker Builder. However, when verified, the offset X and Y distances of the dielines generated in Sticker Builder for all selected rasters are almost identical to the 0.04” offset set in Illustrator. Sizing differences between stickers are evident through the physical comparison which will be explored later in this analysis. Although the Sticker Builder dielines are thicker with a 0.5pt stroke, this difference is negligible for the output of the stickers. Figure 17 shows the comparison between the dielines generated Sticker Builder vs. Illustrator, with the former ones looking smoother. The latter approach produces more anchor points resulting in a “bumpier” look. The excessive nature of anchor points is problematic for cutting on the Roland TrueVIS, the file sizes of the PDFs, and for adjusting the dieline. This could be remedied by simplifying the paths in Illustrator, however the addition of another step into an already extensive workflow might not bode well for rigorous testing

of this workflow. Upon further inspection of Figure 17, the resolution of the stickers in the Adobe Actions workflow differs from Sticker Builder, with the latter having clearer and less pixelated artwork. The resizing algorithm used is more advanced than what was previously assumed for the purpose of this comparative analysis.

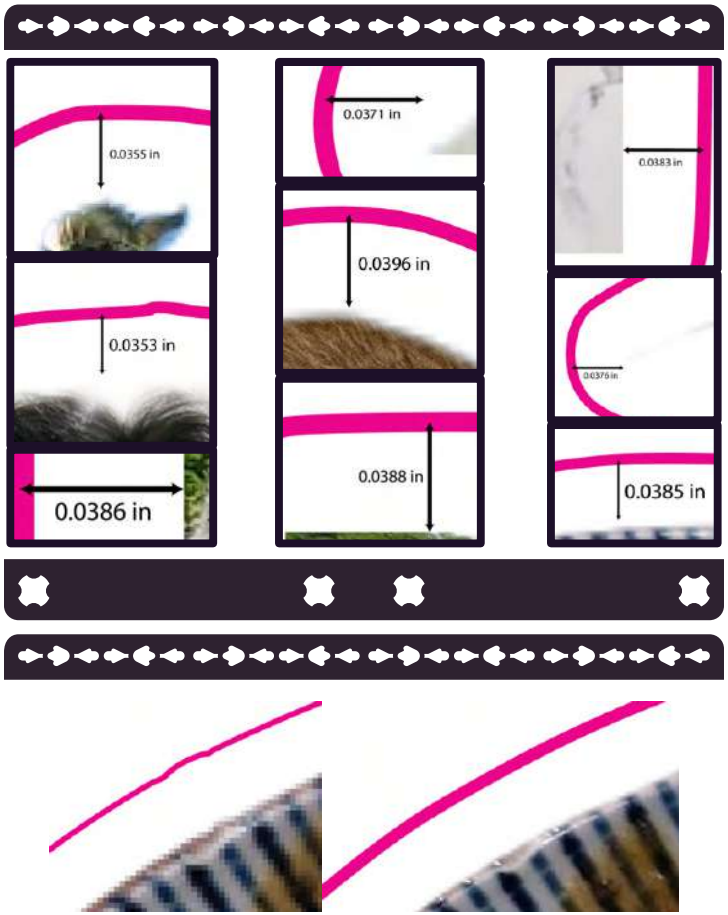

Figure 17: Appearance of dielines in Adobe Illustrator (left) vs. Sticker Builder (right) PDFs

Raster #1 Comparison

Compared to the other selected rasters, there are not as many differences between the stickers produced by both approaches. Aside from resolution and dieline smoothness, the most notable one is the smaller size of the Illustrator sticker. The efficacy of the background removal is nearly identical in both stickers, with Photoshop having a slight advantage as seen in Figure 18. Sticker Builder encompasses a slight blue outline around the statue, whereas Photoshop more successfully isolated the subject. Still, this is a negligible difference that is not noticeable until extreme inspection.

Sticker Builder		Adobe Illustrator	% change
W	1.3167”	1.1647”	-11.5%
H	1.6773”	1.4864”	-11.4%

Table 2: Sizing differences for raster #1

Figure 18: Background removal comparison of raster #1 between a) Sticker Builder b) Adobe Actions

Raster #2 Comparison

Judging the efficacy of the background removal is imperative for this specific raster due to several variables involved. Inspecting the hair of the subject first shows that both approaches were successful in feathering and presenting hair in a visually pleasing appearance. Closer examination shows some discrepancies between Sticker Builder and Adobe Actions (Figure 19). The former does not isolate the subject as well as the latter, ultimately being more noticeable than the differences noted in raster #1. This approach encompasses more of the table the cake sits on in comparison to the isolation of Photoshop. This resulted in a much larger width difference as seen in Table 3, with the height difference being similar to the comparison seen in raster #1. In terms of background removal, Photoshop was more successful but is not without its own quirks. Figure 19 shows that Sticker Builder does a better job at removing the red portion above the subject's shoulder, and a section of the marble table is left over in the bottom left of the artwork.

Sticker Builder		Adobe Illustrator	% change
W	1.1119”	0.7561”	-32.0%
H	1.6781”	1.5043”	-10.4%

Table 3: Sizing differences for raster #2

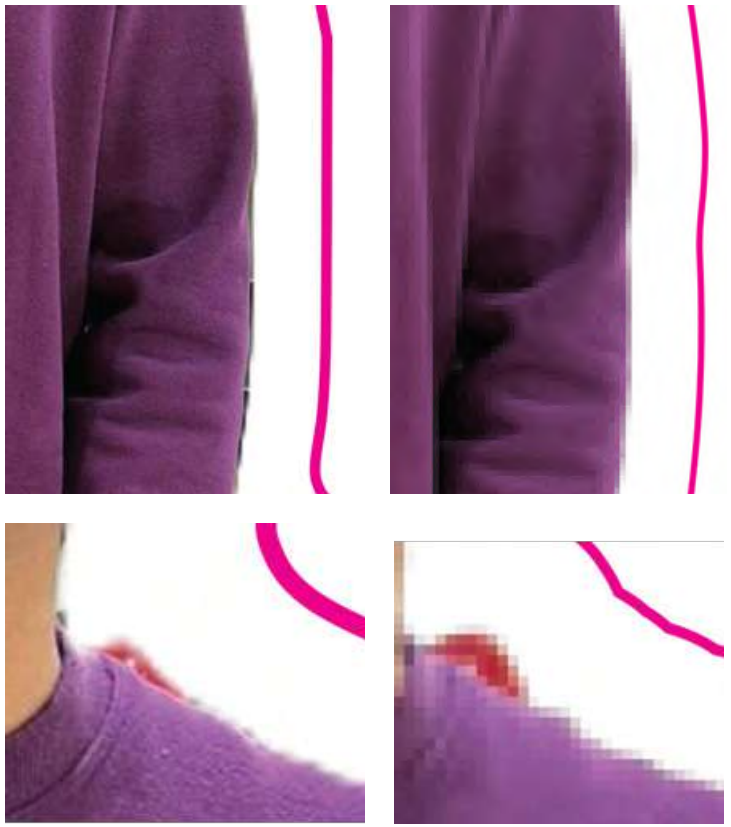

Figure 19: Background removal comparison of raster #2 between a) Sticker Builder b) Adobe Actions

Raster #3 Comparison

Juxtaposed to raster #2, the background removal of the stickers produced similar results but the dielines demonstrate some noticeable differences. The bumpiness of them is exacerbated in the Adobe Actions PDF, especially in comparison to Sticker Builder. The former approach resulted in a small cutline near the whiskers of the tabby cat, which should be negligible for production but does deter from successful personalization and dieline generation for this subject. Figure 20 shows that Illustrator gets closer to the whiskers compared to Sticker Builder. This may be problematic for cutting on the Roland TrueVIS but does amplify the personalization of the sticker by offering a tighter dieline around the subject. The percent change of the dimensions from both approaches is similar to the values seen in the raster #1 comparison, which is appropriate as the background removal seen there was also equally effective in both workflows.

Sticker Builder		Adobe Illustrator	% change
W	1.589”	1.407”	-11.4%
H	1.6784”	1.4794”	-11.9%

Table 4: Sizing differences for raster #3

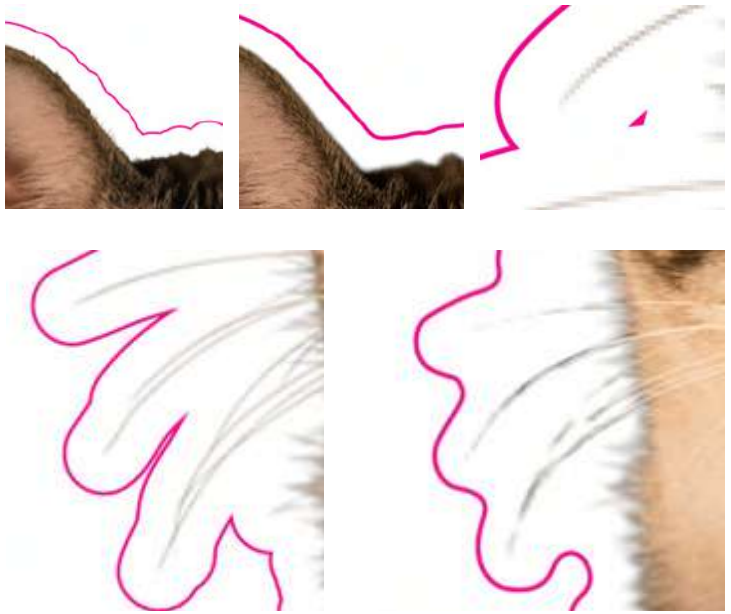

Figure 20: Offset comparison of dielines between a) Adobe Illustrator and b) Sticker Builder

Raster #4 Comparison

The background removal differs greatly between both approaches, with Sticker Builder faltering more than the scripted Actions workflow. It can be presumed that Sticker Builder had difficulty finding the primary subject to isolate within the original image, and tried to unsuccessfully remove everything except the wooden dish. The final result leaves a lot to be desired when compared to Photoshop's isolation of the curry and rice. Adobe's approach is not without its discrepancies as the rice bowl itself has been removed which is not ideal. Another interesting observation to note is the Actions PDF contains stickers with larger dimensions, which is a first occurrence in this analysis. There seems to be an excessive amount of anchor points on the dieline surrounding the rice portion of the artwork (Figure 21). Besides that observation, there is nothing else interesting to note for the dielines generated in both approaches.

Sticker Builder		Adobe Illustrator	% change
W	1.6781"	1.8703"	+11.4%
H	1.1552"	1.3389"	+15.9%

Table 5: Sizing differences for raster #4

Figure 21: Anchor point of dielines comparison between a) Illustrator and b) Sticker Builder

Raster #5 Comparison

Similar to raster #4, background removal across both approaches differs greatly with Sticker Builder being more successful in isolating and encompassing the cliff. The result from Photoshop is almost unrecognizable from the original image, with the notion of it being a cliff being hard to justify to an average viewer. There is much less green foliage and trees in the Photoshop generated artwork, providing insight into how this application deals with background removal. When working with a complex and more involved raster, Photoshop may solely focus on one or two colours and only isolate those compared to the rest of the image. Sticker Builder's result is not wholly ideal with Figure 22 showing an unnecessary aspect of the artwork that should have been erased in the removal process. Upon closer inspection, the stickers in the Actions generated PDF contain unwanted and overlapping dielines which are problematic for cutting operations on the Roland TrueVIS. Due to the difference in the artwork generated across both methods, sizing differences do not provide as meaningful insight as previous rasters. Table 5 does show an increase in width only when comparing Sticker Builder to Illustrator, another first for this analysis.

Sticker Builder		Adobe Illustrator	% change
W	1.6784”	1.754”	+4.5%
H	0.8137”	0.7376”	-9.4%

Table 6: Sizing differences for raster #5

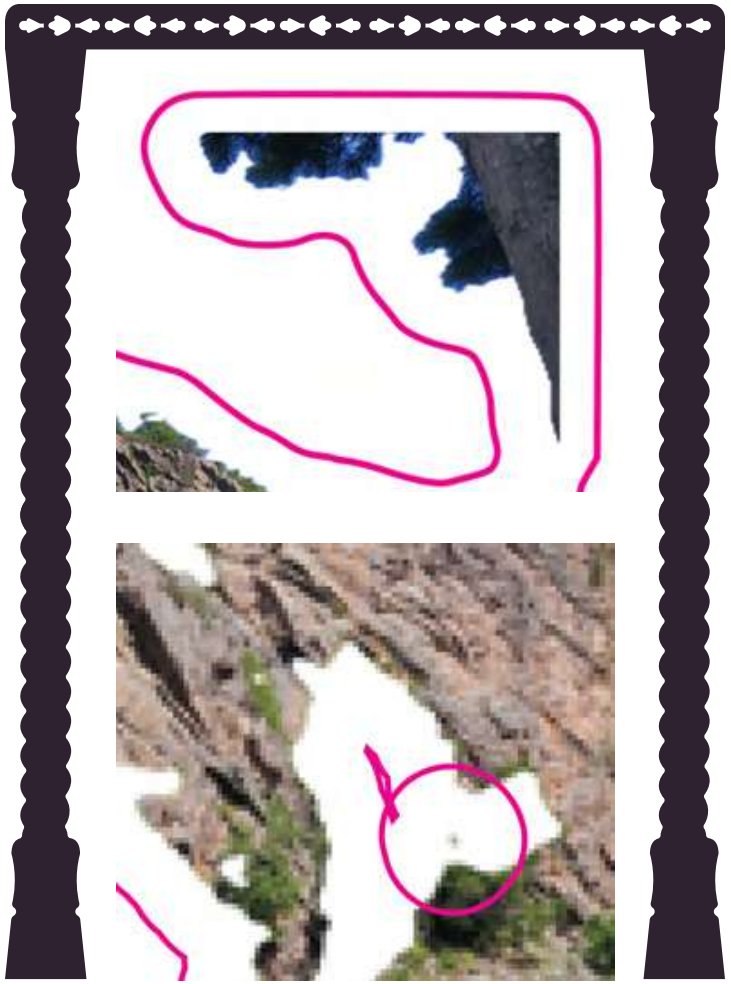

Figure 22: Discrepancies found in Sticker Builder (left) and Actions (right) PDFs

CONCLUSION

Through rigorous testing of the selected rasters, this research can firmly conclude the automated workflow offered by Antigro's Designer Sticker Builder enhances personalization for vinyl prints. By automating dieline generation through CutContour and PerfCutContour application, the integration with RIP software for wide format printers is evident, allowing for ease of print & cut adjustments prior to production. The simplified and smoother dielines, more sheet optimization, higher-resolution artwork, and background removal which is equally as effective as Adobe Photoshop's cloud computing processing are supported by a user-friendly interface which is easier to navigate than Adobe's offerings. However, it is not without its limitations as seen in raster #2 and #4, which Antigro Designer can hopefully mitigate through future updates to the software. On the other end, improvements can be made to the Adobe Actions workflow to closer match the performance and output of Sticker Builder. For resolution, to preserve more data from large images submitted, the rasters can be resized in Photoshop first before being embedded into Illustrator. The "Bicubic Sharper (reduction)" resampling option in Photoshop can

be used rather than automatic resampling. This is more beneficial when downsizing an image by helping maintain as much sharpness as possible (Helen, 2024). Since the tested rasters all have varying sticker dimensions on the Sticker Builder PDFs, finding a suitable solution for resizing and imposition on Illustrator will be more challenging. Using a script that resizes with variable data may be the first step in tackling this predicament but this would involve a CSV file outlining the necessary information required (Adobe Community, 2021). Additionally, creating two more sets of actions that mimic the two-piece and three-piece imposition (see Figure 7) may provide further insight into how Sticker Builder resizes any given raster or vector for 6-up imposition. Personalization and automated workflow solutions have proven to empower commercial printers, but with the advent of Sticker Builder, there is a reshaping in how personalized vinyl prints are produced for the end user, thereby granting more opportunities for research and development for future related software.

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VISUAL INSTRUCTIONAL DESIGN AND CRISIS COMMUNICATION:

EXPLORING THE USE OF VISUAL LANGUAGE TO ENHANCE INFORMATION ACCESSIBILITY WITHOUT DEPENDENCE ON WRITTEN TEXT

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ABSTRACT

Considering recent events that have shaken the world, it is becoming increasingly clear the importance of communicating information effectively to reach as many people as possible. This thesis aims to investigate the relationship between visual communication and information design, and how designers use symbols, illustrations, and diagrams in tandem with the elements of design to make messaging accessible. Framed in the context of crisis communication, a unique area where information needs to be easily understood by groups of people experiencing an array of emotions, designers need to rely less on text to get a message across. The research conducted aimed to answer how visual instructional design improves crisis communication by effectively conveying emergency procedures and information without relying on written language. Through a carefully constructed methodology, four different materials designed to be used in the case of an emergency or urgent situations were studied and examined for their design practices: an airline flight safety card, a Naloxone delivery kit insert, a COVID-19 self-testing kit, and a TTC subway sign. The results supported previous research and reinforced the importance

of symbols in accessible messaging, appropriate colour schemes, and layout techniques to reduce cognitive load in messaging.

INTRODUCTION

In a world increasingly affected by global crises, from public health emergencies to environmental disasters, the need for effective, inclusive communication has never been more critical. Traditional reliance on written language often falls short when information must be delivered rapidly, across diverse populations, and under stressful conditions. This thesis explores the role of visual instructional design in crisis communication, specifically how visuals—such as symbols, pictograms, and intuitive layouts—can be employed to convey vital information without the need for text. Grounded in a comprehensive review of literature and a primary analysis of real-world crisis materials, the study investigates how visual design can bridge language, cultural, and cognitive gaps to enhance public understanding and response. By analyzing design elements in four case studies—an airline flight safety card, a Naloxone administration insert, a COVID-19 self-test kit, and a TTC emergency subway sign—this research highlights the principles that make emergency visual messaging more accessible, memorable, and actionable.

LITERATURE REVIEW

This literature review provides a wide and broad overview of topics pertaining to the thesis. The aim of this research is to first define visual communication design and its objectives, as well as its role in crisis communication and risk messaging. This paper will further examine these topics in the context of the COVID-19 pandemic, as it is the most critical global health crisis in recent years. Overall, the research illustrates the importance of visuals in crisis and risk messaging, and its role in overcoming common communicative barriers, such as limited language proficiency, auditory impairments, and cognitive delays. Specifically, the literature examines the usage of pictograms and symbols as communicative devices used in emergency messaging, in addition to their restrictions and limitations.

What is Visual Communication Design?

Firstly, it is important to define visual communication design and its roles and objectives. The role of design and what it should hope to achieve has been a widely debated topic. In "Graphic Design: Fine Art or Social Science?" Frascara expresses frustration about the focus on aesthetics in design, while neglecting other critical factors such as appropriateness and responsibility (1988). Frascara highlights the connection between design and social responsibility by arguing that graphic design is the "activity that organizes visual communication in society" (1988, p. 20). Evidently, design has the power to be impactful through its ability to communicate messages

and information to the public in alluring ways. The concept of design as a driving force for social change is also enforced by Reading et al., who position design as an action-oriented tool that acts as "one of the most operative agents of the social, cultural, and economic functioning and dysfunctioning human made world" (2024, p. 4). By these definitions, visual communicators are tasked with the goals of informing audiences during environmental, social, and cultural crises (Reading et al., 2024). Designers are also expected to endure a higher level of social and moral responsibility, resulting in more strategic and thoughtful outputs of design (Reading et al., 2024).

In the current state of design, the issues highlighted by Frascara have evolved and changed. Frascara comments that appropriateness should be one of the factors used to judge the quality of a design. That is, how well the designer addresses the audience and their needs, as well as the scope and context of the project. This is relevant because as Frascara addresses, the issue affecting contemporary design is the search for "short cuts, simplification, recipes and mechanistic processes." (2022, p. 10). The role of the designer continues to change, but Frascara argues that designers should not aim to simplify complexity, instead, they should organize it and render it accessible (2022). This information is critical since visual tools are necessary in communicating vital information to the public in its most accessible form.

The concept of information design can be traced back to modernism and the industrial age. According to Kostelnick, "as modernism emerged, the relationship between art, technology and industrialism became largely synergistic rather than antagonistic" (2019, p. 30). During this time, artists such as the Futurists, Cubists and Modernists began to experiment with abstracting human forms. Some key influences that predated the clean, geometrical

forms present in design today are the Bauhaus, which was founded in Weimar, Germany, and greatly influenced modern design. The Bauhaus was known for their universally appealing, simple, and high contrast geometric forms (Kostelnick, 2019). One of the key figures in visual design who is referenced throughout this paper is Otto Neurath and his program for the International System of Typographic Picture Education (ISOTYPE). This program, implemented by graphic designer Gerd Arntz, utilized the principles of early modernism to create a symbol system that could make knowledge accessible to everyone by universalizing information design (Kostelnick, 2019). This system effectively visualized human forms in sparse and functional ways: they were simple, hard edged, high contrast, and geometrical (Kostelnick, 2019). Neurath's work has served as a starting point for many other icon systems that have been developed over the years by different organizations, though their success and effectiveness is yet to be determined (Patton, 2015; Zender, 2006). Icon systems and their role in communication design in the context of crises and risk messaging will be discussed further throughout the paper.

Crisis Communication and Public Health Messaging

Crisis and risk communication are deeply connected with public health messaging. There is much research available on the ways to communicate critical information to the public and how public health campaigns can be successful. According to Ross at al., risk communication "encompasses preventative action to decrease the impact of a threat before it occurs" (2022, p. 10), while crisis communication is defined as the "public relations perspective on mitigating

the consequences of a disaster while it happens or after the impacts are felt" (2022, para. 10). The importance of efficient and successful risk and crisis communication cannot be understated. According to the World Health Organization (WHO), risk communication is one of the eight core capacities used to mitigate the effects and outcomes of public health emergencies (Abdulla, 2020). Information transmitted to the public during these times needs to align with guiding principles, such as create and maintain trust and transparency, acknowledge, and communicate uncertainty, and engage those affected by the crisis (Abdulla, 2020). Moreover, to build trust among members of the public, messaging should be linked to functioning and accessible services, link to self-efficacy, and should be available on multiple platforms, methods, and channels (Abdulla, 2020).

Overall, the aim of crisis messaging is to "produce conviction and [act] as an extension of authority" (Abdulla. 2020, para. 10). One of the challenges that has been identified during the COVID-19 pandemic with concern to crisis communication is the lack of experience, which affected coordination between stakeholders (Landqvist & Blåsjö, 2024). As mentioned previously, crises are characterized by uncertainty even from an expert's perspective, which affects how risk information should be communicated. According to Landqvist & Blåsjö, two components need to be factored: the actual danger present in the crisis and public sentiment (2024). During a global crisis, communicators need to be aware of what knowledge should be spread, or what is classified as common sense, since the crisis may be perceived as too vague by the public (Landqvist & Blåsjö, 2024).

In "Creativity in Crisis Communication: A Systematic Review," Smaliukienė defines crisis communication as being more than just a message to stakeholders before, during, and after a crisis. This article highlights how creativity spawns during crises due to their

unprecedented and distinctive nature. As the situation evolves, the method and content of the message becomes less standardised and more creative (Smaliukienė, 2024). Creative messaging during crises can contribute to crisis management, because it can overcome the "fog of warnings" (Smaliukienė, 2024), which refers to when there is an abundance of public information that is repeated and disseminated. The use of music and visual sensations to convey a message contributes to its emotional impact and appeal, and can fight against disinformation and misinformation, overcome distrust, and protect reputation (Smaliukienė, 2024). Overall, crisis communication plays a critical role in behaviour framing, in that the messages disseminated are meant to define the behaviour of the population at a large-scale.

Now that the importance of crisis communication during public health emergencies has been examined, inclusivity and accessibility can be called into question. Research has found that during the COVID-19 pandemic, crisis communication failed to reach all areas of the population, specifically, groups that experience sensorial, linguistic, cultural, or textural barriers were put at a higher risk. Moreover, it was found that information distrust was high, especially among BIPOC communities, who were affected the most during the public health emergency (Githinji et al., 2024). "Inclusive Crisis Communication in a Pandemic Context" focuses on these issues in detail; Hannes et al., defines an inclusive crisis communication strategy as one that reaches all citizens (2024). Four aspects of crisis communication policy need to be prioritized to ensure inclusivity, mainly, ensuring that the message is in an accessible form and available through retranslations and media access services such as subtitling, sign language, symbols, etc. Crisis communication also needs

to be available through multiple offline and online channels, and have an efficient spread and outreach (Hannes at al., 2024). These aspects enable crisis and risk communication to perform as an open two-way exchange of information, leading to better understanding and decisions between health officials and the public (Hannes et al., 2024).

The barriers that need to be considered for accessibility and inclusivity purposes are sensorial, linguistic, cultural, and textural (Hannes et al., 2024). Sensorial barriers include permanent or temporary visual or auditory impairments like blindness, hearing loss, or deafness. Linguistic barriers refer to low literacy rates or lack of language proficiency. Cultural barriers are when someone is unable to understand the message due to different cultural backgrounds, including different values and belief systems, behavioural patterns and communication practices. Lastly, textural barriers refer to the structure of the message itself and its complexity or lack of clarity. All in all, emergency risk communication needs to factor in these potential barriers to be as accessible and effective as possible. When properly issued, risk communication is efficient in achieving behaviour change, like willingness to be tested, vaccinated, or follow containment measures (Hannes et al., 2024). The research in this area recommends working with non-governmental organizations (NGOs) and migrant community groups during crises to ensure that minority groups receive the crucial information they need and feel confident believing in (Hannes et al., 2024).

Visual Communication in Crisis Contexts

This section of the review will thoroughly study the different ways visuals are incorporated in crisis communication, with an emphasis on material released during the COVID-19 pandemic. Ross & Jaenichen found through their examination of COVID-19 messaging that health communication campaigns aimed at informing the public often included graphic components (2022). The use of visual stimuli is important because it makes the message more memorable, and the reader can recall the information presented for longer periods of time (Ross & Jaenichen, 2022). In particular, line drawings were found to increase the comprehension of the messaging by users. In this article, it was highlighted that the level of organization and the length of components (graphic variables) in a graphic were "perceptible steps that can either present obstacles or help the reader understand the message" (Ross & Jaenichen, 2022, p. 15). When designing for crisis communication, the designer should consider disaster psychology, such as the fact that people under extreme distress will struggle with retaining and processing information due to environmental factors and the prioritization of necessities (Ross & Jaenichen, 2022). In crisis messaging, every visual variable can have an impact on the viewer's understanding and interpretation of the message, so size, texture, colour, orientation, and shape are all factors that need to be considered (Ross & Jaenichen, 2022). Moreover, poorly designed messaging can also confuse and alienate viewers, further undermining their ability to make informed health decisions (Communicating Health Information, n.d).

Lakeridou et al., found in their research that graphic signage became a universal language that replaced words during the

COVID-19 pandemic (2021). However, designers need to adapt and rethink their methods of designing signage. It was noted that the standard design format for instructional graphics, such as the use of a red and yellow colour scheme, was "too hostile for visual corona communication" (Lakeridou et al., 2021). Designers realized that they needed to break away from traditional methods of visual communication to help the public understand and navigate the pandemic. Another key issue in early pandemic messaging was the mix of styles, colours, texts, and placement strategies used by different designers which caused confusion among members of the public (Lakeridou et al., 2021). Abdulla (2020) categorized COVID-19 signage into different themes that communicated key messages, such as a "thank you, togetherness," "safety and security," "heroes and protection," and "fear, danger and caution." The type of visual on the sign depended on the intended message. For example, for signage conveying messages of safety and security, several pictograms were used to show new measures and instill trust. For signage following the theme of heroes and protection, mask imagery was used to imply ideas of protection, safeguarding and shielding. Some variations of the mask included the shape of the common blue surgical mask, pictograms, and line art style illustration. (Abdulla, 2020). Overall, some recurring elements that were found in COVID-19 print-based signage were picograms, figures wearing masks, images of frontline workers, and illustrations of the virus, hearts, hands, and arrows (Abdulla, 2020). Some considerations that were found amongst the COVID-19 signage was its tendency to be too wordy and over-explain certain aspects of a message, resulting in defiance from the public. Some strategies and recommendations for new signage communication that Lakeridou et al. found were for signs to use a friendly tone and use words of encouragement, and for designs to be tailored to people

who are "leaving their safe spaces" (2021, p. 10). Most importantly, new signage should be integrated into communication campaigns. This fact is further supported by Ross & Jaenichen, who argued that maximum visibility is achieved when campaigns are visually unified and present information as one voice, which effectively provides an "authoritative and credible visual voice for pandemic information" (2022, p. 12). All in all, the present research demonstrates the importance of visual stimuli in comprehension and memory recall in health campaigns.

The Role of Visuals in Non-Verbal Communication

The last section of the review is the most specific to the thesis of this paper, which is the role of visuals in non-verbal communication, framed in the context of crisis and risk messaging. Icons are pictorial signs that express words, functions, or instructions in a non-verbal format (Collaud et al., 2022). Icons have been given different names in different disciplines, such as symbols in software, and pictograms in healthcare. Although icons have been examined under different purposes in various disciplines, it can be agreed that they ultimately serve as a communication tool to "enhance visual attention, comprehension, recall, and adherence of instruction provided" (Zender, 2022, p. 3). Their popular use is also due to their ability to make actions, objects, and concepts easier to understand and recognize (Collaud et al., 2022). These factors make icons an important component in design since they optimize information and act as a universal language that can reduce and overcome language barriers (Ramirez, 2018). Research has proven that icons are one of the most effective ways of communicating health information to the

widest audience, in addition to promoting inclusivity and accessibility (Lujie et al., 2024). For example, in a trial with 86 participants, only one person preferred the signs with words to the symbols, and in a trial with 85 participants, 70 said that symbols helped them find their destination easier (Patton et al., 2015). In an emergency, where communication barriers are amplified due to feelings of distress, confusion or anger, and trauma or injury, icons become easy to use tools that facilitate clear and efficient conversation (Patton et al. 2015).

However, despite these findings, icons are widely misunderstood and poorly comprehended (Zender, 2022). Studies have shown that people often fail to understand similar icons in the way designers intended (Patton et al., 2015). The research highlights a gap in understanding between the designer and their target audience, where the designer assumes a graphic has an obvious meaning stemming from their own personal or cultural context. In actuality, the symbol may be baffling to the audience. (Patton et al., 2015). Ramirez identified two types of users for icons: the professional and the public. These groups have different needs when it comes to icon understanding. For the professional, the icons should be clearly distinguishable and highly memorable. For the public, the meaning should be obvious, ideally with no learning required (2018).

Several icon systems have been developed since beginning with the 1936 Olympic Games in Berlin, where systems of pictograms were designed to facilitate communication between athletes (Zender, 2006). One of the most popular and best-known forms of iconography made was published by the American Institute of Graphic Arts (AIGA) and the United States Department of Transportation. This icon system was inspired by Otto Neurath's work in the 1920s, and contains fifty icons, the most ground-breaking

being the human figure icon. This system, known as the "Helvetica of pictograms," was developed to function as a standard icon system for global communication. However, fifty icons are not enough to communicate complex messages (Patton et al., 2015; Zender, 2006). Regardless, the AIGA icon system is widely used for their visual cohesion, and has remained unchanged for decades (Patton et al., 2015). In risk and emergency management, unambiguous iconography can make a huge difference in how the public perceives hazards and critical information. However, ISO states that there is a need for a standardized system of communicating safety information that does not rely on written language (Ramirez, 2018). According to Hablamos Juntos ('We speak together), a US based project funded by the Robert Wood Johnson Foundation, administered by the UCSF School of Medicine:

"Symbols are not the panacea for a poor signage system, nor will they solve wayfinding issues. But they can be part of a viable and dynamic system that can assist all people, regardless of their reading skill, to feel more comfortable and confident (Ramirez, 2018, para. 20)."

Overall, the existing literature on iconography indicates a need for new research on the effectiveness of icons, and for new ways for icons to be used to be investigated. According to Patton et al, icons do not properly convey actionable messages, and some instructive messages require the additional elements of body language and additional instructions. In these cases, some interactivity can increase the effectiveness of icons, as movement can enhance meaning and convey more intricate ideas (2015).

METHODOLOGY

This thesis is composed of two methods of research. Firstly, secondary research was conducted based on existing sources, collected through TMU Omni Libraries. To provide a thorough base of knowledge about the topic to the reader, research was gathered and sorted based on relevant subtopics, beginning from broad to most specific. The material used to support this thesis had to meet the following criteria: peer-reviewed and of recent times. Exceptions were made for older sources if they were books significant in the field, or popular and heavily cited journal articles. Overall, the secondary research was used to understand and define visual and crisis communication, as well as its history. Secondary research helped prove and explain the ways the application of visual communication design was used in crisis settings to communicate information and messaging, such as in the COVID-19 pandemic. The research methods used in the various journal articles used were large in scope, and therefore, helped fill in gaps of research.

As an accompaniment to the collection of secondary research, there was a need to understand what makes a design effective in its

message communication. Essentially, quantitative primary research was conducted with the goal of analyzing what elements need to be present to make a design as accessible as possible to a large number of people. While there is much existing research about how the use of icons in design is important for accessibility purposes, there is little research examining first-hand how they, in combination with other design principles, are used in crisis communication. For this paper, a design framework was developed as guidelines to analyze existing material against, to determine whether the selected material was effective and accessible. The framework also aimed to distinguish any patterns in design practices. Four different designs meant for use in crisis situations were selected: an airline flight safety card, an instructional manual for delivering Naloxone during a drug overdose, a COVID-19 Testing Kit instructional manual and a TTC Subway map with emergency evacuation procedures. These were chosen due to their role in possible crisis situations, where the administrator may find themselves in an emergency and must absorb information in rapid time, while possibly feeling distressed or unstable.

Developing the Framework

The framework that was developed to conduct the research drew from existing guidelines and manuals on designing for accessibility. In addition to the elements of design, the final checklist also contained the following elements and factors that were determined to be critical for effective communication: universal symbols and pictograms, colour, and contrast for meaning, and intuitive layout and form. If a design meant for crisis communication included some form of these elements, then it could be deemed effective

in its messaging. These elements are expanded on in the following section. The treatment of these elements is supported by secondary research and their findings. By analyzing materials commonly designed for use in a crisis, it is hoped that by analyzing their elements, recommendations could be made and applied to other design materials used for and in crisis communication.

Limitations

This study has limitations. The primary research conducted is limited by time, resources, and access to data. Supplementary areas of research could have included a survey asking testers to answer questions about the material or presenting a redesign to testers, in order to formulate more informative results. More time is needed to properly study the effectiveness of certain design choices on users in a crisis.

The Framework

Universal Symbols, Pictograms, Icons, and Illustrations

Does the design use universal symbols and pictograms in tandem with written text? What classification of icons and symbols are being used?

The research cited for this thesis supports the use of multiple symbols to clearly communicate more complex concepts (Collaud et al., 2022; Zender, 2022). This section of the checklist aims to categorize the graphics used in crisis communication. Icon categorization is based on the degree of abstraction or figuration of the icon (graphic). Icons can be classified into four categories (Lujie et al., 2024).

Image related: figurative representation of an object or action graphic. This means the icon is a literal representation, such as trash being depicted as trash and a folder as a paper folder.

Concept related: icons that attempt to visualize a concept that is not far from, but separate from, a concrete image. Examples include depicting maintenance or repair through two crossed wrenches, or settings as a gear or cogwheel.

Arbitrary icon: icons that have no apparent reference to their intended meaning and can only become meaningful through convention and education. A popular example of this is the hamburger menu icon.

Semi Abstract: Combination of All Three.

According to the 2014 study conducted by Lujie et al., "interesting", "simple", "familiar", "recognizable", "concrete", and "close" are the key design features that influence the user's perception of icon quality. Moreover, figurative icons are icons that contain specific characters, actions, and scenes, which are more concrete and vivid and have a sense of familiarity, while abstract icons, which are generalized and simplified icons are more concise and abstract. From the ranking results, users seem to prefer icons that contain specific character images, actions, and scenes. Additionally, figurative icons have higher scores in being recognizable, effective, interesting, familiar, eye-catching, close, and concrete, which are the main factors in determining user preference. Their final recommendations included enhancing the interestingness of icon design, using a figurative and realistic design style, and developing an appropriate colour scheme, specifically avoiding low hues like gray and cluttered colour schemes. Most importantly, the study found that the more specific the icon, the closer the semantic distance, the faster and more accurately the user can respond (Lujie et al, 2014).

Colour and Contrast

Does the design use standard colour codes and avoids relying on colour to transmit information?

Research demonstrates that colour is one of the most important factors in visual design. However, there are some factors that need to be considered when designing with colour. According to research on accessible design guidelines, hue or chroma should never be used as the only distinguishing factor in conveying information, indicating an action, prompting a response, or distinguishing a visual element (Rallos et al., 2019). Moreover, high contrast is a must, with a black and white colour scheme providing the maximum contrast. During a public crisis, the emotions of people easily fluctuate and are dynamic and variable, affecting the interpretation of colour.

Intuitive Layout and Form: People should understand how to interact with a design immediately.

Does the design utilize one of these organization techniques to reduce cognitive load?

In emergency situations, the concept of cognitive load becomes very important since it affects how a user can experience and understand critical information. Several methods can be employed to organize information clearly (Rallo et al., 2019).

Grouping: group pieces of content in a manner that optimizes utility to the reader and clarifies understanding. This characteristic is further supported by Patton at al., who recommended that icons need to be grouped and organized so that they are easiest to understand and use contextually (Patton et al., 2015).

Chunking: avoid large, overwhelming blocks of information by breaking up content into smaller sections with meaningful

groupings or headings (Rallo et al., 2019).

Hierarchy: clearly differentiating the relative importance of each piece of content in the design, maintaining a pyramidal hierarchical structure within a page (Rallo et al., 2019)

Consistency: helps decrease distractions and increase predictability in a design (Rallo et al., 2019).

Grid: a well implemented underlying grid provides additional consistency and predictability for the reader, as well as using left to right or top to bottom flow (Rallo et al., 2019).

The material will be analyzed for these methods in their design.

RESULTS

CASE STUDY 1
2017 Airline Flight Safety Card by Air Canada Rouge

Universal Symbols, Pictograms, Icons, and Illustrations

This design is composed almost entirely of symbols and pictograms, with minimal text. The text that is present throughout the design is necessary, and provides critical information to the passenger, such as: “For your safety,” and “Non-smoking environment. The design uses image-related pictograms, meaning that each symbol is a literal representation of the object, such as a person, an airplane, land, water, and a passenger seat. In addition, the official symbols for no smoking and oxygen are used. The design features time stamps and the Air Canada Rouge logo. Since it is a static design, arrows are used alongside the pictograms to denote movement and action to the passengers.

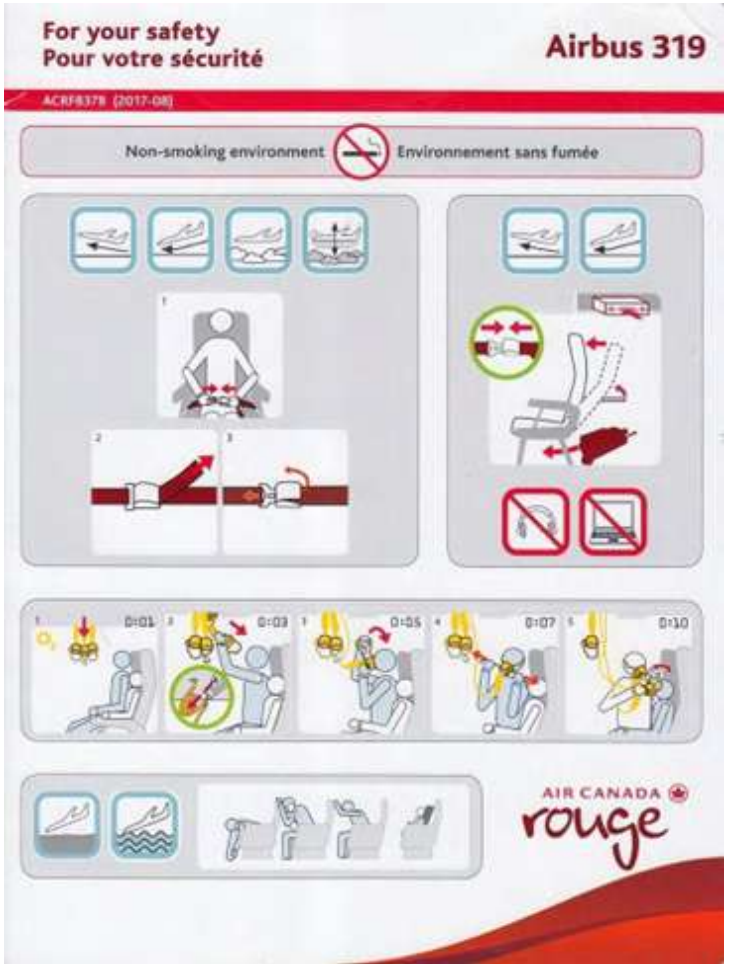


Figure 1. (Air Canada Rouge Airbus 319, 2017)

Intuitive Layout and Form

Chunking	The design is divided into four areas, each illustrating possible scenarios where passengers may need to act from most common: an airplane taking off or landing, to least possible: a land or sea crash.
Grouping	The design avoids overwhelming the passenger by visually breaking up the information, the icons for each scenario are grouped together ensuring they can be interpreted meaningfully.
Hierarchy	Each situation is meant to display the potential scenario as well as the action the passenger needs to take. To organize this information, the less important information that defines the scenarios is drawn in smaller boxes but is placed first in the sequence of events.
Reading Flow	The design implements different flows: In the first two scenarios, the information follows a top to bottom flow. The scenarios are in boxes outlined in blue, then the series of action follows. The boxes dictating the actions are also numbered in the proper order they should be done, with the first action being the first shown in the sequence. In the last two scenarios, the information follows a left to right reading flow.

Elements of Design

Line	The design uses a combination of shaded areas and solid and dotted lines to depict movement and different states of objects. Some objects contain more lines of detail such as the oxygen masks and their components. The more familiar an object is the passenger, such as a place, the less detail it requires to be understood.
Shape	Design is composed of geometric and organic shapes to realistically depict objects simplified forms.
Form	The design is not composed of 3-D shapes.
Colour	The design uses a limited colour scheme: gray, white, light blue, red, yellow, and light green. Since red is the colour that stands out the most, it is used to emphasize important actions and to mark something as bad, like using devices during takeoff.
Value	While the shades of grey are not used to distinguish important visual elements, it does not provide a large amount of contrast between the background and foreground.
Space	Negative space: there is a lot of negative space throughout the design. Each section has a surrounding blank gray space to avoid clutter. The abundance of space creates a feeling of stillness and serenity, which can be appropriate in a crisis.
Texture	Safety cards are often laminated and made of plastic and laminated to withstand the pressures of being handled, providing a sturdy object for a passenger to hold onto. This one is specifically made of cardboard, and it is two-fold.

CASE STUDY 2

Instructions for Responding to An Opioid Poisoning with Naloxone by Alberta Health Services

Universal Symbols and Pictograms

The design contains a combination of text and drawings. More text is present than in the airline safety card, it is necessary for the user to read the information to understand the procedure being shown. The text tells the user what signs they should look for of an overdose and how to administer the drug. Each step contains a diagram and illustration in addition to text. Step 1: Look for Signs of Opioid Overdose is entirely text based; this may be problematic since the user may stop to read all the information first before acting in a scenario where reacting quickly can save lives. While it can be argued that the warnings of an overdose are obvious, everyone reacts to a situation differently, and the average person may take extra precautions when dealing with a compromised person. Notably, the drawings are more detailed and realistic, but are still image related. The human subjects are depicted wearing clothing, hair and have facial features (mouth, nose, expressions). It is a static representation, so arrows, checkmarks and Xs are used to indicate movement and action the user must take. The position of the figures and their meaning are simple and intuitive to decipher. The universal symbol for stop is used as well as 911, which is used in combination with the symbol of a phone to indicate calling.

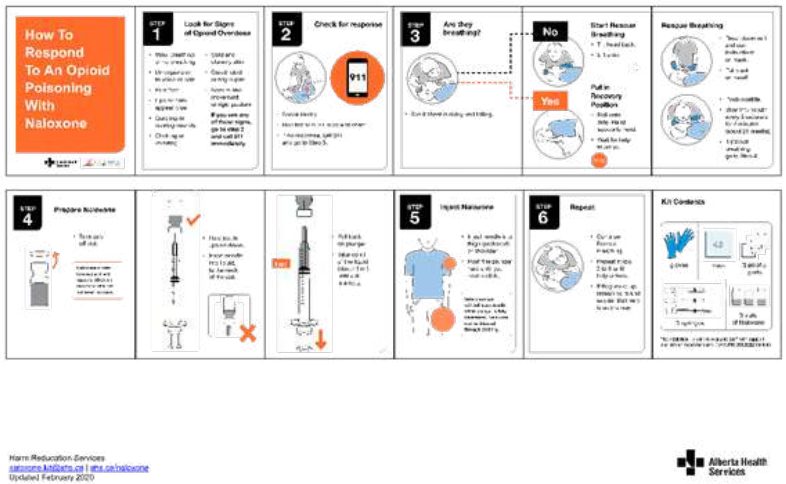


Figure 2. (Alberta Health Services, 2020)

Intuitive Layout and Form

Chunking	Every necessary action in the procedure is visually divided into a step, helping the user digest the information more easily. There are six steps total, with additional information about how to use the needle and deliver CPR.
Grouping	To avoid information overload, every step is neatly organized into their box of information, with the illustrations consistently staying on the left side of the box.
Hierarchy	Throughout the design, the position of the several different types of elements is notable. The most eye-catching element upon a glance is the boxes with the "step," since it has a black fill. The design also employs text hierarchy, as it uses both a bold and a regular font. The bolded text is usually important, so it is placed at the top of step.
Reading Flow	The design consistently uses a left to right reading flow, in addition to other elements to help the reader dictate the reading flow, such as numbering in each corner of the box. This way, the reader also encounters the illustration first while they are reading. The individual steps are top to bottom reading flow.
Grid	A grid is used to organize the information and diagrams in a predictable and consistent manner, a specific example is the illustration of the kit contents.

While not included in the design framework, the text present in the design also needs to be analyzed for its use and characteristics.

Although there is a lot of text, they are mostly organized using bullet points, making it easily digestible. The actual language used is simple, straightforward, and primarily descriptive, such as “speak loudly,” or “pull back on plunger”. A notable feature in the language is the use of questions to help engage the administrator.

Elements of Design

Line	The design uses a variety of different types of linework. Dotted lines are used to direct the viewer to another section of the instructions. The most detailed drawings are the needle and the kit contents. The needle is the most critical object in the kit, so extra care is taken so it is represented in its most accurate form.
Shape	The design uses geometric and organic shapes throughout. Specifically, rectangles and circles distinguish different elements. The illustrations are placed within circles. The circles also keep the size and scale of the illustrations consistent. Important areas are also highlighted through coloured circles.
Form	There are no 3-D elements present in the instructions.
Colour	The main colour scheme of the instructions is black, white, gray, orange, and blue. Orange is used the most to highlight critical information, such as injection areas on the body, and arrows directing motion. Blue is used on the unconscious person and gray is used on the person administering the drug.

Value	Grey is used in some areas of the design to add depth, such as in the needle and bottle. These shaded areas help the viewer better recognize the object.
Space	Overall, the instructions optimize the space on the paper. There is a lot of negative space around the information and the illustrations, reducing potential for clutter. That said, the diagrams could potentially be made bigger, if not, the text could be made bigger in some areas.
Texture	There is no visual texture present in the design.

CASE STUDY 3

GENABIO COVID-19 RAPID SELF-TEST KIT

Universal Symbols, Pictograms, Icons, and Illustrations

Out of all the designs examined so far, this one contains the most amount of text. The document is mostly composed of detailed information on how to use the test and how to prepare the materials. Like the previous materials, each step of the procedure is paired with a diagram or illustration. The style of illustration is mostly consistent across the design, with all of them displaying the same amount of detail and line work, with some exceptions. For example, the hand sanitizer image has more linework and shows tonal value through shadows. A notable characteristic is the lack of a human subject in the demonstrations. Instead, there is only a hand or nose shown throughout the design. Since this is a static design, arrows are used

to indicate movement or action taking place. Overall, some of the illustrations seem too detailed for their size, such as the drawing in step 3 meant to convey to users to not touch the soft end of the nasal swab. The linework used in the drawings also appears very thin in some parts.

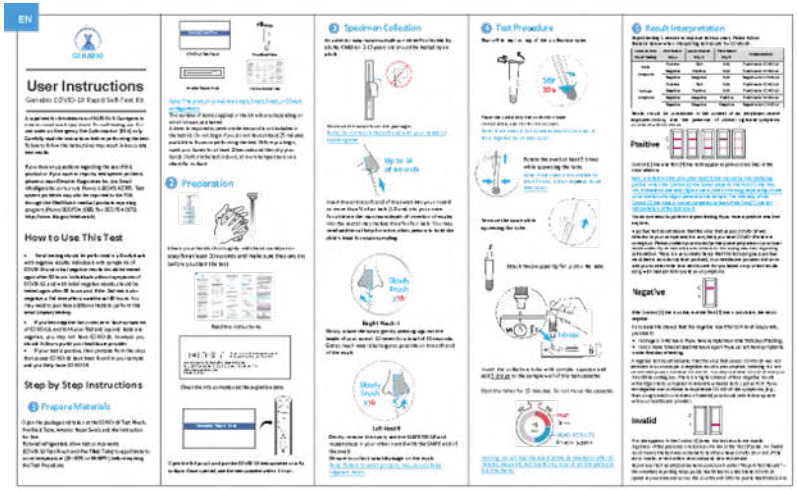


Figure 3. (U.S Food and Drug Administration, 2023)

Intuitive Layout and Form

Chunking	To maximize the small space, the procedure is spread out in columns across the page. Within the set of instructions, there are a total of 5 steps. Each step contains multiple actions that the user needs to do. By using a combination of subheadings and multiple sets of icons, the complicated procedure becomes more digestible to the user.
Grouping	The drawings are grouped with additional explanatory information. When a step requires more than one illustration, such as a zoom in on a particular detail, the icon is placed in a circle. The drawings are always placed near each other so the user can follow along intuitively.
Hierarchy	Hierarchy is used throughout the design by using a header that is bold and a different colour. Each step is also differentiated with a number in a circle that is the same colour of the headers.
Reading Flow	Since the printed product is in a pamphlet form, it strictly uses a Z style reading flow. The user can follow the information by scanning each column from top to bottom.
Grid	There does not appear to be an underlying grid to arrange the elements. While there are columns organizing the overall flow, the elements in the columns appear scattered.

Elements of Design

Line	Lines are a major component in this design. The first thing the viewer sees when opening the manual are the lines dividing the information up. The design mostly uses solid lines in the illustrations. Dotted lines are used in the diagrams of the nose to highlight the right or left nostril.
Shape	The design uses organic and geometric shapes. Geometric shapes are required to accurately depict the tools needed in the procedure, and the body parts.
Form	There are no 3-D elements in the design.
Colour	The design uses a limited color scheme. It utilizes black, gray, blue and red, with red being used strictly to highlight specific details about the step, such as how many times the user needs to brush the inside of their nostril. Blue is used consistently as another method of drawing attention. The motion arrows and some text throughout the design are blue. While the blue works for the symbols, some blue text appears hard to read.
Value	Like other materials examined, value is depicted through grey areas. This is most seen in the dropper figure.
Space	The space distribution across the design appears uneven. The procedures have a lot of space dedicated to them. The instructions do not cramp, and every icon has negative space surrounding it. However, the results interpretation, a critical area, has large chunks of text jammed into a small area.
Texture	There is no texture present in the design

CASE STUDY 4
TTC Subway Map and Emergency Procedures

Universal Symbols, Pictograms, Icons, and Illustrations

The sign extensively uses symbols and pictograms throughout the design. This design is unique compared to previous materials, since it features a simple map of the subway car labelled with symbols that correspond to a legend. In this case, the symbols are to distinguish the different types of emergency exits around the car as well as intercoms and alarms: emergency intercom, emergency alarm, end door emergency exit, side door emergency exit, and the emergency door handles. The arrow symbols correspond to the iconography system developed by (AIGA). The design primarily uses icons to illustrate how to use the different exits step by step. Each step is accompanied by a paragraph of text outlining how to exit. Overall, the icons do not contain much detail. Some of the icons used are hard to interpret without the subtitle, such as “wait for ramp to open.”

Figure 4. TTC Subway Sign, Toronto (own photo)

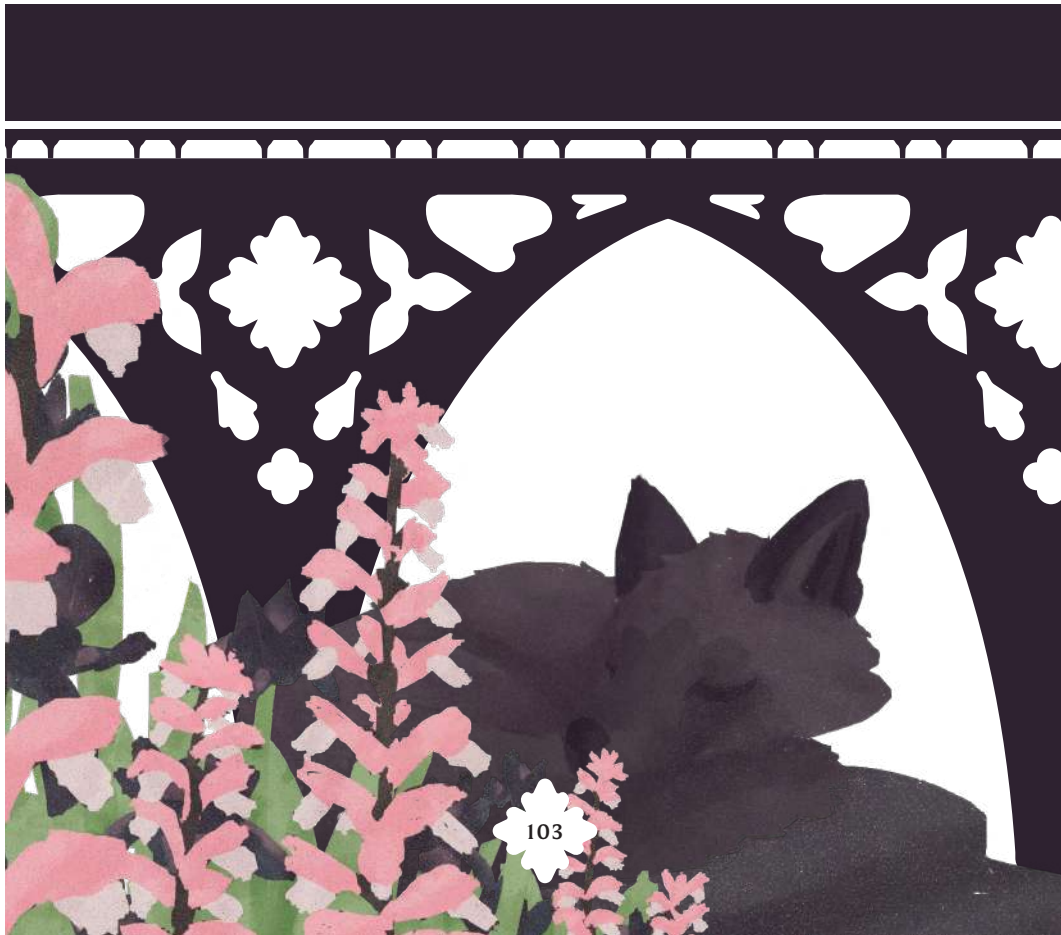
Intuitive Layout and Form

Chunking	The design is divided into three main informational areas. The top half of the design contains the map of the car. The bottom half is split into two sections: passenger safety and emergency evacuation. Each section contains some form of visual aid like symbols or iconography in addition to the text. The reader can start reading any area of the design without being confused.
Grouping	The design breaks up the information through the sections and uses bold subheadings for each. It also uses faint white lines to make visual distinction between each section. All relevant icons are placed side by side for meaningful interpretation.
Hierarchy	The elements in the design are different sizes, showing a clear hierarchy. The subway car map is the largest element, taking up the most space. It is placed near the top of the design after the legend, where viewers are automatically drawn to it and can start their reading there. The title "Passenger Safety and Emergency Evacuation Information" is the largest and most visible text.
Reading Flow	Unlike the previous materials, there is no strict reading flow. There is no wrong way to read this design since all the information is grouped appropriately. Most of the design follows a top to bottom and left to right reading flow, but it is not necessary for comprehension.
Grid	There appears to be an underlying grid since all the information and icons are consistently placed and spaced.

Elements of Design

Line	Lines are important to the formation of the icons and other visuals used in the design. To keep the icons simple but still recognizable, lines are used to include important details to each instruction, such as the windows on the subway doors, and curved lines to indicate sound waves or speaking, like in the icon telling riders to listen to the emergency intercoms.
Shape	Shapes are an important visual characteristic in the design. Every safety feature has a corresponding shape. A yellow circle indicates the emergency intercom while a yellow rectangle indicates an emergency alarm. An upside door triangle indicates an emergency door handle. Every action is separated by a white square with curved corners.
Form	There are no 3-D elements in the design.
Colour	The design uses a primarily black and colour scheme, in addition to red, yellow, and green to highlight critical actions in each group of icons. The symbols for the different exits are red, while the symbols for the alarm and intercom are yellow. Red is the colour that stands out the most against the black background.
Value	There is no indication of tonal value throughout the design. All the symbols and icons have a solid fill or are left as outlines, making them stand out against the background and increasing their recognizability.

Space	Although there is a lot of information in a small space, there is a large amount of negative space around each informational section.
Texture	The sign is made for long-term use in the subway, so it is printed on flexible and durable plastic. However, the signs encountered were ripped or broken in some capacity, affecting the signs readability.



DISCUSSION

Summary of Key Findings and Interpretations

The results of the observational study revealed the ways design concepts and elements are used to communicate messaging in crisis materials. Though the materials all look visually different from each other, they share commonalities.

Universal Symbols, Pictograms, Icons, and Illustrations

All the materials examined utilized a combination of visuals and text, although some relied more heavily on text to communicate their messaging. The design that used the least amount of text was the Air Canada flight safety card, which is almost entirely composed of drawings and icons to guide users. The design that contained the most text was the COVID-19 rapid self-test kit, which included paragraphs of text explaining the procedures in more detail to the user. While all the materials contained some text, it is important to note that the sentences used clear, concise, and impersonal language and were usually short and straightforward. This is most

notable in the kit insert for Naloxone, which featured short and straightforward instructions to the user, such as "speak loudly," and "tilt head back."

There was a lot of variety in the form of illustrations and style of icons used throughout the materials, many ranging from detailed illustrations and diagrams to simple and abstract icons. The designs that featured more detailed visuals were the Naloxone kit insert and the COVID-19 rapid self-test kit. More care was put into accurately representing critical tools within the procedures, such as the needle and the nasal swab. However, all visuals remained relatively simple and minimal. The flight safety card as well as the TTC subway map, used similar icons to those belonging to AIGA, specifically the gender-neutral human. Additionally, the TTC subway map featured other icons by AIGA, like the directional arrows. It was observed that the materials utilized a consistent style of imagery throughout their messaging.

Moreover, all the icons and visuals used were image-related and served as direct representations of an object or concept. The exception is the TTC subway map, which attached separate meanings to symbols and shapes. Since all the materials examined are print-based, the designs used arrows to simulate actionable steps and improve a user's understanding. This issue is also highlighted by Patton et al., 2015, which comments on how icons lack interactivity. Lastly, it was noted upon observation that the less detailed the imagery was the more difficult it was to decipher the meaning immediately. This observation aligns with the literature, which acknowledges the gap of understanding between the designer and their intended meaning, and the user's actual understanding (Patton et al., 2015). This was apparent in the TTC Subway map, such as in the case of the icon depicting "wait for subway ramp to open." This

icon depicts a scenario that users may be unfamiliar with, causing potential confusion. Overall, all materials used multiple symbols to clearly communicate their concepts and control their context, an action supported by the literature (Zender, 2022).

Intuitive Layout and Form

All materials used some form of grouping and chunking to organize their content, regardless of the amount of space and size of the actual printed product. The materials divided their content into steps or scenarios, and grouped drawings and text for user comprehension. Most icons were grouped together to depict a scenario or step in a procedure, and then placed inside a circle or rounded square to separate or contain them. Additionally, all materials employed a reading flow that guided readers, which depended on the primary orientation of the design. Lastly, the elements in the design were organized with some hierarchy. This was usually done through text, but in the case of the airline flight safety card, it was done through icons. Hierarchy was implemented using headings and subheadings to denote the order of information.

Elements of Design

Line and color were the most prominent and important elements in the materials examined. Line is used to determine the amount of detail present in the symbol or pictogram. As stated before, the materials presented a range of detailed to more abstract illustrations. The more detail a pictogram has, the more familiar it becomes to the user. This is referred to as icon concreteness, meaning the pictorialness of the icon or symbol (Collaud et al., 2022). However, there is also the question of visual complexity, which refers to the number of components in the image like the number of horizontal,

vertical, and diagonal lines (Collaud et al., 2022). The literature shows that visual complexity affects visual search, while icon concreteness affects access to meaning (Collaud et al., 2022). Next, it was observed that all the materials used simple colour schemes, with the majority primarily relying on a white background with bold colours, like red or blue to highlight important visuals. The exception is the TTC Subway map, which uses a black background. Another important observation is that hue was not used as the sole distinguishing factor throughout the message, a guideline presented by Rallos et al (2019) in AccessAbility 2. Red was used in some way throughout the designs, commonly to draw attention to critical information.

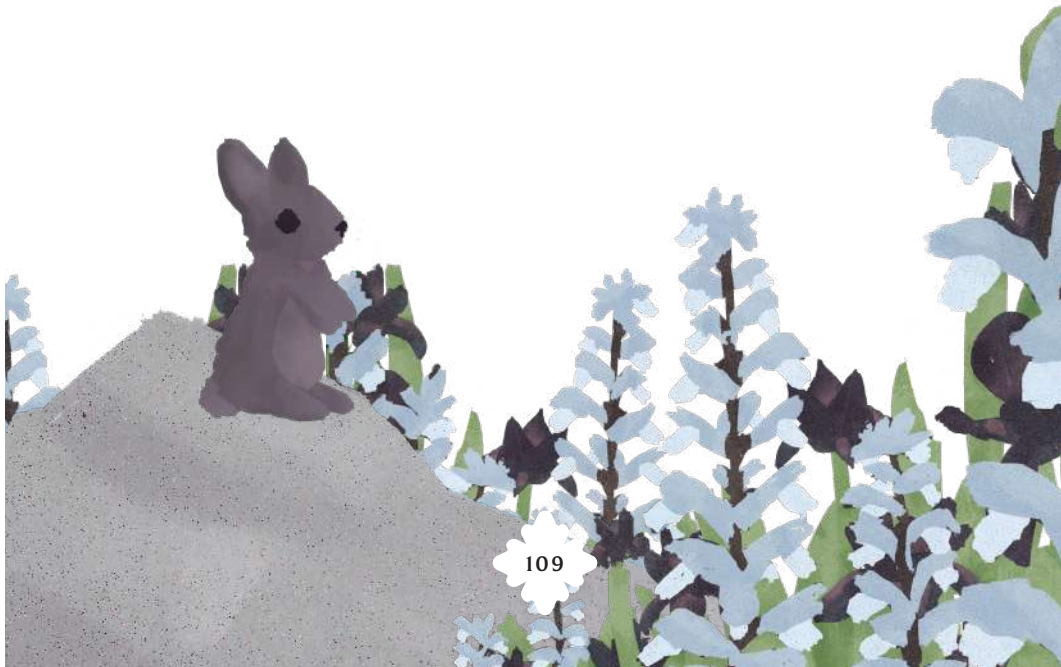
Implications

Ultimately, the key findings illustrate the importance of the situation the product may be used in and the target audience. This context should guide designers who are faced with the challenge of communicating in an accessible fashion. For example, regarding the Naloxone kit insert (Figure. 2), it is critical to keep in mind who will be using the kit and the level of training they may have. The less training the user has to address the situation, the more panicked and pressured they will feel during the health emergency. In this case, the placement and design of the visuals is critical. In Figure. 2 It is notable that the instructions are centered around human subjects, aiding visual understanding about how the drug should be delivered. In Figure. 3, the pictograms seem daunting since they primarily feature just a nose or hands. To highlight another example, the TTC subway signage, while designed using pictograms, is ineffective due to its placement within the train environment. The sign is placed too far away for any riders to comfortably read it, with the

text being too thin, too light, and small. Moreover, the pictograms appear too small and cannot easily be deciphered from a distance. On designs with text and visuals, text needs to be treated carefully in crisis messaging, since critical information may be missed out on if it is not conveyed through illustrations.

Recommendations

Based on the research conducted, instructional design is already using illustrations and pictograms alongside organizational methods to communicate messaging, but there is still a reliance on text to deliver critical information. As long as there is an overreliance on text, communication barriers will continue to be amplified. More research needs to be focused on the development of icons and pictograms for public messaging to reduce communication barriers, and how pictograms can be used for even more complex messaging. The issues highlighted in the literature continue to be relevant, especially the need for unambiguous iconography (Ramirez, 2018).



CONCLUSION

The findings of this thesis affirm that visual communication design is not merely an aesthetic endeavor but a crucial tool for accessibility and public safety in times of crisis. Across all four case studies, effective use of visual elements—particularly universal symbols, structured layouts, and purposeful color schemes—contributed to the clarity and accessibility of information. The research supports existing literature that emphasizes the importance of icon concreteness, intuitive organization, and inclusive design practices. However, it also reveals persistent challenges, such as the misinterpretation of abstract symbols and limitations in placement or readability. Ultimately, this study underscores the ethical responsibility of designers to consider context, user ability, and emotional states when crafting crisis communication tools. It calls for continued innovation, testing, and standardization in visual communication to ensure that critical messages reach and resonate with everyone, regardless of language proficiency or cognitive ability.

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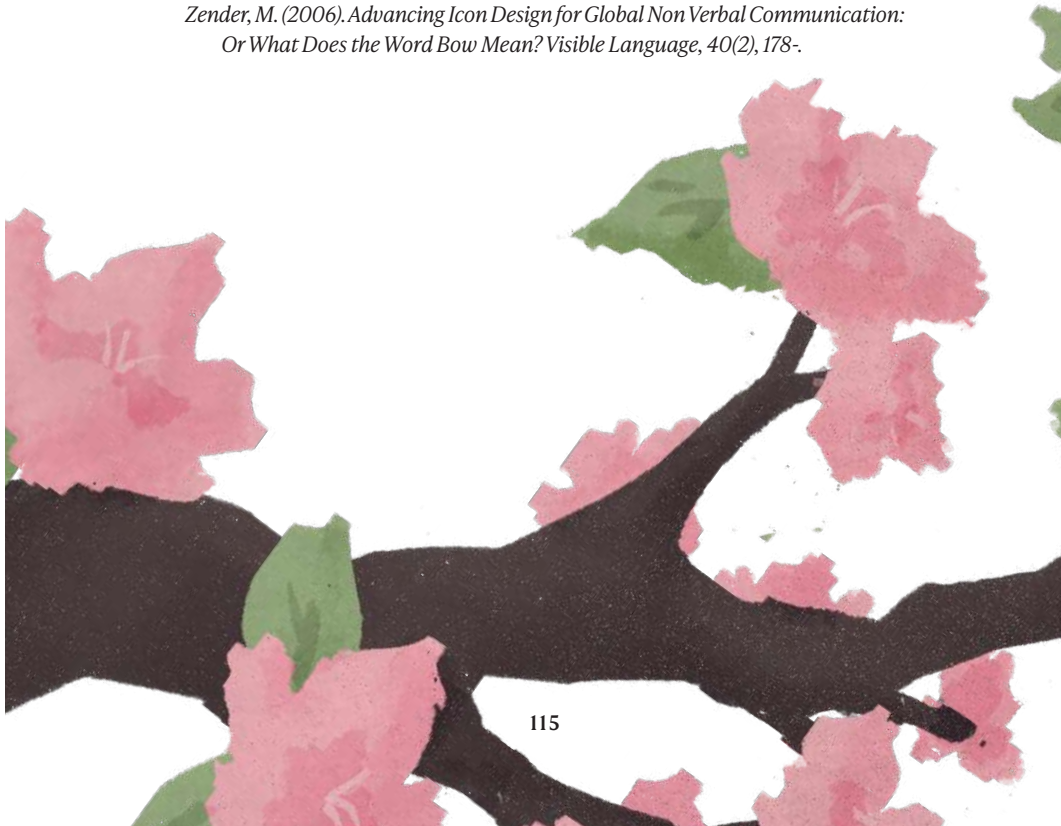
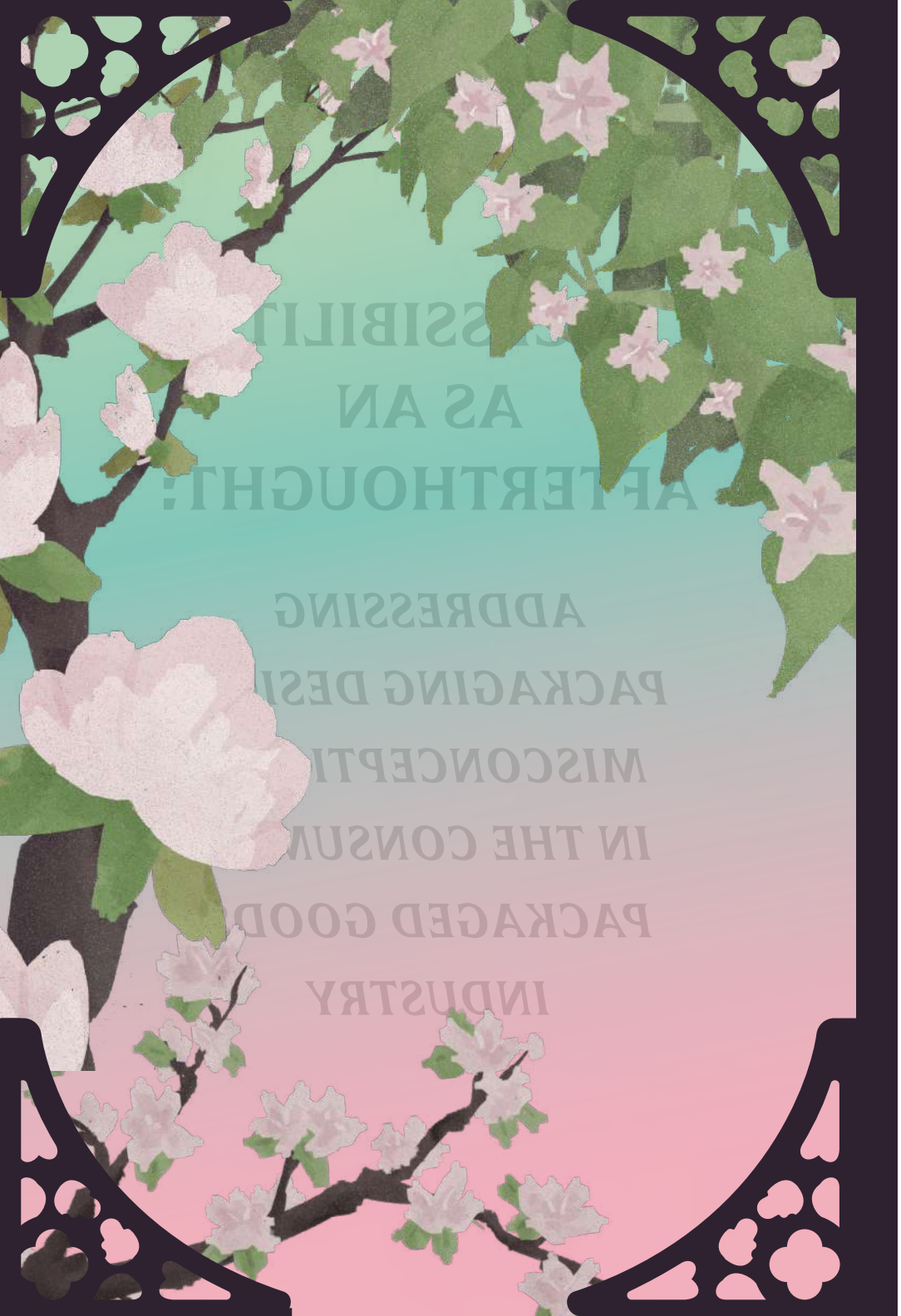


Umme Abiha | ***She/Her***

Umme Abiha is a recent graduate of the Graphic Communications Management program at TMU, with a concentration in Packaging and a minor in Communication Design. During her studies, she built a strong foundation in print and packaging through hands-on coursework and academic projects that explored various printing, finishing, and production processes. With a growing passion for packaging and print, Umme is particularly interested in the intersection of design, production, and accessibility within the industry. She is eager to continue developing her skills, gaining practical industry experience, and contributing to thoughtful, responsible packaging solutions as she begins her professional career.

ACCESSIBILITY AS AN AFTERTHOUGHT:

ADDRESSING PACKAGING DESIGN MISCONCEPTIONS IN THE CONSUMER PACKAGED GOODS INDUSTRY



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ABSTRACT

This thesis investigates the ongoing marginalization of accessibility in the Consumer Packaged Goods (CPG) industry, challenging the perception of accessibility as an afterthought. Despite its growing awareness and evolving legal frameworks, many CPG businesses continue to overlook inclusive design in packaging, often citing cost, time constraints, or competing business priorities. Through a mixed-method approach—combining primary research using Microsoft's Seeing AI app with an extensive literature review—this study evaluates the real-world performance of product packaging meeting the needs of consumers with disabilities. Eleven products across various CPG categories were assessed based on five accessibility criteria: recognition accuracy, text readability, contrast and font size, tactile features, and digital accessibility tools. While Seeing AI successfully identified all products, significant limitations emerged in its ability to relay complete product information, particularly where packaging lacked readability, tactile elements, or accessible QR codes. These findings reinforce that most CPG brands fail to meaningfully incorporate accessibility, aligning with the literature that highlights gaps in

corporate accountability, consumer trust and industry-wide implementation. This study concludes that accessible packaging is not only a legal and ethical responsibility, but also a strategic business opportunity. By shifting from reactive compliance to proactive inclusion, CPG companies can improve consumer autonomy, reduce long-term costs, and unlock untapped market potential.

List of Abbreviations

ACA . . . . . *Accessible Canada Act*

ADA . . . . . *Americans with Disabilities Act*

AODA . . . . . *Accessibility for Ontarians with Disabilities Act*

CPG . . . . . *Consumer Packaged Goods*

CFIA . . . . . *Canadian Food Inspection Agency*

CSR. . . . . *Corporate Social Responsibility*

EAA . . . . . *European Accessibility Act*

FPLA. . . . . *Fair Packaging and Labeling Act*

SKU . . . . . *Stock Keeping Unit*

INTRODUCTION

Accessibility in product packaging has become an increasingly important issue as public awareness and consumer expectations around inclusivity continue to grow. Despite this momentum, many companies in the Consumer Packaged Goods industry still treat accessibility as an afterthought. This is often driven by persistent misconceptions—namely, that implementing accessible design is too costly, too time-consuming, or simply incompatible with other business priorities. As a result, individuals with disabilities are frequently excluded from fully engaging with products that are essential to everyday life, perpetuating inequities in consumer access and reinforcing the false notion that accessibility is a niche concern.

These challenges are compounded by inconsistencies in global regulatory frameworks. In North America, laws such as the Americans with Disabilities Act (ADA) and the Fair Packaging and Labeling Act (FPLA) in the United States, along with the Accessible Canada Act (ACA) and Ontario's Accessibility for Ontarians with Disabilities Act (AODA), offer guidance on accessibility, but rarely impose mandatory standards specific to packaging design (Packaging Distributors

of America, 2024). Compliance is often voluntary and typically pursued only when companies are legally challenged or extrinsically motivated to align with corporate social responsibility goals. By contrast, the European Accessibility Act (EAA) establishes a more proactive approach, requiring companies to integrate accessible features into their product design to comply with clear legal expectations, and yet glaring deficiencies remain. These deficiencies highlight a global imbalance in how accessibility is prioritized—and reveal how, even in regulated markets, companies are more likely to act when accessibility aligns with profitability, public image, or reputational risk.

Given this context, this thesis explores the question: How do misconceptions about cost, time, and competing business priorities lead to accessibility being treated as an afterthought, and what strategies can firms adopt to address these challenges in the CPG industry? Through a mixed-methods approach—combining observational fieldwork using the Seeing AI app with secondary research from academic and industry sources—this study evaluates current packaging practices and investigates the disconnect between inclusive intent and execution. In doing so, it seeks to identify practical, scalable strategies that companies can adopt to embed accessibility into the core of their product development processes. Ultimately, this research repositions accessibility not merely as a matter of compliance or social obligation, but as a critical opportunity for innovation, consumer engagement, and long-term growth in the CPG sector.

LITERATURE REVIEW

Accessibility remains a significant, yet often neglected, aspect of the Consumer Packaged Goods industry. Misconceptions surrounding cost, time constraints, and competing business priorities contribute to accessibility being treated as an afterthought. This literature review synthesizes existing research on accessibility challenges, consumer impact, and business strategies, revealing gaps in the current discourse and opportunities for improvement.

Cost Misconception: Financial Implications of Accessibility Neglect

One of the most pervasive misconceptions is that accessibility enhancements are prohibitively expensive. However, research suggests otherwise. Forbes reports that retailers collectively lose billions due to poor accessibility, indicating that inaccessibility results in significant revenue loss. Some key findings mentioned were that 65% of consumers with disabilities reported that their purchasing choices were limited every day by obstacles, while 43% indicated that they left an online or in-store purchasing task early due to a shortage of information, limiting accessibility (Alexiou, 2022). Sloan expands on this, emphasizing that in addition to the immediate loss of market share, there comes the potential for legal risks and future redesign costs. In fact, Sloan reports that accessibility lawsuits have been steadily increasing since 2017 when over 800 were recorded. In 2022, that figure had risen to over 3,200, signalling heightened legal scrutiny of accessibility compliance. Hence, it was reported that the trend can only be expected to continue,

highlighting the merit of forward thinking design choices by CPGs to minimize future liabilities and redesign costs attributed to accessibility (Sloan, 2023).

For greater context, a recent McKinsey & Company article presents a dual agenda for the Consumer Packaged Goods industry, advocating for balancing financial constraints with sustainable accessibility investments. Their article identifies industry trends that demonstrate how companies that prioritize accessibility achieve long-term financial benefits. Building on this, it is important to understand the broader shifts within the CPG industry that reinforce the need for sustainable investments like accessibility. Once considered a reliable growth engine, the CPG sector has seen its traditional strategies lose effectiveness over the past decade. From the 1980s through 2012, CPG companies experienced steady growth by building strong brands, expanding into growing markets, and maintaining cost efficiency. However, starting in the 2010s, that formula began to falter. Slowing population growth, retailer consolidation, and increasingly fragmented consumer preferences caused revenue growth to drop significantly; averaging just 2% annually from 2012 to 2019 as seen in Figure 1. In response, many companies focused on cost-cutting measures rather than innovation or consumer-centric investments such as accessibility considerations (Moulton, et al., 2024).

This trend of cost-cutting measures was further intensified by the COVID-19 pandemic and recent inflationary pressures, which led to margin compression and a decline in product volumes. In this evolving landscape, CPG brands must rethink their priorities. As McKinsey & Company suggests, balancing short-term financial pressures with long-term, sustainable strategies, such

as accessibility, can help restore growth and unlock new market opportunities. In other words, accessibility is not just a moral or legal imperative; it is an innovative, forward-thinking investment in a time when traditional growth models are no longer guaranteed (Moulton, et al., 2024).

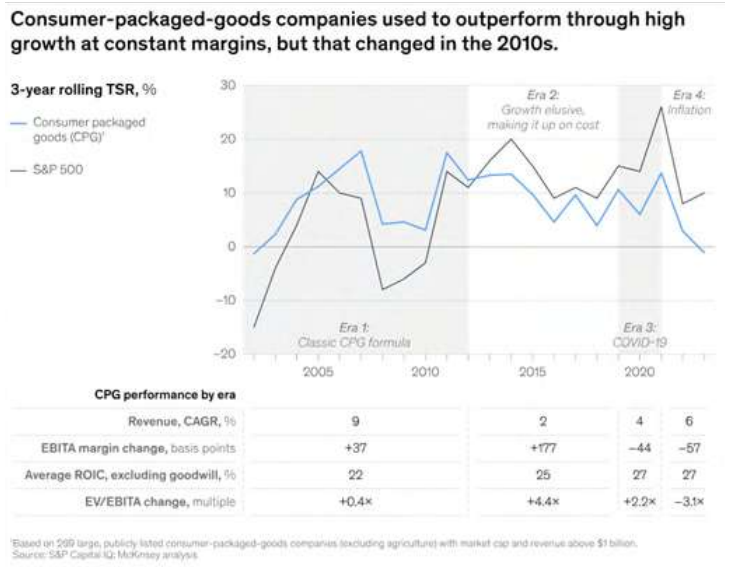


Figure 1. From Outperforming to Underperforming. Graph of CPG performance grabbed from McKinsey & Company (Moulton, et al., 2024).

Additionally, The Retail Touchpoint estimates that CPG businesses lose more than $6.9 billion annually due to inaccessibility, highlighting the direct economic impact of overlooking accessibility measures (Gevorkian, 2024). Despite this, companies

continue to resist accessibility improvements, viewing them as secondary priorities (Omari, 2022). The World Economic Forum supports this claim, emphasizing that inclusive product design not only increases customer loyalty, but also creates market differentiation. They also revealed that 66% of consumers are prepared to pay extra for products made by companies that are committed to good social causes (Girkar, 2024).

Beyond legal risk, accessibility also offers a huge opportunity in the CPG business. It is estimated that between 15% and 25% of the U.S. population has some form of disability, and worldwide, the number is approximately one billion people (Sloan, 2023). The economic influence of this segment is significant; in the US alone, individuals with disabilities collectively have $490 billion in purchasing power. On a global scale, this market represents over $13 trillion in disposable income. Research shows that when factoring in the purchasing power of friends and family, accessibility issues extend into a bigger market of 3.3 billion consumers, and impact the buying decisions of 73% of international consumers (Sloan, 2023).

The evidence above concludes that accessibility is not just an ethical consideration, but a business imperative. CPG companies that do not take notice of accessibility are courting mounting legal risks, significant revenue opportunities, and costly reworks. Studies identify that customers with disabilities tend to forgo purchases due to accessibility barriers, worth billions of dollars in lost sales. Meanwhile, lawsuits against inaccessible companies have also increased, highlighting the cost of noncompliance. However, businesses that actively invest in accessibility bring in increased customer trust, market differentiation, and profitability in the long term. Research shows that inclusive design is not an extra cost, but a source of competitiveness. With more customers

willing to prefer brands that are socially responsible, accessibility is not only a question of compliance with the law, but also a key to business success.

The Time Constraint Myth: Perceived Barriers to Implementation

Another key barrier is the assumption that implementing accessibility measures in CPG business is time-consuming. Husemann, Zeyen, and Higgins analyze marketplace accessibility from a service-provider perspective, revealing that companies struggle with integrating accessibility into existing workflows (Husemann, Zeyen, & Higgins, 2023). Their study suggests that a lack of clear industry guidelines often delays accessibility improvements rather than the implementation process itself. Additionally, research from The World Economic Forum suggests that designing for accessibility from the outset reduces delays and minimizes costly retrofits (Girkar, 2024). This highlights that workflow efficiency is best achieved through a proactive approach—embedding accessibility from the outset not only streamlines implementation, but prevents delays and costly retrofits, ultimately making inclusive design a smarter and more sustainable long-term strategy.

Moreover, research from Sloan and Gevorkian highlights that proactive accessibility strategies streamline production processes and foster brand loyalty (Sloan, 2023; Gevorkian, 2024). Buddeejeen and Kengpol's research also supports this by demonstrating that incorporating accessibility at the beginning of product development leads to more efficient outcomes (Buddeejeen & Kengpol, 2018). Their study of accessibility in consumer products found that early intervention minimizes design changes and production costs

later in the process. Molin emphasizes the importance of usability testing with consumers with disabilities to reduce redesign efforts, highlighting that brands can avoid last-minute regulatory compliance issues by involving users with disabilities in early development phases (Molin, 2024).

Ultimately, the belief that accessibility slows down production is not supported by evidence. Instead, the real challenge lies in the lack of early planning and the absence of clear industry standards. The research makes it clear that when accessibility is considered from the beginning—rather than being treated as an afterthought—it not only improves product usability, but also streamlines development and reduces costly delays later on. Involving users with disabilities early in the design process can prevent redesigns, support compliance, and foster more thoughtful innovation. What emerges is not a story of accessibility as a burden, but rather one of missed opportunity—where businesses could gain efficiency, trust, and competitive advantage by simply rethinking how and when accessibility is prioritized.

Competing Business Priorities: The Perceived Antagonist to Accessibility

When it comes to CPG businesses, they tend to prioritize product innovation and promotion over accessibility compliance. Research from Goodrich suggests that consumers with disabilities are typically provided with lower-quality services due to corporate prioritization of mainstream consumers' needs (Goodrich, 2024). Eskytė concurs, noting that consumers with disabilities in the EU market are often disadvantaged due to inaccessible label information, which negatively impacts both purchasing decisions, and

product usability (Eskytė, 2019). While the European market is generally considered more progressive in accessibility efforts compared to North America, significant gaps remain, pointing to a global issue. Despite various initiatives, research shows that many EU countries still lack comprehensive and enforceable legislation mandating accessibility in consumer packaging. Reports by the European Court of Auditors and other watchdogs reveal that accessibility outcomes across the EU remain limited, with inconsistent implementation and a lack of binding standards preventing meaningful change (European Court of Auditors, 2023). This indicates that even in regions considered to be "ahead," the absence of strong legislative frameworks continues to hinder equal consumer access and inclusive design.

Likewise, Conn, Abisla, and Batra provide a comparison framework for CPG packaging designs with enhanced accessibility. Their study reveals that firms typically have non-standard structures, leading to varied implementation (Conn, Abisla, Batra, 2022). Additionally, Jenkins' and Cummings' articles provide consumer feedback, which states that CPG businesses neglecting accessibility will alienate a significant portion of their customers (Jenkins, 2024; Cummings, 2022). Furthermore, Wight's report points out that CPG businesses that do not incorporate accessibility into their go-to-market strategy stand to lose their competitive edge, especially in recent years when consumer expectations turn towards inclusivity (Wight, 2024). All-in-all, despite previous studies on inclusive design with CPG businesses (Marshall & Lenz, 2025), there is still a gap in company adoption strategies and accountability measures.

In addition, Jenkins reports that many businesses claim to support accessibility, but fail to implement meaningful changes (Jenkins, 2024). Similarly, this is further echoed by Smith, who identifies digital accessibility failures that contradict corporate messaging.

Their report outlines three common accessibility mistakes companies make: failing to provide alternative text for images, inadequate colour contrast, and inaccessible website navigation (Smith, 2025). These recurring shortcomings not only undermine consumer trust, but also reflect a broader trend within the CPG industry, where accessibility in packaging design is also often overlooked or inconsistently applied, revealing a disconnect between stated values and practice.

In connection, Gale's study further discusses how brands may superficially embrace inclusivity without investing in substantive changes. Their research highlights that accessibility marketing often lacks measurable follow-through, reducing consumer trust (Gale, 2023). Additionally, while some studies focus on regulatory frameworks, there is limited research on corporate accountability regarding accessibility claims (Lazar, 2019; Marshall and Lenz, 2025). The Journal of Consumer Policy (Eskytė, 2019) explores legal protections, but highlights gaps in enforcement, suggesting the need for stronger oversight in ensuring brands fulfill their accessibility commitments in the CPG industry.

Several studies propose strategies to integrate accessibility into the CPG industry. For instance, Molin advocates for user-centred design methodologies, emphasizing that collaboration with consumers with disabilities leads to more effective solutions (Molin, 2024). Their findings indicate that co-designing with users with disabilities not only improves accessibility, but also enhances overall product usability for all consumers. This approach is especially relevant for the CPG industry, where involving end users in the design of packaging can lead to more inclusive, functional, and widely accessible products that better serve diverse consumer needs.

Building on this, Manson's GWP industry guide outlines

actionable steps for creating accessible packaging, supported by case studies of brands that have successfully implemented inclusive design (Manson, 2024). Similarly, McKinsey & Company emphasizes that when businesses embed accessibility into their core strategies, they not only strengthen their brand reputation, but also unlock opportunities for market growth and reduce the risk of legal challenges (Moulton, Exarchos, & Teichner, 2024). These insights underscore the clear strategic benefits for CPG companies that prioritize accessibility in both design and operations.

Additionally, Wight emphasizes the importance of placing accessibility at the core of both digital and physical go-to-market strategies, suggesting that brands attuned to these needs are better positioned to succeed across retail channels (Wight, 2024). Similarly, Gale highlights accessible packaging as a potential competitive advantage in an increasingly inclusive consumer market, where demand for socially responsible brands continues to grow (Gale, 2023). However, the limited adoption of these practices across the CPG sector reveals a significant gap between emerging consumer expectations and widespread industry implementation.

Regulatory Frameworks: Proactive Disregard vs Reactive Reality

Across North America, regulatory frameworks play an influential, but largely non-compulsory role in shaping accessibility practices in packaging. In the United States, legislation such as the ADA and FPLA provides broad guidelines for inclusive labelling and communication. However, these laws are not specific to packaging formats, and enforcement typically only occurs when companies face legal complaints or civil litigation. Canada's ACA and Ontario's AODA

present similar limitations. While these laws advocate for inclusive design principles and establish general accessibility targets, they do not impose consistent, sector-wide standards for packaging within the CPG industry (Marshall & Lenz, 2025). As a result, many companies can view compliance as a reactive necessity—implemented only when required by law or when doing so serves branding or CSR interests.

This reactive posture stands in sharp contrast to the European approach. The EAA, which applies to both physical and digital goods and services, explicitly mandates that companies design consumer products and interfaces that are accessible to people with disabilities. Its proactive nature compels businesses to embed accessibility into their product development cycles, rather than treating it as a retroactive fix. Consequently, European firms face greater pressure and clearer incentives to integrate inclusive design at every level of the product experience (Packaging Europe, 2023).

The disparity between these regulatory environments highlights a critical tension: neither North America, nor Europe are immune to gaps in accessibility. The absence of enforceable, packaging-specific mandates allows accessibility to remain optional, supporting the broader misconception that it is secondary to other business goals. In many cases, as noted in Packaging Europe, companies adopt accessibility measures not because they are altruistically motivated, but legally bound to implement and recognize the growing consumer demand for inclusivity and the reputational benefits it can bring (Packaging Europe, 2023). Accessible packaging, when intrinsically implemented, therefore becomes a powerful tool for brand differentiation, consumer loyalty, and market expansion—especially amidst the weight of evolving consumer expectations.

Similarly, Packaging Strategies emphasizes that the future of

packaging hinges on brands' ability to serve diverse user groups through inclusive design. The article argues that while legislation remains an important driver, it is the shift in consumer expectations and business innovation that will ultimately push accessibility forward. From easy-to-open formats to tactile indicators and QR codes with screen-reader-friendly content, brands that invest in accessibility are not only meeting compliance expectations, but are positioning themselves as leaders in consumer trust and modern brand strategy (Bach, 2020).

Taken together, these insights suggest that while regulation provides an important foundation, it is insufficient on its own to drive widespread change. Moreover, where enforcement mechanisms remain subverted, there is an inherent opportunity to emphasize educating businesses about the commercial and social advantages of accessibility. By framing accessibility as a moral imperative that drives tangible returns, stakeholders can help shift industry mindsets away from minimum compliance and toward proactive, consumer-centred design.

Summary of Literature

The literature review collectively demonstrates that accessibility in the Consumer Packaged Goods industry is frequently deprioritized due to persistent misconceptions about cost, assumptions about time constraints, and the tendency for businesses to prioritize other objectives. Despite heightened awareness, most companies continue to view accessibility as an afterthought, not only disenfranchising a significant percentage of the consumer base, but also putting businesses at risk of legal, financial, and reputational harm. While existing research outlines numerous strategies—such

as user-centred design, early integration, and digital innovation—there is still a notable lack of corporate accountability, consistent implementation, and consumer confidence in accessibility claims. These gaps underscore the need for a shift from reactive compliance to proactive inclusion. This review lays the groundwork for future research that could evaluate the effectiveness of current regulatory measures, assess the sincerity and impact of brand accessibility initiatives, and explore scalable, industry-wide approaches for embedding accessibility into mainstream packaging design.

METHODOLOGY

This research employs a mixed-methods approach with primary and secondary research to investigate accessibility challenges in the Consumer Packaged Goods industry. By employing both qualitative and quantitative methods, this research aims to analyze the performance of existing accessibility tools and recommend ways to promote inclusivity.

Primary Research

Primary research will be obtained through the conduction of an observational study within supermarket aisles, where the Seeing AI app will be used to evaluate how much accessibility tools assist consumers with visual impairments. The research aims of this study include:

- To assess the accuracy and effectiveness of Seeing AI in identifying product information.
- To evaluate the accessibility of product packaging based on digital scanning capabilities.
- To determine potential improvements in technology and product design to enhance accessibility.

Procedure

1. Visit the grocery store and select a variety of packaged goods from different brands.
2. Use the Seeing AI app to scan product labels and packaging.
3. Document findings on the clarity, accuracy, and completeness of the information provided by the app.
4. Compare results across different products and brands to identify patterns and gaps in accessibility.
5. Analyze how well these tools integrate with existing consumer needs and whether improvements are necessary.

Secondary Research

Secondary research will complement the main study by sifting through the literature available, industry reports, and regulatory policies governing accessibility in the CPG industry. The main sources are:

- Academic literature on packaging design accessibility issues and solutions.
- Advocacy groups' reports for more inclusive consumer experiences.
- Existing policies and regulatory measures by governmental and regulatory authorities on accessible packaging.
- Examples of case studies of successful brands that have embraced accessibility-friendly features.

Tools & Techniques

The tool used in this research is called Seeing AI, an application developed by Microsoft. It is a shared assistive technology that helps blind consumers identify objects, read text, and recognize product names. The app will be evaluated based on:

- Precision – How much it captures and provides product details.
- Usability – How easy it is to navigate and interact with consumers with disabilities.
- Limitations – Any functionality shortcomings which can impact consumer experience.

Data Collection and Analysis

- Qualitative Analysis: Observations from the grocery store study will be documented to understand user experience and identify recurring accessibility barriers.
- Quantitative Analysis: Data will be collected on the frequency of inaccurate or incomplete product information detected by Seeing AI, providing measurable insights into accessibility gaps.
- Comparative Analysis: Findings from primary research will be compared with secondary sources to highlight discrepancies and validate trends.

Justification for Methods and Tools

The selected methodology allows for a holistic understanding of accessibility in CPG packaging. Primary research provides real-world insights into the functionality of assistive technologies, while secondary research ensures a comprehensive review of existing knowledge and industry standards. The Seeing AI app was chosen due to its prominence in accessibility solutions, making it a relevant tool for evaluating digital assistive technology in the consumer space.

Expected Results

This study anticipates the following outcomes:

- Identification of key limitations in current accessibility tools, such as Seeing AI.
- Insights into how brands can better integrate accessibility technology into their packaging strategies.
- Recommendations for policymakers and businesses to improve accessibility compliance in the CPG industry.

By employing a combination of primary observation and secondary analysis, this research aims to provide a detailed evaluation of accessibility challenges in product packaging. The findings will contribute to developing actionable strategies for brands to enhance inclusivity and consumer experience for individuals with disabilities.

RESULTS

Upon numerous store visits, eleven key products were strategically chosen to accurately represent the 3,000 to 5,000 CPG SKUs featured in the average-sized mid-market Canadian grocery retailer. This study was conducted on-site at Toronto-based No Frills store #3771 spanning different products (See Figure 8 in the Appendix) across the retailer's featured categories of CPG goods including food, personal care, pharmaceuticals, and household items. To evaluate the accessibility of each consumer-packaged goods, five core criteria were used: recognition accuracy via the Seeing AI app, readability of on-package text, contrast and font size, presence of tactile features (such as Braille or ergonomic elements), and the inclusion of digital accessibility tools like QR codes or NFC tags. These criteria were selected to reflect both functional and assistive elements of packaging design that impact consumers with visual impairments. A summary of these evaluation metrics is presented in Table 1.

Metric	Description	Data Collection Method	Notes/ Observations
Recognition Accuracy	Does Seeing AI correctly identify the product name, brand, and type?	Seeing AI test	☑ Yes / ☒ No (If no, note errors)
Readability of Text	Does Seeing AI read aloud key product info (ingredients, warnings, instructions)?	Seeing AI test	☑ Yes / ☒ No (List missing details)
Contrast & Font Size	Does the text meet ACA guidelines for contrast and readability?	Visual Inspection	Score: 1 (poor) – 5 (excellent)
Tactile Elements	Does the package include braille or embossed elements?	Physical Assessment	☑ Yes / ☒ No
Digital Accessibility Tools	Does the package include accessible digital options?	Scan with Smartphone	☑ Yes / ☒ No (Note functionality)

Table 1. This table outlines the criteria used to evaluate the accessibility of Consumer Packaged Goods.

AI Recognition Accuracy

The Seeing AI app successfully identified all eleven products included in the study, demonstrating consistent performance in object and brand recognition as shown in Figure 2. This suggests that the app is effective for basic identification tasks, such as recognizing product names and general packaging features. However, as

reflected in Table 2 (pg. 146), the tool struggled to extract deeper product information, particularly when the contrast was low or the text was too small. This limitation reinforces findings in the literature, which suggest that while current assistive technologies may address surface-level accessibility needs, they often fail to support full consumer autonomy, especially during complex decision-making processes (Sloan, 2023). The data below highlights the need for more accessible packaging that works in tandem with assistive technologies to deliver complete and usable information.

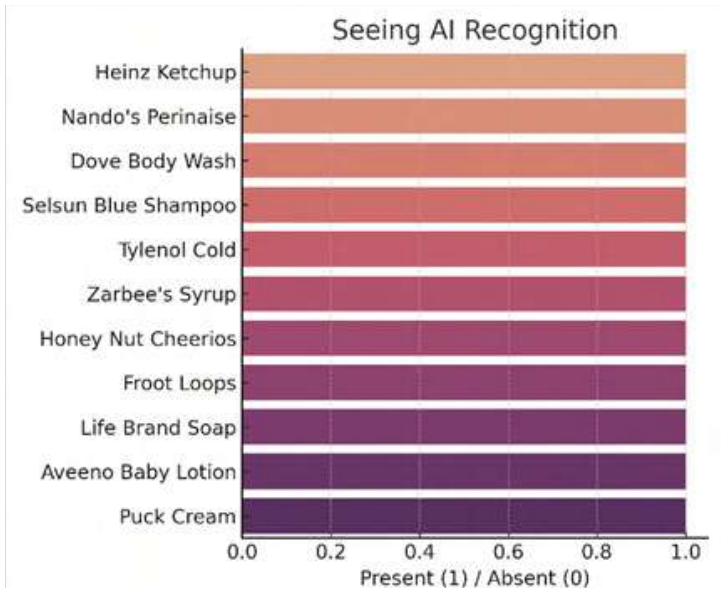


Figure 2. Seeing AI's Effectiveness in Identifying Product Packaging. The figure shows the number of correctly identified products across five categories and eleven products.

Category	Brand	Product Name	Packaging Type	Seeing AI Recognition (☑/☒& Notes)	Text Readability (☑/☒& Missing Info)	Contrast & Font Size (1–5 Score)	Braille/Tactile Elements (☑/☒)	Digital Accessibility Tools (☑/☒ & Notes)
Food	Heinz (Figure 9)	Ketchup Bottle	Plastic Bottle	☑ Correctly Identified	☒ Missing Ingredients	3 (Average)	☒ No Braille, ☑ Ergonomic Shape	☒ No QR Code
Food	Nando's (Figure 10)	Nando's Perinaise	Plastic Bottle	☑ Correctly Identified	☒Missing Ingredients	3 (Average)	☒ No Braille, ☑ Ergonomic Shape	☒ No QR Code
Personal Care	Unilever (Dove) (Figure 11)	Body Wash	Plastic Bottle	☑ Correctly Identified	☑ Readable	3 (Average)	☒ No Braille	☑ QR Code with product info
Personal Care	Selsun Blue (Figure 12)	Anti-dandruff Shampoo	Plastic Bottle	☑ Correctly Identified	☑ Readable	2 (Poor)	☒ No Braille, ☑ Ergonomic Shape	☑ QR Code, but not accessibility-focused
Pharmaceuticals	Tylenol (Figure 13)	Extra Strength Cold Daytime & Nighttime Tablets	Box & Blister Pack	☑ Correctly Identified	☑ Readable	3 (Average)	☒ No Braille	☒ No QR Code
Pharmaceuticals	Zarbee's (Figure 14)	Immunity Syrup	Plastic Bottle with security/ tamper seal	☑ Correctly Identified	☑ Readable	3 (Average)	☒ No Braille	☒ No QR Code
Boxed Cereal	General Mills (Figure 15)	Cereal Box	Cardboard Box	☑ Correctly Identified	☑ Readable	3 (Average)	☒ No Braille	☒ No QR Code
Boxed Cereal	Kellogg's (Figure 16)	Cereal Box	Cardboard Box	☑ Correctly Identified	☑ Readable	3 (Average)	☒ No Braille	☒ No QR Code
Pump bottles	Life Brand (Figure 17)	Liquid Hand Soap	Plastic Pump Bottle	☑ Correctly Identified	☒ Hard to read	2 (Poor)	☒ No Braille	☒ No QR Code
Pump bottles	Aveeno Baby (Figure 18)	Calming comfort Lotion	Plastic Pump Bottle	☑ Correctly Identified	☑ Fully Readable	4 (Good)	☒ No Braille	☒ No QR Code
Canned Food	Puck (Figure 19)	Thickened Creamy Product	Aluminum Can	☑ Correctly Identified	☒ Hard to read	2 (Poor)	☒ No Braille	☒ No QR Code

Table 2. Note. This table summarizes findings from the Seeing AI recognition study, including product identification accuracy, readability of packaging text, visual contrast, presence of tactile elements, and availability of digital accessibility tools. All referenced product images (Figures 3–13) are included in the Appendix.clear that

Text Readability and Information Gaps

Despite correct identification, four out of eleven products had issues with text readability as visible in Figure 3; this was either due to poor contrast, small font sizes, or cluttered design. These findings are consistent with Eskytė's research, which found that consumers with disabilities often face obstacles related to unreadable or insufficient product information (Eskytė, 2019). For consumers with visual impairments, missing ingredients or usage instructions can pose both safety risks, and a barrier to independent purchasing decisions.

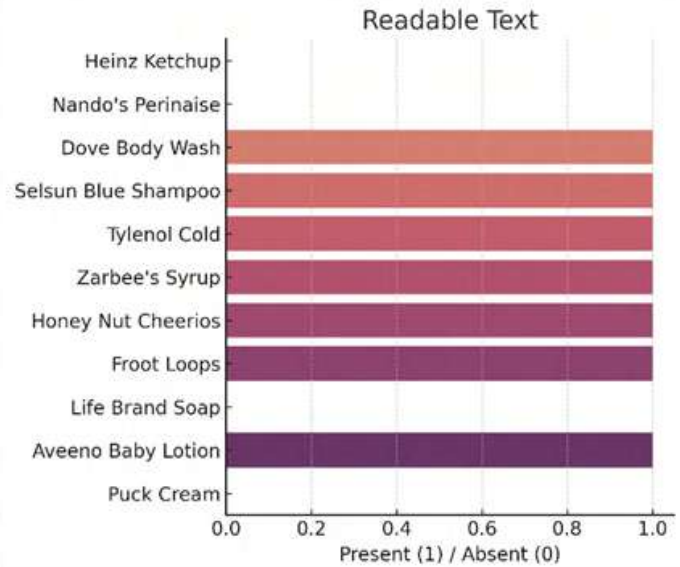


Figure 3. Chart Displaying Seeing AI Text Readability Findings. This figure illustrates the app's ability to read and interpret product text, including brand names, ingredients, and other packaging information.

This research reinforces the notion that product design continues to prioritize aesthetic and branding elements over clarity and legibility, a trend noted in Goodrich's critique of corporate priorities (Goodrich, 2024).

Contrast and Font Size

The average score for contrast and font legibility was three out of five across products as shown in Figure 4 below, with only one product, the Aveeno Baby Lotion, scoring above average (See Figure 18 in the Appendix). Low-contrast text and insufficient font sizing were especially problematic on darker bottles or metallic packaging, such as Selsun Blue Shampoo and Puck Cream as seen in Figure 19 and 12 in the Appendix.

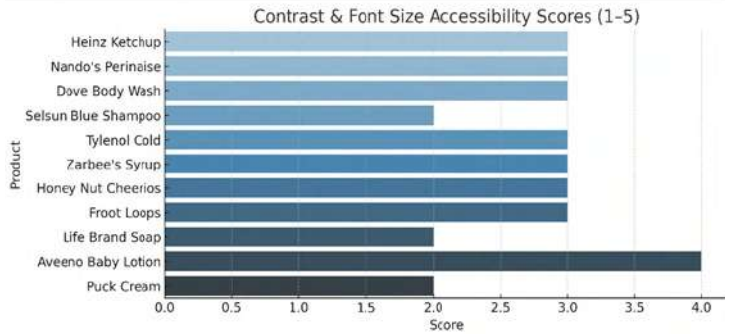


Figure 4. Chart Displaying Contrast and Font Size Accessibility Scores Found in the Study. This figure highlights the evaluated scores (on a scale of 1 to 5) for contrast and font size across a selection of Consumer Packaged Goods, based on visibility and readability criteria relevant to users with visual impairments.

These results echo Cummings' argument that many companies lack awareness of accessibility design guidelines, especially in visual communication (Cummings, 2022). In the literature, Molin emphasizes that user testing with consumers with disabilities could preempt many of these design issues (Molin, 2024). Yet, based on product performance, it is clear that few brands incorporate these feedback loops into the development process. This reality is underpinned by the lack of advancement in this area, given the ten years that have passed since the Canadian Food Inspection Agency's (CFIA's) 2015 Food Labelling Modernization industry stakeholder consultation which first raised many of the accessibility concerns that persist today (Canadian Food Inspection Agency, 2015)..

Tactile Accessibility

As seen in Figure 5, not a single product included Braille or any tactile indicators, reinforcing the neglect of this accessibility layer across mainstream Consumer Packaged Goods.

This observation aligns with Jenkins' report on the disconnect between corporate messaging and real-world implementation of accessibility practices (Jenkins, 2024). Although some products featured ergonomic shapes (See Figure 6), these did not serve blind or low-vision consumers directly and are more aligned with general usability. Furthermore, as highlighted in the literature by Buddeejeen and Kengpol, early-stage integration of tactile elements can reduce production costs and improve inclusivity without major redesigns (Buddeejeen & Kengpol, 2018). Their absence in every sampled product suggests that most brands are still operating under the false assumption that accessibility features are expensive or nonessential (Alexiou, 2022; Sloan, 2023).

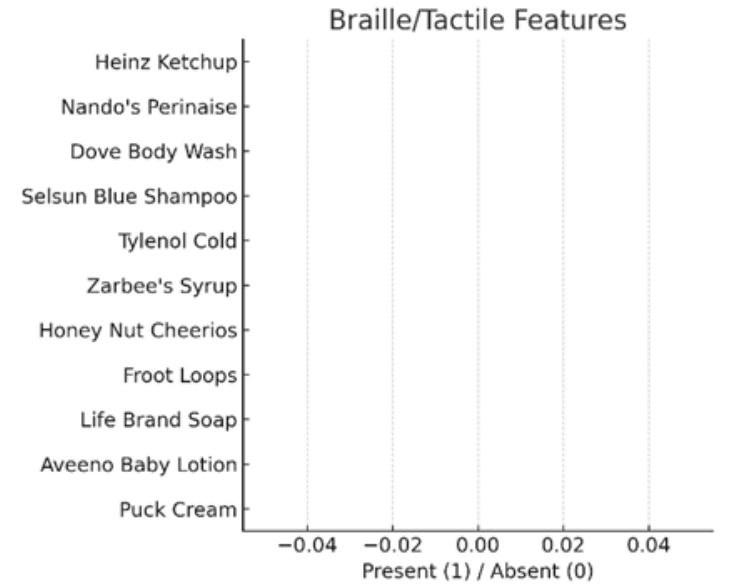
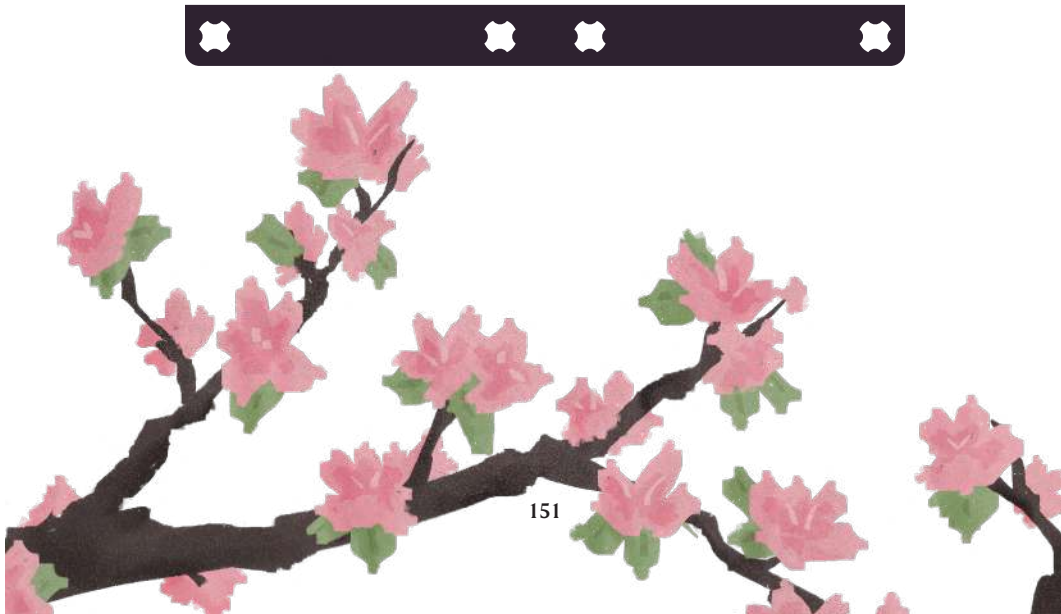


Figure 5. Chart Displaying Presence of Braille and Tactile Features on CPG During Study. This figure illustrates that none of the evaluated Consumer Packaged Goods included braille or tactile accessibility features, indicating a complete lack of such considerations across all product categories analyzed in the study



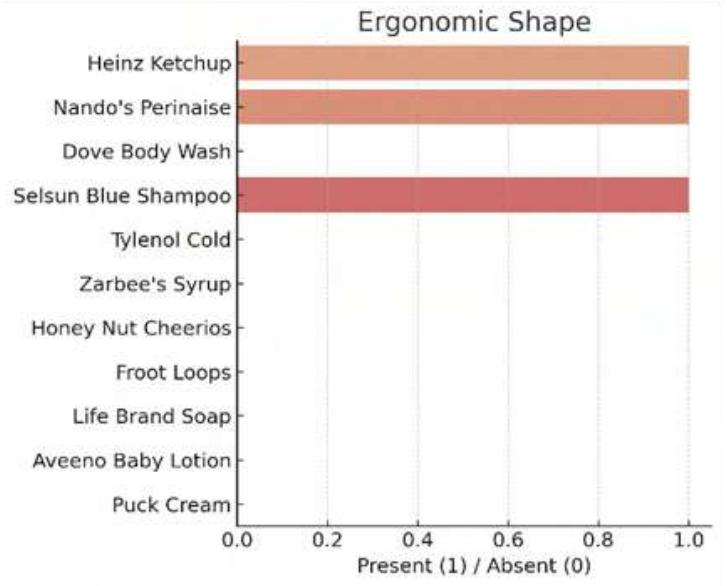


Figure 6. Chart Displaying Presence of Ergonomic Packaging Shapes Identified in the Study. This figure shows that three products included ergonomic design features intended to enhance grip or usability.

QR Codes and Digital Accessibility

Per the research, only two out of eleven products featured QR codes as seen in Figure 7, and none provided content specifically geared toward accessibility. This presents a missed chance for brands to bridge the information gap with technology

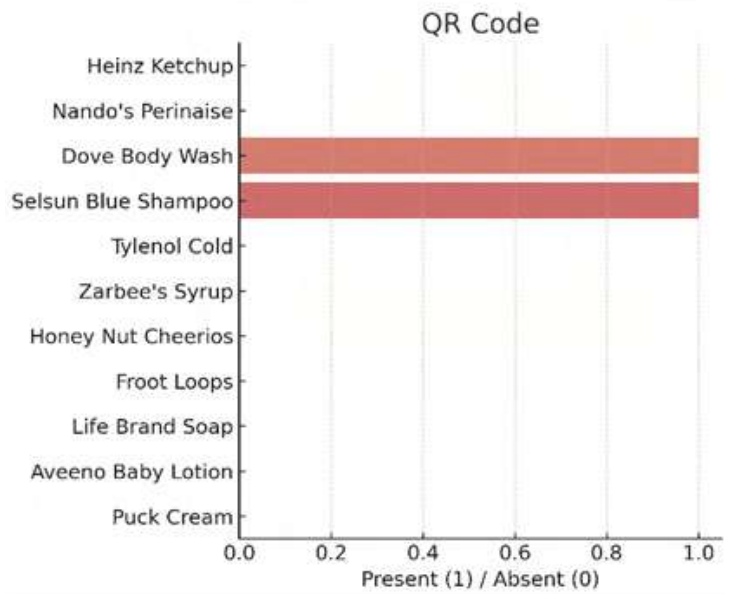


Figure 7. Chart Displaying Presence of QR Codes on Product Packaging During Study. This figure shows that only two of the evaluated products included QR codes. However, neither code was specifically designed for accessibility purposes, highlighting a missed opportunity to enhance digital access.

Dove Body Wash (See Figure 11 in the Appendix) was the sole product whose QR code led to supplemental product information; however, its utility was largely marketing-centric, and lacked the audio guides, multilingual options, or structured navigation features expected for accessible packaging. This finding reaffirms the findings Smith (2025) and Gale (2023) presented in the literature review that accessibility is often superficially addressed, if at all. While QR codes could serve as a powerful bridge between analog packaging

and digital content, their potential remains unrealized due to poor execution and a lack of accessibility-specific optimization.

Summary of Results

Overall, the results of this study reveal consistent and significant accessibility gaps across Consumer Packaged Goods in multiple product categories. While the Seeing AI app proved effective in identifying all eleven products, it struggled to read detailed information in cases where packaging lacked sufficient contrast, font size, or clarity. Text readability problems existed in almost a quarter of the tested products, with some not even showing vital product information such as ingredients or instructions on use. The average score for contrast and font size was middling, reinforcing concerns that visual design often overshadows functional accessibility in the CPG industry. Most notably, none of the products included Braille or any tactile elements, despite well-documented recommendations for early-stage integration of such features. Although two products included QR codes, none delivered accessibility-oriented content, highlighting a missed opportunity for digital inclusion. These findings collectively support the broader critique identified in the literature review: that accessibility in the CPG industry is frequently treated as an afterthought, despite the availability of effective tools, clear consumer demand, and proven long-term benefits. The observational data presented across all criteria reinforce the need for systemic changes to packaging accessibility regulations and enforcement, effectively motivating CPG businesses to provide more inclusive, user-centred approaches that prioritize accessibility from the outset.

DISCUSSION

This study sets out to investigate how accessible current CPGs are for individuals with disabilities. The results are significant in understanding broader systemic gaps in inclusive packaging and underscore the proposed thesis question. Moreover, it helps understand to what extent brands incorporate genuine accessibility into product packaging, and how accessibility features—or the lack thereof—reflect the perception of accessibility as an afterthought within the CPG industry. The findings not only reinforce widespread neglect of accessibility features, but also highlight key misconceptions and strategic gaps raised in the literature review, reaffirming that accessibility continues to be marginalized in consumer product packaging despite its relevance.

Accessibility as an Afterthought

The observational data reveals a consistent trend in that, despite being able to identify all tested products, the Seeing AI app often struggled to extract meaningful and complete information from the packaging. Most significantly, four of the eleven products

contained incomplete lists of ingredients or necessary health-related information, which is not only inconvenient, but also a safety hazard. This supports research findings that poor packaging accessibility limits consumers' ability to make informed decisions and reinforces the systemic disadvantage people with disabilities face in the marketplace (Eskytė, 2019). The absence of tactile features such as Braille across all tested products—despite the availability of this tactile printing technology—supports Sloan's assertion that many CPG companies treat accessibility as a legal checkbox rather than a design priority (Sloan, 2023). It also reflects Lazar's concern that without enforceable protections, companies resort to minimal compliance (Lazar, 2019). Similarly, as mentioned before, research by Jenkins and Smith argues that companies frequently make surface-level commitments to accessibility, but these are rarely reflected in their actual product offerings (Jenkins, 2024; Smith, 2025). The findings from this study support the following claims: the presence of QR codes on only two products—and the absence of accessibility-specific content on all of them—demonstrates that even low-effort digital enhancements are not being effectively utilized to promote inclusive design in the CPG industry.

Cost and Time Misconceptions: A Repeated Theme

The literature consistently challenges the myth that accessible design is too costly or time-consuming. Research by Sloan and Moulton, Exarchos, and Teichner argues that inaccessibility actually leads to greater long-term costs, including legal liabilities, redesign expenses, and the loss of customer trust (Sloan, 2023; Moulton, Exarchos, & Teichner, 2024). Despite this, CPG businesses continue

to forgo accessible packaging features. In this research study, none of the products included Braille or structured tactile guides, and the average contrast and font legibility scores hovered around a mediocre 3 out of 5. Ultimately, these results validate Cummings' assertion that design teams often overlook accessibility in favour of aesthetic minimalism or brand consistency, mistaking it for a luxury add-on rather than a necessity (Cummings, 2022).

Additionally, evidence provided by Buddeejeen and Kengpol states that integrating accessibility from the start leads to more efficient and cost-effective production outcomes (Buddeejeen & Kengpol, 2018). Yet, the products evaluated in this study reveal that such integration is rarely pursued in practice. Instead, brands appear to delay accessibility enhancements, potentially due to workflow disruptions or limited staff training, reinforcing Husemann, Zeyen, and Higgins' finding that internal misperceptions—rather than logistical limitations—are the real barriers to implementation (Husemann, Zeyen, & Higgins, 2023).

The Role of Competing Priorities and Accountability

One of the most compelling observations in this study is the stark gap between what brands claim to value and what they actually deliver. The review of the literature highlights that the majority of CPG companies advertise a dedication to diversity and inclusion in advertising communications, but this does not necessarily mean product-level accessibility (Gale, 2023; Smith, 2025). This can be seen in the observed use of QR codes without accessibility features—such as audio labels, navigation support, or contrast optimization—rendering them ineffective for visually impaired users. In effect, such

digital features on CPG become performative rather than practical, supporting research by Gale's argument that inclusivity is often used as a branding tool rather than a guiding design principle (Gale, 2023).

Furthermore, this also relates to Conn, Abisla, and Batra's findings that CPG structures vary widely in accessibility performance, often because companies lack standardized approaches or accountability frameworks (Conn, Abisla, & Batra, 2022). The diversity of Consumer Packaged Goods formats examined in this research (plastic bottles, pump containers, cardboard boxes, blister packs, as seen in Table 2) offered no correlation between product type and accessibility features. This inconsistency suggests that accessibility is not being addressed at an industry-wide level, and instead is left up to individual brands—many of which lack the internal mechanisms to ensure compliance or innovation in this area.

Likewise, the issue of accountability intersects with legal frameworks. As identified by the European Court of Auditors, even in regions with progressive regulatory environments, enforcement is weak and accessibility outcomes remain poor (European Court of Auditors, 2023). The absence of any Braille labelling across all tested products in this study—despite Canada's existing accessibility legislation (Marshall & Lenz, 2025)—indicates a serious gap between policy intent and business implementation. Subsequently, the results support Lazar's proposal that without enforceable consumer protection policies, companies will continue to deprioritize accessibility in favour of faster go-to-market strategies (Lazar, 2019).

Missed Opportunities

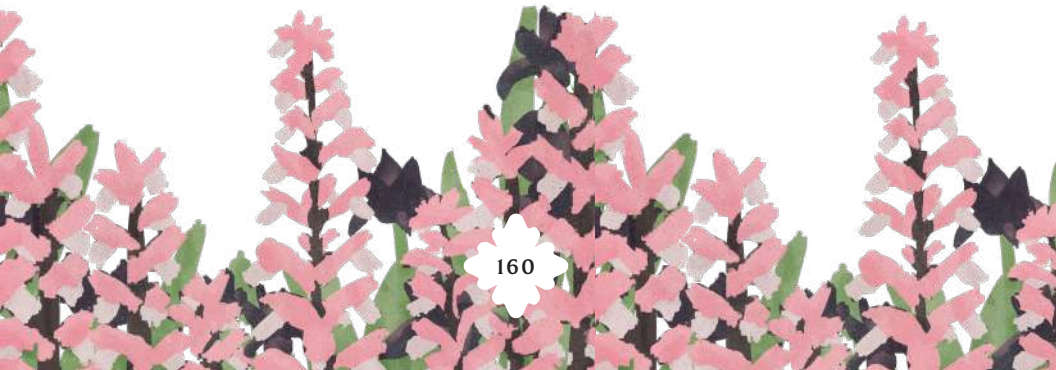
The Seeing AI app was chosen for this research due to its widespread use and positioning as a leading assistive technology for visually impaired individuals. However, the study uncovered several limitations in its ability to fully bridge accessibility gaps, particularly when CPG products lacked structured information or relied heavily on visual design elements. Subsequently, the failure of QR codes or NFC Tags to provide useful or accessible content further exacerbated this challenge. This aligns with Smith's identification of a growing gap between the promise of digital accessibility and the reality of its execution, most notably in CPG environments where accessible technology exists, but is not effectively implemented (Smith, 2025).

Ultimately, this reinforces the need for more accessible packaging within the CPG sector, packaging that works in tandem with assistive tools to support independent product navigation, ingredient identification, and safe usage. The findings of this study affirm that a dedicated accessibility tool could serve as both a practical aid for consumers and a catalyst for brands to rethink their packaging strategies through a more inclusive lens. As Sloan and Girkar emphasize, the growing economic influence of the community with disabilities—valued at over $13 trillion globally—positions accessibility not merely as a compliance obligation, but as a critical market opportunity for CPG companies seeking to stay competitive and relevant (Sloan, 2023; Girkar, 2024).

A Case for Industry-Wide Reform

The discussion ultimately points to a systemic issue: accessibility is not embedded into the foundational strategies of most CPG brands. Despite clear evidence of economic incentives, social responsibility, and available technology, most brands treat accessibility as an afterthought—if they address it at all. The literature strongly supports the conclusion that accessibility is both underleveraged and misunderstood in the consumer packaging industry (Moulton et al., 2024; Wight, 2024). The observational data from this study suggests this, offering tangible proof that the insights from secondary sources are reflected in the everyday consumer experience.

All in all, the implications are profound: unless brands begin to prioritize accessibility from the design phase onward, the CPG industry will continue to marginalize millions of consumers. As shown by Molin's research, consumer-inclusive co-design practices are not only possible, but proven to improve product usability for everyone, not just individuals with disabilities (Molin, 2024). This research supports this notion and strengthens the argument that accessibility should be central to product innovation, not a peripheral concern.



CONCLUSION

This thesis set out to explore how persistent misconceptions about cost, time, and competing priorities contribute to the continued marginalization of accessibility within the Consumer Packaged Goods industry. Through a combination of observational fieldwork and secondary literature analysis, it became evident that accessibility is not being adequately embedded into packaging strategies despite compelling legal, social, and economic incentives. CPG brands often perceive accessibility as either too expensive, too complex, or simply less important than other business objectives—misconceptions that this research has shown to be both unfounded and counterproductive.

While the sample size was limited to eleven products—reflecting common categories across mid-market retailers—the observational study using the Seeing AI application revealed that effective product identification is largely limited to basic attributes, whereas most packages lack more meaningful accessibility features. Key information such as ingredients or instructions was often unreadable, tactile indicators like Braille were entirely absent, and QR codes—when present—failed to offer meaningful or inclusive

content. These real-world findings echoed themes from the literature, highlighting how delayed implementation, superficial inclusion, and a lack of regulatory enforcement perpetuate barriers for consumers with disabilities.

However, the research also identified a clear path forward. Studies show that integrating accessibility early in the design process—through strategies like user-centred design, co-creation with consumers with disabilities, and proactive inclusion planning—can yield long-term benefits such as cost savings, enhanced usability, brand trust, and market growth. Practical pathways to accessible packaging reform can also include inspection protocols, enforced audit systems, and tax incentives from policy makers; QR codes leading to standardized accessible experiences from CPG brands; and retailer-prioritized shelf space for brands that meet accessibility standards. This is particularly relevant as the consumer-with-disability segment represents a global market worth over $13 trillion USD, a demographic that brands can no longer afford to ignore.

Ultimately, this thesis demonstrates that the exclusion of accessibility features in packaging is not the result of technological limitations or consumer disinterest, but rather a failure of strategic vision. To treat accessibility as an afterthought is to overlook both human rights and business opportunities. For the CPG industry to evolve and remain competitive, it must adopt a proactive, inclusive mindset—one that places accessibility at the core of product design and delivery. Doing so will not only close the gap between corporate values and consumer experience, but also foster a more equitable and sustainable marketplace for all.

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APPENDIX

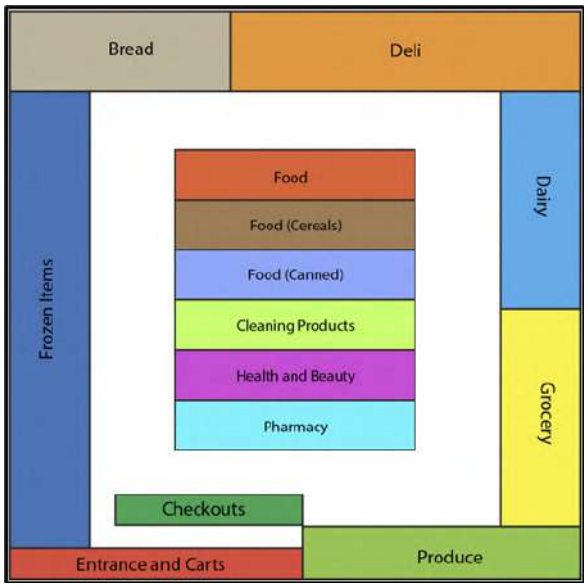

Figure 8. Floor Layout Diagram of No Frills store #3771. This diagram was created to map out the product placement in the grocery store.

Figure 9. Front and Back Pictures of Heinz Tomato Ketchup.

This figure displays the product's packaging layout. The app generated the following text: "The image shows a hand holding a bottle of Heinz Tomato Ketchup. The bottle is positioned upright with the label facing the viewer. The label displays the brand name "HEINZ" at the top, followed by "Tomato Ketchup" and "Aux Tomates" below it. The label also includes an illustration of a tomato with leaves and the text "57 Varieties" beneath it. The volume of the bottle is indicated as 750 mL. The bottom of the bottle, which is the cap, has some printed information, including a date and a code."

Figure 10. Front and Back Pictures of Nando's Perinaise.

This figure displays the product's packaging layout. The app generated the following text: "The image shows a bottle of Nando's PERinaise, a mayonnaise-style dressing. The label on the bottle indicates that it contains 450 ml of product and is labeled as ""HOT PIQUANTE."" The label also highlights that the product is made with cage-free eggs and is gluten-free, vegetarian, kosher certified, and halal trust certified. The ingredients listed include water, rapeseed oil (27%), vinegar, sugar, corn starch, salt, free-range egg yolk (2.2%), and a variety of spices such as African Bird's Eye Chili, cayenne pepper, paprika, mustard flour, black pepper, and white pepper. It also contains onion puree, green chillies, garlic puree, and stabilizers like guar gum and xanthan gum. The bottle has a red cap at the bottom, and the brand name "Nando's" is embossed on the side of the bottle."

Figure 11. Front and Back Pictures of Dove's Sensitive Skin Body Wash.

The app generated the following text: "The image shows a bottle of Dove body wash being held in a hand. The bottle is white with a light blue cap and features the Dove logo, which includes a gold dove symbol and the word "Dove" in blue text. Below the logo, the product is labeled as "sensitive skin" and "hypoallergenic" in both English and French. The bottle also mentions "24hr Renewing MicroMoisture" and indicates the volume as "20 US FL OZ / 591 mL"."

Figure 12. Front and Back Pictures of Selsun Blue Anti-Dandruff Shampoo Packaging.

This figure displays the product's packaging layout. The app generated the following text: "The image shows a person holding a bottle of Selsun Blue anti-dandruff shampoo. The bottle is blue and has a capacity of 300 mL. The label on the bottle indicates that it is designed for itchy dry scalp and contains Pyrithione zinc at 1%. The label also mentions that it has a soothing formula that nourishes the scalp with every use and helps prevent and relieve dandruff and itchy scalp. The text on the bottle is presented in both English and French."

Figure 13. Front and Back Pictures of Tylenol Extra Strength Cold Daytime & Nighttime Tablets.

This figure displays the product's packaging layout. The app generated the following text: "The image shows a box of Tylenol Cold Extra Strength medication. The box is labeled as a "24HR CONVENIENCE PACK" and contains acetaminophen among other ingredients. The packaging is divided into two sections: one for daytime tablets and one for nighttime tablets. The daytime section includes 10 tablets, which are yellow, and is indicated to relieve nasal congestion, dry cough, fever, and aches and pain. The nighttime section also includes 10 tablets, which are blue, and is indicated to relieve nasal congestion, dry cough, runny nose/sneezing, fever, and aches and pain. The total count of tablets in the package is 20, referred to as "20 eZ TABS." The DIN numbers for the daytime and nighttime tablets are 02276186 and 02276259, respectively."

Figure 14. Front and Back of Zarbee's Immunity Syrup.

Note. This figure displays the product's packaging layout. The app generated the following text: "The image shows a bottle of Zarbee's Children's Immunity Syrup being held in a hand. The bottle is designed for children aged 2 years and older. The label indicates that the syrup contains honey, elderberry, vitamin D, and zinc, which are noted to support the immune system, provide a source of antioxidants, and soothe coughs and irritated throats. The flavor is mixed berry. The bottle has a capacity of 118 mL."

Figure 15. Front and Side Pictures of General Mills Honey Nut Cheerios.

This image highlights the front-facing and side-facing design of the product. The app generated the following text: “"The image shows a box of Honey Nut Cheerios cereal, which is a limited edition with ""Happy Heart Shapes."" The box prominently features the word ""Dad"" with the phrase ""Makes My Heart Happy"" below it. The cereal is described as naturally flavored and made by General Mills. The top left corner of the box highlights that whole grain is the first ingredient. In the center of the box, there is a large heart-shaped cereal piece. Below it, a red heart graphic states ""Oat Fibre Helps Lower Cholesterol."" Next to this, there is a cartoon bee character holding a honey dipper. The bottom of the box provides nutritional information, stating that 1 cup (37g) of Honey Nut Cheerios cereal made with oats provides 35% of the daily amount of fibers shown to help lower cholesterol. The net weight of the cereal is 430 grams.”

Figure 16. Front and Side Pictures of Kellogg’s Froot Loops.

Note. This image highlights the front-facing and side-facing design of the product. The app generated the following text: “The image shows a box of Kellogg's Froot Loops cereal. The box prominently features the brand name ""Kellogg's"" in the top left corner. Below this, it states ""SOURCE OF 8 VITAMINS & MINERALS"" and ""MADE WITH WHOLE GRAINS."" The main design includes the Froot Loops logo with the letters ""F"" and ""R"" in white, and the ""O's"" are represented by colorful cereal loops. The character Toucan Sam is depicted in the center, with a rainbow-colored beak and blue feathers, holding a cereal loop. The text ""Great Fruity Taste!"" is on the right side. The bottom left corner indicates ""No artificial flavours or colours"" and ""Made in Canada,"" with a weight of ""320 g."" The bottom right corner mentions ""NATURAL FRUIT FLAVOURS"" and ""150 CALORIES per 27 g."" Various fruit images, such as orange, lime, raspberry, and cherry, are scattered around the box, along with cereal loops.”

Figure 17. Front and Back Pictures of Life Brand's Aloe Vera Liquid Hand Soap.

Note. This figure displays the product's packaging layout. The app generated the following text: ""The image shows a hand holding a bottle of liquid hand soap. The bottle is clear with a pump dispenser on top. The label on the front of the bottle reads ""Life Brand"" and indicates that the soap contains Aloe Vera and Vitamin E. The text is presented in both English and French, with ""Aloe Vera & Vitamin E"" and ""Aloès et vitamine E"" respectively. Below this, it states ""Liquid Hand Soap"" and ""Savon liquide pour les mains."" The volume of the bottle is specified as 340 mL."

Figure 18. Front and Back Pictures of Aveeno Baby Body Lotion Packaging.

Note. This figure displays the product's packaging layout. The app generated the following text: "The image shows a bottle of Aveeno Baby Calming Comfort Lotion being held in a hand. The bottle is white with a pump dispenser at the top, which is light purple in colour. The label on the front of the bottle includes text in both English and French. It states that the lotion contains natural oat and has a lavender and vanilla scent, designed to moisturize baby's skin for 24 hours and help calm the baby before bedtime. The bottle has a capacity of 532 mL, and the product is noted to be free of parabens, phthalates, and dyes. The label also includes a small graphic of leaves and a QR code at the bottom."

Figure 19. Picture of Puck's Thickened Creamy Product

This image highlights the front-facing and side-facing design of the aluminum can, with emphasis on the visibility of product text, contrast, and the absence of tactile or digital accessibility features. The app generated the following text: "The image shows a hand holding a can of Puck Thickened Creamy Product, which is a blend of skim milk powder and palm oil. The can is prominently displayed in the foreground, with the label clearly visible, featuring text in English, French, and Arabic."

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Jacky Luo is a recent Graphic Communications Management graduate holding a Bachelor of Technology, with a minor in Communication Design and a concentration in Packaging. He is currently pursuing a career at TC Transcontinental as a Prepress Operator, where he is learning all aspects of workflow and the various elements of prepress. Jacky has a strong interest in technology and is driven to stay up to date with the latest releases from manufacturers, constantly researching and exploring new developments. As a dedicated and hard-working individual, he takes pride in everything he does and consistently strives to give his best effort.

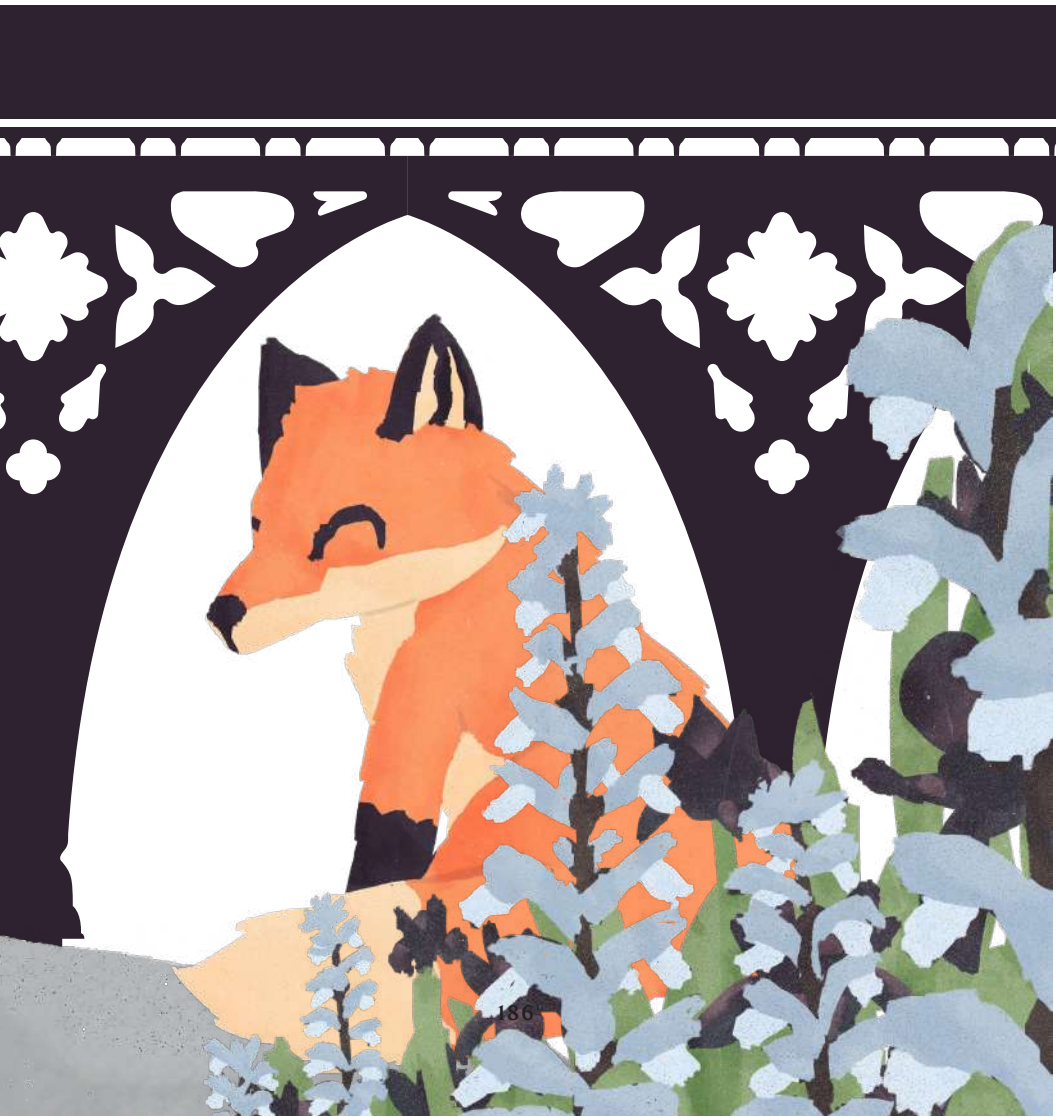
THE ENVIRONMENTAL IMPACT OF PAPER BUBBLE TEA CUPS IN COMPARISON TO THEIR PREVIOUS PLASTIC COUNTERPART:

A COMPREHENSIVE LIFE CYCLE ANALYSIS

ABSTRACT

This study investigates the environmental and economic implications of replacing plastic cups with paper alternatives in the Canadian bubble tea industry, following national regulations banning single-use plastics. Through a Life Cycle Assessment (LCA) conducted using SimaPro software, the research evaluates the sustainability of paper and plastic cups across various impact categories, including greenhouse gas emissions, ecotoxicity, and resource consumption. The study incorporates real-world data from Kung Fu Tea, cost comparisons, and consumer preferences gathered through an anonymous voting activity. Results reveal that while plastic cups contribute more to ozone depletion, paper cups have higher impacts in other categories such as carcinogenics and eutrophication. Transportation, particularly long-distance air freight from Taiwan, emerged as a major environmental contributor for both cup types. Cost analysis showed that paper cups are significantly more expensive, raising concerns about their financial feasibility for businesses. Despite widespread environmental messaging, the majority of consumers still preferred plastic cups, indicating a gap between sustainability values and actual

behaviour. These findings suggest that shifting to paper packaging does not automatically result in better environmental outcomes. A more comprehensive approach that considers full life cycle impacts, supply chain logistics, costs, and consumer perceptions is essential for making informed and effective sustainability decisions.



INTRODUCTION

With the passing of the prohibition on the import and manufacture of single-use plastics in Canada in late 2023, businesses have had to adopt more sustainable alternatives. In response, bubble tea brands such as Kung Fu Tea, CoCo, Chatime, and Real Fruit, among others, have transitioned from plastic cups to paper alternatives. This shift raises important questions about the environmental impact of these materials, as well as their influence on consumer behaviour and marketing strategies.

As of 2021, the Greater Toronto Area saw a surge in bubble tea shops, with brands like CoCo Fresh Tea & Juice expanding rapidly. This growth reflects the beverage's rising popularity among diverse demographics in the region and underscores the importance of evaluating sustainability practices within the industry. (Sotomayor & Zheng, 2023) Through a life cycle assessment, this study will compare the sustainability of paper and plastic cups. In addition, the cost-effectiveness and consumer perception within the bubble tea industry will be analyzed. By examining these factors, the research aims to assess how sustainable alternatives shape business practices in the evolving market.

Understanding the broader implications of this material transition is essential not only for environmental policy, but also for guiding industry decisions in packaging design, marketing, and consumer engagement. While the switch to paper may seem inherently more sustainable, factors such as production energy, recyclability, and end-of-life processing complicate this narrative. A comprehensive life cycle analysis provides a more comprehensive view, ensuring that decisions are made based on evidence rather than perception alone. Furthermore, the bubble tea industry serves as a microcosm of broader sustainability challenges faced by the food and beverage sector. Insights from this research will inform best practices for other niche markets undergoing similar shifts in response to environmental regulations and shifting consumer values.

LITERATURE REVIEW

As sustainability becomes an increasingly critical factor in business operations and public policy, Life Cycle Assessment (LCA) has emerged as a key tool for evaluating the full environmental impact of consumer products. LCAs offer quantifiable data on metrics such as greenhouse gas emissions, energy use, water consumption, and waste generation across each stage of a product's life cycle. In the food and beverage sector, particularly the rapidly expanding bubble tea market, material shifts prompted by regulatory changes require careful assessment that goes beyond assumptions based solely on material type.

Life Cycle Assessment (LCA)

Life Cycle Assessments have been widely used to quantify environmental impacts, emphasizing the importance of evaluating a product's entire life cycle rather than relying on assumptions about material sustainability. The International Standards for Life Cycle Assessment (ISO 14040 and ISO 14044) provide the framework for conducting LCAs and ensure methodological consistency across studies (Finkbeiner et al., 2006). ISO 14040 provides the principles and framework for conducting Life Cycle Assessments, while ISO 14044 specifies the detailed requirements and guidelines for conducting an LCA, including goal and scope definition, inventory analysis, impact assessment, and interpretation. (Committee on Trade and Investment, 2004; iTeh STANDARD, 2006)

There are four phases in an LCA study:

Step 1	The goal and scope definition phase
Step 2	The inventory analysis phase
Step 3	The impact assessment phase
Step 4	The interpretation phase

Through these steps, environmental burdens are associated with different stages of a product's life cycle, from raw material extraction to end-of-life disposal. Critical evaluations of various LCA methodologies illustrate that material composition alone does not determine overall sustainability (Harst & Potting, 2013; Harst et al., 2014). While paper cups may be perceived as the more environmentally friendly alternative, their production processes often involve higher energy consumption, carbon emissions, and water usage than their plastic counterparts (Gao & Wan, 2023).

Environmental Comparisons of Plastic and Paper Alternatives

Similar studies conducted in the United States have compared the environmental impacts of plastic (PP), paper, and biodegradable (PLA) drinking straws. The findings suggest that while all types of straws have significant environmental effects, switching from plastic to paper or PLA straws can lead to other environmental costs, particularly in production. These findings emphasize the need to consider all stages of production and waste when assessing which straw is the most sustainable. (Gao & Wan, 2022) Additionally, paper cups are frequently lined with plastic or bioplastic coatings, complicating their recyclability and reducing their environmental advantages. These findings suggest that regulatory bans on single-use plastics should be supplemented with comprehensive sustainability assessments to ensure meaningful environmental benefits.

Government policies have played a crucial role in driving businesses to transition from plastic to paper-based alternatives. The Government of Canada's (2023) prohibition on single-use plastics aims to curb plastic pollution, but official guidance documents highlight that alternative materials must still be assessed for overall sustainability (Government of Canada, 2022). The regulatory push has led businesses to reassess their material choices, navigating challenges such as cost implications, supply chain adjustments, and consumer acceptance. As businesses adapt to these changes, it becomes imperative to analyze the effectiveness of such policies in achieving sustainability goals.

Consumer Behaviour and the Intention-Behaviour Gap

Consumer response to sustainability initiatives is a key aspect of business decision-making, influencing both branding strategies and purchasing behaviours. A Canadian overview of environmental sustainability shopping habits highlighted that 8 in 10 Canadians value a sustainable lifestyle, and 70% actively seek out foods with environmentally sustainable production (Government of Canada, 2024). While consumers express concern for sustainability, their purchasing behaviours often contradict their stated preferences, a phenomenon known as the intention-behaviour gap (McDonald and Oates, 2006). Greenwashing, a practice where businesses exaggerate or misrepresent their environmental efforts, has further complicated consumer trust in sustainability claims (Gallicano, 2011). A systematic review of greenwashing literature found that interest in the topic has grown significantly, with 69% of total publications occurring in the last five years. Research highlights its impact on branding, consumer attitudes, and purchasing behaviour, further emphasizing its role in shaping perceptions of corporate sustainability (Aggarwal & Kadyan, 2014). In addition, research on sustainable marketing suggests that businesses increasingly recognize that investments in social and environmental improvements not only enhance their credibility but also increase profitability in the long term. However, challenges persist in meeting consumer expectations due to production costs and the need to implement sustainable practices. Thus, sustainable marketing must be integrated into a company's core strategy to effectively contribute to both environmental protection and business success (Park et al., 2022).

Sustainable Marketing and Its Role in the Bubble Tea Industry

In the bubble tea industry, the shift to paper cups may be partially driven by consumer expectations rather than a clear environmental advantage, necessitating an investigation into how sustainability messaging aligns with product impact. Sustainability has become a prominent marketing tool, with businesses leveraging eco-friendly transitions to enhance brand image and customer loyalty (Park et al.,2022). discuss sustainable marketing strategies, emphasizing the need for transparency and consistency in sustainability claims. When companies effectively communicate their sustainability initiatives, they can build stronger consumer trust and brand loyalty (Mohammadi et al., 2023). However, inconsistencies between perceived and actual environmental benefits can undermine credibility and lead to skepticism (Gallicano, 2011). The examination of marketing narratives surrounding paper cup adoption in the bubble tea industry will provide insight into how businesses navigate consumer expectations and regulatory changes.

Despite extensive research on LCA methodologies and consumer behaviour related to sustainable products, there remains a gap in understanding how environmental assessments, regulatory policies, and marketing strategies intersect in the bubble tea industry. The economic implications of transitioning to paper alternatives, as well as the long-term effects on business operations, warrant further exploration. Additionally, while LCAs have been conducted on various types of disposable cups, their specific application to the bubble tea industry remains limited.

METHODOLOGY

Life Cycle Assessment

This study will conduct a quantitative life cycle assessment (LCA) to compare the environmental impact of paper and plastic cups, alongside an evaluation of sales data and literature on sustainable marketing to assess the broader effects of this transition. SimaPro software will be used to conduct the LCA, as it enables a comprehensive environmental impact assessment across multiple indicators, including carbon footprint, water usage, and energy consumption. The study will collaborate with Kung Fu Tea to obtain real-world production, supply chain, and disposal data, supplemented by secondary data from academic publications and government reports. SimaPro is widely used in sustainability research due to its extensive database and compliance with ISO 14040/14044 standards, making it an appropriate tool for this analysis (Oele & Dolfing, 2020). Consumer behaviour will be analyzed through anonymous data collection rather than direct surveys or sampling.

Goal and Scope

This study compares paper and plastic (polypropylene, PP) single-use cups used in the bubble tea segment of the specialty beverage category. It focuses specifically on commonly used small and large cup sizes, reflecting typical consumer choices in the Canadian market. The cup samples analyzed in this research were provided through a collaboration with Kung Fu Tea, a leading bubble tea franchise, ensuring the materials assessed are representative of real-world products currently in use (Figure 1).

This analysis will use TRACI 2.1 (Tool for the Reduction and Assessment of Chemicals and Other Environmental Impacts), version 1.05, with the normalization and weighting set for Canada (2005). TRACI 2.1 is a midpoint-oriented Life Cycle Assessment (LCA) methodology developed by the U.S. Environmental Protection Agency (EPA). Although originally designed for use with U.S.-specific input parameters, it remains a widely adopted method for characterizing environmental impacts and can be adapted for other regions, including Canada, when appropriate normalization sets are applied.

Characterization factors are used to quantify the potential impacts that inputs and emissions have on specific environmental impact categories, expressed in common equivalence units. These impact categories include ozone depletion, climate change, acidification, eutrophication, smog formation, human health impacts, and ecotoxicity.

While recent regulations in Canada aim to reduce single-use plastic waste, there remains uncertainty regarding the comparative sustainability of alternative materials, such as paper-based options. Current Canadian standards do not provide sufficient clarity on whether these regulations lead to improved environmental

outcomes. The study expects to determine whether paper cups are genuinely more sustainable than plastic cups or if their environmental benefits are overstated. The analysis of sales data will help determine if sustainability claims impact consumer behaviour. By understanding these findings, the study aims to provide a holistic understanding of the environmental, economic, and marketing implications of transitioning from plastic to paper cups in the bubble tea industry.

Figure 1. Small and large: Plastic and Paper Cups

Life Cycle Inventory (LCI)

This study began by identifying the materials commonly used in the manufacturing of both paper and plastic (polypropylene, PP) cups within the bubble tea industry (Figures 2 & 3). Five samples of each cup were obtained through a collaboration with Kung Fu Tea, ensuring the selected cups reflect real-world usage (Table 1). The analysis included determining the material composition, average weights, and volume capacities of both small and large cup sizes for each material type. A simple cost analysis will be conducted to compare the relative cost-effectiveness of paper and plastic cups (Table 2).

Figure 2. Information on Plastic Cup Base

Figure 3. Standard Paper Cup with print

	Price per Cup	Franchise Cost	# in a box	Caliper	Volume
Small Paper	$0.090	$0.087	600	90mm	525 ml
Large Paper	$0.110	$0.106	720	90mm	725 ml
Small Plastic	$0.050	$0.040	900	26-28 gauge	500 ml
Large Plastic	$0.070	$0.045	900	26-28 gauge	700 ml

Table 1. Kung Fu Tea Provided Data on Each Cup

1	Small Paper Cup	Large Paper Cup	Small Plastic Cup	Large Plastic Cup
1	12.98 g	15.35 g	10.15 g	12.51 g
2	12.86 g	15.35 g	10.22 g	12.65 g
3	12.94 g	15.45 g	9.83 g	12.42 g
4	12.89 g	15.44 g	10.15 g	12.72 g
5	12.99 g	15.41 g	9.92 g	12.92 g
Avg.	**12.932 g**	**15.4 g**	**10.054 g**	**12.644 g**
Vol.	**525 ml**	**725 ml**	**500 ml**	**700 ml**

Table 2. Average Weight of 1 Cup With Test of 5

The assembly processes for paper and plastic cups differ notably. Paper cups require full-surface printing, die cutting, gluing, and multi-step assembly, resulting in higher machinery and energy use. In contrast, plastic (PP) cups are injection molded in a single step and typically feature minimal printing, making their production less resource-intensive (Figures 4 & 5).

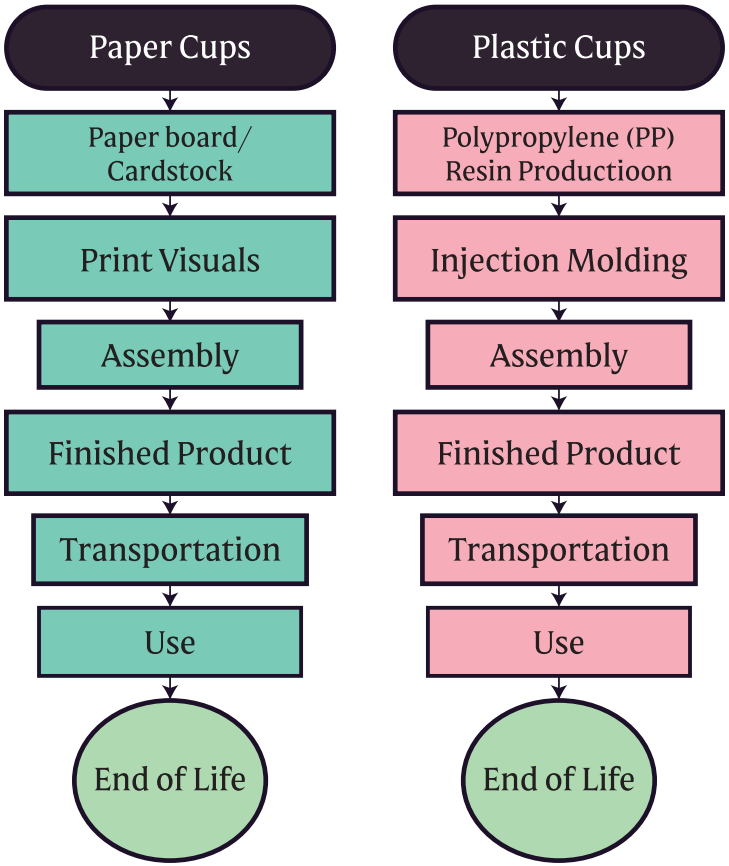


Figure 4. Materials, Assemblies & Processes Life Cycle

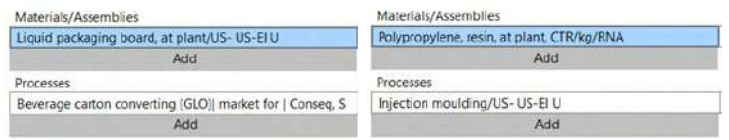


Figure 5. SimaPro Inputs

Functional Unit

A functional unit describes a quantified reference for a product system based on the function it performs, allowing for objective comparisons between different products or systems that serve the same purpose. In this study, the functional unit is defined as 100 litres (L) of bubble tea beverage served using single-use drink cups (Table 3). This unit allows for a standardized comparison of the environmental impacts of delivering an equivalent volume of product in either paper or plastic cups.

Volume Per Unit = 100,000 / Volume = Cups/100L			
100 L = 100,000 ml			
1. Small Paper	190.4762	Rounded	191
2. Large Paper	137.9310	Rounded	138
3. Small Plastic	200.00	Rounded	200
4. Large Plastic	142.8571	Rounded	143

Functional Unit = Volume Per Unit x Average Weight			
1. Small Paper	2470.0120	Rounded	2470
2. Large Paper	2125.2000	Rounded	2125
3. Small Plastic	2010.8	Rounded	2011
4. Large Plastic	1808.0920	Rounded	1808

Table 3. Functional Unit Calculation

Printed Area of Paper Cup

The paper cups are largely covered in printed graphics, and the printed surface area represents a significant variable in their production process. To accurately assess the material and energy inputs related to printing, it is necessary to calculate the total printed area

of the cup. This involves determining the cup's flat size, which serves as the basis for estimating ink usage and associated environmental impacts within the Life Cycle Assessment. This is needed for SimaPro Input (Table 4).

Small Paper Cup	*81,667.78 cm²*	**Large Paper Cup**	*70,709.82 cm²*
Top Diameter: 9 cm Radius: 4.5 cm *Bottom* Diameter: 6 cm Radius: 3cm *Circumference = 2πr* Top = 28.27 Bottom = 18.85 *Area of Circle = πr²* = 28.27 *Area of Product* Height (+⅛ for lip) = 14.125 cm Diameter (top) = 9 cm Radius (top) = 4.5 cm Circumference (top) = 28.27 ~ 28.27*14.125 = 399.31 = 399.31 + 28.27 = 427.58		*Top* Diameter: 9 cm Radius: 4.5 cm *Bottom* Diameter: 6 cm Radius: 3cm *Circumference = 2πr* Top = 28.27 Bottom = 18.85 *Area of Circle = πr²* = 28.27 *Area of Product* Height (+⅛ for lip) = 17.125 cm Diameter (top) = 9 cm Radius (top) = 4.5 cm Circumference (top) = 28.27 ~ 28.27*17.125 = 484.12 = 484.12 + 28.27 = 512.39	
Functional Unit 191*427.58 = 81,667.78 cm²		*Functional Unit* 138*512.39 = 70,709.82 cm²	

Table 4. Flat Size Area Calculation

Transportation

Transportation impacts were also accounted for in the life cycle assessment. The cups analyzed in this study are manufactured in Taiwan and transported to Canada, covering an approximate distance of 12,240 kilometres. This long-distance international shipping contributes significantly to the overall environmental footprint, particularly through fuel consumption and greenhouse gas emissions. The process used in the assessment is categorized under air transportation and specifically modelled as “transport, aircraft, freight/US”. This includes emissions from all key flight phases, such as landing, takeoff, approach, and idle cycles, and is classified under Scheduled Freight Air Transportation. The technology modelled represents a typical cargo aircraft profile. Including these transportation emissions ensures a more accurate reflection of the environmental costs associated with global supply chains in the production and distribution of single-use cups (Table 5).

tkm = ((Functional Unit x Distance) / 1000)	
Distance from Taiwan to Canada = 12,240 km	
1. Small Paper	30232.9469
2. Large Paper	26012.4480
3. Small Plastic	24612.1928
4. Large Plastic	22131.0461

Table 5. Calculation of tkm from Taiwan to Canada

Disposal

As there is no Canadian data for disposal, this LCA will use data from the US, using the

U.S. Life Cycle Inventory Database (USLCI) database for packaging waste scenario, 2015/US U. This waste scenario is based on data applicable to non-durable goods in the United States. Non-durable goods, also referred to as soft goods, are typically consumed after a single use or have a lifespan of less than three years. These include a wide range of products such as food, cosmetics, cleaning supplies, office materials, paper products, packaging, personal care items, plastics, rubber, textiles, clothing, and footwear. Given that disposable drink cups fall within the packaging and container category, this classification is appropriate for modelling end-of-life scenarios.

Consumer Perspective Data Collection

Consumer preference data was collected during the GCM Colloquium through a poster presentation. Participants were invited to take part in a fully anonymous voting activity in which they independently selected their preferred cup material: paper or plastic. The process was designed to be strictly impartial, ensuring that participants were not influenced or encouraged toward any particular choice. The survey considered a range of factors that could affect preference, including styling, sustainability, weather-related considerations, and overall perception. This qualitative data provides meaningful insight into consumer attitudes toward different packaging materials beyond their environmental impact (Figure 6).

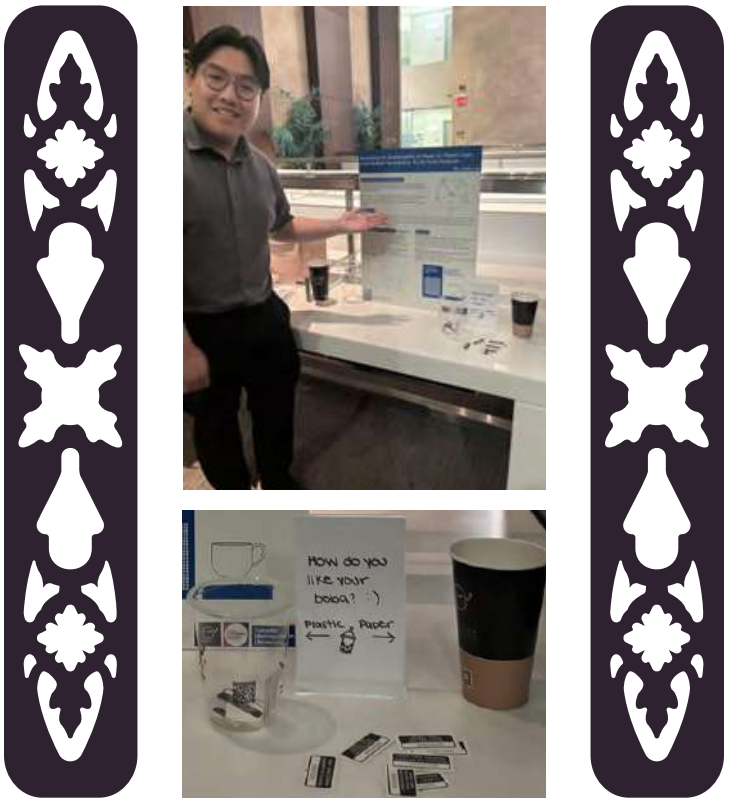


Figure 6. GCM Colloquium

RESULTS

The results will present key findings derived from multiple sources, including SimaPro modelling, life cycle impact, and consumer preference insights gathered during the GCM Colloquium.

Assembly

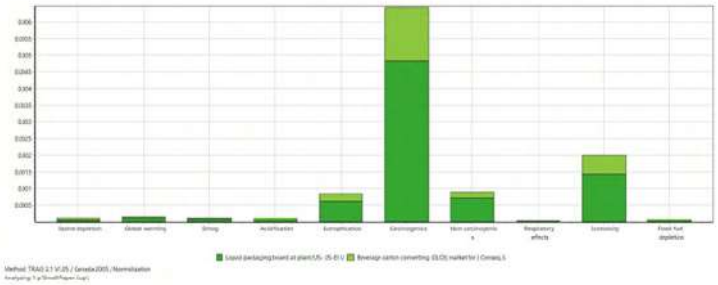


Figure 7. Small Paper Cup Normalization TRACI 2.1

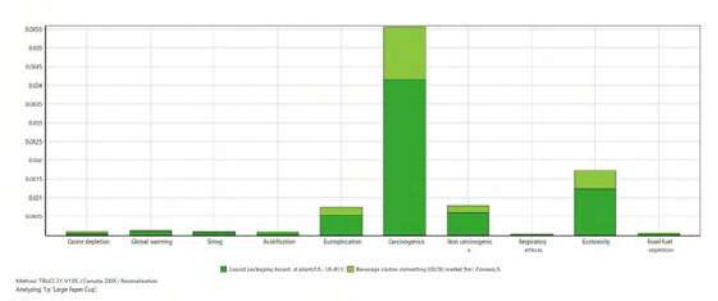
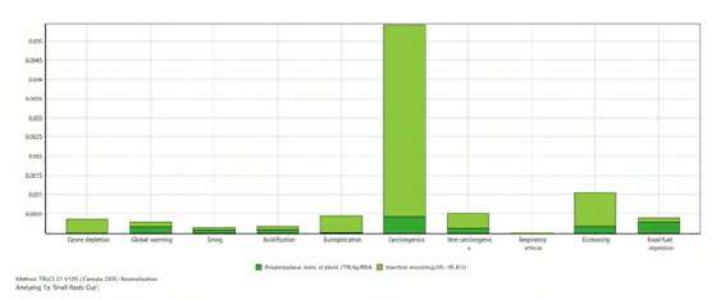


Figure 8. Large Paper Cup Normalization TRACI 2.1



igure 9. Small Plastic Cup Normalization TRACI 2.1

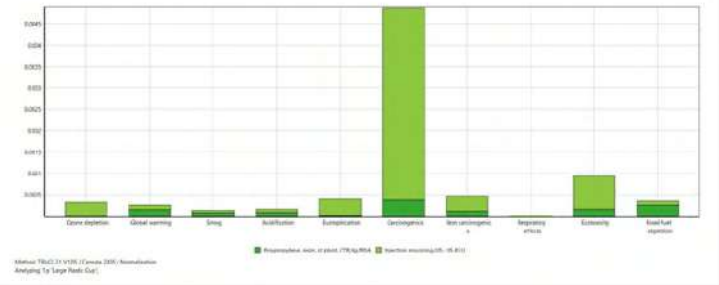


Figure 10. Large Plastic Cup Normalization TRACI 2.1

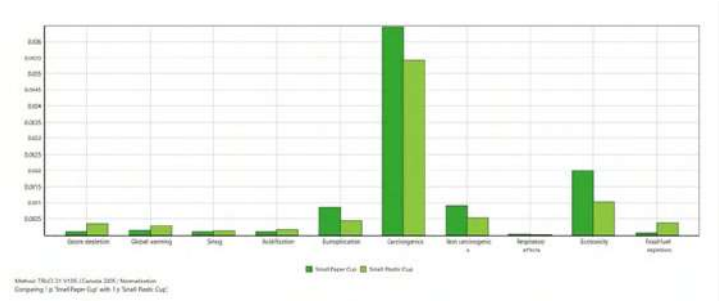


Figure 11. Small Paper vs Plastic Normalization TRACI 2.1

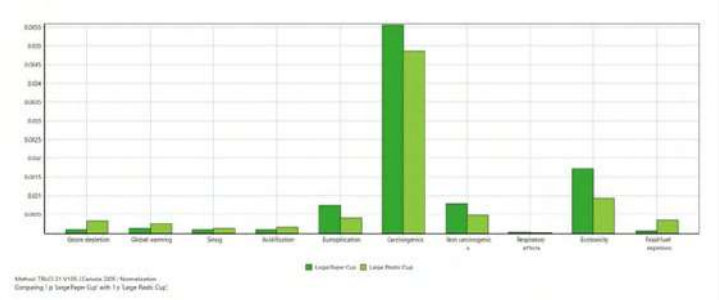


Figure 12. Large Paper vs Plastic Normalization TRACI 2.1

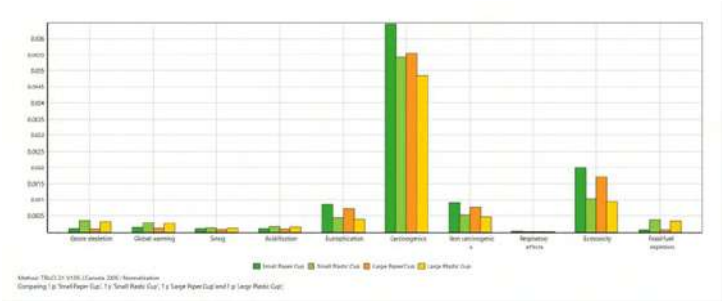


Figure 13. Combined Comparison Normalization TRACI 2.1

Categories	Small Paper	Large Paper	Small Plastic	Large Plastic
Ozone Depletion	0.0004857069512	0.0004182301781	0.0006780358345	0.000609374412
Global Warming	1.580617965	1.359825861	1.287112726	1.156088526
Smog	2.366009898	2.03553292	1.926387956	1.730287078
Acidification	1.193812921	1.02706591	0.9720466254	0.8730951055
Eutrophication	0.7611142784	0.6548073223	0.6211388637	0.5579107588
Carcinogens	23.77528398	20.45442738	19.35781372	17.38724722
Non-Carcinogens	5.92416957	5.096706226	4.82415464	4.3330705
Respiratory effects	0.0382713628	0.03292590668	0.03115512999	0.02798364372
Ecotoxicity	9.87887836	8.499026102	8.057247803	7.237057665
Fossil fuel depletion	1.384265226	1.19091674	1.127357778	1.012596232

Table 6. Process contribution Top 8, Normalization, Cut-off 1%

Life Cycle Impact

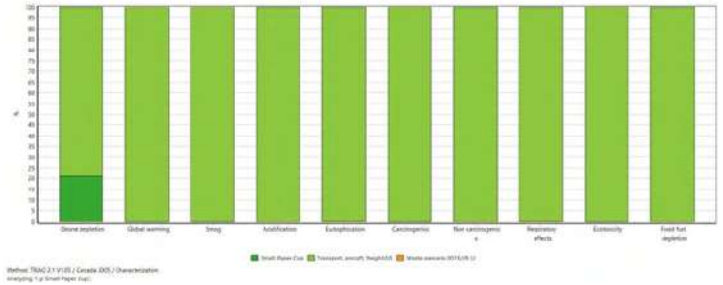


Figure 14. Small Paper Cup Life Cycle Characterization TRACI 2.1

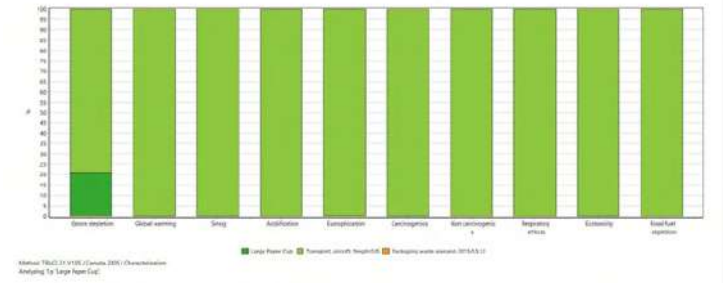


Figure 15. Large Paper Cup Life Cycle Characterization TRACI 2.1

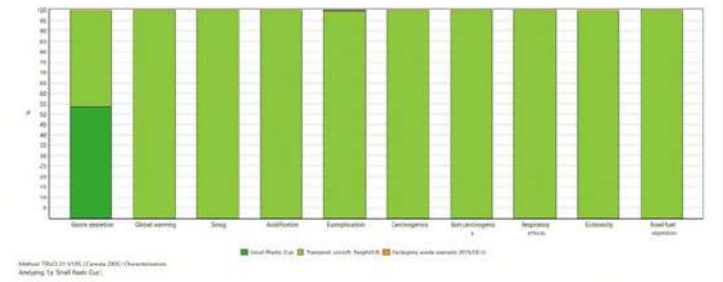


Figure 16. Small Plastic Cup Life Cycle Characterization TRACI 2.1

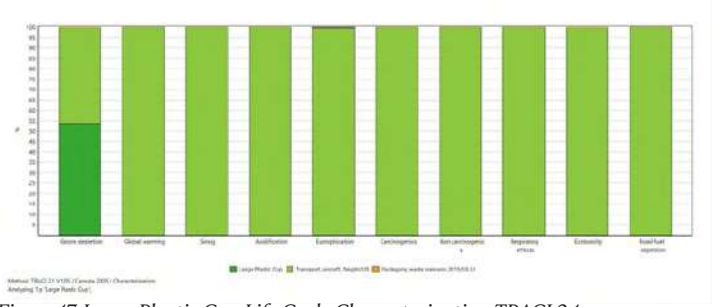


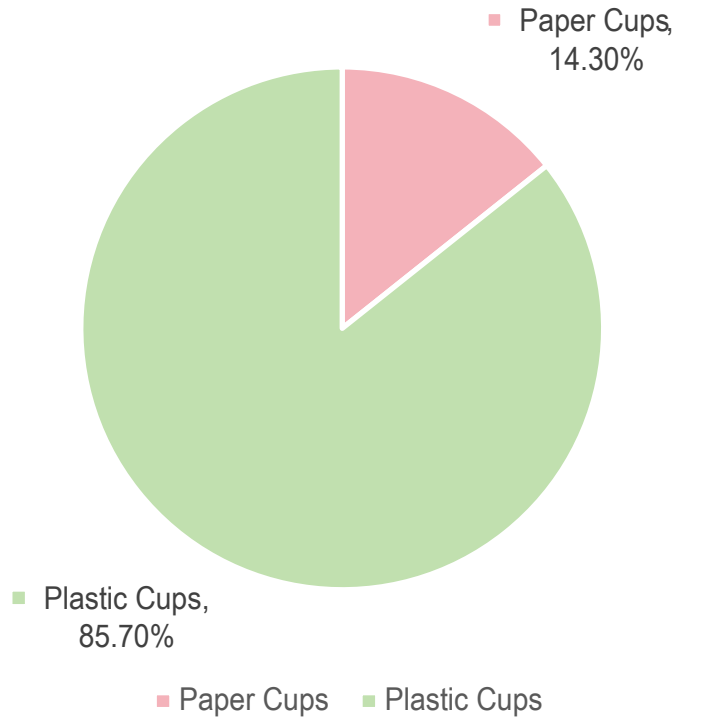
Figure 17. Large Plastic Cup Life Cycle Characterization TRACI 2.1

Process	Small Paper	Large Paper	Small Plastic	Large Plastic
Total of all processes	0.000101642422	0.000087764117	0.000364417474	0.000327680684
Beverage carton {GLO} Conseq, S	0.000057341423	0.000049647507	0	0
Crude oil, RAF US-EI U	0.000006440149	0.000005541108	0.000002756108	0.000002478266
Crude oil, RME US-EI U	0.000010512296	0.000009044787	0.000003880015	0.000003488872
Crude oil, RU US-EI U	0.000006969808	0.000005996828	0.000002530280	0.000002275203
Dichloromethane, US- US-EI U	0.000000004656	0.000000004006	0.000100355846	0.000090239010
Polypropylene, resin, CTR/kg/RNA	0	0	0.000005449714	0.000004900331
Tetrachloroethylene, WEU US-EI U	0.000000010338	0.000000008895	0.000224677223	0.000202027596
Transport, natural gas, pipeline, long distance/ US-US-EI U	0.000001039369	0.000000894274	0.000004132302	0.000003715726

Table 7. Contribution Across Categories Normalization TRACI 2.1

Consumer Perspective Results

At the GCM Colloquium, anonymous voting showed that 85.71% of participants preferred plastic cups, while 14.29% chose paper. This suggests that plastic is still favoured by many consumers, possibly due to its durability, familiarity, or convenience.



(Figure 18)Figure 18. Pie Chart Visual

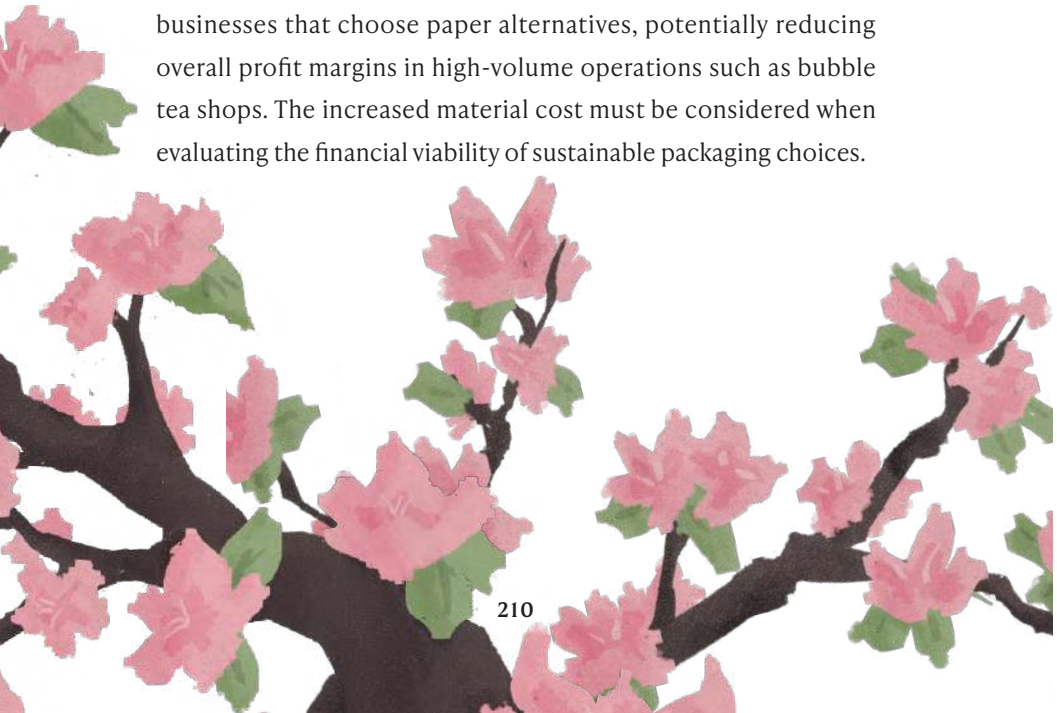
Cost Analysis

A basic cost comparison between paper and plastic cups reveals a noticeable difference in material expenses. Small paper cups cost approximately $0.090 each, while small plastic cups cost $0.050, making the paper option 80% more expensive. For large sizes, paper cups cost $0.110 compared to $0.070 for plastic, indicating a 57% increase (Table 8).

	Price per Cup
Small Paper	$0.090
Large Paper	$0.110
Small Plastic	$0.050
Large Plastic	$0.070

Table 8. Cost per cup

These margins highlight a significant cost burden for businesses that choose paper alternatives, potentially reducing overall profit margins in high-volume operations such as bubble tea shops. The increased material cost must be considered when evaluating the financial viability of sustainable packaging choices.



DISCUSSION

Combined Comparison of Assembly & Process

Large portions of the impact charts are dominated by carcinogenic effects, indicating that this category is a major contributor to the overall environmental footprint of the analyzed cups. Ecotoxicity and eutrophication also account for significant portions of the charts, while non-carcinogenic impacts are present to a lesser extent. Among all the cup types, small paper cups had the highest impact in these major categories, suggesting that despite common perceptions of paper as a more sustainable option, its life cycle processes may result in greater exposure to harmful substances.

In the lower-impact categories, such as ozone depletion, global warming potential, smog formation, acidification, respiratory effects, and fossil fuel depletion, plastic cups demonstrated slightly higher environmental impacts than paper cups. However, these differences were relatively minor. This comparison shows

that although plastic cups are often criticized for their environmental effects, paper alternatives can also contribute significantly to certain impact areas. Overall, the findings emphasize the need to assess sustainability from a comprehensive viewpoint that considers multiple environmental categories rather than focusing solely on the material used (Figures 7-13).

Process Contribution

The process contribution analysis included only the top eight contributors, with a cut-off threshold set at 1%. Certain processes, such as Beverage carton {GLO} Conseq, S and Polypropylene, resin, and CTR/kg/RNA were excluded from the comparison, as they are specific to each cup type and not universally applicable. It was observed that smaller-sized cups showed a higher relative impact from these processes. Overall, both small and large plastic cups exhibited the highest total environmental impact across all assessed processes. Among the top contributors, crude oil, RAF, RME, and RU US-EI U were most prominent in small paper cups. In contrast, dichloromethane US-US-EI U and tetrachloroethylene WEU US-EI U had a greater influence in the plastic cup category. Regarding transportation, small paper cups showed the highest impact from long-distance natural gas pipeline transport in the US, while large paper cups demonstrated the least impact in this category (Table 6).

Life Cycle Characterization

The life cycle characterization of the cups was conducted using TRACI 2.1, a midpoint-oriented impact assessment methodology, which allowed the environmental impacts to be visualized

and compared on a standardized scale of 100 (Figures 14-17). This approach provided a clearer understanding of the relative contributions of each life cycle stage and process to the overall environmental footprint. The results revealed that plastic cups contributed more significantly to ozone depletion compared to paper cups, highlighting one of the key environmental trade-offs in material selection.

However, the most prominent contributor across nearly all impact categories was the process categorized as "transportation, aircraft, freight/US." This process includes emissions from landing, takeoff, approach, and idle cycles for cargo aircraft, reflecting the energy-intensive nature of international air freight. Given that both paper and plastic cups used in this study are manufactured in Taiwan and transported to Canada over a distance of approximately 12,240 kilometres, the majority of their environmental impact occurs during the distribution phase. This underscores the importance of considering not only material type but also geographic sourcing and transportation logistics in sustainability assessments. Reducing reliance on long-distance shipping by partnering with local or regional suppliers could be a practical and effective strategy for minimizing the environmental footprint of single-use packaging. This change would not only reduce emissions associated with air freight but could also enhance supply chain resilience and responsiveness, aligning with broader sustainability and operational goals.

Contribution Across Categories

Across all impact categories, both small and large plastic cups contributed more significantly to ozone depletion than paper cups. For all other environmental categories including global warming, smog formation, acidification, eutrophication, carcinogenics,

non carcinogenics, respiratory effects, ecotoxicity, and fossil fuel depletion, the ranking from highest to lowest impact environmental burden was as follows: small paper cups, large paper cups, small plastic cups, then large plastic cups with the least impact overall. This order highlights the complex tradeoffs between material types and cup sizes in assessing environmental performance (Table 7).

Limitations & Assumptions

This study faced several limitations and assumptions that may influence the interpretation of the results. As this was the first time using the SimaPro software, there exists a possibility that some outputs may not be entirely accurate due to a lack of familiarity with the tool and its full capabilities. When selecting materials for the paper cups, assumptions had to be made about the exact material composition. In the absence of detailed specifications, standard settings were used instead of a more tailored breakdown of raw materials, which may have impacted the accuracy of the environmental modelling. Additionally, due to time constraints and limited access to data, several intended analyses could not be carried out. For instance, sales figures before and after the transition from plastic to paper cups were not available, making it difficult to evaluate changes in purchasing patterns. It was also challenging to isolate which specific variables may have influenced sales data. Moreover, while this study aimed to assess sustainable marketing practices in the bubble tea industry, the planned content analysis of major brands such as Kung Fu Tea, CoCo, Chatime, and Real Fruit could not be fully executed within the project timeline.

CONCLUSION

This study examined the shift from plastic to paper cups in the bubble tea industry through a life cycle assessment, cost comparisons, and consumer preference analysis. While paper cups are often seen as more sustainable, the findings show that their production involves higher environmental impacts in categories such as carcinogenics and ecotoxicity. Plastic cups, although associated with ozone depletion, had lower impacts in several other areas.

Transportation, especially international shipping, was a major contributor to environmental harm for both materials, highlighting the need to consider supply chain logistics when evaluating sustainability. A cost analysis revealed that paper cups are significantly more expensive, potentially affecting businesses' profit margins. Despite growing awareness of environmental issues, most consumers surveyed still preferred plastic cups, pointing to a disconnect between values and behaviour.

Overall, the transition to paper cups does not guarantee better environmental outcomes. Sustainability decisions should be based on complete life cycle data and consider economic and

consumer factors. Future research should explore detailed material inputs, long-term sales trends, and the role of marketing in shaping perceptions.

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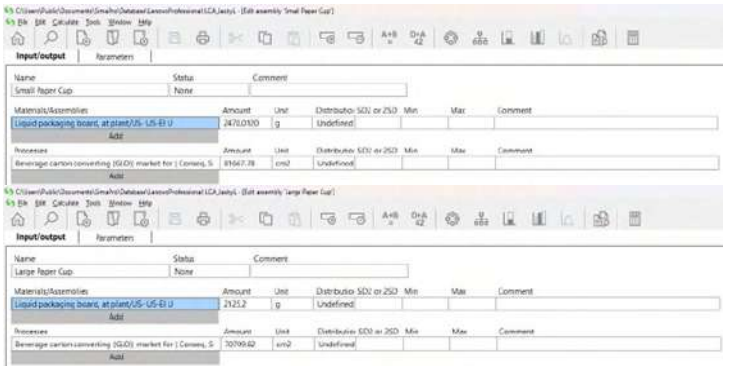
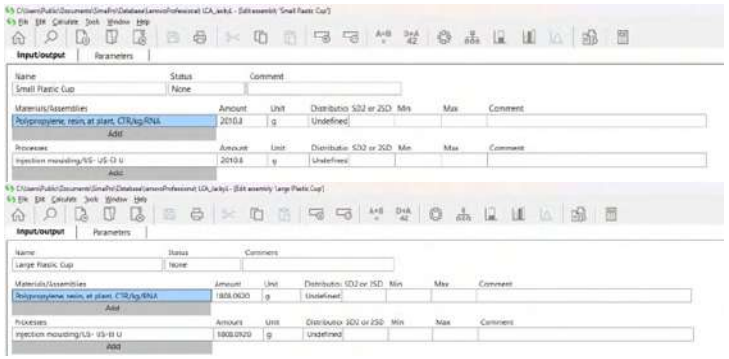
APPENDIX

Small & Large Paper Cups



Small & Large Plastic Cups



Descriptions from SimaPro

Method: TRACI 2.1 v1.05 / Canada 2005

TRACI. Tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) is a midpoint oriented LCIA methodology developed by the U.S. Environmental Protection Agency specifically for the US using input parameters consistent with US locations. Contact info: https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci. For more information see the SimaPro Database manual Methods library.

Process: Transport, aircraft, freight/US

Included processes: Include emissions from landing, takeoff, approach, and idle cycles for cargo aircraft

Category: Air Transportation

Subcategory: Scheduled Freight Air Transportation

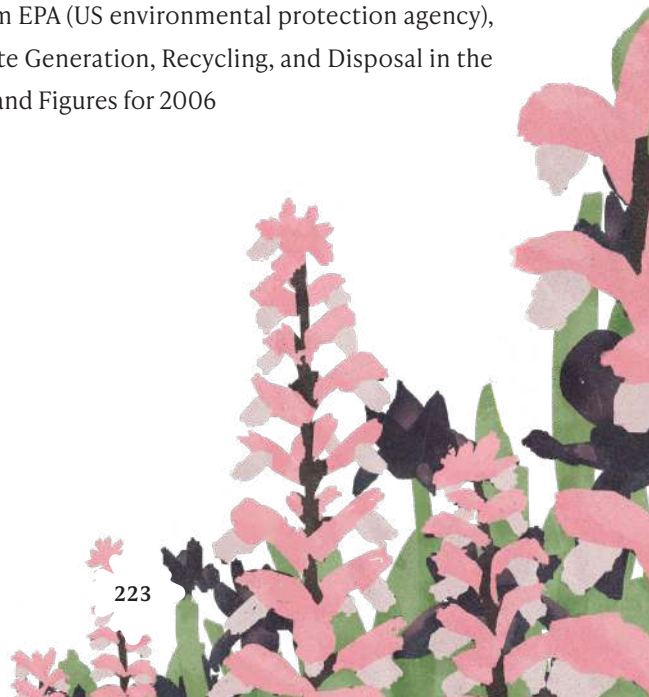
Technology: Typical

Waste/ Disposal scenario: Packaging waste scenario 2015/US U

This waste scenario should be used for non-durable goods in the USA. Nondurable goods or soft goods are the opposite of durable goods. They may be defined either as goods that are used up when used once, or that have a lifespan of less than 3 years.

Examples of nondurable goods include cosmetics, food, cleaning products, office supplies, packaging and containers, paper and paper products, personal products, rubber, plastics, textiles, clothing, footwear and most services.

The data is from EPA (US environmental protection agency), Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2006



Sasha Au Yong

Sasha Au Yong is a designer and environmental advocate from Toronto. She holds a Bachelor of Technology with a concentration in packaging and a minor in English from Toronto Metropolitan University. Sasha is currently pursuing a Master's of Applied Science in Environmental Applied Science and Management at Toronto Metropolitan University. In her free time, Sasha enjoys drawing, painting, reading, fishing and exploring the natural world. One day, Sasha hopes she can make a difference in the world of packaging by creating more sustainable solutions for manufacturers.

CHARACTERIZING THE THERMAL PROPERTIES OF MYCELIUM-BASED BIOPLASTIC THROUGH COMPOSITE MATERIAL INTEGRATION

ACKNOWLEDGMENTS

Words cannot express my gratitude to my thesis supervisor, Hayden McGreal for being a tremendous help in my research. Hayden provided feedback and sources of information when I was choosing which materials I needed to buy. He helped me sift through reliable suppliers that would give me the cheapest and best materials. During the two official supervisor meetings, he helped me look through my thesis proposal, literature review, and sources to ensure that everything was in order. Hayden was also there to train me on the equipment in the SPRL Lab, and patiently explained how each step was related to the scientific method. Without his counsel and guidance, I would not have been able to properly execute this thesis project.

I would also like to extend my thanks to all the members of the SPRL Lab and Professor Ehsan Behzadfar for allowing me to use the lab equipment and space. Members including Sahand Sabzparvar gave me useful tips on how to ultilize the Pyris software for the Thermogravimetric Analysis (TGA) tests. It was thanks to this welcoming and supportive environment that I was able to confidently execute my planned methodologies.

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Lastly, I would like to thank all of my classmates and peers in the Thesis Course as well as the GCM program. All of whom gave me words of encouragement and support during my four month long research project. Without them, I would not have been able to confidently continue as the semester progressed.

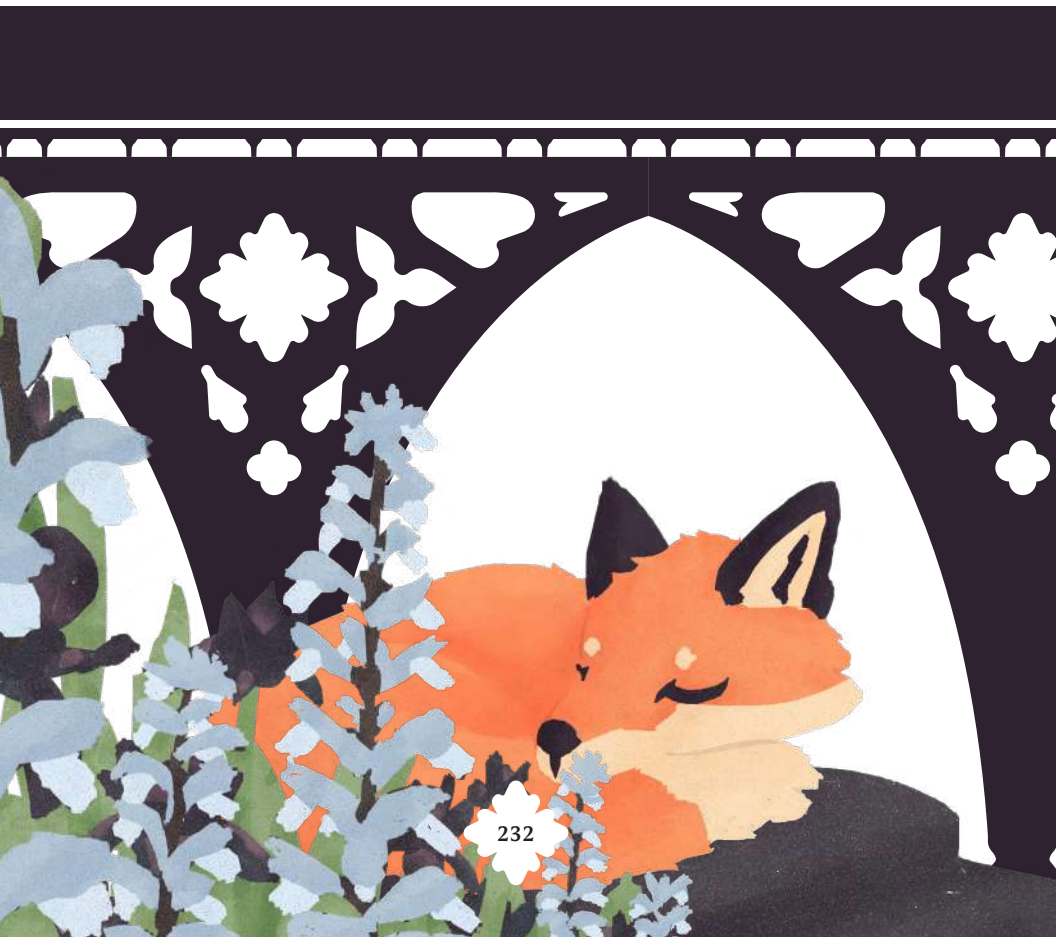
ABSTRACT

The increasing demand for sustainable materials has increased interest in biodegradable alternatives to conventional plastic packaging. Mushroom mycelium, the root-like structure of fungi, offers a promising solution due to its low environmental impact and unique mechanical properties. This research investigates the processability and thermal behavior of treated and untreated *Pleurotus ostreatus var. Columbinus* mycelium to assess its potential as a scalable biopolymer alternative. Using a combination of experimental techniques, this study explored how incubation time, Heat-Pressing conditions, and plasticizer treatments (specifically glycerol) affect mycelium films' physical structure and thermal degradation.

Five samples were incubated for 14, 21, and 28 days, then treated with varying amounts of glycerol and pressed using a Heat Press under controlled conditions. A Thermogravimetric Analyzer (TGA) was used to assess thermal degradation patterns across different sample groups. Results showed that incubation time significantly influenced film quality, with 21 to 28 days yielding the most uniform films. The addition of glycerol improved flexibility and

transparency, while TGA analysis revealed three major weight loss stages, with the most stable samples appearing around the 12% glycerol treatment mark.

This study found that mushroom mycelium can be processed into thin, translucent, semi-thermally resistant films when grown and treated under optimal conditions. It also highlights the importance of plasticizer dosage and process control in developing a viable mycelium-based material for packaging applications. Overall, the findings support further exploration of mycelium as a biodegradable, moldable alternative to thermoplastics in industrial use.



INTRODUCTION

The packaging industry has long relied on the use of crude-oil based plastics. In 2024, around 220 million tons of plastic waste was generated and one third of that waste, around 68.6 million tons, was mismanaged at the end of its lifecycle (Sousa, 2024). As awareness surrounding the negative environmental impacts of single-use plastic packaging grows, demand for affordable and biodegradable packaging has been gaining popularity. Businesses have turned to a variety of bio-based and biodegradable plastics as a solution to reducing their carbon footprint. However, there is a misconception that all bio-based and biodegradable plastics require the same methods of disposal, leading to contamination in waste streams. In recent years, mushroom mycelium has started to become an attractive alternative to petroleum-based polymers. Mushroom mycelium quickly grows and has excellent biodegradable, compostable, and mechanical properties. These properties make mycelium a promising alternative within the packaging industry. Although mushroom mycelium has already been used in packaging applications such as packing foam, edible and dissolvable film, architecture materials and mulch coverings

for horticulture, studies have mostly focused on its biodegradability and similarities to polystyrene rather than its processability and mechanical properties. This research paper aims to answer how treated and untreated mushroom mycelium behaves under a certain thermal environment. By examining how mycelium responds to heat, pressure, and forming techniques, this research investigates its potential for broader manufacturing applications beyond loose-fill packaging. Understanding these properties is essential to determine whether mycelium can be shaped and molded with the same flexibility as conventional plastics while still maintaining its environmental benefits. Ultimately, the goal is to assess whether mushroom mycelium could be a scalable and sustainable material solution for replacing thermoplastics in industrial packaging contexts.

LITERATURE REVIEW

Mycelium-based bioplastics have garnered attention for their sustainability and potential as alternatives to conventional plastics. However, their mechanical and thermal properties often require enhancement to meet industry standards. Research indicates that integrating chitosan, a biopolymer derived from chitin found in fungal cell walls, can improve the flame-retardant properties of bioplastics. The upcoming listed research also proves that adding glycerol improves mycelium film's tensile strength and colour. Additionally, studies have explored using chitin-based coatings to enhance biodegradable films' antimicrobial and gas barrier properties, suggesting potential improvements in mechanical

performance. Despite these advancements, further research is necessary to optimize mycelium-based bioplastics' mechanical strength and flame resistance for broader applications.

Due to their versatility and durability, plastics have become key materials in industries such as packaging. Their strength, flexibility, light weight, and easy and low-cost production make them ideal materials for application in many industrial and consumer products (Narancic, 2018). However, while synthetic plastics have become highly valued for their long-lasting functional use, multiple perspectives on plastic-related environmental hazards and energy crises have been raised (Moshood et al., 2022). Most plastic produced is single-use, and approximately 40% of it goes towards the packaging sector alone. Most synthetic-based plastics are highly resistant to biodegradation, posing a long-term risk of hazardous chemicals leaching into the surrounding natural environment (Moshood et al., 2022). While replacing single-use synthetic plastics is highly unlikely due to the cheap and easy manufacturing costs, new kinds of polymers share similar characteristics that are being explored. Consumers often confuse the difference between bioplastic and biodegradable plastic. Bioplastics such as bio-PET and bio-PE can contribute to reducing GHG emissions. However, the bio-based origin of these plastics does not mean that bio-based plastics are also biodegradable or compostable. Biodegradable plastics such as thermoplastic starch (TPS), polylactic acid (PLA) and polyhydroxyalkanoate (PHA) can be derived from renewable resources and are thus bio-based and biodegradable plastics (Narancic, 2018). Developing these polymeric materials from natural resources such as lignin, cellulose, pectin, and polyesters from bacteria is sustainable and biodegradable. However, from the extraction and

processing of their bioresources, the development of these materials usually can be costly and time-consuming and have low production yields (Mungwari et al., 2024).

A potential solution to overcome these problems is developing biomaterials with controlled and tunable properties during their growth (Haneef et al., 2017). Mycelium, the vegetative lower part of fungi, has been identified as the largest living organism on earth, with a network occupying nearly 10km² in Oregon's Blue Mountains (Casselman, 2007). Mycelium is mainly comprised of natural polymers such as chitin, cellulose, and proteins. Its fast growth, unique structure, and composition hold the potential to produce large amounts of mycelium-based materials (Haneef et al., 2017). Currently, mycelium is mainly used by an American company, Ecocative. They use unprocessed agricultural feedstock (Hemp Hurd) that is bonded together by mycelia to create thick, foamy packaging that shares similar uses to Polystyrene foam (Ecovative, 2025). While Ecovative creates mycelium-based composites using a thermoform mould, research has also discussed 3D printing the mycelium. Biomaterials have caught the eye of architects and designers looking for a sustainable alternative in the construction industry (Mohseni et al., 2023).

Film Type	Maximum Tensile Strength	Elongation at Break (%E)	Toughness (KJ/m3)	Young's Modulus
G. lucidum	1.14 MPa	19.05%	127.32 KJ/m3	5.89 MPa
A. Ploytricha	0.75 MPa	15.77%	71.95 KJ/m3	4.80 MPa
P. ostreatus	1.21 MPa	11.15%	87.52 KJ/m3	6.81 MPa
G. lucidum + Glycerol	3.4 MPa	35%	720 KJ/m3	10 MPa
A. Ploytricha+ Glycerol	2.5 MPa	31%	420 KJ/m3	7.5 MPa
P. ostreatus + Glycerol	3.2 MPa	26.50%	490 KJ/m3	13 MPa
Sauce residue/ PVA	3.67 MPa	10.65%		
Citric acid fermentation residue/PVA	4.22 MPa	38.40%		

Table 1: Comparison of differently treated mycelium-based film types after tensile strength tests. Data compiled from ref highlighted green (Shao et al., 2023) and ref highlighted orange (Shi et al., 2012).

Additives such as glycerol and PVA have been added to mycelium films, improving their mechanical properties. The mycelium's surface structure is correlated to its properties. The G. Lucidum film has an average fungal hypha diameter of 1.21 micrometers (µm), A. Polytricha has a diameter of 1.33µm, and P. ostreatus has a diameter of 2.21µm. Unsurprisingly, the fungi, G. Lucidum, with the lowest fungal hypha diameter displayed better overall results for maximum tensile strength, elongation and toughness before and after Glycerol treatment (Shao et al., 2023). Feeding substrates are also crucial in determining the mycelium film's stiffness and elongation. In all three tests studying mycelium-based biopolymers done by (Shao et al., 2023), (Shi et al., 2012) and (Haneef et al., 2017) Potato dextrose broth (PDB)

was shown to stimulate the biosynthesis of lipids and proteins and reduce the production of rigid polymers such as chitin. Other similar feeding substrates, including potato dextrose agar, honey and malt extract, are also known to be effective (Grow Mushrooms Canada, 2025). However, in most of the studied cases of mycelium blend films, only one main additive or plasticizer is used, while multiple species of fungi are tested. More tests and studies need to be done to determine the best type of biodegradable additive, compatible with the mycelium film, further improves its mechanical properties and displays water and air barrier properties. Apart from glycerol, which has been proven to strengthen the mycelium's mechanical properties, polymers such as polyurethane, potato and tapioca starch, and shrimp shell chitosan present other alternative blends (Dean et al., 2013). Polyurethane is especially promising as it is a versatile plastic material that can be applied as a coating, adhesive, foam, sealant and paint. It has remarkable mechanical and physical properties such as elasticity, adhesion, hardness, durability, etc (Khatoon et al., 2021). It also combines the hardness of metals and plastics with the flexibility of rubbers (Das et al., 2020).

There is still space for further development and improvement in mycelium-based biopolymers, including high moisture permeability, low tensile strength and low flame resistance. Polymeric materials including bulk polymers, textiles and foams, will easily ignite if not inherently flame retarded (Malucelli, 2020). Mycelium film by itself has been proven to be brittle, and its mechanical properties typically exhibit high stiffness in the absence of strain, limiting its application in advanced engineering fields (Shao et al., 2023). Despite these challenges, researchers have already started filling this gap with more to improve in the future. Mycelium biomaterials have several advantages over traditional synthetic materials, including

low cost and carbon footprint, reduced energy consumption, and excellent biodegradability (Jones et al., 2019).

Observing the compiled data in Table 1, we see a connection between material composition, additives, and structural properties. Haneef et al. highlight mycelium's rapid growth and polymer composition as key for sustainable materials, while Shao et al. (2023) and Shi et al. (2012) show that feeding substrates like Potato Dextrose Broth (PDB) influences its mechanical properties. Since the mycelium feeding substrate directly impacts the film's mechanical strength, this research paper will use what was previously successful. Potato dextrose agar will be chosen as a close substitute, and a subspecies of *Pleurotus Ostreatus* will be chosen as the culture for mycelium growth. It was selected as it showed the second-best tensile strength and the best Young's Modulus results (Shao et al., 2023). Additives and plasticizers such as glycerol and chitin were chosen as they improve the film's overall density (Appels et al., 2020).

Past research provides a comprehensive analysis of mycelium-based biomaterials, emphasizing their composition, processing methods, and applications. Studies highlight the structural properties of mycelium, primarily composed of chitin and cellulose, which contribute to its mechanical strength and biodegradability. The role of feeding substrates, such as Potato Dextrose Broth, in modifying mycelium's stiffness and elasticity has been investigated, demonstrating their influence on biosynthesis.

Researchers have explored different processing techniques, including thermoforming and 3D printing, to optimize mycelium-based composites. Companies like Ecovative have commercialized mycelium-based packaging as an alternative to polystyrene foam, showcasing its viability in sustainable packaging solutions. Additives such as glycerol and polyvinyl alcohol (PVA) have been

incorporated to enhance flexibility and mechanical performance. However, further research is needed to identify optimal biodegradable additives that improve durability while maintaining sustainability.

Additionally, studies have explored mycelium's potential in bioplastics, construction materials, and flame-retardant applications. The intersection of mycelium with other biopolymers, including chitosan, glycerol and polyurethane, presents promising avenues for improving water resistance, mechanical properties, and gas barrier functionality. While biodegradable plastics offer a potential solution to plastic pollution, concerns remain regarding their large-scale production and end-of-life disposal.

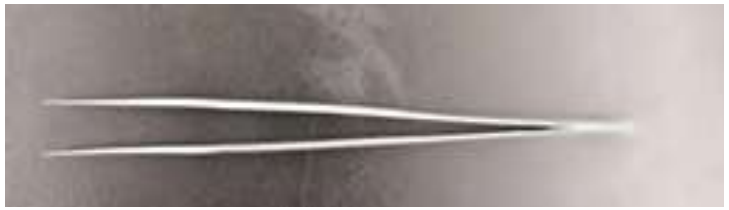
Overall, previous research underscores the need for continued material innovation and testing to enhance the functional properties of mycelium-based biomaterials.

METHODOLOGY

Tools and Materials

Glass Petri Dishes Purchased off of Amazon

Scalpel & tweezers Purchased off of Amazon



Potato Dextrose Agar Powde Puchased off of Amazon & Light Malt Extract Purchased off of Grow Mushrooms Canada

Pleurotus ostreatus var. Columbinus Liquid Culture Purchased off of Grow Mushrooms Canada.

Liquid Glycerol Available in the SPRL Lab

Methods

1. Scientific method with experimental research. Secondary observational research on mechanical and flame resistant qualities
2. Secondary observational research on mechanical and flame resistant qualities.

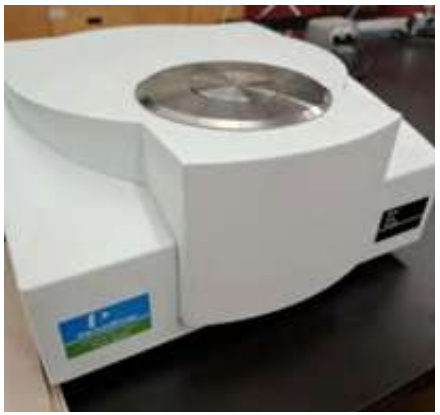
Techniques:

1. Preparation of feeding substrate using a mix of Potato Dextrose Agar Powder (PDA), Light Malt Extract and deionized water.
2. Mycelium incubation and growth
3. Harvest, flatten and kill further mycelium growth to create the film.
4. Polymerization of mycelium film with plasticizer. Coat the mycelium film with glycerol and use the Heat Press to flatten it further.

Autoclave

SPRL Lab Heat Press

Fume Hood



SPRL Lab Thermogravimetric Analyzer

5. Use the Thermogravimetric Analyzer (TGA) to test its thermal degradation properties.

Machines, Devices and Mechanical Tools

Autoclave Purchased off of Amazon

The Aries Outlets 1.5L Mini High Temperature Sterilizer Autoclave Machine will sterilize the tools needed for mycelium inoculation and growth. These small tools include the scalpel, tweezers, petri dishes, potato dextrose agar (PDA) and light malt extract. Sterilizing all tools for mycelium growth will ensure no dirt and spore contamination. The goal is to grow a pure sample from a pure culture.

Heat Press Available in the SPRL Lab

The 15-ton Carver automated heated press (model 4531 AutoFour1515-PL) will hot-press the mycelium films at 1.5 MPa at 120 °C for 1.5 - 2 minutes to even out the surface.

Fume Hood

The Fume hood will ensure that all dust and debris are removed from the area. It ensures that there will be no spore contamination when inoculating the liquid culture.

Thermogravimetric Analyzer (TGA 4000 Series) Available in the SPRL Lab.

The Thermogravimetric Analyzer will use a supply of nitrogen and compressed air for a method starting at 30 C, increasing 10 C every minute until the temperature reaches 800 C.

The methods and techniques stated previously were chosen mainly because they are achievable within a three-month time frame. Completing this thesis had five main steps, each requiring its own scientific technique.

Feeding Substrate

Create a nutrient-rich feeding substrate and environment for the mycelium of the Pleurotus ostreatus var. Columbinus.

This technique uses tools such as glass Petri dishes, potato dextrose agar powder, light malt extract, and deionized water. These will all be sterilized using the Aries Outlets 1.5L Mini High Temperature Sterilizer Autoclave. These tools and materials were selected because they follow similar successful incubation and growth methods (Haneef et al., 2017; Shao et al., 2023).

Incubation

Successful mycelium incubation and growth.

Tools such as a liquid culture of Pleurotus ostreatus var. Columbinus will be used for this experiment. Once the incubation period of 14 and 28 days passes, a scalpel may be needed to separate the mycelium from its feeding substrate. The samples will be stored in a dark, sealed box at room temperature. These tools and materials were chosen as the *Pleurotus ostreatus var. Columbinus*, commonly known as the Oyster Mushroom, is known to grow quickly within 14 days.

Heat Pressing

Flatten and kill further mycelium growth to create the film.

Tools and machines such as the and Heat Press are needed for this step. Using a method proposed by Haneef et al., the subsequent films will be put into an Autoclave Oven at 60 °C for 2 hours to kill

the fungi and stop further growth. The Mycelium films will then be hot-pressed using the 15-ton Carver automated heated press at 1.5 MPa at 120 °C for 1.5 - 2 minutes to even out the surface. Mushroom mycelium is a living organism that will continue to grow unless treated. These machines ensure the mycelium is no longer a potential biohazard.

Plasticizer Treatment

Polymerization of mycelium film with plasticiser by coating the mycelium film with glycerol.

Tools and materials such as liquid glycerol and chitin power are needed. Glycerol, which will be dripped onto the mycelium films using a previous method by Shao et al.., is an excellent bio-based plasticizer. It is cheap and non-toxic, making it a suitable candidate. Chitin powder, a biopolymer derived from shrimp shells, is biodegradable and flame retardant. It is an excellent additive to aid in improving mushroom mycelium films.

Thermal Testing

Use the Thermogravimetric Analyzer (TGA) on the polymerized mycelium film.

The Thermogravimetric (TGA) was selected as the standard for measuring and recording the change of weight in a sample as it is heated, cooled and held at constant temperatures. It will test thermal degradation in the mycelium bioplastic films. Smaller samples ranging from 4 mg to 6 mg will be collected from each batch and tested under the same conditions. A supply of Nitrogen and Compressed Air was used. Each sample's temperature started at 30 C and was heated at 10 C/min until it reached 800 C. The Pyris Software that connects to the TGA Device records the loss of weight in the sample as the temperature increases.

RESULTS

Creating The Feeding Substrate

For the feeding substrate, materials such as a 100g of Potato Dextrose Agar (PDA), 100g of Light Malt Extract (LME), five 100 mm diameter petri dishes and 1.5 L of deionized water was purchased. Below features a chart that shows the ratio of each material needed per petri dish

Material Amount	Amount Per Dish
PDA 100g	0.5 g per dish
LME 100g	0.5 g per dish (1 to 1 ratio with PDA).
Deionized Water 1.5 L	Approx. 62.5 ml of water per dish (calculated according to Seaweed Solution Lab's package).
Total	62.5 ml + PDA 0.5 g + LME 0.5 g = 1 petri dish
	312.5 ml + PDA 2.5 g + LME 2.5 g = 5 petri dishes

Boiling The Feeding Substrate NV

Figure 2: The PDA and LME mixture is boiled for 15 min at 100 C

Incubating The *Pleurotus ostreatus var. Columbinus*.

Once the feeding substrate has cooled in each petri dish, the liquid culture will be inoculated under a fume hood to ensure no spore contamination. Approximately 1.5 CC of liquid mycelium will be added to each petri dish. This is to ensure that there is even growth throughout all five dishes. Once inoculated, all five petri dishes are placed in a sealed container at room temperature. Throughout the course of 14 days, images are taken of the five petri dishes shown in Table 2.

Mycelium Growth Progression

Day 1	Day 2	Day 3
		
Day 4	**Day 5**	**Day 6**
		
Day 7	**Day 8**	**Day 9**
		

Day 4	Day 5	Day 6
		
Day 13	**Day 14**	
		

Table 2: A 14-Day Timelapse Of Mycelium Growth. All Images Taken Between 4:00 pm - 6:00 pm

After 14 days, the results from harvesting two petri dishes worth of mycelium did not give the expected outcome. There was not enough mycelium growth for a uniform film, and after Heat Pressing with no glycerol, the film crumbled and flaked.

Mycelium Film Under A Microscope

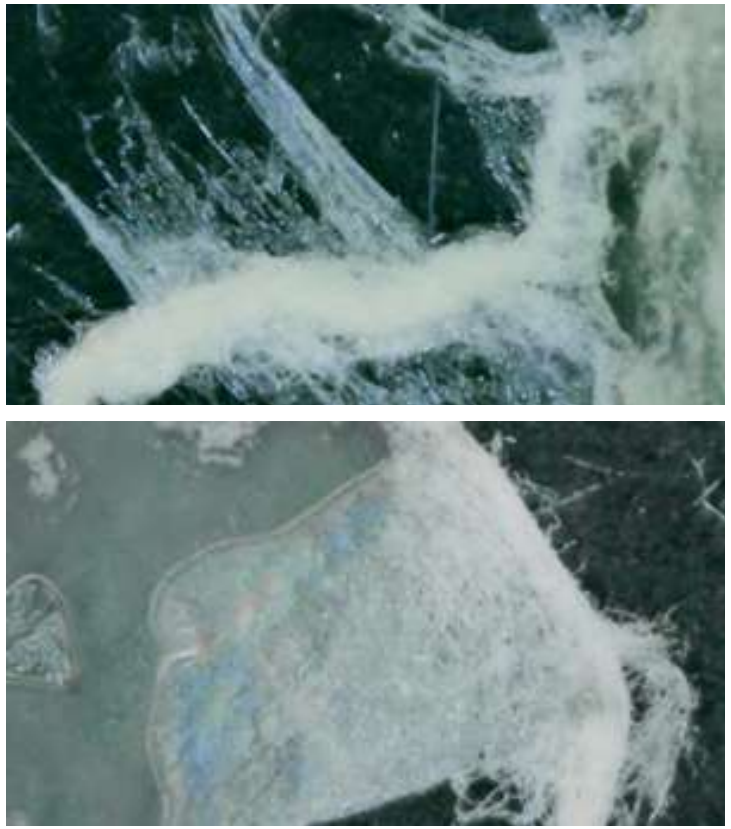


Figure 4: The Heat-Pressed Mycelium Under 8x Magnification

Heat Press No Glycerol

Sample Weight	Clamp Force	Time	Temperature
0.24 g	1.5 MPa (30,000 Lbs)	1:30	120 C

Figure 5: Shows 14 Days Of Incubation & Heat Pressing

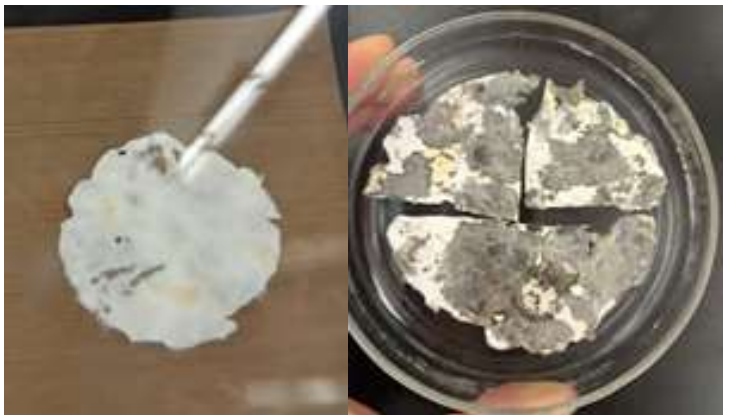
Once it was determined that the rest of the petri dishes needed to be incubated longer, they were left for another 14 days; twenty-one days was the ideal time for incubation, as the following sample showed a more filled-out and uniform film.

Heat Press With Glycerol

TGA Name	Sample Weight	Glycerol Weight	Clamp Force	Time	Temperature
Sample 3a	0.0516 g	0.00258 (5%)	1500 Lbs	4:00	80 C

TGA Name	Sample Weight	Glycerol Weight	Clamp Force	Time	Temperature
Sample 3b	0.1800 g	0.018 (10%)	2500 lbs	1:30	80 C
Sample 3c	0.0395 g	0.00395 (10%)	5000 lbs	2:00	80 C

Figure 6: Shows 21 Days Of Incubation, Heat Pressing & Glycerol Treatment



The last two petri dishes were incubated for 7 more days, making the total incubation time at 28 days. Below is what they looked like after adding glycerol and Heat-Pressing.

Heat Press No Glycerol

TGA Name	Sample Weight	Clamp Force	Time	Temperature
Sample 4a	0.3925 g	5000 lbs	2:00	100 C

Heat Press With Glycerol

TGA Name	Sample Weight	Glycerol Weight	Clamp Force	Time	Temperature
Sample 4b	0.5956 g	25%	5000 lbs	2:00	100 C

Results

Figure 7: Shows 28 Days Of Incubation. Left With No Glycerol, Right Is With 25% Glycerol

Heat Press With Glycerol

TGA Name	Sample Weight	Glycerol Weight	Clamp Force	Time	Temperature
Sample 5	0.7932 g	12%	5000 lbs	2:00	100 C
Sample 5	0.9188 g	12%	5000 lbs	2:00	100 C

Result

Figure 8: Shows 28 Days Of Incubation With Glycerol

Once each batch from different petri dishes had been Heat Pressed and treated with Glycerol, smaller samples between 4-6 mg were put into the Thermogravimetric Analyzer (TGA) for further analysis. Every sample was tested under the same conditions and method.

TGA ANALYSIS RESULTS

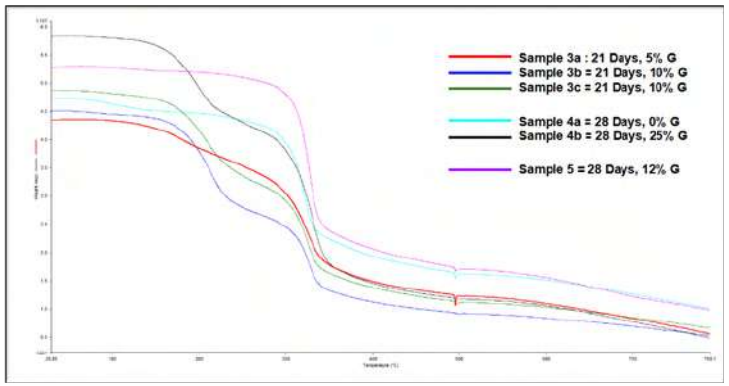


Figure 9: Shows The TGA Analysis Of The Different Pressed Samples

DISCUSSION

Incubation Time

The reason that samples were a week apart from one another at 14 days, 21 days and 28 days was due to the variance in mycelium growth across the five petri dishes. Since the samples were not kept in a regulated incubation chamber, important factors such as temperature and humidity were not constant. It is also due to the fact that while 1.5 CCs of liquid culture was added to each dish, the amount of mycelium added was not the same. This was because some strands of mycelium in the liquid syringe were larger than others, and it was difficult to separate them evenly through injection. Therefore, after 14 days, it was determined that the remaining samples needed to be incubated for longer in order to produce a larger mycelium yield.

Heat Pressing

Due to time constraints, the Heat Press was used to both flatten and kill further mycelium growth, eliminating the need for a Vacuum Oven. Heat pressing uses a combination of heat, pressure and time to flatten different plastics into films. In this research project, different methods were used on different samples. The reason was to find out the ideal method for a film that was uniform and as transparent as possible. The tables shown on the next two pages represent how each petri dish of mycelium was treated and heat pressed, with the exception of Sample 1, where two petri dishes were combined.

As shown in correlation to Figure 5 under the Results section, Sample 1's method was unsuccessful as the film crumbled and flaked. This was due to too much pressure being applied to too little mycelium.

TGA Name	Sample Weight	Clamp Force	Time	Temperature
Sample 1	0.24 g	1.5 MPa (30,000 Lbs)	1:30	120 C

As shown in correlation to Figure 6 under the Results section, Sample 3's method proved to be successful in terms of producing an even film. Clamp force and temperature were both reduced after learning from Sample 1. Glycerol was also added to the mycelium's surface before Heat Pressing. This petri dish was divided into three samples to test if different amounts of Glycerol and clamp force made a difference on the film's physical properties. After observing the samples shown in Figure 6, it was concluded that the films with 10% Glycerol produced a more translucent film than 5% Glycerol.

TGA Name	Sample Weight	Glycerol Weight	Clamp Force	Time	Temperature
Sample 3a	0.0516 g	0.00258 (5%)	1500 Lbs	4:00	80 C
Sample 3b	0.1800 g	0.018 (10%)	2500 lbs	1:30	80 C
Sample 3c	0.0395 g	0.00395 (10%)	5000 lbs	2:00	80 C

As shown in correlation to Figure 7 under the Results section, Sample 4's method was more experimental in the sense that two extremes were compared to each other. For Sample 4a, no glycerol was added and for Sample 4b, 25% of Glycerol was added. The physical difference one could see after both films were Heat Pressed was

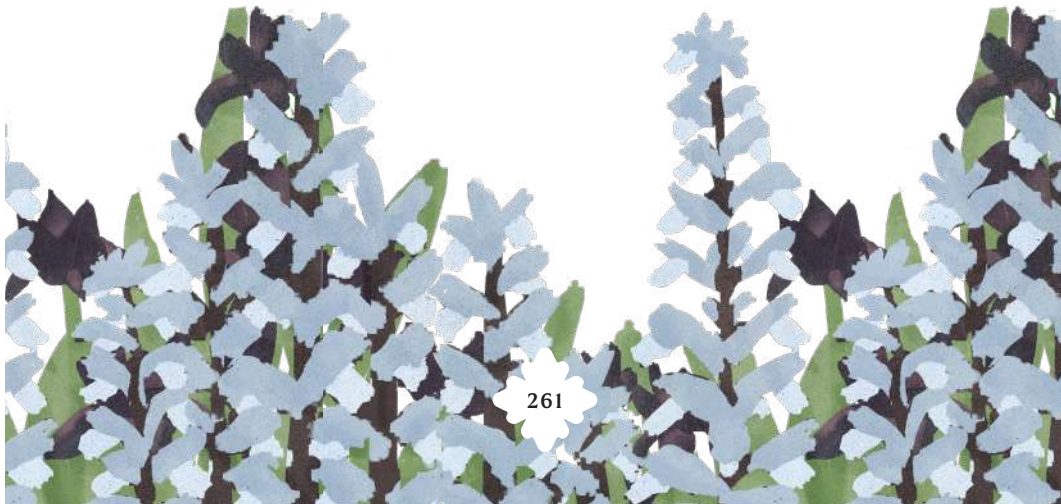
the transparency. Sample 4a turned out dryer and more flakey, while Sample 4b was more flexible. Both films has a similar degree in translucency.

TGA Name	Sample Weight	Clamp Force	Time	Temperature
Sample 4a	0.3925 g	5000 lbs	2:00	100 C

TGA Name	Sample Weight	Glycerol Weight	Clamp Force	Time	Temperature
Sample 4b	0.5956 g	25%	5000 lbs	2:00	100 C

As shown in correlation to Figure 8 under the Results section, Sample 5's method tried to find the perfect percentage of Glycerol to add. This time, the same Heat Pressing method was taken from Sample 4. The result proved to be the most successful in creating the clearest film.

TGA Name	Sample Weight	Glycerol Weight	Clamp Force	Time	Temperature
Sample 5	0.7932 g	12%	5000 lbs	2:00	100 C
Sample 5	0.9188 g	12%	5000 lbs	2:00	100 C



TGA Analysis - Pyris Software

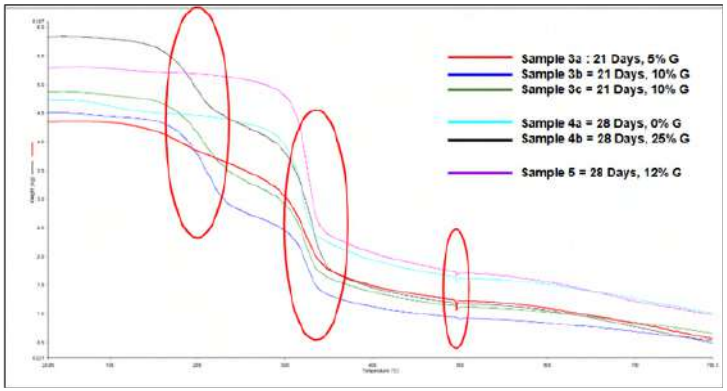


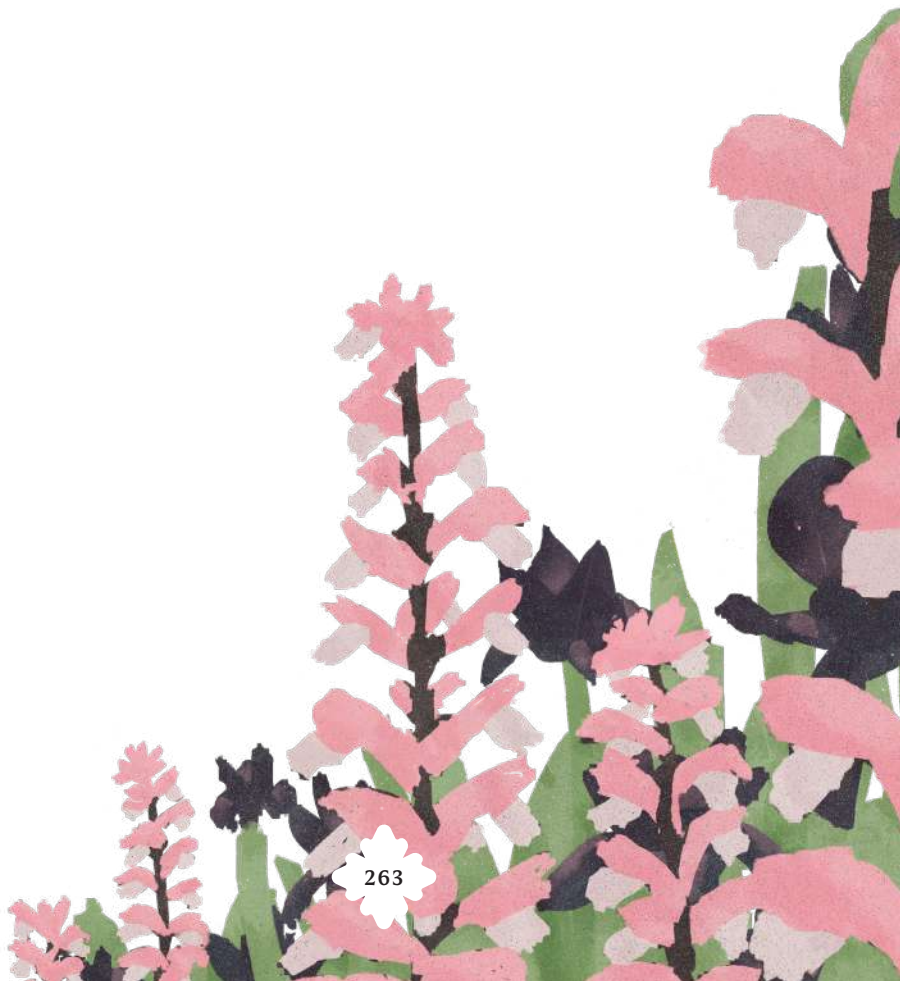
Figure 10: Shows The Main Weight Drop-Off Points

Through TGA analysis, we are able to observe three main drop off points that are consistent with all samples. The first drop-off point happens at around 200 C. There seems to be slight variances in weight loss among Samsples 4b, 3b, 3c and Samples 3a, 4a and 5.

Samples 4b, 3b and 3c all lose around 40% of their weight at 200 C, suggesting that it was due to their Glycerol content or the method used for Heat Pressing.

Samples 3a, 4a and 5 did not see a major drop off until around 340 C, suggesting that perhaps the mycelium itself is more resistant to thermal degradation when either treated with no Glycerol or the "perfect" amount. The second drop-off in weight we see at 340 C in all samples seems to be at the temperature that mycelium normally burns off. The last drop-off we see is a very slight dip, suggesting that it is the remainder of the glycerol that has burned off.

From the six TGA tests, we can conclude that Sample 5 showed the highest thermal "resistance." This would suggest that an incubation period of 28 days with 12% glycerol added may be the best for creating an ideal bioplastic film from mycelium.



CONCLUSION

This research explored how mushroom mycelium, specifically the mycelium of the Pleurotus ostreatus var. Columbinus behaves under various thermal treatments and forming techniques. The goal was to evaluate and characterize its potential as a sustainable alternative to thermoplastics in packaging. Over 28 days, mycelium was incubated, heat-pressed, treated with varying amounts of glycerol, and tested using thermogravimetric analysis. The results showed that both incubation time and glycerol content significantly affected the mycelium films' physical properties and thermal stability. Films treated with 10-12% glycerol produced the most translucent, flexible, and uniform results, suggesting that this ratio balances structure and processability. TGA testing revealed three consistent points of thermal degradation, films treated with either no glycerol or the optimal 12% demonstrated greater resistance to early weight loss, which may imply improved thermal resilience. These findings suggest that mycelium, when properly treated, can behave similarly to synthetic polymers in terms of being moldable and resistant to heat while remaining biodegradable and environmentally friendly. While further testing

is needed to understand its scalability, moisture resistance, and long-term durability, this study reinforces mycelium's potential as a viable alternative in industrial packaging contexts. With more refinement, this material could offer a real path toward reducing reliance on petroleum-based plastics and transitioning to circular, low-impact packaging solutions.

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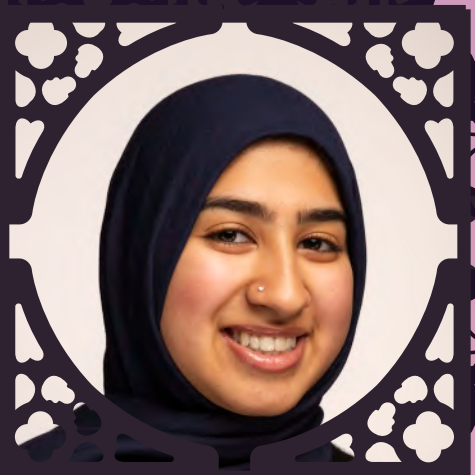
ABOUT THE JOURNAL

MEET THE TEAM

Meet our amazing team who worked non-stop to bring you this year's journal!



***Aliyah Jaffer** | She/Her*
President

Hey there! My name is Aliyah and I am honoured to be this year's TMUTAGA President! I am a third year GCM student concentrating in Publishing and minoring in Disability Studies. I am proud to be a part of this incredible team, without any of whom this project would not be possible. As president, I am responsible for overseeing all aspects of TMUTAGA. I work closest with (the team/my Admin team) on financials, planning and organizing, and ensuring all aspects of our production are conference-ready and align with TMUTAGA's values.

***Eimmie Chan** | She/Her*
Vice President

Hi hi! I'm Eimmie (a.k.a Eims) and I'm delighted to be TMUTAGA's Vice president this year! I'm currently a third year pursuing a minor in communication design and a publishing concentration. I'm so excited to be a part of TAGA and to showcase our proud work. Working side by side with our prez, it has been a joy overseeing our hardworking team to create everything from scratch. I can't wait for everyone to see our work!

Alicia Dos Santos | *She/Her*
Multimedia Director

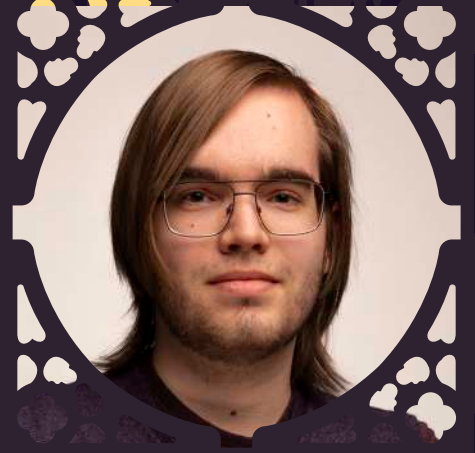
Hey there! I'm Alicia (ah-lee-see-ya) and I am the Multimedia director of TMUTAGA for 2025-26! It's my second year on the team, and I'm so glad to be working with such a talented bunch again. My team and I have been working hard to create complimentary aspects for the journal like this website, augmented reality, and ebook versions of the journal! As I face graduation, I'm so proud to have shown off the hard work of GCM grads one last time!

Nicole Downey | *She/Her*
Editorial Director

Hi! I'm Nicole, and I'm this year's Editorial Director for TMUTAGA! I'm a fourth-year GCM student pursuing a concentration in Graphic Output and a minor in Communication Design. I really enjoy getting to read and highlight the amazing research done by GCM students, and I'm excited for everyone to explore the work featured in this year's journal!

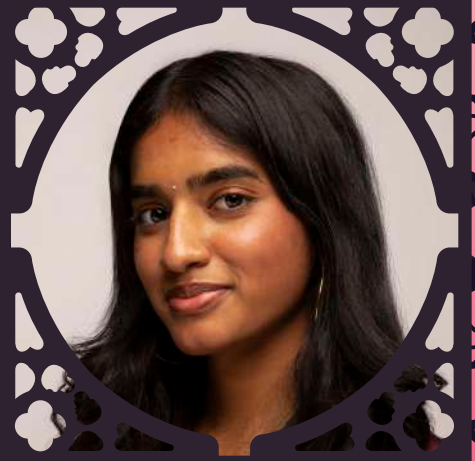
***Yi Jia Lin** | She/Her*
Finance Director

Hiya! My name is Yi Jia, and I'm this year's Finance Director for TMUTAGA! I'm a fourth-year GCM student working toward a concentration in Packaging and a minor in Communication Design. It's been incredibly exciting to see everything our team has been working toward come to life, and I'm looking forward to what's to come next!



***Matthew Karton** | He/She*
Creative Director

My journey in TMUTAGA has certainly been a long and winding road, but satisfying for the view. It has been an interesting experience watching the team reinvent itself in this new era. This edition of TMUTAGA concludes my third and final year as a member of the student chapter, one full of rewarding mayhem. I would like to thank my associates for their assistance in bringing my vision to life, and for my fellow executives for never doubting me throughout this process. Much of my work this year could've only happened with your support.



Jeevana Saravanabavan | She/Her
Marketing & Events Director

Heyo! I'm Jeevana, this year's Marketing & Events Director for TAGA! I'm a fourth-year GCM student completing a concentration in Packaging and a minor in Marketing. I'm so grateful to be working with amazing people and spreading the word to TMU about TAGA and all that we do!

Alyssa Varone-Ferreira | She/Her
Production Director

Hello!! I'm Alyssa (she/her) and this is my second year on TMUTAGA. I'm honoured to be this year's Production Director and I have the privilege to being part of such an amazing team. I'm a fourth-year GCM student pursuing a concentration in publishing, who enjoys the intersectionality of design and anything book/production related. I'm so excited to showcase all the incredible work our team has put into producing this beautiful journal, and I hope you enjoy it as much as we enjoyed creating it!

TMUTAGA ASSOCIATES

Creative

- Zahra Bhiwandiwala
- Linda Hatoum
- Amelie Thomson
- Mariah Williams

Marketing

- Alexa Caruana
- Gurnoor Dhillon
- Anujiga Elangovan
- Pooja Patel

Multimedia

- Saba El-Hayek
- Haqeeqat Singh Mangat

Production

- Rina Chong
- Tara Nguyen
- Ella Reed
- Andrew Whelan

COLOPHON

Software

- Adobe InDesign CC
- Adobe Illustrator CC
- Adobe Acrobat CC
- Fiery Command Workstation
- Krita
- VersaWorks

Stock

- Creator Digital Silk 80lb Text
- Creator Silk 100lb Cover
- Supreme Matte 100lb Text
- ORAJET 3651G White Vinyl

Typefaces

- Mestiza
- IvyPresto Text

Equipment

- Ricoh Pro C7210X
- Roland SOLJET XR-640
- Polar 78 Paper Cutter
- Muller Martini Amigo Plus

PRODUCTION NOTES

This year's journal was made possible by the efforts of students, faculty, and industry partners, it is thanks to all of you that this journal was able to be made.

Our journal was made possible thanks to the resources provided by the School of Graphic Communications Management (GCM) and our industry partners __.We received help from our faculty advisors Scott Millward, GCM's Printing Processes, Binding and Finishing Technician, and Kris Krystosiak, one of GCM's packaging and print experts.

Our paper for our journal was supplied by Spicers, whom we are extremely grateful. The interior pages of the journal were printed at GCM on the Ricoh Pro C7210X using Fiery Command Workstation and trimmed into book blocks using the Polar 78 Paper Cutter. The sticker sheet was printed at GCM on a Roland SOLJET XR-640, hand-trimmed, and then inserted into the book block by hand. The journal was perfect bound at GCM on a Müller Martini Amigo Plus then trimmed on a Polar 78 Paper Cutter.

MEET OUR DONORS

On behalf of the 2025-2026, we would like to express our gratitude to our donors for their generous contributions and support in creating this year's journal.

Graphic Communications Management

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