An Alternative to Stretch Wrap Using Triple Bottom Line

by

Christian Guirola

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California Polytechnic State University, San Luis Obispo

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Executive Summary

Packaging products has always been a major sector of industries. Mass producing manufacturing companies use wooden pallets to store and transport items; these products are stacked and then secured by wrapping stretch wrap around them. The main issue with this packaging method is that millions of pounds of waste is produced. Some of the other effects include green house gas emissions during its production, limited recycling, and high packaging costs. In order to reduce the amounts of stretch wrap used by industries and distribution centers, there was a need to research and evaluate alternate methods to secure products on pallets. This study was completed using a Triple Bottom Line approach to acquire the most sustainable method to package pallets evaluating the social, environmental, and economical effects of each. Four other alternate methods were compared to stretch wrap: tie down straps, adhesive, cargo nets, and pallet covers.

After having conducted the analysis, the recommended method to secure pallets was using the adhesive material with the pallet covers. Now instead of having to use 38 barrels of oil to produce stretch wrap to secure 22,000 pallets, only 1.38 barrels would be needed. A considerable amount of petroleum is saved. As far as costs, this proposed method has a total daily cost of $17.32 instead of $71.03 spent with stretch wrap.

It is possible to conclude that this new alternative is a more sustainable method to secure items on wooden pallets. This could be a feasible solution that warehouses and distribution centers could use.

Introduction

During ancient times, humans packaged their things using the natural resources that were available. These began with baskets made of reeds, animal organs, and hollowed logs. With the discovery of different chemicals and ores, various other types of packaging materials were developed such as ceramics, paper, glass, and metal. There are various reasons for packaging, such as: easing storage and transportation of products, maintaining products together, and preventing products from becoming damaged.

The newest packaging material that emerged was plastic. With its discovery during the 19th century, it soon replaced many materials used before. One of the types of plastic developed was plastic film wrap made out of low density polyethylene (LDPE). This material was discovered by accident in 1933 by Reginald Gibson and Eric Fawcett in Northwich, England. It was mainly used in the military during World War II as a protective covering for radar and submarine telephone cables, and to package medication tablets. It was not until the late 1950's that this plastic film first began to be commercially used for packaging. Currently, stretch wrapping is one of the more popular methods warehouses/distribution centers (W/DC's) use to secure their products on pallets for storage and transportation. With its elastic capabilities, it is able to secure products. Currently plastic film continues to be made out of LDPE, which is a thermoplastic made from petroleum.

By packaging pallets with stretch wrap, there are various options warehouses/distribution centers may consider. As far as machines, they are either semi-automatic, simple automatic, or fully automatic. All these are based on a low, medium, or high quantity of units to be packaged respectively. A noticeable difference between

semi-automatic and an automatic system is that the semi automatics require more operator attention and have lower output speeds.

Stretch wrapping today is one of the most widely used methods of packaging. According to The Freedonia Group, the demand for this plastic film is expected to reach 15.2 billion pounds in 2010 with a value of $12 billion. LDPE will account for 64% of the total in 2010 and will continue to be the leading film produced. This demonstrates that warehouses/distribution centers plan on continuing their high use of stretch wrap for packaging purposes. It results in having to spend large amounts of capital to acquire rolls of plastic, costs of running and maintaining the wrapping machine, and the costs of getting rid of waste.

Stretch wrap can be considered one of the largest sources of waste in warehouses and distribution centers. These places either recycle this material or pay to have it transported away to dispose with the rest of the waste. Each year, thousands of pounds of film are generated which translates to large sums of money spent to get rid of the waste. The issue with plastic waste is that it is very durable and takes hundreds years to degrade this non-biodegradable material. Various companies aware of environmental issues are recycling used stretch wrap. These include Costco, Pepsi Co., Anheuser-Busch, etc. Depending on their location, there are various programs that recycle their used wrap. The process of making polyethylene releases carcinogenic fumes into the atmosphere that can be extremely toxic.

It's clear that these great amounts of stretch wrap are causing economical, social, and environmental issues. Companies that have warehouses and distribution centers could save money by using other alternate methods for packaging pallets, and at the same time practicing sustainability. Since environmentally friendly manufacturing is a major

issue today, it is important to consider the quantities of stretch film used. In order to achieve the goal of reducing the amount of stretch wrap used, the ideal approach would involve a Triple Bottom Line analysis of the current use and then of other working methods. First, it would entail analyzing alternate cost-effective methods of pallet packaging. This would include studying various existing techniques used, and coming up with new ones as well. Then, it would be necessary to examine the environmental and social impacts from all of these. Finally, the most sustainable (economical, environmental, and social) pallet securing method should be proposed.

Literature Review

Stretch Wrap

Stretch wrap is a widely used method to package products by various industries. There are hundreds of stretch wrap and stretch wrapping product manufacturers, but one very distinguished producer is Orion Packaging Systems, LLC. For 20 years, they have been a top manufacturer of heavy duty industrial wrapping technology. They have provided their machines to a large number of well known companies. Some of these include: Best Buy, FedEx, Frito Lay, Wal-Mart, Shell, Sarah Lee, and Kellogg's. (Orion). These are high volume producing industries that practice this packaging technique. Kellogg's, for example, stated in 2000 that they were generating between 10,000 and 17,000 lbs of stretch wrap waste in their facility in Williamsport, PA. (Lycoming County Stretch-Wrap Plastic Recycling Report).

Currently, the major use of this packaging technique is to pack products together on pallets in order to distribute. The plastic film is stretched as it is wound up around the

products in a circular motion. The amount of wrap used is usually at the operator's discretion and he decides when enough has been applied (Abdel-Bary). An operator can either manually wrap the load or use a machine; it all depends on the quantity of pallets that must be packaged per day (Dieltz). The manual approach has its benefits. It is inexpensive for low volume applications, it can be performed throughout the facility, and does not entail a high capital investment on equipment. The issues with this method includes: limited production speed, operator fatigue resulting in potential injury, and poor looking packaging. The other technique uses a machine to wrap the loads. This allows all loads to be consistently packaged, uses less amounts due to film stretch and application, and pre-stretch capability reinforces the film. Subsequently, this requires periodic maintenance on the machines and capital investments in stretch wrap equipment (General Purpose and High Performance Stretch Film Products).

Another factor that is also taken into consideration is the type of plastic; this entails the production process that was used to manufacture. The most common types used are blown or casted film. Blown film has a greater puncture and tear resistance, but requires more force to stretch. Cast processed film is easier to stretch, but may easily tear (Hanlon).

There are three distinct configurations that pallets have been divided into depending on the size and shape of the loads. The stacking pattern dictates the quality of the stretch wrap that needs to be used. If there are irregular sides and/or corners as seen on Figure 1 on B or C profiles, there is a higher chance that the film may get punctured. In such a situation, a higher quality of film must be used to avoid poor packaging (Young).

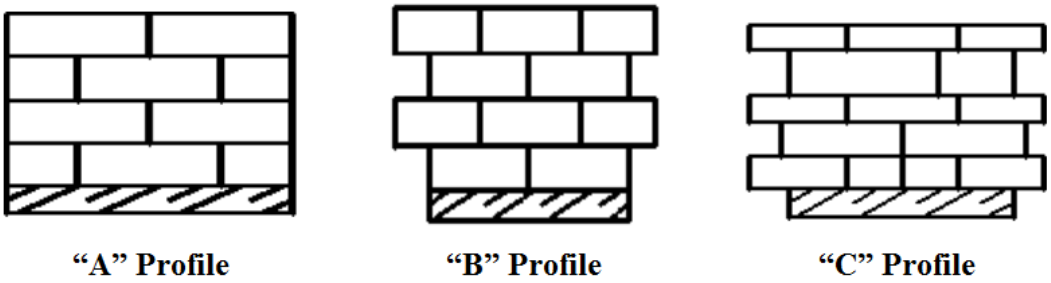


Figure 1 Source: Bozer

Pallet Covers

This new packaging technology is made of light, but extremely durable polypropylene (PP) or polyethylene (PE) material. Both of these have a good damage resistance to ultra violate (UV) rays (Massey). It works like a large plastic cover strapped with strong plastic buckles. With this packaging method, the tension that is created aids to protect and stabilize the load. Due to its reusable nature, it Reduces stretch wrap costs, damage claims, waste expenses, plastic stretch wrap by 80-90%, and other shipping wastes. The covers also have the benefit of being easy to handle for operators. It provides personnel with a consistent and uncomplicated method to secure loads (Amici Products)

Adhesive

In order to replace the use of stretch wrap, alternate methods have been created to package pallets. One of these innovations is called Lock n' Pop. This packaging technology "is a water-based, environmentally friendly palletizing adhesive that eliminates slippage between palletized layers of boxes, bags, or shrink-wrapped trays" (Lock n' Pop). It is considered a material stronger and less costly than stretch wrap, and

at the same time more environmentally friendly. To manufacture this adhesive, less oil is needed and carbon dioxide emissions are minimal, as seen on Figure 2.

	Stretch Wrap	**Lock n' Pop**
Carbon dioxide released into atmosphere	14,030 lbs.	40 lbs.
Solid waste	176 ft^2	1 ft^2
Barrels of oil required	28.6	1.2

Figure 2 **Note: Per 10,000 pallets unitized**

The equipment needed for this packaging technique only includes the easy to use adhesive applicator. They are compact, low costing, and almost maintenance free; there are three different designs available depending on what they would be used for (Lock n' Pop).

Cargo Nets

Major occupiers of cargo nets have always included cargo transporters travelling through air and sea. For the amount of motion these vehicles endure, this restraining method works particularly well. This approach would also work for securing products on wooden pallets. These are made of high tenacity polypropylene (HTPP) with a wide range of chord diameters and mesh sizes. They may be re-used many times with no need of disposing (Singh). In order to apply them, an operator slips the rectangular box shaped net over the items being secured. At the bottom, the net is looped around small metal hooks located on each side.

Tie-Down Straps

Tie-down straps is another possible method of securing products to pallets. They are made out of a synthetic fabric known as nylon, and are equipped with a metallic fastener that holds the load in place. These can be easily applied and re-adjusted if necessary without having to replace like stretch wrap; they can also be re-used thousands of times. Since there is such a broad range of strap sizes (width/length), they can be used to hold different sized loads with a holding power of up to 2,500 pounds (Forcinio, Hallie).

Plastic Waste Recycling

Over the years, the use of polymers (plastics and rubbers) has been steadily increasing and at the same time it has resulted as a large source of industrial waste. Due to escalating environmental pressures, the need to recycle plastics has become a key issue for industries that work with these materials. In 2003, the United States had a total waste of 5 million tons of low density polyethylene (Abdel-Bary).

Approach to Stretch Wrap Recycling

Recycling stretch wrap falls into the category of tertiary recycling, which includes chemical recycling. Tertiary packaging is used for bulk handling, warehouse storage and transport shipping. The steps involved for starting a recovery/recycling program include finding potential markets, designing a collection and handling system, educating program participants, and implementing a quality control program (American Plastics Council).

Markets

The first step in developing a stretch wrap recycling program consists of identifying possible recycling markets. In this case, a "market" is considered as businesses that handle and process plastics back into the form that producers of recycled plastic products use. These could be haulers, handlers, re-claimers, and end product manufacturers. These will dictate the prices paid and specifications for the recovered film. It is important to consider the location of the future partner. By having a near market, transportation costs can be minimized and it would also facilitate visits between the warehouse/distribution center and the market. Firms that acquire stretch wrap tend to visit their customers to make sure that quality control systems are acceptable (American Plastics Council).

Collection/Handling System

The first section of the collection system entails the receiving personnel which is the first opportunity to collect stretch wrap. At this point, it should be removed from the pallets and placed immediately in the correct recycling container, since this material can quickly attract dirt, dust, and other contaminants such as paper labels. Some facilities label arriving pallets as an aid for storage and tracking. To avoid having to remove all of the labels later, they should be placed on one of the boxes under the plastic film (Harper). Another option would be to use labels made out of polyethylene (PE) or polypropylene (PP) which can be placed directly on the plastic. Another area that handles stretch wrap is shipping; this is where employees assemble pallet loads. This process might take place throughout many areas at warehouses/distribution centers, therefore, proper stretch wrap bins should be strategically placed (American Plastics Council).

The next step for preparing stretch wrap in the collection period is baling. This allows to lower costs of storage and transportation. Fortunately, most warehouses/distribution centers have balers for corrugated cardboard; these can be easily modified for baling the plastic film. There are also balers specially made for stretch wrap which provide with more compacted bales.

Storage Required for Baling Stretch Wrap

Storage of loose material before baling:
• Loose stretch wrap is collected in gaylord containers (42" cube).
• A gaylord container typically holds 50 lbs of loose stretch wrap. Approximately 20 containers are required per bale of stretch wrap.
• Each container requires 12.25 sq ft of floor space; 20 containers require 245 sq ft.

Storage of baled stretch wrap:
• Typical bale weight is 900 – 1,200 lbs; typical bale dimensions are 3' x 4' x 6'.
• There are 38 – 42 bales per trailer truck.
• Space required to store one truckload of bales, assuming bales are stacked two high, is 240 sq ft.

Source: Arkansas Department of Environmental Quality

Employee Education

The key to a successful recycling program is proper employee training and motivation. To do so, it is important to let them know the importance of their actions in order to achieve the company's environmental goals. They must be provided with proper instruction on how the recycling system works and what is expected from them (Twede).

Quality Control

Delivering clean stretch wrap to recycling centers yields higher prices for that material. In order to achieve these conditions, quality control is essential. Recycling sites may be seen as the final places for quality control. Film that is extremely contaminated and cannot be easily cleaned should not be sent. An effective method for quality control is to have the person baling inspect the film as it gets baled. Any debris (tape, strapping, labels, etc.) should be removed beforehand. Finally, all bales should be stored indoors on pallets or concrete pads to keep them from getting dirty or wet (American Plastics Council).

Overall, stretch wrap recycling is a benefit to companies and the environment. It allows companies to save energy, decrease disposal costs, preserve resources, and generate revenue. At the same time, sources of landfill waste are being reduced and natural resources are preserved.

Costs of Recycling

Worksheet: Estimating Handling and Processing Costs		
Example assumes recovery of 200,000 lbs. of stretch wrap per year.	**Per Pound**	**Annual**
Revenues	$.035	$7,000
Recovery Costs		
Employee training	$.005	$1,000
Special containers	$.004	$750
Baling labor and wire/strapping	$.008	$1,500
Labor costs*	$.010	$2,000
Subtotal	$.026	$5,250
Net Revenue	$.009	$1,750
(Revenue – Recovery Costs)		
Avoided Disposal Savings		
Hauling costs:		
40-cu-yd compactor container		
$100/pull – 33 pulls per year		
(1 cu yd compacted film + 150 lbs.)	$.017	$3,300
Tipping fee $30/ton	$.015	$3,000
Subtotal	$.032	$6,300
Net Benefit	$.040	$8,050
* Extra handling plus transportation from receiving dock to baler.		
Will vary depending on the program.		

Source: Arkansas Department of Environmental Quality

Design

Triple Bottom Line Approach

Throughout the last several decades, society has begun to realize the impacts and issues of the earth's environmental changes. These areas have included green house gas emissions, weather and climate, the oceans, snow and ice, and societies and ecosystems. There is undisputable evidence that human daily activities, such as use of transportation or generating energy have been exponentially contributing to these mutations. One major sector of society that needs to significantly change its practices is the manufacturing industry. Currently, such a solution exists. Triple bottom line is a reporting framework that currently exists to improve all impacts businesses have.

Triple bottom line serves as a guide and a set of principles to help any type of business practice sustainable growth. It is the development that meets the needs of the present without jeopardizing the ability of future generations to meet their own needs (Munier). This entails taking into account the impact that a business has in terms of environmental and social standards while obtaining a financial return. This model was taken into account when evaluating the impacts stretch wrap and other alternative packaging methods had.

People

This sector involves primarily social responsibility. It means to develop human potential within the organization, and as well as the community and region. This includes safe labor practices, respect for others, promoting happiness, and positive returns to the community.

Plastic production has health and socially related consequences. It is made out of natural resources that are toxic, it creates waste, its production consumes large amounts of water, etc. Actually, stretch wrapping pallets is a process that requires human labor; whether it is monitoring a machine or physically applying the plastic. Hand wrapping pallets can be a very strenuous task, while machine wrapping requires training and understanding of the process.

After having researched alternate pallet securing methods, their social impacts needed to be analyzed. In order to evaluate the numerous social aspects, Figure 3 shows the evaluation chart was created. The different attributes that were evaluated where the most relevant for the effects that each of the pallet securing methods had; for example, the values for off gassing were obtained by researching the amount of fumes that the material used gives off when produced. Human toxicity took into consideration how toxic the material used in each packaging alternative is. The ease of use attribute measured how long (minutes) it would take an operator to fully secure a pallet with each of the alternatives. Finally, health impacts measured the human factors behind each method. This chart used a scoring system that proposed the best alternate method while assigning each attribute a certain weight.

		Stretch Wrap					
Social	**Weight**	**Hand Applied**	**Machine Applied**	**Tie Down Straps**	**Adhesive**	**Cargo Nets**	**Pallet Covers**
Human Toxicity							
Off Gassing (kg of gas)							
Ease of Use (min)							
Health Impacts							
Score							

Figure 3

Environment

This division concentrates on how the earth's environment is affected. It is the attempt to cure, preserve, and enhance the living systems that the world depends on. To accomplish that goal, it is necessary to carefully manage energy, non-renewable materials, reducing the amount of waste produced, and disposing it properly.

The use of stretch wrap in warehouses and distribution centers definitely has negative consequences on the planet. First of all, this material is primarily made from petroleum, a non-renewable resource that is finite. Another resource consumed in processing and applying stretch wrap to loads is energy. After having used the plastic to unitize a load, it must be discarded due to its one time use. It is either disposed as waste or recycled. In the end, this material's life cycle produces a carbon footprint on the environment.

In order to select the pallet securing method with the least impact on the environment, certain attributes were used to compare them. These were chosen because they are some of the most impacting factors that affect the environment. Using the table found on Figure 4 on the following page, the values for each were found and then analyzed for each method. Waste produced measured the amount of material that is wasted after each use. Since petroleum is one of the main raw materials used to produce plastic, the number of barrels to produce each securing method was measured. Energy to unitize loads analyzed how many joules were required to secure a pallet. The carbon footprint attribute took into account the amount of CO_2 released into the environment during the production of each material for the different methods. The amount recycled measured the realistic amount of material of each packaging method would actually be recycled. Again, the chart was also analyzed using a scoring method.

Most of these values were obtained from researching environmental websites and books with the chemical components of each material, but others were calculated with using certain formulas and educated reasoning. These calculations can be found on the Appendix A-2.

Environment		Stretch Wrap					
	Weight	**Hand Applied**	**Machine Applied**	**Tie Down Straps**	**Adhesive**	**Cargo Nets**	**Pallet Covers**
Waste Produced (lbs.)							
Natural Resources Used (barrels of oil)							
Energy Required to Unitize Loads (Mega Joules)							
Carbon Footprint (kg CO_2)							
Amount Recycled (lbs.)							
Score							

Figure 4

Assumptions made:

- 22,000 pallets
- Pallet size: 48" x 40" x 64" (L x W x H)

Economy

This is the sector of the triple bottom line system that concentrates on a business' profitability. This entails how money is handled to gain profit and economic growth. For the business, it involves efficient and responsible spending in order to increase savings. At the community level, the business may have direct and indirect impacts through suppliers, consumers, investments, outsourcing, etc.

The use of stretch wrap to secure pallets is considered a packaging cost to a business. With stretch wrap's one time use per pallet, new material needs to be constantly

purchased to have in stock. In order to analyze which pallet securing method was the most economical, different factors were considered. These values were obtained as sales prices from the distributers of each different alternative. The table on Figure 5 illustrates which attributes were chosen. Item cost consisted of the actual sale price for each securing system. The next attribute consists of the number of times the equipment to hold down the load can be used. Labor time was also an important element since it illustrated how many pallets per hour can be fully packaged. For the stretch wrap sections, a cost calculator from a stretch wrap machine producer named Wulftec was used to obtain the different economical values. The other values where obtained from different company websites.

		Stretch Wrap					
Economy	Weight	Hand Applied	Machine Applied	Tie Down Straps	Adhesive	Cargo Nets	Pallet Covers
Item Cost ($/pallet)							
Number of Uses							
Labor Time (pallets/hour)							
Daily Cost ($)							
Score							

Figure 5

Assumptions made:

- Pallet size: 48" x 40" x 64" (L x W x H)
- Max load weight: 2,500 lbs.
- Stretch wrap dimensions:
  - Hand Wrap: .80 GA
    - 20" x 1500 ft.
    - Stretch ratio: 150%
  - Machine Wrap: .80 GA
    - 20" wide x 6000 ft.
    - Stretch ratio: 250%
- Hand plastic wrap cost: $14.01
- Machine plastic wrap cost: $51.89

Method

Various steps were taken in order to obtain the most sustainable method to secure pallets. First, alternate packaging techniques needed to be researched. After having obtained these, a table was needed to compare each under the triple bottom line divisions (People, Environment, Economic). Each of these had different attributes that were considered to be the most relevant to compare each alternative. Next, each table was filled with the proper values as seen on Figure 6.

Figure 6 **Note: All values are per 22,000 pallets**

	Stretch Wrap					
Economic	**Hand Applied**	**Machine Applied**	**Tie Down Straps**	**Adhesive**	**Cargo Nets**	**Pallet Covers**
Item Cost	$.47 per pallet	$.30 per pallet	$2.00 per pallet	$.18 per pallet	$84.00 per pallet	$40.00 per pallet
Number of Uses	1	1	142,720	1	214,080	285,440
Labor Time	12 pallets/hour	55 pallets/hour	20 pallets/hour	12 pallets/hour	30 pallets/hour	40 pallets/hour
Daily Cost	$71.04	$132.00	$0.002	$17.28	$0.10	$0.04
	Stretch Wrap					
Environment	**Hand Applied**	**Machine Applied**	**Tie Down Straps**	**Adhesive**	**Cargo Nets**	**Pallet Covers**
Waste Produced	975 lbs.	682 lbs.	66,000 lbs.	26.5 lbs.	88,000 lbs.	110,000 lbs.
Natural Resources Used	54 barrels of oil	38 barrels of oil	1224 barrels of oil	1.08 barrels of oil	1227 barrels of oil	674 barrels of oil
Energy Required to Unitize Loads	20,483 MJ	60,000 MJ	18,422 MJ	9,300 MJ	16,248 MJ	17,644 MJ
Carbon Footprint	5,718 kg CO_2	4,000 kg CO_2	388,008 kg CO2	500 kg CO2	388,959 kg CO2	213,658 kg CO2
Amount Recycled	48.75 lbs.	34.1 lbs.	49,500 lbs.	17.23 lbs.	66,000 lbs.	82,500 lbs.
	Stretch Wrap					
Social	**Hand Applied**	**Machine Applied**	**Tie Down Straps**	**Adhesive**	**Cargo Nets**	**Pallet Covers**
Human Toxicity	Moderate	Moderate	Moderate	Low	Moderate	Moderate
Off Gassing	Low	Low	High	N/A	Moderate	Low
Ease of Use	Difficult	Moderate	Easy	Easy	Easy	Easy
Health Impacts	Moderate	Low	Moderate	Low	Moderate	Moderate

The economics section was determined using the costs to purchase each of these items. Then the price per pallet was calculated for each of the alternate methods. The values for the environment table were obtained with the assumption that those would be the by-products of securing 22,000 pallets. For the energy required to unitize pallets, the hand applied methods are based on a human's physical energy, while the others (machine wrap and adhesive) are machine based. Due to the lack of quantitative data on the social impacts of each of the alternatives, the table's data was determined based on estimations and educated reasoning from research.

After having obtained all the figures for each pallet securing alternative under each of the various criteria, an evaluation chart was created. This approach worked by giving all of the data values a point system from 1 being the lowest, to 6 being the highest score. Next, a weight column was added with a certain weight for each of the attributes being tested. Under each weighed attribute, every alternative was given a score based on its rank. This analysis presented the most beneficial packaging alternative.

Results and Discussion

After having used the triple bottom line approach to analyze all the data for each alternative, a more favorable method to stretch wrap was obtained. The results to the analysis can be seen on the next page on Figure 7. The adhesive method was considered to be the most sustainable approach to secure pallets, which was the expected outcome to the analysis. From all the quantifiable data, the adhesive did have the most favorable values for each of the triple bottom line sections followed by the pallet covers. Based on these results, it is possible to

		Stretch Wrap					
Economic	**Weight**	**Hand Applied**	**Machine Applied**	**Tie Down Straps**	**Adhesive**	**Cargo Nets**	**Pallet Covers**
Item Cost	0.0769	4	5	3	6	1	2
Number of Uses	0.0769	1	1	2	1	3	4
Labor Time	0.0769	1	5	2	1	3	4
Daily Cost	0.0769	2	1	6	3	4	5
Environment							
Waste Produced	0.0769	4	5	3	6	2	1
Natural Resources Used	0.0769	4	5	2	6	1	3
Energy Required to Unitize Loads	0.0769	2	1	3	6	5	4
Carbon Footprint	0.0769	4	5	2	6	1	3
Amount Recycled	0.0769	3	2	4	1	5	6
Social							
Human Toxicity	0.0769	3	3	3	6	3	3
Off Gassing	0.0769	5	5	1	6	3	5
Ease of Use	0.0769	2	4	5	5	5	5
Health Impacts	0.0769	3	5	4	5	3	3
Score	100%	2.923	3.615	3.076	**4.461**	3.000	3.692

Figure 7

recommend that pallets should be secured with the adhesive and with the pallet covers for extra support. This design can be seen in the Appendix A-5. By using this alternative, warehouses and distribution centers would be able to practice sustainable packaging while efficiently securing their products. Future adjustments can be made to the results by changing the weights for all the attributes being tested. For these calculations, each attribute was given an equal percent weight, but depending on the person analyzing the chart, these values can be changed depending on how they judge importance of each attribute.

For each alternate pallet securing method, some difficulties were encountered when obtaining the raw data before evaluating. Most of these values were obtained from company websites, but some required further research. The most difficult data to obtain was for the attributes under the environment section. These were found on only a few books on the chemical properties of plastics and other environmental websites. No questions were left unanswered, but the attributes under the social section could possibly be tested further since quantifiable data available was very limited.

Overall, using adhesive and pallet covers to secure pallets would be a beneficial alternative to stretch wrap. Based on the results, warehouses and distribution centers could be contributing to sustainability and progressively be making a difference in the world. Some of the problems that could be faced for implementing this new method include: operator training and learning curves, quantity of adhesive and covers to be purchased, and a pallet cover retrieval system. A few limitations could be faced using the adhesive and pallet covers. One could be when certain products on a pallet cannot be secured due to their size and/or weight. Another limiting factor could also be the weather. Depending on the environmental conditions where pallets are stored, this method could possibly not work to its full potential.

Conclusion

Presently, stretch wrap is one of the most commonly used ways of packaging pallets in warehouses and distribution centers. This method uses a thin plastic film made out of low density polyethylene; it is wrapped various times around the items on the pallet to hold everything securely in place for either transportation or storage purposes.

The issue with this approach is that a large amount of non-biodegradable waste is created. Even though LDPE is recyclable, it is very difficult to collect all the stretch wrap waste and have all of it fulfill the recycling standards.

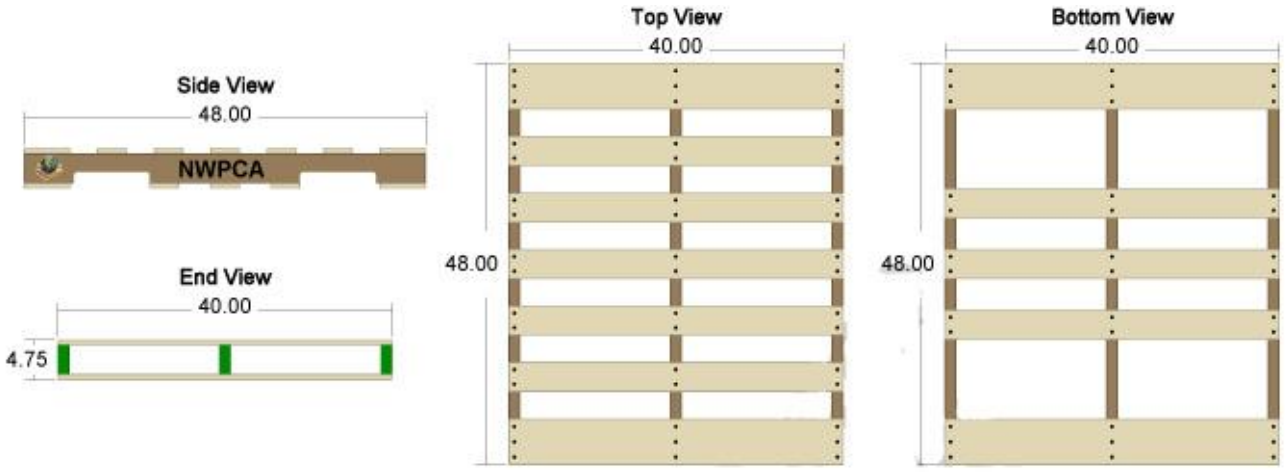
In order to decrease the large amounts of waste produced using this packaging method, it was necessary to study different alternatives to secure pallets in order to recommend a more sustainable approach. By using a triple bottom line approach, it was possible to use a guide and a set of principles to examine the other pallet securing methods. It entailed an analysis of each based on the effects on society, the environment, and the economy to recommend a sustainable method to package pallets.

After the analysis, a more sustainable alternative to stretch wrap was obtained. Out of the several methods, using the adhesive along with the pallet wraps was the solution recommended. The theory behind triple bottom line does actually have a direct relation to the results. The adhesive and pallet covers presented the most sustainable data, so the results from the evaluation reflected on these.

By successfully accomplishing this project, a deeper understanding on the grave impact industry has on the planet was obtained. There are enormous possibilities for the future in the green industry, for example, the packaging sector. The next steps for this project would probably be to study the current design of the pallet wraps and possibly find improvements. Base on the results from this analysis, it is possible to recommend this new method to package pallets.

Appendix

A-1: Wooden Pallet Dimensions



A-2: Environment Table Formulas

Waste:
Waste Produced = weight of material x 22,000 pallets

Carbon Footprint:
1 barrel of oil = 317 kg CO_2
Carbon Footprint = barrels of oil to produce material x 317 kg

Natural Resources to Produce:
250 MJ per kg of nylon
1 barrel of oil = 6.1 GJ of energy
Natural Resources = (mass of material x 250 MJ) x (.001)/ 6.1 GJ

Recycled Amounts:
Recycled Amount = waste produced x (estimate of what % is realistically recycled)

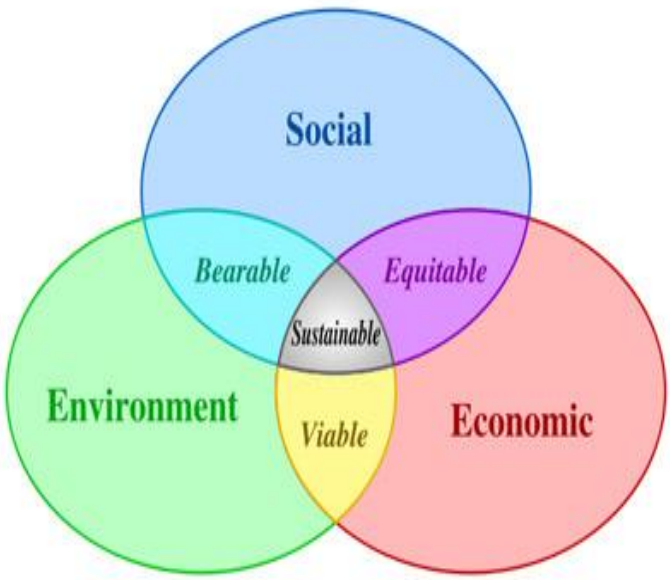
A-3: Wulftec Calculator

M. J. MAILLIS
WULFTEC.com

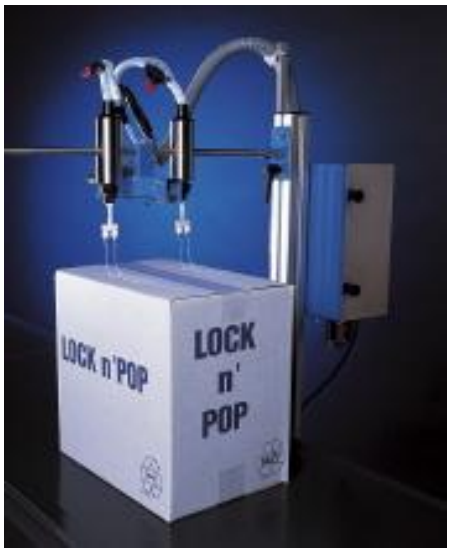
FILM COST CALCULATOR & RETURN ON INVESTMENT

	Existing	Proposed		Existing	Proposed
Load Dimensions:			**Wrapping pattern:**		
Width (in) :			Spiral :	Up & Down	Up & Down
Length (in) :			# of top wrap :	2	2
Heigth* (in) :			# of bottom wrap :	2	2
			Film overlap :	2	2
Film information:					
Film thickness (Gauge) :			**Labor:**		
Film width (in) :	20	20	Machine feed rate (LPH) :	30	30
Total length of the roll (ft) :			Work Hours daily :	8	8
Film Cost per roll ($) :			Days Worked / week :	5	5
Pre-stretch ratio :	0	250	Weeks worked / Year :	52	52

A-4: Tripple Bottom Line Chart



A-5: Recommended Design



Source: LocknPop.com

Source: Envirowrapper.com

Works Cited

Singh, Jay. Personal interview. 19 Apr. 2010.

Abdel-Bary, Elsayed M.. *Handbook of Plastic Films*. Chicago : Smithers Rapra Press, 1998. Print.

American Plastics Council. "Stretch Wrap Recycling: A How-To Guide." *American Chemistry Council* 1 (1997): n. pag. *Commercial Recycling*. Web. 7 Jan. 2010.

Arkansas. Department of Environmental Quality. *Stretch Wrap Alternatives, Reduction and Recovery.* North Little Rock: Arkansas. Department of Environmental Quality. [2008]. Print.

Bozer, Yavuz A., J. M. A. Tanchoco, James A. Tompkins, and John A. White. *Facilities Planning*. 3 ed. New York, NY: Wiley, 2002. Print.

Dieltz, John, and David E. Mulcahy. *Order-Fulfillment and Across-the-Dock Concepts, Design, and Operations Handbook*. 1 ed. Boca Raton: CRC, 2003. Print.

"Envirowrapper." *Envirowrapper*. N.p., n.d. Web. 31 May 2010. <http://www.envirowrapper.com/product/index.html>.

Forcinio, Hallie, Joseph F. Hanlon, and Robert J. Kelsey. *Handbook of Package Engineering, Third Edition*. 3 ed. Boca Raton: CRC, 1998. Print.

"General Purpose and High Performance Stretch Film Products - Full Service Customized Film Plan." *Flexible Packaging Specialists: Stretch wrapping and shrink wrap packaging supplier*. N.p., n.d. Web. 31 May 2010. <http://www.mdapackaging.com/packaging-supplies/stretch-film.html>.

Harper, Charles A.. *Modern Plastics Handbook*. 1 ed. New York: McGraw-Hill Professional, 2000. Print.

"Lycoming County Stretch-Wrap Plastic Recycling Report." *Gannett Fleming, Inc.*. N.p.,

n.d. Web. 31 May 2010. <http://www.gannettfleming.com/>.

"Lock n' Pop - Environmental Benefits." *Lock n' Pop*. N.p., n.d. Web. 31 May 2010. <http://www.locknpop.com/environ.html>.

Massey, Liesl K.. *The Effect of UV Light and Weather: On Plastics and Elastomers, 2nd Edition (Pdl Handbook)*. 2 ed. Ames: Plastics Design Library, 2006. Print.

Munier, Nolberto. *Introduction to Sustainability: Road to a Better Future*. 1 ed. New York: Springer, 2005. Print.

"Pallet Shrink Wrap Customer List - Orion." *End-of-Line Pallet Packaging Solutions - Automatic and Semi Automatic Stretch Wrapping Machines - Orion*. N.p., n.d. Web. 31 May 2010. <http://www.orionpackaging.com/orion-customer-list/>.

Young, Jan. *Selecting, Buying, Installing and Using a Modern Warehouse Management System*. Raleigh: Lulu.com, 2009. Print.