PRODUCT DESIGN AND DEVELOPMENT FOR BEER CRATE TO ENHANCE TRANSPORTATION COST AND SAFETY

BY

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ABSTRACT

Proper beverage packaging is one of the most significant factors which drive high quality of product protection during transportation. Especially, "Crate" has been introduced as a package or container for supporting bottles as glass beverage. For the recent design of the crate, gaps between bottles are the main issues which need to be eliminated. During transportation and load-unload activity, vibration and shock around or/and in between bottles might have a direct effect on the beverage quality. The impact or force distributed with high frequency or often enough causes the broken bottles. Proposed in this research is about the alternative design of a crate where the support devices are introduced to reduce force distributed around/in between two consecutive surfaces of two bottles where the gaps or spaces are eliminated. Product Design and Development (PDD) and Finite Element Analysis are applied for accomplishing task. For the force simulation, the different scenarios in static and dynamic platforms are raised where the three designs of crate are compared on each scenario testing; stacking, lifting and interference fit condition. The simulated results illustrated that the developed designs of crate (two versions of design); the crate-assembly style and the crate-fourteen platform could provide more slots for putting the bottles in; the number of glass bottles per crate of 8% and 16%, respectively. This set of results was compared to the existing design based on the

same size – external shape consideration. Applying the additional inserts (supporters) could absorb the vibrations and shocks of beer glass bottles during transportation.

Keywords: Product design development, Conceptual design, 3D CAD model, Finite element analysis, Static simulation, Product packaging, Truck transportation

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Symbols/Abbreviations	Terms
3D	3 Dimension
ABS	Acrylonitrile Butadiene Styrene
ANSYS	Analysis of Systems
APC	Alcoholic per capita consumption
ASEAN	South East Asian Nations
BTS	Bureau of Transportation Statistic
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CFD	Computational fluid dynamics
CLMV	Cambodia Laos Myanmar Vietnam
FEA	Finite Element Analysis
GDP	Gross Domestic Product
HDPE	High-Density Polyethylene
MFR	Melt Flow Rate
PDD	Product Design and Development
PDSs	Product Design Specifications
PSD	Power Spectral Density
RMS	Root Mean Square
RP	Rapid Prototype
STL	Standard Triangle Language

CHAPTER 1
INTRODUCTION

1.1 Background

Easy-to-access transportation concept has been played as an important role of logistics and supply chains where the well communication between manufacturers and customers can be accomplished quickly in minutes comparing to the traditional platforms. This means transferring a product from one place to another place; from a company (origin) to a detailer (destination) can provide high satisfaction level with less damage found. Many ways and modes of transportation are available in the current marketing strategy; for example, land, water, and air by applying vehicles as truck, train, vessel, airplane and pipe (road, railway, water, pipeline and air-carried).
Based on the advantages of the economic cost, applying "truck" with high loading amount can easily process and deliver products to the customers. In some countries that share border within land to each other, they are more useful for using truck transportation. According to transportation models, some researchers had tried to implement and develop platform for supporting fast-and-safe track to support logistics and supply chains; however, some applications, currently, are quite difficult to be applied in the real world. The main issues found can be expressed as the increasing of transportation planning processes, and the requirement of truck transportations - accordingly truck drivers has been increased when volumes of surging and in e-commerce increased (Mittal, Udayakumar, Raghuram & Bajaj, 2018; Soares, Marquesb, Amorim & Rasinmäki, 2019).

Since transporting by truck is very important and it can make more profits for companies when goods can be well prepared and delivered to the customers at the right time while maintaining quality of the packages or products; minimizing defects found. Using packaging is one of many solutions that have been applied to support and protect products without damage during transportation, and the packaging is also required for easily loading and unloading products. Beyond these practical advantages, packaging is used to improve the physical characteristic of products, brands, and support fast-moving consumer goods (Magnier & Schoormans, 2015; Simmonds & Spence, 2017). In the past few decades, packaging has extensively been realized that product packaging composes a potent trade tool in its own way. Packaging can support reach these targets at the sale point and consumption point, and it is an important part of food/drink processing that can keep longer time of product shelf life and quality of food/drink product is improved too (Simmonds & Spence, 2017; Amalin, Norziah, Khan & Haafiz, 2018). There are different types of packaging. The styles and platforms are varied according to the specific characteristics or physical shape(s) of product of interest. They can be divided into groups by using material-based consideration; wood, metal, plastic, paper, foam, or composite materials.

Moreover, “shapes” are applied as one set of the key consideration; flexible like plastic bags, four-corner like boxes, cylindrical-or-round like bottles, slot-provided inside part like crates, and cushion-provided inside like pack. However, all packaging types can be divided into two categories (Fadiji, Berry, Coetzee & Opara, 2018).

(i) For retail packages: these groups protect and packed subject from damage and include propagate subject for sale as well. There are glass bottles, plastic bottles, metal cans, sachets and wraps.

(ii) For shipping packaging: this provides nice protection for preventing unexpected things happened during shipping, distribution, and other purchasing functions. There are sacks, tanks, drums, boxes, crates, baskets, foil bags, corrugated paperboard cartons and wrapped containers.

The food-and-drink packaging platform drives a significant role in product and development stage of product design and development where this platform can deliver and transmit attribute of product as well as brand image that might help to increase selling volume when clean and clear plus attractive prints are well provided. Applying this positive strategy and platform can support and extract hidden issues of customer’s needs since the first priority or impression of physical characteristic of product has been emphasized on “package”. However, the details of product (i.e., specifications, ingredients, cautions or manufacturing date and time) need to be well prepared and announced with nice communication. This has been become as an essential consideration to convey the important messages to hit customers’ requirements. Purchasing decisions are often not only evaluation systematic and product critical feature, but it is considering on heuristic, ‘‘fast and frugal - careful in spending or using supplies” processing of packaging cues (Simmonds & Spence, 2017; Ooijen, Fransen, Verlegh & Smit, 2016; Soo & Sarbon, 2018). Whole the three decades of past, a succeeding body of obvious research has focused how food/drink packaging can notify, entice, and bias consumer all of two at sale point and during consumption. Even relatively minor adjustment to the visual design of packaging such as to the shapes, colors, orientation, and positions of design element can highly hurtle consumer’s product evaluation and buying purpose either positively or negatively are indeed suggested from ongoing investigation. This is particularly relevant with the moment that they are in the supermarket, due to consumers increasingly extend their food/drink buying decisions (Ooijen, Fransen, Verlegh & Smit, 2016).

According to product estimated: at the sale point, it is the major point that has a direct effect on making decision to purchase food/drink - getting over three-quarter. After checking the front of pack, the purchases have reached around 90% of consumers, and without getting picked up a product choice have reached 85% of consumers. Therefore, the factor should be considered and taken into consideration where the designers, marketers, and brand managers should take some actions on that where the effects of packaging to the quality of the product should be well managed (Simmonds & Spence, 2017).

Using numerous visual techniques can help designers to accrue the consumer’s interest, such as the use of materials, shapes, and colors in their packaging are responded marketers (Ooijen, Fransen, Verlegh & Smit, 2016). Getting new opportunity for packaging design by using easy-to-access platform might become a bright direction to improve the packaging pattern for minimizing waste and material used (Soo & Sarbon, 2018).

Nowadays, most products of food/drink are presented in a wide range of packaging platform with different types, materials, sizes and shapes. Both consumers and firms, they consider with several significant issue when selecting packaging for food/drink: packaging ability to preserve the quality of food/drink and freshness, pretty image and attractive, right product identification, facility to store and distribute, and environment effect. In recent years, changes have been occurred by using plastic to instead the other materials for packaging. Plastic has been selected because of these following reasons; the lighter-weight, being recycled container, and lower price. This recedes carbon footprint through keeping in transport chain (Balzarotti, Maviglia, Biassoni & Ciceri, 2015).

Every day, there are still tons of packages found in the landfill. This issue is the most deleterious to the environmental (Babalis, Ntintakis, Chaidas & Makris, 2013), and a serious disadvantage of packaging is that after packaging is used and unavoidably added, it is usually leaved directly to our environment footprint. Each European citizen procreates approximately 160 kg of ulcerated packaging per year. That means when considering ecological disability packaging is a significant problem. Then ecological design is an urgent idea that mentions to design that encourages sustainable and ecological ability (Magnier & Schoormans, 2015).

Since the food/drink are categorized as one of the basic need. They have been eaten and directly affect to healthy human; if they good or bad quality. For fresh and processed food/drink product, providing indispensable protection from external factors occur from contaminants, gas composition, decadence microorganisms, mechanical loadings and physical damage is necessary and required. Packaging is necessary for food/drink safety component to guarantee secure disposal and deliver fresh and processed products without damage from production point to the destination.

Recently, packaging has performed and delivered the necessary function in the postharvest disposal and shipment of fresh and processed food/drink. They are forced to meet numerous standards of packaging-design and development. The high delicateness of packaging fresh produce results in the mechanical damage and flavor instability of food/drink. It is prevalent and is a main point of postharvest losses during export (Fadiji, Ambaw, Coetzee, Berry & Opara, 2018; Fadiji, Berry, Coetzee & Opara, 2018; Fadiji, Coetzee, Berry, Ambaw & Opara, 2018). During transportation, the food/drink quality can be affected by these factors such as transportation vehicle, transportation route, payload, platform location, road surface conditions, driver, packaging type, temperature, and humility due to occurring vibrations and shocks. The physical and biological damage from vibration and shock stress during shipment can decrease quality of food/drink as well (Jung, Lee, Lee, Cho & Lee, 2018). Fresh food/drink, including electronic cargo is sensible to quality wasting or setback by reason of vibrations and shocks. Postharvest wasting of foods, that means the losses arising during transportation, disposal and storage ahead of the food product arrive consumer, getting as high as 25% of the preliminary reaping or procedure product (Paternoster, Vanlanduit, Springael & Braet, 2018).

Since market globalization has persuaded the popular requirement and higher beer production and export amounts. Some problems found of beer transportation have been raised and reviewed for finding ways to solve. These problems are detected during long shipment time and changing storage, and these bad conditions bring to the unfavorable and reducing in beer quality. The beer flavor in stability might be influenced by changing temperatures, vibrations and shocks exposing bottled beer during transportation, and these represent as the influencers to develop the mud in beer. And all these shipping and storage conditions head to the reaction of chemical reaction that makes the chemical compositions of beer are changed. Beer transportation and pattern are built on the same platform as the food products where it is pleasurable to keep longer on the shelf life. With nice and clear method, it can directly reduce losses due to mechanical damage (Paternoster, Vanlanduit, Springael & Braet, 2018).

The design and creating of packaging impact and play an essential part in defining product shelf life where the quality or product shelf-life is also influenced from different materials of product packaging. Also, it possess a range of performance properties too (Fadiji, Berry, Coetzee & Opara, 2018). Identifying the type of forces, vibrations and shocks as well as designing optimum packaging, great packed management and correct placement in the vehicle can decrease the damage of food/drink (Soleimani & Ahmadi, 2014). The new changes for packaging design are gotten with improvements in packaging technology (Simmonds, Woods & Spence, 2018). Thus, logistical handling can be facilitated with the design of packaging, at the same time, this is surely protecting the product from physical damage which is, thus, an elevated prerogative to the fresh produce industry (Fadiji, Berry, Coetzee & Opara, 2018).

In order to satisfy the customer's needs and getting successful with new product design, the concept of product design development (PDD) has been applied to generate the optimal design. The designing and developing product would be helped by PDD technique, and also the manufacturer processing to be more important. In PDD process, it consists of five phases, the first phase as conceptual design that is a phase - gathering the diversity of ideas together to procreate a sketching model of a not smoothly product image. The second phase is system-level design, this phase describes that manufacturer will move more artesian into the product's details with kind physical characteristics of the own product or architecture of product. The third phase is detailed design, after the manufacturer got what function the product will be had, creating more substantive with details is asked to perform. Next, matching among form, fit, and function of the product like that it should be is required. The fourth phase is about refinement and testing where the prototype is fabricated for checking some functions and feelings - rapid prototype (RP) technique is applied. Then, the obtained prototype will be tested with mechanical properties. The last phase is production ramp-up where the prototype is done with mechanical process then is performed and getting ready to transfer into market (Unger & Epping, 2011).

In the design of product, to save time and production cost in first step processing and before started manufacturing, applying finite element analysis (FEA) technique to use simulation CAD model for checking potentiality of 3D model is introduced. 3D model is played as the key component for supporting FEA where the loading force distributed on the product structure is considered and analyzed. FEA is a computer testing technique that is mostly applied by engineers, mathematicians, and scientists. It is a technique of numerical that can be applied for forecasting how subject responds to actual-life force, heat, vibration, fluid flow, and other physical influence.

Over the past 20 years, computer-based platform has been used for high volume computations; FEA is one of the mechanical-properties checking platforms which can simulate and analyze whether or not when a subject will be broken and worn out, and where is/are critical point(s) of subject. FEA has transformed a powerful and widespread technique in many industries. The computation of engineering in FEA have the major target of getting information regarding the reaction of physical systems to certain define conditions, which way to assist in conducting and justifying engineering designs and decisions. Beyond, FEA achieves more regions being applied vastly in structure mechanics area, such as fluid dynamics, heat transfer and conduction, electric and magnetic fields, food processing, and packaging. These areas have also been achieved by its application. Therefore, FEA has become a major part of many engineering designs, within reason of its capability that supporting before doing or implementing the prototypes, which predict the performance of new designs or processes (Fadiji, Ambaw, Coetzee, Berry & Opara, 2018; Fadiji, Berry, Coetzee & Opara, 2018; Fadiji, Coetzee, Berry, Ambaw & Opara, 2018; Hopmann & Klein, 2015; Pathare & Opara, 2014).

In this research project, developing the existing product based on its restrictions is considered where the proper ways to creating new prototype within more capability and most useful waking are introduced. Therefore, for achieving the goal, the engineering techniques have been required; Product Design Development (PDD), CAD/CAM drawing, Rapid Prototype (RP), and Finite Element Analysis (FEA).

1.2 Statement of problem

According to the problem of transportation which crates contain too heavy items and full pallets that are stacked height, falling items are a considerable harm. The stacking design might make the situation that some of the parts are fallen down from the top, and these might be destroyed. Moreover, the workers are more likely to get hurt or injured because of this problem.

The transportation process generally focuses on the part of management to deliver products to customers quickly on time. The factors that make the broken/damaged product are overweight, nature trails, the size of the bottle, and the vibration of an object during transportation. The above factors, the data are analyzed about the factors affecting transport each time. Furthermore, transportation cost is the key area based on government rule of truck weight (each season per type of truck per route). To make the transportation of goods from the warehouse to the customer safely, the proper method and developed technique should be introduced to prevent damage or loss of goods in transit, and to make transportation more efficient while reducing cost.

1.3 Objective

To apply the technique of product design and development (PDD) for creating new design (crate) within appropriate truck transportation that reduce transportation cost while considering about physical properties of beverage packaging (crate) between new designs and existing design that influence to product (beer glass bottle). Comparing about transportation cost of beverage packaging (caret) between new designs and existing design that influence to product (beer glass bottle) is required to accomplishing task.

1.4 Organization of research

To accomplish the research objective, the following issues are addressed:

1. *Studying type of beverage container*: using original product (crate) is applied to identify and analyzing the issue that can translating into the product design of engineering. Applying appropriate shape in the proposed new packaging design might become increasing loading capacity, it can reduce transportation cost that get advantage to company.
2. *Analyzing material selection*: base on simulation to find material appropriate match with each situation, the technique is widely applied to analyze 3D model as Finite Element Analysis (FEA). This technique is provided to simulate large scale and many conditions, the reason as reduce time and cost in case is real testing.
3. *Checking prototype:* mechanical properties are applied to test the new product. Base on comparison with computer simulation, which is equivalent to same scale. Mechanical properties testing give result that can compare from computer simulation that they have close accuracy or not.

CHAPTER 2
LITERATURE REVIEW

Presented in this section are about the related works which are about transportation platform, beverage/drink types, packaging design, and characteristics of crate. Those were researched from various sources; national/international journal plus articles, news, and reports from some projects. The details about existing products (the bottles and pallet/beverage packaging) were mentioned and reviewed including material selection or style applied for making packages and containers. For the last phase of this chapter, product design and development (PDD) was explained.

2.1 Truck transportation using

Based on the U.S. department of transportation's Bureau of Transportation Statistics (BTS), in Figure 2.1 illustrate all transportation modes which is five major of transportation modes like truck, train, pipe, boat and airplane carried value in 2017 more than in 2016 in U.S. freight including Canada and Mexico. And from the U.S. Energy Information Administration. In five modes of transportation, the top rank of transportation mode is still mode of truck transportation, which is highest and most heavily utilized that use for transport cargo to and from all Canada and Mexico, with carrying around 63.3% of the freight shipped. Though, point of percentage decrease from 2016 for around 2.2 in share carried, and trucks accounted for around $720.8 billion from all modes account were taken of $1.1 trillion, in freight flows to and from both Canada and Mexico in 2017, that present in Table 2.1. The second rank mode of transportation as railway was remained moving of 15.3%, with train accounted for $174.1 billion, this is followed by vessel, pipeline and air, each of which has respectively a 6.6%, 5.7% and 3.8% (Figure 2.2 and Table 2.1) (Bureau, 2018).

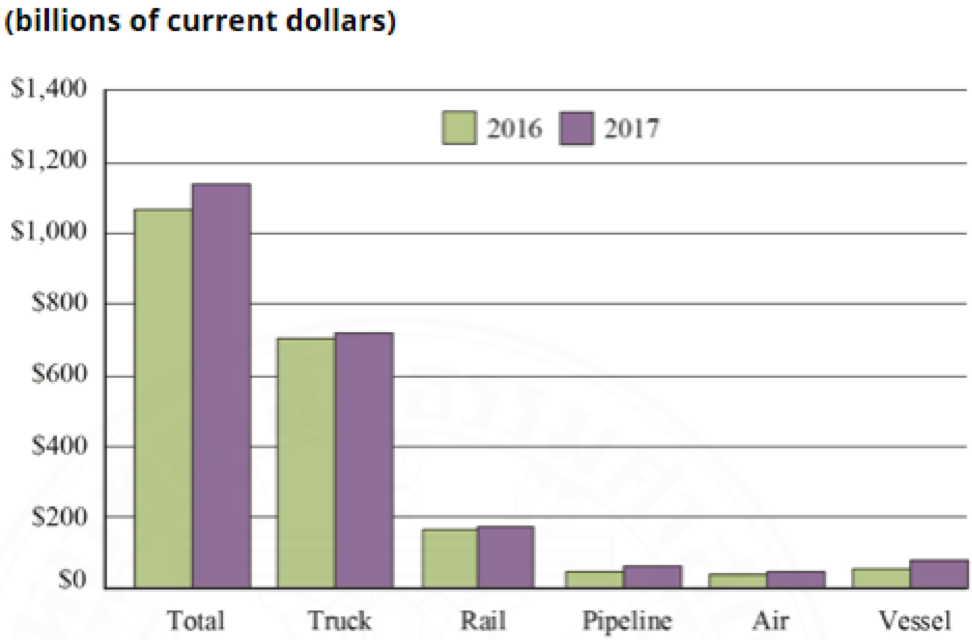


Figure 2.1 U.S.-North American freight by mode: 2016-2017.

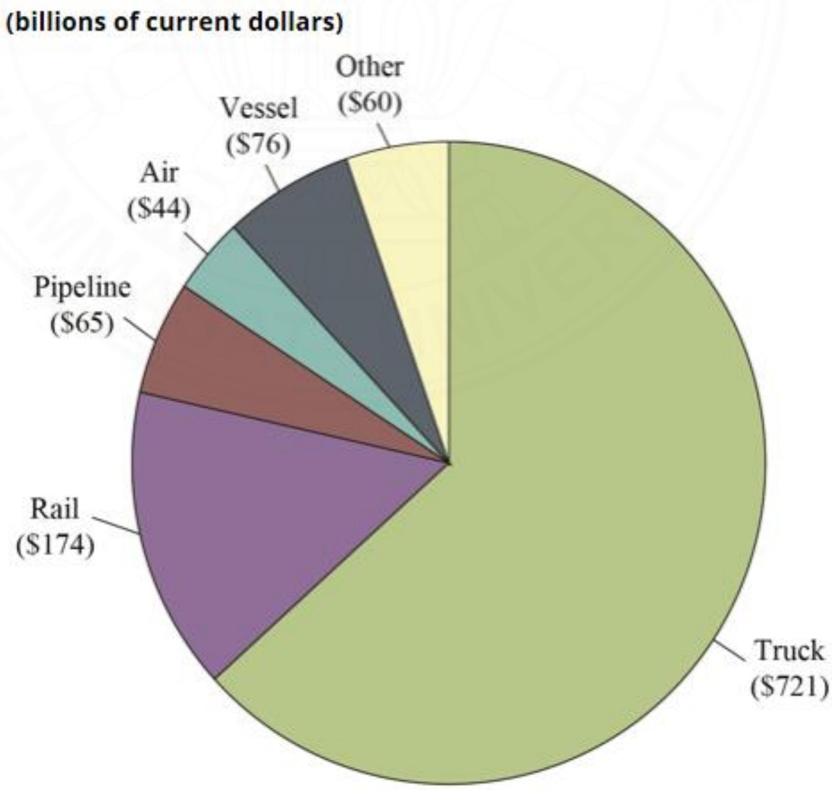


Figure 2.2 North American freight by mode, 2017.

Table 2.1 Total value and modal shares of U.S.-North American freight flows.

Mode		2016	2017	Percent change 2016-2017
All modes	Imports	$527,217.8	$614,020.4	7.3
	Exports	$456,919.7	$525,460.3	5.7
	Total	$1,069,137.6	$1,139,480.8	6.6
Share of total by mode (percent of total value)				Percentage point change 2016-2017
Truck	Imports	63.3	60.2	3.0
	Exports	68.0	66.8	-1.2
	Total	65.5	63.3	-2.2
Rail	Imports	18.8	18.5	-0.3
	Exports	15.5	11.5	-0.2
	Total	15.5	1	-0.2
Pipeline	Imports	6.6	8.4	1.8
	Exports	2.4	2.6	0.2
	Total	4.6	5.7	1.1
Vessel	Imports	5.2	6.4	1.3
	Exports	5.8	6.9	1.1
	Total	5.4	6.6	1.2
Air	Imports	3.1	3.1	-0.1
	Exports	4.8	4.8	0.0
	Total	3.9	3.8	-0.1

Truck transportation is one of neural system is most significant and necessary which is widely used in the global to distribute retail of products (Amorim & Rasinmäki, 2019; Berardinelli, Donati, Giunchi, Guarnieri & Ragni, 2003; Jarimopas, Singh & Saengnil, 2005; Lee, Lee, Cho & Lee, 2018; Lu, Ishikawa, Kitazawa & Sataka 2010; Lu, Ishikawa, Shiina & Sataka, 2008; Mittal, Udayalumar, Raghuram & Bajaj, 2018; Garcia-Romeu-Martinez, Singh & Cloquell-Ballester, 2008; Paternoster, Vanlanduit, Springael & Braet, 2018; Soleimani & Ahmadi, 2014; Soares, Marquesb

& Böröcz, 2018; Singh, Singh & Joneson, 2006). Due to truck transportation is used to apply for supply chain system which transport products from manufacturer to consumer. However, truck transportation got many types such as rigid truck, semitrailer truck, and trailer truck, including difference of axles and wheels, for open truck, closed truck, suspension of air ride, and suspension of leaf spring (Berardinelli, Donati, Giunchi, Guarnieri & Ragni, 2003; Jarimopas, Singh & Saengnil, 2005; Lu, Ishikawa, Shiina & Sataka, 2008; Garcia-Romeu-Martinez, Singh & Cloquell-Ballester, 2008; Soleimani & Ahmadi, 2014; Singh, Singh & Joneson, 2006). In Laos, there were various types trucks were used for the transportation such as 2 axles, 3 axles, 4 axles, 5 axles, and 6 axles which start within 4 wheels, 6 wheels, 8 wheels, 10 wheels, 12 wheels, 18 wheels, etc. The weight limitation admission must be taken to discuss in each season. Due to Lao government needs safety seasons, so for each type of trucks are given a maximum limit weight. And considering of weight limitation permission that are advantage part of decree have been followed are, in dry season begin from December 1st to May 31st, the maximum gross weight is indeed limited with all types and moving of truck sizes on any public street are concrete road, asphalt concrete road, asphalt road, gavel road, earth road, and natural road. As with raining season start June 1st to November 30th, the maximum gross weight of 20% shall was reduced from dry season (Table 2.2). Furthermore, the percentage account of truck types was considered as; 63.7% of open truck (6 and 12 wheels), 18.2% of closed truck (6 and 12 wheels), 9.1% of trailer truck, 4.5% of semitrailer truck, and 4.5% of tractor truck as illustrated in Figure 2.3 (Phlernjai, Rianmora & Phommixay, 2019). The transportation demand needed was around approximately 348,000 trucks in Iran. Approximately 365 million tons of goods were dedicated with truck transport method in the annually (Soleimani & Ahmadi, 2014). For almost 90% of all tonnes-kilometers of manufactured parts, in Spain, they were transported by truck (Garcia-Romeu-Martinez, Singh & Cloquell-Ballester, 2008). Moreover, in Japan, truck transportation applied to ship fruits and vegetables are accounted for almost 90% (Lu, Ishikawa, Shiina & Sataka, 2008).

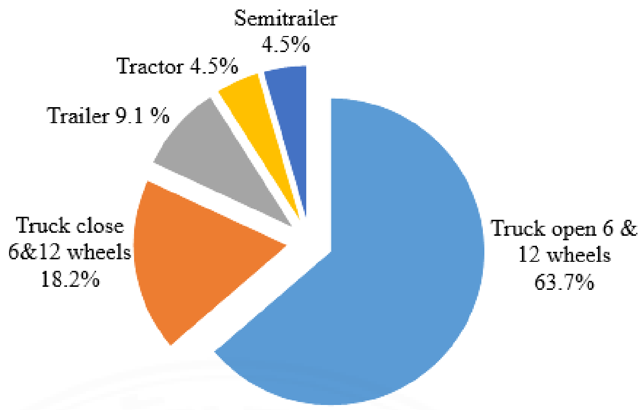


Figure 2.3 Percentage using of truck types for transportation in Laos.

Table 2.2 The agreement of maximum gross weight for truck on road transportation in Laos.

Types		Axles		Wheels		Maximum Load (kg)
		Front	Rear	Front	Rear	
Rigid truck	2 axles 4 wheels	1	1	2	2	8500
	2 axles 6 wheels	1	1	2	4	9100
	3 axles 6 wheels	1	2	2	4	15300
	3 axles 10 wheels	1	2	2	8	21000
	3 axles 6 wheels	2	1	4	4	10500
	3 axles 8 wheels	2	1	4	4	14000
	4 axles 8 wheels	2	1	4	8	18800
	4 axles 12 wheels	2	2	4	8	25200
Semitrailer truck	3 axles 10 wheels	1	2	2	8	21100
	4 axles 14 wheels	1	3	2	12	30100
	4 axles 14 wheels	1	3	2	12	28400
	5 axles 18 wheels	1	4	2	16	37400
	6 axles 22 wheels	1	5	2	20	40000
Trailer	2 axles 4 wheels	1	1	2	2	13600
	2 axles 6 wheels	1	2	2	4	15900
	2 axles 8 wheels	1	1	4	4	18200
	3 axles 12 wheels	1	2	4	8	25500
	4 axles 16 wheels	2	2	8	3	32800

2.2 Beverage/Drink

In recent year market globalization, beverages form an essential world industrial have continually grow, increasing to 950 million hL of beverages consumption volume in 2017, the sector steady keep going to expansion each year since 2008 to 2017, with growing of consumption averaged an annual drink account of 3.8% are presented in Figure 2.4. In global market of beverage is divided two major groups are first group is non-alcoholic which is called soft drinks such as mineral waters, carbonated drinks, soda, energy drinks, healthy drink, sports or electrolyte drinks, fruit juices, tea, and coffee. In the market, this group had annual consumption volume for drink account round of 65%. Second group was the group of alcoholic drink (i.e., beer, spirits and wine). In terms of the annual consumption, the volume of this group remains drinks account of 35% base on first group. Based on the area of consumption distribution for non-alcoholic drink, the region of Asia-Pacific was considered as the largest area of the world population lives within drink account for around 33%.

For North America, Western Europe, and Latin America, there were recorded as 22%, 15%, and 15% of global world market, respectively. For alcoholic drinks were also considered as the same style with non-alcoholic drinks where, around the region of Asia-Pacific, "beer" was famous (around 36%), the second place was recorded in Latin America (20%), the third place was recorded in North America with (19%), and Western Europe was recorded as 13% of global spirit consumption. While spirits, the areas of world spirit consumption were Asia-Pacific region (market share of 56%) and Western Europe region (market share of 17%). However, in case of wine, the biggest world spirit consumption were found on two areas; Latin America region (36%), and Western Europe region (32%) as illustrated in Figure 2.5 (Krungsri, 2019). For the number of consumptions that was growing up to 78 million hL, this presented the bright direction for exporting European beer to all around the world, 2012 (Paternoster, Vanlanduit, Springael & Braet, 2017).

For "Association of South East Asian Nations (ASEAN)", four countries; Cambodia, Lao PDR, Myanmar and Vietnam, were recorded as new members and called as CLMV. In 2016, Cambodia, Laos, and Vietnam or CLV group reported with high level of volume per capita where Cambodia was recorded as 6.7, Laos was about

10.4, and Vietnam was around 8.3 liters per capita. For Myanmar, the value was considered as low level for liter per capita (i.e., 4.8) comparing to a whole world level of 6.3 liters per capita. Furthermore, in Laos, the value of import for alcoholic drink in million US dollars was the highest one; 199.5. The second place was reported as Cambodia (168.3) where the third and the fourth place were found in Vietnam and Myanmar with 155.7 and 94.7, respectively. In Laos, the reported data was analyzed as the highest prevalence of heavy episodic drinking that was accounted around 14.6%. This could be translated as selling alcohol drinks in Laos might be the bright way since the value was identified in double the whole world average value. This number presented evidently higher than the other countries (Table 2.3) (Markchang, Chaiyasong, Trairatananusorn & Pitayarangsarit, 2019).

Figure 2.4 The global market of beverage.

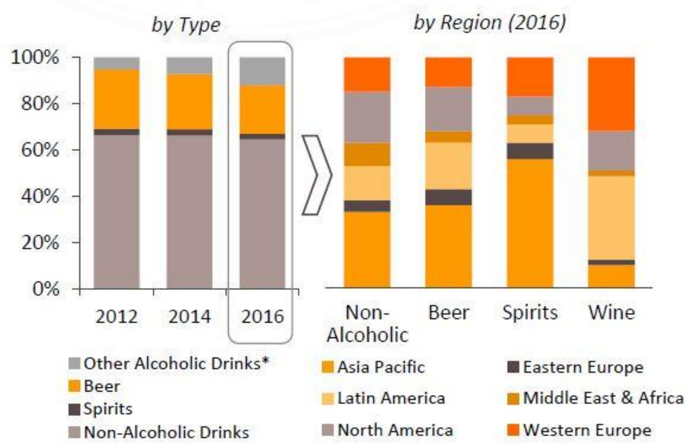


Figure 2.5 Showing global beverage consumption volume.

Table 2.3 Summary of the alcohol consumption in CLMV.

Indicator	Cambodia	Laos	Myanmar	Vietnam	Thailand	ASEAN	Global
APC							
2010	5.0	7.0	2.9	4.7	7.6	3.9	6.3
2016	6.7	10.4	4.8	8.3	8.3	4.9	6.3
(% change)	(34.0)	(48.5)	(65.5)	(76.6)	(9.21)	(25.8)	(-)
Prevalence of heavy episodic Drinking** in 2010 (million USD)	1.4	14.6	0.1	1.4	1.1	1.4	7.5
Alcohol import (million USD)							
2012	26.7	15.5	42.2	76.2	302.6	-	-
2016	168.3	199.5	947	155.7	298.6	-	-
(% change)	(528)	(1,180)	(123)	(104)	(-1.32)	-	-
GDP growth (%) in 2017	6.8	6.9	7.6	6.3	3.9		

* APC: consumption of alcohol per-capita, ** Consumed at least 60 grams or more of pure alcohol on at least one occasion in the past 30 days † Average among ASEAN members.

2.3 Omnirak beverage rack

Omnirak is the beverage racking system with adjustable multi-level where the feature gaps are provided to support the users to easily put object with loading and unloading activity quickly. It can carry bottles and cans, and using this can dominate the minimum floor area. For supporting all types of vehicles, this rack style (its dimension and size) can fit to the provided portions or corners of the vehicles. Moreover, this can support importing and exporting platforms with many sides, and the result can present extremely increasing in efficiency. Applying this can make products more accessible and easier to be reached and rotated by their flow-thru design; saving time with “first-in/first-out rotation”. Omnirak is a pallet jack portable, a forklift loadable, and it is adjustable. With the specific characteristic of this rack style, it can protect the products from shaking during transportation. Moreover, the omnirak can support manufacturers to easily facilitate packaging size changes based on the requirements since it can be adjusted the spacing of rack simply where the supplementary shelves are simply installed. Omnirak is very strong due to it is performed of extrude high-strength aluminum. However, it is quite easy to be broken when the aluminum extrusion parts/rods (the structure of this rack style) are removed or stacked up (built up the level) with upright style. The joins and connections among rods are fastened with screws and assembled – according to “portable-and-foldable concept”. Due to its modular construction, it is available for all styles of truck (Home, 2019).

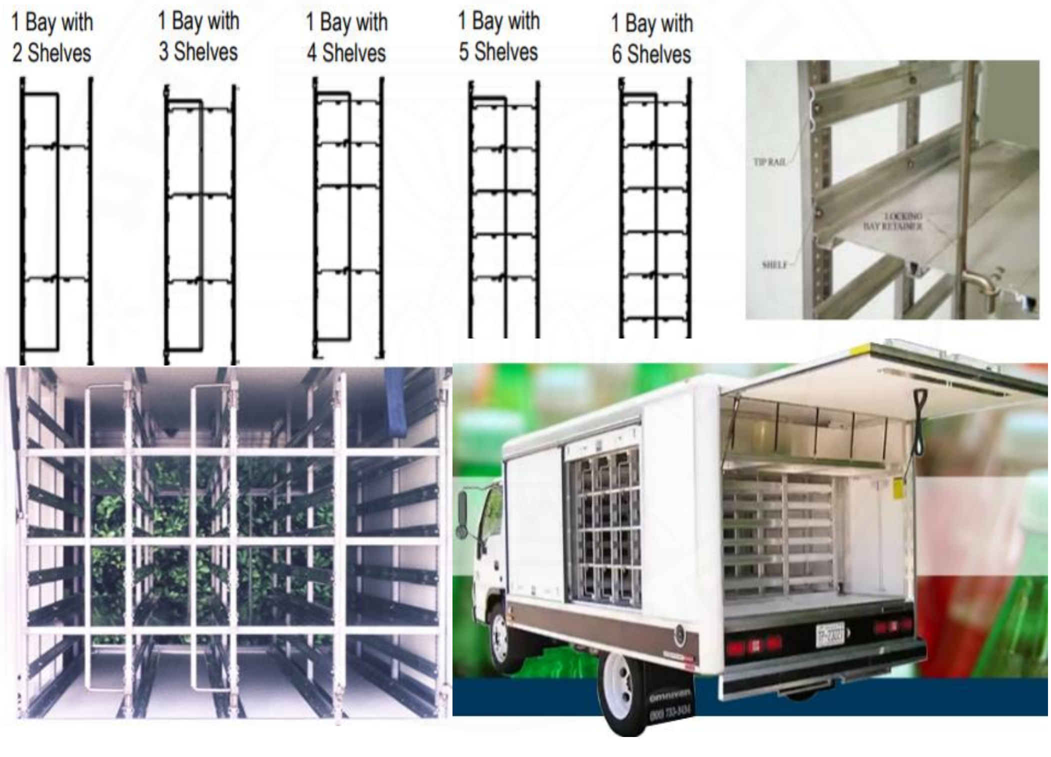


Figure 2.6 Beverage racks for cans, bottles, or both.

2.4 Product design and development (PDD)

The growth of technologies has been increased quickly that it makes the development of new products are also grown as well. However, for supporting customer’ needs, it is quite hard because behavior, characteristic, and attitude of human are different. Poston, (2009); Kaur (2013) divided the levels of need as a pyramid. The first area was expressed as the widest bottom area (the bottommost area), it was called as "basic needs of human" or "physiological needs" (i.e., food, water, air, and shelter), and safety needs (i.e., security, safety). The second area was mentioned as the middle portion, it was "psychological needs" that consisted of belongingness and love needs, (i.e., family, friend, work and social), and esteem needs (i.e., feeling, position and honor). For the topmost area was considered as "self-fulfillment needs" (i.e., achieving's full potential and creative activities).

For the modern manufacturing industry, its platform has been developed year by year for increasing the number of selling volume plus benefits. "Integrating multiple technologies together" platform has been introduced in this era where the combination innovation of mechanical engineering and information technology is raised considerably. Moreover, the absolute three ingredient recipes; automation, computation, and communication are mentioned and applied in modern manufacturing platform for minimizing time spent for producing a new product. In manufacturing factory, the automated environment for production has been established frequently by applying computer numerical controller (CNC) equipment or machine with easy-to-access software.

Using easy-to-access technics can help to enable manufacturing and engineering plan to manage principles of fundamental design quickly where the typical-based engineering issues are addressed and analyzed in sequence (Yue, Xing, Hu, Wu & Su, 2018). In concept development phase, the unmatched challenges are being carried by the information that is extracted from customer's voice where the product features might be expressed as artworks or free hand sketching platform. However, the appropriate design and idea should be formed in 3D virtual model that can support the designers to easily and quickly modify the physical shapes of a new product. This allows the manufacturer to launch a new product to the competitive market faster than the traditional process (Shao, Lu, Zeng & Xu, 2016).

A significant amount of attention, within the community of business, has been received by Mass Customization, and with product customization; the rapid development of information technology is demanded by the users' increasing, an effective way to implement the mass customization has been widely recognized from a product family development. A product family is considered as a group of related goods produced by the same firm under the same brand. A firm might generate "a product family" to leverage the existing customers loyalty toward its original brand. Moreover, platform-based product family design is an effective strategy where the design of a product family is typically more challenging than typical designing single product (Xiao & Cheng, 2016). For the process of designing a new machine or product, One of the biggest challenges designers face is "a design parameter" that denotes a parameter that a designer can directly determine (Gabriel-Santos et al., 2016). The concerned issues of "design parameter" can be addressed as:

- The number of design parameters is greater than the number of functional requirements;
- The design parameters are considered as "a large number";
- The range of values of some design parameters is unknown;
- Several design parameters are interrelated.

The new product development is an essential process if enterprises want to survive, presently within high dynamic and competitive of small business environment. Particularly small businesses, who want to stand with these competition situations from multinationals, their products must be continuously updated to conform which match with current trends. Indeed, the palpable product or service development, which is only a small part of the new product development process, including the consummate travel from conceptualization, which is starting idea then go to final for bring the product into the market. The new launching products divide two processes as making a new product and creating a new product is called Product Design Developing (PDD). The designing and developing products would be supported by PDD method, and same as the processing of manufacturer to be more important. In five phases of PDD, which is initial with Conceptual Design, System Level Design, Detail Design, Refinement Testing, and Production Ramp-up as last phase, respectively (Bader, Gebert, Hograve & Tracht, 2018; Boejang, Hambali, Hassan, Esa & Rauterberg, 2017; Maass, 2012; Nafisia, Wiktorsson & Rösiö, 2016; Phlernjai, Rianmora & Phommixay, 2019; Patil, Sirsikar & Gholap, 2017). PDD comprises of five phases are presented in Figure. 2.7 (Weigel, 2000).

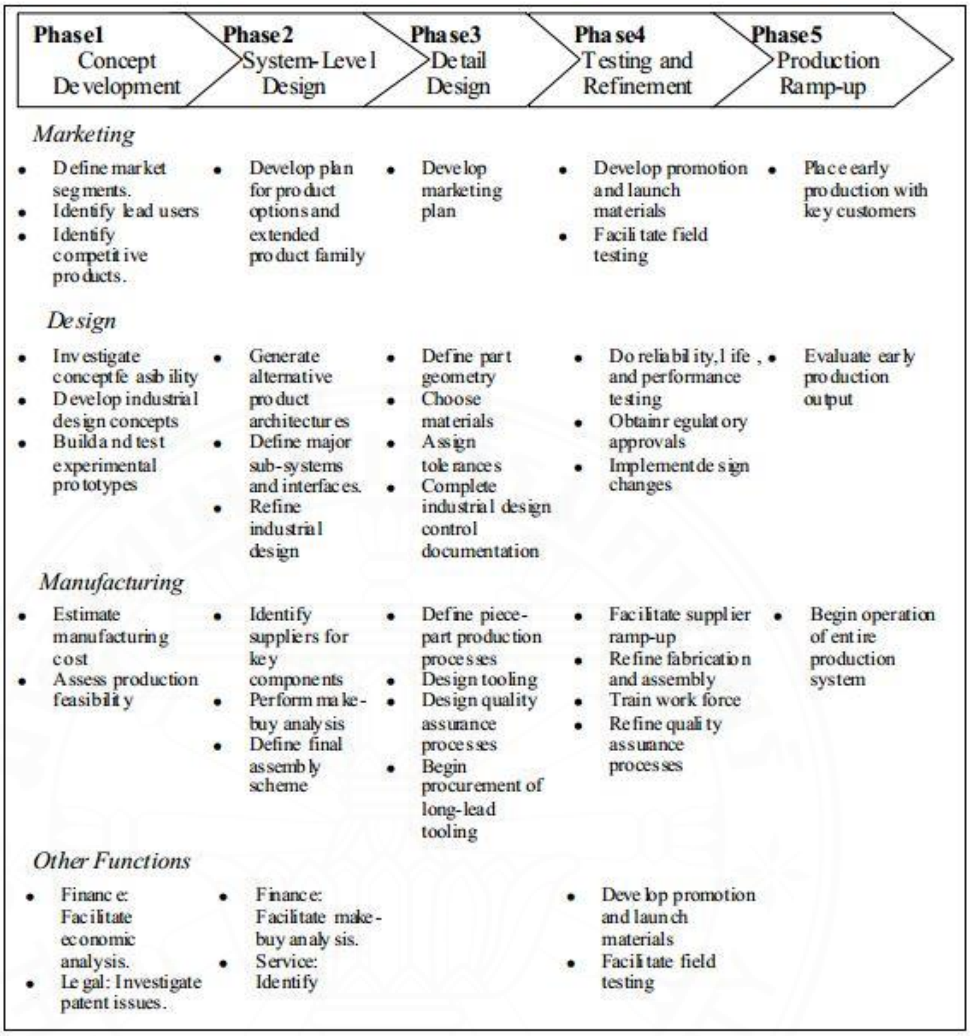


Figure 2.7 Phases of product design development creating from Ulrich and Eppinger.

2.4.1 Conceptual design

Conceptual design or conceptualization can be called as idea generation, which is the starting point of initial stage of design process. It is a stage that would gather variety of all ideas together to generate a drafting model of product's outlook. Generally, the whole design technic can monitor the development of designers where their product processes start with a market investigation until the generation of product design specifications (PDSs) is obtained. Conceptual design consists of two main consideration; the identification of the issues and definitions; and the customer needs plus the information collecting, which includes a market survey and PDS. Moreover, two main activities are required to accomplish task; concept generation and concept evaluation (Mazani, Sapuan, Sanyang, Atiqah & Ilaya, 2019).

2.4.2 System level design

System level design was also known with other leads were parametric design and configuration design phases. It is second stage which falls in the transition from concept to detail design. Various designers have proposed that absolute activities be finish or decisions made in order to build this transition as smoothly and as effectively as possible (Sobek, 2006). Including whole determination of the location and position for components, parts and features are consisted in this design activities. For first order calculation and study as identified the established parameters. The diagrams of function decomposition were preparing for functional specification of each components and subsystems (Boejang, Hambali, Hassan, Esa & Rauterberg, 2017). And in this system level design can generate the all-detail components of product design which comprises what kind of each part, how many parts, how many levels are divided, and including whole methodology are applied. However, managing the group of each functions which functions are compatible and which are not this is main matter that how does designer is decided. Thus, the easiest method is to begin compounding similar functions into group or section, and then determine if the compound is compatible (Curtis, 2010).

2.4.3 Detailed design

Detail design, or design for manufacture, is presentation of whole designs which begin from basic till deep design displays all of detail, concept, idea, method to creating. It is the phase that after the manufacturer knew what functions the product will have, to make it more realistic is to put details into design to match between forms, fit, and function of product, such that it will be more visualize. This stage is process of necessary engineering was done for every product component. In this period stage, each part was identified and engineered that complete specification of geometry, material, completions were scheduled, and all the parts tolerances of designs was documented with detail drawings, assembly drawings, and general assembly drawings or computer files. The consequence from this stage is the complete and accurate physical description of all the parts in the product. Thus, these drawings can be forwarded to the function of manufacturing for accurate and assembly. Furthermore, this phase uses the concept design and applies it to components of material and, include result to plans the manufacture and product assembly. In this period process, the materials, manufacturing techniques, machine tools, and processes like forging, injection molding, and casting can be considered for selecting (Boejang, Hambali, Hassan, Esa & Rauterberg, 2017; Patil, Sirsikar & Gholap, 2017).

2.4.4 Testing & refinement

Testing & Refinement is phase that had activities involve between the verification and the proposed new product validation, its marketing, and production. The entire viability of the project was tested and validated from this phase (Boejang, Hambali, Hassan, Esa & Rauterberg, 2017). Testing & Refinement as multiple production versions of product within construction and evaluation. The materials that simulate the actual material usually built early prototypes, then it is hereafter called as alpha prototypes. As parts were converted via soft tooling or any rapid tooling technic. The actual manufacturing process usually fabricated parts supplied within later prototype, which is called as beta prototypes. But using in the actual assembly line facilities may not assembled. And output was received as beta prototypes from evaluating internal and also typical testing by customers in their own environment (Maass, 2012).

During development process, new iterations of the design of product need to be tested and verified its functions and physical characteristics. Organized and well-plan of research and product development platform can help designers to quickly create virtual representations of product. These digital environments allow companies to test products simultaneously as the activity that performs in the real-world application where the conditions, environmental considerations, and potential user errors are taken into consideration. Increasing smart machines can identify flaws or areas for improvement in the drawn designs before they even reach the prototyping stage. Prototypes are still a vital component of the product development stage. Moreover, fabricating physical representations of the product allow companies to test the product in real conditions and discuss potential flaws based on the feel or ease of use of the product (Braithwaite et al., 2009).

2.4.5 Production ramp-up

Product ramp-up is applied as a final phase in product design development, where the improvement activities are performed and be ready to lunch into market. Ramp-up has a dominant importance for firm, due to the financial success of a product was directly affected with time-to volume. The guidance of new product into market needs to be carefully evaluated in order to handle them effective and efficiently. During the entire course of product development, it is significant to build a marketing strategy. For the companies, they need to make the potential consumers to understand the product in both negative and positive ways where the ways to promote its advantages should be mentioned as the first priority; however, the drawbacks are sometimes options to inform the customers about difficulties that might be found during using the product. All instruction plate or product's description should be well prepared and printed on the screen of the product's label with easy-to-reach and -read platforms before launching the product to the shelve. Moreover, proactively marketing product can ensure more purchases and a faster return on investment. This might allow the company to analyze the research of market to check whether or not the product is still working successfully and feasible in its current target market (Ball, Roberts, Natalicchio & Scorzafave, 2011; Filla & Klingebiel, 2014; Nugroho, 2011; Surbier, Alpan & Blanco, 2014).

2.5 Product packaging

Product packaging is so essential that play main role in the industrial, which make products are branded, unique, promote benefit, safe, easy moving, functional. Packaging help supporting and protecting products are packed/contained, they are useful and effective in logistics and supply chain systems, especially mode of transportation. Product packaging is divided to two main types which is directly packed with products that means connect to products like plastic pack, plastic bottle, glass bottle, foam, paper, aluminium foil are called firstly packaging. For second packaging type is called secondary packaging which is common designed like container and box or bottle that have big shape and size which contain firstly packaging type and can be contained many parts, normally second type packaging is applied with condition of transportation mode (Albaar, Budiastra & Hariyadi, 2016).

The material characteristic of firstly packaging type is most important that use for packing food/drink, due to not consider for saving food/drink from various attacking of environment outside but it involves with safety of human health that means the materials using must be good and high quality, sensitive, and friendly with products. However, type of material packaging is selected which depend on appropriate of characteristic and convenience of products (Amalini, Norziah, Khan & Haafiz, 2018; Magnier, Schoormans & Mugge, 2016; Soo & Sarbon, 2018). Preventing are attacked by any forces form several conditions like transportation mode and storage situation that affect to food/drink spoil and damage (Sing, Gaikward, Lee & Lee, 2018; Simmonds & Spence, 2017). Packaging of food/drink have difference of style, type of material, and the view image is contained which is also consequence respond to consumer perceptions and behavior of purchase. Therefore, there are packaging material, shape and design as the implications that are discussed (Babalis, Ntintakis, Chaidas & Makris, 2013; Gregory & Spence, 2017; Magnier & Schoormans, 2015; Simmonds, Woods & Spence, 2018; Ooijen, Fransen, Verlegh & Smit, 2016)

2.5.1 Difference of packaging material

The material types are used to pack the food/drink there are many things such as plastics, foam, wool, glass, ceramic, metal, paper, although various composite materials. The packaging materials are used for food/drink must be high quality which consider within friendly, convenient and safe. And selecting of packaging material depend on characteristic and convenience of food/drink. However, the difference of packaging materials got affective judgment of peoples after visual and haptic exploration. The experimental using glass packaged (wine, honey, and chocolate cream) and plastic packaged (yogurt, milk, juice). So, the consequences illustrated that pleasantness judgments of glass packages were higher than plastic packages. Likewise, participants reported to like the product come from glass packages more than products contained in plastic packages were believed (Balzarotti, Maviglia, Biassoni & Ciceri, 2015). Furthermore, current the claims of verbal sustainability about food/drink procedure which is communicate eco-friendliness, then the applications of sustainable packaging are being developed by companies are more and more. Due to considering about environmental, the packaging is one thing in group of stuff is produced and using so many a day, if the materials are used could not recycle or products no re-use after using. These products are waste, and they will increase more and more, so they are big problem in the way of environmental (Magnier & Schoormans, 2015). However, considering with glass packaging and wood packaging are great alternative are selected to apply with the packaging of fluid product are olive oil, tsipouro and raki. Because wood wastes in ecological aspects, and glass could re-use or recycle (Babalis, Ntintakis, Chaidas & Makris, 2013).

2.5.2 Shape/style of different design

Selecting fit and form of product packaging, especially food/drink which influence to consumer perception and purchase behavior, so making several design of food/drink packaging is a process in food/drink procedure that is too significant and could add potential for selecting of consumer. Food is contained with many styles of design packaging which occur many images in view of consumer that influence purchase behavior. The image of food has become noticeable visual incentive in the consumer mind. They are efficient of promoting for food like both feelings of hunger and desire as well. The visual design is demonstrated by using many product packages and prints. Conventionally, using the attractive visual imagery illustrating the product in packaging from outside which has primarily achieved. Presently, however, in packaging have been developed that increasingly make enabling designer could add elements of transparent more, so it is allowing before consumers purchase, they could directly see product. Normally, transparency is used in product packaging as marketplace of food/drink that is appearing more frequently. According to the estimation results from US, they were suggested that transparency was presented in between 20% to 77% of all packaging, depending on product category (20% of chips, 20% of cookies, 23% of crackers, 77% of nuts. Furthermore, similarly from comparing results, they really knew about the packaging of transparent that was more than the effectiveness of product imagery. For packaging designs, the product image on opaque packaging, or plain opaque packaging, and a window of transparent were the key considerations. Therefore, the fact about willingness to purchase, expected freshness, and expected quality were taken into considerations and increased where the value of transparent packaging was more than the one used food-imagery platform. The windows of transparent on product packaging could lead to increase willingness to purchase. This was suggested with mediation analysis results (Simmonds & Spence, 2017; Simmonds, Woods & Spence, 2018).

2.6 Shock and vibration of product during transportation

2.6.1 Road characteristic and distance

Shocks and vibrations are occurred from many factors that directly affected to product shipments during handling and transportation, in those several factor both the road characteristic and road distance are two main factors that have frequently in product shipments. Especially, road characteristic that means different type of road conditions received different values of shocks and vibrations. The types of road conditions such as laterite road surface, asphalt road surface, concrete road surface, and highway. However, all of those road conditions were presented about level of rough or smoot road surface, and all through road curvature, beside behavior of drive as speed was depended with them. Furthermore, the ways were indicated there were not only road characteristics of truck, but they still guided and used with any mode of transportation like water for boat, railway for train, pipeline for pipe, and air for airplane, and these modes of transportation occurred resonances to products, that got different frequency of vibrations and shocks too. Similarly, distance of road that means different length of road was occurred different frequency values of shocks and vibrations. The long distance of road as illustrating in the way of times were exactly long, which consequence as shock and vibration were more increased (Berardinelli, Donati, Giunchi, Guarnieri & Ragni, 2003; Böröcz, 2018; Jarimopas, Singh & Saengnil, 2005; Lu, Ishikawa, Kitazawa & Satake, 2010; Lu, Ishikawa, Shiina & Satake, 2008; Paternoster, Vanlanduit, Springael & Braet, 2018; Soleimani & Ahmadi, 2014; Singh, Singh & Joneson, 2006).

2.6.2 Difference of product packaging, and product loading

Selecting the different material for secondary packaging packed products, e.g. product beer bottles were contained within container as crate. The types of crates are taken for experiment comprise plastic crates, corrugated boxes, and cardboard crates with plastic foil. All of those crates were used for experimental values of frequency vibrations and shocks, thus results demonstrated corrugated boxes and cardboard crates with plastic foil behaved a similar manner, both of them are good vibration damper that means they are low-frequency then plastic crate. However, cardboard crates with plastic foil got some air movement from the beer packaging sides, thus this packaging types are best over all of them, plastic crate are hard body and inside crate has free space between bottles and crate which make beer bottles freedom moving too much that really hard uncontrollable amplification of the vibration, thus it performed worst. Similarly, for shocks were absorbed in corrugated boxes, so save beer bottles, the performing of corrugated is better over plastic in case shock as well (Paternoster, Vanlanduit, Springael & Braet, 2018; Paternoster et al., 2017). Furthermore, amount of product loading, which is capacities of vehicle was carried with different mode transportation when traveling per route also influenced to products and received any frequencies values of vibrations and shocks that each time is not same. Commonly, in case of product loading also presented with mode of any vehicles type that means difference of vehicle such as vehicle model, and vehicle size (e.g., transportation that difference between truck and train) (Paternoster, Vanlanduit, Springael & Braet, 2018). And considering about any trucks were just different capacity of loading as four-wheel truck, six-wheel truck, rigid truck semi-trailer truck, and trailer, including truck two-axle, truck three-axle, truck four-axle. In case, many kinds of trucks were applied within different loading, consequence shown when add more amount of product, the frequency value of vibrations and shocks will be positively increased as well. Furthermore, apart from discussion of truck-axle which also considerer about type of trailer suspension as air ride and leaf spring. Thus, trailer suspension is one more thing that quiet significant lots about type of truck which also fluence to frequency vibration and shock, there are air ride and leaf spring (Berardinelli, Donati, Giunchi, Guarnieri & Ragni, 2003; Böröcz, 2018; Lu, Ishikawa, Shiina & Satake, 2008; Jarimopas, Singh & Saengnil, 2005; Soleimani & Ahmadi, 2014). From experimental data were recorded to found about the average Root Mean Square (RMS) of (G) for 100% was 0.092 G in air ride suspension trailer compared with 0.245 G in leaf spring suspension trailer with an empty condition. Similarly, with loading condition, the RMS (G) were 0.089 G and 0.194 G for air ride suspension trailer and leaf spring suspension trailer, respectively (Singh et al., 2006). A comparison of leaf spring suspension and air ride suspension are illustrated in Figure 2.6. Fadiji, Berry, Coetzee & Opara (2018) showed vertical frequencies range and acceleration of maximum during transportation and distribution were encountered in Table 2.4.

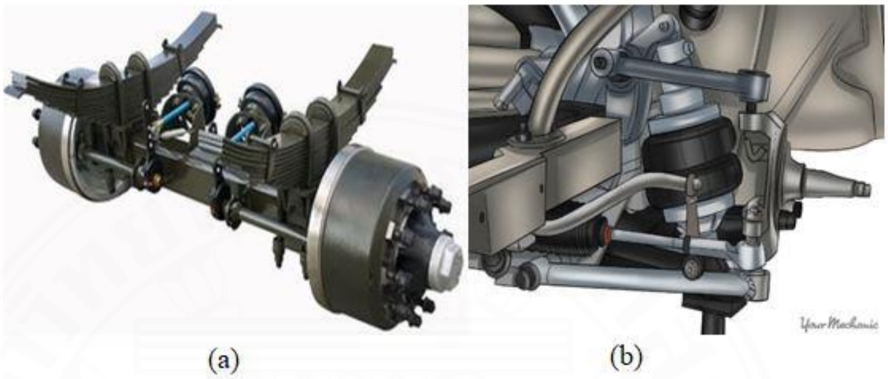


Figure 2.8 Type of truck suspension (a) leaf spring suspension and (b) air ride suspension.

Table 2.4 Vertical frequencies range and acceleration of maximum encountered during transportation and distribution (Brandenburg & Lee, 1993; Eagleton, 1995; Marcondes, 1994; Schlue, 1968; Tevelow, 1983).

Transport mode	Vibrating system	Frequency rang (Hz)	Maximum acceleration (g)
Rail cars	Vertical suspension	2-7	0.5
	Lateral suspension	0.7-2	0.8
	Structural	50-70	0.3
	Rolls	≈ 1	0.1
Trucks	Suspension	0-7	0.5
	Unsprang suspension	10-20	0.3
	Structural and tyres	50-100	0.3
	Damaged suspension	>100	
Trucks on flat cars	Vertical	2-4.6	1
	Rolls	0.7-3.1	10
Aircraft	Propeller	2-10	0.5
	Jet	100-200	0.5
Ships	Sea	0.1-0.2	0.2
	Engines	100	0.4

2.6.3 Location and altitude of product on vehicle

Any positions on vehicle were done with experiment for finding resonance, which is frequency of vibrations and shocks, these positions were presented as type of different products putting on any areas of vehicle such as rear, intermediate, front, bottom, middle, top, left side, and right side. According to, consequence experiments were done with any positions (ground, middle, up and rear axle, front axle), thus considering with position of the container column was presented the average value of Power Spectral Density (PSD) with ground, middle and top there were of 0.0566 G^2/Hz, 0.0861 G^2/Hz and 0.0869 G^2/Hz, respectively in the range 0.1–5 Hz. And observing of the Root Mean Square (RMS) acceleration in the range 11–32 Hz was largely amplified from the position of bottom to the middle and top of the container column. For some frequencies of box level on truck, commonly, the boxes were vibrated within top box were higher more than the bottom and middle boxes, comparing the products were positioned on the column top got whole vibration were also higher than the products in the middle and ground, respectively. Furthermore, comparing between the positions of rear axle and front axle, for the RMS acceleration ranged from 0.95 - 1.48 m/s^2 and 0.65–0.96 m/s base in rear axle and front axle, respectively (Soleimani & Ahmadi, 2014). In case of altitude, when packaging was contained within items which were stacked into many layers of packaging, when observing the difference of level that increasing stack height of packaging, the RMS-values of the vibrations were positively increased as well. From researches were done with plastic crates and cardboard boxes, consequence illustrated the RMS-values of the vibration domain with peak from 5-25 Hz in level of seven compared with 7 -150 Hz in level of nine Paternoster, Vanlanduit, Springael & Braet, 2018).

2.7 Finite element analysis (FEA)

The theory of FEA was initially introduced over sixty-nine years ago, but the computer based design of thermoplastic materials using the FEA has become the standard method over the last 20 years (Hopmann & Klein, 2015). FEA is a computer simulation technique used mostly by mathematicians, engineering and scientists. The technique of FEA is a mathematical system used to solve real-world engineering problems by simplifying them. This numerical method can be used for predicting how a subject reacts to actual forces, stress, strain, frequency, linear and nonlinear, heat, fluid flow, and other physical effect. (Fadiji, Coetzee, Berry, Ambaw & Opara, 2018). Ferthurmore, FEA basic role was that complicated structural model which could be devided into many part component that were too small, then were called elements. A sub-dividing sustem was used in which the differential equation reached the nearby solution. A complex system was used by numerical analysis where is pointd called nodes which made a grid called mash. So this mash was programmed to held the properties of material which determine how the migration will arise. There were software of commercial FEA shuch as ANSYS, ABAQUS, MSC MARC, and MSC NASTRAN. These softwares contained different types of element and properties of material for input variable. Based on the advantages of FEA software, it s about the unlimitations on geometry of package, condition of boundary, and condition of loading. Using FEA software to solve some issues requires three steps: preprocess or structural modelling, numeriacl analysis, and post processing (Fadiji, Ambaw, Coetzee, Berry & Opara, 2018; Fadiji, Coetzee, Berry, Ambaw & Opara, 2018; Pathare & Opara, 2014). And some examples of FEA application in corrugated packaging/paper industry are summarized in Table 2.5 (Pathare & Opara, 2014).

Table 2.5 Examples of FEA applications in corrugated packaging/paper industry.

Study purpose	Research output	References
Predict the top to bottom compression strength of corrugated box	Agreement with a experimental values.	Pommier and Poustis (1989)
Bending stiffness of corrugated board structures	Results were insufficient to determine the terms of the bending flexibility matrix of an equivalent orthotropic sheet.	Pommier and Poustis (1990)
Dynamic interactions between wood pallets and corrugated containers during resonant vibration within the unit load system	Improved the efficiency of the unit load system during transportation and distribution.	Weigel (2001)
Buckling behavior of corrugated paper packages	Able to reproduce with a very good accuracy of buckling loads.	Biancolini and Brutti (2003)
Determine appropriate pattern, Location and size of the vent/hand holes.	The appropriate pattern and location of both the ventilation holes and hand holes based on the FEA simulation agreed well with laboratory test results.	Han and Park (2007)
Study the mechanical characteristics of the layers of the corrugated paperboard affect its complex mechanical characteristics	Model results compared to experimental data showed good agreement.	Gospodinov et al. (2011)
FE simulation with homogenization model and experimental study of free drop tests of corrugated cardboard packaging	Model results were found to be in good agreement with experimental observations	Djilali Hammou et al. (2012)
To predict steady-state moisture transport through corrugated fiberboard	Model showed reasonable agreement with experimental observation	Bronlund et al. (2014)

CHAPTER 3
MATERIALS AND METHODOLOGY

New design of beverage container was carried out and reported in this chapter, also the process of Product Design Development (PDD) was investigated as well. According to the experiment, there are consisting of computer design and computer simulation. Computer designs were used by SolidWorks software, also computer simulation used static simulations were conducted under conditions of stacking, lifting, and interference fit. Based on an existing container (crate) in the market, they are commonly contained of 12 units. The design of new crates with 13 and 14 units is explored in this study. A new first design of a crate with 13 units of bottle consists of two main parts, for example, crate part and insert part. In particular, the dimension of container is similar to an existing container of 12 units. A new first design of crate can be arranged for the units of bottle to 13 units compared to an existing container of 12 units. Furthermore, the new second design of container can be arranged to 14 units of bottle compared to an existing container of 12 units at the same dimension of container.

Firstly, all of the existing crate and newly designed crate were designed by SolidWorks software. Next, the simulation of all crate designs was created under conditions of static loading via Finite Element Analysis (FEA) technique. Based on static conditions, it can be divided into crate stacking, crate lifting, and interference fit. In addition, High-Density Polyethylene (HDPE) and Natural Rubber are considered as main materials for container design. A newly designed crate of 13 units is required to simulate under three different conditions of static loading, while the existing crate and new design crate with 14 units are investigated under two conditions such as crate stacking and crate lifting. This is due to the new design crate of 13 units is composed of the crate body part and inside part, in which HDPE is used for crate body part and natural rubber is made for the inside part. After computer design and simulation of crate design, all designs of the crate were conducted with Rapid Prototype (RP) process, which were made prototypes by 3D printing machine.

Acrylonitrile Butadiene Styrene (ABS) was selected as friendly material for 3D printer. Besides, Figure 3.1 displays the overall processes of this research.

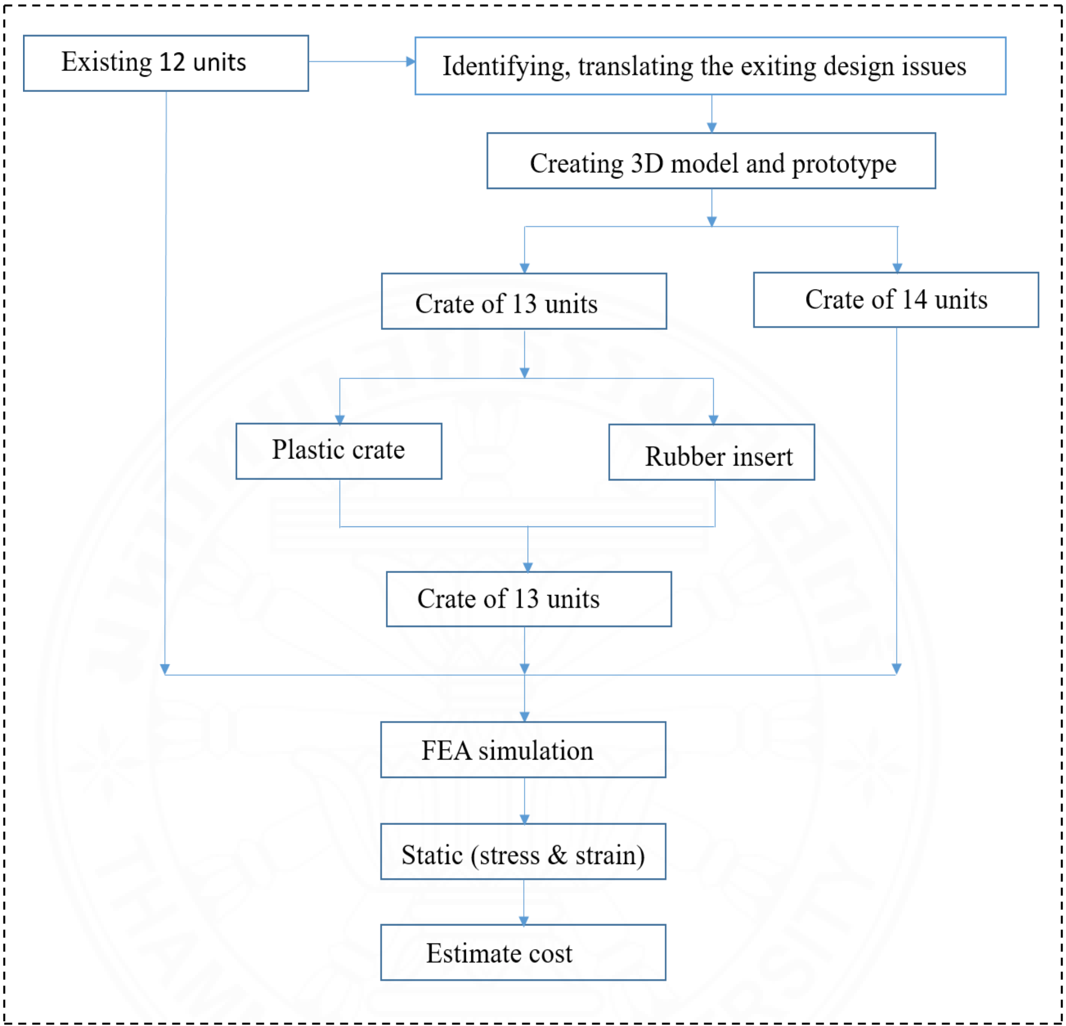


Figure 3.1 Overall experimentation in this study.

3.1 Material

In computer simulations of container designs, HDPE, natural rubber, and glass bottles were selected as components. HDPE has a density and Melt Flow Rate (MFR) of 0.95 g/m^3 and 10 g/s, respectively. Additionally, HDPE can withstand external forces, and resist cracking or bending. Apart from that, HDPE has a lightweight and long shelf-life, where suitable for industrial processing and packaging application. Natural rubber is collected from Heavea Brasilensis, in which possesses high tensile strength, good heat resistance, and low cost. Besides, glass bottles are commonly cylindrical, which has good physical and chemical durability. The cylindrical shape is considered to be an appropriate bottle for beverages because it can maintain the taste of drink and resist pressure. In addition, glass bottles can withstand changes of temperature such as hot and freezing conditions. Also, glass bottles can be recycled up to 50 times. However, ABS material is suitable for 3D printing method, therefore the designed containers were printed by using ABS material. Table 3.1 exhibits the comparison on mechanical properties of HDPE, natural rubber, glass bottles, and ABS.

Table 3.1 Mechanical properties of materials.

Mechanical properties	Materials			
	HDPE	Natural rubber	glass	ABS
Elastic modulus (MPa)	1070	0.01	68935	2000
Poisson’s ratio	0.46	0.45	0.23	0.394
Mass density (kg/m^3)	960	960	2457.6	1020
Tensile strength (MPa)	15-40	22	50	31-51
Yield strength (MPa)	13.8	20	50	29-48
Maximum strain (%)	11	20.2	-	10

3.2 Identification of existing design

Based on Lao Brewery Company, they normally produce beer containers in glass bottles or aluminum cans, in order to distribute the produces to retailers and customers. For domestic transportation, glass bottles are packed within hard plastic crates, while aluminum cans are packed within cardboard boxes. The main reason that companies use hard plastic crates for glass bottles is based on their policies of returning and reusing glass bottles. These policies induced the companies to accommodate the recycling logistics and reduced the production time as well. In addition, the policy on returning glass bottles encourages sustainable environments. Moreover, both of them are packed with cardboard boxes for overseas transportation. Figure 3.2(a) illustrates the commercial products where the glass bottle volume is 640 ml. Glass bottle height is 285 mm, while the diameters of bottom and top parts are 67 mm and 24 mm, respectively. In general, HDPE is used for plastic crates with a dimension of 375 mm x 280 mm x 298 mm, in which the total weight is 1800 g. HDPE crate can contain glass bottles of 12 units. Besides, Figure 3.2(b) displays the 3D model of a commercial crate (simplified) (Phlernjai, Rianmora & Phommixay, 2019). According to transportation and delivery of beer products, there are many types of trucks are used such as rigid truck (6–wheels to 12-wheel with both closed and opened container types), semitrailer truck (10-wheels to 18-wheels, and trailer (4-wheels to 16 wheels). In transportation, pallets are used for supporting the beer packaging. Pallets are generally made from wood and plastic, which the biggest dimension is 1200 mm x 1200 mm x 15 mm. The biggest pallets size can arrange with 3 x 4 crates array at the first level, and maximum loading is approximately 8-10kN (1000 kgf). However, there are limitations in the transportation of beer products; the dimension of truck containers and beer crates. Therefore, the design of inside plastic crates could increase the capacity of glass bottles.

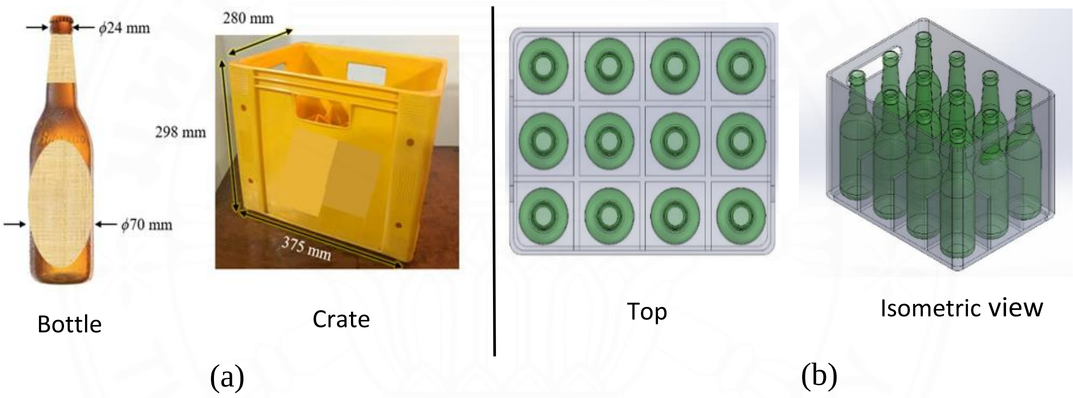


Figure 3.2 (a) Existing 640 ml glass bottle and plastic crate, (b) 3D Model of existing crate (simplified).

3.3 Identification of new design

3.3.1 System-Level Design

A new design of beer crate presents the physical characteristic with two main components as crate body (outer) and insert part, in which insert part is considered as level one. For crate body is considered as level two, which consists of four parts. These four parts are the number of bottles, size of bottles, layout of sockets, and applied force. Particularly, applied forces can be considered in conditions of stacking and lifting. Static loading of the conditions is simulated via FEA software. On the other hand, an insert part is required for condition of interference fit. An interference fit condition is simulated via FEA software, where considers on insert part and applied forces that act between glass bottle and insert part. Diagram of physical characteristics of newly designed crate is presented in Figure 3.3 (Phlernjai, Rianmora & Phommixay, 2019).

On the other hand, an insert part is required for condition of interference fit. An interference fit condition is simulated via FEA software, where considers on insert part and applied forces that act between glass bottle and insert part. Diagram of physical characteristics of newly designed crate is presented in Figure 3.3 (Phlernjai, Rianmora & Phommixay, 2019).

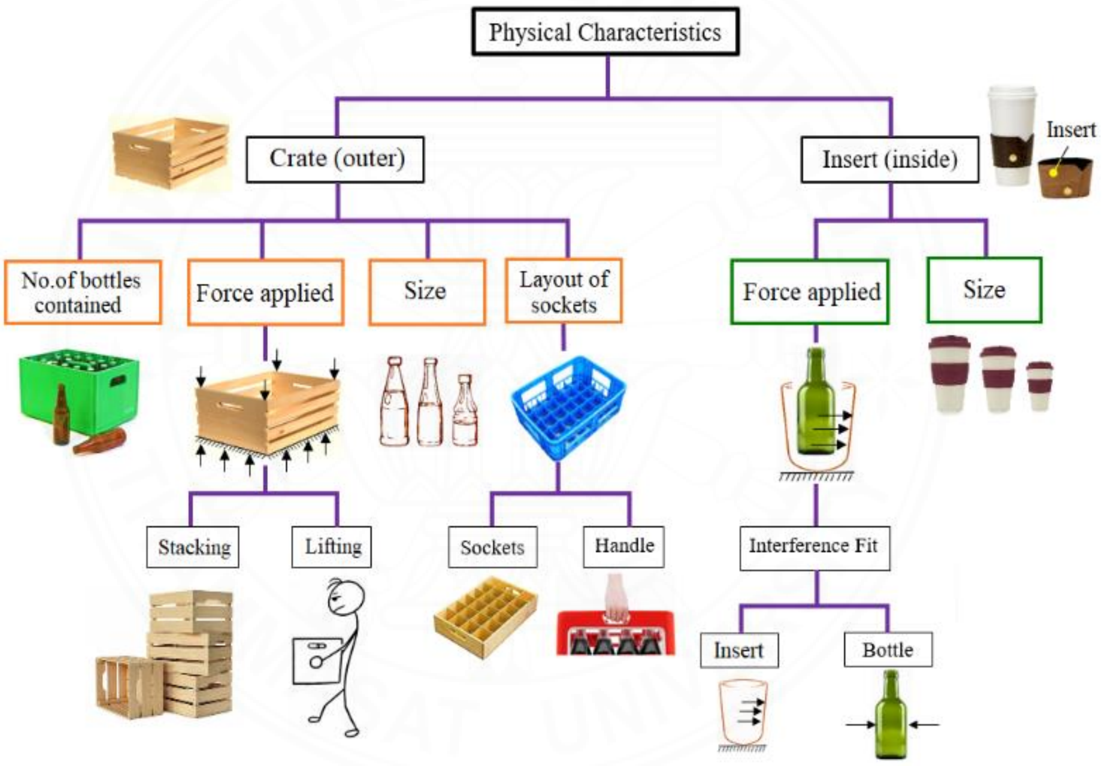


Figure 3.3 Structure diagram of the propose approach.

3.3.2 Detailed design

Incremental loading of beer capacity and reduction of vibrations and shocks during transportation are the achievements required in this study. Based on an existing design, a crate is divided into 12 units with square shapes. However, beer glass bottles are generally cylindrical shape, in which there is a gap between glass bottles and crate slots, so circular slots should be a better alternative. These gaps create the frequency vibration during transport. Therefore, design on crate slots from occupies shape to a circular shape can reduce the gap approximately 6.5%. Figure 3.4 illustrates the concept, where the dimension is reduced from 2D to 1.87D (Phlernjai, Rianmora & Phommixay, 2019).

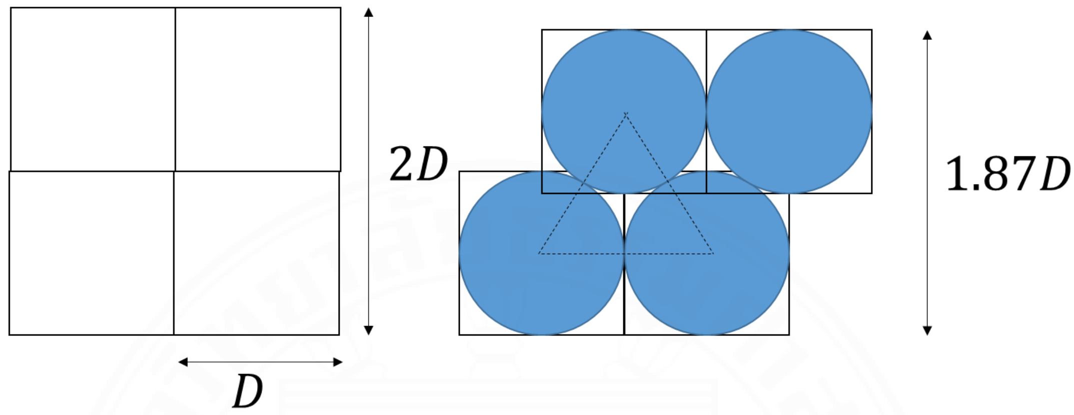
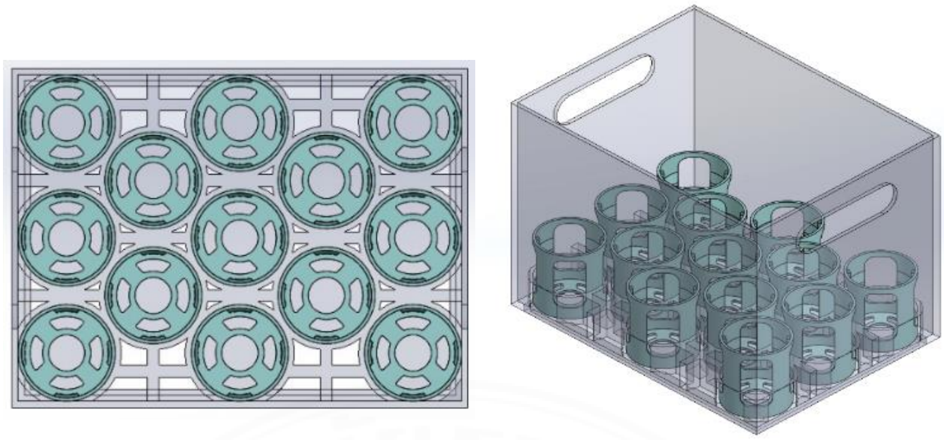


Figure 3.4 Concept of using circular socket instead of rectangular socket.

Development and improvement of new crate design are aimed to increase the capacity of crate compared to an existing design of 12 units. New designs of crates are crated based on the same dimension of the existing design. In this study, the capacity of beer glass bottles are created from 12 units to 13 and 14 units for new crate designs.

First, the new crate design is created with 13 slots, which can contain 13 glass bottles as exhibited in Figure 3.5. This new design has two main piece such as crate body and insert parts, which is different with existing crate design has a main piece and difference of inside crate (occupies for existing and cylinder for new design). In addition, individual part is inserted as an assembly with diameter and height of 80 mm and 90 mm, respectively. An insert part is designed with locking system with 4 positions, in order to absorb the vibration and movement of glass bottles as displayed in Figure 3.6. Insert part possessed an inner diameter of 68.5 mm. The next name of this new crate design will be called as “crate-assembly platform” (Phlernjai, Rianmora & Phommixay, 2019).



Top view Isometric view

Figure 3.5 First proposed crate-assembly design with insert plus socket.

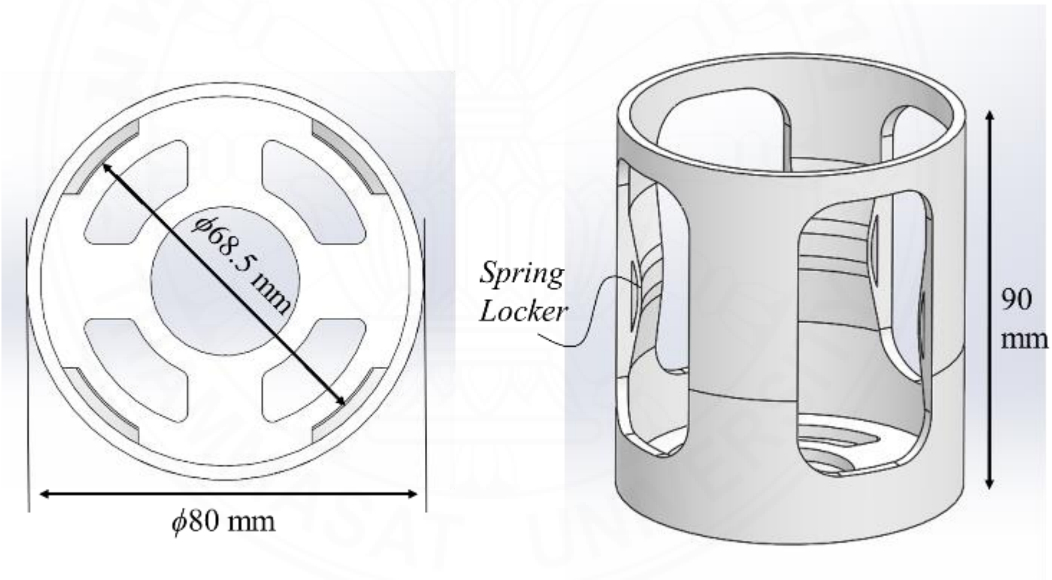
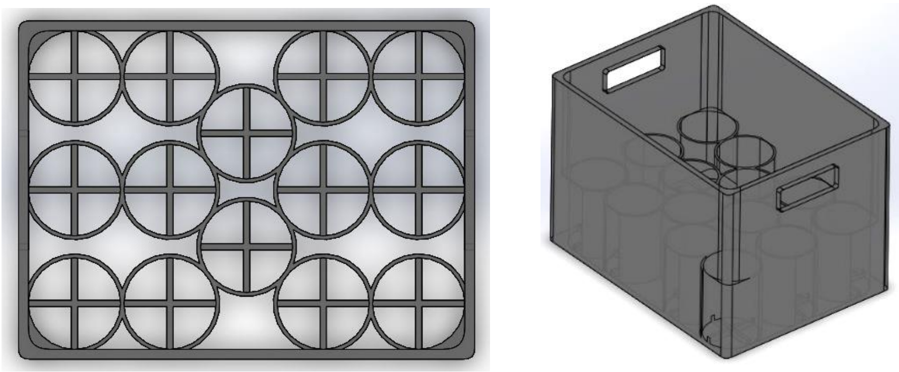


Figure 3.6 Second proposed design of the insert for plugging into crate sockets.

Second, the new design is created with 14 slots, which can contain 14 glass bottles compared to an existing design. The circular shape slots have a diameter of 76 mm with a height of 123 mm as presented in Figure 3.7. This new design is a main piece along with crate body and slots parts, which same with existing crate design but it is different inside crate (occupies for existing and cylinder for new design). The next name of this new crate design will be called as crate-fourteen.



Top view Isometric

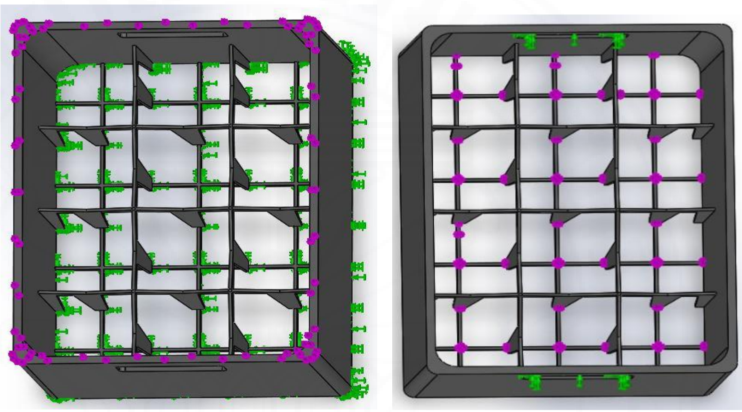
Figure 3.7 Proposed design of crate-fourteen as 14 slots.

3.4 Static simulation with FEA

According to static analysis, there are three conditions are required, such as crate stacking, crate lifting, and interference fit. These three conditions are applied by using the FEA simulation; however, an interference fit is only specific for the crate-assembly design. In stacking crate conditions, the force loading with an accumulated weight of stacking crates is considered, where crates can be stacked of 5-7 crates. The stacking crates are notably full capacity of glass bottles. Besides, crate lifting conditions related to force loading with the weight of total bottles inside the crates. Conditions of interference fit are specific for crate-assembly, which only consider on load with the fixture. To conclude, the existing design and new design of crate-fourteen are investigated under crate stacking and crate lifting, while an crate-assembly with 13 units is required to be investigated under 3 conditions of crate stacking, crate lifting, and interference fit.

3.4.1 Existing crate model

Normally, an existing crate with 12 units has 13.8 kgf in weight with total loading. The weights of an empty crate and filled-up crate are 1.8 kg and 12 kg (12 of 1-kg beer glass bottle), respectively. Based on static stimulation with FEA, the existing crate is considered to simulate in 2 conditions of crate stacking and crate lifting. Figure 3.8(a) illustrates the simulation of an existing crate under stacking crate conditions. Simulation is applied with stacking height of 4 to 6 crates with full capacity of glass bottles during transportation per trip, which equal full capacities of 55.2 to 82.8 kgf, approximately. However, this static simulation the crate model was subjected to force load approximately of 90 kgf. Positions of the action forces and the fixed position were considered as the whole area of crate's wall and bottom parts, respectively. Figure 3.8 (b) presents the crate lifting conditions of an existing crate design, this simulation was considered the carrying condition of the crate. The total load was simulated with the weight of glass bottles inside the crate slots, the crate was subjected to a total capacity of 2 kg where 1 slot could support of 1 kg. Fix positions were considered at the two holdings and load acting on the bottom of inside crate.

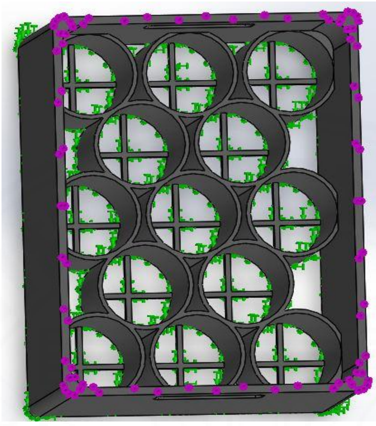


(a) (b)

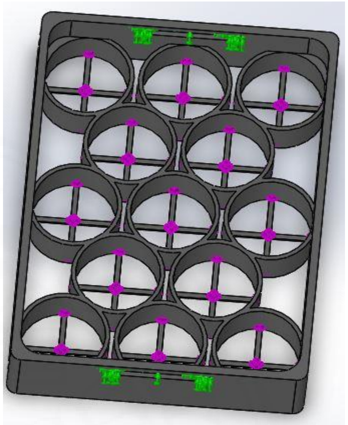
Figure 3.8 Force position and fixed position of existing crate model, (a) Stacking condition and (b) Lifting condition.

3.4.2 Crate-assembly (crate body) model

Based on the assembled crate, it composes of two main parts; body part and insert part. This section describes about the model of crate at the body part, while the insert part will be explained in the next section. In static stimulation with FEA, the body part was tested with two conditions as same as the existing crate model. A full-up crate with 13-glass bottles (1 kg each) with the insert parts indicated the fully loaded weight of 15 kgf; this means the sum of "13 groups of 1 (13 bottles x 1 kg each)" and "2-kg weight of crate". Stacking conditions of 4 to 6 crates with full capacity exhibited the loading approximately of 60 to 90 kgf during transportation. However, loading under stacking conditions was purposed to achieve about 100 kgf (Phlernjai, Rianmora & Phommixay, 2019). The acting force direction and fixed positions are presented in Figure 3.9(a). In the second conditions of crate lifting, carrying by hands as everyday-life processes was considered. During the crate was handed, the total weight of crate with full capacity of beer glass bottles was approximately 13 kgf. Figure 3.9(b) illustrates the direction of acting forces and fixed positions.



(a)



(b)

Figure 3.9 Force position and fixed position of crate-assembly model. (a) Stacking condition and (b) Lifting condition.

3.4.3 Insert part of crate-assembly

According to crate-assembly platform, it was considered under interference fit condition where the flexible insert part (i.e., natural-rubber material) was designed to have interference fit with glass bottle. The load-fixture and fix positions setting are displayed in Figure 3.10. Insert parts can support and absorb the shock and vibration of beer glass bottles during transportation. Also, the glass bottles should not be exerted force of excessive and damage from fitted inserts. This simulation is conducted to verify the stress distribution around the insert and the glass bottle with interference fit (assembly) condition. Doing this can check and ensure that there are no excessive forces found after putting the glass bottle inside the rubber insert. For the simulation, the size different is assigned as the load where the insert-bottle assembly is divided into 4 portions as a quarter form. The symmetric constraints are applied to minimize the time spent for calculating FEA simulation. The area around bottom part of insert and the lower portion that is attached with the socket of crate are assigned as the fix positions (or areas) in the simulation platform (Phlernjai, Rianmora & Phommixay, 2019).

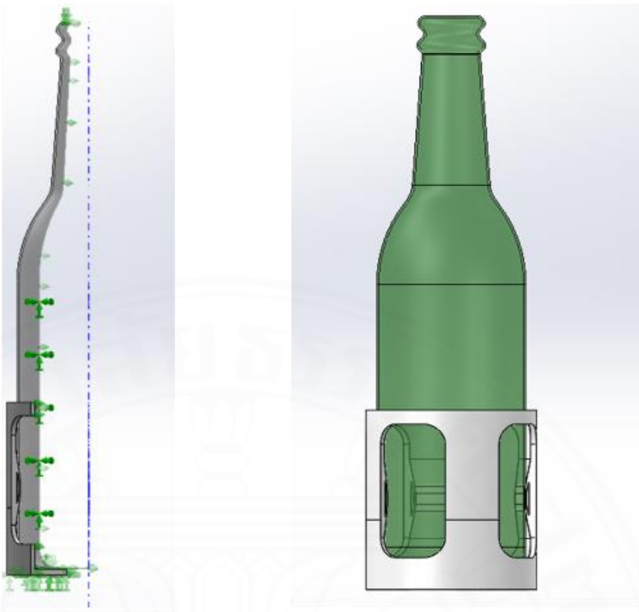
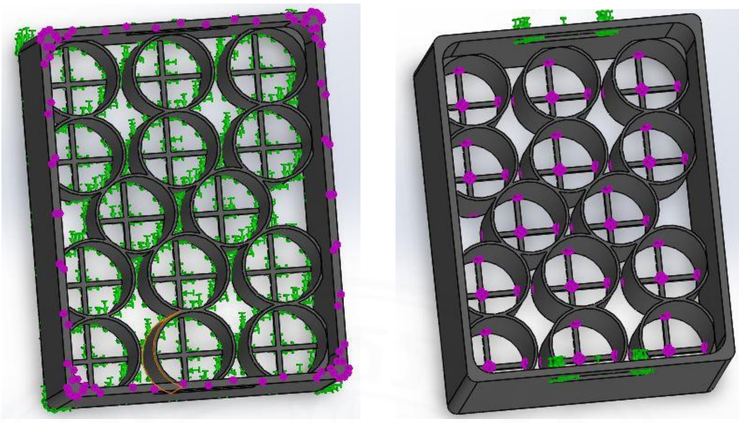


Figure 3.10 Simulation setting for interference fit between insert and glass bottle.

3.4.4 Crate-fourteen model

A new crate design of 14 units (for each bottle, its weight was almost a one-kilogram) was counted with the weight of 2-kg crate; the total weight (full capacity) was around 16 kgf. For testing activity, two conditions were applied. The first one was about stacking level of height 4 to 6 crates; therefore, total loading capacity of a crate was approximately 64 to 96 kgf, respectively. For the calculation or total load capacity was implied about the force occurred around the walls of crate. In order to estimate the loading capacity with concerning about safety during transportation, assigning higher value of loading capacity than the maximum of the calculated one (96 kgf) might be better and suitable enough. Therefore, in the simulation of crate-fourteen model, the loading capacity was approximately assigned as 120 kgf. The force acting direction and the fixed position are illustrated in Figure 3.11. Continually with the second condition, the crate lifting was purposed with the same concepts as the actions performed by human; carrying and holding a crate by two hands. Since the crate was handed and carried from one place to another with different speeds and forces, the total loading weight was considered around the bottom areas of a crate (according to the gravitational force concept) where the weight of 14-glass bottles contained inside the crate was the key consideration.



(a) (b)

Figure 3.11 Force position and fix position of crate-fourteen. (a) Stacking condition and (b) Lifting condition.

3.5 Prototype making

In this research, three prototypes of crate were fabricated by applying 3D printing machine (XYZ printing - da Vinci 1.0). The maximum size of subject could be made as 200 × 200 × 200 (mm), the ABS filament with 1.75-mm diameter was applied. Firstly, the STL file of 3D-crate model (the first model) was imported to the computer via "XYZware software" platform. Then, adjusting the proper scale, rotation view, and some printing parameters were needed. Next, the machine started to warm the nozzle (printing head) and the calibration activity was performed according to the standard and requirement of the machine. Finally, the prototype was fabricated layer by layer where the scale of a prototype was reduced by 20% from the full size of the actual crate designed in CAD platform. Repeatedly, all steps mentioned above were required for completely fabricating model no.2 and no.3 which were uploaded and imported to the XYZware platform in seconds. Moreover, the setting parameters for supporting smooth and clear features of the prototype were assigned for all three prototypes of the crate models. Figure 3.15 illustrates 3D printing machine used to fabricate three crate prototypes.

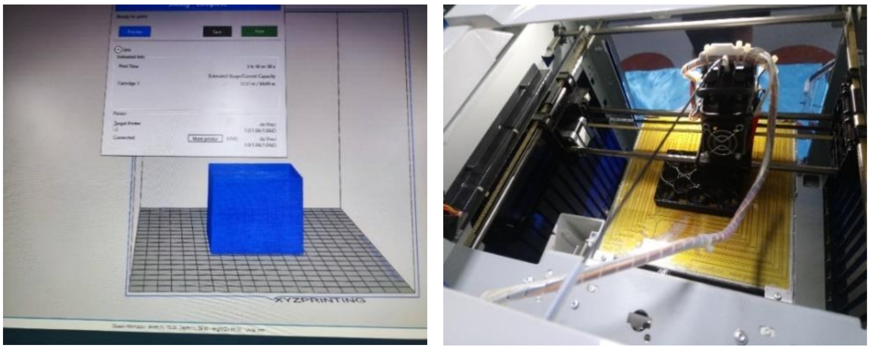


Figure 3.12 Process of making prototype with 3D printing machine.

3.6 Mechanical testing

Strength of mechanical is the potentiality of materials what is the maximum stress or physical loading force applied onto it. The mechanical strength (i.e., compressive strength) was applied to test the specimen for getting values of stress. The parameters of testing are as follow. The testing of compressive strength is performed by persevering force downward on top of specimen to the bottom is shown in Figure 14. During testing, the applying loading force onto the specimen keep going until it fractured. Then, the value of stress was formulated by pervading the loading force at fracture by cross-sectional area using the Equation of 3.1. The compressive strength value is the load applied during fracture and represents the cross-sectional surface area of the rectangular shaped specimen.

$$\boldsymbol{\sigma = \frac{F_{max}}{A}} \qquad \text{(Eq 3.1)}$$

Where:

σ = Compressive strength (MPa)

F = maximum load applied (N s/m^2)

A = Cross sectional area (mm^2)

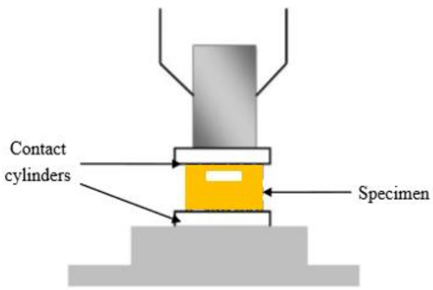


Figure 3.13 Schematic illustration for the compressive strength measurement.

CHAPTER 4
RESULTS AND DISCUSSIONS

This chapter discusses about the results of the packaging designs where the sets of comparison between the exiting crate design and the two designs (crate-assembly and crate-fourteen platforms) of 3D CAD models are presented. Using the simulation of Finite Element Analysis (FEA) technique where the High-Density Polyethylene (HDPE), natural rubber, and glass are applied as the main materials for supporting the simulation stage. Three main conditions of static simulation are considered; stacking, lifting, and interference fit. In this static simulation, it was conducted to verify the stress-strain distributions of the exiting crate model, the crate-assembly model, and the crate-fourteen model. In model of existing crate was finished with two conditions of static simulation like crate stacking and crate lifting. Two simulation conditions (i.e., crate stacking and crate lifting conditions) applied in the existing model case were performed again in both designs of crate; the crate-assembly, and the crate-fourteen platforms.

Moreover, for the crate-assembly design, one more simulation condition was required; “interference fit condition”. Thus, the crate-assembly design was totally conducted under three conditions. Since the crate-assembly platform composed two main components; sockets of crate, and inserts parts. The interference-fit situation was found around the contacting areas between bottles and inserts.

For the existing and the crate-fourteen designs, these two provided the set of slots or pockets with organized pattern inside the crate to keep bottles in place (i.e., one slot could hold and keep one bottle). However, some gaps between a glass bottle and a slot were found. These gaps might make some noises or vibrations during transportation. With high frequency of noise and vibration, force was produced and this could perform as the impact or the action of one object coming forcibly into contact with another (this action might break a glass bottle). Containing gaps between objects could not apply the concept of “interference-fit condition”.

4.1 Simulation with "the existing crate model"

4.1.1 Crate stacking condition

According to the static simulation of the existing crate; with the condition of crate stacking, the external loading force was totally considered as 90 kgf at the top area of the crate, and the fixed positions were assigned around the whole area of bottom part of the crate. The consequents were occurred from this simulation where all considered points were affected and appeared around the whole area of the crate model. The point was gotten less effect until most effects were presented with shape changing and color shown in the red areas of all corners of the holding positions.

Most points were presented around two (topmost) areas of both sides of holding parts, and these areas were indicated as the points which were gotten the most negative effect of force applied. It was also called as the critical point as illustrated in Figure 4.1. The stress and strain were defined by the simulation of static condition. Base on the material applied in the existing crate; HDPE, this was applied as the input information for the simulation purpose. Looking from the consequent of static simulation could convey the results that the maximum values of stress and strain were about 0.8096 MPa and 0.0004825, respectively.

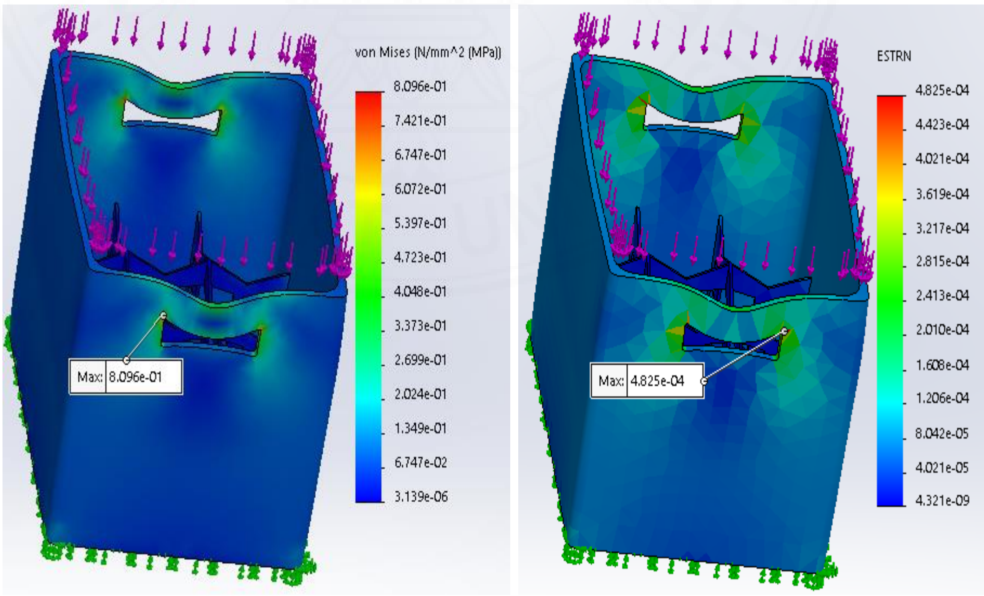


Figure 4.1 Stress-strain simulation results when crate stacking condition was applied (the original crate design).

4.1.2 Crate lifting condition

For the static simulation of crate lifting condition, the method was similar to the case of crate stacking where the fixed and loading positions were applied as the concerned parameters. However, both positions were changed where the fixed positions were moved from the bottom areas of the crate to be the two areas of holding portions of the crate, and the loading positions were applied around the sockets (internal portions) as shown in Figure 4.2.

The total capacities of loading are equal to all weight of full glass bottles contained inside the crate; the loading forces were applied as 12 kgf. According to the consequents of this simulation, the condition of crate lifting one was defined as stress-strain distribution. The red positions could be represented as the critical points which were occurred around two (top) areas of the entire part of middle sections. These sections were used as the walls for dividing each unit. The side areas were indicated as the maximum values of stress and strain which were presented as 13.72 MPa and 0.00768, respectively.

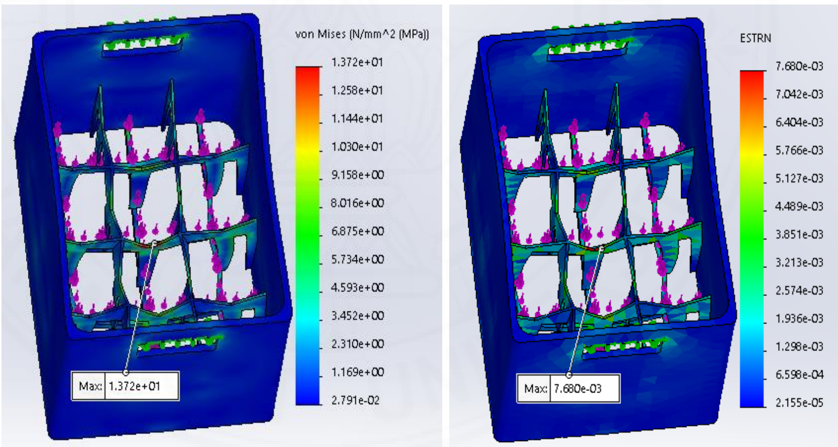


Figure 4.2 Stress-strain results from the simulation of crate lifting condition (the original crate design).

4.2 Simulation with "the crate-assembly model (crate body)"

4.2.1 Crate stacking condition

This section will present about the simulation result from FEA where the crate-assembly model has been applied in this study based on the same outer profile and specific characteristics (i.e., dimensions, weight, and material) as the existing crate. However, the inside type of this design was different from the existing one. The new one (i.e., the crate-assembly design) was improved for supporting more spaces and containing areas; from 12 units (the original crate) to be 13 units (the crate-assembly design). The setting parameters of static simulation were assigned as: load was 100 kgf which acted on the top of model with the same pattern as the existing crate, and also, the fixed positions were distributed around the bottom areas of model.

For crate-assembly crate and the existing crate, the consequents and the results obtained from the simulation could convey the same style of data where the critical points indicated as red color were appeared at the area of interest similarly to how the simulated existing crate were obtained; these two designs contained same pattern of shape and size. However, the values of stress and strain distribution were different; 1.233 MPa for the stress, and 0.0007619 for the strain. These values were higher than those of the existing crate model.

Even though the testing condition (i.e., crate stacking platform) of the existing model and the new model was the same, the result of new model obtained from FEA could be implied about the load applied (90 kgf) that was higher than the existing one. The values of stress-strain simulation were higher than the previous one.

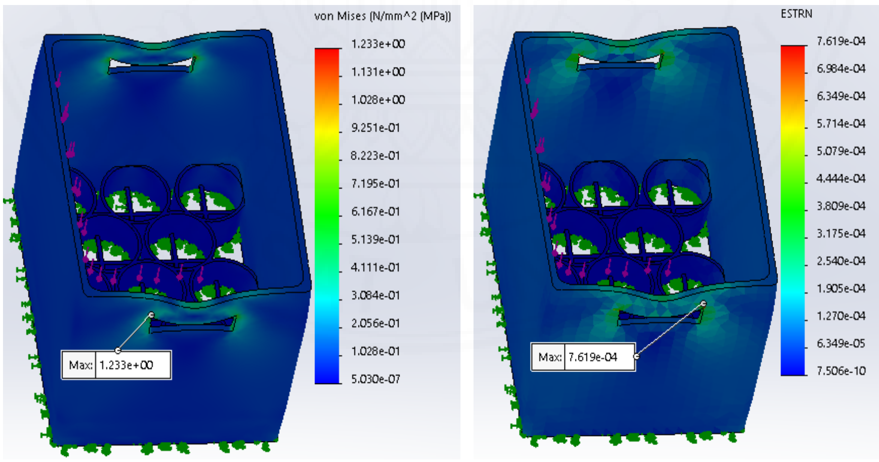


Figure 4.3 Simulation results of stress and strain with crate stacking condition (the crate-assembly design).

4.2.2 Crate lifting condition

This condition applied in this simulation was related to "the crate lifting scenario" where the crate-assembly model that contained 13-glass bottles plus 13-

inserts were plugged into the slots or sockets inside the create. The crate model was subjected within load-fixture totally of 13 kgf where 1 kgf means one beer glass bottles combined within insert could be supported by a socket. The pattern of simulation was similar to how the crate stacking condition was applied; however, the fixed positions were assigned around two handles and the load acted around the bottom area inside the crate model.

Figure 4.4 illustrates the consequents of stress-strain distribution obtained from FEA where the reddest color areas were presented within the top areas of two handles. These results presented some details differently comparing to the positions found in the existing crate model with crate lifting condition. The stress and strain values were appeared as 9.996 MPa, and 0.006456, respectively.

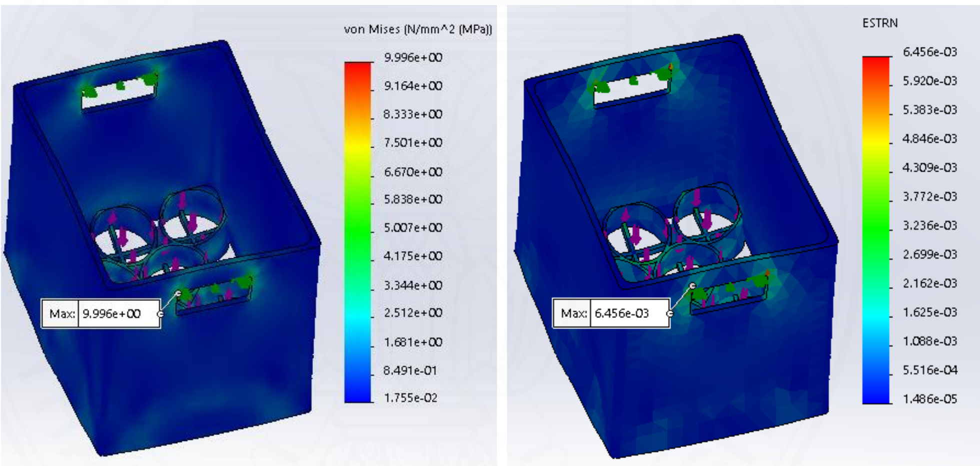


Figure 4.4 Simulation results of stress and strain with crate lifting condition (the crate-assembly design).

4.2.3 Interference fit condition between insert and bottle

In general, the most ordinary way to protect against breakage is to place the glass bottle carton or glassware in a bigger carton box, and fill the space with over packing materials, which acts as a cushioning material or supporter to absorb normal vibrations, forces, and collisions during transit or handling.

Thus, in this study, the key consideration was about "*how do we stop bottle from breaking during transportation?*", and "*no space between the insert and the bottle*" concept might be the proper direction to be applied. These had let to the proposed concept where the inside portion of each cylindrical-shaped slot was attached with four inserts which were used for reducing gap or space between the slot and the glass bottle.

"Interference fit" was mentioned as the condition that shape and size of the inserts were contacted and fitted to the outer boundary of the geometric shape of a bottle. Phlernjai *et al.* (2019) introduced about the simulation of interference fit condition that was different from the previous two conditions: *crate stacking*, and *crate lifting case*. The consideration of simulating activity was emphasized around the attached areas or the areas between insert part and glass bottle part during transportation. The fixed positions were assigned around three main areas of a glass bottle; bottom, body, and bottleneck. For the expected results, around fitting areas, the glass bottle should not be received the excessive force from the insert where the bottle could be positioned tightly in place for a whole period of transportation activity. The result was divided into two main portions; insert part, and glass bottle part. The stress-strain distributions occurred on both portions were verified. Illustrated in Figure 4.5 are the simulation results of stress-strain distributions where the real deformation and X10 deformation were appeared in the insert part. The material applied for this simulation was the natural rubber, and the pattern of insert was formed as four-locking positions. Thus, during combining with a glass bottle (i.e., the quarter touching areas), the constraints of symmetric platform were used to decrease the calculation time of FEA. The maximum values of stress and strain found in each quarter as 0.000311 MPa and 0.00216, respectively. Figure 4.6 illustrates the stress and strain distribution of the single unit of glass bottle. From the consequents of simulation, it was found that around the contacted areas between the four locking positions of insert and the bottle were affected by force or compressing action. Based on the glass material, it was slightly affected to the shear force or the impact one comparing to the natural rubber used for making the insert. The maximum stress and strain values were around 0.000836 MPa and 0.00000000662, respectively.

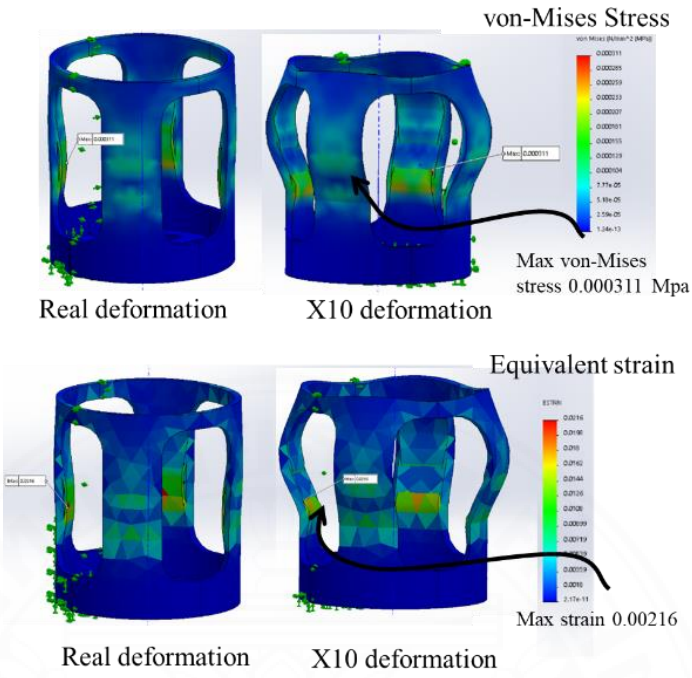


Figure 4.5 Stress-strain contribution with interference fit condition (rubber insert part).

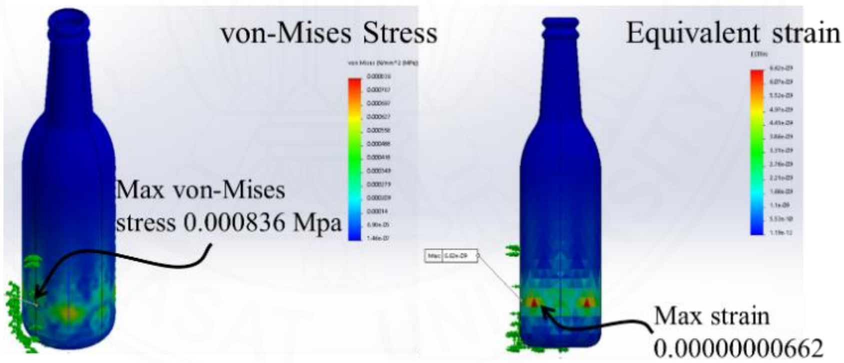


Figure 4.6 Stress-strain contribution with interference fit condition (glass bottle part).

The conclusions obtained from this testing were explained like these following statements:

- According to simulations consequents (Figure 4.5 and Figure 4.6), the insert and bottle were attached, the inserts were applied around four areas inside the cylindrical-shaped socket and acted as four locking positions.
- In each position, it presented as the red color which indicated the maximum points of them, and also were called as the critical points.

- The consequent within glass bottles was a bit different, it was true where was effect area as side of glass bottle contact with four locking areas, but the effect areas was always changed, when every time is taking for assembly.
- Anyway, the considering to results both of insert and glass bottle were leaded to verify stress-strain contributions were very low, especially glass bottle, which to ensure that no excessive both of stress and strain were found due to the interference fit assembly condition.
- Therefore, the FEA simulation with interference fit condition was accepted with this type of insert was designed and rubber material was selected (insert).

4.3 Simulation with "the crate-fourteen model"

4.3.1 Crate stacking condition

The crate-fourteen design was considered in this testing platform 14-glass bottles could be inserted and positioned inside the crate. Method and testing platformed applied were the same pattern as in the existing model and the developed version (i.e., the first model). The fixed and loading positions were assigned according to the platform and pattern used in the previous designs. However, the capacity of loading or the amount of bottle was in that could be placed inside the crate was increased; thus, the force applied was increased well. Figure 4.7 illustrates the simulation of steps which were occurred within any area of crate model where the presented areas were considered as the most affected zones which were in red color. This emphasized red color appeared to verify type of the maximum values of stress and strain: 1.163 MPa and 0.0006509, respectively. The result of stress-strain based on this new design with HDPE indicated that the final design could support one more glass bottle comparing to a new crate of the first version and two more slots added comparing to the existing crate. However, the areas which had been affected and occurred errors were still the same as the previous two designs of the crate. The maximum values of stress and strain were occurred which were too low; therefore, this simulation of the stacking-crate condition was interesting enough for being applied in the real-world application – since the obtained conditions were accepted and followed the set points.

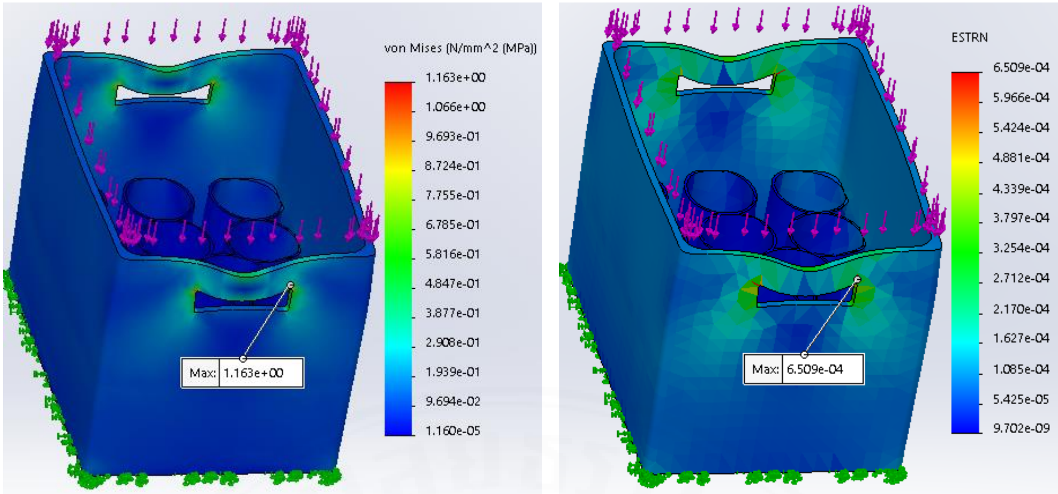


Figure 4.7 Stress-strain results of crate stacking condition (the crate-fourteen design).

4.3.2 Crate lifting condition

In the crate lifting condition of a new design of the second model – the final model, all of simulating activities were performed under the same constraints and conditions set by the researcher – same as the previous two models: the existing crate model, and the crating-assembly model which was considered to fix the positions and the direct force performing to crate areas around the bottom portions.

According to a crate lifting condition, the simulation was focused on how to carry a whole object (i.e., a crate with full-slot bottles – 14 glass bottles) with applying speed (both decreasing and increasing scales of movement) and full containing of glass bottles. Figure 4.7 illustrated the affected areas which were occurred from the simulation of a crate model of the final design. Around the two holding positions of this final design, the results presented details which were similar to the lifting conditions of crate-assembly model. However, appearing of red areas or critical points were similar to the previous design. For the values of stress-strains distributions, they were quite different from the lifting conditions of a crate-assembly model.

Due to the capacities per crate which were larger than the existing crate and a new crate of the first version, the load or force at the area of interest was increased; it was the reason that the negative effect was huger. The result of the simulation is shown in Figure 4.7. The values of stress were 10.47 MPa and strain was 0.006744;

these values of stress-strain were high comparing to the lifting conditions of existing model and a new model of the first version.

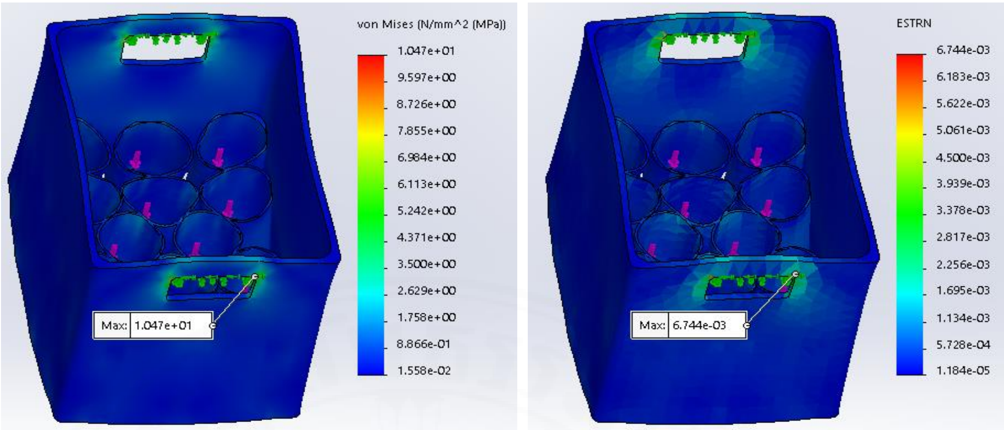


Figure 4.8 Simulation results with stress-strain of crate lifting condition (the crate-fourteen design).

CHAPTER 5
CONCLUSION AND ECONOMIC

This chapter consists the consequence of static dynamic simulations which are appeared in three different types of crate design; *existing design*, *crate-assembly design*, and *crate-fourteen design*, and the simulation of three conditions; *crate stacking*, *crate lifting*, and *interference fit between insert and glass bottle* (only crate-assembly). The calculation parts of transportation cost are constructed by considering the specific conditions of the two designs (crate-assembly and crate-fourteen platforms) and the existing design during transportation per route where the rigid truck with six wheels is applied. For the final section of this chapter, the manufacturing cost was considered to compare three types of crate based on processing of producing crates; however, during COVID-19 pandemic situation, creating a real workpiece as plastic forming process could not be performed. To investigate the physical characteristics and functions of the provided slots inside the crate, fabricating a prototype with rapid prototyping technique (i.e., 3D printing technique) was applied.

For supporting a design team or division, some recommendations of crate design platform were mentioned and discussed to minimize the risk of falling, equipment failure, and broken part during transportation with trucks.

5.1 Conclusion

The objective of this research is to develop an alternative channel for supporting beverage-crate transportation where the glass bottle is the key addressed issue. Applying this proposed approach, the manufacturer can deliver glass bottles easier with higher capacity or the number of bottles comparing to the traditional style of crate. The proposed design involves the concept of circular sockets provided inside the rack or the crate to improve and increase the number of bottles positioned inside the crate comparing to the traditional rectangular ones. In this study, a beer rack or crate has been applied as the case study where these new platforms can support 13-glass bottles and 14-glass bottles, whereas the existing one can support only 12-glass bottles with the same size of the outer profile of crate. From this design, the distributors or transport companies can apply the new platform in production ramp-up phase for launching the beverage products with safety condition while increasing the capacity of crate (the number of bottles) per trip. However, the crate should be strong enough to withstand the additional weigh and ensure safety of the bottle during transportation. According to static simulation of finite element analysis (FEA) method, which is conducted verify the stress-strain distribution based on three crate condition such as crate stacking, crate lifting and interference fit.

For *the crate-stacking condition*, the positions are the most important factors or critical points where the handles or holders need to be tough, durable and strong enough since, after simulating force distributed, the red zones were shown around both sides of holding areas which were all top corners of holding positions. These positions presented similar results with negative feelings for all three designs of the crate – critical zones which might be broken first. The values of stress-strain were appeared and presented in three different values based on different simulating conditions: the largest value was shown through the create-assembly model, the second place was seen in the crate-fourteen (slots) model, and the lowest one was presented in the existing crate model.

For *the crate-lifting condition*, the most critical point – with red zone of each design platform was presented in different area and it was illustrated some areas of red zones differently. Also, some concerned areas were simulated with different factors when this lifting condition was compared to the crate-stacking condition. Coincidently, the emphasized areas of the crate-lifting condition were appeared around both sides of holding - all top-surface corners of holding positions which indicated the same results comparing to the crate-stacking condition. However, for the original crate design, the critical point was appeared around two areas of the top surfaces – at all middle sections which were applied for dividing bottles into a single unit or slot (i.e., cylindrical-shaped slot inside the crate).

For *the stress-strain values of these three crate models*, the largest value was appeared in the original crate model, the second place was shown through the crate-fourteen model, and the lowest value was presented in the create-assembly model.

For *the interference fit condition*, it was appeared only in the crate-assembly. This might be come from the attached areas between the insert and the bottle. The crate-assembly provided only two main parts which were combined or assembled together – contacting area between the crate and the inserts. The critical point was mentioned and considered in the interference fit condition since the entire body of a glass bottle was attached (touched) directly with four positions of the inserts for reducing impact force or load during transportation, lifting or carrying with fluctuated speed randomly.

For verifying the stress-strain distribution of both insert and glass bottle, the values were received from the static simulation of three conditions; three crate models. Table 5.1 presents the static simulation results of three crate models.

To maintain safety condition, finite element analysis (FEA) technique was applied to verify the crate design for achieving the proper strength. The virtual test and simulation could convey the guidelines for the design team to create a crate with providing higher quality and capacity (the amount of bottles positioned inside the crate) at the same time. The results were shown as these following statements;

- For "the new design of the crate": It is mentioned about the stacking weight of 100 kgf to 120 kgf, and this implies about 6-stack height of the typical loading scenario in the trucks.
- For "the socket design in the crate": It is considered as 13-beer bottles (i.e., 13 slots in total) when it is fully loaded; 1-cylindrical slot can support 1 kg.
- For "the internal stress and strain": They should not exceed the elongation limit and the yield strength of the material in both cases.
- For "the interference fit simulation": The fit should not produce the excessive stress and strain onto the areas of insert and glass bottle. This implies about the situation that the insert can safely grip the bottle inside the socket of the crate.

The design targets set in the conceptual design phase can be served by applying the proposed design platform where the material of insert was also made of flexible material (i.e., high strength plastic or polymer) that could vibration and absorb shocks during transportation while preserving the safety and quality of the beverage products contained inside the crate

Table 5.1 Static simulation results of three crate models.

Area of interest	Existing crate model	Crate-assembly model		Crate-fourteen model
		Insert	bottles	
stress	-	0.000311	0.000836	-
strain	-	0.00216	6.62×10^{-9}	-
stress	0.8096	1.233		1.163
strain	0.0004825	0.0007619		0.0006509
stress	13.72	9.996		10.047
strain	0.007680	0.006456		006744

5.2 Estimate cost

5.2.1 Transportation cost

The cost of transportation was determined from the weight of products and the time spent for transportation activity by truck per route. The cost of a typical plastic crate for containing glass bottle was around 12.46 USD/crate – 12-bottle slots. Due to the transporting company of shipment, a cost of transportation was considered approximately 461.33 USD per a travelling time. Normally, for a rigid truck with six-wheeled platform, time spent for transporting product was less than 300 hours - size of container (Width x Length) is equal to (2.4 m x 6.4 m) as illustrated in Figure 5.1.

In this research, two designs of beer crate provided the same dimension with the previous crate with an additional storage capacity of 1 bottle/crate, and 2 bottles/crate for crate assembly and crate fourteen, respectively. A six-wheeled truck is supposed for this taking, which carries 6 pallets of 432 beer crates (72 crates/pallet) within six levels in one way of transportation. Due to, to satisfy the pallet needs of the warehouse and shipment, then typical wooden or plastic pallet is fit with a level of 12 crates per pallet, which has approximately one square meter (1200 ×1200 × 150 mm) of plan area and usually has unit loads of approximately 8–10 kN, the wooden and plastic pallets are illustrated in Figure 5.2.

Hence, for crate-assembly, it is contained totally capacities of 5616 bottles (13 bottles/crate) comparing to the existing crate is contained within 5184 bottles of total loading (12 bottles/crate). It means this crate-assembly can contain 432 more bottles, which also means for previous crate need to contain whole equivalent amount of glass bottles with this crate per route as 36 more crate. The transportation cost of average per trip would be decreased from 0.089 USD/bottle to 0.082 USD/bottle (7.8% reduction). And also to reach the same capacity with the original crates, it need to pay more cost of 448.56 USD, it is not just carrying costs are increased but also stacking levels are increased, which is making height risk to fall and limit highly for a six-wheeled truck during transportation as well (Phlernjai, Rianmora & Phommixay, 2019). And furthermore, crate-fourteen the total capacity of glass bottles as 6048 bottles (14 bottles/crate) compare to the 5184 bottles with the original crate (12 bottles/crate). So it means this crate-fourteen can contain 864 more bottles, that it is double time of bottle number is increased more from original crate of crate-assembly comparing (432 bottles more).

The transportation cost of average per trip would be decreased from original crate of 0.089 USD/bottle and crate-assembly of 0.082 USD/bottle to 0.076 USD/bottle for crate-fourteen, which is reducing cost as 14.61% and 7.32% respectively. And to achieve the equivalent capacity of three crates design are 72 crates with of 897.12 USD for original crate and crate-assembly around 33 crates with of 411.18 USD. These mean the company can ship more beer (per one trip of shipping) under the weight limitation admission of truck transportation, especially in Laos. Simply saying that more quantity of beer bottle in transporting one trip can reduce the shipping cost. Table 5.2 presents the comparison of three crates based on rigid truck within six wheels.

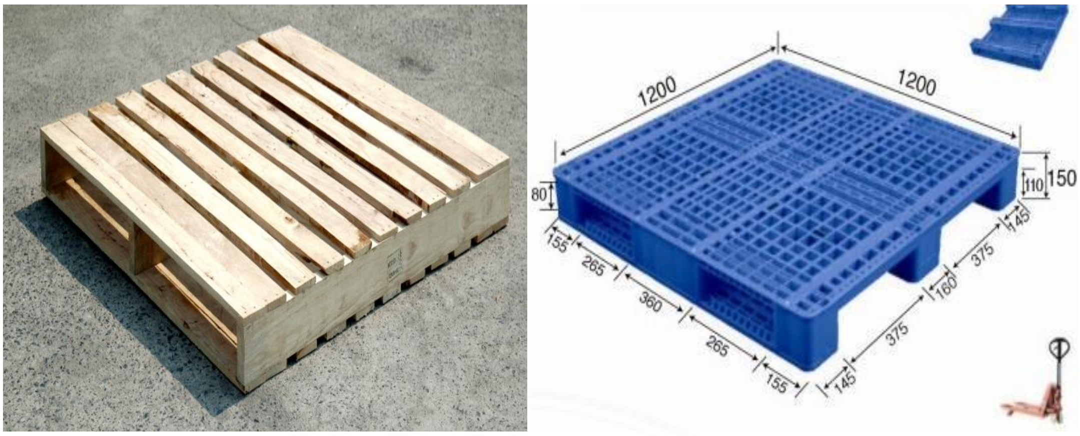
According to calculation of transportation cost, from above consequence with three crates, it is illustrated the maximum number of slots available for containing bottles is presented in the second design of crate where the second place is shown through the crate-assembly, and the last place is indicated in the existing crate platform (the traditional style). In same way by using the crate-fourteen could receive minimum transportation cost comparing to crate-assembly and existing crate on one way per trip.

(a) Comparison between two styles of vehicle – rigid closed truck and opened truck.

(b) Traditional style of truck used for transporting beer rack in Laos (Arno, 2015)

(c) Extra activity required during transportation with traditional opened container (Brook, 2016).

Figure 5.1 Transportation by six-wheeled truck.



(a) (b)

Figure 5.2 Pallet size 1200 ×1200 × 150 (mm) (a) two way entry reversible and (b) heavy duty rackable plastic pallet.

Table 5.2 Attibution comparison of three crates design basing rigid tuck with six-wheel.

Key consideration	Existing design	First design	Second design
Size of crate	280 × 375 × 298 (mm)	280 × 375 × 298 (mm)	280 × 375 × 298 (mm)
No. of bottle	12	13	14
Loading capacity (6-wheel truck)	5184 bottles (432 crates)	5616 bottles (432 crates) *8.33% increase capacity*	6048 bottles (432 crates) *16.67% increase capacity*
Haul cost (USD/trip)	461.33	461.33	461.33
Reduce vibration	No	Yes	No

5.2.2 Manufacturing cost

The manufacturing cost of products basically depends upon the spending time, raw materials cost, and value of machine or labor are used. In this task, the prototype of three designs of the crate: existing crate, crate-assembly and crate-fourteen were made from process of Rapid Prototyping (RP) - 3D printing machine where the ABS filament material was used. Therefore, the main costs of this task were considered based on the comparison among all three crate designs where the amount of filament used and time spent were the key considerations. Furthermore, all three crates were not performed with full size scale of actual crate design, which just was made to section one per five of whole size as 20%, within dimension length, wide and high as 75 × 56 × 59.6 (unit in mm) that type of three crate prototypes indicate in Figure 5.3. And the same three crate design were fabricated with same size and parameters as presented in Table 5.3.

Figure 5.3 Prototype of three-crate design (with the size of 20% from full actual version): (a) original crate, (b) crate-assembly and (c) crate-fourteen.

Table 5.3 Comparison of three crates design from 3D printing making.

Area of interest	Existing crate	Crate-assembly		Crate-fourteen
		Crate	Insert	
Time spending (min)	221	237	11	295
Filament using (mm)	10870	12310	270	14730
Layer height (mm)	0.2	0.2	0.2	0.2
Number (pc)	1	1	13	1
Weight (g)	25.6	30.625	0.575	36.7
Size of crate (mm)	75 × 56 × 59.6	75 × 56 × 59.6		75 × 56 × 59.6

5.3 Recommendation for future study

This task is focused on product design of container packaging where the crate of glass bottle is considered and applied as the case study. The existing design platform of inside details of the crate are taken into consideration as the guidelines for the starting point of the design stage. The concept of new design is tried to arrange and identify the proper amount of inserts or slots used for positioning the glass bottles during transportation. Final stage of the concept development phase, new designs with two styles of inserts are created. In order to purpose the capacity of crate to receive and support more amount of glass bottles than original and recent design ones (supporting 13-slot of glass bottle), providing 14 units inside a new crate platform (i.e., the second design) is presented. The outer profile and structure of the new designs (proposed in this research; the 1st and the 2nd designs) are considered and applied with the same directions as presented in the recent and existing crate. Only the number of slots and layout of them are changed and modified for supporting more glass bottles while maintaining the safety conditions during carry by human and transporting by trucks where the supporting locks of four positions are applied. The main benefit of the locks are about helping to absorb the shocks and vibrations of glass bottles which are fitted with inserts. From fitting assembly of them, the glass bottles should not be exerted too excessive force and damage by the inserts.

However, it would be better to consider and apply more points of supporting areas inside the slot or insert where the physical structure, property, and dimensions should be performed and designed according to the material simulation and testing. Multi-directions and options should be provided with different categories to let the customers select the proper choice of their own based on the situation happened.

Based on this condition of dynamics behavior like shock and vibration occurred during transportation, more techniques and concepts should be added to improve this proposed design where the number of bottles should be increased while preserving the safety condition. The future work which could be taken into consideration further are suggested as:

1. Study on testing about shock and vibration of the crate-assembly, also including comparison with these two crate designs as existing crate and crate-fourteen

2. Study on the other type of design and raw material that would help absorbing and protecting beer glass bottles from shocks and vibration.

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