COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
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Center for Packaging and Unit Load Design

CPULD News

Quarterly Newsletter

The current edition of the newsletter contains the following exciting topics from CPULD:

- Investigation into the effect of plastic pails on pallet deflection and pressure distribution for stringer class wooden pallets.
- Characterizing the environmental impacts of common e-commerce packaging options for sustainability-minded stakeholders
- Evaluation of the horizontal compression forces that pallets experience during grab handling
- Results of recent undergraduate research projects.
- Alumni spotlight: Nicolas Navarro.
- Student spotlight: Rosa Williams.
- Updates from CPULD alumni.
- Summaries of three projects accepted for presentation at the 30th annual IAPRI conference.

Featured Research — The effect of plastic pails on pallet deflection and pressure distribution for stringer class wooden pallets

Image 1. Mary Paz Alvarez moving a unit load of plastic pails for testing.

Modern-day supply chains have a great reliance on wooden pallets. Around 513 million new wooden pallets are produced annually, which are used by 94% of companies in supply chains. Most new wooden pallets are built for specific applications. The current supply chain is made up of three interacting components: products, pallets, and material handling systems. By understanding the interactions between these components, the design of each component can be optimized, and the cost and sustainability of the overall system can be improved.

Graduate student Mary Paz Alvarez has been studying the interaction effects of drums and pails on pallets' strength and deflection levels since 2019 (*Image 1)*. Her research is funded by the Pallet Foundation and the National Wooden Pallet and Container Association.

One of the ways that the supply chain components interact is called load bridging. During load bridging, the packages on top of the pallet act as discrete loads, causing the load to be unevenly distributed across the top of the pallet. Although corrugated boxes are the most ubiquitous packages in supply chains, representing 72% of products being shipped, plastic pails are also an essential packaging type.

Plastic pails are shipping containers that are used primarily to ship fluids and powders. Pails are created to be either be tight-headed or open-headed. A tight-headed pail has a nonremovable lid and is meant to be liquid tight. Open-headed pails have larger openings and a removable lid for easy emptying. Based on a survey conducted by Modern Materials Handling magazine in 2020, 7% of goods that were shipped on pallets were in plastic pails. The estimated size of the global plastic pail industry was $5.54 billion in 2019 and is estimated to increase to $6.88 billion by 2024.

The objectives of Alvarez's research were to investigate the effects of 5-gallon plastic pails on the deflection of pallets compared to a uniformly distributed load, modeled by an airbag for testing purposes. Another objective was to investigate the pressure distribution between pallets and pails as a function of pallet design and support conditions. The most common failure mode for plastic pails is the buckling of their side walls, which can cause the pails to leak or a column of pails to become unstable and collapse. Both modes of failure can result in product damage and an unsafe work environment. In addition, pails' circular shape might cause more concentrated pressure distributions across the top of the pallet, which could affect pallet performance.

The experimental design for this project utilized one pail design, four pallet designs, two pail stacking patterns, and four support conditions. There were three repetitions for each pallet design. The support conditions included warehouse racking across the length, warehouse racking across the width, single floor stack, and double floor stack. The greatest measured pallet deflection for each support condition was used for statistical analysis via an analysis of variance (ANOVA) test. The dependent variable was pallet deflection while the independent variables were the pallet design and the loading method.

The pressure data revealed that the load predominantly transfers to the pallet through the bottom perimeter of the pail (*Image 2a and 2b)*. This is indicated by the circular distribution of the pressure. Therefore, the size of the perimeter and the design of the bottom of the pail are crucial factors that can influence the performance of the pallet. It also was observed that, due to the bending of the pallet, the entire perimeter of the bottom of the pail is not always engaged in supporting the load. The pressure tends to distribute towards the stringers parallel to the direction of pallet bending. This redistribution of pressure indicates the presence of load bridging, which explains the consistent reduction in pallet deflection when a unit load of pails is used instead of a flexible airbag.

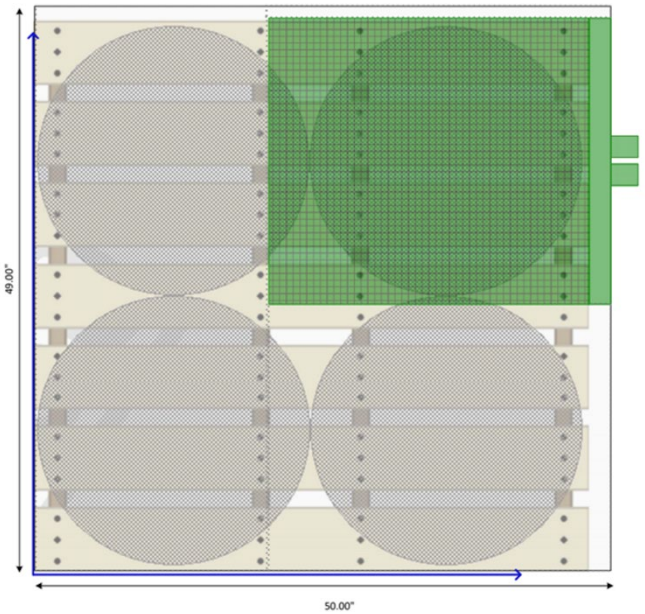


Image 2a. Pressure map setup for one quarter of pallet.

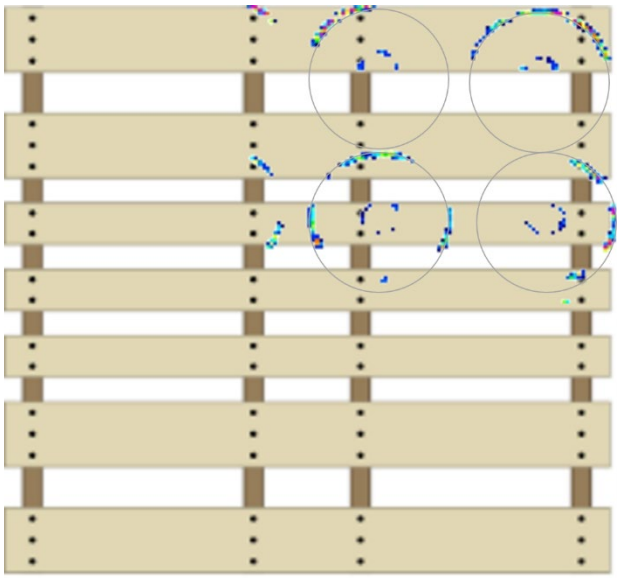


Image 2b. Pressure map reading for plastic pails.

For both the warehouse racking across the length and the warehouse racking across the width support conditions, deflection decreased significantly when the pallet was loaded with pails rather than the flexible airbag. The decrease in deflection ranged from 56% to 61%. The largest reduction (61%) was found on the

pallet designs with 1.27 cm top deckboard thicknesses where the pails were column stacked without nesting. The deflection of the column stacked and nested pail patterns resulted the exact same deflection for the 3-stringer pallet design with 1.27 cm top deckboards. The statistical analysis of the interaction effects revealed that the loading method has more effect on the 4-stringer and 3-stringer pallets with 1.27 cm top deckboards than for the other designs, indicating the load bridging has a greater effect on pallets with lower stiffness top decks.

Regarding the single and double stack support conditions, the ANOVA results of the single stacked support condition indicate that the pallet design and the loading method were statistically significant along with the interaction effects. Pallet deflection decreased significantly when the pallet was loaded with pails rather than the airbag. This decrease in deflection ranged from 70% to 89%. The maximum decrease in deflection (89%) was observed for the 4-stringer pallet design with 1.27 cm thick top deckboards (*Table 1*).

For the double stacked condition, the deflection reduction ranged from 43% to 80%. The maximum decrease in deflection (80%) was observed for the 3-stringer pallet design with 1.27 cm thick top deckboards.

When the interaction effect between the loading method and the pallet design was further investigated, the effect of pails (vs. the airbag) had the greatest change for the 3-stringer pallet with 1.27 cm top deckboards, indicating the load bridging has a greater effect on pallets with lower stiffness top decks.

	Pallet Deflection (cm)									
	4-Stringer				**3-Stringer**					
Loading Method	**1.59 cm deckboard thickness (D1)**		**1.27 cm deckboard thickness (D2)**		**1.59 cm deckboard thickness (D3)**		**1.27 cm deckboard thickness (D4)**		**1.27 cm deckboard thickness nested (D5)**	
Airbag	0.217		0.255		0.323		0.373		0.357	
Plastic Pails	0.046 (32%)	-79%	0.028 (5%)	-89%	0.098 (1%)	-70%	0.069 (35%)	-81%	0.094 (4%)	-74%

Note: Values in parentheses are Coefficient of Variance values.

Table 1. Summary of average pallet deflections for the investigated pallet designs and loading methods in the single floor stack support condition.

When comparing the deflections of pallet designs, similar to the warehouse rack across the width support condition, the effect of deckboard thickness was found to be significant for most scenarios. This illustrates the ongoing deflection trend by comparing the uniformly distributed load and the unit load of plastic pails while the unit loads were double stacked.

Based on her research, Alvarez has concluded that the effect of loading method was statistically significant in every support condition. Pallet deflection significantly decreases when loaded with pails compared to a flexible airbag. This reduction ranged from 32% to 89% for most pallet designs. This finding indicates that pallets

supporting unit loads of pails will deflect significantly less than what they are currently designed for, and this reduced deflection could increase the load capacity of some pallet designs.

The greatest effect of the loading method was found for the single stack support condition, with 71% to 89% reduction. The load predominantly distributes down through the bottom perimeter of the pails, indicating that the size and design of the bottom of the pail could have a major effect on the load capacity of pallets. The effects of pallet design and the interactions between loading method and pallet design were statistically significant in every support condition. The effect of pallet design was proven to be important because it influenced the way pressure distributes throughout the bottom perimeter of the pail.

Overall, these results reveal that wooden pallets should be designed for the specific type of packages they will be carrying in order to optimize the cost of the pallet and reduce the amount of raw materials used to manufacture wooden pallets.

Image 3. Mary Paz Alvarez building a unit load of pails.

Alumni Spotlight — Nicolas Navarro, Field Application Engineer, JFR Holdings

Image 1. Nicolas Navarro, 2018

Nicolas "Nico" Navarro, who is from Costa Rica, says he was attracted to Virginia Tech's high-quality programs and its learning environment. "My research in graduate school focused on exploring the concept of Internet-of-Things (IoT) implementation in pallets." He graduated in August 2020 with two master's degrees: industrial and systems engineering with a focus in management, and sustainable biomaterials with a focus in packaging.

While he earned his degrees, Nico collaborated closely with engineers and executives in the packaging and manufacturing industry to develop case studies and identify business needs relating to supply chains, distribution processes, and packaging design. He was able to translate business needs into technical system requirements that a system must fulfill using IoT technology to satisfy the identified needs. "I also applied a model-based system engineering approach to develop an operational concept of an IoT system for the distribution packaging supply chain to continuously capture critical transportation and cargo information that allows improved packaging design and enhances supply chain operations efficiency."

In looking back at his time here, Nico said, "One of the most important skills that you develop at the CPULD is working in a team. The ability to communicate with others highly impacts success in your career. Indeed, this is one of Warren Buffet's main advice to young professionals. In the end, you are going to work with people, and it is people who get things done, so you need to know to handle the soft side of business."

Nico worked as a graduate lab manager during his time at CPULD. In that role he learned to prioritize and assign activities among the interns in order to achieve the laboratory's daily schedule objectives. This generally included supervising and conducting standardized and customized product testing that allowed for the optimization of packaging design and development — achieved by making sure that the integrity of products was preserved along the supply chain, while procuring cost and material waste reductions, as well as increased safety during handling and storage.

Nico also conducted inspections of reusable packaging solutions and products in order to determine modes of failure and assess their survivability and performance. He learned how to put together elaborate reports to provide clients with technical information relating to their packaging performance and failure modes, which, in turn, assisted clients in the decision-making process when choosing a packaging solution. Nico was instrumental in implementing and providing continuity to the lean management programs that CPULD was focused on by ensuring workstation organization, reducing operators' movements, and increasing productivity and safety.

It was not just leadership skills and teamwork that Nico learned; he also had quite a few classes that he recommends for any grad student. Particularly for those interested in statistics and decision modeling, Nico said, "At the CPULD I got to learn how supply chain operations are heavily impacted by packaging systems and how this field presents an opportunity for efficiency and cost improvements. I took a class in the College of Engineering called Decision Analysis for Engineering, which I recommend to any graduate student interested in decision modeling, statistics, and probability. The contents of the class are applicable to a wide variety of fields, from science and engineering, to marketing and finance."

Before he graduated, Nico had secured a position as a field application engineer with JFR Holdings, which works with clients to design, build, and/or repair wooden boxes, crates, and pallets for shipping any client's products anywhere in the world. Nico says his duties now include supporting the company from a technical standpoint by developing product specifications using CAD software, and assisting existing and potential customers with design and cost estimation. And he is "currently working on a project to implement an ERP [enterprise resource planning] system at one of their manufacturing facilities and another project on customer engagement."

On a personal note, Nico shared that his entire family still lives in Costa Rica. "Unfortunately, COVID-19 has prevented me from visiting them this past year, but I am hopeful that as things start to get back to normal, I will be able to visit them soon. Outside of work, I enjoy hiking, reading, listening to music, and working out in the gym, and I am currently taking virtual classes on Python programming." Nico also added that his ideal location for living and fun would be at the beach.

Image 2. Nicolas Navarro, 2020

Research Highlight — Characterizing the environmental impacts of common e-commerce packaging options for sustainability-minded stakeholders (case study)

Image 1. Package transportation around the world for corrugated boxes, virgin paper envelopes, and rLDPE bags.

Electronic commerce (e-commerce), defined as an application of electronic means and technologies to conduct commerce, is a method of retailing that is currently drawing huge attention. Since the internet has become ubiquitous, e-commerce continues to grow and expand its influence at a remarkable pace. In the U.S., e-commerce sales have been growing at a rate of 28% annually for over 20 years. This is significantly different from traditional retail sales, which only grew 3% per year.

As such, there is increasing research focused on assessing and mitigating the environmental impacts of e-commerce packaging across a range of impact areas: energy consumption, greenhouse gas (GHG) emissions, waste generation, and comprehensive areas of environmental performance, including global warming potential, abiotic depletion, acidification, eutrophication, ozone depletion, freshwater and marine aquatic ecotoxicity, human toxicity, terrestrial ecotoxicity, and photochemical ozone creation potential. The acceleration of the concept of a "circular economy" around the world is also prompting research and interest in the role of packaging in the transition to more circular material production and consumption systems.

Apparel is one of the most common products sold within e-commerce systems. The apparel industry accounts for the largest share of e-commerce sales in the U.S.: 18% in 2015, totaling $52.1 billion. Hence, the need for e-commerce packaging in the apparel industry has also continued to increase. As e-commerce packaging waste and its impact on the environment continue to attract attention, several major multinational brands are working to transform their packaging systems to be more sustainable and environmentally conscious.

Master's student Saewhan Kim *(Image 2)* has worked with circular economy expert Dr. Jennifer Russell of Virginia Tech's Department of Sustainable Biomaterials to investigate the sustainability of different packaging solutions used by a European apparel company.

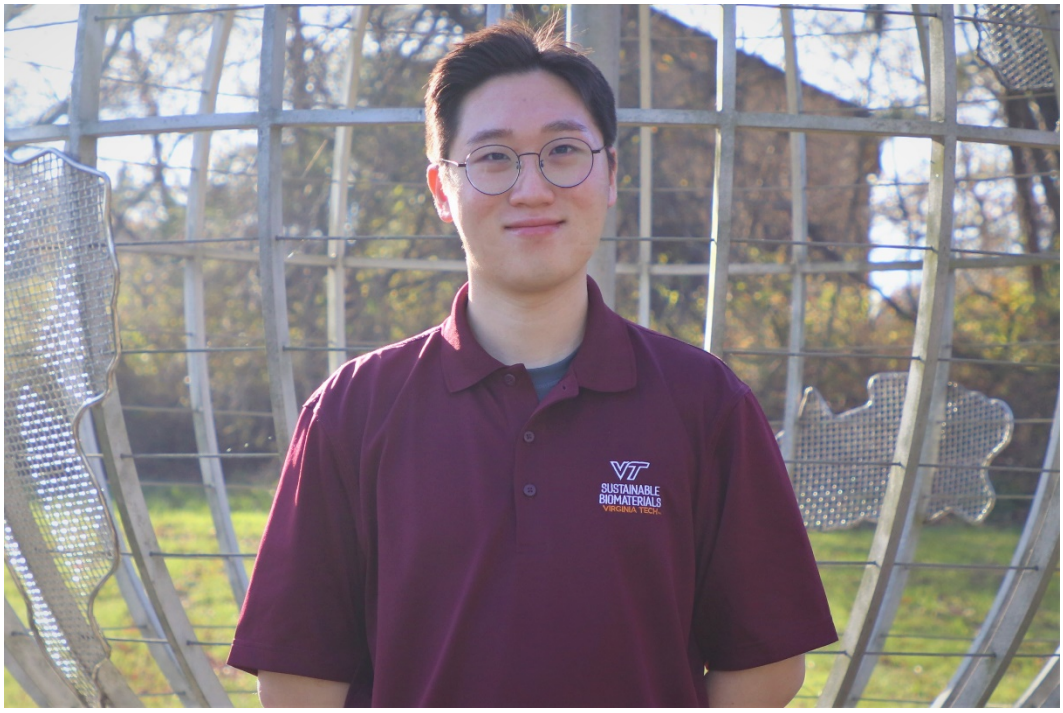


Image 2. Master's student Saewhan Kim

Employing a life cycle assessment (LCA) method, this research study compared the environmental impacts of three different e-commerce apparel packaging systems commonly used for distribution into U.S. market: a corrugated board box, a virgin paper envelope, and a recycled-content, low-density, polyethylene (rLDPE) bag. LCA methodology examines the potential environmental impacts and risks of the product or system by evaluating input and output data throughout its entire life cycle. This research complied with ISO 14040-44 standards 27-31, which require compliance in four main steps: (1) goal and scope definition; (2) life cycle inventory (LCI) analysis; (3) life cycle impact analysis (LCIA); and (4) interpretation. The life cycle impacts of the three apparel e-commerce packaging options were assessed and their relative environmental impacts compared.

Basically, this project involved conducting a quantitative analysis of environmental impacts of popular e-commerce packaging options and then informing decision-makers, consumers, and retailers of the objective comparisons of the environmental burdens generated by the various e-commerce apparel packaging systems. A "cradle-to-grave" perspective, including raw material extraction, packaging manufacturing, transportation processes, and end-of-life scenarios, was applied to this study.

In accordance with the requirements of our collaborating European multinational apparel company (hereafter identified as "industry collaborator"), the studied scenarios assumed that package input materials (corrugated board, virgin paper, and rLDPE) were sourced and manufactured in Europe (Sweden and Spain) and then shipped into the U.S. e-commerce marketplace. Thus, two geographical scopes were selected in this study: Europe (Sweden and Spain) for the raw material extraction and packaging manufacturing and the U.S. for post-manufacturing processes.

The life cycle for each packaging scenario was separated into four different stages and individually assessed to evaluate each stage across different environmental impact categories. The first stage of the life cycle was raw material production, which included the logging process for paper-based packaging scenarios and plastic granules production for the petrochemical-based packaging scenario. The next life cycle stage, intermediate processing, included paper packaging manufacturing processes such as milling, linerboard production, medium

fluting, gluing, and box shaping, and plastic formation processes such as plastic film extrusion and other supporting activities. The third stage of the life cycle, transportation/use, includes the distribution of manufactured packaging to each destination point throughout the supply chain. The final life cycle stage, end-of-life (EOL), included waste treatment scenarios for recycling, incineration with energy recovery, and landfilling.

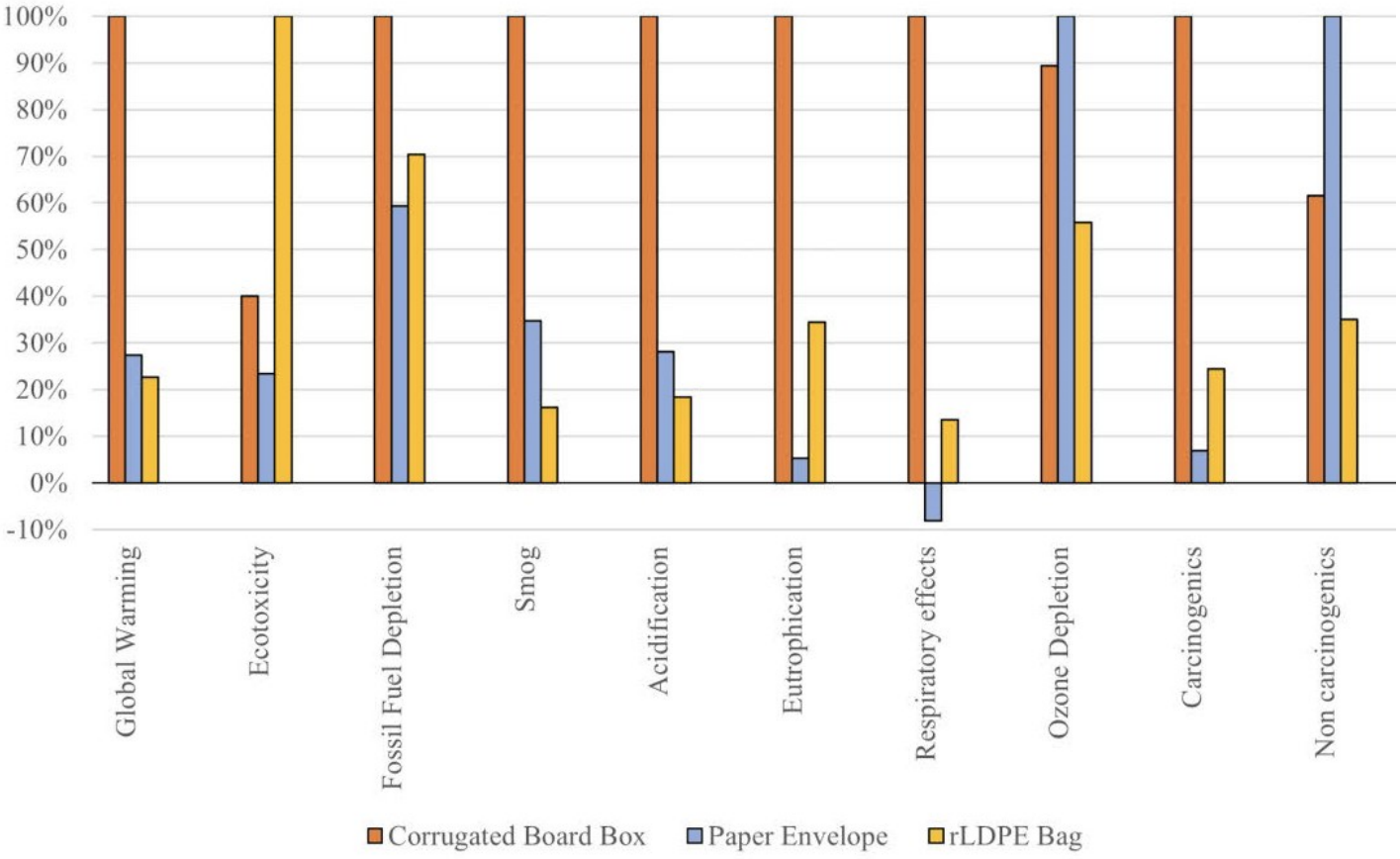


Image 3. Comparison of the relative environmental impacts generated by the corrugated board box, the virgin paper envelope, and the rLDPE bag. (For each impact category, the package scenario yielding the greatest impact was set to 100% to demonstrate relative impact reduction made possible via the alternative package options.)

The comparison of the three packaging scenarios *(Image 3)* reveals that the impacts of the e-commerce corrugated board box scenario resulted in the greatest environmental burdens across seven different environmental impact categories (Image 3). For global warming potential, the corrugated board box (0.299kg CO_2-e) was 3.5 times the impact of the virgin paper envelope and 4.4 times the impact of the rLDPE bag. For fossil fuel depletion, the corrugated board box (0.156 MJ surplus) was 1.4 times the impact of the virgin paper envelope and 1.7 times the impact of the rLDPE bag. And for smog, the corrugated board box (0.0495kg O3-e) was 2.9 times the impact of the virgin paper envelope and 6.2 times the impact of the rLDPE bag. Similarly dramatic impacts were observed for the corrugated board box in impact categories for acidification (0.00216kg SO_2-e), eutrophication (0.00159kg N-e), respiratory effects (0.000373kg PM2.5-e), and carcinogens (0.000000122CTUh). The primary driver behind these significant impacts of the corrugated board box is its relatively greater material weight. At approximately 209g, the corrugated board box required significantly more material input to produce and equated to a greater package weight to be transported.

Another factor driving the environmental impact differential between the corrugated board box and the rLDPE bag was the distance that the material was required to travel. For the paper-based packaging options, the input

materials were located 3,252 km away from the packaging manufacturing facility, while the input materials for the rLDPE bag were able to be sourced from only 53 km away. Thus, the difference in transportation distance required by the industry collaborator's supply chain system as well as the greater material weight of both paper-based packages contributed to significant environmental impacts from transportation activities. Although this specific material sourcing scenario cannot be generalized for other e-commerce companies, it greatly affected the sustainability of corrugated board boxes for the partner company.

Under the defined scope of this research, the corrugated board box resulted in the highest environmental burden of the three packaging options. Although paper is generally perceived to be the environmentally preferable material when compared to plastics, the rLDPE bag actually resulted in a lower environmental burden. While a high recycling rate helps to offset some of the environmental burdens of the corrugated board box and the virgin paper envelope, in most categories, it was not enough to overcome burdens associated with transportation, material requirements, and weight.

A sensitivity analysis found that supply chain distance optimization can help to improve the environmental performance of the paper-based options in these scenarios. But there is still a need for improvement. In particular, apparel brands operating in e-commerce markets should consider the geographic implications of, and transportation modes within, their package supply chain configurations. Future work is needed to explore the implications of varied package weights and percentage of recycled-content adjustments in order to balance package performance and its environmental impacts within the e-commerce system.

Research Highlight — Environmental benefits of increasing the stiffness of the pallet top deck for unit loads carrying corrugated boxes

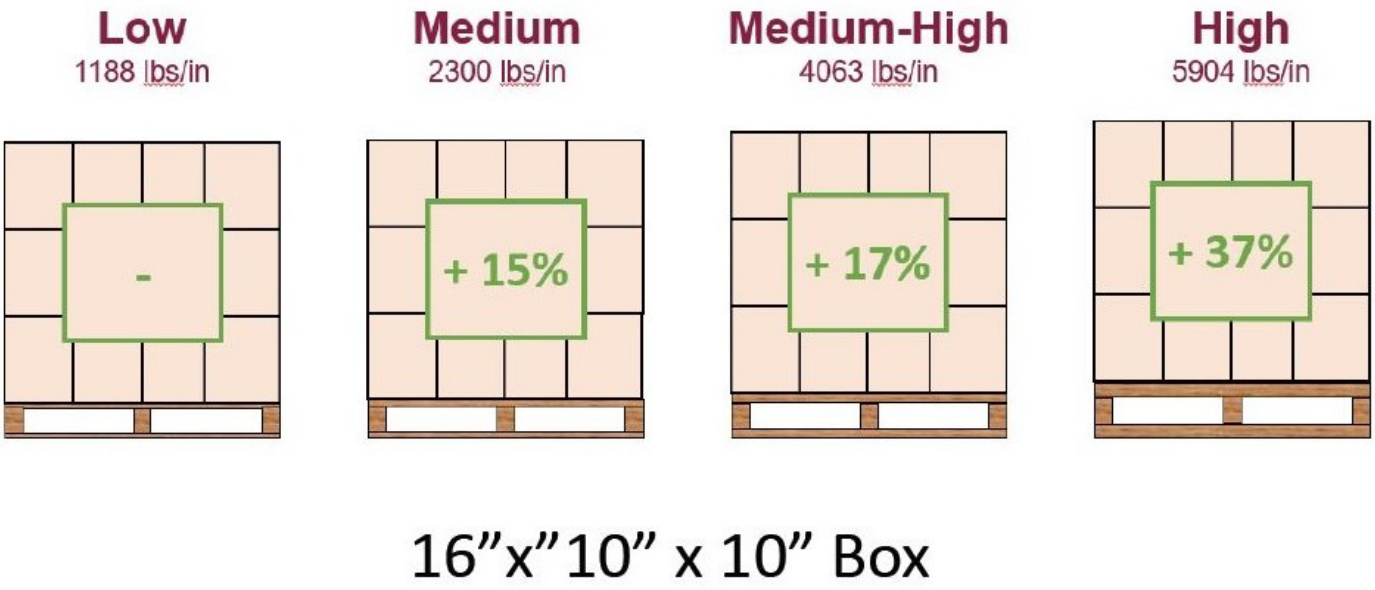


Image 1. Box compression strength changes due to pallet top deck stiffness.

This research project expanded on former graduate student Chandler Quesenberry's research into the financial benefits of increasing the stiffness of pallet top deck boards for unit loads of corrugated boxes. In his initial project, Quesenberry determined that there was a 37% reduction in box compression strength when carried on lower stiffness pallets; hence, a savings of $1.30 per unit load when using a higher stiffness pallet *(Image 1)*. The objective of this subsequent study was to quantify the environmental benefits of increasing the stiffness of pallet top deckboards for unit loads of corrugated boxes.

The pallets and packages used for this research were built into two types of unit loads. Pallets were 48 in. x 40 in. stringer-class pallets with seven top and five bottom deckboards that were 3.5 in. wide and made of #2 kiln-dried SPF using two nails per connection. The 48 packages used to build the unit load were 16 in. x 9.75 in. x 20 in. Regular Slotted Container (RSC) style corrugated boxes. Unit Load 1 used 3/8 in. thick deckboards and B-flute corrugated board with 40 lb./in. nominal Edge Crush Test (ECT) value, while Unit Load 2 used 5/8 in. thick deckboards and B-flute corrugated board with 32 lb./in. nominal ECT value.

There are many aspects and items in a palletized unit load that can have environmental impacts. The manufacturing and recycling of corrugated board and liners impacts ozone depletion and global warming, consumes fossil fuels, and contributes to adverse respiratory effects. The electricity used during manufacturing and the waste treatment of corrugated boards contribute to acidification and ecotoxicity.

The life cycle analysis for this research project *(Image 2)* was conducted using SimaPro v9.0 LCA software based on ISO 14040.2006. It was done using the methods outlined in Traci 2.1 v1.05 and US-Canadian 2008 examining 1,000 unit loads and took into account raw material extraction, manufacturing, distribution, use, and end-of-life processes.

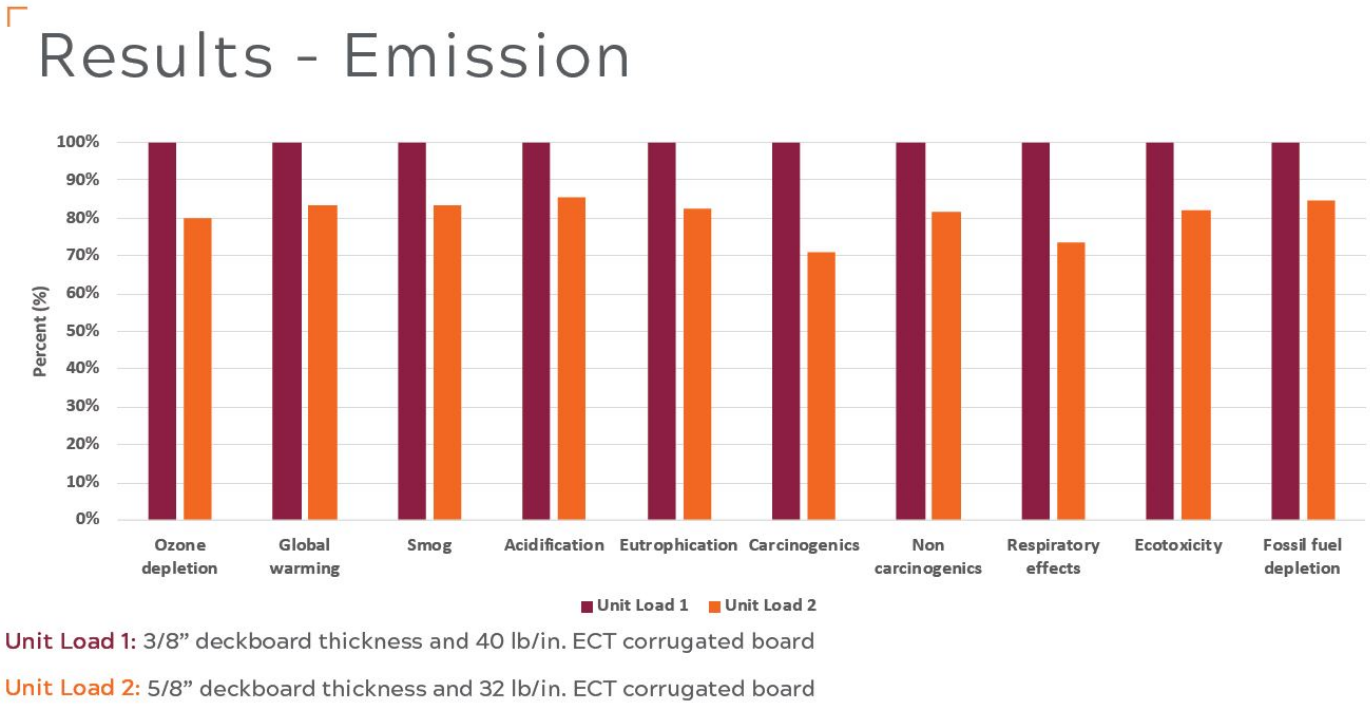


Image 2. Life cycle analysis (LCA) of emission impacts of palletized unit loads based on pallets' top deckboard thicknesses. (For each emission category, the deckboard thickness yielding the greatest impact was set to 100% to demonstrate relative impact reduction made possible via the alternative deckboard thickness option).

The environmental impact was reduced by an average of 20%, and 17% less CO2 was released when the unit load with stiffer top deckboards was used. Considering these facts in addition to Quesenberry's original research's savings of $1.30 per unit load, it can be concluded that, for most distribution supply chains, it will be more beneficial overall for companies to use pallets with thicker top deckboards.

Research Highlight — Reusable apparel packaging in e-commerce: Tests and suggestions for a European clothing retailer

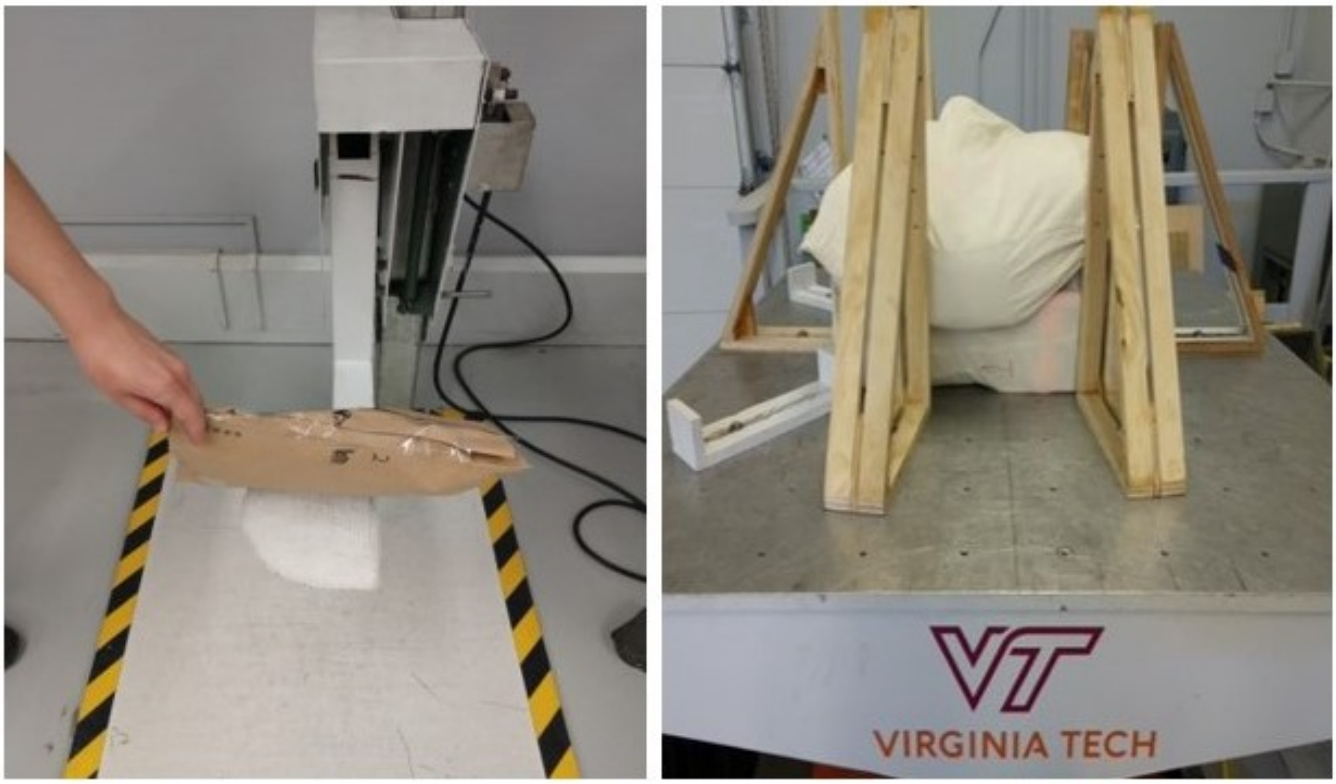


Image 1. A) Drop testing reusable packaging, and B) vibration testing of reusable packaging.

Today, many companies are trying to make their products and packaging systems more economical and environmentally friendly in response to a rapidly changing industry. There is currently a major market trend of using more sustainable and green packaging for commercial products. Reusable packaging can be described in many ways, each fitting different functions or end-of-life purposes. Packages can be reused by a consumer to find a new life for the package or can be taken to recycling and reusing centers. Packaging can also be reused within a business' supply chain, shipping in special containers between their own warehouses and distribution centers.

This research project was conducted by Victoria Dashevsky, a senior from Alpharetta, Georgia, and Jordan Wells, a junior from Roanoke, Virginia, who are both undergraduates in Virginia Tech's packaging systems and design program *(Images 2 and 3).* Their goal was to research and present the current state of the reusable packaging market and then develop working proposals for their client, a major European clothing retailer who sponsored the study (referred to hereafter as the "Sponsor"), with suggestions on how to change some of their packaging to more sustainable solutions. First, they presented a literature review of the two main types of supply chain models that currently use forms of reusable packaging: business to business (B2B) and business to customer (B2C).

Image 2. Victoria Dashevsky

Image 3. Jordan Wells

Business to business (B2B) is a model of packaging logistics that involves items being shipped between or within a company's infrastructure, including distribution centers, warehouses, stores, or other locations used in the operation of the business. Packaging systems used in B2B supply chains predominantly include reusable pallets, various forms of corrugated boxes, and reusable plastic containers. Reusable packaging is extremely common within B2B; there is no concern about enticing consumers to return the packaging. All of the materials stay within the company's supply chain, which reduces expenses related to loss of packaging. There is also less of an initial investment since existing shipping routes are utilized. However, since reusable packages are often returned in batches to maintain shipping efficiency, they end up accumulating before being shipped back, presenting a safety hazard as well as taking up space. This leads to cases of idle inventory, and, in addition to safety and space concerns, hygiene is also a potential issue.

The alternative supply chain model is business to customer (B2C). These systems cover shipping to customers directly as opposed to between business locations. Most of the reusable packaging solutions in this market are for common consumer goods. Polybags, polymer sleeves, fabric totes, glass containers, metal containers, and plastic boxes are all common types of B2C reusable packaging. The packages can be viewed as a marketing asset. In fact, many reusable packages are designed with a secondary user function, such as a canvas tote. Proper sanitation and hygiene of the packages that are returned and reused must be ensured. Companies also need to incentivize the return of the packages, as people need some financial benefit to adjust. Two of the best ways that companies can incentivize returns is through deposits or purchase discounts.

A circular economy (CE) is routinely described as "closing the loop" of the supply chain. This is accomplished with the application of several main principles. First, waste and pollution are designed out of the process. Next, products and materials must be kept in use to avoid waste. Finally, natural systems must be regenerated in order to ensure future resource availability. These guiding statements shape what CE must be in the future and how the Sponsor's goals can match them.

In the case of the Sponsor, the products that they ship are considered fast moving consumer goods (FMCG), which presents its own set of challenges to the company. All segments of the supply chain must be efficient and well-designed with CE principles in mind for new solutions to be effective. To make CE much more attainable for e-commerce packaging systems, a model called reverse logistics needs to be implemented. Reverse logistics deals with the recollection, preparation, modification, and ultimate repurposing of already used economic outputs.

Given the data collected about both the industry trends in reusable packaging markets and the examples of existing systems, four potential reusable packaging systems were presented to the Sponsor. Each option was chosen and then examined in lab tests to determine its efficacy. In considering the potential choices, previous successes of these solutions, the marketability/uniqueness of each, and how well they match the Sponsor's stated sustainability principles were all taken into account.

- Solution 1: Returnable Polymer Pouch. In this option, the apparel is shipped to the consumer in a durable polymer pouch, which can then be folded up, placed in a mailbox, and returned back to the company. Once returned, the sponsor can repack the polymer pouch and ship it to another consumer.
- Solution 2: Recycled Fabric Waste Bag. This solution involves using fabric waste from the clothing production process or extra stock clothing items to make a bag to ship the clothing or products in. This bag can then be reused by the consumer for any purpose that they want.
- Solution 3: Hyper-recyclable Paperboard Pouch/Container. One of the sponsor's principles for sustainability is using both recycled and recyclable materials. This option, a paperboard pouch, is recyclable instead of reusable. Being light, inexpensive, and easily disposable, this solution creates waste that isn't harmful to the environment like discarded plastic film is.
- Solution 4: Heavy Corrugated Box or Plastic Corrugated Box. These solutions are commonly used in a B2B environment; however, their introduction into the B2C environment could generate significant environmental benefits but also comes with challenges.

After getting feedback from the sponsor, the students identified five package solutions (*Image 4)* for further evaluation: a single-use, apparel polybag; a single-use, apparel paper bag; a standard corrugated box (determined by Amazon overbox standards); an Orbis corrugated box; and a RePack sample bag.

Image 4. Currently existing packaging options from the Sponsor and its competitors: (A) apparel poly bag, (B) apparel paper bag, (C) standard corrugated box, (D) Orbis corrugated box, (E) RePack sample bag.

To determine the ability of the packaging solutions to protect the products throughout the physical distribution, an ISTA 3A testing sequence was then conducted on all five packaging solutions (*Image 1*). The packages were filled with four products: two T-shirts, one pair of shoes, and a container of lip gloss. Due to the small size and weight of these products, the polybag, paper bag, and the RePack solutions were all categorized as “small” packages while the Orbis box and the standard corrugated box were categorized as “standard” packages. The durability test results were conclusive and clear; all sample packages went through all tests without any failures.

To determine the difference in the environmental performance of the different solutions, a graduate student group is working on a comprehensive Life Cycle Analysis.

Research Highlight — Evaluating the effect of pallet deckboard gaps and overhang on the compression strength of plastic pails

Image 1. Rosa Williams conducting compression testing of a plastic pail on the Lansmont Squeezer.

The objective of this undergraduate research project, conducted during the fall 2020 semester, was to measure and analyze the effect of varying sizes of pallet deckboard gaps and pallet overhang gaps on the compression strength of three different sizes of plastic pails, assuming completely rigid deckboards.

Three undergraduate students participated in this research project: Jon Porter, a senior from Chesapeake, Virginia; Carter Engvall, a senior from Alexandria, Virginia; and Rosa Williams, a freshman from Marietta, Georgia. The project was sponsored by the National Wooden Pallet and Container Association through their industrial affiliate membership. The students investigated three different sizes of pails: 3.5-gallon, 5-gallon, and 7-gallon (all had a bottom diameter of 10.5 in.). They conducted the study using ASTM D642 guidelines and a Lansmont Squeezer Fixed Platen Compression Tester (*Image 1)*.

Pails are an essential part of modern packaging and are used for a variety of fluids, ranging from chemical coatings and paints to juices and other food products. Despite their many uses, there has been little to no research done on the compression strength of pails within the context of palletization. As pails are a common form of packaging, understanding this complex relationship will greatly benefit the packaging industry. The general objective of this research project was to better understand the effect that pallet deckboard gaps and overhang have on three different sizes of plastic pails.

To simulate the effect of rigid deckboards with gaps and overhang, the pails were supported on a 5.5 in. wide a pallet deckboard simulator made of 0.75 in. plywood *(Image 2)*. The deckboard simulators were positioned to create three different sizes of gaps and two sizes of overhang. The gaps were centered under the pails. To simulate the load distribution observed for stacked pails, a circular jig made of a bottom section of a pail reinforced with plywood was developed and used for the load application.

The guidelines of ASTM D642 (202) were used for the experiment that was conducted in order to find the compression strength of the pails being evaluated.

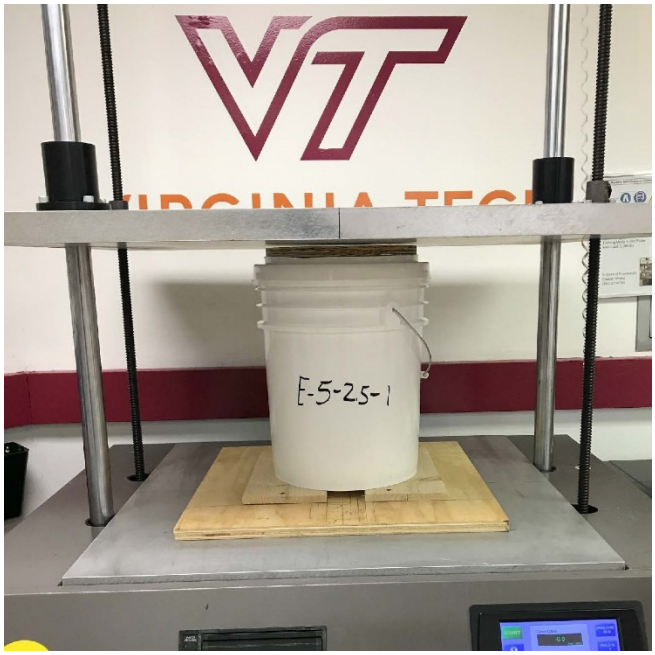


Image 2. Experimental setup for compression strength of a plastic pail on a 2.5 in. pallet gap.

The results revealed that the pail was the strongest on the support with no deckboard gap (control) and this support condition was significantly different from the rest of the support types. When the pail was supported on deckboards with varying sizes of gaps, the strength of the pails decreased by 1% to 30% depending on the design. However, the statistical analysis revealed that the pails' strength measured for the different deckboard gap scenarios were not significantly different from each other. The support condition where the pail was overhanging the deckboard resulted the lowest pail strength values, reducing the pail strength between 12% and 46%. Contrary to the effect of deckboard gaps, there was a significant difference between the pail strength values observed for the different overhang scenarios. The pail strength decreased significantly when the overhang increased.

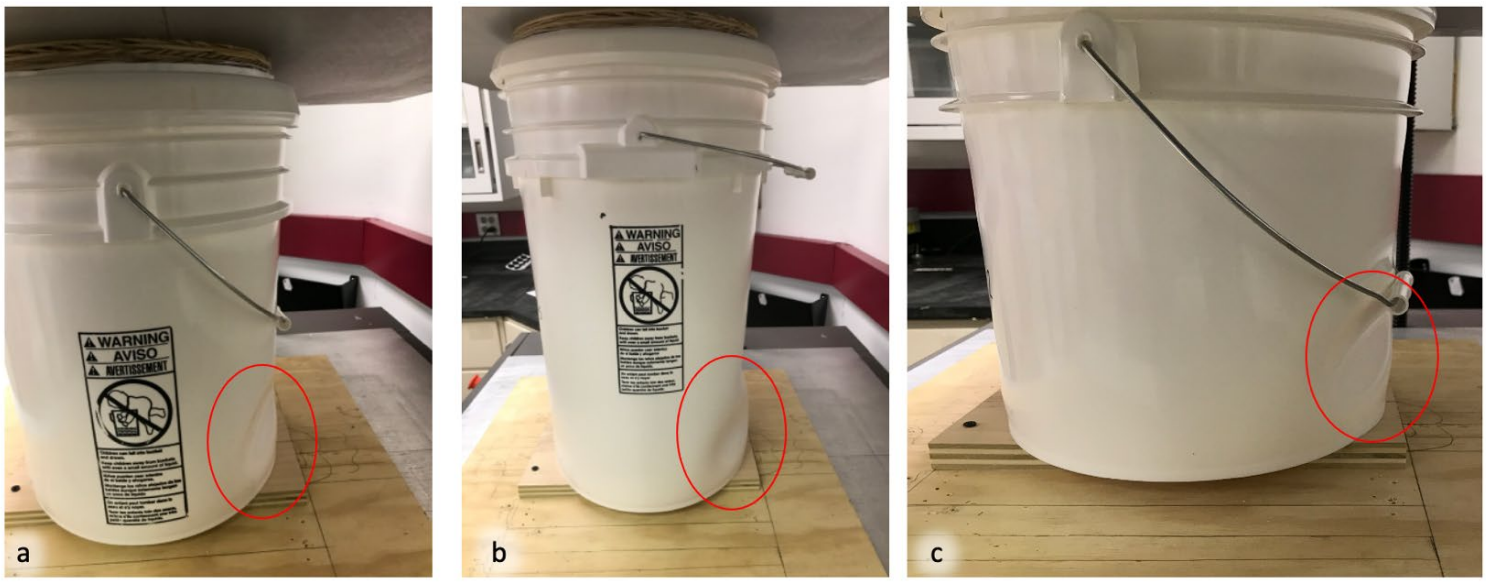


Image 3. Pail failure mode: sidewall buckling of the three sizes of pails tested.

The most common pail failure mode seen during testing was sidewall buckling (*Image 3)*, while lid failure was observed for only a limited number of samples and designs. Sidewall buckling was present on all sizes of pails; lid failure was only present on the 3.5- and 7-gallon pails.

Based on the findings of this research project, it is recommended to avoid overhang, as it causes a much greater reduction in pail compression strength. While deckboard gaps reduce strength as well, the reduction in compression strength due to overhang is much more severe.

Research Highlight — A comparative study of hazards that packages experience in the FedEx and UPS shipping systems

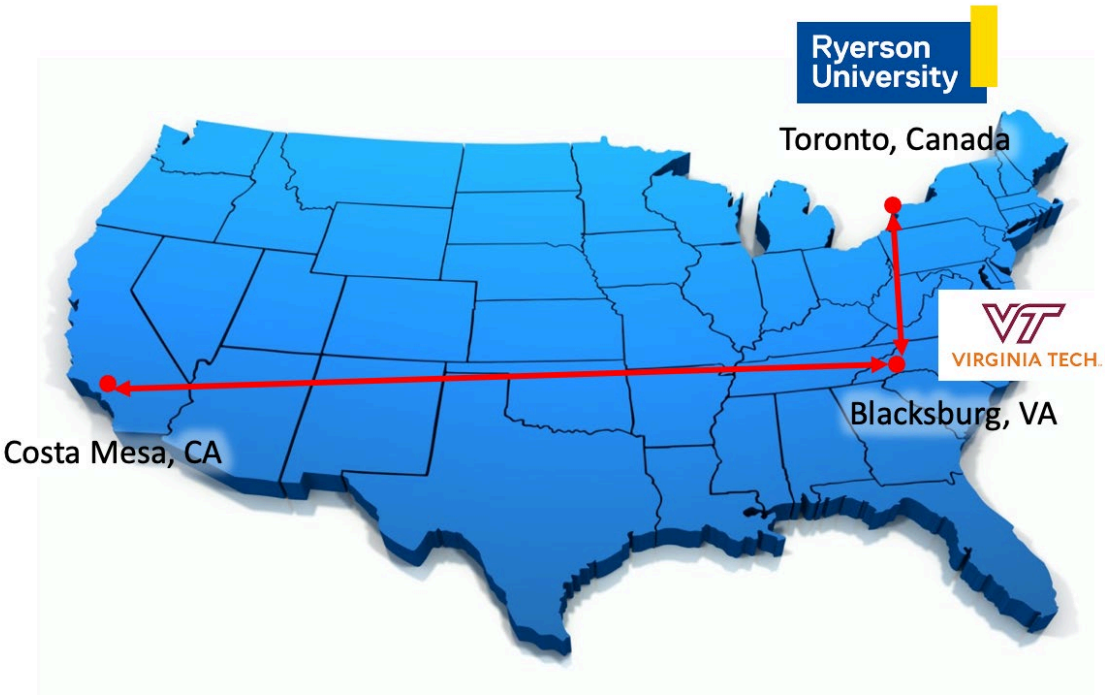


Image 1. Parcel movement during comparative study of hazards experienced.

The coronavirus pandemic has intensely transformed the imminent progress of e-commerce. It reshaped consumer behavior as social distancing, quarantining, store closures, and lockdown regimes pushed consumers to shop online and vendors to sell online. Thus, e-commerce has grown rapidly as consumers demanded convenience, security, and multiple delivery options. Goods are handled and shipped as part of a complex network of distribution supply chains. These are networks of facilities and distribution options that procure materials and transport finished products to customers. One key process of a supply chain is the physical distribution that involves moving the products throughout the supply chain.

Transportation is a vital component as the transportation of a product, whether inbound to the warehouse/distribution center or outbound to the customer, requires adequate handling. Improper treatment may result in customer dissatisfaction, damaged goods, higher costs, poor service, or even unnecessary levels of inventory. To meet demand, supply chain distribution systems have emerged to ensure that deliveries are made at the most efficient rate possible. Package delivery companies like FedEx and UPS utilize various conventional modes of transportation to deliver various types of packages.

During the holiday season, the increased number of package shipments put extra stress on parcel delivery companies. This extra stress could lead to increased handling severity. The pandemic caused a boom in the e-commerce sector and increased the number of packages that are shipped through traditional parcel distribution channels. In addition, due to restrictions and safety precautions due to COVID-19, many delivery companies operated with reduced staff.

Packaging systems and design students at Virginia Tech were interested in whether the increased demand for parcel delivery and the potentially reduced staff at delivery companies resulted in an increase in handling severity compared to the levels accounted for in industry testing standards. This research project was conducted by students Ben McMurray, a senior from Lorton, Virginia, and Hathaipat Janvamethakul, a senior from Samut Prakarn, Thailand. The main objective of the project was to measure and analyze the parcel shipping

environment within FedEx and UPS from November to December 2020. The goal of the project was to obtain information on the harshness of holiday delivery during the global COVID-19 pandemic. Two sizes of packages were examined: a small box with dimensions of 7.25 in. x 7.44 in. x 5.13 in. and a weight of 1.9 lbs., and a medium box with dimensions of 14.25 in. x 12 in. x 6 in. and a weight of 3.34 lbs.

All packages contained a Lansmont 3x90 or 9x30 data logger that was protected using a foam enclosure (*Image 2*). These sensors recorded all vibrations, shocks, and drops that the packages experienced during the shipments. Two shipping routes were investigated. Shipping route 1 was between Blacksburg, Virginia, and Costa Mesa, California, representing a long delivery route in the U.S. Shipping route 2 was between Blacksburg, Virginia, and Toronto, Canada, representing an international delivery *(Image 1)*; a lot of goods purchased through e-commerce channels in Canada come from the U.S.

Image 2. Instrumented box used during the study.

The students found that the packages experienced an average of 124 impacts, out of which an average of 26 impacts were considered significant. The ISTA 3A standard only allows 17 impacts, which is well below the observed values. The results revealed that packages can experience much greater impacts during the parcel delivery that is happening during the COVID-19 pandemic than what is tested for during preshipment procedures. Some of the impacts were equivalent to free fall drops of 89 in.; per standards, packages are only tested with 24 in. drops. In one case, the sensors picked up an event where the package was tossed 56 in. during the loading process of the vehicle during a return trip to Blacksburg *(Image 3).*

Although there were multiple impacts that were above the industry norm, the students found that 90% of the impacts were below 25 in., which confirms that the industry accepted pre-shipment tests cover the majority of impacts experienced by packages.

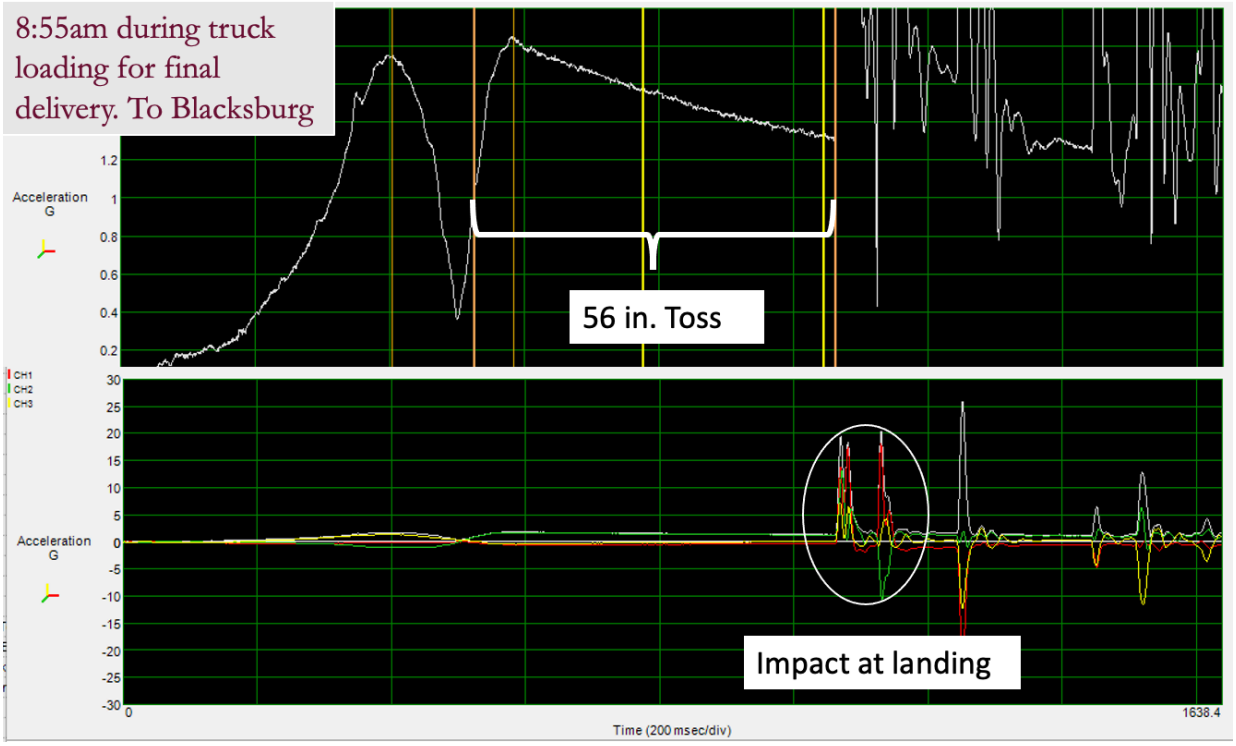


Image 3. An impact representing a 56 in. toss event and consecutive impacts upon landing were found during the loading of the parcel delivery vehicle during a return trip.

Also, ISTA FedEx 6A testing standard requires 60% of the drops be face drops; the ISTA 3A standard lists 50% of the drops as edge drops, 31% as corner drops, and only 19% as face drops. This study found that the majority of drops for small boxes were corner drops (44.16%) while the medium boxes experienced mainly edge drops (58.97%). Thus, the ISTA 3A test protocols accurately represent drop orientations that the packages experience during parcel delivery while the FedEx 6A test protocols do not. ISTA FedEx 6A mainly focuses on face drops, which were found to be the least common in this study.

Therefore, this study concluded the following:

- 90% of the drops experienced by packages are below the drop height limit recommended by ISTA 3A.
- Packages experienced a greater number of drops during physical delivery than what they are subject to via the testing standards.
- The drop orientations used in ISTA 3A better represent drop orientations observed during the study than the drop orientations used in the ISTA 6 FedEx standard.

Research Highlight — Evaluation of the horizontal compression forces that pallets experience during grab handling

Image 1. Example of grab handling of a palletized unit load at a construction site.

Wooden pallets are commonly designed either by computer software, such as the Pallet Design System (PDS), or specifically to pass ISO or ASTM standards. But none of these design methods take into account the horizontal compression forces that a pallet would encounter during grab handling. Grab handling is a common method of moving palletized unit loads around construction sites or other commercial locations (*Image 1*), especially in the United Kingdom. This system is often preferred as it reduces the off-load time required and can be done by one operator instead of needing multiple people involved. However, pallets are generally designed to be lifted from underneath the top deckboards by fork tines. The grab handling method uses pincher type equipment to squeeze the pallets from the sides, compressing inwards, to lift them and their product loads.

Prior to this research, it was commonly believed that these grab handling methods, designed initially for moving incompressible payloads (such as bricks or blocks on a construction site), would cause irreparable damage to any wooden pallet. There were even fact sheets distributed in the U.K. claiming that the only way to use grab handlers on palletized unit loads was “for no part of the lifting pads to touch or overlap the pallet.” The recommended usage was for the pinchers/arms to grab the product directly and not horizontally compress the pallet at all.[1]

Because of this unique lifting method and due to CPULD’s long history of pallet design and customized testing options, The Pallet Loop company, based in the U.K., contacted CPULD and inquired about working with our engineers and technicians to develop a new test procedure. Their goal was to simulate the horizontal compression forces that grab handling would exert on a pallet and use the procedure to determine the payload capacity for pallets that would be grab handled. CPULD worked with Virginia Tech’s College of Engineering to design an apparatus to test palletized unit loads for strength and durability during grab handling conditions.

The pallets being tested were 1070 mm x 1200 mm, non-reversable, two-way, flush, stringer class, wooden pallets built by The Pallet Loop. Pallets make up 70% of the total wood packaging materials (WPM) in the

European Union. Pallets can be made from a variety of materials, but 90% to 95% of EU pallets are made from wood by 2,910 different manufacturing companies.[2]

The pallets were first tested in a Tinius Olson compression tester equipped with four 10,000 lb. load cells (*Image 2)*. The pallets were positioned vertically between two rubber-block grab arms and loaded with weight by the machine until either the machine capacity was exceeded or the pallet failed. The pallets were tested both parallel and perpendicular to the direction of the stringers. The goal of the test was to determine the initial strength of the pallet. The strength of all pallets tested exceeded 24,000 lbs.

Image 2. Horizontal compression test setup in Tinius Olson machine — testing perpendicular to the stringers.

Then, in order to evaluate the ability of the investigated pallet design to survive the compressive forces during simulated grab handling, a custom testing jig was developed (*Image 3)*. The testing jig was composed of a metal frame that contained one fixed and one movable I-beam, which were used to apply the horizontal compressive forces. A rubber-block grab arm was secured to each I-beam to simulate the actual surface that would interface with the pallet during grab handling. The horizontal load was applied by two hydraulic bottle jacks. The jacks were connected to two digital load cells to measure the applied load. The pallets were then loaded with concrete blocks to simulate a commonly shipped load in the construction industry.

In order to simulate grab handling, pressure equivalent to twice that of the payload was applied by the jacks pressing the two I-beams into the sides of the pallets. Three pallets were evaluated parallel to the stringers using a 3-ton payload, and one pallet was evaluated perpendicular to the stringers using a 1.5-ton payload. Once the required pressure was applied, the entire jig, with the palletized unit load of blocks, was lifted with a crane and held suspended for five minutes. Following this test, the pallets were inspected for damages.

Image 3. Custom jig setup to mimic grab handling of a palletized unit load of bricks perpendicular to the stringers.

The results of the evaluation of the maximum payload that can be supported by the investigated pallet design when handled by a grab handling system are presented in Table 1. The investigated pallet design was able to support 2.75 tons of a semirigid payload such as concrete blocks when lifted, parallel to the stringers, by a grab handling mechanism. But when the pallet was handled perpendicular to the stringers, the maximum payload was only 1.2 tons; the load capacity in this direction greatly depends on the fasteners used and the location or placement of the grab arms.

Test Type	Safe Payload[1] (ton)	Average Pallet Horizontal Strength (ton)	Maximum Horizontal Handing Pressure[2] (ton)
Parallel to the Stringer	2.75	10.9	5.5
Perpendicular to the Stringer	1.2	4.8	2.4

[1] Safe payload was calculated by dividing the safe horizontal grab handling pressure by a factor of 2 based on the manufacturer guidelines that the pressure needs to be twice of the payload.
[2] Safe load values are calculated by dividing the average strength by a safety factor of 2 recommended by ISO 8611.

Table 1. Summary of the safe payload, strength, and safe horizontal handling pressure of the investigated pallet designs.

1. PalletLink. (2019). *Hydraulic and mechanical grabs – not suitable for pallets*. PalletLink Datasheet Ref: 48d/JH/06/08/2019.

2. Agra CEAS Consulting. (2012). *Quantification of the economic, environmental and social impacts of introducing mandatory treatment requirements for wood packaging material circulating inside the European Union.* Final Report: Framework contract for evaluation and evaluation related services – Lot 3 Food Chain. Published by Food Chain Evaluation Consortium (FCEC).

Student Spotlight — Rosa Williams, PSD freshman

Image 1. Rosa Williams outside the Brooks Center.

Rosa Williams is a freshman in the packaging systems and design major and has quickly made herself a valued team member here at CPULD. She is from Marietta, Georgia, and expects to graduate in 2024. Rosa says she decided to attend Virginia Tech "because our packaging program has a major focus on sustainability, which really sets us apart from other universities. In my senior year [of high school], when I toured the Brooks Lab with Professor Horvath, I knew I had to attend Tech. I love the packaging program here at VT and I am so proud to be a part of it."

When Rosa was younger, she was invested in her school's engineering programs but always felt her assigned projects lacked a human connection. "That all changed when I entered high school and began working on capstone projects," she said. "My first real capstone project was designing insulative material out of plastic waste for countries that couldn't effectively recycle it. Even though a package can claim to be recyclable, this does no good to the environment if the area it is being sent to has no way to recycle it. That was one of the major factors that led me to packaging systems — there's a lot of good to be done here. For impoverished countries, people with disabilities, and destroyed ecosystems, packaging innovation can dramatically improve conditions around the world."

"Being able to dive right into hands-on experiences during my freshman year has been really helpful!" she continued. "Working in the Brooks Lab with Mary Alvarez was amazing, as I had peers with more knowledge and experience to guide me through my first real steps into the packaging world. I am currently working on an e-commerce package redesign project for Smurfit-Kappa, and I've loved being able to look into how market research is done within the industry."

Rosa, who enjoys many of her classes, said, "All of my sustainable biomaterials courses have been wonderful this year! Through Professor Horvath's SBIO 3005 and 3006 courses, I have been able to throw myself directly into practical applications of the concepts I am learning in other packaging classes. Working in the Brooks Lab on a pail compression strength project has really given me a better idea of what a possible day-to-day experience within the industry might be like. In addition to my packaging course work, I have loved being able

to take Intro to Wood Craftsmanship and Design with Professor Loferski! Although I'm not the best at wood identification yet, I have really enjoyed learning more about the materials that surround me every day."

Rosa is thankful to have received the Atlanta Alumni Chapter scholarship and the G. Scott Francis Pulp scholarship, and she's put them to good use already. "As a freshman, I'm just really happy to be involved," she said. "I've been attending job fairs in CNRE and doing as much as I can to learn about the industry. My long-term career goal is to design packaging that is inclusive to people with disabilities because one of the many things that I have learned during my time at Virginia Tech is the different ways packaging influences people's lives. There are millions of Americans with disabilities and countless more who live with conditions that make opening traditional packaging difficult. My long-term career goals are to create sustainable packaging built with an understanding of disabilities. I've learned through my classwork that packaging can create a large obstacle to disabled people's ability to live independently. Design with an emphasis on empathy, in addition to practicality, economic factors, and sustainability, is essential to creating a more inclusive world."

Rosa is among those students who haven't had what many of us would consider the "normal" college experience. "As a freshman who's going to school during the pandemic, my first year of college has been way different than I expected. I live in the Orion science living-learning community on campus, and it's been a great way to meet people who are just as passionate about their majors as I am. I feel really lucky that I joined the Orion community because it has provided me an opportunity to develop friendships and meet people. It's definitely made it a lot easier for me to transition to college, and I'd recommend any science-loving freshman to do the same. Also, I am going to be a student mentor in the Orion living-learning community next year, so I would likely be the mentor for any incoming packaging freshmen!"

On her own time, Rosa is into gaming and crafting. She says she has "a great Dungeons and Dragons group, and every week we do what we call 'D&D at D2.' I do a lot of crafting, too. It's not anything big or bold, I really just like to hot glue googly eyes and make resin earrings. I enjoy playing video games, even though I'm genuinely bad at everything other than Animal Crossing. If I were an animal I think I'd be a bird, like a raven or a crow. I really like collecting things, mostly small useless objects that most people would consider trash. I'm also very loud, and if you feed me I will be your friend."

Image 2. Rosa finds a pallet!

Image 3. Rosa with her gnomies!

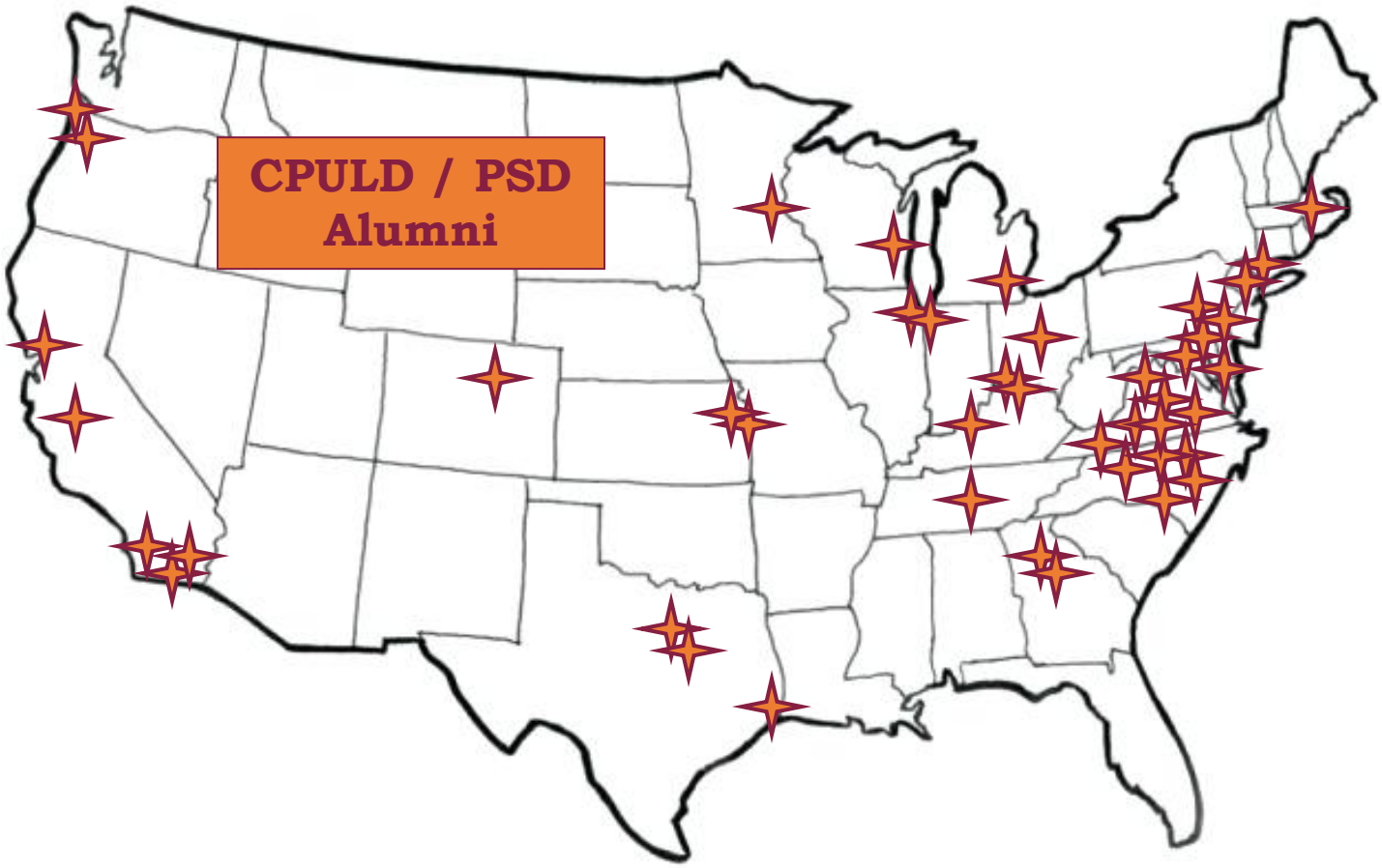


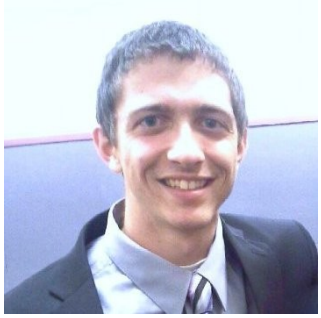
Image 1. Stars represent current locations of CPULD / packaging systems and design (PSD) alumni (per self-reporting and LinkedIn profiles).

We were interested in learning how the pandemic had affected the packaging industry on a personal level, so CPULD reached out to our alumni with a survey and asked them to share what was going on in their lives and with their careers since COVID-19. As usual, many of our alumni were happy to share their stories with us!

From what we learned, 90% of our packaging professionals were not negatively affected by the pandemic. In fact, 40% of respondents told us that their jobs have improved and/or they've gained new responsibilities due to the pandemic's changes to the workplace. Of responding alumni, 40% are now working partly-to-mostly from home and have a lot less work-related travel to contend with. Only one packaging engineer among our alumni lost his employment due to the pandemic; he said that he could have gotten another packaging job fairly quickly but chose instead to go back to school for his Master's degree.

Between the responses received recently, previous updates from alumni, and scouring their LinkedIn profiles, it appears that 90% of our packaging systems and design alumni have found work directly in packaging. Whether it's being a structural designer for International Paper, a packaging engineer for Coca-Cola, or a project engineer for Rehrig Pacific, most alumni stay in the field after graduation. And, while the majority of our alumni seem to stay in the Southeast, we do have alumni connections from New York City to Costa Mesa, California, and in a dozen states across the country *(Image 1)*.

If you're interested in learning what a packaging professional's day-to-day job looks like and what our alumni have to say about the industry during the pandemic, read the following responses.



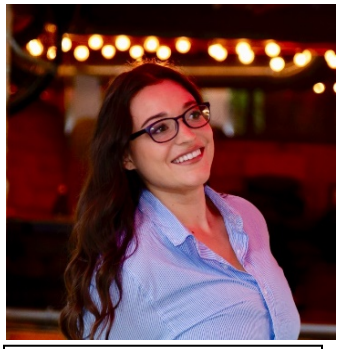
Trey Good, *Senior Packaging Engineer,* Newell Brands

Daily activities: I am heavily involved in various activities, but mostly support new product development projects. We are involved with projects that can be as short as a couple months to as long as a couple years from start to finish. We do a lot as packaging engineers, but some tasks I am involved with are competitive benchmarking, concepting, prototyping, giving feedback/input on product development, collaboration with suppliers, building specifications, creating robust test plans, testing result analysis, etc.

You really are involved with designs and setting up the full packaging system from primary packaging all the way through unit load design. It is very exciting to see how far product and packaging comes from start to finish then to eventually see it sitting on shelf.

Life during the pandemic: In the world of packaging, the pandemic has created a very challenging environment that has directly impacted the way the consumer shops. Even though e-commerce is not a new trend, the pandemic has accelerated the need for e-commerce packaging.

On a more day-to-day basis, we have had to work through challenges of working from home, for example, not being able to go to a CAD table to cut out samples, not being able to go review testing results in person, or navigating virtual team meetings/conference calls. We all have had to adapt our ways of working, and, while challenging, it has been amazing to see the resiliency and dedication from all team members working during this time.



Tabby Partin, *Area Manager,* Amazon

Daily activities: Currently, I am responsible for the internal operations of the business. In short, this means I map out and analyze all processes to ensure operational excellence. Being in this position requires process optimization skills and the ability to spot and act on opportunities to drive efficiencies. My role is designed to reduce wasted time, pain points, and increase profitability - all which becomes evident through our key performance indicators.

I will be starting a new role as the area manager of a fulfillment center at Amazon, and my duties will be similar. I will oversee a team of 50 to 200 warehouse associates and be responsible for maintaining production in my designated area of the floor. I will be responsible for my team's safety and monitoring our KPI's [key performance indicators] to ensure that all workflows run smoothly and efficiently, while meeting, if not exceeding, customer expectations.

Life during the pandemic: There are opportunities everywhere! Amidst the pandemic, it became apparent that many businesses were not equipped to face the challenge. The pandemic forced businesses to do a deep dive and drive systematic changes to improve their current processes.

Right now, every business wants to cut costs and increase productivity. But if you can do those things, there will always be roles available. I am very excited to work for Amazon and extremely grateful for the time I have previously spent learning about the implementation of Lean Six Sigma and operations.

Megan Stallings, *Quality Facilitator,* Packaging Corporation of America

Daily activities: I started full time in Corrugated Sales in 2015 and moved into my current role in 2018. I manage and am responsible for all employee training for our local Food Safety Certification (ISO 22000), Quality Management System (ISO 9001), Haz-mat Packaging requirements, and Sustainability (PEFC, FSC, SFI). Learning to think critically, technical writing skills, and understanding testing standards have helped me to excel.

I work with our local team to execute continuous improvement projects that make an impact on our key drivers. I work as a liaison between our customers and production team to resolve quality issues and drive mutually beneficial improvement. Good communication skills and the ability to work with a diverse team who have conflicting objectives has proved beneficial.

Life during the pandemic: While my day-to-day life and responsibilities have not changed greatly, there have been some changes. I work in the office four days a week, wear a mask, and socially distance. I have become a resource to my local team as we all have had to rapidly become more tech savvy. I manage a lot of the documentation and communication with employees regarding the pandemic response.

The greatest changes to my role have been how to train and engage our workforce through wearing masks, small gatherings, and social distancing – often over Teams. Being able to adapt to change, communicate change positively, and help others understand the benefits of these changes have been some of the challenges I have faced.

Amanda Augugliaro, *Homologation Project Leader of the Packaging Qualification Laboratory,* L'Oreal

Daily activities: My work in the lab involves validating packaging components for skincare and makeup projects (jars, bottles, lip gloss applicators, nail polish) to ensure they meet the proper specifications. The basic requirements of primary packaging are that they do not leak or crack and perform overall as they should for the consumer.

I also work with packaging engineers to trouble shoot problems seen in the market (leaking jars, bad pumps, etc.). E-commerce is booming, so a huge part of my job is also to test products through ISTA6 A.

Life during the pandemic: Like any changes that come in your career, look for the unexpected opportunities brought by the challenges. The pandemic has made jobs difficult in many ways, but if you are willing to try new things and continue learning, you can work on things that you otherwise may have never had visibility to.

All in all, companies appreciate proactive employees who are continuous learners.

Jessie Arevalo, *Packaging Engineer Specialist,* GE Healthcare

Daily activities: In my team, there are currently five packaging engineers who fall under the Plant Modernization division, three of us are based in Milwaukee, Wisconsin, one in Juarez, Mexico, and one in Wuxi, China.

My main role is supporting the global service and repair operations by being the main point of contact for any issues or packaging-related needs. Much of the medical equipment we offer like CT scanners, X-rays, and ultrasounds are serviced at hospitals. They have spare parts that, instead of being scrapped, are sent to repair centers and are then are sold at lower costs than new spare parts.

My main goal is to address the packaging related damages that the parts have through either packaging redesign or review. The parts I work with range from small circuit boards to large amplifiers that can weigh over 200 lbs. and require wooden crates for shipment. Other responsibilities are supporting NPI [national provider identifier] projects at other sites, validating packaging to ISTA standards, and addressing packaging issues with the suppliers that sell spare parts.

Life during the pandemic: As part of the Plant Modernization group, my manager is constantly working on projects that involve automation. At the beginning of the pandemic, he saw a need to increase production for some ventilator parts using automation. And he brought me along to assist in developing two fully automated packaging cells for parts that are used in ventilators and anesthesia equipment.

I defined the packaging material and method of packing as well as some of the equipment we used. We worked with a local engineering firm that designed the whole layout and built/sourced all the components for the cell. The cells consist of using UR co-bots to pick a part, bag it, form a box, and pack the part inside the box with some padding. They are expected to be completed and installed at one of our sites within the next two months.

With this project complete, I am looking forward to working on other packaging automation projects.

Jack Cook, *Product Engineer,* small start-up company, Michigan

Daily activities: I oversaw all testing both in house and 3rd party. For in house testing, I developed, completed, and improved the testing methods to best meet the national standard requirements. For 3rd party testing, I contacted the testing facilities, set up what materials were to be tested and how, and received the final reports.

I also worked on improving the pallet both for general use and for special cases. A lot of my time was spent making Excel reports and meetings.

Life during the pandemic: The pandemic resulted in me losing this job, but I was not happy in the position and have found myself much happier now that I've gone back to school to pursue a Masters in packaging.

Jayne Little,
Packaging Engineer,
Newell Brands

Daily activities: Currently, I'm working at the writing division of Newell (Elmer's, Sharpie, Papermate, etc.) to design new packaging structures for e-commerce and on shelf for new product launches in Europe. I work primarily with ArtiosCAD for new product design, and create samples using CAD table.

There is a lot of collaboration with cross-functional teams such as brand, chemistry, test lab, and legal to ensure that packaging meets aesthetic requirements for the brand team and will hold up during distribution through multiple channels. One of my major focuses is on sustainability and designing packaging that is both cost-effective and within sustainability requirements in European markets, especially as retailers push for plastic-free wherever possible.

Life during the pandemic: Working from home during the pandemic has made me realize the importance of an office environment, especially working in a role where collaboration and hands-on work is encouraged and often required.

It has been a challenge to design with limited access to a CAD table, but Newell has been flexible in allowing employees to return to the office safely.

Landon Holbert,
Structural Designer,
International Paper

Daily activities: Currently, I do a lot of work spec'ing out boxes and other corrugated packaging, as well as designing new items to meet customer, supply chain, and manufacturing needs.

I also work on analyzing package failures and determining how to fix the problems. This includes working with machine suppliers and the IP machine team to solve issues on customer case packers and erectors. I also help with pallet optimization throughout my company and our suppliers.

Life during the pandemic: The packaging industry has provided a stable and enjoyable career even through the rough times that the pandemic created. I am as busy as ever, largely with helping our customers adapt to supply chain shortages, new consumer trends, and, of course, the rapid growth of e-commerce.

Cyrus Adibpour,
Project Engineer,
Rehrig Pacific Co

Life during the pandemic: My job has remained the same, but I now work 90% from home instead of 50/50 working at the office and traveling.

The pandemic has brought exposure to how tough the labor market can be for finding front line workers.

It has driven many companies to have a stronger focus on automation (especially with demand for increased wages). Directly because of this labor scarcity, my company has focused on automating more and more processes.

News — Dr. Eduardo Molina has been promoted to associate director for the Center for Packaging and Unit Load Design

Image 1. Dr. Eduardo Molina

We are excited to announce that Dr. Eduardo Molina has been promoted to the role of associate director for the Center for Packaging and Unit Load Design (*(Image 1)*. Molina completed his Ph.D. in December 2020 with his dissertation entitled "Modeling the fundamental mechanical interactions of unit load components during warehouse racking storage." His research presented a new method to study the load bridging effect through computer simulations of unit loads. This will allow for more efficient evaluation and design of both pallets and unit loads.

Since Dr. Molina started managing the Corrugated Packaging Materials Laboratory for CPULD in 2018, the lab has assisted more than 30 outside companies through over 300 testing projects. He also managed 15 undergraduate student workers (*Image 2)*, giving students the opportunity to gain experience in a working laboratory as well as becoming familiar with corrugated board testing procedures.

Image 2. Molina overseeing students testing boxes in the Lansmont Squeezer.

When asked in what direction he hopes to lead the corrugated side of CPULD's packaging and pallet testing efforts, Molina said, "I am a strong believer that we are currently perfectly positioned to begin reaching new areas of the packaging industry and expand our network to create valuable research for a wider audience, and I can help lead this effort. There is currently an ongoing push to develop new, sustainable materials. This is happening at the scientific community level as well as in the industry. There are also changing political winds; thus, concrete actions to offset climate change will be taking a more prominent role in the coming years. These efforts might begin with more research, and they can eventually lead to new, more stringent regulations and requirements. We, as the packaging industry, need to be fully prepared, and CPULD is uniquely positioned to tackle these types of exciting yet urgent problems."

It's not only corrugated board that Molina is interested in. He believes that the new fastener testing methods that he helped implement have assisted in propelling CPULD forward as well. Explaining further, he said, "An additional function that we have in the lab is the testing of fasteners such as nails and staples. Virginia Tech developed the Mibant test years ago, and it is our responsibility to keep offering high-quality, third-party testing options for manufacturers and users. We have worked hard to develop new and updated testing methods. This has allowed companies to evaluate the fasteners they use on many different levels, be it as a standalone fastener test (i.e., Mibant test), as a study of joints considering the effect of materials (i.e., withdrawal and pull-through tests), or as part of the overall pallet structure (i.e., pallet incline impact testing and pallet fast-track simulation). This whole side of testing being offered was made possible by the expanding capabilities of the center as a whole unit. We will continue to work and coordinate in a better manner, improving the customer experience that we provide."

Image 3. Molina working on a package design to be cut from corrugated board.

As associate director, Dr. Molina will have greater influence on the research being done and ensuring it will benefit the industry. He hopes to help bridge the gap he sees between the scientific community and the industry. Molina explained his hope for future research efforts: "I would like to create a new research area for the center focused on sustainable cushioning. In this area, we can act as a bridge between the material scientists developing new sustainable biomaterials that could be used as cushioning for packages and the potential users, such as packaging or consumer-packaged-goods companies. These users need someone to guide them through the adoption process of new cushioning materials. Can we generate design methodologies for these materials? If you are adopting a new, paper-based cushion for your product, can we develop engineering guidelines to help you choose the correct thickness, density, or size of said cushion? We think that by closing this gap, we can expand and accelerate the adoption of new materials in the packaging arena. The current disconnect between the scientific community and industry applications is hindering the progress of the packaging industry becoming more sustainable."

Dr. Molina believes that his new role presents “a very exciting opportunity for the center to expand its reach, strengthen its current operations, and make a positive impact in the community.” He is looking forward to expanding the lab’s reach and offerings for the industry as well as beginning new research into more sustainable packaging options!

Image 4. Molina putting together a corrugated box.

News — Three graduate student research papers accepted for the IAPRI 2021 conference

Image 1. IAPRI Conference banner

Like most conferences during this pandemic, the 30th annual International Association of Packaging Research Institutes (IAPRI) conference is being held virtually in June 2021 (*Image 1)*. Established in 1971, IAPRI is a "unique global network which allows organizations to communicate and develop ideas, exchange experiences and in many cases reduce duplication of effort." CPULD is a longstanding member of IAPRI and is one of its 90-member research/educational institutions from 31 different countries.

This year, three of our graduate students have had their research accepted by IAPRI. Their papers, summarized below, will be a part of the conference in June. This is a great opportunity for our students to network and learn about the latest research projects, as IAPRI conferences bring together the best packaging researchers around the globe.

Doctoral student Mary Paz Alvarez's paper is "The effect of plastic pails on pallet deflection and pressure distribution for stringer class wooden pallets." Her research found that pallet deflection significantly decreases when pallets are loaded with pails compared to a flexible airbag. The reduction ranged from 32% to 89% for most pallet designs. Her findings indicate that pallets supporting unit loads of pails (*Image 2a & 2b*) will deflect significantly less than what they are currently designed for, and this reduced deflection could increase the load capacity of some pallet designs. Overall, these results reveal that wooden pallets should be designed for the specific type of packages they will be carrying in order to optimize the cost of the pallet and reduce the amount of raw materials used to manufacture wooden pallets.

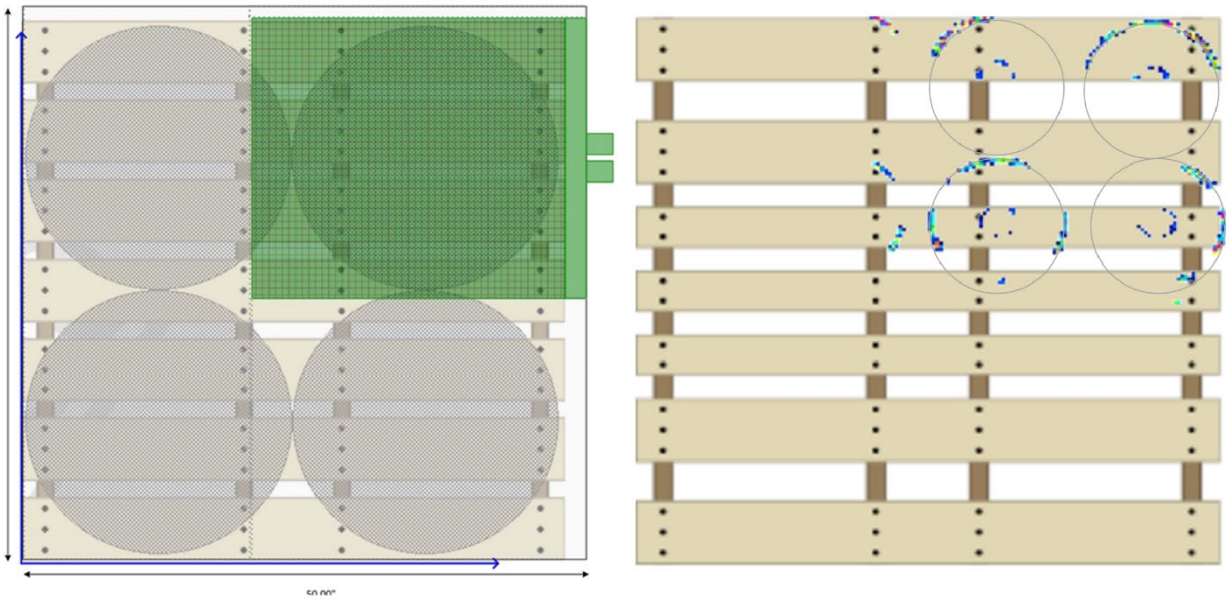


Image 2. a) Pressure map setup for one quarter of pallet and b) pressure map reading for plastic pails.

Master's student Yu Yang Huang's project was an "Investigation into the effects of various factors on the vibration levels experienced by unit loads under forklift handling conditions." The goal of the first phase of Huang's research was to understand how the vibration experienced by unit loads while being transported on forklifts is affected by speed, road conditions, unit load weight, forklift type, and sensor location. In short, his results showed that an increase in forklift speed increases vibration intensity. It was also discovered that forklifts on asphalt experienced a higher level of vibration compared to forklifts on concrete. On the other hand, an increase in the forklift load weight decreases vibration intensity. Among the three forklifts studied (gas-powered, electric-powered, and a reach truck), the gas-powered forklift has the highest Grms (root-mean-square) values on an asphalt road surface. Finally, he found that ISTA trailer trucks experience higher vibration levels than any of the forklifts (*Image 3*).

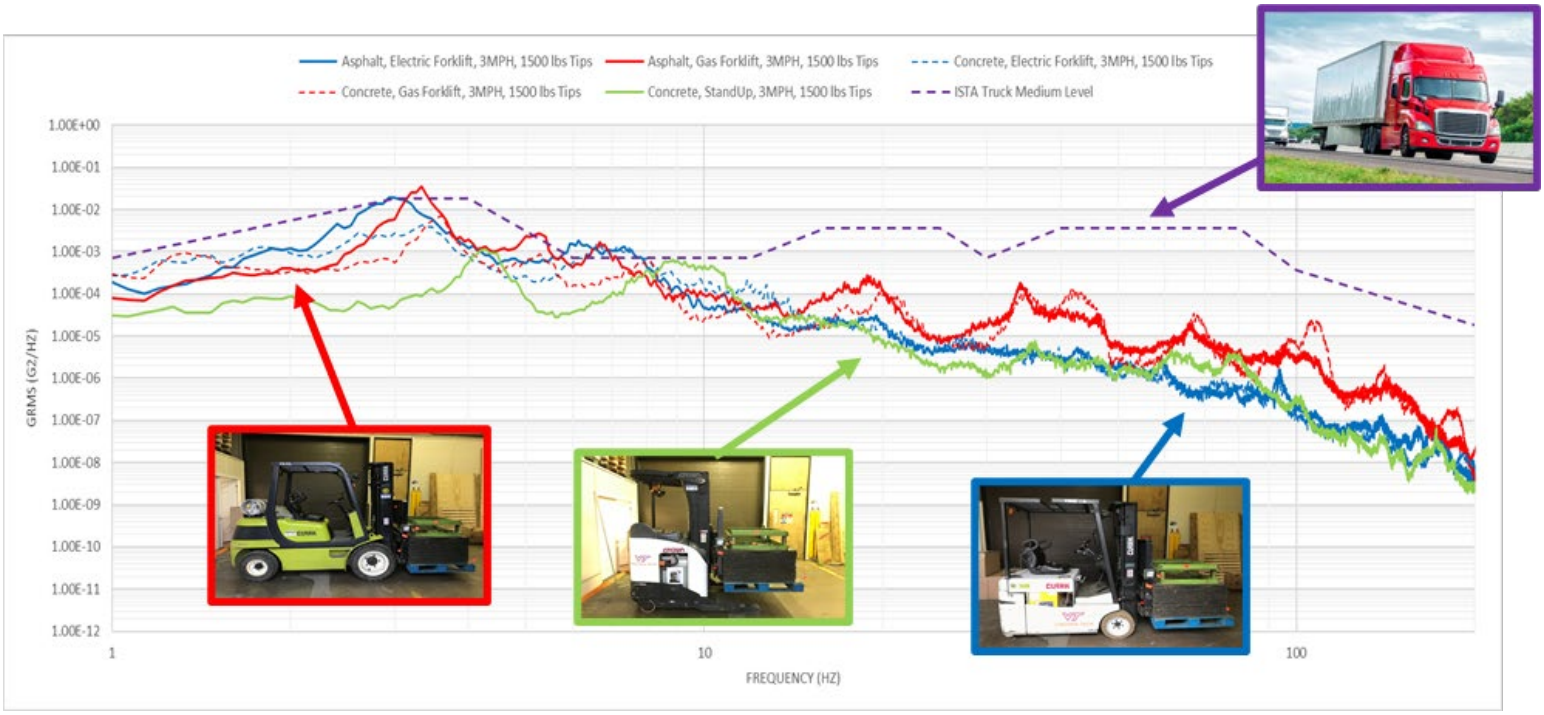


Image 3. Comparison between ISTA truck and forklifts in vibration levels experienced.

Master's student Saewhan Kim's project is "Characterizing the environmental impacts of common e-commerce packaging options for sustainability-minded stakeholders." The goal of this study was to conduct a quantitative analysis of environmental impacts of popular e-commerce packaging options. Employing a life cycle assessment (LCA) method, the study compared the impacts of three e-commerce apparel packaging scenarios commonly used for distribution into the U.S. market: a corrugated board box, a virgin paper envelope, and a recycled-content, low-density, polyethylene (rLDPE) bag. When all three packaging scenarios are compared, it is clear that the corrugated board box e-commerce package scenario results in the highest environmental burdens across the greatest number of impact categories (*Image 4*). Although paper is generally perceived to be an environmentally preferable material to plastics, the rLDPE bag resulted in a lower environmental burden. Kim concludes that future work is needed to explore the implications of varied package weights and percentage of recycled-content adjustments to balance package performance and environmental impacts of the package within the e-commerce system.

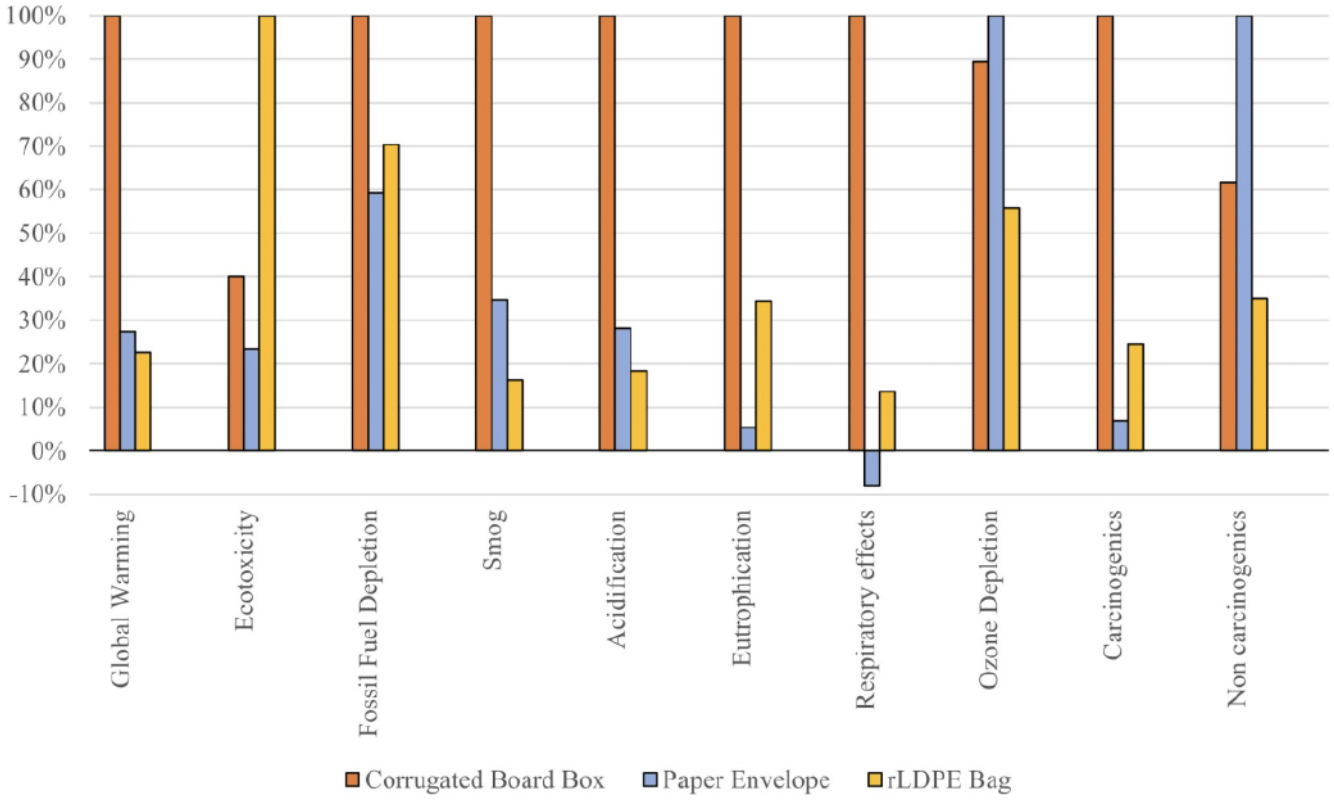
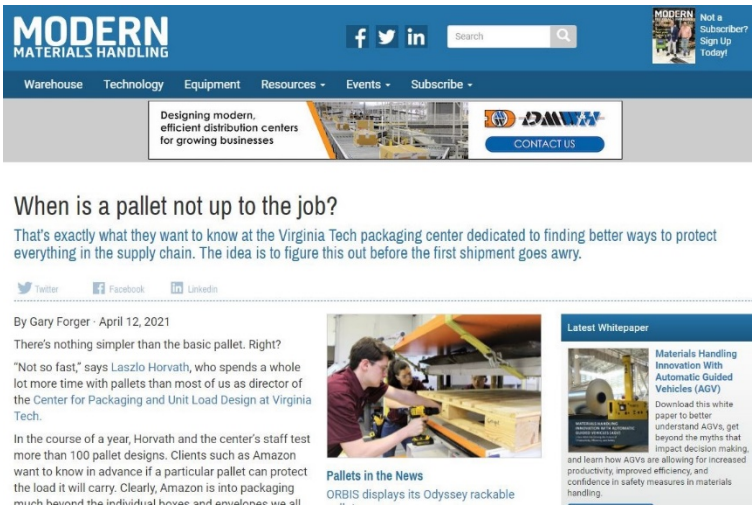


Image 4. Comparison of the relative environmental impacts generated by the corrugated board box, the virgin paper envelope, and the rLDPE bag. (For each impact category, the package scenario yielding the greatest impact was set to 100% to demonstrate relative impact reduction made possible via the alternative package options.)

Outside News – Links to other articles and interviews about CPULD



MODERN MATERIALS HANDLING

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When is a pallet not up to the job?

That's exactly what they want to know at the Virginia Tech packaging center dedicated to finding better ways to protect everything in the supply chain. The idea is to figure this out before the first shipment goes awry.

By Gary Forger · April 12, 2021

There's nothing simpler than the basic pallet. Right?

"Not so fast," says Laszlo Horvath, who spends a whole lot more time with pallets than most of us as director of the Center for Packaging and Unit Load Design at Virginia Tech.

In the course of a year, Horvath and the center's staff test more than 100 pallet designs. Clients such as Amazon want to know in advance if a particular pallet can protect the load it will carry. Clearly, Amazon is into packaging

Pallets in the News

ORBIS displays its Odyssey rackable

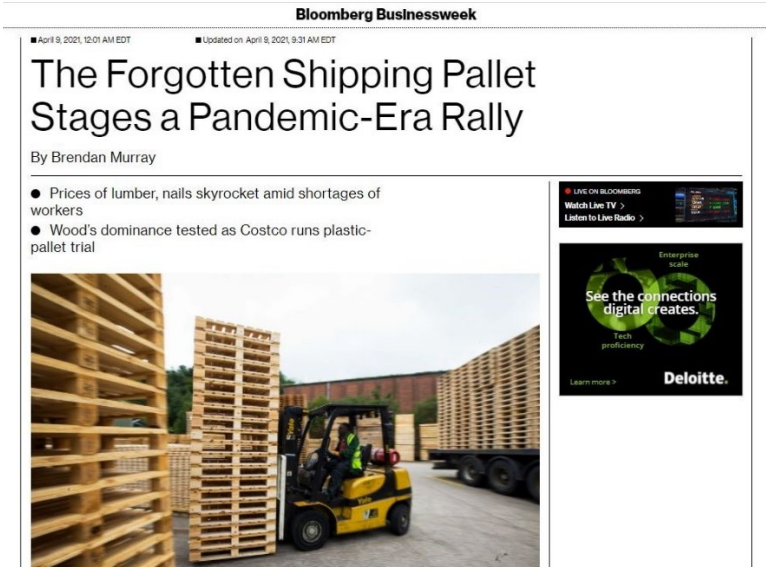
Latest Whitepaper

Materials Handling Innovation With Automatic Guided Vehicles (AGV)

Download this white paper to better understand AGVs, get beyond the myths that impact decision making, and learn how AGVs are allowing for increased productivity, improved efficiency, and confidence in safety measures in materials handling.

Dr. Laszlo Horvath was interviewed by Gary Forger with Modern Materials Handling for an article titled "When is a pallet not up for the job?":

https://www.mmh.com/article/when_is_a_pallet_not_up_to_the_job



Bloomberg Businessweek

April 9, 2021, 12:01 AM EDT Updated on April 9, 2021, 9:31 AM EDT

The Forgotten Shipping Pallet Stages a Pandemic-Era Rally

By Brendan Murray

- Prices of lumber, nails skyrocket amid shortages of workers
- Wood's dominance tested as Costco runs plastic-pallet trial

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Brendan Murray with Bloomberg Businessweek, interviewed CPULD director Dr. Laszlo Horvath about how "The forgotten shipping pallet stages a pandemic-era rally":

https://www.bloomberg.com/news/articles/2021-04-09/the-forgotten-shipping-pallet-is-staging-a-pandemic-era-rally

~ Continuing Education Opportunities ~

2021 Webinars

CPULD is pleased with the response to our webinars. Director Laszlo Horvath gave four separate lectures in 2019, which were free to our members. Each webinar had around a dozen participants and received high satisfaction ratings from the survey sent out to attendees. And, in 2020, CPULD partnered with NWPCA to offer a series of webinars designed to help train the industry on various new aspects of NWPCA's Pallet Design System (PDS) software which is regularly updated with research findings from CPULD projects. Our webinars reached 680 attendees in 17 countries. If there are any topics in particular that you or your company would be interested in, please feel free to suggest them to us! Stay tuned to learn when 2021 webinars are announced!

Wood Pallet Design and Performance Short Course, TBD 2021

Pallet design is an integral part of the material handling system. Wood pallet suppliers, sales professionals, professionals responsible for pallet purchases, packaging engineers, and pallet specifiers will all benefit from an understanding of how to design pallets that will last longer and perform better.

This intensive three-day short course will teach techniques that pallet designers can use to save money when designing pallets by considering the interactions between all of the components of the material handling system. The course will use state-of-the-art pallet design software called the Pallet Design System (PDS) to better demonstrate the steps that go into the pallet design process. You will also be taken on a tour of a working, state-of-the-art, pallet testing laboratory!

Unit Load Design and Performance Short Course, TBD 2021

Unit load design is a revolutionary, systems-design approach that significantly reduces the cost of distributing products to consumers by understanding how pallets, packaged products, and handling equipment mechanically interact. Unit load design is a new and valuable service that pallet, packaging, and handling equipment suppliers can offer their customers.

This intensive three-day short course will teach techniques that pallet and packaging designers can use to save money on corrugated board and plastic packaging materials when designing pallets and packages by considering the interactions between all of the components of unit loads. The course will use a state-of-the-art unit load design software called Best Load to better demonstrate the steps of the unit load design process. You will also be taken on a tour of a working, state-of-the-art, packaging and pallet testing laboratory!

To learn more or register for these courses, visit:
www.unitload.vt.edu/education/continuing-education/

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Spring 2021

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Quotes for new testing projects, distribution packaging projects, unit load design projects, membership with the center, new research projects

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