COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
SUSTAINABLE BIOMATERIALS
VIRGINIA TECH.

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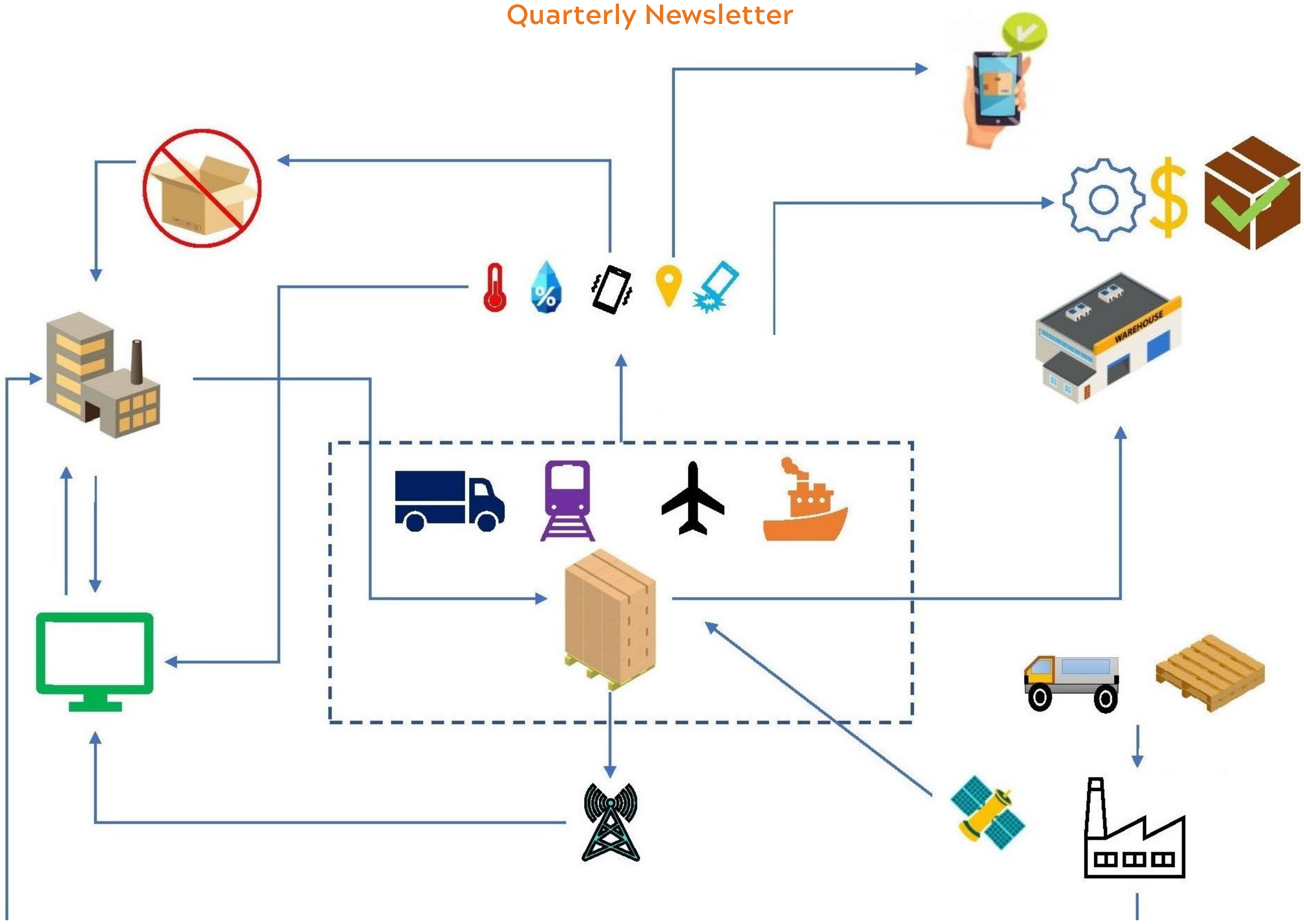
Center for Packaging and Unit Load Design

CPULD News

Quarterly Newsletter



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

- An operational concept of an IoT system for supply chains.
- Results of two recent graduate research projects.
- White Paper published about fasteners and pallet durability.
- Alumni spotlight: Page Clayton.
- Student spotlight: Meredith Brooks.
- New equipment in CPULD's laboratories.
- Two research projects presented at the IAPRI conference.

Feature Article – An Operational Concept of an Internet-of-Things (IoT) System for the Palletized Distribution Supply Chain

Research project by Nicolas Navarro

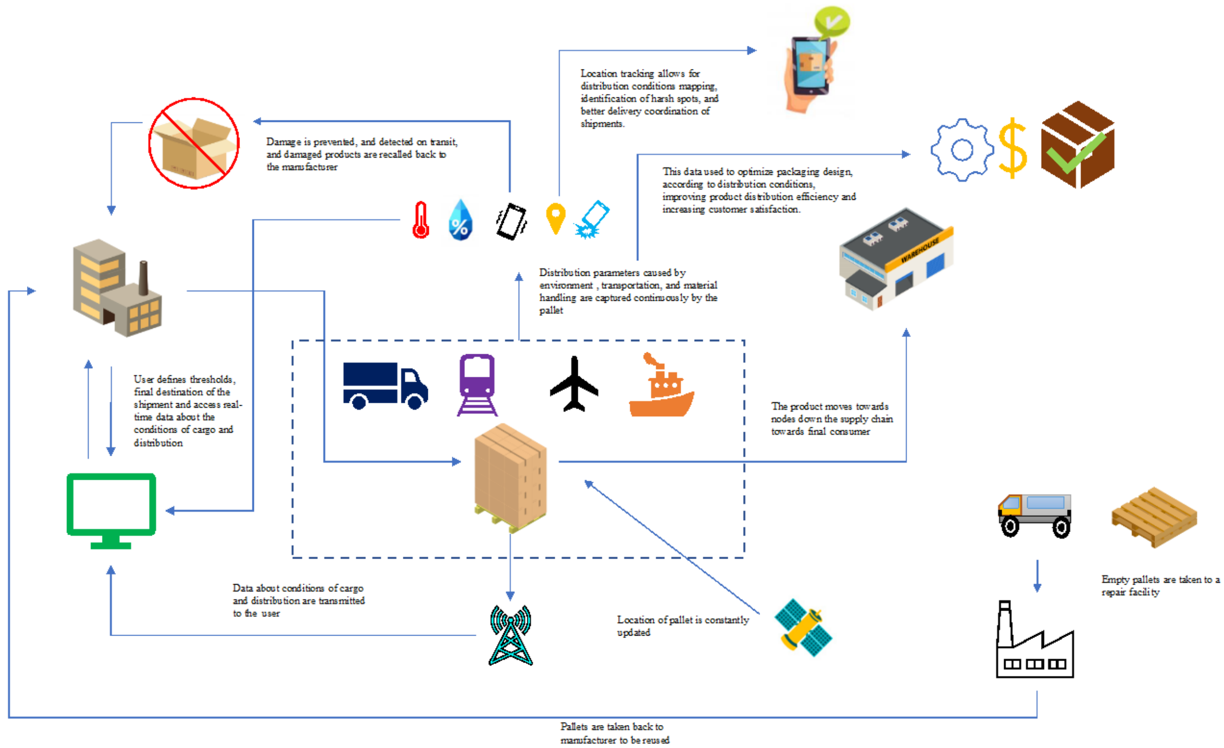


Image 1. Concept of Operations illustration on how the system with IoT sensor could function.

Distribution implies that products are interacting with multiple external conditions, including known hazards: shock, vibration, compression, and atmospheric. The role of distribution packaging during the distribution of products along the supply chain is to minimize the negative effects that these hazards pose to the products being transported and help guarantee that the product reaches the customer in an acceptable condition. However, due to the variability of distribution channels, there is a high level of uncertainty associated with which distribution hazards are present during a specific supply chain's handling and transportation of products. Established pre-shipment testing protocols for packaging are limited in their capacity to accurately simulate the real-world conditions that occur in specific supply chains, which has resulted in suboptimal packaging designs.

This study, conducted by master's student **Nicolas Navarro**, surveyed industrial companies and found that they are most concerned with avoiding damage to their products during transportation as a result of temperature, relative humidity, shock, and vibration. It was also discovered that there is a great desire among companies to increase the visibility of the movement of their products along their supply chain.

This project puts forth the theory that, by having greater certainty about the conditions present in their specific distribution supply chain, it would be possible for companies to design more efficient and effective packaging solutions for any given product. In order to achieve this certainty, this research proposes a system that uses Internet-of-Things (IoT) technology, namely sensors, to capture data about the conditions in a company's specific distribution environment in order for a company to be able to design packaging and systems that perform better and that satisfy their needs relating to product protection during distribution.

Pallets are a key component of distribution operations in supply chains, as they are the main interface that connects material handling equipment and packaged products. Based on this distinctive characteristic, this research contends that pallets would be effective carriers for IoT devices; therefore, they could be used to gain insight into the realities of what is experienced by a company's products and packaging during distribution. This will eventually allow for more customized and optimized packaging designs supported by more reliable and representative information.

Using a model-based systems engineering approach, a Concept of Operations (ConOps) was proposed to show what is needed to be able to track all of these conditions and parameters. The ConOps illustrates the way something is done at the current time as opposed to how it will be done in the future after implementing internet-of-things (IoT) technologies (Image 1). Furthermore, the application of a systems engineering framework makes it possible to lay out a clear value proposition for the adoption of new IoT technology in the field of distribution packaging and supply chains so there is higher certainty that the new system will be responding to genuine user needs.

In order to achieve its purpose, a proposed IoT system must interact with the physical environment and collect the inputs for the distribution parameters. This research project divided system interactions into five different types and represented them using sequence diagrams.

1. A pallet pairing and input definition sequence diagram focuses on the interaction between the user and the system. As part of this interaction, the pallet containing the IoT device is linked to the user's account, the required thresholds are defined, and a final destination is specified that will indicate to the system to stop recording.

2. A distribution parameters recording sequence diagram outlines which parameters need to be monitored continuously throughout transportation, such as temperature, relative humidity and location.

3. A distribution events tracking sequence diagram (Image 2) focuses on outlining variables that only need to be recorded once a critical threshold is exceeded, such as shock or temperature and humidity extremes.

4. The recording of vibration data was separated into its own sequence diagram because of the enormous amount of data that needs to be collected in order to build a useful vibration profile. But to conserve battery life and data storage, this research proposed a way to collect only the minimum amount of vibration data needed to construct a representative vibration profile. Basically, a procedure was developed to ensure that only meaningful, representative vibration data is collected.

5. The final sequence diagram used in the system is for monitoring environmental parameters. This is when a user creates an inquiry to the system and the system then shows them all of the collected data so far on the shipment.

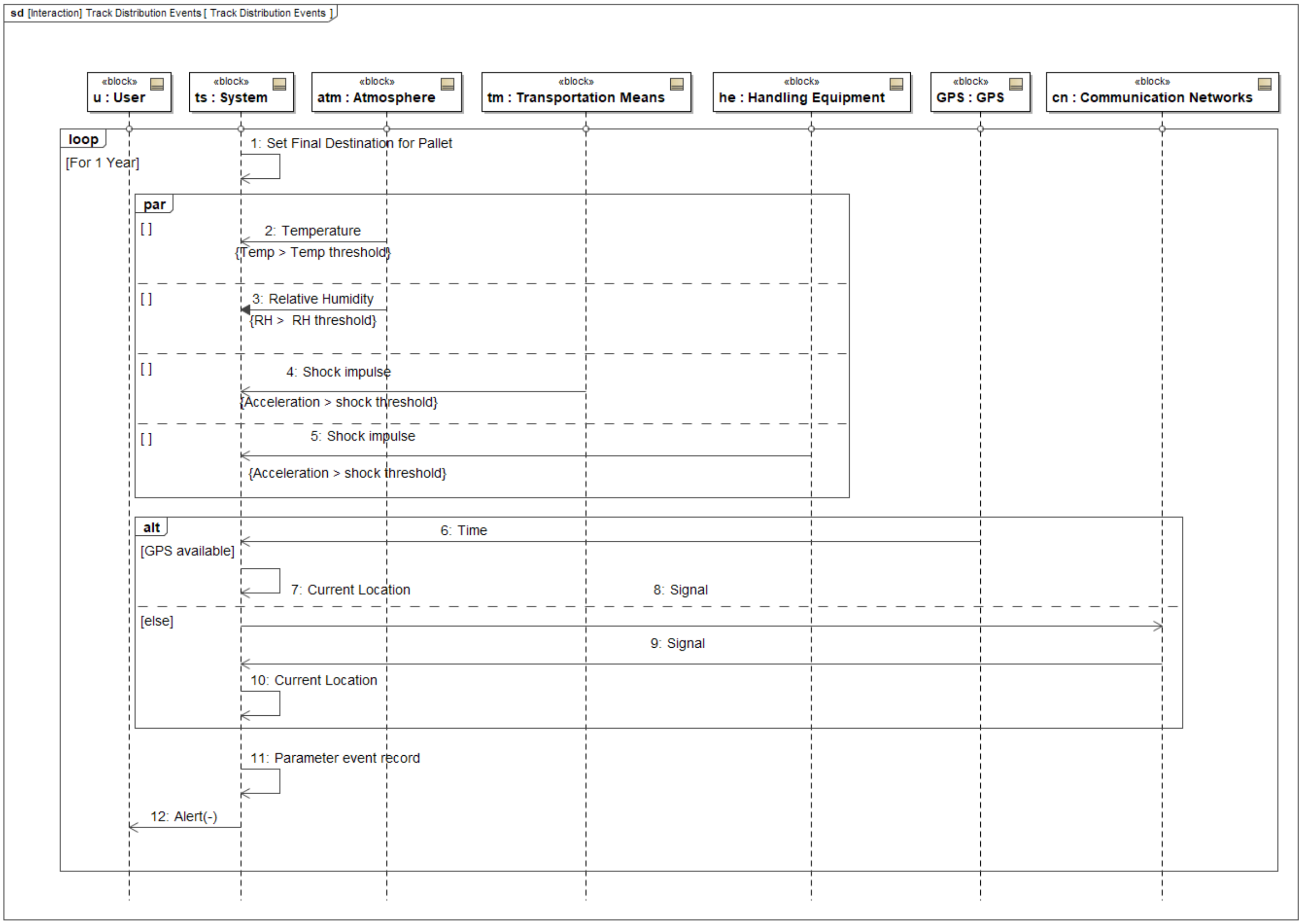


Image 2. Sequence diagram for distribution event tracking.

From a physical point of view, the system is composed of two basic elements: the smart sensor and the software platform that uses, stores, and transmits the data that the sensor collects. A smart sensor is the device that measures the physical parameters of processes or environments; it is what makes possible the execution of the needed functions. However, sensors alone cannot provide end-to-end supply chain visibility. They need an entire cyber-physical-system that involves the software platform as well as a means of connectivity to process and transmit the data collected. The software platform is the component by which data is transmitted and the collected information is conveyed to the user.

The study also explored the potential challenges that companies could be faced with during the implementation of the proposed cyber-physical technologies such as security concerns, the energy requirements of IoT sensors, service life, sensor location on the pallets, and computational requirements.

The study found that leveraging on model-based systems engineering works for this application because it allows the users to utilize the complexities presented by the nature of IoT technology so that the system developed is more likely to meet the requirements necessary to satisfy the user's needs. Furthermore, the application of the systems engineering framework makes it possible to lay out a clear value proposition for the adoption of a new technology, like IoT, in the field of distribution packaging and supply chain, so there is higher certainty that the new system will be responding to genuine user needs.

Alumni Spotlight — Page Clayton, Packaging Sales Engineer, Litco International

Image 1. Page Clayton, 2020

Alumnus Page Clayton is from Exmore, Virginia, on the eastern shore. Clayton says he chose Virginia Tech because there was a large offering of interesting majors and he had entered as undecided. He ended up choosing packaging "because it was a mix of many different disciplines and I felt that the industry was very hands-on and allowed you to have an impact.… I enjoyed the feel of the program and the department it was in. In the future I wanted to be able to make a difference by using more sustainable biomaterials in packaging."

Clayton completed his bachelor's degree in packaging systems and design in 2015 and his master's degree in 2018. His graduate research investigated "The Effect of Corrugated Boxes on the Distribution of Compression Stresses on a Pallet." His analysis found that box size can have a significant effect on the deflection of pallets, which means that pallets can carry more or less weight/product based on the size of the boxes in the unit load. His research has helped engineers design pallets in a more sustainable way.

Some of his most helpful courses were the ones focusing on wood science, plastics, packaging dynamics, and warehousing/distribution. These classes grabbed Clayton's interest because he realized that all of them taught knowledge that would "ultimately affect how a packaging engineer appropriately selects the packaging system they chose. There are many more important classes that expand on these topics, but I feel those four are the ones that build the foundation."

But the best part of his time at CPULD was his yearlong Distribution Packaging Internship, specifically, his work in the distribution packaging laboratory. This internship began with a retreat in May full of team-building exercises for all of the program's interns and then consisted of a full-time job all summer helping in the testing lab. Clayton said the best part of the work was "learning how to perform all the tests and taking on some exciting projects from real clients."

Image 2. Page Clayton (left) and other 2013 interns around the Brooks Center globe.

Now Clayton works as packaging sales engineer at Litco International in Vienna, Ohio. Litco is a long-standing supporter of Virginia Tech's packaging program and one of the Silver level members of the Center for Packaging and Unit Load Design. His general responsibilities include selling engineered wood products, writing technical information for the company, maintaining product inventory, and assisting manufacturing on new developing projects. Between his internship with CPULD, an internship with the Packaging Corporation of America, and his current engineering job, Clayton worked with many different helpful engineering and design software packages such as EskoArtos CAD, SAS JMP, and Best Load/Best Pallet.

Clayton credits his education at CPULD as being a big help at his current job. "My education background in wood, pallets, and polymers has helped me to excel at my job where we bind together repurposed wood fibers to create packaging solutions," he explained. "An average day involves contacting current clients, prospecting for new business opportunities, testing and evaluating products, editing documents for advertisements, and managing our new product line."

The position at Litco International fits Clayton well. On his LinkedIn profile, he shares that "I'm highly interested in packaging and systems design. I love the idea of taking a single product or SKU and designing the package to optimize its performance throughout its life cycle. However, at the same time I want to be able to provide a sustainable solution. One that provides the client and the consumer a happy medium, while appeasing my goals (sustainability) and ethics (resource management) realistically. Sustainability is more than just cutting costs and saving money in the short run. It's reducing the effect a product takes from our stores of resources whether they be renewable or nonrenewable."

While at Virginia Tech, Clayton received his ISTA's Certified Packaging Laboratory Professional (CPLP) – Technician level certificate during his summer as a lab assistant. At Litco, he's continuing to build his CV by working on another certification, the Certified Packaging Professional, through the Institute of Packaging Professionals.

Clayton enjoys living in the Ohio countryside. "I've lived in the country both by the ocean, in the mountains, and hills. I think it's more preferable compared to the city." He has been married for about a year to Shuo Huang, whom he met at Virginia Tech. His hobbies include plastic modeling and terrain building for tabletop games. For social activities, he attends a local gaming club, and he enjoys tending to his balcony garden and going to the dog park with his wife and their dog, Leo. A lot of his free time, both pre- and post-pandemic, is spent with his wife and dog. In fact, he said, “If I were an animal, I would have to be a Chow Chow, it’s the only dog breed I have ever owned and there is just something about their personalities that I relate to.”

Images 3 & 4. Page and the other 2013 interns working on unit load projects in the pallet lab.

Image 5. Page and the other 2013 interns with Dr. Laszlo Horvath.

Research Highlight — An Analysis of CPULD as a Learning Organization

Image 1. Definition of a learning organization

A learning organization is an entity that is constantly engaging their members with innovative practices, transferring knowledge effectively, and being able to adapt to the unpredictable faster than their competitors. It can be described as one in which the people taking part in it continually expand their capacity to create the results that they want, where creativity is fostered, and where people continually improve their team learning performance. Graduate students Nicolas Navarro and Yu Yang Huang conducted a continuous improvement project that looked at the current practices at two of the units at the Center for Packaging and Unit Load Design (CPULD) with Garvin's assessment tool and with the disciplines from Peter Senge. The basic question investigated was "what are the enablers and the inhibitors that affect the learning processes/culture at CPULD?"

Rapid technological, cultural, and political changes on a global scale put pressure on organizations to innovate in order to tackle the increasing complexity of the global environment. These changes require organizations to constantly evaluate themselves in order to be aware of whether or not their organization's structure and culture is adequate to face the challenges of a rapidly changing world. Understanding the current culture in a learning organization enables the identification of practices and behaviors that are contributing to the success of the organization, so that they can be strengthened. It also helps in identifying behaviors and practices that are preventing the organization from achieving greater success and from adapting to a changing environment, so that concrete actions can be proposed to improve organizational performance. The methodology used to understand CPULD in this context is shown in Image 2.

Methodology

Objectives	Activities	Methods and Tools	Output
Identify key concepts to evaluate the current practices of a Learning Organization	Conduct a literature review to understand the theory	Literature review	Key concepts to be used in the assessment tool and the open-ended questionnaire
Analyze the Center for Packaging and Unit Load Design at Virginia Tech from the perspective of a learning organization.	Collect information from the members of the organization, regarding the current practices from the organization's learning environment, processes, and leadership.	Assessment questionnaire developed by Garvin, Edmondson, and Gino (2008).	Strong and weak points of each building block in the organization
Identify characteristics that support the idea of the learning organization as well as those that are contrary to it.	Evaluate the current practices of the organization based on the five disciplines from Peter Senge.	Application of qualitative open-ended questions based on Peter Senge's five disciplines. (2006) Assessment questionnaire developed by Garvin, Edmondson, and Gino (2008).	Perception from the members of the organization about practices and characteristics of their working environment.

Image 2. Methodology used to evaluate CPULD as a learning organization.

Garvin's assessment tool is a method used to show whether teams are learning and how that learning is benefitting the organization. It consists of three building blocks that Garvin believed are needed for creating a successful learning organization: a supportive environment, concrete learning processes, and leadership that reinforces learning. The *supportive learning environment* block tries to determine whether the employees feel safe disagreeing with others, asking naive questions, owning up to mistakes, and presenting minority viewpoints. The *concrete learning processes* block evaluates if a team or company has formal processes for generating, collecting, interpreting, and disseminating information. It also examines if the team or company has a process of gathering intelligence on competitors, customers, and technology. The *leadership that reinforces learning* block evaluates if the organization's leaders demonstrate: a willingness to entertain alternative viewpoints; signal the importance of spending time on problem identification, knowledge transfer, and reflection; and engage in active questioning and listening.

This project also used the five disciplines of Peter Senge to analyze CPULD. First there is *personal mastery*, which refers to having individuals in the organization who have the desire and capacity to learn and grow. Next is *team learning*, which are the processes by which these individuals develop shared goals and work together to reach them. *Mental models* refer to the deeply internal images that people hold about how the world works. This affects organizations when individuals aren't able to behave in productive ways due to their fundamental assumptions about the world, causing them to have conflict with each other and not be open to creativity. On the other hand, *systems thinking* is when individuals are able to understand complex structures and phenomena as a functioning whole. Instead of trying to solve a problem, this helps people recognize that the problem is only a symptom of a larger, overarching issue. Being able to correctly identify these interrelationships and to conceive specific, targeted actions to treat the whole is essential systems thinking for successful problem solving in an organization. Finally, a *shared vision* is the end goal that a leader establishes and guides his team to work towards together. It's essential for a learning organization to have this since, when individuals make it their personal goal to meet the organizations goals, it becomes a shared vision and will provide focus and energy for learning.

Garvin's assessment was used to analyze CPULD from the perspective of a learning organization by collecting information from the members regarding the current practices surrounding the learning environment, processes, and leadership. In order to identify characteristics that support the idea of a learning organization and those that run contrary to it, this project evaluated the current practices of the organization based on Senge's disciplines. Garvin's assessment and Senge's disciplines were both applied to two different units (the pallet lab and the corrugated lab) within CPULD through the application of an assessment questionnaire and a qualitative, open-ended questionnaire, respectively. Once responses were obtained, they were analyzed separately and compared to each other. The answers were combined and summarized (Image 3) using many of the same keywords as Senge's disciplines.

Image 3. Summary of responses received during assessment questionnaires conducted of CPULD personnel.

It was found that the organization has good structured procedures in place to rapidly include new members in the organization's goals: there are training camps, explicit focus on hands-on approaches, and leadership that enhances learning capacity among individuals. Everyone felt that customized testing performed in both lab units allows for the people working in the organization to be more creative, launch experiments, and be open to new ideas. The corrugated lab unit got high marks in communication, with individuals stating that this unit often engages in productive debates and discussions, and is always looking at the underlying issues and not just the current problem. This unit also quickly and accurately communicates all knowledge to all personnel levels. The pallet lab unit offers time for overall discussion and reflection after projects are complete.

One important issue found by these assessments is a lower than desired psychological safety score, which the pallet lab unit obtained on the first questionnaire and was supported by low results in the open-ended questions as well. It is important to address this issue, given the significance that open communication and the willingness of people to express their ideas have on creativity, new ideas, and the overall performance of an organization. These results indicate that some members of the pallet lab unit might be afraid to speak up and that they, as a group, perceive a lack of communication between management and others in the organization.

These results made evident the differences that exist between the Corrugated Laboratory unit and the Pallet Laboratory unit. This project concluded that these differences are largely explained by the size of the units. The corrugated lab only has two hierarchy levels: undergraduate interns and upper management. The pallet lab, on the other hand, has four hierarchy levels: undergraduate interns, graduate students (managers), managing director, and director. By its very nature, having this many levels in the pallet lab's chain of command makes it hard to communicate important information down the levels.

This study's suggestions for bettering CPULD's assessment scores include the following:

- Establish incentive mechanisms that invite members of the organization to offer suggestions for improving processes (and/or offer an anonymous way for these suggestions to be made by those not comfortable with speaking up publicly).

- Have regular pre-project meetings with all staff, up and down the chain of command, to explain the overall purpose and value of the upcoming project.

- Better utilize the technological devices in the labs to communicate valuable information such as upcoming deadlines, safety reminders, etc.

Overall, the results obtained in this study regarding education, training, and experimentation reaffirm the effectiveness of the efforts that the CPULD has taken over the years to engage its students in learning processes through training and research by means of team building activities, certification trainings, and research projects in the laboratory, all with a focus on experiential, hands-on learning.

Research Highlight — Investigating the Interactions Between Pails and Pallets, and Pail Compression Strength

Image 1. Representative setup of pail crushing with Michael Phelps and Meredith Brooks.

This is the second part of a two-semester undergraduate research project conducted to learn more about the interaction between pails and wooden pallets. The research was funded by the Pallet Foundation of the National Wooden Pallet and Container Association (NWPCA). Meredith Brooks, a junior pursuing a degree in packaging systems and design (Image 2), and Michael Phelps, a senior pursuing a degree in sustainable biomaterials (Image 3), were selected for this project. Both students were taking part in the Distribution Packaging Internship Program through CPULD and had been working as laboratory technicians in the pallet testing lab prior to being selected.

Image 2. Meredith Brooks

Image 3. Michael Phelps

Pails are frequently used in industry to ship smaller quantities of liquid products such as paint. Due to their design, pails are sensitive to the support conditions such as the size of deckboard gaps and the position of the pail on the deckboards. The project had two main goals: the first was to gain further understanding on the mode of pail failure under different stacking conditions, the second was to investigate how deckboard gaps and overhang affects the failure mode and mechanical strength of pails. Prior to this project, effects of these factors have only been investigated using corrugated boxes.

For the first phase of the project, eight pail designs were investigated (Image 4). They varied in volume, material, dimensions, and the type of closure. Each of the pail designs was placed in a compression tester with a data collection program to measure the amount of load needed to fail the pail design. The plastic pail designs were centered and tested in the Lansmont Squeezer, which had a fixed platen with a 5,000 lb. load cell. The metal pail designs were tested in the MTS 10/GL as it had a higher load capacity. The maximum load before failure was recorded using a computerized data collection system for each test. Each of the pail designs were tested using three different stacking conditions: single stack, double stack, and no lid configurations.

Metal	 5 gal open head Mauser	 1 gal open head Mauser	 5 gal tight head Mauser	 1 gal tight head Mauser
Plastic	 5 gal open head M&M Industries	 5 gal open head Uline*	 1 gal open head Mauser	 5 gal tight head Uline

Image 4: Representative photos of pail designs tested.

The modes of failure for the compression strength tests varied between the different stacking configurations and pail designs. The two modes of failure that were observed were sidewall buckling and lid failure (Image 5). The most common mode of failure for all of the designs and configurations was sidewall buckling; however, in some of the double stack tests, the mode for failure was lid failure.

It was observed for all of the pail designs, except for the 5-gallon tight head metal, that the average peak load at failure decreased when the pails were double stacked, which led to the conclusion that the compression strength of the pails decreases when double stacked. The decrease in average peak load observed during the double stack tests may have been caused by a redistribution of the concentration of the load from the top pail to the interior portion of the lid of the bottom pail rather than a rigid plate evenly distributing the load around the rim of the lid. This redistribution of load concentration may have also been the cause of the lid failure seen in some of the double-stack tests.

The most common pail used in industry is the 5-gallon open plastic pail. When tested, these pails fell in the middle of the range of compression strength. The average peak load capacity for the single stack configuration was about 3,000-4,000 pounds. For the double-stack configuration, the average peak load capacity ranged between 2,500-2,800 pounds.

It was observed that the closed head metal pails, both 5-gallon and 1-gallon, are the stronger pail designs. The weakest designs were the 1-gallon open plastic pails and the 5-gallon closed plastic pails. The rest of the designs were relatively similar in compression strength. While the size of the pail did not have a significant effect on its compression strength, the material had a major influence.

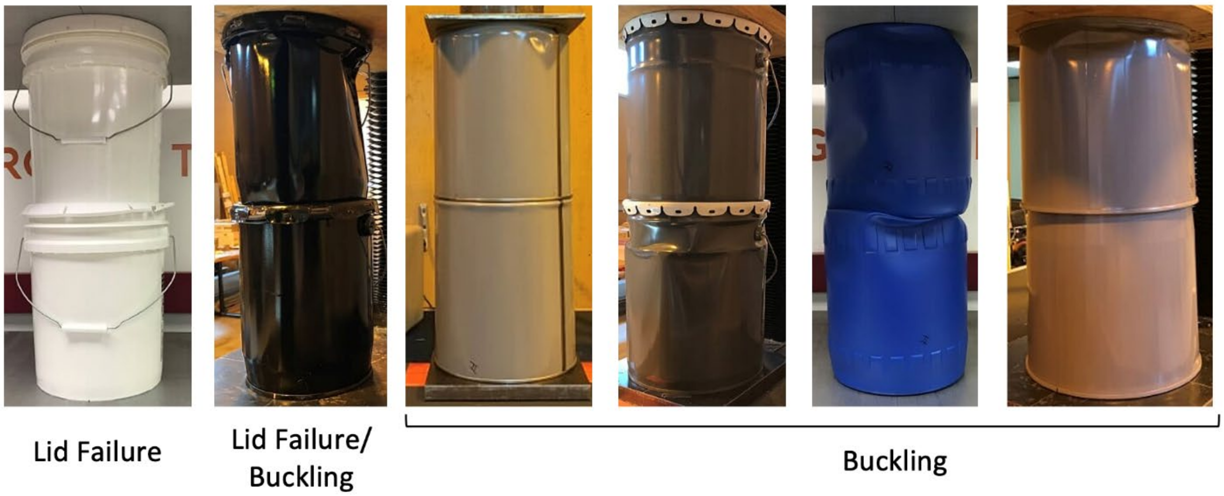


Image 5. Representative modes of pail failure during the double-stack compression tests.

During the second phase of the study, the effect of deckboard gaps and overhang was investigated. The pails were double stacked for this experiment and the loading was conducted in the Lansmont Squeezer compression tester. The modes of failure for each deckboard configuration were the result of a failure in the bottom pail (Image 6). Pail buckling was the primary mode of failure for each setup, with the exception of the 2 in. gap configuration, which also had a lid failure. The results showed that increasing the size of deckboard gaps can reduce the compression strength by 21.8% while the increase in overhang decreased the compression strength by as much as 48.7%. This trend aligns with similar research done on corrugated boxes. However, the severity of the decrease in compression strength was slightly greater than that of corrugated boxes. The students are planning to continue the study during fall 2020 with more replicate tests to be able to produce results that can be produced statistically.

Image 6. Pail failure modes on simulated pallet deckboards.

Research Highlight — Performance Measurement System Design Project Using Key Performance Indicators for Tracking Employee and Overall CPULD Performance

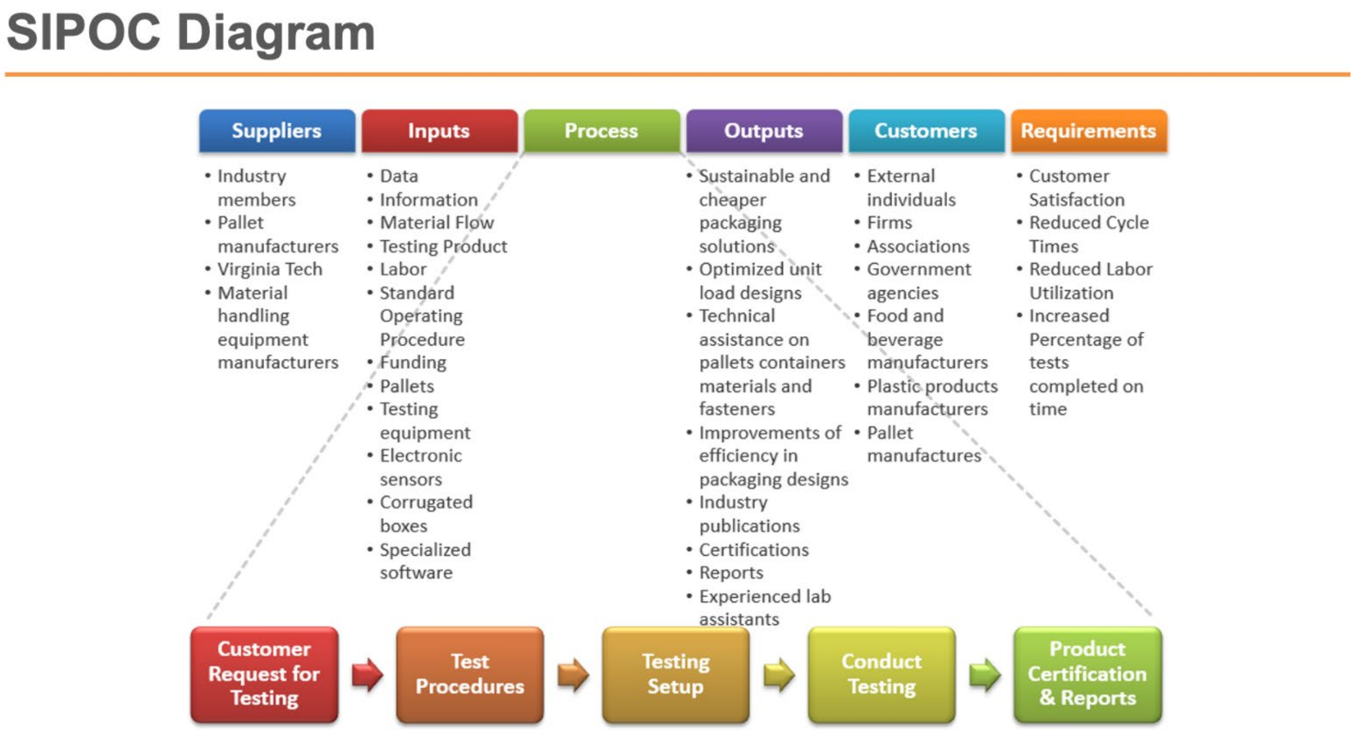


Image 1. Suppliers, Inputs, Processes, Outputs, and Customers (SIPOC) diagram for CPULD

The primary aim of this team project was to design a Performance Measurement System (PMS) for the Center for Packaging and Unit Load Design (CPULD) using Key Performance Indicators (KPIs) and to make their use a regular part of CPULD's organization and performance validation systems. Currently CPULD only uses quarterly financial reports to track employee performance (based on hours worked and projects completed). This continuous improvement project was designed to begin helping CPULD to better quantify its processes, measure its overall performance, and keep track of individual employee performance. The project was conducted by graduate student Yu Yang Huang.

This project's methodology was first to define the importance of creating a PMS for the organization and to outline the basic functioning model of CPULD. This step is called SIPOC (Suppliers, Inputs, Processes, Outputs, and Customers) and the diagram (Image 1) shows the organizational outline of CPULD that the project team created.

After outlines were created, a SWOT analysis was conducted that defined the Strengths, Weaknesses, Opportunities, and Threats to overall company performance and individual employee performance. CPULD has many strengths and opportunities, such as many of its employees have a high education level, the work environment is set up well for experiential learning, and the lab itself already has many national and international certifications. Prior to this project, CPULD knew many of its weaknesses and had a rough picture of where it was lacking. This project confirmed that individual performance had never been highlighted, quantified, and documented. CPULD embraced this project, as it understood that having an overall PMS is the best option to provide a clear picture — both of its strengths and of areas needing improvement — and that knowledge is beneficial for growth.

A standard "balanced scorecard" of metrics was used to analyze the SIPOC, SWOT, and CPULD's outline. This approach has been proven to be a good platform under which to develop and implement growth strategies for an organization. The cause-and-effect relationships between different strategic objectives can be of great importance to managers when it comes to visualizing a business model for organizations like CPULD. A balanced scorecard helps to have a consensus between the interrelated strategic objectives and helps to create a complete picture of what strategies need to be implemented. It looks at all of the aspects of a business from four perspectives and tries to "balance" the organization by having equal effort put towards each (Image 2).

Image 2. Balance scorecard showing consensus between interrelated strategic objectives

After finding that more defined metrics needed to be employed for both overall performance and for individual performance in the lab, the project concluded that the Financial Perspective should not be the only aspect looked at for performance ratings; the Customer Perspective was already being handled well, based on the retention of long-term clients and the regular surveying of said clients for satisfaction; and the Internal Business Perspective had already been looked into by other projects. Therefore, the team decided this research project would focus on bettering the Learning and Development Perspective. Once this focus was decided upon, the project then moved on to Phase 2, which was designing and implementing a series of surveys distributed anonymously to CPULD employees in order to discover their levels of satisfaction and engagement with their jobs in the lab as well as how they feel they can develop/grow within their job.

In order to facilitate the best performance possible from employees, it's necessary for the organization to have a strong mission statement with which the employees can relate and base their work around. Although CPULD does have a strong mission statement, it was not found to be communicated well across the different levels of the organization.

The initial survey asked 52 specific questions, but was then reduced to 19 questions, all of which fell into the following main categories:

1. Employee Satisfaction:
    a. Does the employee feel valued at his job?
    b. Does the employee fit his job, both qualification-wise and personality-wise?

c. Has the employee learned things through his job that will help in life?

2. Employee Development:
    a. Is the employee capable of/skilled in performing his duties?
    b. Does the employee feel he brings improvements to the job?
    c. Is the employee provided with enough training to do his job?

3. Employee Engagement:
    a. Does the employee feel there a sense of teamwork among his peers?
    b. Does the employee feel his feedback is appreciated by the job?
    c. Does the employee know and relate with the mission of CPULD?
    d. Is the employee proud of being associated with CPULD?

Employee Satisfaction is defined as a measure of whether an employee's needs are being met at work and how satisfied they are with their overall work experience. The focal point in Employee Satisfaction is on the employee's feelings, positive or negative, about their employment relationship. The questions in the Employee Satisfaction section are a means of gaining insight into the employee's emotional state of happiness with their job and the organization in general.

Through the survey, the project found that 100% of employees agreed (slightly agreed, agreed, or strongly agreed) that their work was valued by their supervisors, they're treated with respect by their supervisors, the supervisors are genuinely interested in them and their careers, and their own personal research projects are helped by their work in the lab. Also, 100% of employees felt they were comfortable with their current roles and could be themselves at work. When asked if they liked their work and if they were challenged by it, 87% of employees agreed. However, 25% feel they don't have the space/freedom to express their opinion in the workplace, and 13% don't feel that good work is fairly recognized by management.

Employee Development is defined as a process during which employees, with the support of their employer, go through professional training to improve their skills and grow their knowledge. The Employee Development questions ask about employee competency in their current jobs and their perceived value to the organization.

Through the survey, the project found that 87% of employees agreed (slightly agreed, agreed, or strongly agreed) that their supervisors facilitate their learning new tasks in their work, 87% agreed that their peers help them learn as well, and 87% believe that working at CPULD has helped them grow as a person. However, this also means that 13% feel their peers are not contributing to their growth as an employee, and the project also found that 26% of employees felt that their job is not helpful in their personal education/research.

Employee Engagement is defined as the extent to which employees feel passionate about their jobs, are committed to the organization, and put discretionary effort into their work. The Employee Engagement questions ask about the levels of collaboration among the employees and their sense of belonging in the organization.

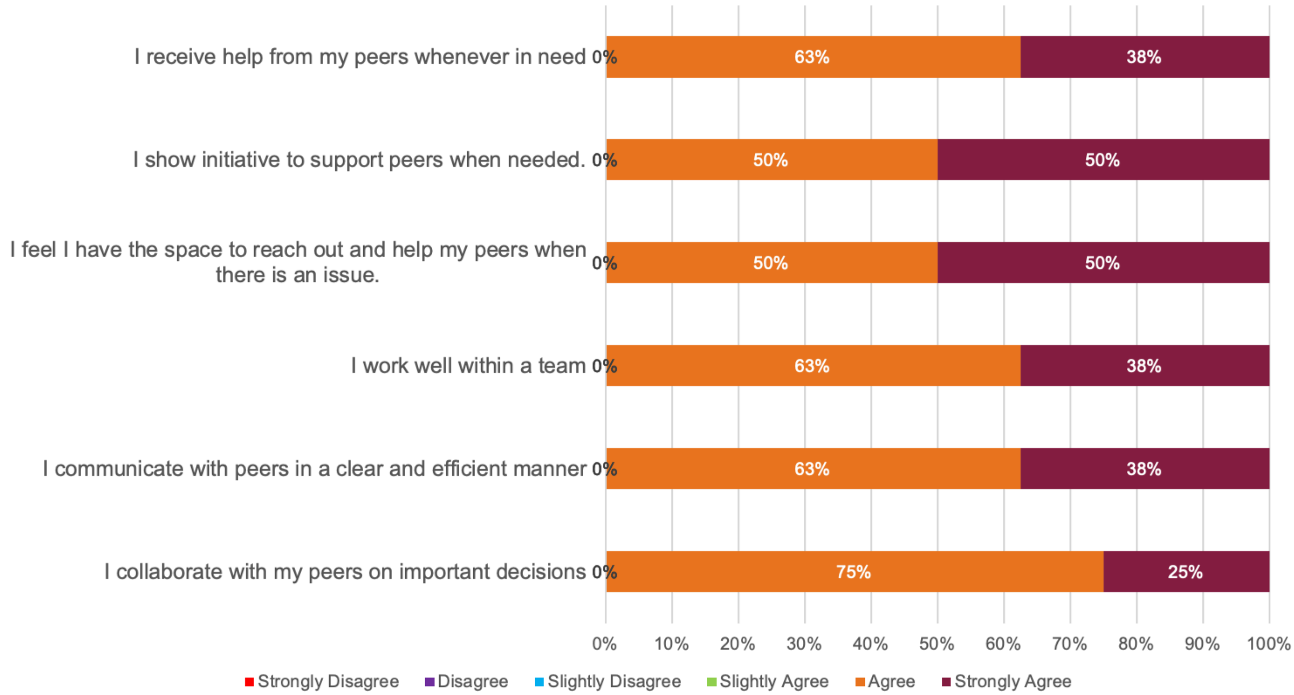


Image 3. Scorecard showing 100% agreement that CPULD has a great team mentality among employees.

Through the survey, the project found that 100% of employees feel good (slightly agreed, agreed, or strongly agreed) about the work they do as a team at CPULD and that CPULD is a great place to learn (Image 3). In addition, 100% feel they receive support from their team whenever they need it and that they offer support to others, 100% feel communication and collaboration among team members is one of the greatest strengths of the workplace here, and, 87% claim that the strong feeling of teamwork they have with their peers is one of the main motivations for doing good work. However, 26% feel that upper management doesn't do enough to communicate a strong sense of vision/mission for the work, and 26% don't even have a clear idea of CPULD's objectives as an organization. Also, 13% of employees stated they feel that they aren't encouraged to give their opinion on issues that involve them, and that they aren't given enough feedback about their work.

As these types of questions/metrics had not been measured by the organization before, it gave the project team a fair chance to conduct an unbiased pilot test of their survey with the employees at CPULD and then to conduct analyses that could be used to further optimize the surveys to make them better to deploy in the future. Many analyses were done on the survey responses, including Factor Analysis, Correlation Matrix, Scree Plot, Cronbach's Alpha, and Varimax and Oblimin Methods.

The overall conclusions reached through analyses of the survey results are that CPULD employees feel valued in their jobs and that the environment is set up well for teaching and learning. They also feel they work with a strong team of collaborative peers and that they all receive adequate training to feel good at their jobs. The main issues revealed by the surveys is that many employees would prefer to be included more often in decision making about the tasks/procedures that involve them and would like to receive more feedback about their individual performance.

White Paper — Effect of Pallet Fastener Quality on Pallet Durability
Research paper by Owen Wright and Luke Guyre

There are three common types of nails that are used in pallet construction: helically threaded, annularly threaded, and plain shank (Figure 1). Plain shank nails are regular nails with a smooth shank. Helically threaded nails have continuous spiral threads along the shank. Annularly threaded nails have a series of rings along the shank that grip the wood and help to prevent the nail's withdrawal. The effectiveness of pallet nails is dependent on a variety of parameters including head diameter, wire diameter, thread crest diameter, thread angle, helix, flute, thread length, and effective nail length (Figure 2).

Figure 1. Common nail types used for pallet construction: (top to bottom) helically threaded nails, annularly threaded nails, and plain-shank nails.

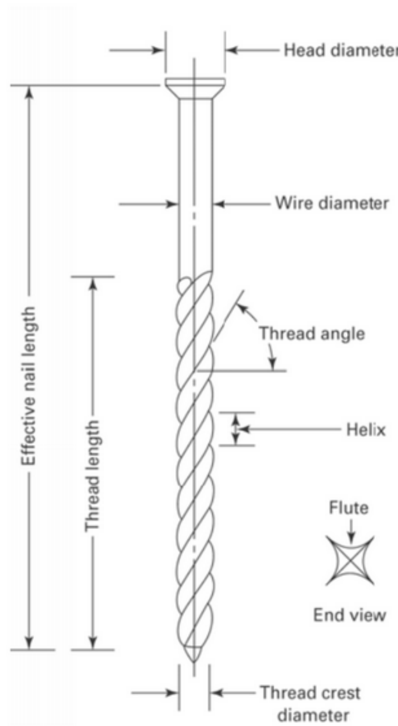


Figure 2. The anatomy of nails used in fasteners.

The Uniform Standard for Wood Pallets (NWPCA, 2014) lays out guidelines for nailing pallets. Nails used must penetrate the pallets' block or stringer to at least a certain depth. For deckboards with thicknesses over ½ in., nails must penetrate at least 1¼ in., while for deckboards with thicknesses of ½ in. and under, nails must penetrate at least 1 in. The standard also defines the minimum number of nails that must be used per connection. For example, a minimum of two nails must be used for deckboards that are a width of 5¼ in. or less, and a minimum of three nails must be used for deckboards that are 5¼ in. to 7 in. wide. Nails must also be arranged in a way that minimizes the splitting of the wood and must have a minimum head-to-shank ratio of 2 (except for new, reusable pallets, which need to have a ratio of 2.25). This standard also defines minimum nail quality based on the fastener withdrawal resistance (FWI) and the fastener shear resistance (FSI). The minimum FWI is 65 for multiple-use pallets and 50 for limited-use pallets, and the minimum FSI is 55 for multiple-use pallets and 40 for single-use pallets.

Pallet Durability Modeling

In 1982, Wallin and Whitenack developed a model to determine when a pallet needs to be repaired. The model was built based on the data that was collected during the Pallet Exchange Program (PEP) study conducted by the USDA between 1967 and 1971 (Wallin et al., 1972). This three-year study analyzed 17 different types of stringer pallets that were exposed to 16 different handling environments. The data collected from this study were about pallets' total number of handlings, locations of damages, number of damage occurrences, and relative severity of damage after each trip. This data allowed the authors to develop a classification system about the types and levels of damage a pallet endures. They came up with nine levels of damage severity. It was found that the optimal time to repair a pallet is when the damage severity level reaches 7 or higher.

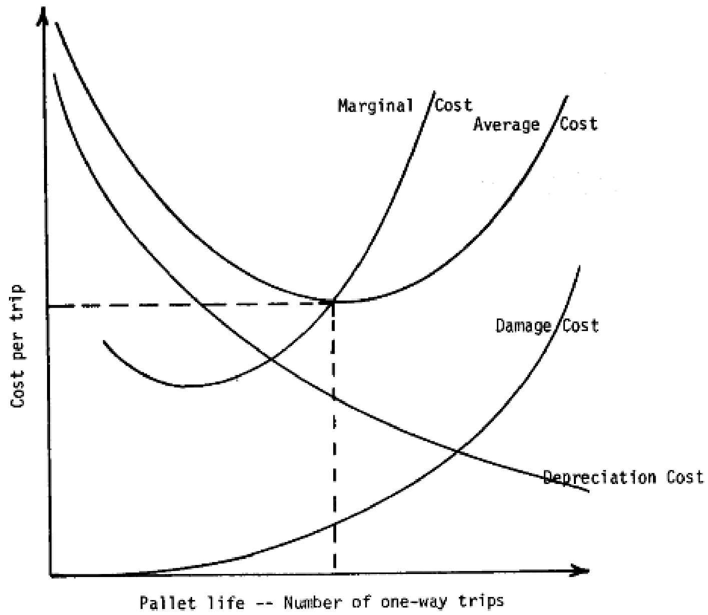


Figure 3. Wallin and Whitenack's economic model to predict the overall durability of a pallet.

Wallin and Whitenack's 1982 study also developed an economic model to predict the overall durability of a pallet (Figure 3). Their model calculates the maximum number of trips for which it makes economic sense to continue use of a pallet. The economic model is based on the average cost, damage costs, marginal cost, and depreciation cost. The average cost represents how much it will cost to use the pallet. This is a parabolic trend since the more times one uses a pallet the more the price goes down, but after a certain point the extra costs required to repair the pallet (damage costs) causes the user to start paying more per use. The damage costs represent the total amount spent in repairs to the pallet. It is a positive trend since damage costs are accumulated throughout a pallet's lifespan. The marginal cost represents the value one gets out of a pallet if it's used for one more trip. Finally, the depreciation cost represents the decreasing value of the pallet over its lifespan due to damage repairs.

This model utilizes the cost of damages to predict the overall durability of the pallet. To estimate the damage cost per trip, the model calculates the cost to repair each damage (C), which is calculated based on three variables (Equation 1). The first variable in the equation is the economic coefficient (c) which makes the cost calculated reflect the real-world cost of repairs. The second variable is the technical coefficient (b) and considers the design of the pallet. The last variable is the severity of the damage (S).

$$C = cb^S \qquad \text{Equation 1}$$

To calculate the total cost of damage (D) throughout the life of the pallet, this model uses the expected damage rate (r), the cost of repairing each damage (C), and the number of one-way trips the pallet will take (U).

$$D = C((r + 1)^U - 1) \qquad \text{Equation 2}$$

With this cost defined, one can easily determine if it makes economic sense to repair the pallet. According to Wallin and Whitenack, the pallet should only be repaired if the value of the pallet before the repair is greater than the total cost of damage (D).

To calculate the average cost of a pallet per trip (A), the model uses the total damage cost to a pallet during its life (D), the purchase price of the pallet (P), and the number of one-way trips the pallet can survive (U). Based on this analysis, the pallet should be used until the average cost per trip is the lowest is can reach (Figure 4).

$$A = (D + P)/U \qquad \text{Equation 3}$$

The economic life of the pallet depends on the damage rate (r), the damage severity (s), and the economic factors (c) that influence the repair costs. Another study done by Wallin and Whitenack (1982b) describes an equation that relates the damage rate (r) to the damage severity (S) and the average number of trips survived.

These researchers developed the equations through a joint study that observed the damages to 877 pallets that represented 17 different pallet designs. The study found that damage severity (S) and damage rate (r) are strongly interdependent. This means that when a pallet receives damages more often, it is likely that the pallet will be damaged more severely.

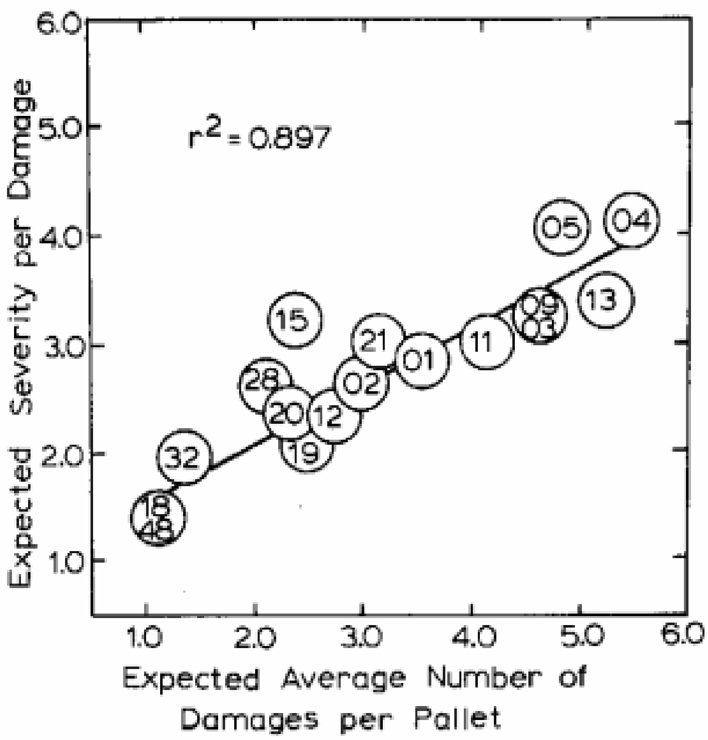


Figure 4. Frequency of pallet damages compared with the severity of each damage incident.

Another major finding of this study is that there is a correlation between the damage severity (S) and damage rate (r) to the lifespan of a pallet. This was discovered through an equation for expected cumulative damage (E(Z)). This equation uses the damage severity (S) and damage rate (r) to calculate the severity and frequency of damages after the initial damage to the pallet. A higher value indicates that a pallet is more fragile while a lower value indicates that a pallet is more durable. It was found that the greater the expected cumulative damage, the lower the frequency of damages and the less severe each incident of damage was. This led to the pallet surviving more handlings then before the initial damage (Figure 4) (Wallin and Whitenack, 1982b).

The damage rate (r) and damage severity (s) can be calculated using nine pallet damage factors, which are numerical evaluations of the pallet design.

$$r = [1 + F(1)]\,[1 + F(2)]\,[1 + F(3)]\,[1 + F(4)]\,[1 + F(5)] \,*\, [1 + R(1)]\,[1 + R(2)][1 + R(3)][1 + R(4)]\,[0.01]$$

Equation 4

$$S = [1 + F(1)]\,[1 + F(2)]\,[1 + F(3)]\,[1 + F(4)]\,[1 + F(5)] \,*\, [1 + R(4)/2]\,[2.0]$$

Equation 5

The pallet damage factors are as follows:

- F(1) = factor for fastener-withdrawal resistance
- F(2) = factor for fastener-shear resistance
- F(3) = factor for connection-splitting resistance
- F(4) = factor for shook quality
- F(5) = factor for selective shook-quality placement
- R(1) = factor for flexural strength of stringers
- R(2) = factor for flexural strength of decks
- R(3) = factor for deck construction
- R(4) = factor for materials-handling environment

The two pallet damage factors that are directly influenced by the fasteners are the fastener withdrawal resistance F(1) and the fastener shear resistance F(2).

Fastener Withdrawal Resistance F(1)

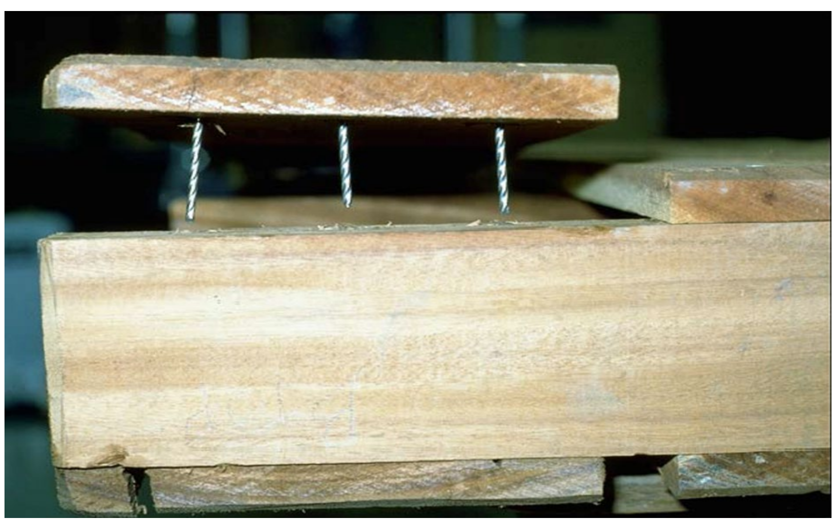


Figure 5. Showing fastener withdrawal causing pallet joint separation.

The F(1) damage factor is related to the resistance of the pallet joint to separation (Figure 5) (ASME, 1997). It is dependent on the fastener withdrawal resistance (FWR), which is a measure of the total withdrawal resistance of the fasteners in a pallet described in pounds per linear inch of penetration. The FWR is determined by the head pull through resistance (HPR) or fastener withdrawal resistance of a single fastener (FWRF), depending on which value is lower. For most nails, the FWRF is the governing factor and, thus, is the one used for this calculation. The FWRF is influenced by the specific gravity, the depth of penetration, the moisture content, and the fastener withdrawal index (FWI). FWI represents the relative resistance of a fastener against withdrawal compared to a base nail. The base nail has a wire diameter of 0.113 in., a thread crest of 0.133 in., nine helixes along the shank, 1.625 in. of threaded shank, and an average withdrawal resistance of 320 pounds per inch of penetration.

$$FWI = 221.24WD[1 + 27.15\,(TD - WD)\,(H/TL)] \qquad \text{Equation 6}$$

The FWI increases with increasing wire diameter, press out (which is the difference between thread-crest diameter [TD] and wire diameter [WD]), and the reduction of thread angle. The relationship between nail anatomy and a nail's resistance to withdrawal has been thoroughly examined in a study performed by Wallin and Whitenack (1982c). They present the FWR as the fastener quality index (FQI). Their study looked at nails of varying measurements and found the FWR for each.

The study showed how changing wire diameter, press out, and thread angle can influence the FWR of the pallet joint (Figure 6). The thread angle is related to the other dimensions discussed previously. It was found that the thread crest diameter, number of helices, and thread length all play an important role in determining the overall withdrawal resistance of a nail.

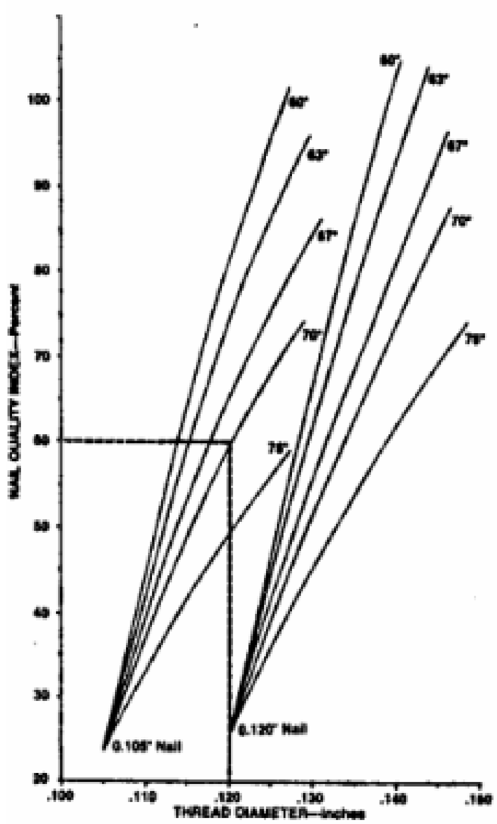


Figure 6. Effect of nail parameters on the FQI or FWR. (Wallin and Whitenack, 1982c).

Wallin and Whitenack (1982c) also examined plain shank nails and staples. They isolated and observed the effects of wire diameter and how it affected the fasteners' resistance to withdrawal. In short, the FWI is the comparative measure of how much force it will take for the fastener to withdraw from the wood joint. Figure 7 shows the FWI comparative to a base nail — meaning that an FWI of 60 indicates that the nail has 60% of the performance of the base nail. The base nail used here has a wire diameter of .113 in., thread crest of .133 in., 9 helixes along shank, 1.625 in. threaded shank, and an average withdrawal resistance of 320 pounds per square inch of penetration.

		Minimum Depth of Penetration of Fastening Member	Minimum Fastener Withdrawal Index (FWI)		Minimum Fastener Shear Index (FSI)		Minimum Ratio of Nail Head/Shank Diameter		Minimum Staple Crown Length
			Multiple Use (M)	Limited Use (L)	Multiple Use (M)	Limited Use (L)	Multiple Use (M)	Limited Use (L)	
Block or stringer fasteners	New Pallet Assembly	1.25 in. (32 mm) [Notes (1) and (2)]	65	50	55	40	2.25	2.00	0.375 in. (9.5 mm)
	Pallet Repair		40		30		2.00		
Clinched mat fasteners [Note (3)]	Completely through the fastened and fastening members and clinched		25	20	25	20	2.00	2.00	0.375 in. (9.5 mm) [Note (4)]

Figure 7. Minimum quality of driven fasteners comparative to a base nail.

Fastener Shear Resistance F(2)

Figure 8. Showing fastener shearing causing pallet joint separation.

The F(2) damage factor is related to the resistance of the pallet joint against shear (MHI, 1997). It is dependent on the fastener shear resistance (FSR), which is the total shear resistance of fastener couples in pounds. The FSR is dependent on the fastener shear index (FSI), the oven-dry specific gravity, the thickness of deckboards, the moisture content at assembly, and the number of fastener couples per joint. The FSI represents the relative shear resistance of pallet fasteners compared to the base nail.

$$FSI = 263.260\, WD^{1.5} \,/\, (3M + 40) \qquad \text{Equation 7}$$

The FSI increases with increasing wire diameter. The FSI has an inverse relationship with the Morgan Impact Bend Angle Nail Test (MIBANT) angle. The MIBANT angle is determined by the MIBANT test (Figure 9), which drops a 3.5 lb. weight 15.4375 in. onto the head of a nail that is secured in a vice. The amount that the fastener bends is the MIBANT angle. The MIBANT test is basically a test of fastener impact resistance.

Figure 9. MIBANT tester

Example

In order to illustrate the impact that fasteners have on pallet durability, we utilized the fastener durability input and fastener input analysis functions of the Best Load™ pallet design software. This function allows the user to input all the details of multiple nails and compare their durability results. For this example, we compared 11.5-gauge bulk nails and 12.5-gauge collated nails in a standard GMA pallet. Figure 10 shows the different nail characteristics for these two nail types, including that the 11.5-gauge nail has better FSI and FWI values (67 and 55) compared to the 12.5-gauge nail (37 and 31).

Nail Type	11.5 gauge (bulk)	12.5 gauge (collated)
Wire Diameter (in.)	0.112	0.099
Thread Diameter (in.)	0.122	0.104
Head Diameter (in.)	0.28	0.25
Thread Length (in.)	1.5	1.5
Nail Length (in.)	2	2
Helix Count	6.8	4.7
MIBANT Angle	36	60
Thread Angle	68	77
Flute Count	4	4
FSI	67	37
FWI	55	31

Figure 10. Characteristics of two differing nail types.

Nail Type	Cycles to 1st Repair	Cycles Before Replacement	Relative Damage Rate	Relative Damage Severity
11.5 gauge (bulk)	2	4	0.193	7.117
12.5 gauge (collated)	1	2	0.281	10.343

Figure 11. Pallet durability based on different nail types used.

Pallets can be rated on their "relative damage rate," which shows how rapidly the pallet will sustain damages from use. And they can be rated on their "relative damage severity," which indicates how severe the damages are that the pallet sustains. The results in Figure 11 indicate that a pallet using 11.5-gauge bulk nails has significantly better durability performance than a pallet using 12.5-gauge nails. The pallet built with 11.5-gauge nails lasts twice as many trips before needing repairs as well as twice as many trips before requiring replacement. Also, the pallet with 11.5-gauge nails had lower relative damage rate values as well as lower relative damage severity. These values determine that the pallet made with 11.5-gauge nails is 85.6% more durable than the pallet made with 12.5-gauge nails.

Another article, by Stern (1979), also describes several relationships that have been explained here regarding nail characteristics and their durability. Stern found that more helices per thread length increases nails' withdrawal resistance, and as the MIBANT angle decreases the shear resistance increases. His data further support the relationships already outlined between the nail characteristics and withdrawal and shear resistances.

Conclusions

- Better fasteners improve the durability of pallets, which saves time and money used to repair the pallet and better protects the product.
- Fastener withdrawal resistance and fastener shear resistance are major factors in pallet durability.
- Fastener withdrawal resistance is most affected by wire diameter, the difference between thread diameter and wire diameter, and the number of helices per thread length.
- Fastener shear resistance is most affected by the wire diameter.
- Using a 11.5-gauge bulk nail instead of a 12.5-gauge collated nail can improve pallet durability by 85.6% and double the life of the pallet.

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Student Spotlight — Meredith Brooks

Image 1. Meredith Brooks

Meredith Brooks is a rising senior from Virginia Beach who will graduate in spring 2021 with a bachelor's degree in packaging systems and design. She is an only child and considers her parents amazing. According to Brooks, she was adopted from China when she was 11 months old by her mom, who later met and married her dad when she was about five years old. While she started out in private school, Brooks switched to public school in 9th grade in order to be able to play violin in a larger orchestra and to socialize with new people. Brooks chose to come to Virginia Tech because she already knew that she liked the people here and would fit in well. The big school feel, tons of clubs and activities, and having pretty good sports teams were some of what drew her to the Hokie community. Also, she stated that "the food around here is so good!" In fact, the local Mexican restaurant's white dipping sauce is her all-time favorite food!

Brooks says her favorite class has been Principles of Packaging. "It was a very interesting class because it was the first packaging class I took at Virginia Tech. It showed me the diverse industries that packaging plays a role in and the many possibilities that a packaging degree can [offer]. I also had a project where I had to design my first package. It felt like jumping in the deep end since I was using ArtiosCAD and Illustrator for the first time, but at the end, I was super proud of myself."

Packaging was a major that Brooks didn't know existed until she was having second thoughts about her initial major, which was international studies. She found packaging on a list of majors at Virginia Tech, and after looking into it, she recalls that she realized that it made perfect sense for her as she really wanted the potential to go abroad, and also really cares about the environment. "Packaging is an international industry with companies for every business in every area imaginable. It also has huge environmental impacts. One small decision like decreasing the amount of plastic in a package by 10% or using a different type of pallet to ship a product can have huge ramifications on the environment. These decisions usually are desirable for businesses as they usually save money and are better for the environment, which is super unique."

In the future, Brooks hopes to get involved in the logistics aspect or supply chain of packaging or possibly testing of packages. "Packaging requires a holistic view of the entire process of developing a package and distributing it to consumers, and I think this is only becoming more relevant with the rise of online shopping where packaging aesthetics, although still important, are becoming less of a factor in a consumer's choice of product in the online market. What matters more is whether or not the product arrives in one piece."

Brooks credits her education here at Virginia Tech with giving her a "really good understanding of the different processes that go into making a package." She elaborated by saying that the curriculum here offers "really well-rounded coursework with courses such as Design Fundamentals as well as Packaging Distribution Systems that covers both design and distribution. It also has classes that discuss the different packaging materials and processes required to make them. With this understanding of packaging, I hope to aid in developing packages that fit into the distribution process well and are efficient but appealing in design."

Image 2. Meredith Brooks (front, center) receiving her ISTA certificate with other interns and grad students, (2019).

During her internship with CPULD, Brooks received her ISTA Technician certification and her forklift license. In fact, there are many ways Virginia Tech has helped her, but "the most helpful skill I have learned through classes is how to manage time well. Until college, I always prioritized school to the extent that I didn't know how to enjoy myself and balance school and fun. Being in school has taught me how to work hard and play hard. Outside of school, one of my favorite hobbies is running, which I started just about a year ago. A group of my friends trained together and ran the Hokie Half Marathon in the fall, which [was] super fun! I also really enjoy cooking with friends and just relaxing with good company. I've also gone old school again with using snail mail to write to friends, since I think it's something special to get mail! I've also gotten to have more quality time with my parents, and we usually go on walks every day. I also [still] enjoy playing the violin in my spare time."

Brooks hopes "to find a job in a company that produces products that I really enjoy and am passionate about. I hope to aid in the testing of their packaging to make the distribution of their products efficient and make the product appealing to customers." Her future goals have been guided and clarified through her time at Virginia Tech and the people she's met here. She says that the "best part of being a student at Virginia Tech has been getting to know my peers and professors more. The students here are great, and we help each other when we get stuck on something instead of being super competitive. The professors also genuinely care about the students and are very helpful in connecting their students with internships and jobs. The most helpful thing I learned at VT has been to ask questions. Being proactive and asking questions shows that you are listening, care about understanding properly, and are interested in learning more."

Image 3. Meredith and other interns during a hike on the intern retreat in the spring of 2019.

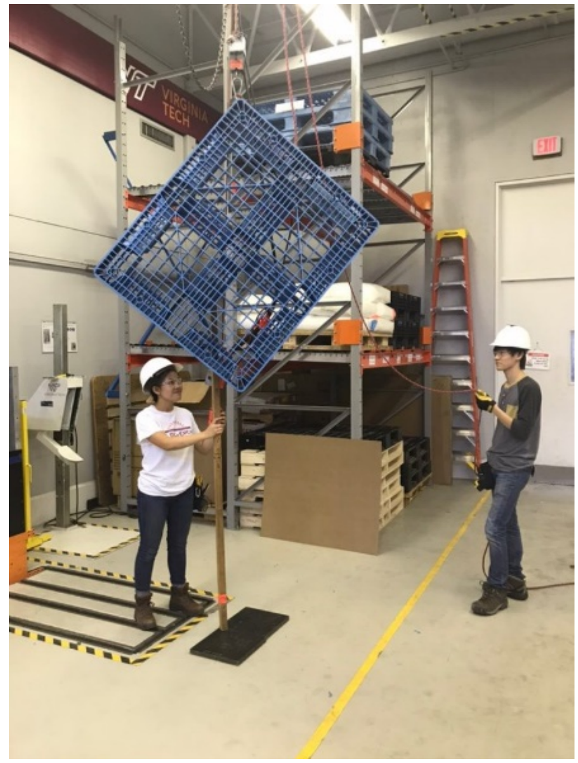

Image 4. Meredith helping with a corner drop test on a pallet in the summer of 2019.

Image 5. Meredith after the Escape Room Challenge done in the summer of 2019 with the other interns.

News — Graduate Student Mary Paz Alvarez Invited to Give IAPRI Presentation About Research on Palletized Drums in Warehousing and Distribution

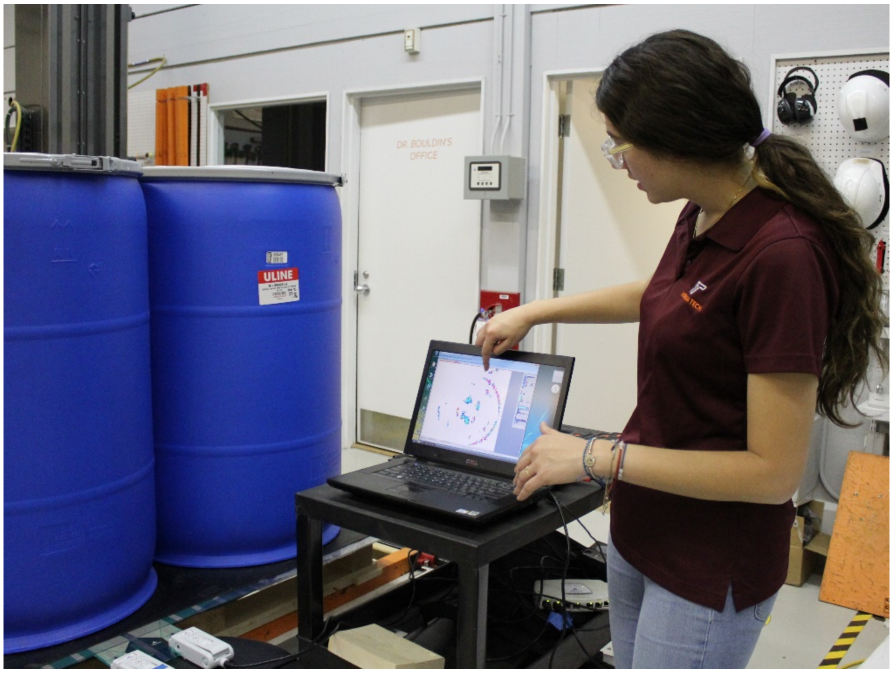

Image 1. Mary Paz Alvarez conducts research on palletized drums.

Mary Paz Alvarez (Image 1), under the guidance of Dr. Laszlo Horvath, Virginia Tech, and Farhad Shahabi, NWPCA, is working on a research project looking at how well wooden pallets perform during distribution when they're carrying large drums. The research project is funded by the Pallet Foundation of the National Wooden Pallet and Container Association (NWPCA). Mary was recently asked to present the current finding of her research at the IAPRI conference, which was held online this year due to the COVID-19 pandemic.

Pallets are an integral part of the modern-day supply chain. Pallets are currently designed assuming that they will be supporting a uniformly distributed and flexible load; however, the types of product being carried by the pallet can cause the load to redistribute unevenly on the pallet. This phenomenon is called load bridging. Load bridging has been extensively studied for unit loads of corrugated boxes. It was observed that during pallet deflection (bending), the pressure of corrugated boxes is redistributed to the ends of the pallet instead of being distributed evenly across the pallet's top deck. This pressure redistribution can have a large impact on how much load the pallet can ultimately carry, which can affect the sustainability and safety of the unit load.

Even though it is one of the main phenomena that affect the load capacity of pallets, load bridging had not previously been characterized for drums. Understanding the effect that drums have on deflection/load bridging will allow pallet designers to design more efficient and sustainable pallets. So the objective of Alvarez's study was to gain more understanding about how pallet deflection, and the pressure distribution on top of the pallet, is influenced by the shape, weight, and material of drums.

The experiment included four 48 in. x 48 in. stringer class, non-reversible pallet designs with 1/2 in. and 5/8 in. top deckboards (Image 2). All lumber used to construct these pallets was kiln dried to 19% moisture content and had a grade of standard or better. The investigation utilized four steel drums and four plastic drums filled with water (Image 3).

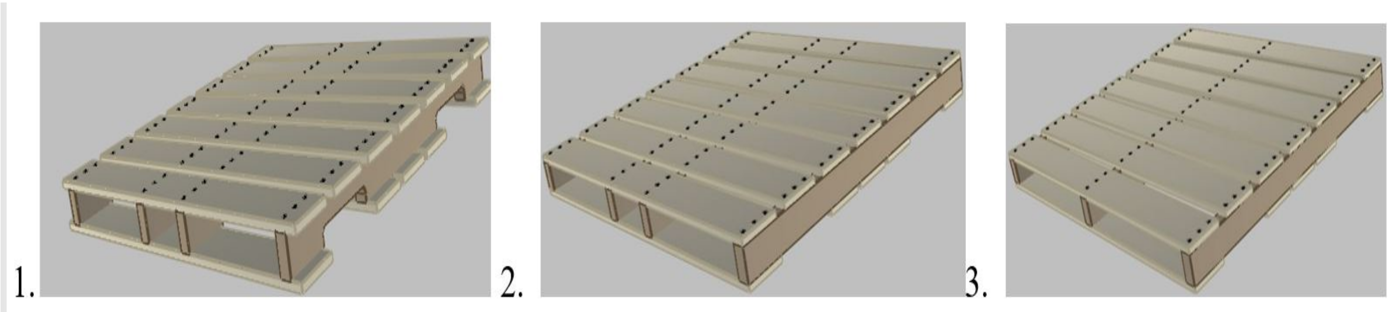

Image 2. Representative views of the three investigated pallet designs: (1) 4-stringer, winged, notched pallet design (D1); (2) 4-stringer, flush pallet design (D2); and (3) 3-stringer, flush pallet design (D3 and D4).

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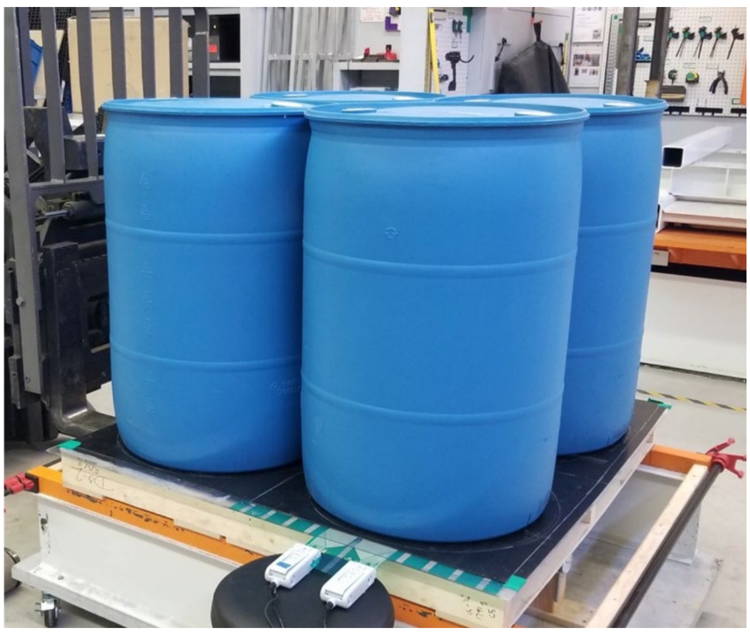

Image 3. Experimental setup for the research project.

When creating the drum unit load, a pressure mat (Tekscan model #7202) was sandwiched between two .06 in. thick polypropylene sheets, and a .063 in. EPDM roofing rubber mat was placed on the pallet first. The Tekscan equipment utilized I-scan software, which is what was used to record the pressure mat readings for each support condition that the unit load experienced. The drums were loaded on individually as close together as they could possibly be without any overhang. There was no containment used on the drums.

The research's experimental design was based on two different drum materials, four different stringer pallet stiffnesses, and five different support conditions. Three repetitions were conducted for each combination of drum material and pallet design. The experiment was conducted in cycles following the same order of steps: single stacked support, double stacked support, warehouse racked support across the width, and warehouse racked support across the length. Deflection measurements and pressure mat readings were collected for every support condition. Each pallet experienced three cycles with both drum materials.

The effect of drum material on pallet deflection is statistically significant for every investigated support condition:

- In warehouse racking across the length support condition, the difference averaged 23%.

- In warehouse racking across the width, it averaged 29%.
- In single and double stack floor support, it averaged 93% and 59%, respectively.

The difference between the behavior of the metal and plastic drums was attributed to their material rigidity. The plastic drums are more flexible than metal drums; therefore, they exhibit lower load bridging because they are able to follow the bending of the pallet more. This was confirmed by measuring the pressure distribution where more even pressure distribution was found for plastic drums, while the pressure for metal drums was mainly found under the chimes (Image 4).

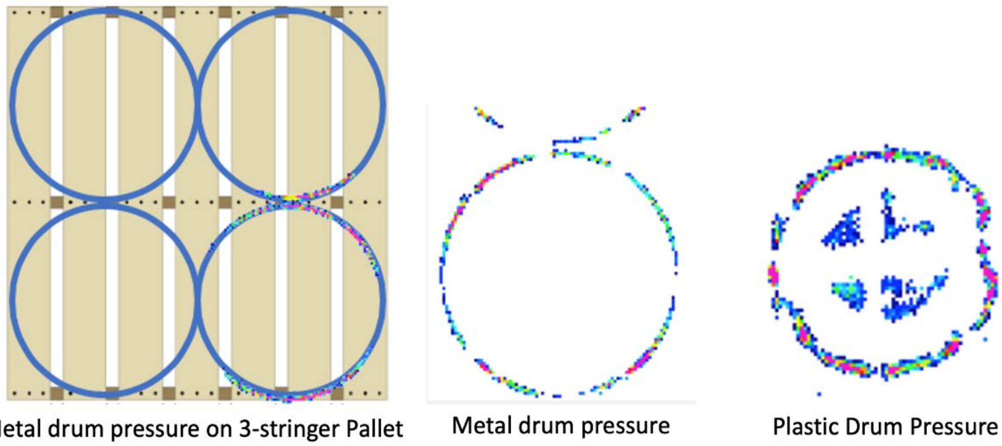

Image 4. Pressure distribution between drums and top surface of pallet.

In short, Alvarez found that the drum's material had a significant effect on the deflection of the pallet. Metal drums resulted in 46%-81% reduction in pallet deflection when compared to an airbag. Meanwhile, plastic drums created concentrated pressure areas on the pallet that, in most cases, resulted in more pallet deflection than what was measured for the airbag. These results indicate cost saving opportunities, especially for pallets supporting metal drums in scenarios where the load capacity of the pallet is limited by pallet deflection. However, it was also revealed that there is a significant difference in pallet behavior depending on the type of drum; therefore, the exact drum material and design need to be considered during pallet design.

News – New Digital Cutter Modernizes Packaging – Eduardo Molina

The Packaging Systems and Design program at Virginia Tech is excited to have a brand-new cutting table for use in bringing to life the packaging designs created by students in their program. An Esko Kongsberg X Edge sample maker was installed this summer at the Brooks Center and represents a significant addition to the capabilities offered to students.

Helping with one of the key aspects of the teaching mission of the packaging program, the digital cutter will enhance experiential learning for the students. Through this equipment, the instruction of package design and prototyping will be improved by allowing our students to try out new designs in a faster, more streamlined workflow. This new cutting table integrates seamlessly with the digital tools currently available for package design students such as ArtiosCAD, Esko Studio and Adobe Illustrator.

The improved quality of the samples created and the extended tooling capabilities of this cutting table present the opportunity to better showcase students' work at national and international package design challenges. The packaging program prides itself on emphasizing the development of sustainable solutions to everyday challenges and having a cutting table that allows experimentation with a wide array of materials and designs maximizes the opportunities available. The sample maker is capable of cutting all of the common packaging materials such as paperboard and corrugated fiberboard as well as a wide variety of foamboards, honeycomb boards, and different plastic materials, extending the packaging design students' experience in developing prototypes for structural and protective packaging.

Multiple other areas of the Packaging System and Design program will also benefit directly from this latest acquisition. The table is equipped with state-of-the-art technology, including functions and tools such as precise graphics registration using a laser pointer and automatic tool calibration to ensure simple, yet accurate, operating procedures.

The Esko Kongsberg X Edge digital cutter represents a significant improvement in the equipment available for our students by providing access to one of the most advanced technologies in the market. For years to come, this table can be upgraded as new tools and requirement changes support the teaching and research missions of the packaging program.

News — Dr. Laszlo Horvath Presented Research About the Effects of Pallet Top Deck Stiffnesses on the Strength of Corrugated Boxes to the IAPRI Conference

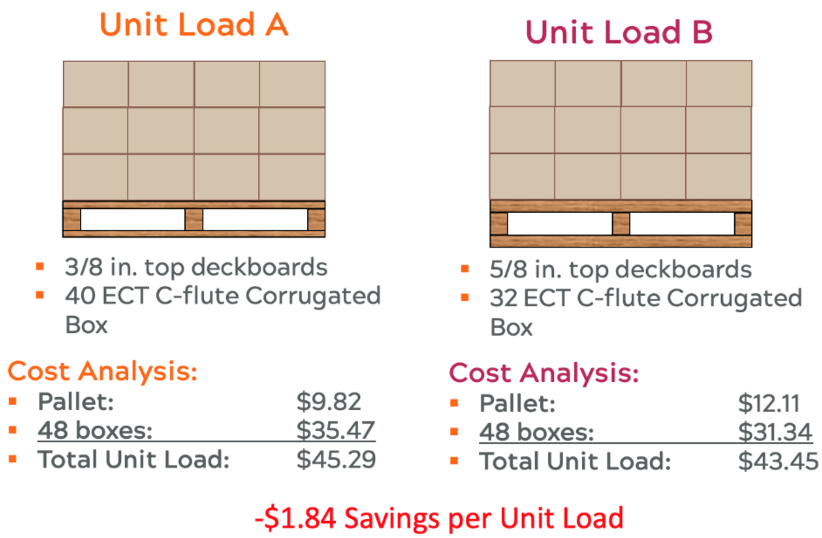

Image 1. Showing financial analysis of various unit loads.

Dr. Laszlo Horvath, director of the Center for Packaging and Unit Load Design (CPULD) at Virginia Tech, was recently asked to present the findings of his graduate student Chandler Quesenberry's research project, which focused on quantifying how pallet top deck stiffness levels affect the compression strength of asymmetrically supported corrugated boxes (Image 1). The presentation was given to the IAPRI conference, which was held virtually in 2020.

A unit load is formed with a pallet as the base, supporting a group of packaged items, usually in corrugated boxes and stretch-wrapped to keep them together and in place on the pallet. When these unit loads are moved through the supply chain, the bottom boxes in the unit load experience significant compression stresses. The harshest condition for these boxes is when unit loads are stored in floor storage sometimes double, triple, or even stacked five levels high to conserve space in a warehouse. When boxes can no longer support the load, their sidewalls buckle (Image 2), which often leads to unit load instability or even product damage.

Image 2. Showing sidewall buckling of corrugated boxes on a less stiff pallet.

Corrugated boxes are designed to survive the known hazards of physical distribution. During design, their strength is often determined using physical tests or using the McKee equation (an industry accepted formula). Then the strength of the box is adjusted using factors designed to consider the effect of environmental conditions such as relative humidity, storage time, and various pallet-related factors (e.g., the effect of deckboard gaps, interlocking, overhang, and unsupported box corners).

However, the effect of pallet top deck stiffness is not currently considered. This means that, during box design, we assume that the boxes will act the same whether they are placed on a single use pallet with thin, low-stiffness deckboards or a pool pallet with a really stiff top deckboard. Quesenberry's research project looked into this by studying four different levels of top deckboard stiffness on a 48 in. x 40 in., 2-way, non-reversible, flush GMA-style wood pallet (Image 3).

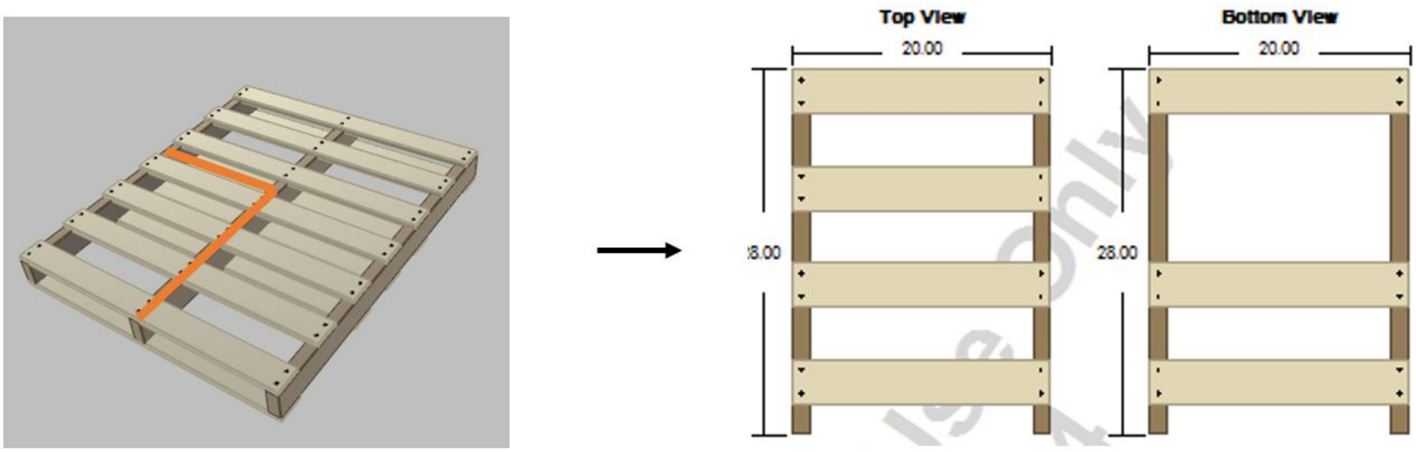

Image 3. 48 in. x 40 in., 2-way, non-reversible, flush GMA-style wood pallet.

The results of the study showed that when the pallet top deck stiffness increased from low to high, the strength of the corrugated boxes increased by as much a 37%. The results were consistent for all investigated scenarios (Image 4). The increase in compression strength as a function of pallet stiffness was gradual; however, the change between the boxes on medium and medium-high pallets was not statistically significant using 95% confidence interval. The change between the other scenarios was significant, as indicated by the different letters on the top of the bar charts.

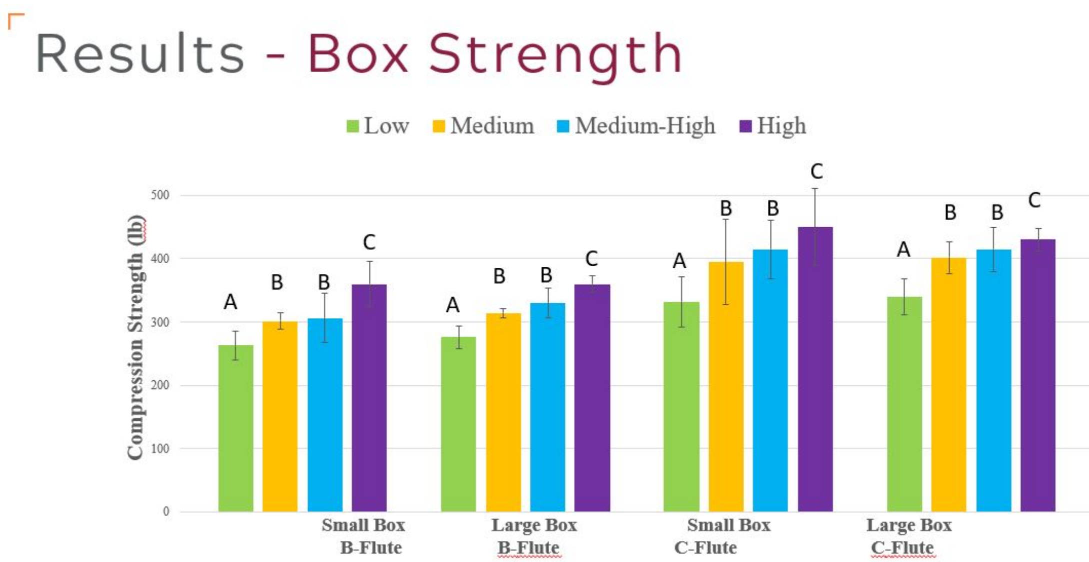

Image 4. Box compression strength as a function of box design and pallet stiffness.

This study also investigated the bending of the deckboards throughout the tests. The researchers wanted to see whether there were any observable differences in pallet top deck deflection at the investigated test load levels. It was found that the deflection of the lower stiffness deckboards was almost twice as much as the deflection of the high stiffness deckboard. This indicates that the support under the boxes was different, and, for the lower stiffness deckboards, it was more uneven. The pressure distribution was also investigated and found that for the lower stiffness deckboards, the pressure redistributes and creates a significant pressure concentration on one side of the box. This same behavior was observed for all investigated box sizes and materials. This phenomenon could explain the reduction of the box compression strength.

So, a certain box compression strength can be attained by re-designing the unit load in multiple ways. Conventionally, this is done by adjusting the boxes' board grade and flute type. But, using this systems-based design methodology, the boxes' compression strength can be changed by utilizing the pallet top deck stiffness effect on box performance — it is possible to deliver similar changes to the boxes' compression strength without changing the boxes' cost. Utilizing the effects of pallet top deck stiffness on box compression performance found by this research project, a unit load cost analysis was finally conducted showing that a stiffer pallet can be used to carry boxes with less board material; hence, it can reduce the total unit load packaging cost (Image 5).

Box Specification	Pallet Top Deck	Average Corrugated Box Cost (48 Boxes)	Average Pallet Cost (1 pallet)	Unit Load Cost	Savings per unit load	Savings per million unit loads
40 ECT C-flute	0.375 in.	$35.47	$9.82	$45.29	-	-
32 ECT C-flute	0.625 in.	$31.34	$12.11	$43.45	-$1.84	$1,840,000
32 ECT C-flute	0.750 in.	$31.34	$13.04	$44.38	-$0.91	$910,000
40 ECT B-flute	0.375 in.	$34.22	$9.82	$44.04	-	-
32 ECT B-flute	0.750 in.	$30.72	$13.04	$43.76	-$0.28	$280,000

Image 5. Financial analysis showing unit load savings based on thicker top deckboard instead of higher grade corrugated board.

Three box suppliers and three pallet suppliers were surveyed to determine the total costs of hypothetical unit loads. The reasoning behind a cost analysis was to investigate potential per unit load cost savings from altering pallet top deck stiffness instead of adjusting boxes' board grade or flute type to obtain a better compression strength performance. According to this study, the overall cost of the unit loads with stiffer deckboards is less than the cost of unit loads using higher grade corrugated board to obtain the desired compression strength. Changing the pallet cost instead of the box cost will result in a $1.84 savings per unit load, which could add up to $1,840,000 in savings per year for companies with at least a million palletized unit loads in their supply chain (Image 5).

Additionally, the average pallet price reported was the initial purchase price of the pallet, but that initial price doesn't account for the lifespan of the pallet. If a company has control over its supply chain and reuses pallets for additional future unit loads, the initial price accounted for decreases by the number of life cycles of the pallet. A stiffer pallet, utilizing thicker deckboards, is more durable during handling compared to the same design with thinner deckboards, which results in more life cycles. Companies that recycle rather than reuse their pallets still experience cost savings by using stiffer pallets because they will have less deckboard damages that would result in a higher recycling price. Using more durable pallets also creates the added benefit of reducing the chance that the pallet gets broken during shipping and handling, which reduces downtime and the chance for product damage.

Overall, the study revealed that box designers should be aware of the variability of pallet top deck stiffnesses and how it can impact the compression performance of boxes shipped on pallets. Designers should use pallet top deck stiffnesses to their advantage as an option for cost cutting or redesigning unit loads to achieve better performance. The pallet top deck stiffness should be included as an adjustment factor for current pallet and box design methodologies, similar to other box-pallet factors such as pallet gaps, overhang, pallet pattern, and stacking alignment. This research showed that pallet top deck stiffnesses can be used to save a company money during its distribution processes if this knowledge is taken into account during the design process.

News — New Sample Cutter for the Corrugated Packaging Materials Lab

Image 1. Corrugated Packaging Materials Lab worker, undergrad student Julia Barbosa, demonstrates the new sample cutter.

CPULD's Corrugated Packaging Materials Lab purchased a new piece of equipment this summer! It is an L&W Billerud-type pneumatic cutter used for making straight and parallel-sided samples specifically for the Edge Crush Tests (ECT) conducted in the lab. This cutter can make 25 mm samples for the ISO 3037 test, ensuring perfect parallel cuts to have straight edges (within 0.1 mm).

The high level of accuracy provided by this cutter is vital to ensure proper material evaluation. Edge Crush Tests measure the ability of corrugated boards to resist crushing when loaded perpendicularly to the flute structure. Putting corrugated materials through this crush resistance testing helps CPULD instruct its clients on how to better design the board itself and packaging in general. This way, when their packaging experiences edge crush forces, it has the greatest strength possible to resist any damages.

The Corrugated Lab has been conducting ECT tests since its inception, but this equipment will allow for faster turnaround times. The accuracy that was previously ensured by technicians' careful preparations can now be done quickly by this equipment. A raw sample is placed against the backstop and the handle is pushed. The pneumatically driven cutter head, with its two knives, cuts the samples along the top and bottom edges in two parallel straight lines. The two knives are fully guided to ensure an accurate cutting result. Sharp knives are of great importance to the end result; therefore, the cutter comes with a built-in counter. This counter helps monitor knife-wear as it's known how many samples can be cut before the blades dull.

This equipment joins a series of specialized cutters that CPULD's Corrugated Packaging Materials Lab has available for testing samples preparation.

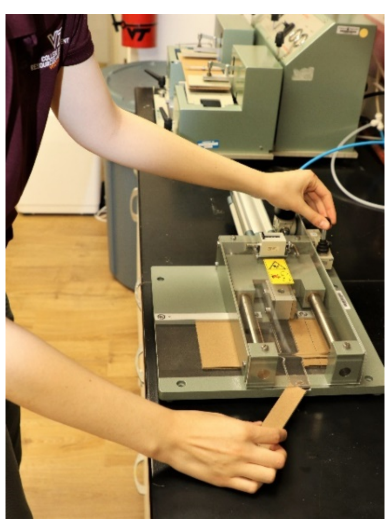

Image 2. (left) Inserting corrugated board to be cut into ECT test samples by the pneumatically driven knives in the new sample cutter.

Image 3. (right) Showing the smaller, highly precise, rectangular samples needed for ECT testing.

Center for Packaging and Unit Load Design

2020

Interns & Graduate Students

Victoria Dashevsky

Graduation: Spring, 2021

E-Mail: vicky98@vt.edu

Skills: ArtiosCAD, illustrator, Microsoft office, forklift driving, hand tools and light machinery, Russian

Geographical Restrictions: None

LinkedIn Profile

Benjamin McMurray

Graduation: Spring, 2021

E-Mail: benm98@vt.edu

Skills: ArtiosCAD, Adobe Illustrator, Forklift operation, Microsoft applications, Experience with hand tools and light machinery

Geographical Restrictions: None

LinkedIn Profile

Carter Engvall

Graduation:

E-Mail: carter3@vt.edu

Skills:

Geographical Restrictions:

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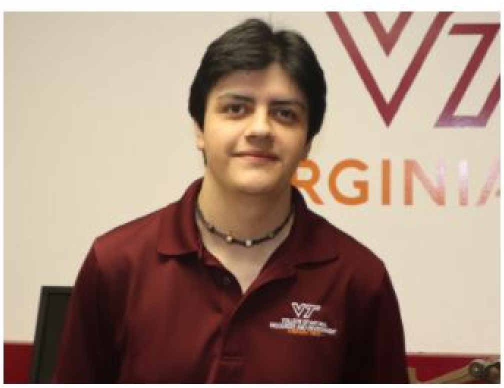


Jorge Masis Ulloa

M.S. Student

jorgamu13@vt.edu

Find Jorge on LinkedIn

Learn about all of CPULD's internships on the
Distribution Packaging Internship Program webpage!

Learn more about CPULD's graduate students on the
Current Graduate Research webpage!

News — COVID-19 Impact on CPULD

As felt everywhere, we have also been greatly impacted by COVID-19 here at CPULD. We are currently back to operating at full capacity but with new safety rules and operating procedures in place for the protection of our workers and the products coming through our testing labs.

Back on March 9, 2020, Virginia Tech stopped all in-person instruction and moved everything possible to remote operations. CPULD was able to receive "essential" status, which allowed us to run reduced operations, but it was a difficult transition as most of our lab technicians were (and are) students who were no longer on campus, or even in Blacksburg. At the end of May, we were given permission to restart research operations; by July 1, we'd brought back our student workers under new health and safety protocols.

Our new procedures include extensive deep-cleaning of the lab regularly, additional PPE being worn by everyone in the lab, social distancing practiced by lab managers and workers, and new signage instructing everyone on the COVID-19 procedures, as well as lots of additional training on these new procedures and restrictions on out-of-state travel for any lab workers.

Unfortunately, another side effect of COVID-19 is that we can no longer allow outside visitors in our labs. However, we have made up for this latest restriction by offering online video chats for clients who wish to be part of the testing of their products. These sessions are conducted through Zoom using Apple iPads, which can be carried around the lab to help include the client in all processes that are taking place.

We are pleased that we have been able to work within the new parameters to continue to provide our clients with any and all of the tests that we have always offered. You can be assured that, if you send your packages/products/unit loads/pallets to CPULD, they will be tested in the safest, most sanitary way possible by workers who are practicing all suggested health-conscious procedures. We look forward to continuing to offer our clients the great service they expect when using CPULD labs for their testing needs!

SBIO Department Interview Series
One of Us: The Person Behind the Professional
Dr. Laszlo Horvath

Laszlo joined our department in November 2010 as an Assistant Professor of Practice. He is currently an Associate Professor and is the Director of the Center for Packaging and Unit Load Design (CPULD). Laszlo earned his Bachelor's degree in Wood Products and his M.S. degree in Wood Engineering, specializing in wood building construction, from the University of West Hungary.

Laszlo's interest in the industry began because his father owned a custom kitchen manufacturing company. Due to this, he was exposed to the business at an early age by working first as a carpenter and then as a floor supervisor in his father's company. While in college, Laszlo realized that an engineer does not only need to have great technical skills but also needs to know about the business side of a company, thus, he double majored in Wood Engineering and Engineering Management.

After graduating from the University of West Hungary, Laszlo had the opportunity to pursue his Ph.D. at North Carolina State University. There his research focused on predicting the micromechanical properties of genetically engineered trees. This was a topic of great interest because, during his Master's studies, Laszlo had been exposed to the mechanics of full structures, so he found investigating these same mechanics on a micro scale very intriguing.

Because he was interested in the versatility of wood and how it could be used for construction, he started out his career with a focus on wood engineering. Laszlo told us that "when I applied to Virginia Tech, I was excited to use my engineering knowledge to help the packaging and pallet industry to be more competitive. First, I considered pallets to be a really simple structure and I could not figure out why we are making a big deal about it. It did not take me long to realize how challenging simple structures such as pallets or boxes could be."

Laszlo loves being a professor because of the mix of responsibilities. As the Director of CPULD, he gets to work with the industry to provide rapid solutions for their most pressing needs. As a researcher, he gets to work on complex problems for which no one yet has solutions. And, finally, as a teacher, he gets the opportunity to share his knowledge with packaging students and give them the tools they'll need to be successful once they graduate.

Laszlo's favorite thing about Virginia Tech is the community because he has an opportunity to work with amazing people every day. One of his favorite classes to teach is SBIO 3005-3006 Sustainable Packaging Design and Innovation. In this class, he stated that he "has a chance to work with super talented students on real life industrial projects and to see them continuously develop work ethics and professional skills throughout the process."

One of the most rewarding research projects that Laszlo has been involved in is the "Investigation of the effects of packages on the load capacity of wooden pallets." He feels this is a great project because it has the potential to transform the wood pallet industry by changing the way pallets are designed. Laszlo informed us that "currently, we are overdesigning every pallet, which wastes our natural resources and increases the cost of the pallets."

Because the interactions between packages and pallets is such a complex phenomenon, this project is a multi-year endeavor. "Thus," Laszlo explained, "we took a step by step approach. First phase of the project focused on the interaction between pallets and corrugated boxes because 85% of the products travel in corrugated boxes. We worked collaboratively with the National Wooden Pallet and Container Association throughout the project, which resulted in the findings of the study being built into the computer software called The Pallet Design Systems (PDS) that is used by pallet designers all over the world. One of the best parts of the research is to see the knowledge that the project generated being used by the industry pretty much right after we finished the work. Presently, pallet designers can optimize their pallet designs using the new version of the software and can ensure that they only use the optimal amount of natural resources for their pallet."

Laszlo is originally from a small town in Hungary called Kiskoros, and he enjoys visiting family and friends in Hungary when he can. Laszlo and his wife have a 1-year-old son who currently occupies all of their free time. Laszlo enjoys the outdoors and traveling. He feels very fortunate to have traveled to many different places of the world, but he is also happy to spend time with his family and work around the house.

One of the things his wife finds hilarious about Laszlo is that yoga stresses him out. If you have been around him for very long you probably know Laszlo is a highly energetic person and is always thinking about the next project or research grant. Therefore, when he tries to do yoga, he ends up spending the time thinking about the work he needs to complete and receives no relaxation from yoga whatsoever.

Laszlo is so passionate about the packaging industry that if he were not a professor, he believes he would probably be in a leadership position in the packaging industry. That way, he would still be using his skills to make a difference in the world and helping the environment.

Quote from a former student:

"Dr. Horvath, with the Department of Sustainable Biomaterials at Virginia Tech has created an exceptional packaging program that allowed me to develop my curriculum around the topics I was most passionate about. The program also allowed me to work on industry projects; which granted me the opportunity to economically support myself through grad school, accumulate work experience, and network.

I am a very proud Hokie, who had the great opportunity to be mentored by Dr. Laszlo Horvath. He is a bright man, who strives to and creates positive changes in everything he develops. Working with him, I learned to always seek improvement and never give up. Dr. Horvath is a practical professor, who allows his students to experiment and create their own solutions while using sustainability science.

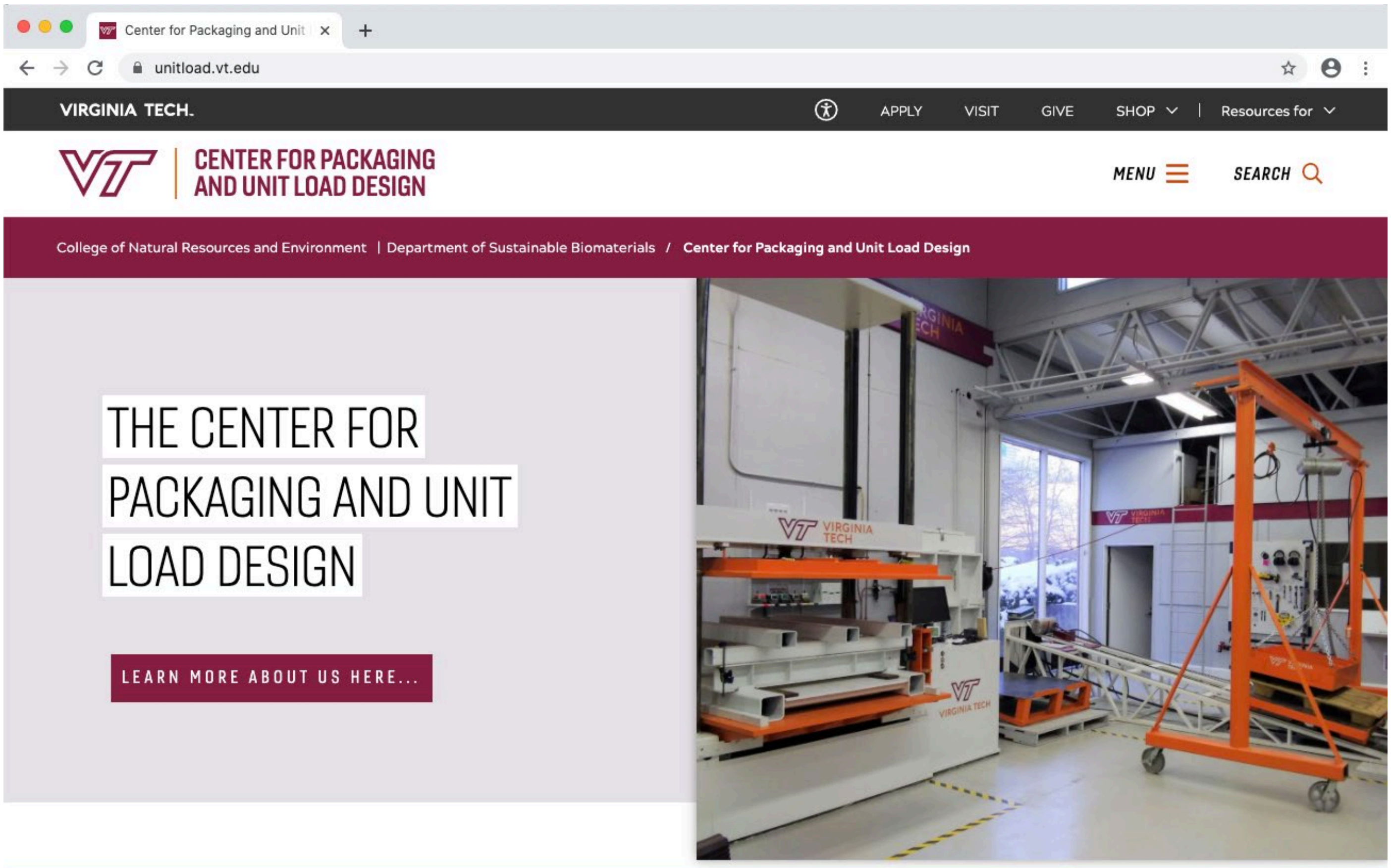
I am confident when I say that Dr. Horvath is one of those professors/mentors who motivates you to succeed!"

Alina Mejias Rojas

Laszlo has won numerous awards. They include:

- Laszlo has received the highest “Professional” level of the ISTA Certified Packaging Laboratory Professional certification. Thus far, only 28 “packaging engineers received the “Professional” level in the world.
- Best Scientific Presentation from the International Association of Packaging Research Institutes, June 2017
- Certificate of Excellence, XCaliber Award – for an Individual Making Exemplary Contribution to Technology-Enriched Learning Activities. 2013
- George Marra Award in recognition of excellent writing and research from the Society of Wood Science and Technology, June 2013
- North Carolina State University Provost Fellowship (2007)
- Outstanding Graduate Student Award, Faculty of Wood Science, University of West Hungary (2007)
- Hungarian National Academic Scholarship Award, (2006 and 2007)
- Scientific Student Research Competition, 1st Place (2005)

News — New Website Roll-Out; Membership Area Coming



Over this summer, we released our new CPULD website! The site is in line with current Virginia Tech branding (colors and fonts) and follows the same format you're used to seeing on many Virginia Tech affiliated websites. You've probably already noticed the new look and feel, but we'd like to point out a few of the new features of this upgrade.

Our testing laboratories and capabilities often take precedent for our industry members. As before, each lab has its own area on the website, and all tests conducted therein are explained in detail along with a listing each of the labs' pieces of equipment linked to the tests they help us conduct. In addition to our main labs (Distribution Packaging Lab, Corrugated Packaging Materials Lab, and the Sustainable Packaging Materials Lab), we now also have separate pages for our IKEA testing and our Amazon testing, as well as our Fastener Testing Lab.

CPULD research into pallets, unit loads, corrugated board, and primary packaging materials is in-depth and ongoing. Our current graduate students are all listed on the Graduate Research page and their research projects are detailed. We also list the recent Undergraduate Research projects that have been conducted. Whether you're interested in learning about new technologies available for supply chains or how a pallet handles carrying drums and pails, you can read about the projects in process on these pages. Easily linked from both are pages detailing how you can become involved in graduate and undergraduate research projects here at CPULD.

We offer many different options for industry members who would like to sponsor, become involved in, and/or benefit from the research being done in our labs. The main way to connect with us is through our Industrial Affiliate Membership Program. There are three different levels of membership, each with its own list of benefits, outlined on the membership webpage. Any level is an opportunity for leading pallet and packaging companies to work with researchers at Virginia Tech to advance the field of pallet and distribution packaging through systems-based unit load design, find talented employees, and network with world-leading researchers and industry professionals.

The new website also has an extensive About Us section, including links to CPULD's social media, newsletters, articles of interest, and a new Meet Our Team page. Contacting CPULD is easier than ever with a new form on the Contact Us page that delivers your message directly to a CPULD team member who can best answer your questions.

Coming soon is a dedicated Members Only area of the website, which will be accessible only to companies who are members of CPULD's Industrial Affiliate Membership program. Members will be able to access new research prior to the general public, learn about upcoming member-only webinars and events, and have access to our Searchable Library of Info and Center Knowledge (SLICK). SLICK is our database of thousands of research articles that are not available to the general public and which have proven to be very helpful to our industry partners.

Please explore the new website and let us know if you have any questions!

Summer 2020

~ Continuing Education Opportunities ~

2020 Webinars

CPULD is pleased with the response to our new webinar series. 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 April 2020, CPULD partnered with NWPCA to offer a series of 3 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. This series of 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 future webinars are announced.

Wood Pallet Design and Performance Short Course, Fall 2020

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, Spring 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/

COLLEGE OF NATURAL RESOURCES AND ENVIRONMENT
SUSTAINABLE BIOMATERIALS
VIRGINIA TECH.

Summer 2020

Center for Packaging and Unit Load Design
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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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