IMPROVEMENT OF HARD DRIVE COMPONENT PACKAGING BY USING SIX-SIGMA METHODOLOGY

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วรภูมิ จตุวรพัฒน์ : การปรับปรุงบรรจุภัณฑ์ของชิ้นส่วนฮาร์ดไดร์โดยวิธีการแบบซิกซิกม่า (IMPROVEMENT OF HARD DRIVE COMPONENT PACKAGING BY USING SIX-SIGMA METHODOLOGY) อ. ที่ปรึกษา: รศ.ดร. ปารเมศ ชุติมา, 106 หน้า, ISBN974-17-6557-6

วิทยานิพนธ์ฉบับนี้มีเนื้อหาเกี่ยวกับการศึกษาปรับปรุงบรรจุภัณฑ์ของชุดหัวอ่าน ซึ่งเป็นส่วนประกอบสำคัญของฮาร์ดดิสไดร์ มีวัตถุประสงค์เพื่อลดต้นทุนของการขนส่ง และต้นทุนของบรรจุภัณฑ์ ผู้เขียนได้ศึกษาการประยุกต์ใช้แนวทางการปรับปรุง และออกแบบบรรจุภัณฑ์ โดยวิธีการแบบซิกซิกม่า ซึ่งมุ่งหวังจะได้บรรจุภัณฑ์ ที่สามารถสนองทุกความต้องการของลูกค้าได้อย่างมีประสิทธิภาพ และยังคงความสามารถในการป้องกัน ความเสียหายที่อาจเกิดขึ้นจากการขนส่งผลิตภัณฑ์

การวิจัยได้เริ่มต้นตั้งแต่การหาระบบการวิเคราะห์ปัญหาที่เหมาะสมเพื่อที่จะได้แก้ไขปัญหาได้อย่างตรงจุดและรวดเร็ว ในโครงการได้มีการวิเคราะห์หาปัจจัยหลัก ที่มีผลต่อต้นทุนของบรรจุภัณฑ์มากที่สุด และได้ทำการเลือกปรับปรุงในหัวข้อต่างๆ ตามลำดับความสำคัญ ที่ได้มาจากการศึกษา บรรจุภัณฑ์ที่ได้จากการศึกษามีการเปลี่ยนแปลงรูปแบบไปจากบรรจุภัณฑ์เดิมซึ่งถูกออกแบบเพื่อการค้า เป็นกลุ่มไปเป็นบรรจุภัณฑ์เพื่อการขนส่งระหว่างสายการผลิตเป็นหลัก บรรจุภัณฑ์แบบใหม่ได้ถูกออกแบบและทดสอบโดยใช้การวิเคราะห์เชิงสถิติก่อนที่จะได้มีการนำผล ที่ได้จากการศึกษาไปใช้กับผลิตภัณฑ์ จากการปรับปรุงบรรจุภัณฑ์ บริษัทสามารถประสบความสำเร็จในการลดต้นทุนของบรรจุภัณฑ์ จาก 0.598 เหรียญสหรัญต่อหน่วยชุดหัวอ่าน ลงเหลือ 0.156 เหรียญสหรัญต่อหน่วย และสามารถช่วยลดต้นทุน การขนส่งผลิตภัณฑ์ ระหว่างประเทศไทยกับประเทศจีนจาก 0.582 เหรียญสหรัญต่อหน่วย ลงเหลือเพียง 0.205 เหรียญ สหรัญต่อหน่วย บรรจุภัณฑ์แบบใหม่ยังได้ถูกนำไปทดลองใช้ในสภาพจริงเพื่อเป็นการประเมินผลกระทบทางด้านลบต่อคุณภาพของสินค้า ที่อาจเกิดขึ้นจากการลดต้นทุนของบรรจุภัณฑ์ก่อนจะนำไปใช้งานจริง ตลอดขั้นตอนการดำเนินโครงการผู้เขียนได้ทำการจัดการกับปัญหาที่เกิดจากบุคลากรทั้งในระดับผู้บริหารในระดับหัวหน้างานและพนักงานในสายการผลิตไปในเวลาเดียวกัน

จากผลการศึกษาสามารถสรุปได้ว่ารูปแบบของบรรจุภัณฑ์ควรจะถูกเปลี่ยนแปลงจากบรรจุภัณฑ์ เพื่อการค้าเป็นกลุ่ม เป็นบรรจุภัณฑ์เพื่อการขนส่งระหว่างโรงงานเป็นหลัก ผลจากการศึกษาแต่ละตัวแปรในการออกแบบได้ถูกรวบรวมเพื่อเป็นเอกสารอ้างอิงในการออกแบบและปรับปรุงบรรจุภัณฑ์ให้ดีขึ้นต่อไปในอนาคต

ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต...
สาขา...การจัดการทางวิศวกรรม..............	ลายมือชื่ออาจารย์ที่ปรึกษา..........................
ปีการศึกษา...........2547....................	

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This thesis is about improvement of Head Stack Assembly packaging that is the major component in Hard Drive. The purpose of thesis is to provide the new packaging design and concept that reduces freight cost and packaging cost. The author had decided to use Six-Sigma methodology in packaging development process and tried to fulfil all customer requirements with Quality Function Deployment flow.

The study was started with searching for an appropriate quality improvement process that can be applied to solve the packaging problem in both macro and micro level. The factors that were related to the problem had been prioritised. And the factors that have most impact to objective will be selected for analyse and improve.

The new concept packaging from the research had been totally changed from the original design that was designed for group packaging to be the transport packaging. The new concept packaging had been tested and evaluated by using statistical analysis. New packaging is also implemented as the pilot run to assess the negative impact to the quality that may be occurred from packaging cost reduction. The success from this project can help company reduces the packaging cost per HSA from 0.598 US dollars to 0.156 US dollars. Moreover, the new packaging also reduces freight cost per HSA from 0.582 US dollars to be only 0.205 US dollar.

During packaging development process, the author also applied force field analysis to build up the co-operation in packaging improvement from management level and shop floor worker level at the same time.

After the research, the main purpose of HSA packaging has been changed from group packaging for sales to be packaging for transportation between factories instead. The outcome from research have been summarised and documented to be the reference for packaging improvement in the future.

The Regional Centre for Manufacturing Systems Engineering Student's signature…………..……

Field of Study...…Engineering Management.. Advisor's signature ……..……...

Academic Year….2004……

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CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

Figure **Page**

Figure **Page**

CHAPTER 1
INTRODUCTION

Nowadays, packaging is a very important part in manufacturing industry. The company can not maintain the quality of product without good packaging. On the other hands, good packaging can help company enhance their product competitiveness in term of quality, reliability and cost also.

Hard drive is one of the most sensitive products to handling and transportation. It also requires good protective packaging to keep the quality during manufacturing process and transportation.

HSA packaging has to be designed appropriately. If that packaging is better than necessary or it is an over packaging, the company will also lose money. To have appropriate packaging, the design engineer needs to understand and get all necessary requirements.

The study in this thesis will describe how can we design and discover the new packaging concept that can reduce cost and enhance the company competitiveness by using a systematic quality improvement method, such as Six-Sigma.

1.1 Background of research

Seagate Technology was established in United Stated in 1979 as a hard drive manufacturer. The company has manufacturing plant in the United Stated of America, Ireland, Singapore, China and Thailand.

Seagate has segregated the component of the Hard Drive to build and assembly in many countries. Read and write components (wafer & slider) are built in United States and Northern Ireland. Recording Head (HGA & HSA) that is the most sensitive part to handling is assembled in Thailand. Recording Media (Disc) and Motor are built in Singapore. PCBA is built in Malaysia. Finally, all components will be shipped to Hard Drive assembly plant in China, Singapore and the United States.

The follow figure shows the component of hard drive.

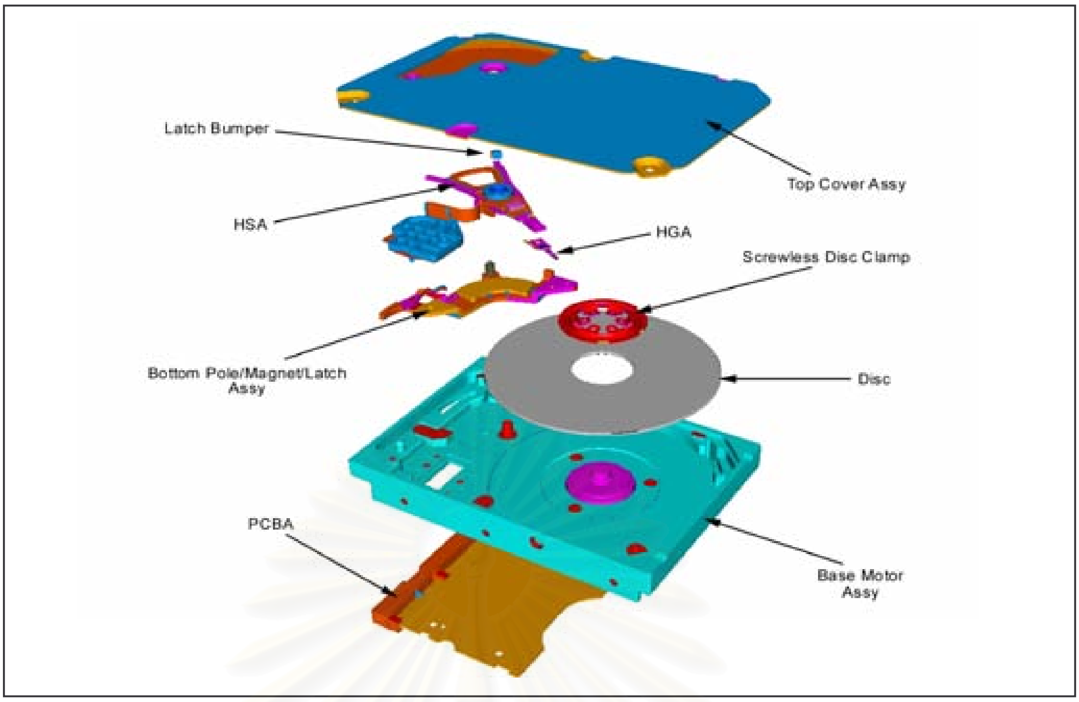


Figure 1.1 Component of Hard Drive *(from Seagate engineering department)*

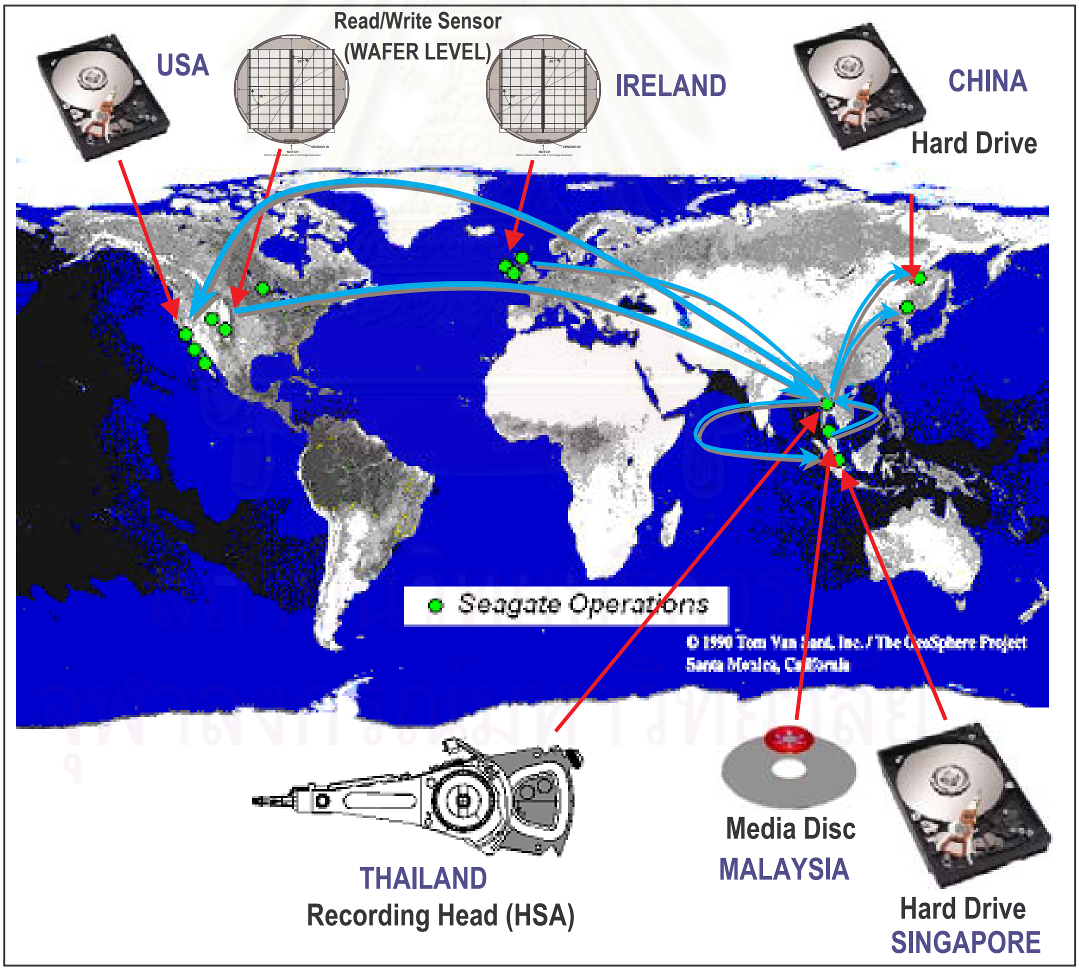


Figure 1.2 Location and responsibility of each manufacturing site *(own creation)*

Shipping the hard drive components to assembly in the different countries. The company needs to spend a lot of money for freight cost and packaging cost, especially for the Head Stack Assembly (HSA) that is very sensitive to handling.

HSA is a very fragile part, so it requires special package for ship it to the other sites. Moreover the trend of new technology also requires smaller hard drive with the bigger capacity. This trend also makes HSA more fragile and requires better protective package to transfer. These reasons have increased the packaging cost and freight cost dramatically.

During the last three years, packaging and freight cost have been increased from 0.18 dollars per HSA to be 0.58 dollars per HSA. And this makes the company spending increases about 6,800,000 US dollars per annum.

1.2 Statement of the problem

HSA (Head Stack Assembly) is a major component in Hard Drive that is very sensitive to handling and transportation. The company has got the impact from damage HSA during transportation about 3-5%. This problem effect to quality and reliability of product.

And to reduce this defect, the company needs to spend 6.8 million US dollars per year for the extra cushion packaging. This problem also effects to the cost of product seriously.

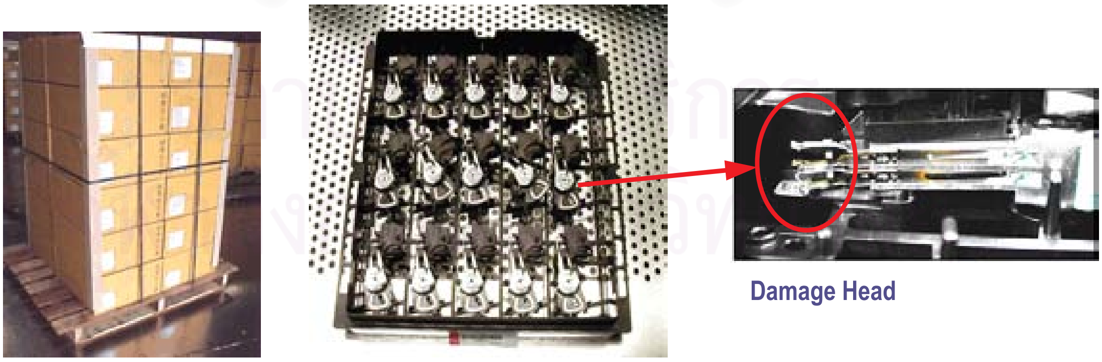


Figure 1.3 HSA Defect from Handling and Transportation

The following figure shows the comparison between current packaging and the extra cushion packaging. The extra cushion packaging makes a huge impact to packaging cost and freight cost. Mainly, this packaging has reduced the capacity of shipping pallet from 1,080 HSA per pallet to be 720 HSA per pallet. This is because the size of box is very big and it takes a lot of space on the shipping pallet.

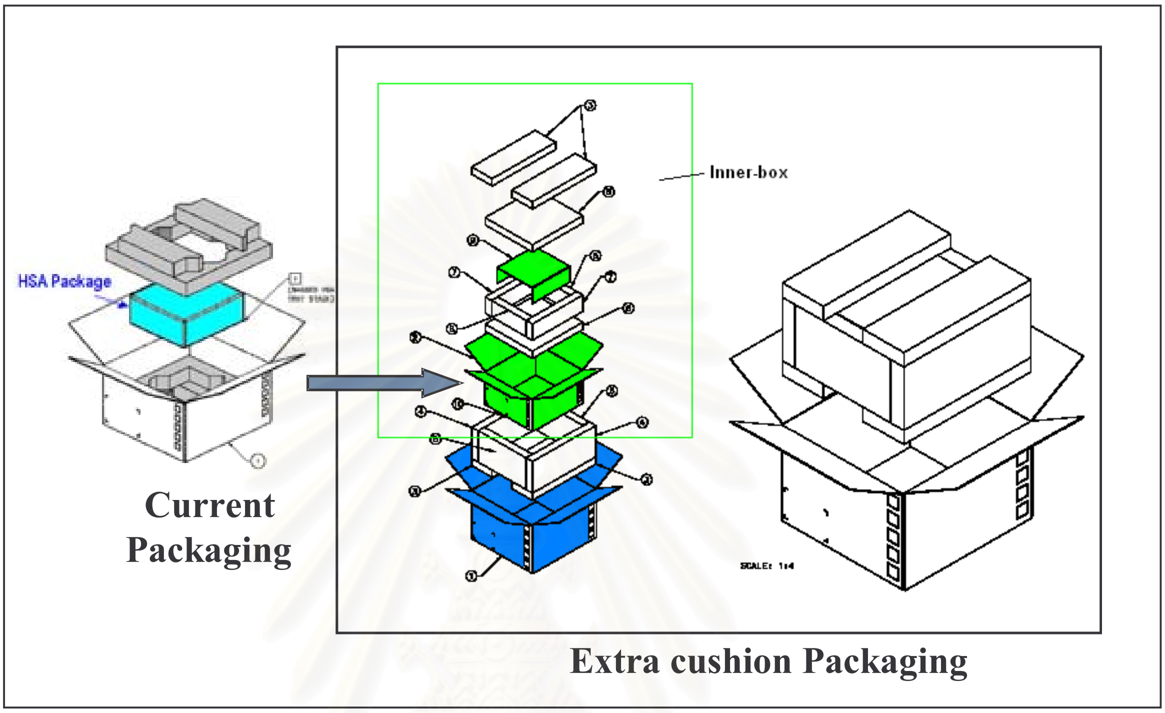


Figure 1.4 Comparison between current packaging and extra cushion packaging *(own creation)*

1.3 Objective of research

- To design and implement new packaging that reduces cost.
- To create procedure and strategy for new product packaging.

1.4 Scope of the research

We will focus on the HSA packaging design. The study possibly related to Value Engineering, Quality Function Deployment, TQM, Six-Sigma, and Design for Six-Sigma.

The major customer of HSA is the Hard Drive factory in Singapore and China. Moreover, the customers in this project also include shop floor worker in packaging area, freight forwarder, material planner, quality engineer, and other people that are concerned with HSA packaging activities.

The requirements from customer will be collected and analysed by using QFD method. After that, Failure Mode and Effect Analysis (FMEA) will be used to prioritise all of their requirements.

The new design will be analysed and validated with the simulation method that is included physical and computer simulation to shorten the packaging development cycle times.

1.5 Methodology of the research

1. Study and compare the design concept with the literature that has been published.
2. Compare the problem statement with the case study in the journal.
3. Interview and discuss with the relative staff in each area. The scope will be included packaging room, warehouse, traffic department, freight forwarder, and customer.
4. Discuss with team to get the appropriate strategy and packaging design.
5. Try to do benchmarking between each solution. And select the best one to validate.
6. Simulate the functional of the design with the simulation software.
7. Provide the prototype and validate the expected solution with existing product.
8. Optimise the solution for effectiveness
9. Summarise the benefit and the improvement from the research.
10. Write up the thesis

1.6 Benefit of Study

The study will benefit to Hard Drive Manufacturing and Packaging Department. The customer requirements and design requirements will be clearly defined. And it will be used to design the packaging that can reduce freight cost, minimise waste, reduce packaging material inventory and maintain the HSA quality during transportation.

1.7 Expected results

1. The packaging design that meet all customer requirements.
2. The appropriate packaging strategies for hard drive industry that help company reduce freight cost and packaging cost.
3. The design procedure and new HSA packaging concept for the future.

CHAPTER 2

THEORY AND LETERATURE SURVEYS

2.1 Packaging Development Process

(Demaria, 2000)

The Packaging Development Process can be segregated into 3 phases, Planning, Proving Functionality, and Package Launch. These 3 phases of packaging design process can be described with the block diagram below.

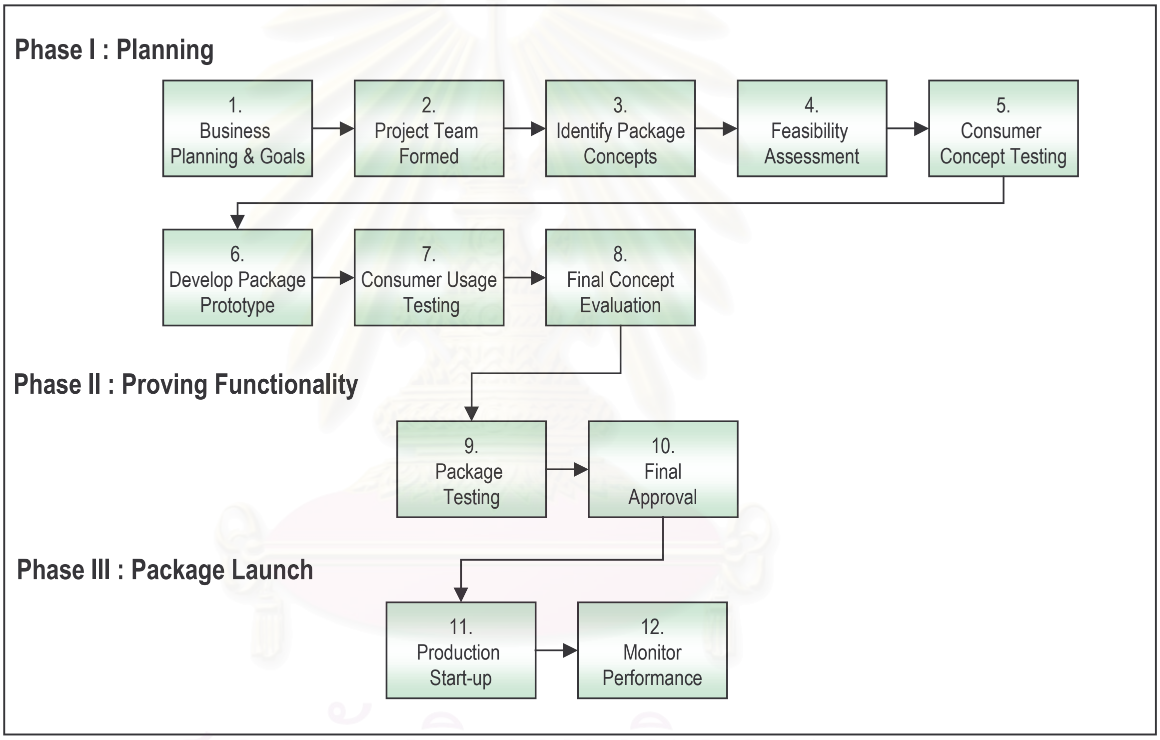


Figure 2.1 Packaging Development Process Flowchart. *(Demaria, 2000: X)*

2.2 Types of packaging

(Ackerholt and Hartford, 2001)

Packages are generally categorised into three main types:

- **Primary or Consumer packaging**

  It is a packaging containing one sales unit to end-user or consumer

- **Secondary or Group packaging**

  It is a packaging designed to contain a number of primary packages to retailer or store.

- **Tertiary or Transport packaging**

  It is a packaging that facilitates transport and handling of a number of primary or secondary packages with the aim of preventing damage to the product.

The different type of packaging can be summarised in the table below.

Table 2.1: Three types of packaging

Primary packaging	**= Sales packaging**
Sales packaging designed in such a manner as to form a sales unit for the end user at the point of sale.	
Secondary packaging	**= Group packaging**
Group packaging designed in such a manner as to form a group of a certain number of sales units sold as such to the end user or used to fill display stands.	
Tertiary packaging	**= Transport packaging**
Transport packaging designed to prevent damage during the handling and transportation of products.	

(From http://www.valipac.be/agreement/_en/definitions/definitions2.htm)

2.3 Six-Sigma and Design For Six Sigma

(Hill, 2003)

Six-Sigma has at least three different meanings depending upon the context.

(1) Six-Sigma is the structured application of the tools and techniques of Total Quality Management on a Project Basis to achieve strategic business results.

(2) Six-Sigma is a management philosophy. Six-Sigma is a customer based approach realising that defects are expensive. Fewer defects mean lower cost and improved customer loyalty, The lowest cost, high value producer is the most competitive provider of goods and services. Six-Sigma is a way to achieve strategic business results.

(3) Six-Sigma is six sigma in a statistic. Six-Sigma processes produce less than 3.4 defects or mistakes per million opportunities. Many successful six sigma projects do not achieve a 3.4 PPM (part per million) or less defect rate (or 99.99966% good). That just indicates that there is still opportunity.

(4) Six-Sigma that is a six-sigma process. To implement the six sigma management philosophy and achieve the six sigma level of 3.4 defects per million opportunities. There is a process that is used. The Six-Sigma process includes five steps (a) define, (b) measure, (c) analyse, (d) improve, and (e) control. Note that Six-Sigma is not a set of new or unknown tool. Six-Sigma tools and techniques all are found in total quality management. Six-Sigma is the application of the tools on selected important projects at the appropriate time.

Design for Six-Sigma (DFSS) drives quality measurement into design. The rational is that it is much easier to design quality into product than it is to try to fix problems after they occur.

(Mazur, 2003)

Six Sigma and Design for Six-Sigma (DFSS) offer a new approach to Total Quality Management with a more integrated approach, standardised training and certification, and financial accountability for investment in improvements. A core principle of DFSS is the Transfer Function $y=f(x)$, whereby customer requirements are transferred into Critical-to-Quality requirements (CTQ). DFSS uses the House of

Quality and other QFD matrices to perform this Transfer Function and then cascade it down to lower level specifications and parameters.

Six-Sigma and TQM; These quality principles have been organised into a problem solving algorithm called DMAIC. Not too dissimilar from TQM's classical 10-step Quality Improvement Story, the DMAIC is more measurement oriented and uses more sophisticated statistical tools that require trained specialists to lead the improvement efforts.

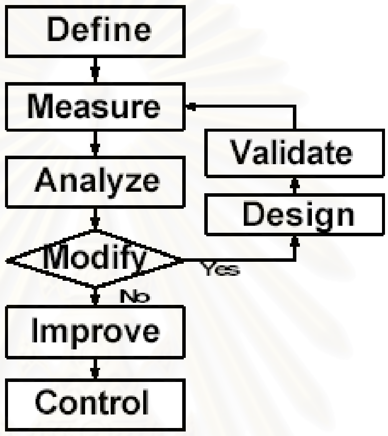


Figure 2.2 DMAIC Flow Diagram (Mazur, 2003)

(Keren, 2001)

DMAIC is a five-step methodology for implementation of Six-Sigma: Define, Measure, Analyse, Improve, and Control. Implementing Six-Sigma is not different than any other project launching. A project team, which is not under the authority of the area owner, will be selected to initiate the implementation, and will be very well trained.

Define – the team should focus on process mapping in the early stage, and should initiate customer research. This stage consists of a preliminary evaluation of customer limits, and definition of CTQs.

Measure – Measurements are fundamentals of Six-Sigma, and therefore they are critical to a successful launching. CTQs characteristics are the main issue in this stage. Measurements should be conducted with a well-defined checklist that should address representative sampling, focused surveys, and methods of collecting data. The data should be arranged in a way that they will be able to be analysed in a later stages and be presented (normal distributions, CTQs.)

Analyse – This stage is characterised by the following: applying inferential statistic methods, detailed process map analysing, identification of root causes of poor quality, verify customer satisfaction limits, and obtaining the currently sigma metrics.

Improve – A major part of the improvement stage is dealing with solution finding for the problem noted in the ‘analyse stage’. A variety of solutions will be suggested. Making decision is not a simple issue. The ideal solution should be selected. When applicable, running a pilot and testing is recommended, in order to verify the solutions that have been chosen. The last step in this stage is implementation of the solutions. Failure Mode Effect Analysis (FMEA) has been recommended with other methods as tools to verify whether the solution can be applied to carry out the desired results.

Control – The control stage contains a routine measurement (as conducted in the measure stage). The average and standard deviation should be calculated and plotted on control charts with relation to customer limits. A change in the distribution pattern can imply that the distribution is no longer randomise and intense root cause analysis should be conducted to improve the process. In order to maintain adequate Six-Sigma quality, a deviation in the process should be identified early enough so that the performance of the process will be kept within the limits.

(De Feo and Bar-Ei, 2002)

Design for Six-Sigma (DFSS) is an established, data-driven methodology based on analytical tools that provide users with the ability to prevent and predict defects in the design of a product, service or process. Making significant reductions in cost and cycle time requires a major departure from traditional design methods. The DFSS process produces the kind of data that show the way to achieve Six-Sigma level of quality. Focused on creating new or modified designs that have higher levels of performance, the design for Six-Sigma procedure: DFSS methodology follows a Define-Measure-Analyse-Design-Verify (DMADV) sequence.

Define – The Define phase sets the tone for the entire design project by establishing goals, charter and infrastructure. Activities are shared between management and project design teams. Management defines the design problem, but projects are nominated consistent with the overall business strategy and selected based on the optimal impact on that strategy.

Measure – The Measure phase is concerned with identifying key customers, and determining their critical needs and the measurable critical-to-quality (CTQ) requirements necessary for a successfully designed product, service or process. A design scorecard is created to track the design evolution and predict what the final product defect level will be after all design elements have been integrated.

Analyse – In the Analyse phase, a design is selected from several alternatives, followed by the development of design requirements against which a detailed design is to be optimised. The design team them develops several 'high-level' options. On of the designs or a combination is selected, followed by the selection of the 'best-fit' design.

Design – The Design phase builds on the detail design produced in the Analyse phase to deliver an optimum functional design that also meets the manufacturing and service requirements. Experiments result in an optimum design represented by a mathematical prediction equation. The phase is concluded with a design verification test that use simulation, prototyping and pilot testing to validate the design.

Verify – The purpose of the Verify phase in the DMADV sequence is to ensure that the new design can be manufactured and supported in the field within the required quality, reliability and cost parameters. After verification tests and pilot runs, the design is finalise and a ramp-up to full-scale production occurs to highlight any potential production problem.

(Algase, 2003)

Six-Sigma and DFSS are linked together. If we are trying to improve the existing product or process, we will use DMAIC (Define, Measure, Analyse, Improve and Control) as the improvement the process. On the other hands, if we need to create the new product or process, we will use the DFSS methodology or IDOV (Identify, Design, Optimise and Validate) as the improvement process.

(Kuchar, 2000)

At General Electric, the DFSS Process has been defined into 5 phases, Define, Measure, Analyse, Design and Verify. Briefly, these 5 phases are about, set objective, roles and responsibilities, understand customer needs; specify CTQs, project requirement & quality target, establish high-level design, identify key design parameter and limits, predict sigma; literate to meet quality target, and assess performance, reliability.

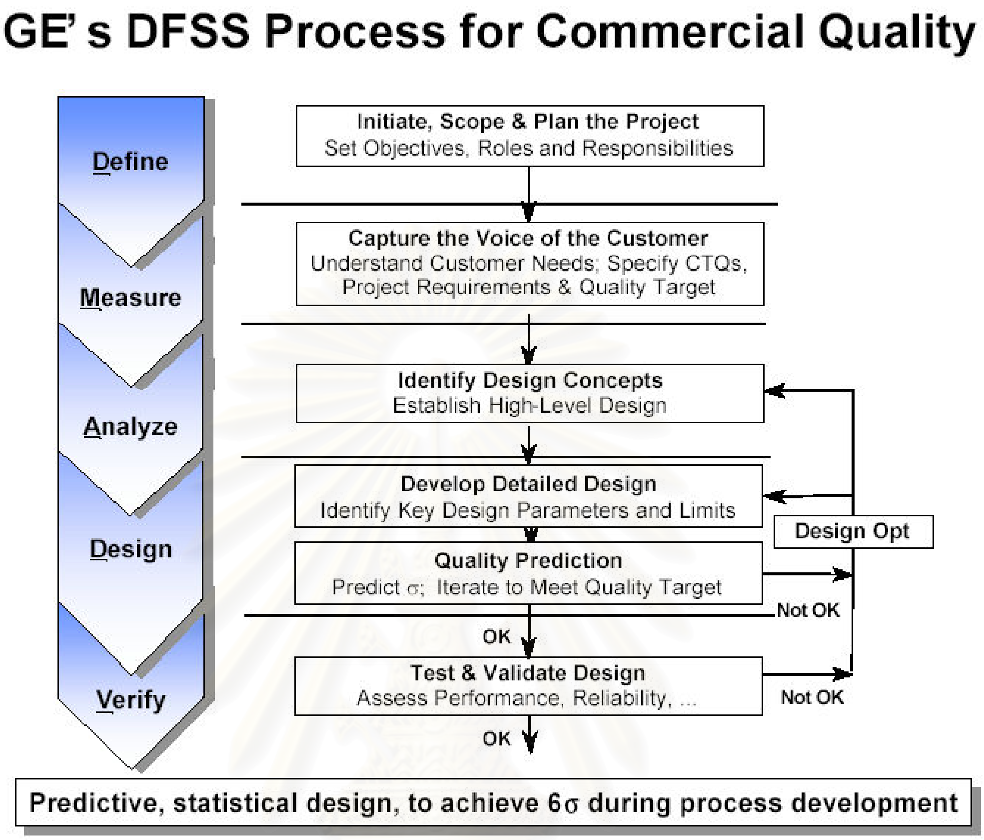


Figure 2.3 Diagram of DFSS flow at GE (Kuchar, 2000)

(Defeo and Bar-Ei, 2002)

DFSS is an established, data-driven methodology based on analytical tools that provide users with the ability to prevent and predict defects in the design of a product, service or process. Making significant reductions in cost and cycle time requires a major departure from traditional design methods. The DFSS process produces the kinds of data that show the way to achieve Six Sigma levels of quality. Focused on creating new or modified designs that have higher levels of performance.

2.4 Quality Function Deployment

(Mazur, 1997)

Quality Function Deployment (QFD) is the only comprehensive quality system aimed specifically at satisfying the customer. It concentrates on maximising customer satisfaction (positive quality) – measured by metrics such as repeat business. QFD focuses on delivering value by seeking out both spoken and unspoken needs, translating these into actions and designs, and communicating these throughout the organisation. Further, QFD allows customers to prioritise their requirements and benchmark us against our competitors, and then direct us to optimise those aspects of our organisation that will bring the greatest competitive advantage. What business can afford to waste limited financial, time and human resources on things customers don't want or where we are already the clear leader?

(Kiemele, Schmidt and Berdine, 1997)

QFD is a structural tool that helps any group create optimal designs that meet customer needs. This concept of focusing on the "Voice of the Customer", ensuring that product and service features are chosen to maximise the benefit to the customer. At the same time, QFD helps organisations succeed by ensuring prudent design trade-offs are made based on competitive benchmarks and process analysis, minimising costs and overall project risks.

Initial QFD matrix, normally referred to the House of Quality (HOQ). The customer requirements are brainstormed and then analysed using affinity and three diagrams. The customer requirements referred to as the "voice of the customer" or the "What" are then validated, prioritised, and benchmarked using direct feedback from customers. Next, design requirement, or the "HOW" are brainstormed and analysed in a similar manner to the process used for customer requirements. Design requirements are defined as those things we would measure to ensure that all customer requirements are met.

(Watson, 2003)

QFD is a detailed system to translate the needs of customers into product design requirements. QFD also translates design requirements into component parts and processes for producing them.

QFD provides a systematic way to record agreements on the means to satisfy high priority customer requirements through the design of the core product, its extended product and the production process. It is a powerful design and documentation tool for recording product-level decisions about customer needs, design rules, competitive positioning, and requirements for quality for suppliers as well as requirements of the production process. QFD enables product design teams to prioritise these competing needs, develop innovative responses, and orchestrate successful cross-functional efforts to meet these needs.

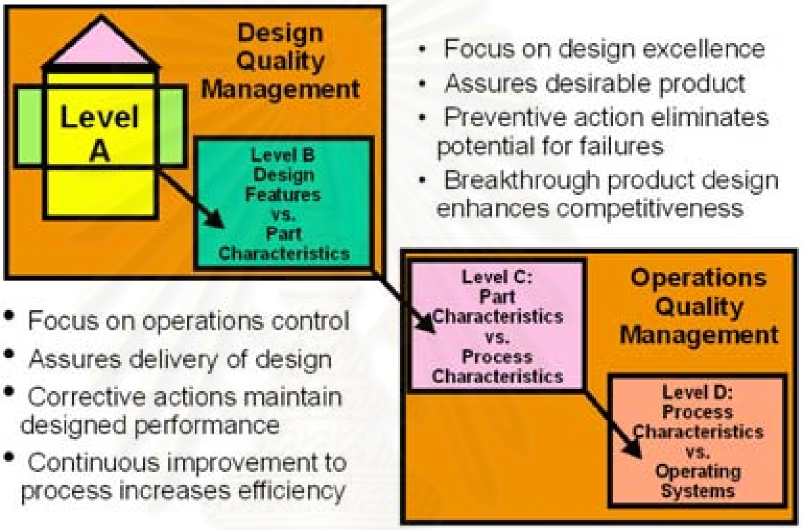


Figure 2.4 Bad design quality limits operation quality (Watson, 2003)

(Blair, Townsend, and Verderaime, 1996)

Before start development the design, we need to get the customer requirements. When we need to focus on many requirements, such as, size, weight, manned or unmanned, cost, reliability, reuse (how many times), operational turnaround, Quality Function Deployment (QFD) is an excellent tool for developing or flowing these requirements down throughout the project.

(Ishii, 2004)

Quality Function Deployment (QFD): is a powerful tool for relating customer requirements, functional specifications, product design, and process characteristics. Whereas QFD guides design teams in achieving the integration, engineers can further benefit from a more quantitative methodology.

(Watson, 2003)

QFD provides a systematic way to record agreements on the means to satisfy high priority customer requirements through the design of the core product, its extended product and the production process. It is a powerful design and documentation tool for recording product-level decisions about customer needs, design rules, competitive positioning, and requirements for quality for suppliers as well as requirements of the production process. QFD enables product design teams to prioritise these competing needs, develop innovative responses, and orchestrate successful cross-functional efforts to meet these needs.

(WixSon, 2004)

The basic Quality Function Deployment methodology involves four basic phases that occur over the course of the product development process. During each phase one or more matrices are prepared to help plan and communicate critical product and process planning and design information. This QFD methodology flow is represented below

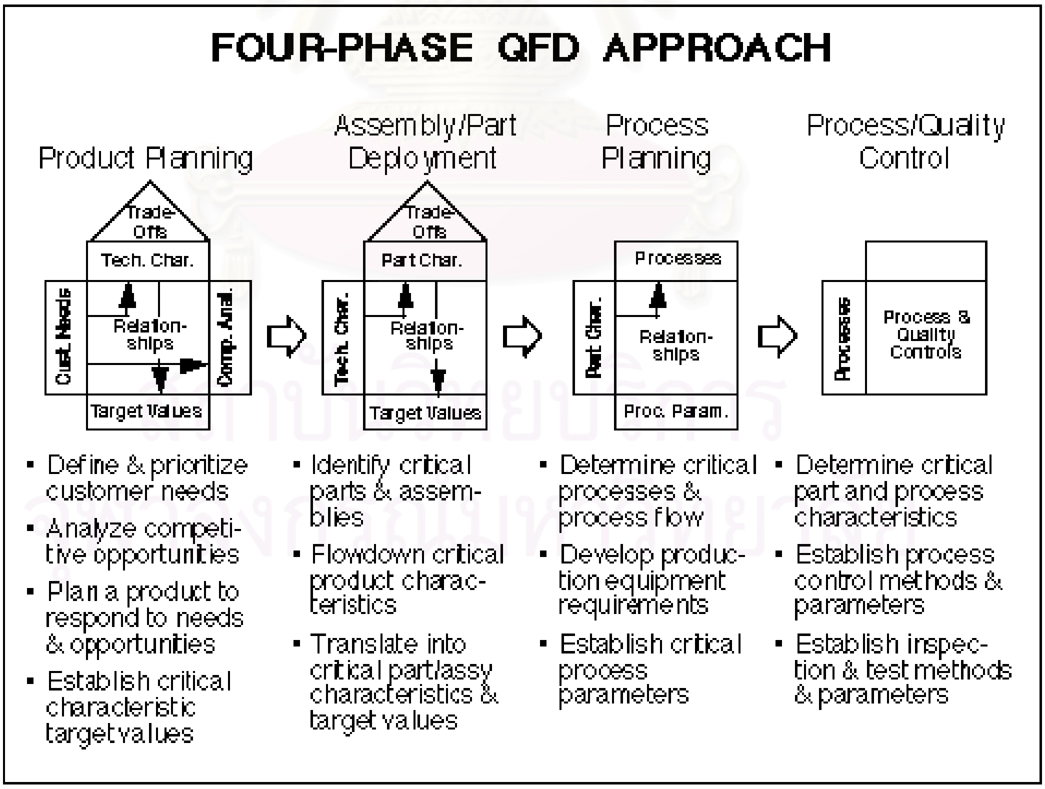


Figure 2.5 The basic methodology flow (Wixson, 2004: 17)

2.5 Value Engineering

(Deimsey, 2002)

Value Analysis was developed by Larry Miles of General Electric during World War II to lower the cost of manufactured products. Miles' approach was to examine the function of the product rather than the product itself, so that designer could develop alternative solutions to perform the same functions at a lower cost. Through its method of value analysis and function analysis, value mismatches are identified where the criticality of the function and the cost of the parts that perform that function are examined. Where cost exceeds the value of the function, cheaper alternatives to those parts are sought.

(Algase, 2003)

Value Analysis (VA) or Value Engineering (VE) is a proven team oriented, creative, systematic, cross-functional approach that enhances decision making, improves products and processes, and increases customer satisfaction. The objective of VA or VE is to improve value, as defined by: **Value = Function / cost**

Where function is performance or quality and cost is the overall cost to deliver the functions. This goal help company continually striving to eliminate waste or unwanted functions and cost in product design.

2.6 Affinity Diagram

(Breyfogle III, 1999)

Using an affinity diagram a team can organise and summarise the natural grouping from a large number of ideas and issues. From this summary teams can better understand the essence of problems and breakthrough solution alternatives.

(Hill, 2003)

Affinity diagram is a group decision-making technique designed to sort a large number of ideas, process variables, concepts, and opinions into naturally related groups. These groups are connected by a simple concept. Group us Affinity Diagrams to clarify complex issues and reach a consensus on the definition of a problem. It answers a "What" question; for example, it might be used to clarify the question, "What are the root causes of even that determined or impacted the quality of our product?"

Affinity diagrams or charts are a simple way for a group to cluster qualitative data and come up with a consensus view on a subject. It is often used with QFD to sort and organise the large amount of customer needs data. In this instance, statements of customer needs are written on cards or post-its. The group organises the cards or post-its and then develops headings under which to cluster these needs. The cards or post-its are moved to the appropriate group headings.

2.7 Force Field Analysis:

(lles and Sutherland, 2001)

Force Field analysis (Lewin, 1951) is a diagnostic technique which has been applied to ways of looking at the variables involved in determining whether organisational change will occur. It is based on the concept of 'force', a term which refers to the perceptions of people in the organisation about a particular factor and its influence.

- **Driving forces** are those forces affecting a situation that are attempting to push it in particular direction.
- **Resisting forces** are forces acting to restrain or decrease the driving forces.

A state of equilibrium is reached when the sum of the driving forces equals the sum of the restraining forces.

Lewin formulated three fundamental assertions about force field and change.

1. Increasing the driving forces results in an increase in the resisting forces; the current equilibrium does not change but is maintained under increased tension.
2. Reducing resisting forces is preferable because it allows movement towards the desired state, without increasing tension.
3. Group norms are an important force in resisting and shaping organisation change.

CHAPTER 3

APPLICATION OF SIX-SIGMA IN PACKAGING IMPROVEMENT

There are many problem solving tools and quality improvement methodologies. Such as Kaizen, Quality Control Circle (QCC), and Total Quality Management (TQM), all of these approaches have been realised that it can help company to set up the long-term continuous improvement. Sometime only one of these quality improvement methodologies can not help company increase their competitiveness fast enough to survive in the business. Many times, Six-Sigma has been presented as the magic tool to help company get the breakthrough improvement.

In fact, there is noting new or unknown in Six-Sigma. Six-Sigma is a combination of quality improvement tools and techniques, and includes the philosophy to select the improvement project that has the most effect to company benefit. Six-Sigma philosophy will encourage people to look for the breakthrough improvement. Everything is not good enough until it can reach 3.4 defect per million. There is not many Six-Sigma projects that can reach this quality level, but most of the Six-Sigma project can reach the breakthrough improvement.

Packaging is an area that many companies ignore the opportunity to gain the improvement for a long times. Nowadays, competition in the business has forced us to look for improvement in all areas that is included packaging also. The product cost has to be reduced as much as possible to gain competitive advantage and deliver more value to the customer. The big question is how we can improve package cost quickly. This is because packaging is concerned with many organisations both inside and outside the company. We need to get the effective tool or guidance that can help us improve the packaging quickly and effectively.

Six-Sigma can be a good methodology to generate long-term improvement. It can be applied and has the effect to many levels in the company. When talking about Six-Sigma many people think that it is about DMAIC problem solving process. It is true but Six-Sigma can also has the effect to the higher business level too.

Panda (2000), he has defined three broad levels of objective for Six-Sigma application. There are Business Transformation, Strategic Improvement, and Problem

Solving. It is based on the scale of impact that we want to make improvement on the organisation. These can be summarised in the table below.

Table 3.1: Three Levels of Six Sigma objectives (Pande, 2000)

Objective	Description
Business Transformation	A major shift in how the organisation works; "culture change"
Strategic Improvement	Targets key strategic or operational weaknesses or opportunities.
Problem Solving	Fixes specific areas of high cost, rework or delays.

Similar to macro and micro process, Six-Sigma methodology can be looked in the different level. In the macro process for the organisation improvement, Six-Sigma methodology can be divided into 5 steps as listed below.

1. Identify core processes and key customers.
2. Define customer requirements.
3. Measure current performance.
4. Prioritise, analyse, and implement improvements.
5. Expand and integrate the Six-Sigma system.

These five steps can be illustrated in the flow diagram as following.

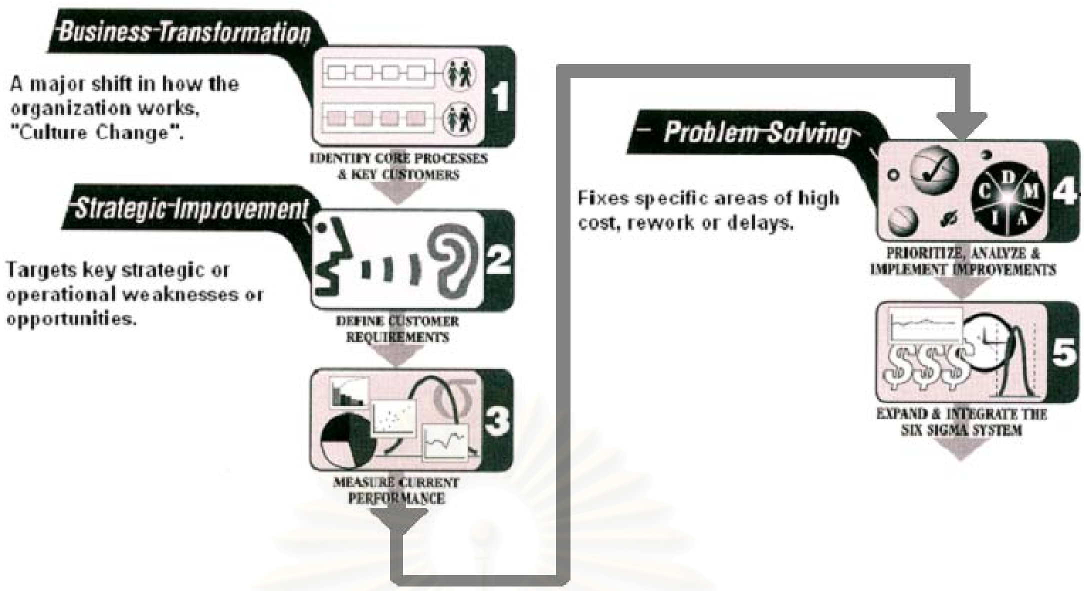


Figure 3.1 The Six Sigma Road map (Adapt from Pande, 2000)

And Six-Sigma can also be applied in the micro management level. The Six-Sigma methodology in this level mostly presented with the MAIC (Measure, Analyse, Improve, and Control) problem solving process step. Moreover, for the problem that may requires process change or design change, we can also adapt the Six-Sigma process step to be DMADV which means Define, Measure, Analyse, Design, and Verify. Many literatures call this DMADV that Design for Six-Sigma process (DFSS). Design for Six-Sigma process can also be illustrated as the following figure.

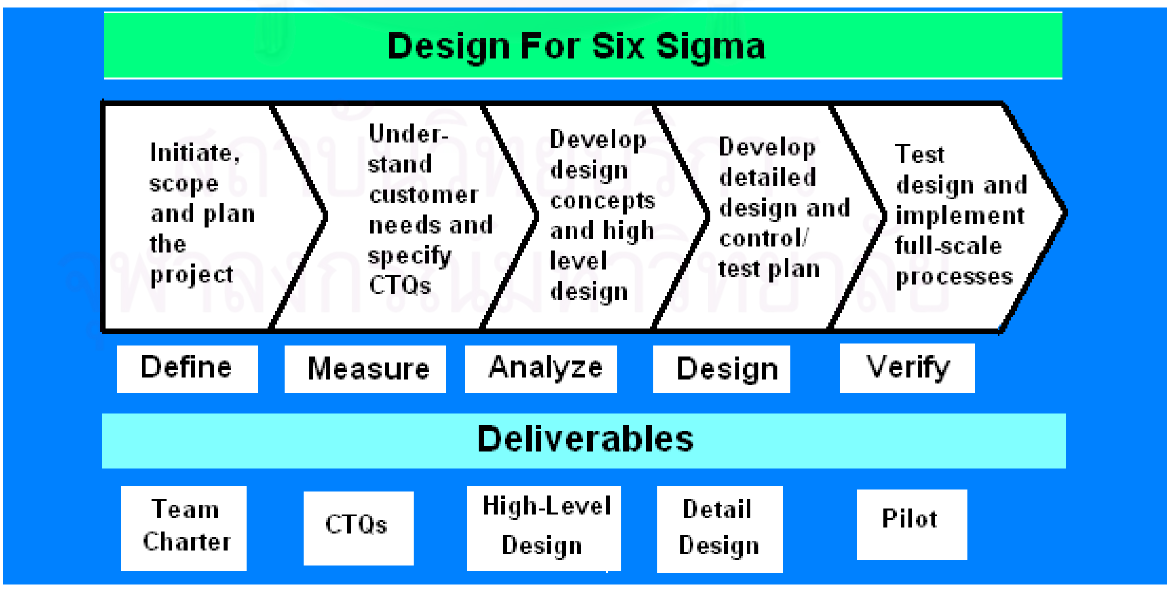


Figure 3.2 DFSS Process of Juran Institute (DeFeo and Bar-Ei, 2002)

3.1 Six-Sigma Process for Macro and Micro Improvement

Since we are going to analyse and improve packaging in widely perspective. We need to understand packaging problem in detail, and apply Six-Sigma to that key issue or process appropriately. To have the methodology that we can use for tackle all packaging problems. We have combined Six-Sigma methodology for macro and micro level together and adapted it as shown in the figure below.

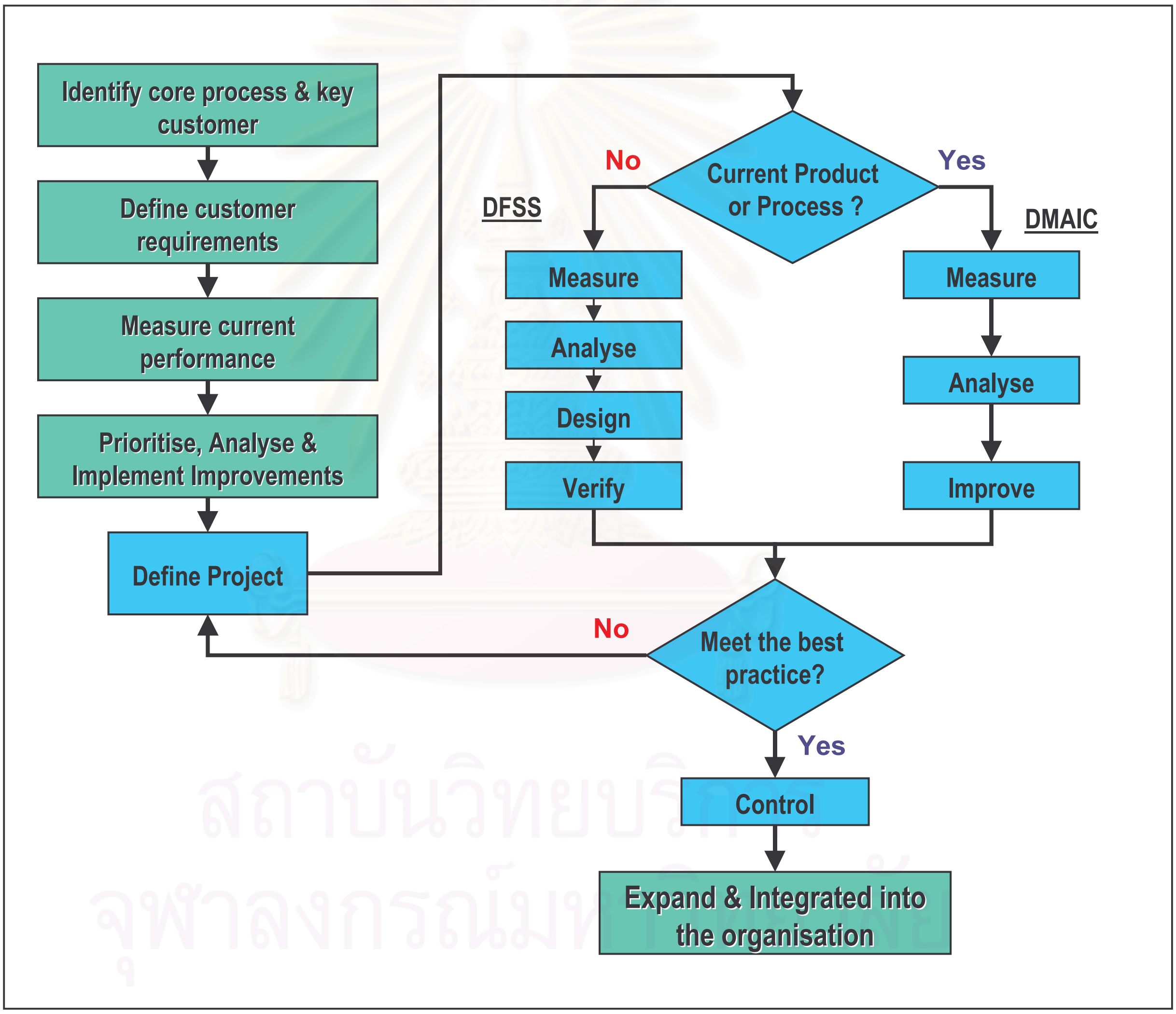


Figure 3.3 Six-Sigma process for macro and micro improvement
Adapt from (Pan de, 2000) and (Algase, 2003)

When we are going to improve any product or process in the corporate level. Firstly, we need to identify the core process and key customer that is concerned with our problem. Secondly, we need to define customer requirements. This step will guide us to deliver the thing that has effect to customer satisfaction. Thirdly, we need to measure the current performance, set the baseline for comparison analysis. Fourthly, we need to prioritise what have to be improved first. This step is very important because it helps Six-Sigma improve the problem in the organisation quickly and effectively.

At this step, the improvement project should be defined. The selected project has to be assessed that it requires product change or big process change or not. If it requires big change we can use Design for Six-Sigma process that is included Measure, Analyse, Design, and Verify phase. Sometime DFSS process is defined as Identify, Design, Optimise, and Validate phase. In generally, they are similar to each other. When finish verify phase, we have to check that our project has achieved the goal or meet the best practice or not. If it has achieved our goal, so we can expand or announce it to be the case study for entire organisation.

If our selected project does not require big process change or design change, we can use Measure, Analyse, Improve, and Control as improvement process. This is because the tool in improve phase, such as Design of Experiment (DOE), can help us to find out the best setting for a very detail system.

After we achieve the best practice, we have to make sure that it can be sustained for the future. The control phase can help us to establish the documentation and quality control system to sustain our best practice.

Once the project has been completed. We should announce it to be the case study, and integrate it into the organisation for wide. This phase may be included reward and recognition also.

In the following chapter, we are going to improve our HSA packaging by using the Six-Sigma improvement process that has been presented to be the guidance.

CHAPTER 4

CURRENT PACKAGING ANALYSIS

4.1 Identify Core Process and Key Customer

4.1.1 Analyse Packaging Problem in Macro Level

Refer to the problem statement and objectives, we need to deliver the new packaging design that reduces cost and freight cost. The problem is how can we get the new packaging that meet all of customer requirements and add more value to make our new packaging design better than their expectation.

To achieve the goal, we need to have clearly understanding about the purposes of current packaging, and how it has been handled and transferred. To have clear understanding about our packaging problem, we can start with process mapping.

4.1.2 Process Map of Current Packaging Handling and Transfer

Process Mapping is the effective tool to understand the current process. In this case, we have decided to use process mapping to study how our packaging has been used and transferred, and who are the concerned people in our packaging area. The process is started since we receive raw material until we build and ship HSA to customer. The study will be included reuse process of packaging also.

Since we receive incoming material, Supplier Quality Engineer will work with supplier to control the quality of incoming material. Their responsibility is included the quality of packaging piece part also.

Process Mapping of Current Packaging Handling and Transfer

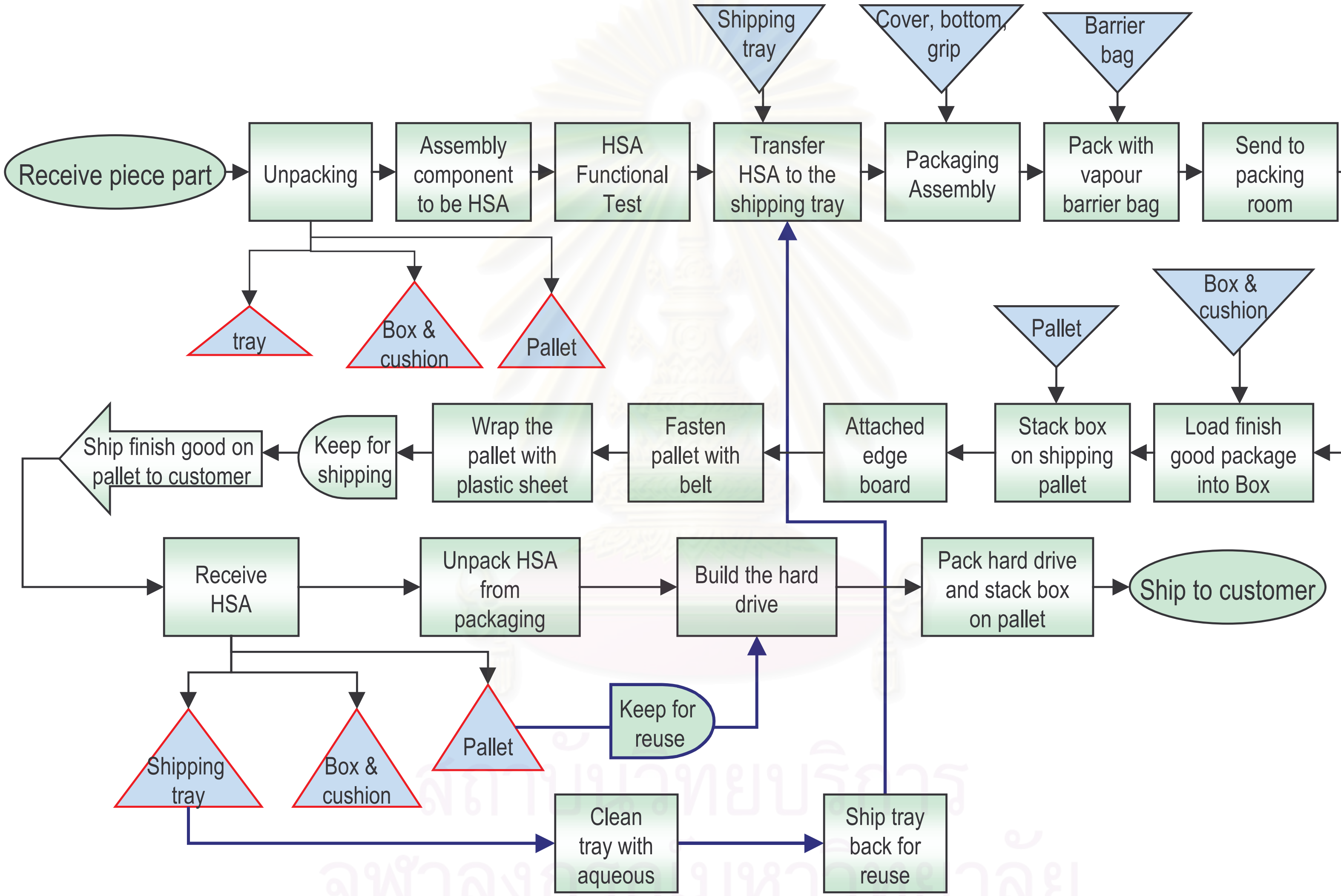


Figure 4.1 Process mapping of packaging handling process *(own creation)*

After receive the package of HSA piece part, staff from store and warehouse department will open the package, forward HSA raw material to manufacturing process. And they will separate packaging piece part that is remained for sale as the recycle material.

When HSA piece parts are loaded into manufacturing line, process engineer and quality engineer will take responsibility to make sure that it has been assembled to be finished HSA and has good quality.

After we finish HSA assembly, HSA will be transferred to the packaging area. Operator will load HSA into box that has cushion inside, stack the box on pallet, fasten the belt, wrap that pallet assembly with plastic sheet, and forwards the pallet assembly to shipping store.

Pallet assembly will be transferred to freight forwarder by logistic department. Forwarder will pick up the pallet assembly, load it into the truck and ship it to HDA plant by either truck or air shipment.

At the customer site, when they receive the pallet assembly, they will unpack the pallet and forward HSA to HDA manufacturing line. HDA plant will separate cushion and box for sale as the recycle material, and return HSA tray back to HSA factory for reuse.

4.1.3 Define the type of current HSA packaging

There is three types of packaging, primary packaging, secondary packaging, and tertiary packaging. Sometime tertiary packaging can be called "Transport Packaging".

We have found that current HSA packaging is designed and qualified by using Free-Fall Impact criteria that is the drop test criteria for secondary packaging. In Free-Fall impact test, packaging will be dropped ten times in difference directions without the pallet.

This shows us that so far the HSA packaging has been design as the secondary packaging.

The observation from process mapping, we have found that defining HSA packaging, as the secondary packaging is not right. This is because the company ships all HSA packages on the pallet.

HSA packages in carton boxes are stacked on the pallet, fasten with belt and wrap with plastic sheet. The pallet Assembly is transferred from the gate of HSA plant until arrives the gate of HDA plant without disassembly.

Our HSA packaging is always shipped on the pallet, so it should be defined as “Transport Packaging”.

Defining the correct type of packaging will help us to select the appropriate packaging design that is matched with actual transportation and handling.

Figure 4.2 Secondary Packaging changed to Transport Packaging

4.1.4 Packaging Qualification Methods

The different type of packaging requires the different qualification method.

Any packaging has to be qualified with drop test and vibration test. These two tests represent the transportation environment. (Appendix A)

Vibration Test:

Vehicle Vibration: uses reference specification of ASTM D999 method B.

Loose Load Vibration: uses reference specification of ASTM D4728.

Drop Test:

Mechanical Handling: use reference specification of ASTM D1083.

Free Fall Impact: use reference specification of ASTM D775.

Figure 2.9 Vibration Tester at Thai Automotive Institute and Drop test at Thai Packaging Centre

The secondary packaging requires both types of vibration test. For drop test, secondary packaging will use Free Fall Impact to be the condition for testing.

The transport packaging also requires both types of vibration test. For drop test, transport packaging will use Mechanical Handling to be the condition for testing. The different condition of drop testing can be shown in the figure below.

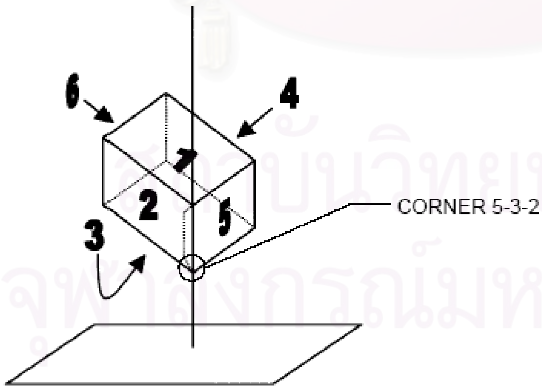
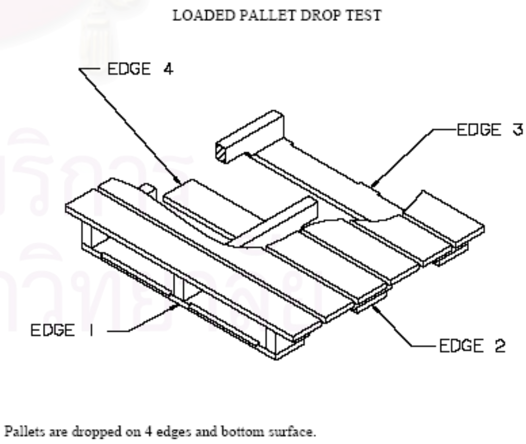
Free Fall Impact Drop test for Secondary Packaging (without pallet)	**Mechanical Handling** Drop test for Transport Packaging (with pallet)
	

Figure 4.4 Drop Test condition of Free Fall Impact and Mechanical Handling

4.1.5 Identified Key Customer

In hard drive manufacturing process, there are both external supplier and internal supplier. Seagate has plant to build Slider, HGA, HSA and HDA. Seagate plant that builds hard-drive component and supply it to other Seagate plants will be defined as the internal supplier of the receiving plant. On the other hand, the company that supplies piece parts component but it is not Seagate plant will be defined as the external supplier.

Slider plant, HGA plant and HSA plant are the Seagate plant. All of them are the internal supplier of HDA plant. If we focus on relationship between HSA and HDA, we can say that HDA plant is the key customer of HSA plant.

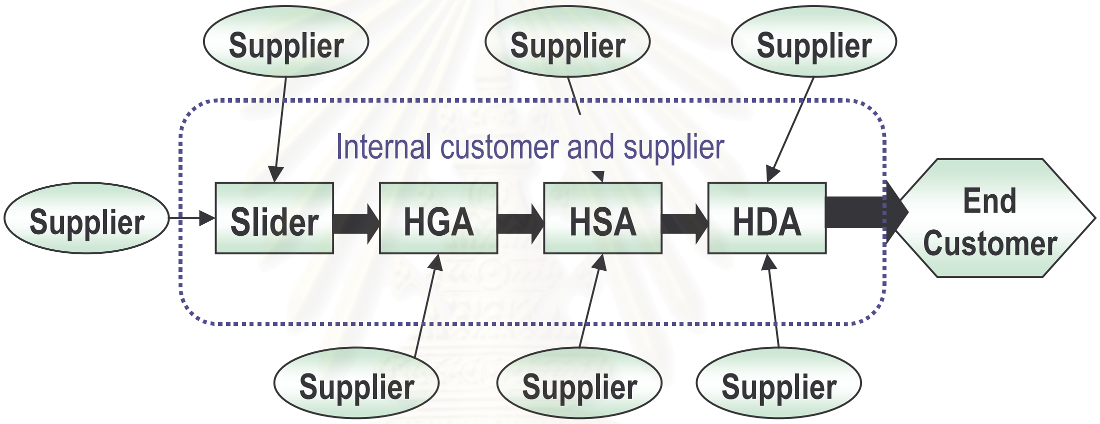


Figure 4.5 Internal and External suppliers *(own creation)*

To have success packaging improvement project, our customer need to be included the concerned people in HSA packaging area also. According to process mapping the customers of this project should also include traffic and logistic department, store and warehouse, manufacturing operator, quality control, packing operator and supplier quality engineer. Without their co-operation, we can not implement the project successfully.

4.1.6 Costs that are related with Transport Packaging

Total Distribution Costs:

There are many activities that are concerned with packaging. All of these activities also generate the cost. The big picture of these costs can be described with the diagram below.

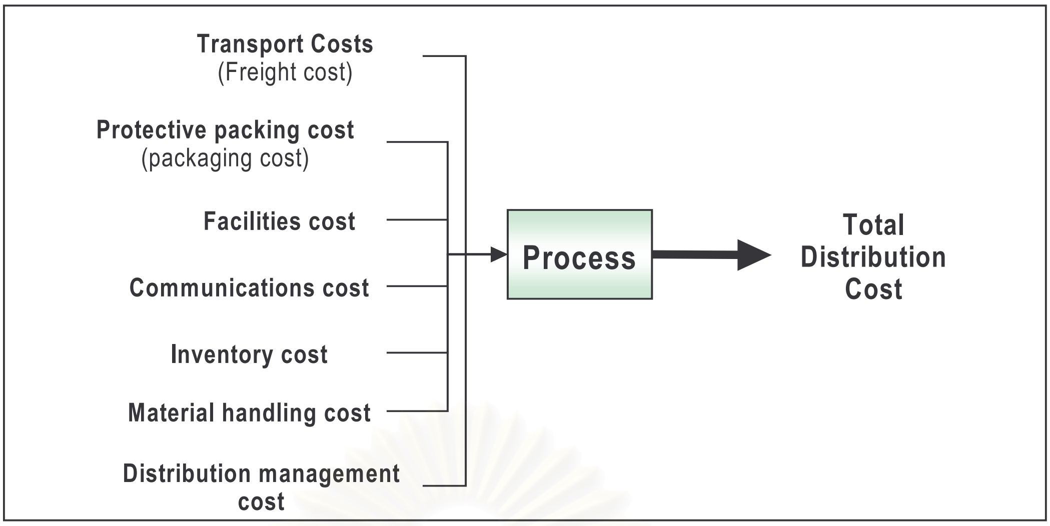


Figure 4.6 Total Distribution Cost *(summarise from Ackerholt,2001)*

Total distribution costs in the equation form, according to Christopher (1985) be expressed as follows: *(Ackerholt, 2001: 42)*

$$TDC = TC + FC + CC + IC + HC + PC + MC$$

TDC	=	Total distribution costs
TC	=	Transport costs *(Freight Cost)*
FC	=	Facilities cost (depots, warehouse)
CC	=	Communications cost (order processing, invoicing etc.)
IC	=	Inventory cost
HC	=	Material handling costs
PC	=	Protective packing costs *(Packaging Cost)*
MC	=	Distribution management costs (control and administration of the flows)

When calculating the costs of packaging systems, one has to take several cost sources into consideration; transport costs (and return transport costs for reusable systems), inventory costs for full and empty packages, handling of packages, and control and administration of the flows (and return flows).

Cost that is related to packaging is not only the packaging material. It is included the cost of managing package and the cost of transportation also.

In this thesis, we will focus on the packaging costs and freight cost that are the major parts of company spending.

4.2 Define Customer Requirements

The goal and objective of Transport Packaging can be defined as the following.

(From www.transport-packaging.com)

Transport packaging, also known as “distribution packaging” in North America, includes the shipping container, interior protective packaging, and any unitising materials for shipping.

The goal in transport packaging is to provide the correct design for packaging such that its contents will arrive safely at its destination, without using too much or too little packaging material. In other words, the package designer must assure that this equation is maintained:

Product + Package = Distribution Environment

We need to make sure that these three variables have well balance, with no excessive over-packaging cost or loss from damage.

Transport packaging should address the following objectives;

- **Product Protection** – The primary purpose of any transport package is to insure the integrity and safety of its contents through the entire distribution system.
- **Ease of Handling and Storage** – All parts of the distribution system should be able to economically move and store the packaged product.
- **Shipping Effectiveness** – Packaging and unitising should enable the full utilisation of carrier vehicles and must meet carrier rules and regulations.
- **Manufacturing Effectiveness** – The packaging and unitising of goods should utilise labour and facilities effectively.
- **Ease of Identification** – Package contents and routing should be easy to see, along with any special handling requirements.
- **Customer Needs** – The package must provide ease of opening, dispensing, disposal, as well as meet any special handling or storage requirements the customer may have.

- **Environmental Responsibility** – In addition to meeting regulatory requirement, the design of packaging and unitising should minimise solid waste by any of the following: reduction-return-reuse-recycle.

4.2.1 The Theory of Transport Packaging Design

(Root, 1997)

Ideally, the package system will provide enough protection to exactly match the requirements of product and distribution environment. There are two pitfalls that may occur if a systems approach to package design is not adapted. In the first situation, the package falls short of the protection requirements and a significant amount of damage occurs during shipment. This "under-packaging" is fairly obvious to detect, but is avoidable and easily corrected with changes to the method of shipment, package design, product design, or combinations of the above. In the second situation little or no damage occurs, but the product is "over packaged". In effect, the package is providing more protection than is required. Just as "under-packaging" wastes money through damaged product and loss of customer good will. "Over-packaging" siphons money directly from a company's bottom line.

The general concept of product and packaging design can be illustrated as the bar chart below.

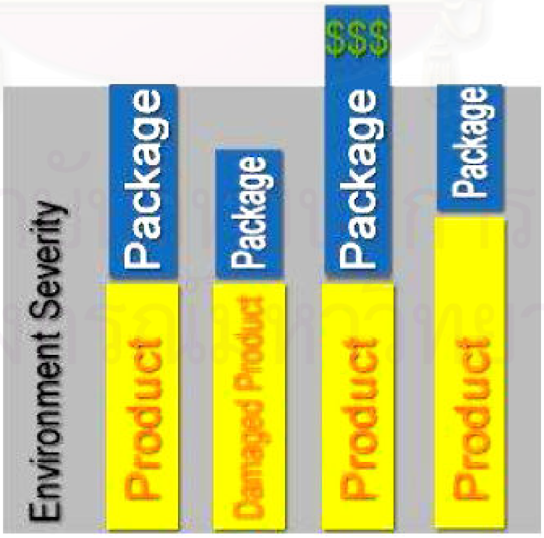


Figure 4.7 Transport packaging design concept (Root, 1997)

The shade background can be thought of as the level of environment intensity or severity for the distribution channel. The product has some inherent ability with stand this abuse, however it usually is not robust enough to make it through shipment on its own. The role of package, therefore, it to make up the difference between what the environment has to offer and what the product can withstand. The ideal case, as depicted by the first product and package system bar, is where the package exactly make up the difference between the product robustness and the environmental inputs. If the package falls short, as depicted by the second product and package system bar, “under packaging” has occurred and damage in shipment will most likely result. If the package provides too much protection, as depicted by the third product and package system bar, “over packaging: has occurred and money is being wasted on protection that is not required. In certain instances it will actually be cheaper to increase product robustness rather than put an expensive package around the unit. This product improvement is shown in the fourth product and package system bar.

Since transport packaging should always be economical, the above goals should be balanced or optimised to achieve the lowest overall cost.

4.2.2 Ideas generation:

We have started generating the ideas with a group of people that are concerned with packaging. The representative from the department that we have listed from process mapping had been invited to discussion together. We decided to use the affinity diagram to be the tools for ideas generation. The result from our brainstorming is shown below.

Product Protection

- Can absorb shock load.
- Met cleanliness and out-gassing specification.
- Achieve vibration test requirement.
- Suggest to use quality guarantee tape
- Can maintain the good quality of product
- Protect finish good from Electrostatic discharge
- Protect Contamination
- Quality of cushion and box from supplier

Ease of Handling and Storage

- Packaging from raw material should be the same as Finish good packaging
- Less packaging configuration will save space due to ease inventory management.
- Prefer to make the order at minimum quantity.

- Total height of pallet should be common.
- Each shipping tray should be stacked firmly.
- Need shipping space utilisation

Shipping Effectiveness

- The total height of pallet can not higher than 160 cm.
- More unit per box is better
- Total weight of shipping pallet should less than 326 kg.
- Size of shipping box should match with the size of carrier.

Manufacturing Efficiency

- Prefer light weight package
- Meet ergonomic requirement for worker.
- Request for universal packaging
- Number of assembly part should be minimised.
- Quantity of part per box should be the same.
- Package transfer rate should be continuous.
- No shortage material
- Each box should have weight less than 5 kg.
- Need document to be the reference.
- Can pack with short time

Ease of Identification

- Do not prefer to re-used box and cushion many times.
- Marking or Identification should be human readable. (not only barcode)
- Has readable identification

Customer Need

- Can use with all transportation modes (Air, Truck, Ocean)
- Can pack and ship with small lot size
- Can ship product with small lot size
- Can carry information with shipping unit
- Engagement between tray and cover should not too tight and ease to open.
- The tray should has proper size per ergonomic
- Can do out of box audit
- Prefer Low Cost
- Compatible with tray cleaning process
- Compatible with customer packing process

Environmental Responsibility

- Size of label should be reduced.
- Would like to eliminate sticker label.
- No bad smell
- Can track time of reuse
- Has Cleaning Identification
- Can be reused
- Material shall be recycle (environmental friendly)

We have got many ideas from the brainstorming. We have tried to group them with the requirement of transport packaging. These requirements and comments will be used to create the QFD. There are many levels of requirements per quality function deployment concept. Normally, there are 4 levels of quality function deployment. The 1st house is about transferring customer requirement to design requirement. The 2nd house is about transfer design requirement to part characteristic. The 3rd house is about transfer part characteristic to key process operations. And the 4th house is about transfer key process operations to production requirements.

We may not able to generate all four houses of quality in this packaging improvement project because many requirements need to be improved at vendor site, such as making the corrugate paper strong and light, or controlling the variation in sponge density. We have decided to generate the 1st house of QFD first that is about transferring customer requirements to design requirements. So we have selected only the items that are related to design requirement to build our first QFD.

In the QFD table, it also has Kano Classification to be the guideline for rating the priority of each requirement. The meaning of Kano Classification is illustrated in figure below.

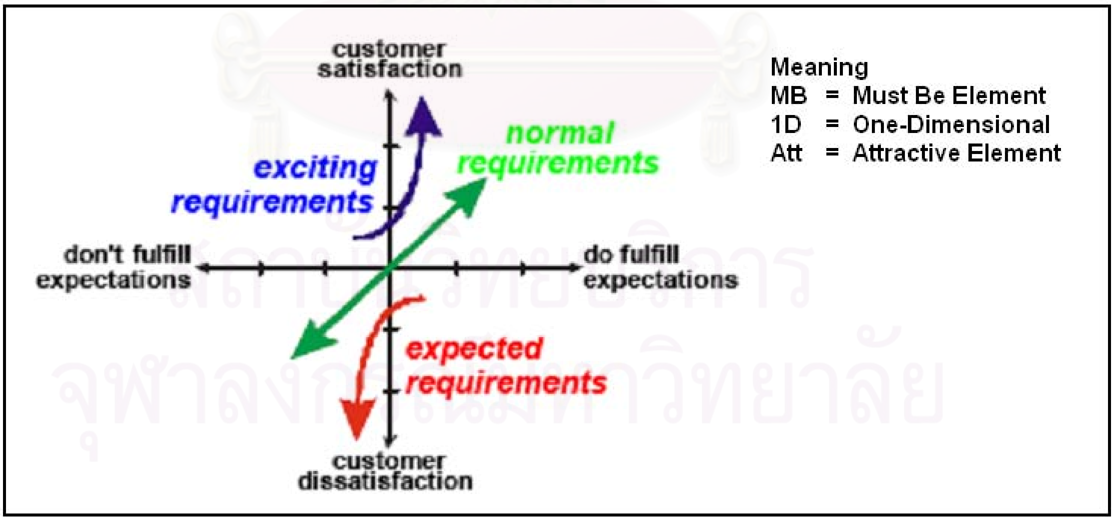


Figure 3.6 Kano's Model of Quality (Mazur, 2003: 1)

There are many requirements from customer. To gathering all requirements in an appropriate format, we need to use the format that can help us to communicate with the other people easily. QFD matrix can help us in this phase.

The first level QFD help us to convert Customer requirements to be Design Requirements.

We have requested our customer to rate the importance score for each transport packaging requirement. The number of important is between 0-10. Number ten means the most important requirement.

We have rated the relationship number between each customer requirement to our design requirement. There are three levels of the relation.

9 means strong relationship

3 means medium relationship

1 means weak relationship

The relationship number will be multiplied with important number of each item and all of them will be accumulated to be the importance rating number.

The highest important number will be the factors that we selected for analysis first. The specifications of each design characteristics have been put into the QFD table for the reference also. This information will help the person who generates part characteristics in the second house of QFD also.

The QFD table of customer requirement and design requirement is shown in the following page.

Table 4.1 : The 1st Level QFD (Customer Requirements to Design Requirements)

Design Planning
Product: Packaging

1st House
Design Requirement

Importance of the Hows is "Importance Rating *Sum of Relationships/20"

Customer Requirements (WHATs / Outputs) \ HOWs / Inputs	Kano Analysis	Importance	Meet Shock load requirement	Meet vibration test requirement	Meet cleanliness specification (LPC)	Meet out-gassing specification	Protect Electrostatic Discharge	Protect contamination	Tray should be stacked firmly	Quantity of part per box	Save space to storage	Weight of shipping pallet assy	Universal packaging	Number of packing assy part	Readable identification	Small lot size	No bad smell	Can be reused	Can be recycle (material level)
Direction of Improvement			↑	↑	↓	↓	✖	✖	✖	↑	↓	↓	✖	↓	✖	↓	✖	↑	✖
Product Protection	MB	10	9	9	9	9	9	9	9		1	3			3				
Ease of Handling and Storage	MB	4							3		9	9	9	3		3			
Shipping Effectiveness (low freight cost)	1D	7							1	9		3	1						
Manufacturing Effciency (low labour cost)	1D	6							1	9	9	3	3	9			3		
Ease of Identification	MB	5											1		9				
Can ship with all transportation modes	MB	5	9	9							1	3					3		
Can carry sufficient information	MB	8													9				
Can do quality audit	MB	5								1		1		3	1	3			
low pacakaging cost	1D	8							3	9		1	3	3				9	3
Compatible with current process	MB	6	3	3	9	3		1	3	3	1	3		1			1		
Environment Responsibility	MB	3	1	1	1	3	1			1	1			1			9	9	9
Importance Rating			156	156	147	117	93	96	157	215	114	151	90	114	152	27	66	99	51
Importance of the HOWs			8	8	7	6	5	5	8	11	6	8	5	6	8	1	3	5	3
Objective Measures																			
Units			G.	Hz.	particle /cm2	ng/cm2	Ohm	enclose	include	unit	m3	kg.	include	piece	include	unit	include	include	include
Target													Y						Y
Lower Limit			100	300						45	1.7								
Upper Limit				3	500	770	10^5	Y	Y		1.9	326		6	Y	120	Y	Y	

4.3 Measure Current Performance

4.3.1 The metrics to measure the performance of current packaging.

Six-Sigma uses term KPOV (Key Process Output Variable) to call the output that we consider. In this thesis, we will use Packaging Cost per HSA and Freight Cost per HSA to be our primary metrics.

Moreover, we can not ignore the negative effect that may be occurred when we try to improve our primary metric. Reducing the packaging cost, we need to make sure that our package is still good enough to protect HSA. In this packaging improvement project, we use the percentage of head damage defect to be the secondary metric.

Percentage of head damage is the attributed data. Only percentage of defect may not sensitive enough to detect the risk of new packaging design. We also use HSA Gram-load that is the variable data to detect the risk of our new packaging also.

Metrics:

Primary metric: **1. Packaging Cost per HSA**
2. Freight Cost per HSA

Secondary metric: **1. Percentage of head damage defect**
2. Gram-Load of HSA

(The secondary metric will be presented in the following chapter)

4.3.1.1 Measure Packaging Cost per HSA

In the past, the company calculated packaging cost per HSA from secondary packaging concept. We calculated packaging per HSA by using packaging cost per box divide by number of HSA per box.

With the transport packaging concept, we need to change the way we calculate packaging cost per HSA to be the cost of packaging per pallet divide by number of HSA per pallet. The table below shows how we calculate the packaging cost per HSA.

Packaging Cost per HSA

Unit in US$

A.) Packaging Before Problem Occure (Baseline)

		Cost/set	Cost/pallet
Pallet Cost	1	8.5	8.5
Wrap +Belt +Edge Board	1	16	16
Carton box & Cushion	24	3.5	84
Tray (set)	24	22.4	537.6
Number of HSA per pallet	1080		
Packaging Cost per HSA		=> US$	**0.598**

B.) Packaging with extra cushion (Short term solution)

		Cost/set	Cost/pallet
Pallet Cost	1	8.5	8.5
Wrap +Belt +Edge Board	1	16	16
Carton box & Cushion	16	10	160
Tray (set)	16	22.4	358.4
Number of HSA per pallet	720		
Packaging Cost per HSA		=> US$	**0.754**

To have accurate cost, we have not included times of reuse in the calculation

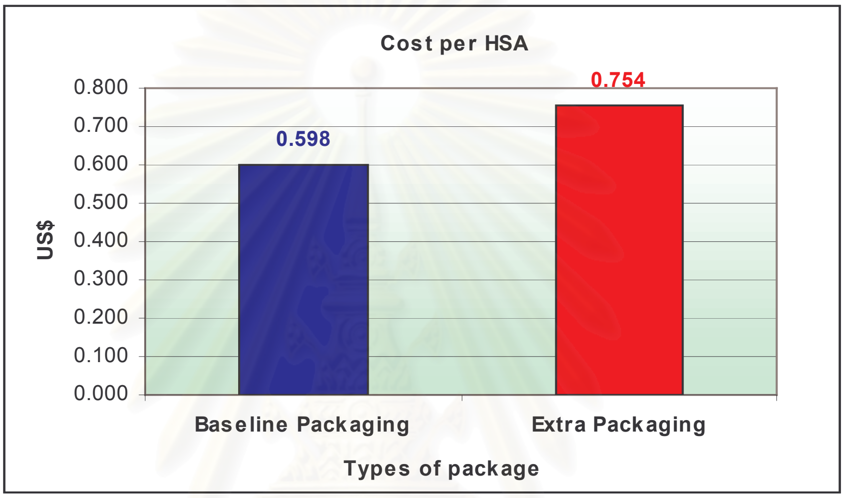


Figure 4.9 Packaging cost comparison

4.3.1.2 Measure Freight Cost per HSA

Firstly, we need to understand the structure of freight. Freight forwarder charges our company by the freight cost per shipping pallet (freight per one set of transport packaging).

The calculation of freight cost per HSA is shown below.

(Base on airfreight from Thailand to China)

1.	Freight charge	=	58 Baht per kg.	(Variable cost)
2.	Custom charge	=	1,400 Baht per shipment	(Fixed cost)
3.	Destination charge	=	6 Baht per kg.	(Variable cost)
4.	Crisis charge	=	2 Baht per kg.	(Variable cost)
5.	Fuel charge	=	3 Baht per kg.	(Variable cost)

Calculation method of chargeable weight:

1 Full pallet dimension = 104 x 124 x 160

= 2,063,360 cubic centimetres

(6000 is international coefficient to calculate chargeable weight)

Chargeable weight = 2,063,360 / 6000 = 344 kgs.

Total freight cost per pallet = [344 x (58 + 2 + 3 + 6)] + 1400

= 25,136 Baht

= 628.4 US$. *(Convert to US$)*

The freight cost per HSA of current packaging is shown below.

<u>Freight Cost per HSA</u>

Unit in US$

A.) Packaging Before Problem Occure (Baseline)

Freight Cost per pallet	628.4	US$
Number of HSA per pallet	1080	HSA
Freight cost per HSA	**0.582**	**US$**

B.) Packaging with extra cushion (Short term solution)

Freight Cost per pallet	628.4	US$
Number of HSA per pallet	720	HSA
Freight cost per HSA	**0.873**	**US$**

Figure 4.10 Freight cost comparison

We have found that baseline of freight cost per HSA is 0.582 US dollar. Freight cost per HSA from extra cushion packaging is higher than baseline packaging but it is only shorten solution, so we did not use it as the baseline for improvement.

CHAPTER 5

START SIX-SIGMA IN MICRO PROCESS

5.1 Prioritise, Analyse and Implement Improvements

The fourth phase of our Six-Sigma Roadmap is about how to tackle each problem in detail.

In this thesis, we need to find out the solution for packaging improvement. Refer to the objectives, our project is to have the new package that reduces cost. This cost includes both packaging cost and freight cost.

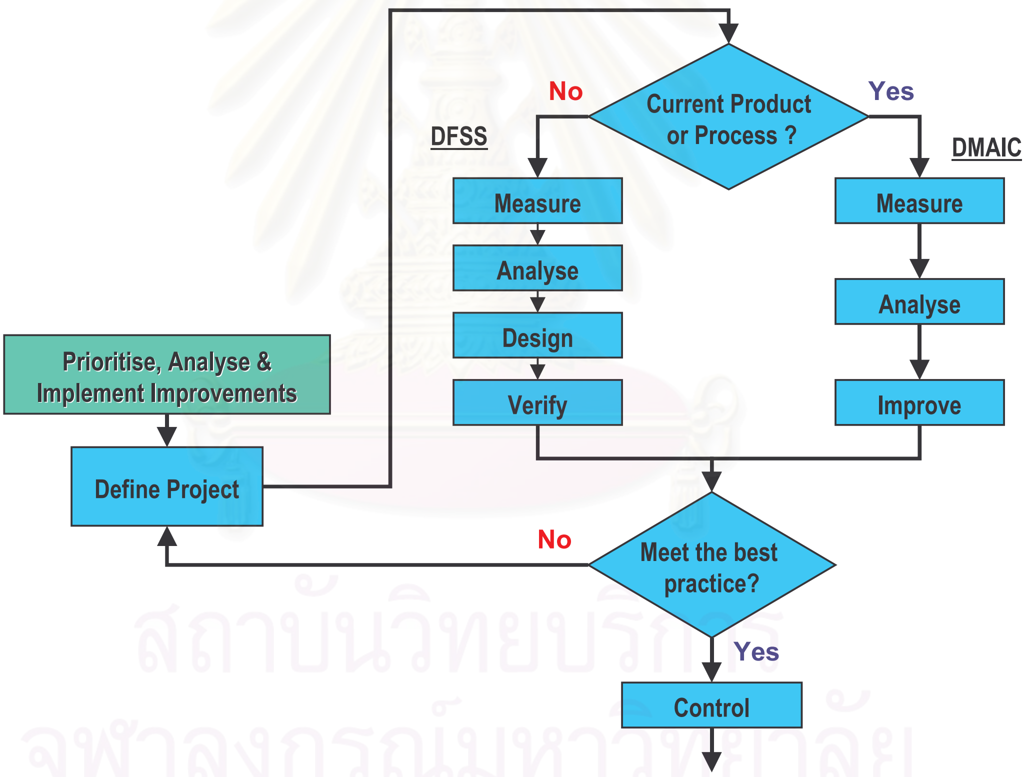


Figure 5.1 Six-Sigma micro process.

(Adapt from Algase, 2003: 31 and Pande, 2000)

Currently, there is no packaging that is design for transport packaging criteria. To get the breakthrough improvement from our study, we have decided to use DMADV process.

5.1.1 Define Phase

HSA package is composed of many components. We need to select the one that has most effect to the cost and do the improvement project on it.

To generate big improvement in cost, we have linked our improvement project to company spending. The actual expenditure of each packaging component is shown in the pie chart below.

Thailand	Q1'04	
Description	Value	Percentage
Tray	3894000	66%
Comb	611000	10%
Carton box	1351000	23%
Others	84000	1%
Total	5940000	
	0.30	

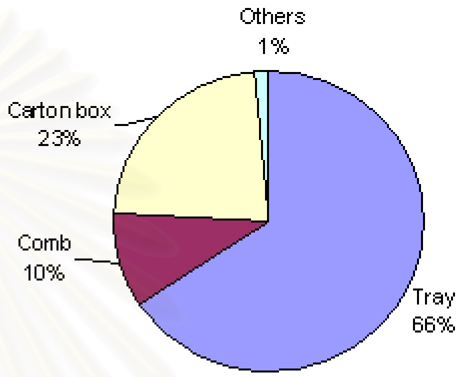


Figure 5.2 Actual packaging spending per component

Company has expensed for Shipping Tray about 66% of overall packaging cost, the expense for Carton box (include sponge) is about 23%, and expense for shipping comb is 10%. The other component, such as bag, belt, pallet, and edge board are less than 1%.

(Anderson, 1999)

Pareto's Principle, the 80/20 Rule, should serve as a daily reminder to focus 80 percent of your time and energy on the 20 percent of you work that is really important. Don't just "work smart", work smart on the right things.

Refer to Pareto concept, 20% of our factors, may help us reduce 80% of our problem. The pie chart is reported by grouping some component together. The detail of each group is shown below.

Tray: Tray is composed of Top Cover, Bottom Cover, Clip and tray.

Comb: Comb is composed of Comb, and HSA Head Guard.

Carton Box: Carton Box is composed of Corrugated Box and Cushion

Others: Pallet, Belt, Edge board, Plastic wrap, bag and tape.

We can see that we should try to improve **Tray** as the 1st priority.

Comb is one of the major spending but it is not the packaging part. So we remove it from our list.

Carton Box and **cushion** are also the major parts that we need to have improvement.

5.1.1.1 Setting the objective goals

To have clear objective for project improvement, we have defined our goal by using our historical data.

In the year 2000, HSA had packaging cost at 0.18 US$ per unit. And the cost has been increased dramatically to 0.87 US$ within 4 years. Sine extra cushion packaging is only short-term solution. We are going to use 0.58 US$ per HSA that is the cost of current packaging to be the baseline for our project.

When we discussed with management, they have requested us to reduce the packaging cost to be 0.18 US$ per HSA. The packaging cost per HSA at 0.18 US$ is a very aggressive goal. If we can achieve this goal that means we can save 0.40 US$ per HSA. This is a huge improvement.

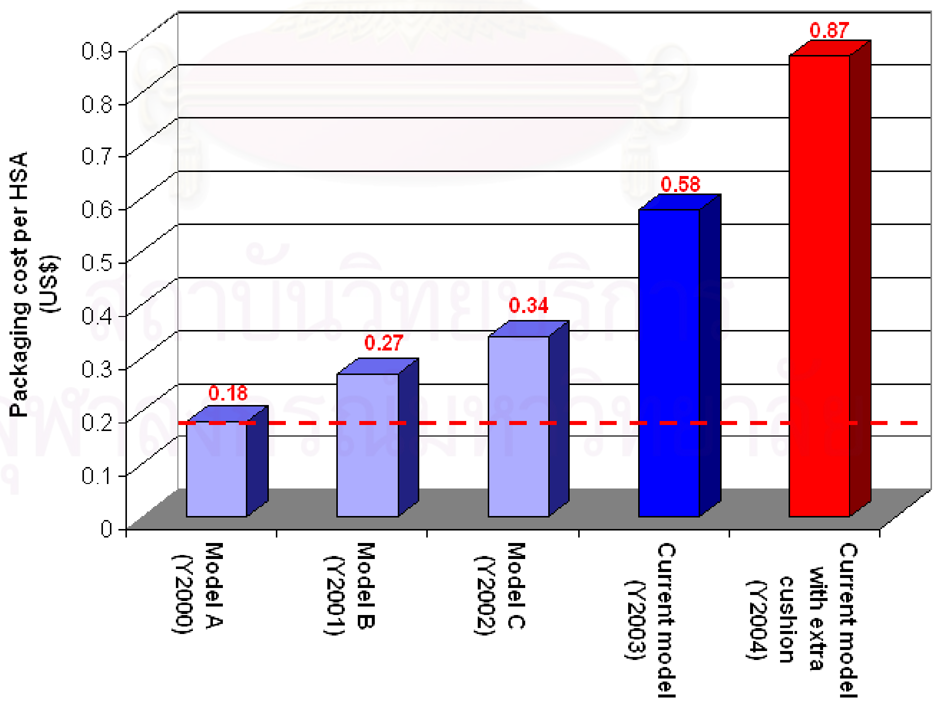


Figure 5.3 Comparison of Packaging cost by model

5.1.1.2 Set up the quality improvement team

Only one person can not get the breakthroughs improvement, we need to have enough support to achieve breakthrough improvement. Joe Defeo of Juran institute has recommended things that are needed to get breakthrough in the figure below.

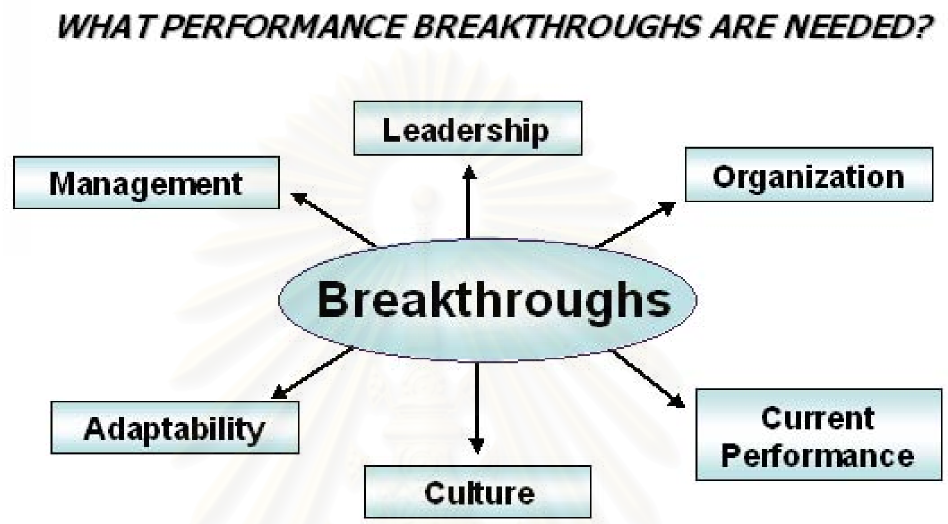


Figure 5.4 (Defeo, 2002)

To get breakthrough, we need co-operation from every group of people that are concerned with our packaging improvement project. We need to have a strong leadership, support from top management, authority from organisation, enough knowledge, adaptability skill to find out the solution, and good quality improvement culture from the concerned area.

I have requested everybody in the team searching for improvement from his or her responsibility. I have forwarded packaging requirements to each of them. The QFD table can help us a lot to flow our requirements down in this phase.

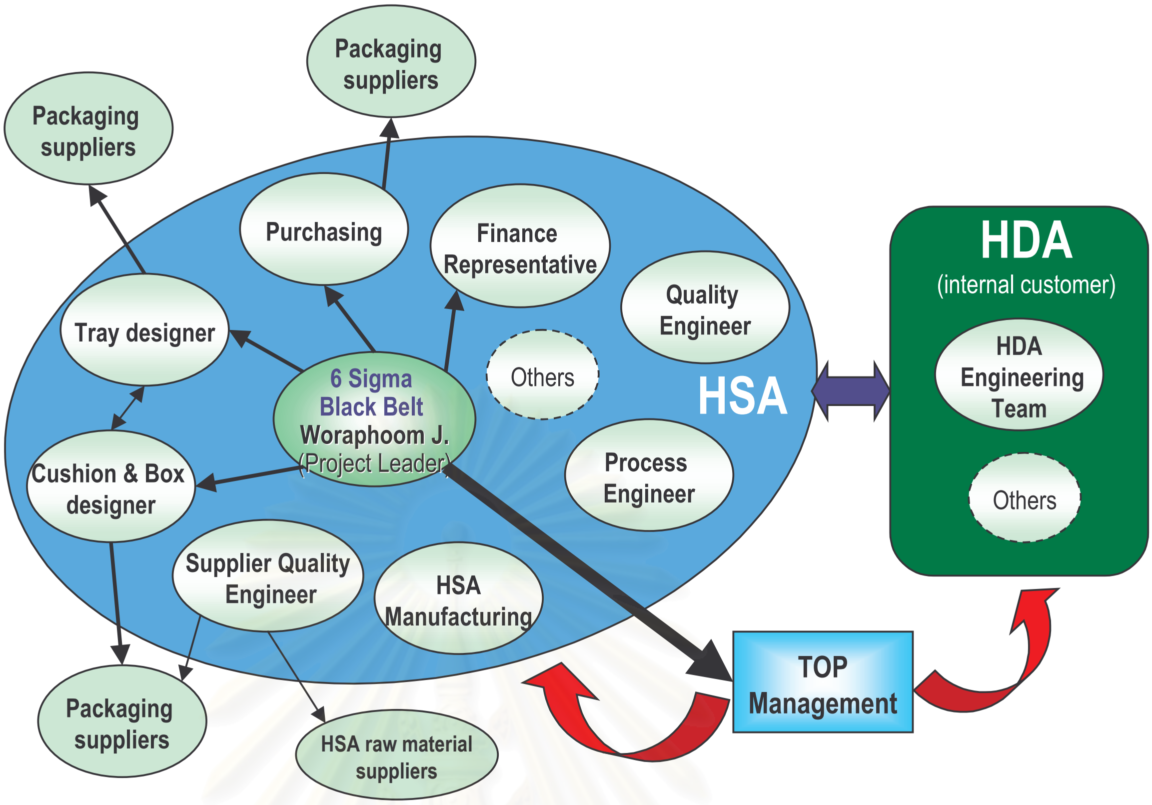


Figure 5.5 Linkage between team members *(own creation)*

To set up the team, I as the project leader had started the project by sending requirements to packaging design engineer. We have communicated and announced the goal to all team members. We also try to get the support from top management by presenting the cost saving opportunities that our team can generate from this packaging improvement project. Top management was very interested in packaging improvement and informed HDA plant to support the HSA packaging improvement project.

With this approach, we can get the support from both HSA and HDA site. Once Top Management focused on this project. Everybody in the company work collaboratively and try to achieve the goal.

5.1.2 Measure Phase

5.1.2.1 Identify Key Process Input Variable (KPIV) of Freight Cost

Freight Cost:

Packaging Assembly on pallet (Pallet Assembly) is a major factor that company uses for calculating freight cost. Freight forwarder or logistic company will quote the freight price by using volume of completed pallet assembly. Generally, if the weight of pallet assembly more than 326 kg. Freight forwarder will quote the price from the actual weight but if the weight of our pallet assembly less than 326 kg, freight forwarder will quote the price by using the outer dimension of our pallet assembly.

HSA weight is light. So far, the total weight of our pallet assembly is always less than the triggering limit of weight charge.

The pallet assembly and its volume that is used for quoting the freight price are shown below.

Figure 5.6 The cubic volume that is used for freight charge calculation

Freight cost or transport cost has the direct relation with packaging. Normally, weight of electronic product is light. Freight forwarder will charge the company by volume weight. To get the lowest freight cost per HSA, we need to have the package that can contain more HSA per pallet as much as possible.

When we discussed with traffic and logistic manager who is the responsible person for freight charge. She has highlighted that the freight cost is concerned with many things. How can her staff know what can be improved to reduce the freight cost?

To help everybody understands which activities cause actual high freight spending; we have started with the process mapping of shipping HSA. The purpose of this process map is to understand the step of generating invoice and shipping HSA to the customer. The process map diagram is shown below.

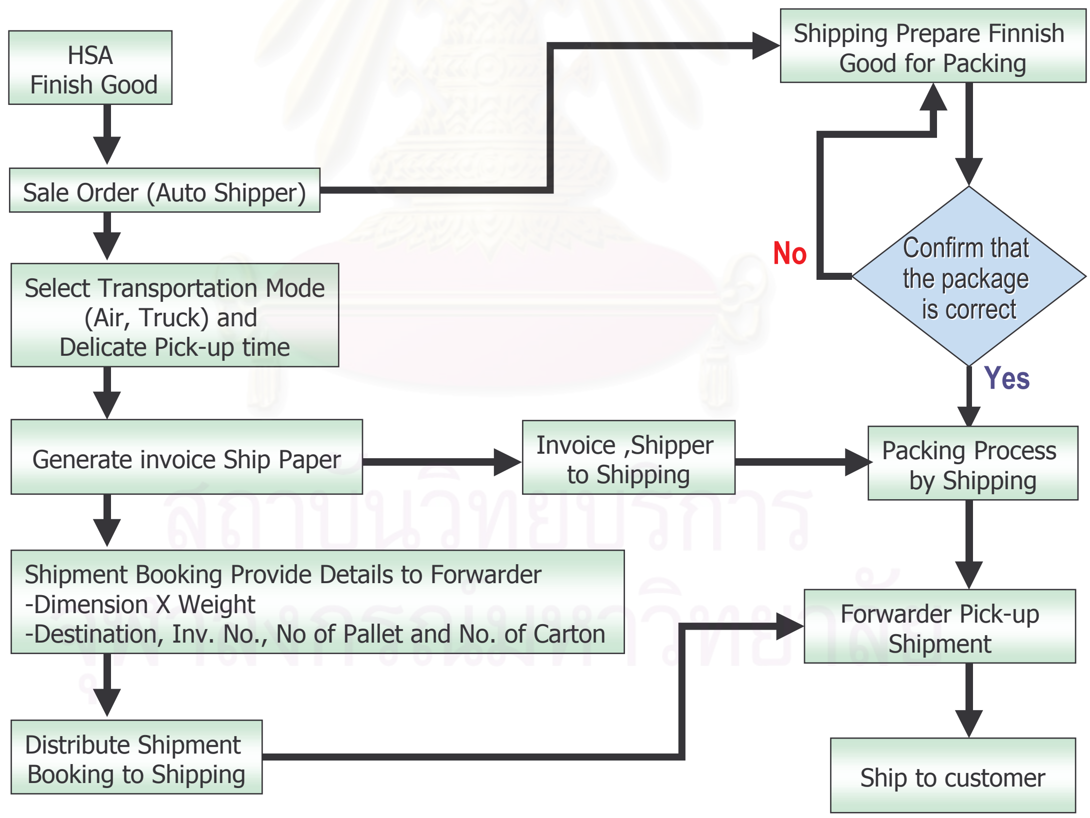
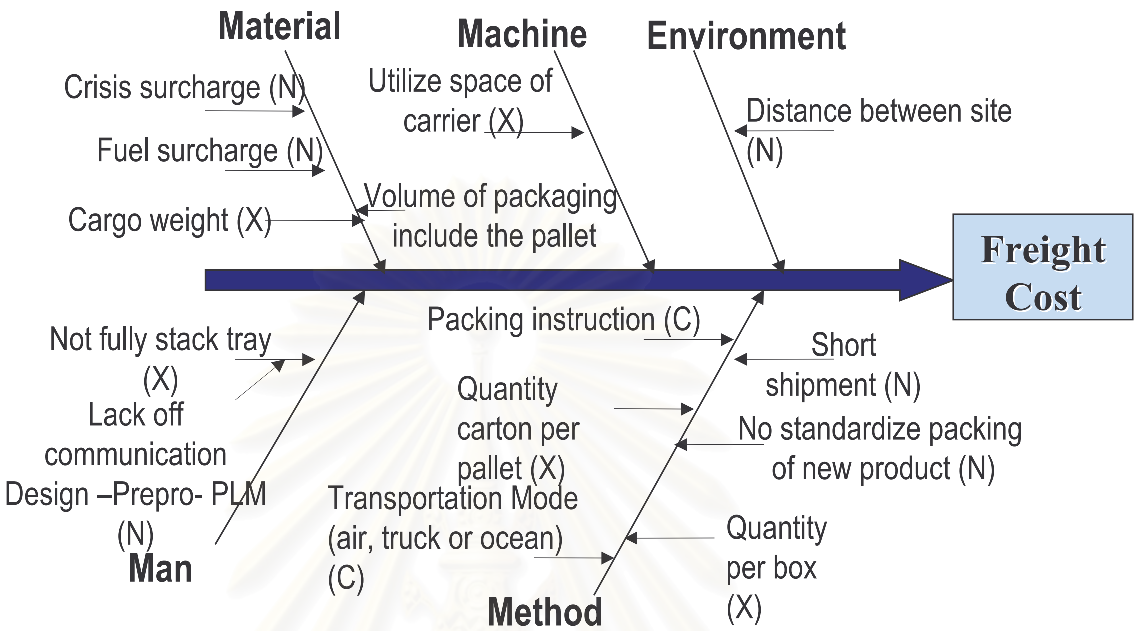


Figure 5.7 Process Mapping of Shipping HSA (focus on freight spending)

The process mapping help us to understand the shipping process. We also us the process mapping to list the possible KPIV that is related to the freight cost.

We have listed the factors that are related to the freight cost. We used man, machine, material, method and environment for brainstorming.



(C) = Controllable factor, (X) = Candidate for detail analysis, (N) = Noise factor

Figure 5.8 Cause and Effect Diagram of Freight Cost *(own creation)*

There are 14 factors that can be listed by using Cause and Effect diagram. C&E diagram can help us to list the KPIV (Key Input Variable) but it does not show us which KPIV is the most important to freight cost. We need to have another tool that can help us set the priority for each factor. Six-Sigma method recommends us to use FMEA (Failure Mode and Effect Analysis).

In FMEA, there are three parameters that guide us to set the priority of each KPIV. Letter 'S' means severity, it is about how serious of that KPIV to the freight cost. Letter 'O' means occurrence, it is about how often of that item occur. 'D' means Detection, it is about the effectiveness of detecting system of that item. All three number from S, O, D will be multiplied together to be Risk Priority Number (RPN).

(The equation; $S \times O \times D = RPN$*)*

The FMEA table of activities and things that are related to freight cost is shown in the next page.

Table 5.1: FMEA of HSA Freight Cost

Process or Product Name:	HSA	Prepared by: Woraphoom J.		Page _1___ of _1__
Responsible:	Woraphoom J.	FMEA _____ (Rev) _1___________		

Process Description/ Function	Potential Failure Mode	Potential Effects of Failure	SEV	Potential Causes of Failure	OCC	Current Controls	DET	RPN	Action Priority	Corrective Action
Sale Order (Auto shipper)	Low number of part per invoice	too many invoice	2	special SBR, build schedule not match with shipping schedule	8	Issue invoice 1 time a day	3	48		
Select Transportation Mode (air / truck)	High freight cost	High freight cost per HSA	7	Urgent request from customer, incorrect default transportation mode	5	Manage to ship with truck as the default.	4	140	5	Improve accuracy of requirement and build plan
Generate Invoice	delay the shipment	Shipment delay and need to change from truck to air shipment	6	incorrect invoice	3	Auto shipper	3	54		
Shipping Prepare Finish Good for Packing	Finish good not enough to ship the full pallet	High freight cost per HSA	7	Production miss output, low volume build, short shipment	5	waiting until pallet is full	4	140	5	Set mimum total height of pallet before ship
	Incorrect packing	Delay shipment and high freight cost	7	operator selects the wrong box	3	Supervisor inform	4	84		
			7	No standardize packing of new product	5	Supervisor inform with reference document	3	105	6	Implement the universal packaging
Shipment Booking, Dimension, weight, Distination, no. of part per pallet	high freight cost	Ship to wrong destination	8	human error, lack of communication	1	Check with build plan	2	16		
		Not utilize space of carrier	7	Low quantity of carton per pallet	9	Operator check	6	378	1	Increase number of box per pallet
			7	Quantity of HSA per box not full	7	Build plan per shift	7	343	2	Increase number of HSA per box
			7	Unfully stack tray	5	Refer to official drawing	6	210	4	Increase number of tray per stack
			7	Volume of package with pallet	7	Check that it not exceed maximum height	6	294	3	Design the package with appropriate dimension
		High air freight charge	7	High crisis and fuel surcharge	3	Global rate	1	21		
			7	Heavy weight packaging	1	Freight forwarder cross check	1	7		

FMEA table gives us the RPN number. The highest number of RPN means the most important item that we should focus to reduce the freight cost down.

The RPN number of each factor is shown in the figure below.

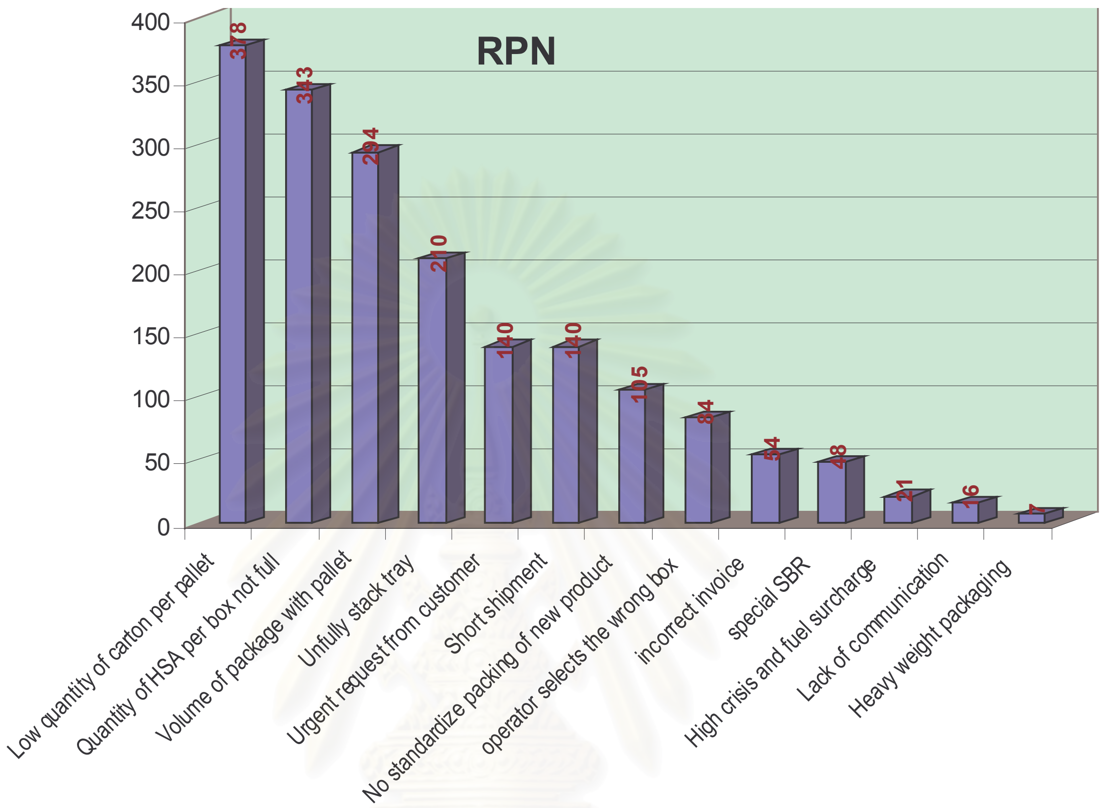


Figure 5.9 Risk Priority Number Chart

We have realised that the major factors that we should focus to reduce freight cost are mainly about shipping capacity of pallet. The RPN number shows us that the first four factors that we should focus, all of them are about the quantity of HSA per shipment. And the factor that is about fuel charge and weight charge are less important.

With the result of this analysis, traffic and logistic department agree to ship the shipping pallet with full capacity. And they have requested us to improve the packaging to contain more HSA.

5.1.2.2 Identify Key Process Input Variable (KPIV) of Packaging Cost

Packaging Costs:

The company will consider the packaging cost per HSA. This is because it is directly related to the product cost.

We can calculate the packaging cost per HSA by using the price of packaging per pallet divide by number of HSA on that pallet.

Packaging cost per pallet is composed of the cost from box, pallet, edge-board, belt, plastic wrap, cushion, vapour barrier bag, tray and clip.

If the packaging has high shipping capacity, the packaging cost per unit will be reduced. And the freight cost per unit will be reduced as well.

$$PCU = \frac{(B + C + A + T + G + P + L + W + S)}{N}$$

When	PCU	=	Packaging Cost Per HSA
	B	=	Box cost
	C	=	Cushion cost
	A	=	Bag cost
	T	=	Tray cost
	G	=	Clip cost
	P	=	Pallet cost
	L	=	Edge board cost
	W	=	Wrapping cost
	S	=	Tape cost
	N	=	Number of HSA per pallet

This equation can help us to see the big picture of overall packaging cost. According to the pie chart of company spending, the major packaging components that have the big impact to cost are HSA tray, Carton box and Cushion. Our problem is how can we reduce the cost of these packaging components. After we have discussed with purchasing department and packaging designer. We have found that there are many activities that can reduce the cost, such as reuse the package, price negotiation with supplier, find out the alternative packaging material that has lower cost, or extend time of reuse package. Anyway we found that there is a common factor that is effect to every component cost. It is the quantity of HSA per transport package.

If we can increase the number of N in the equation, the cost of every packaging component will be reduced also.

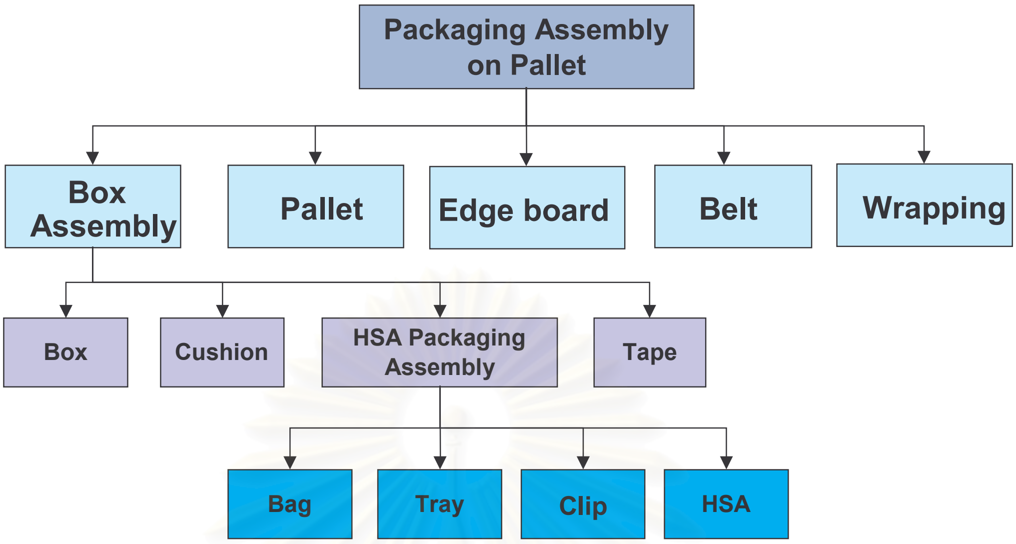


Figure 5.10 Tree diagram of packaging component *(own creation)*

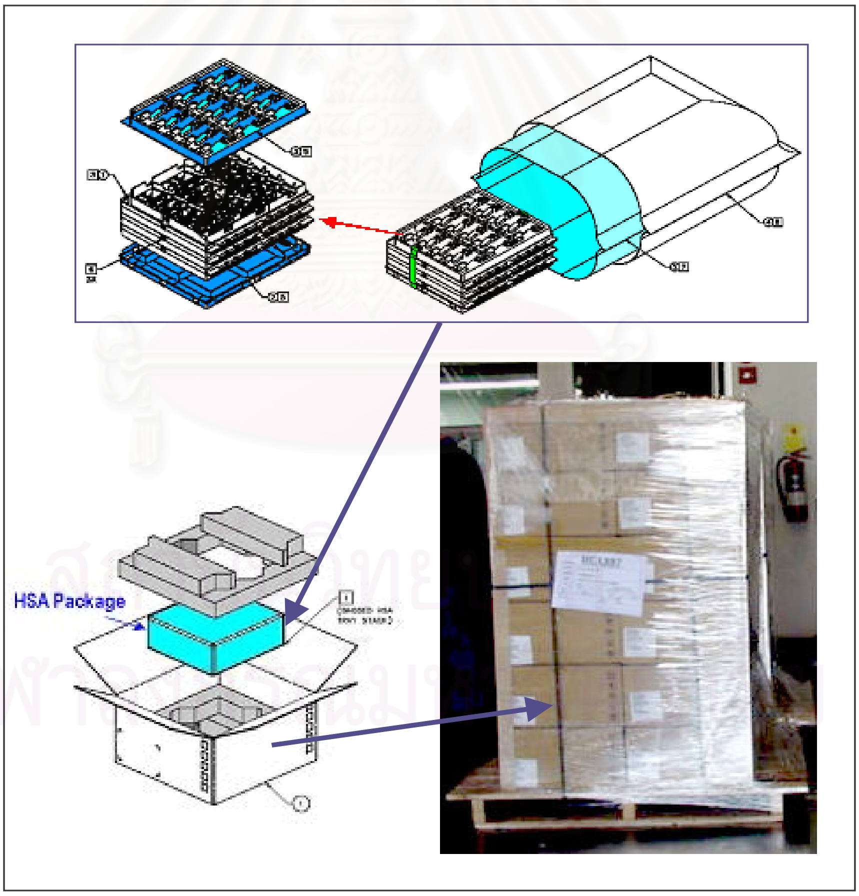
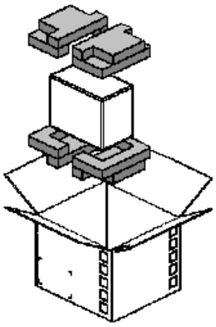
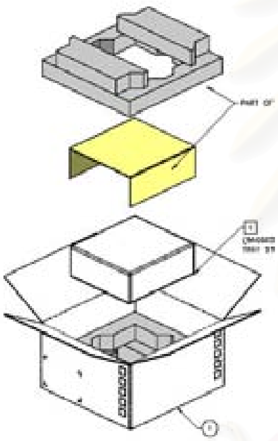
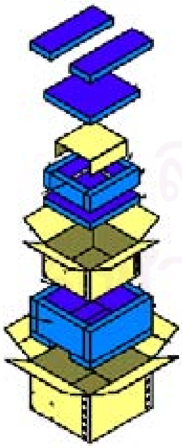


Figure 5.11 Component of baseline packaging *(own creation)*

<u>**Table 5.2: Packaging Design Comparison**</u>

Design	Description
Model A (packaging in year 2000)  	Capacity per pallet **1,200 units** Weight of HSA package per box **1.416 Kg.**
Baseline Packaging  	Capacity per pallet **1,080 units** Weight of HSA package per box **2.657 Kg.**
Extra Cushion Packaging  	Capacity per pallet **720 units** Weight of HSA package per box **2.950 Kg.**

All of the existing packages have been designed with secondary packaging concept. The company never has the transport packaging yet. This is the big challenge.

We have decided to design the new packaging by using the transport packaging concept. According to Six-Sigma methodology, we have decided to use Design for Six-Sigma process that is included Measure, Analyse, Design and Verify to be our design improvement process.

Before we start Analyse phase, we did the comparison among the existing packaging design. In this case, we use benchmarking analysis between the current design with all packaging designs that has been used in the past 4 years.

We can found many interesting things from our observation. The HSA package that was used with model-A packaging has the lightest weight. It has weight only 1.416 kg. When we compare it with the newest HSA package that requires extra cushion packaging, the new package has weight at 2.950 kg that is the heaviest weight.

And we also had observed that the orientation of HSA packaging between current packaging and model-A packaging are different. This is because model-A packaging holds HSA tray in the vertical direction but current model holds HSA in horizontal direction.

In the next phase, we are going to deploy our QFD requirements to sub-system level. The sub-systems that we have selected are Box, Cushion and HSA tray. This is because these components have the biggest impact to the freight and packaging cost.

Conclusion of Measure Phase:

To achieve the lowest freight and packaging cost, we should focus on the shipping capacity of the pallet. If the number of HSA per pallet is increased, both freight cost and packaging cost will be reduced as well.

In the next phase, we are going to analyse the conceptual design of HSA packaging in detail.

5.1.3 Analyse Phase

(DeFeo and Bar-Ei, 2002)

Analyse – In the Analyse phase, a design is selected from several alternatives, followed by the development of design requirements against which a detailed design is to be optimised. The design team them develops several 'high-level' options. On of the designs or a combination is selected, followed by the selection of the 'best-fit' design.

According to Transport Packaging concept, the robustness of product can help us to reduce the level of packaging requirement also. We have discussed with the HSA design engineer about how can we increase the robustness of HSA. Design engineer has agreed that they need to increase the robustness of HSA in the next generation of Hard Drive.

During the discussion, HSA design engineer also helps us to analyse our assumption about the orientation of packaging has effect to the robustness of HSA or not by using computer simulation.

We used Computer Aid Design software that is called "IDEAS" to do Finite Element Analysis.

The simulation shows us that vibrating HSA in the horizontal direction, HSA will be more fragile than vibrating it in the vertical direction. We have decided to test this hypothesis by comparing the packaging performance between vertical packing and horizontal packing.

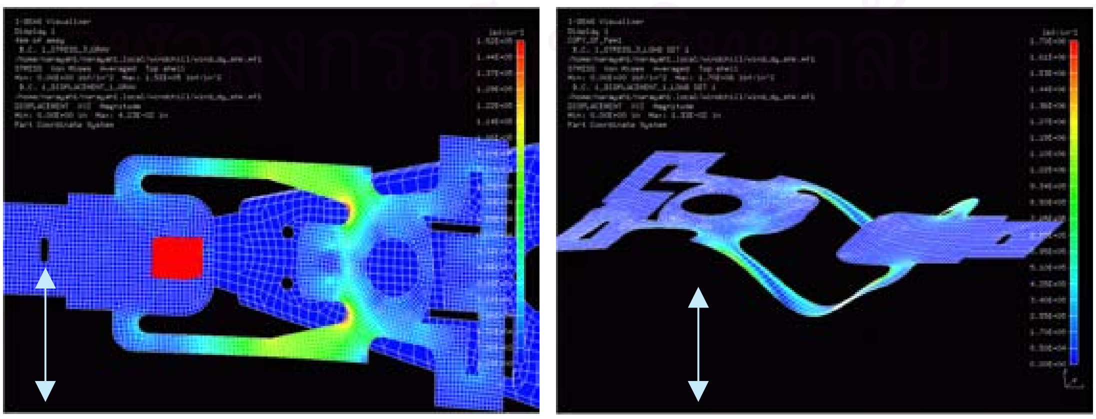


Figure 5.12 Finite Element Analysis from IDEAS program *(Narayan & Woraphoom)*

5.1.3.1 Hypothesis testing:

The orientation of packaging has the effect to quality of HSA or not?

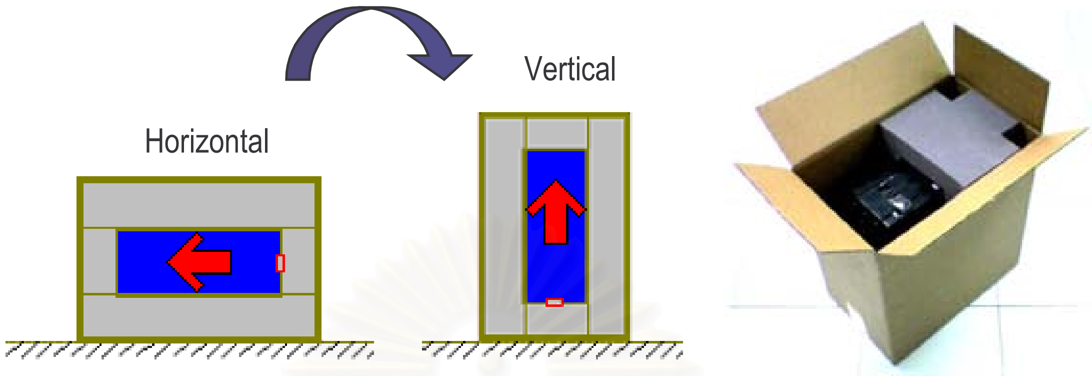


Figure 5.13 Change box orientation

Hypothesis Statement:

H0: Different orientation has the same effect to HSA.

H1: Different orientation has different effect to HSA.

The purpose of this evaluation is to analyse that which orientation is better for protecting HSA. We did the evaluation by request the sample box and cushion from vendor. The thickness of cushion and other cushioning properties are the same as the baseline packaging design.

The sample part has been measured gram-load and inspected that it is the good HSA. HSA in the box is numbering to make sure that we can compare the gram-load after drop test and vibration test of each individual HSA. The process flow of evaluation is shown below.

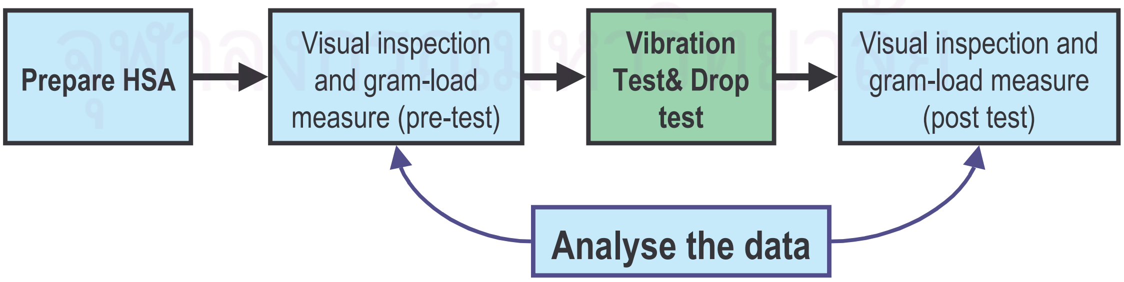


Figure 5.14 Process of packaging qualification test *(own creation)*

Metrics for Packaging Evaluation:

We need to select the metric to measure HSA robustness. In this evaluation, we use the gram-load of HSA to be the primary metric. This is because gram-load is the variable data. Using variable data will help us reduce the sample size of HSA for the testing also.

To make sure that we have not overlooked the other problems that may occur to HSA, we have decided to do visual inspection for detecting the mechanical defect also. So the percentage of HSA damage defect is the secondary metric in this evaluation.

- **Primary metric:** The difference of Suspension Gram-load before and after packaging qualification test.
- **Secondary metric:** Percentage of Head Damage Defective.

<u>Measurement System Analysis:</u>

Percentage of head damage defective:

Head damage is the visual inspection criteria. We dispose HSA to be a good part or bad part by human eye. To make sure that we have reliable gage, the inspectors need to pass GR&R with screen % effective score vs. attribute at 100%. This is because we did qualify our packaging with 0% failure.

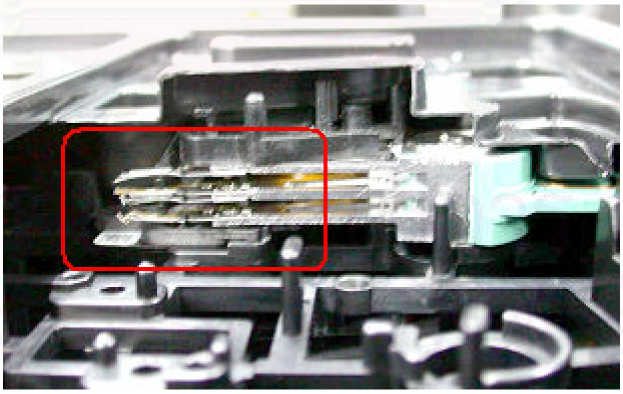


Figure 5.15 HSA head damage defective

<u>Gram-load of HSA:</u>

Gram-load is a variable data. It was measured by load sensor on the tester. Load sensor will read the spring force from the suspension and report the result in grams.

The figure below shows how we measure gram-load.

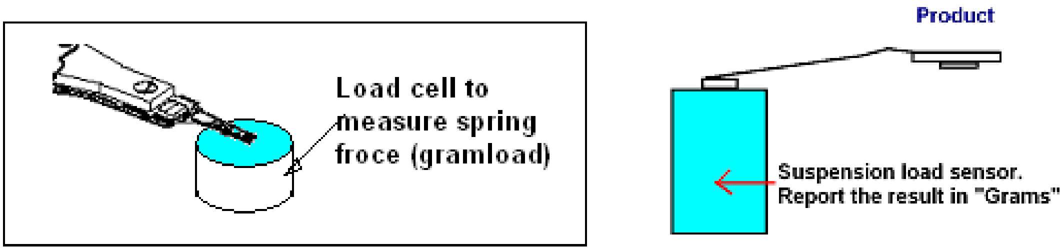


Figure 5.16 Gram-Load measurement *(own creation)*

Before we use Gram-load tester to be the gage, we have to make sure that it has enough capability to be our measurement system. Gram-load is the variable data. In this case, we use the measurement system analysis with variable GR&R study to qualify gram-load tester. Tester needs to be qualified with the specification below.

Table 5.3: Criteria variable GR&R study

		%R&R	DR	P/T
BAD	Red Zone	> 7.7%	< 5	> 30%
ACCEPTABLE	Yellow Zone	2 - 7.7%	5 -10	10 - 30%
GOOD	Green Zone	0 - 2%	> 10	0 - 10%

Summary from (Joglekar, 2003) and (Scutoski, 1998)

Selecting the statistical analysis for compare two groups of data

In this evaluation, we are trying to compare the mean of two groups of data. So we selected two-sample t test to for statistical analysis.

Calculate the sample size of hypothesis testing:

The sample size is very important in hypothesis testing. This is because insufficient sample size may cause the mistake in our conclusion. The estimation of sample size is shown below.

2-Sample t Test *(With MINITAB software)*

```
Testing mean 1 = mean 2 (versus not =)
Calculating power for mean 1 = mean 2 + difference
Alpha = 0.05  Assumed standard deviation = 1

            Sample  Target
Difference    Size   Power  Actual Power
         1      17    0.80      0.807037
         1      23    0.90      0.912498
```

```
        1       27     0.95       0.950077
        1       38     0.99       0.990402

The sample size is for each group.
```

The statistical analysis shows us that to get power of the test at 99%. We need to have sample size more than 38 data points. Anyway if we can have more sample size that means it will be better to detect the different between two distribution, but we need to keep in mind that too many sample size will cause high testing cost also.

Testing the Hypothesis:

We recorded the gram-load data before and after packaging testing (Drop test and vibration test). Ideally, gram-load of HSA should not change after the packaging testing. To detect the change effectively, we use the delta (different value) of gram-load before and after testing to be the packaging performance indicator.

We have collected the baseline data for comparison. The result is summarised in Statistical format as following.

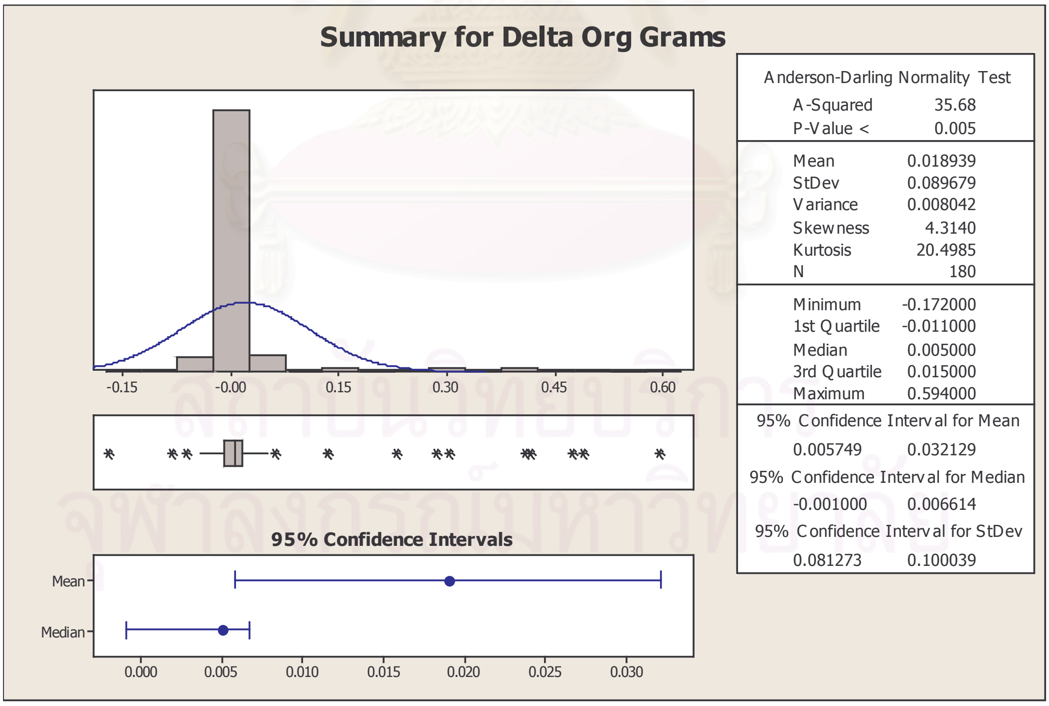


Figure 5.17 Statistical Summary of gram-load difference from Horizontal Packaging. *(with MINITAB)*

We have measured the performance of current packaging in term of product protection by using data of gram-load change. Gram-load data is the variable data. It should help us to investigate the performance of packaging sensitively.

And the result of evaluation group (vertical package) is summarised with statistical as following.

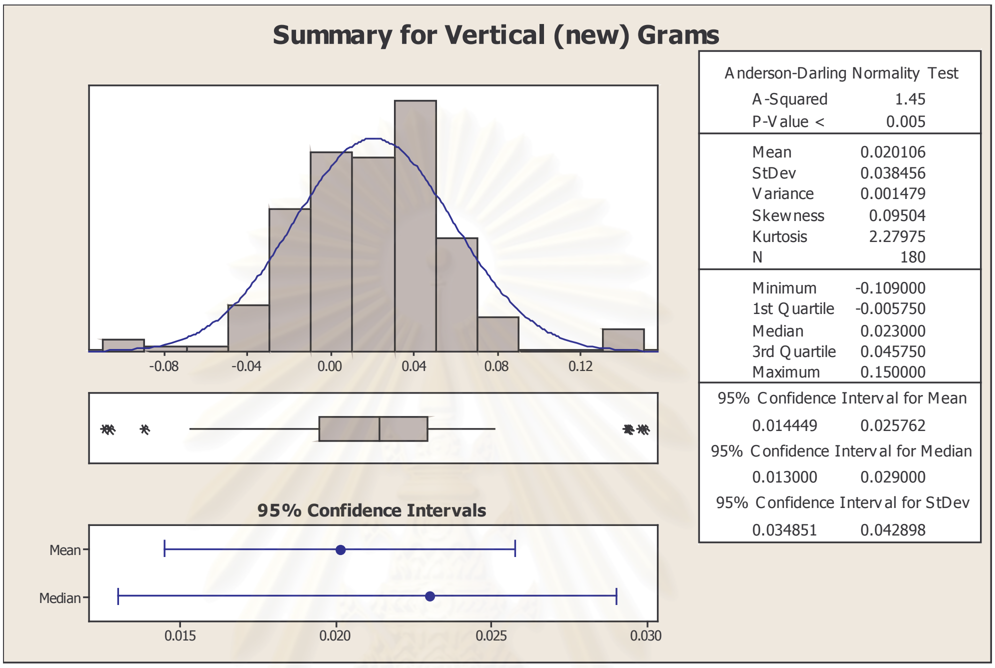


Figure 5.18 Statistical Summary of gram-load difference from Vertical Packaging *(with MINITAB)*

We have calculated gram-load change by using gram-load before minus gram-load after packaging test. The gram-load differences from both groups are presented in the box-plot below.

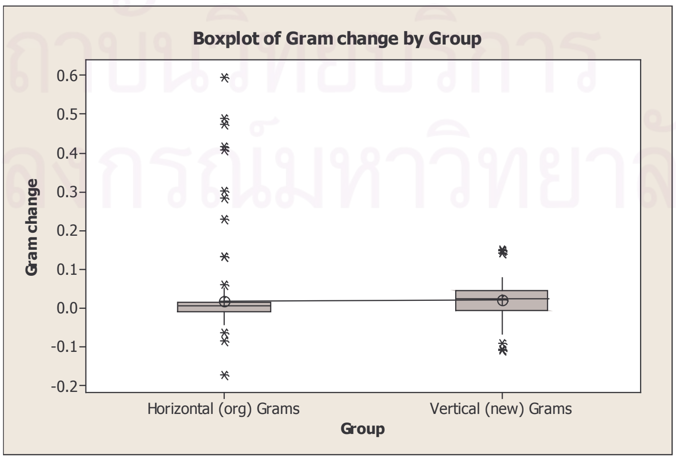


Figure 5.19 Box plot of Horizontal packing vs. Vertical packing *(with MINITAB)*

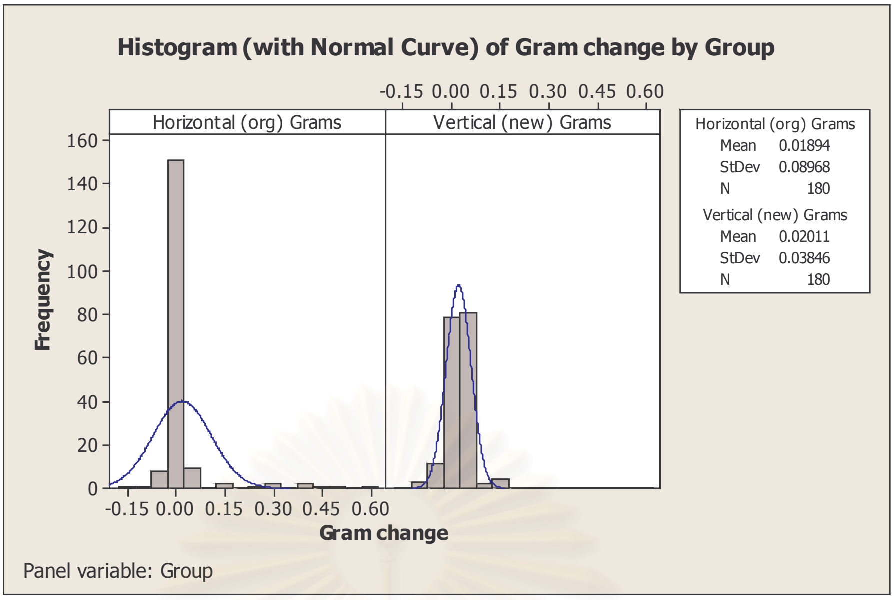


Figure 5.20 Gram-load difference between Horizontal and Vertical packaging *(with MINITAB)*

We need to compare the HSA robustness from vertical oriented package with the horizontal package. In this hypothesis testing we use two-sample t test. Our testing has sample size at 180 data points that is more than the minimum requirement. Anyway we have aware that too many sample size will cause high evaluation cost also.

The result of our evaluation is summarised with statistical software as shown below.

Two-sample T for Gram change *(with MINITAB)*

```
Group               N    Mean    StDev   SE Mean
Horizontal (org)  180  0.0189  0.0897    0.0067
Vertical (new) G  180  0.0201  0.0385    0.0029


Difference = mu(Horizontal(org)Grams)- mu(Vertical(new)Grams)
Estimate for difference:   -0.001167
95% CI for difference:  (-0.015493, 0.013160)
T-Test of difference = 0 (vs not =): T-Value = -0.16
P-Value = 0.873  DF = 242
```

The result shows P-Value = 0.873. This means that we should accept our hypothesis.

So with Two-sample T test, the mean of HSA gram-load change between Vertical orientation package does not have significant difference with mean of gram-load change from Horizontal package.

Anyway we can not make the conclusion that orientation of HSA has no effect to HSA robustness yet. We should also compare the variation of gram-load change between these two groups also.

Comparison of Variance

The interesting thing is there are many outliners of gram-load difference from horizontal package compare to the vertical package. Actually, the outliners that occurred in packaging testing are not good. This is because there is a high chance that some of the outliner in gram-load difference will be transformed to be the head damage failure in the future.

We also analyse the variation of gram-load change from these two groups by using F-Test analysis.

Test for Equal Variances: Gram change versus Group

```
95% Bonferroni confidence intervals for standard deviations
                 Group    N      Lower      StDev     Upper
Horizontal (org) Grams  180  0.0801549  0.0896786  0.101659
  Vertical (new) Grams  180  0.0343717  0.0384556  0.043593


F-Test (normal distribution)
Test statistic = 5.44, p-value = 0.000
```

(P-Value < 0.05; means reject null hypothesis)

With F-Test analysis, we found that the Horizontal orientation can help reduce the variation of gram-load change significantly.

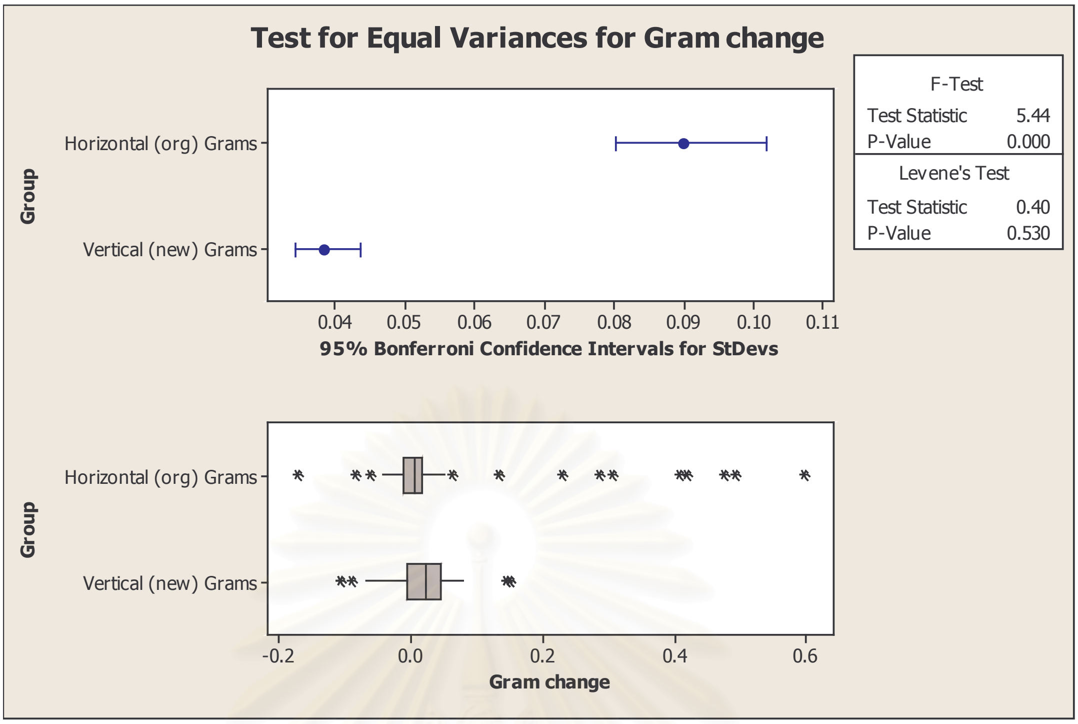


Figure 5.21 Test for Equal Variances *(with MINITAB)*

Conclusion of Vertical package and Horizontal package evaluation:

The evaluation result shows us that the vertical package can helps reduce the variation in gram-load change of HSA. On the other hand, we can conclude that HSA should have more robustness if it is shipped with vertical orientation packaging.

When we compare this result with the historical packaging, we found that the model-A packaging that has lowest cost had held HSA in the vertical direction also. So, we have decided to request packaging designer to design the packaging that holds HSA in the vertical direction.

5.1.3.2 Weight of Packaging and its Part Protection Performance

Another factor that we have observed from benchmarking analysis is weight of packaging. The current HSA package has weight at 2.95 kg. This is the heaviest HSA package that company ever has. And this weight may be one of the factors that cause the implementation of extra cushion packaging. Generally, the impact from weight can be described with equation below.

(Montegomery, 2000)

The impact momentum (mv = m$\sqrt{2gh}$) and the impact energy (e = mgh) both depend on the mass *m* of the dropped part, and the height *h* through which it is lifted. The lifted height will control the final velocity of the dropped part at contact with the soil.

This equation can be illustrated in the figure below.

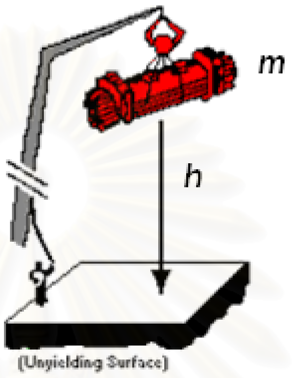


Figure 5.22 Drop test, $e = mgh$ (Adapt from Earton)

The equation can help us to explain why weight is concerned with packaging performance. (W = *mg)* The impact energy in the drop test is the representative of distribution environment of the dropped package. And because of height in our drop test is fixed at 12 inches. The factor that can reduce the impact energy from drop is the weight.

We have concluded that we should reduce the weight of HSA package as much as possible also.

5.1.3.3 Summary of all actions from Analyse Phase

The analysis that we have done, show that we should reduce the weight of HSA package. If we can reduce weight of HSA package, we will able to reduce amount of cushion that is related to volume of box on the shipping pallet. The smaller box means more quantity of HSA that we can load on the shipping pallet also.

The orientation of HSA tray can increase the robustness of HSA in the package.

The new packaging should be designed with transport packaging requirements. And it should include error proof for protecting freight forward to handle HSA package wrongly. Ideally, Pallet Assembly should be transform with fork lift or hand lift only. It should not be disassembly until it is arrived HDA plant.

5.1.4 Design Phase

After we understand that what KPIV has the effect to packaging performance and what are design requirements that should be focused in designing HSA packaging. We had forwarded all requirements to the packaging designer by using QFD deployment process. We have found that QFD house is a powerful tool because it can summarise all necessary information for designer in only one page.

In the past, it is quite difficult to summarise all of our requirements because many times, sub-component engineer will has a question that why they have to follow our specification. With the QFD, it shows item by item that which parameter is related to which customer criteria.

5.1.4.1 Requirement Flow down

We can use QFD to flow our requirement down to sub-component level. The cushion and box engineer can use our requirements to design box and cushion in detail. On the other hands, Tray designer will also get another house of QFD to design and deliver the better tray. In this case, there is only one engineering team that takes care both cushion and box design. So we can combine QFD of cushion and box together.

The QFD deployment flow is presented in the figure below.

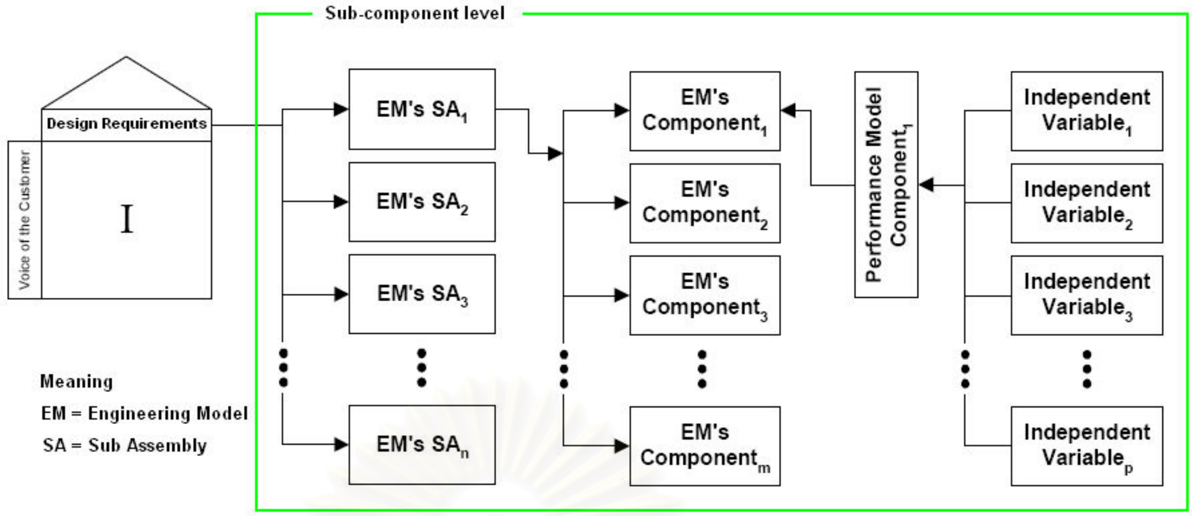


Figure 5.23 QFD deployment flow (Ishii, 2004)

Table 5.4 : QFD of Part Planning for Cushion and Box design team

Part Planning — Importance of the Hows is "Importance Rating *Sum of Relationships/20"

Design reuirements: WHATs / Outputs \ HOWs / Inputs	Kano Analysis	Importance	Cushion: Cushion density	Cushion thickness	Cushion Elongation	Dampening feature	Number of cushion parts	Weight of cushion	Dimension not change after use	Recycle material	Hold HSA in the vertical direction	Box: No open gap on the box	Weight of box	% utilisation of Shipping space	Readable barcode & symbol	Dimension not change after use	Recycle material
Direction of Improvement			✖	✖	✖	✖	↓	↓	✖	✖	✖	✖	↓	↑	✖	✖	✖
Meet Shock load requirement	MB	8	9	9	3	9	1	3	9		9	3	9			9	
Meet vibration test requirement	MB	8	9	9	3	9	1	3	9		9		3			9	
Protect contamination	MB	5										9					
Should be stacked firmly	MB	8							3					9		3	
Quantity of part per box	1D	11		9			1						1	9			
Save space to storage	1D	6	1	3			3		1	1	3			9			1
Weight of shipping pallet assy	1D	8	3	3				9					9	3			
Universal packaging	ATT	5	3	3	3	1	3				1			1	3	1	
Number of packing assy part	1D	6				3	9										1
Readable identfication	MB	8													9		
No bad smell	MB	3	1							1							1
Can be reused	MB	5	1	1	1		3	3	3						3	9	
Can be recycle (material level)	ATT	3	1	1	1		3	1		9	9						9
Importance Rating			200	308	71	167	138	138	189	36	194	69	179	254	102	218	42
Importance of the HOWs			**10**	**15**	**4**	**8**	**7**	**7**	**9**	**2**	**10**	**3**	**9**	**13**	**5**	**11**	**2**

Table 5.5 : QFD of Part Planning for Tray design team

Part Planning

Importance of the Hows is "Importance Rating *Sum of Relationships/20"

	HOWs / Inputs — WHATs / Outputs	Kano Analysis	Importance	Tray: Liquid Particle count (LPC)	Out-gassing requirement	Surface resistivity	Has stacking feature	Total Height of stacked tray	Perimeter of tray (width)	Perimeter of tray (Length)	Quantity of HSA per tray	Weight of tray	Dimension not change after use or clean	Recycle material
	Direction of Improvement			↓	↓	✖	✖	✖	✖	✖	↑	↓	✖	✖
Design reuirements	Meet Shock load requirement	MB	8				9	3			3	9	9	
	Meet vibration test requirement	MB	8				9	3			3	9	9	
	Meet cleanliness (LPC)	MB	7	9	1	3	3							3
	Meet out-gassing specification	MB	6	1	9									3
	Protect Electrostatic Discharge	MB	5	3		9								3
	Protect contamination	MB	5	9	9	3	3						3	
	Tray should be stacked firmly	MB	8	3			9	3					3	
	Quantity of part per box	1D	11				3	9	9	9	9	1		
	Save space to storage	1D	6				3	3	3	3	9			1
	Weight of shipping pallet assy	1D	8								3	9		
	Universal packaging	ATT	5					9	9	9	3			
	Small lot size	ATT	1								9			
	No bad smell	MB	3		9									1
	Can be reused	MB	5	3		3	3						9	
	Can be recycle (material level)	ATT	3											9
	Importance Rating			168	133	93	312	225	154	154	243	219	223	86
	Importance of the HOWs			**8**	**7**	**5**	**16**	**11**	**8**	**8**	**12**	**11**	**11**	**4**

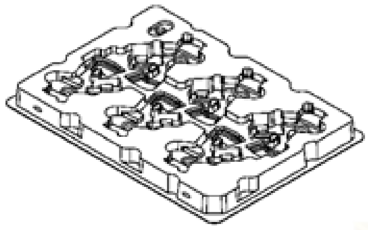
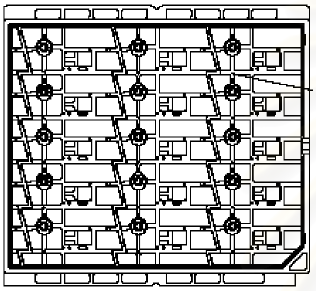
5.1.4.2 Detail Design

Find out the appropriate specification for part characteristics.

Tray design development:

The part planning QFD of tray shows that we should focus on stacking feature of tray, quantity of HSA per tray, total height of stacked tray, weight of tray, and reusable of tray. Firstly, we had tried to find out the proper dimension of tray and total stacked height of tray. We did the comparison between the tray that was used in Model-A packaging with the current tray. We have found that the tray that was in Model-A packaging is the tray that our operator prefers. This is because the size of tray is appropriate with operator’s workbench. And it is not too big. The tray in Model-A also has the lightest weight when we compare with all kind of tray. The table below is the comparison between Model-A tray and the current tray.

Table 5.8 : Comparison between trays

Model	Weight per set	Weight per HSA	Opportunity for improvement
Model-A tray 	0.146 kg. Can contain 6 HSAs. W x L: 8” x 11”	0.024 kg.	Increase number of HSA to be 8 cavities. So weight per HSA can be **0.018 kg**.
Current Tray 	0.422 kg. Can contain 15 HSAs. W x L: 11” x 12”	0.028 kg.	10% weight reduce from mass reduction So weight per HSA can be **0.0252 kg.**

The perimeter of Model-A tray is appropriate for workbench because it is not too big when compares to the perimeter of current tray. And there is the opportunity to reduce the weight per HSA of Model-A tray to 0.018 kg per HSA that is lighter than the current tray.

With the proper perimeter dimension and the weight per HSA, the design engineer had selected to use the concept of Model-A tray for further improvement.

After we get the concept of tray, we had started design the tray in detail. The new tray should include the requirements that we have listed in the QFD. Each item is analysed and has the solution as listed below.

- **Has Stacking Feature:**

  The stacking feature is included in the new tray design to make sure that the tray was stacked firmly. The picture of design evaluation is shown below.

Figure 5.24 Stacking feature of HSA tray

- **Quantity of HSA per tray:**

  We found that there is gap between each HSA cavities and when we reduce the gap, we have found that we can increase the quantity of HSA per tray from 6 to 8.

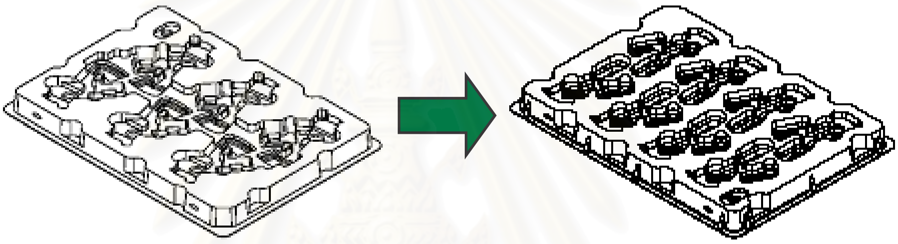


Figure 5.25 Increasing tray cavities

- **Weight of Tray:**

  The weight of each tray is the same so when we increase the number of HSA from 6 to 8, the weight per HSA is reduced to 0.018 kg.

- **No Dimension Change After Use:**

  We have increased robustness of tray to extend its life cycles. It will also help us to reduce the cost of tray, because more reused times will also reduce the cost of tray per HSA.

Figure 5.26 Feature on the tray

- **Total Height of Stacked Tray:**

  We have requested the appropriate stacked height from our Industrial Engineer. The number that we get is 6.5 inches. So we recorded this number to be our design specification.

The other items in the QFD are about the properties of raw material that we require for new Tray. And because the current material has met all of those requirements already, so we have decided to use the current material in this project.

Development of Cushion and Box:

The QFD of cushion and box shows us that we should focus on the cushion thickness, percent utilisation of shipping space, and cushion density. And holding HSA in the vertical direction need to be included in new packaging design also.

In tray development, we have decided to reduce the weight of HSA package with tray as much as possible, and we have selected the light tray with the modification to increase the number of HSA per tray from 6 to be 8.

Before we start design cushion and box, we need to make sure that there is no change that may be occurred during cushion and box design. This is because we need to freeze the weight and the size of HSA package before design the box and cushion.

The box and cushion will be optimised for HSA package that has weight at 1.69 kg and dimension at 8 inches x 11inches x 6.5 inches.

There are two factors that we are going to analyse for the new box and cushion design. They are Cushion Density and Cushion Thickness.

To analyse these two factors, we have decided to use Full Fractional Factorial Analysis. We had set the experiment as show in the table below.

Table 5.7: Factors and level in DOE

Factor	*Low*	*High*
Cushion Density	1.0 Lbs. / cubic ft.	1.8 Lbs. / cubic ft.
Cushion Thickness	1.5 inches	2.5 inches.

Power and Sample Size *(with MINITAB)*

```
2-Level Factorial Design

Alpha = 0.05  Assumed standard deviation = 1
Factors:    2   Base Design: 2, 4
Blocks:  none
Center                Total  Target
Points  Effect  Reps   Runs   Power  Actual Power
     0       2     3     12    0.80      0.857290
     0       2     4     16    0.90      0.955776
     0       2     4     16    0.95      0.955776
```

We did calculate the number of replications by using computer software. To get power of the test at 95 percent, we need to have 4 replicates of the DOE test.

Result of Experiment:

Have had ran the experiment with four replicate. The total run number is 16. The results are shown in the table below

Table 5.8: Result from DOE experiment

Density	Thickness	Replicate 1	Replicate 2	Replicate 3	Replicate 4
1	1.5	0.00635	0.01476	0.00941	0.00868
1.8	1.5	0.03380	0.01974	0.02163	0.03437
1	2.5	0.00120	0.00105	0.00218	0.00260
1.8	2.5	0.00674	0.00849	0.01826	0.00986

Analysis of DOE:

Factorial Fit: Mean versus Density, Thickness

Estimated Effects and Coefficients for Mean (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		0.012445	0.001249	9.96	0.000
Density	0.013332	0.006666	0.001249	5.34	0.000
Thickness	-0.012295	-0.006147	0.001249	-4.92	0.000
Density*Thickness	-0.004253	-0.002126	0.001249	-1.70	0.114

S = 0.00499557   R-Sq = 82.25%   R-Sq(adj) = 77.82%

Analysis of Variance for Mean (coded units)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Main Effects	2	0.00131569	0.00131569	0.00065785	26.36	0.00
2-Way Interactions	1	0.00007234	0.00007234	0.00007234	2.90	0.114
Residual Error	12	0.00029947	0.00029947	0.00002496		
Pure Error	12	0.00029947	0.00029947	0.00002496		
Total	15	0.00168749				

Estimated Coefficients for Mean using data in uncoded units

Term	Coef
Constant	-0.0160644
Density	0.0379281
Thickness	0.00258875
Density*Thickness	-0.0106313

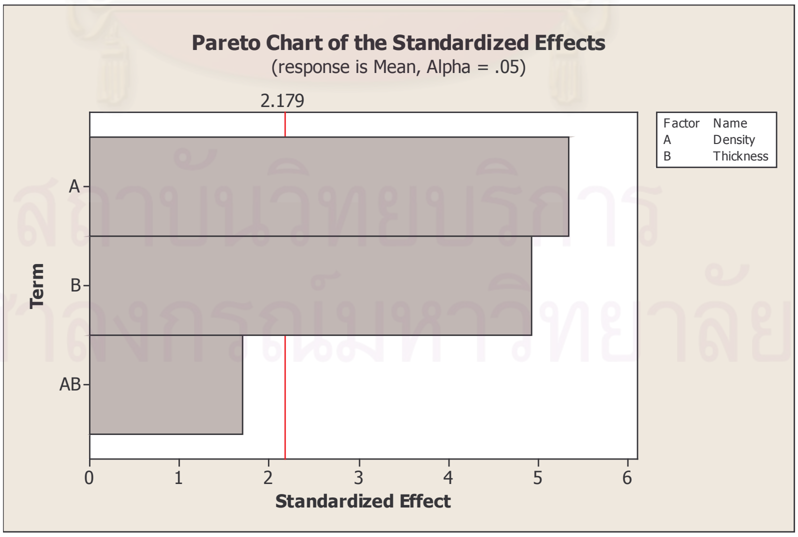


Figure 5.27 Effect Pareto for gram-load change (for mean) *with MINITAB*

The result shows that cushion density and cushion thickness that are the main effects of this experiment have significant effect to the HSA gram-load change. This is because P-value of both cushion density and cushion thickness are less than 0.05. *(With confident level at 95%)* The effect of interaction between density and thickness is not significant to gram-load change.

Graphs of main effect plot and interaction effect plot are shown below.

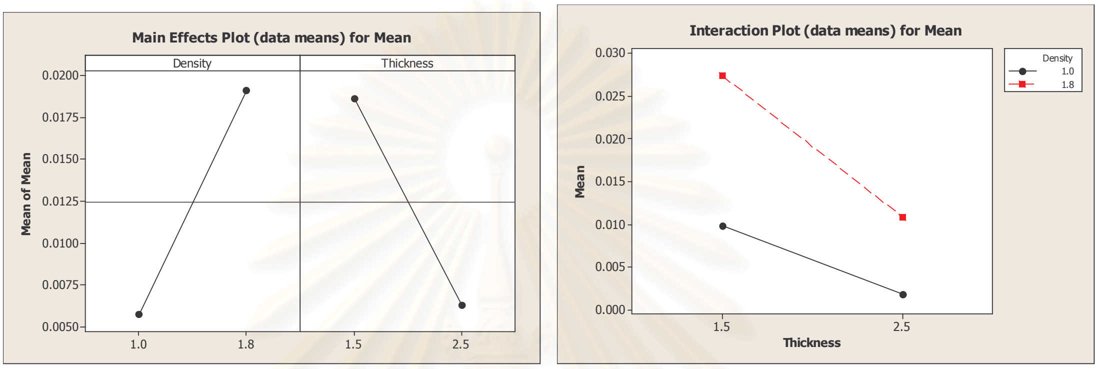


Figure 5.28 Main effect plot and interaction effect plot between density and thickness

And we can do cube plote to see the best setting of cushion density and thickness.

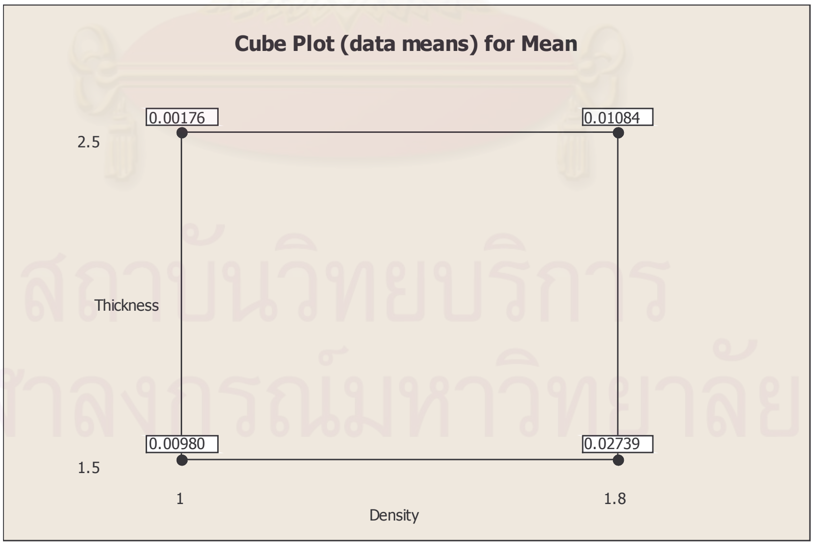


Figure 5.29 Cube plot of cushion density and cushion thickness *(with MINITAB)*

Conclusion of cushion density and cushion thickness

We are trying to find out the appropriate thickness of cushion density and cushion thickness. The DOE result shows that the condition that we should use to get the lowest gram-load change is cushion density at 1.0 lbs/ ft3 and cushion thickness at 2.5 inches.

Utilisation of Shipping Space

After we get the specification of cushion, we need to define dimension of box. The new box should have percent pallet utilisation close to 100 percent. In the box, it will have HSA package with the cushion that has thickness at 2.5 inches.

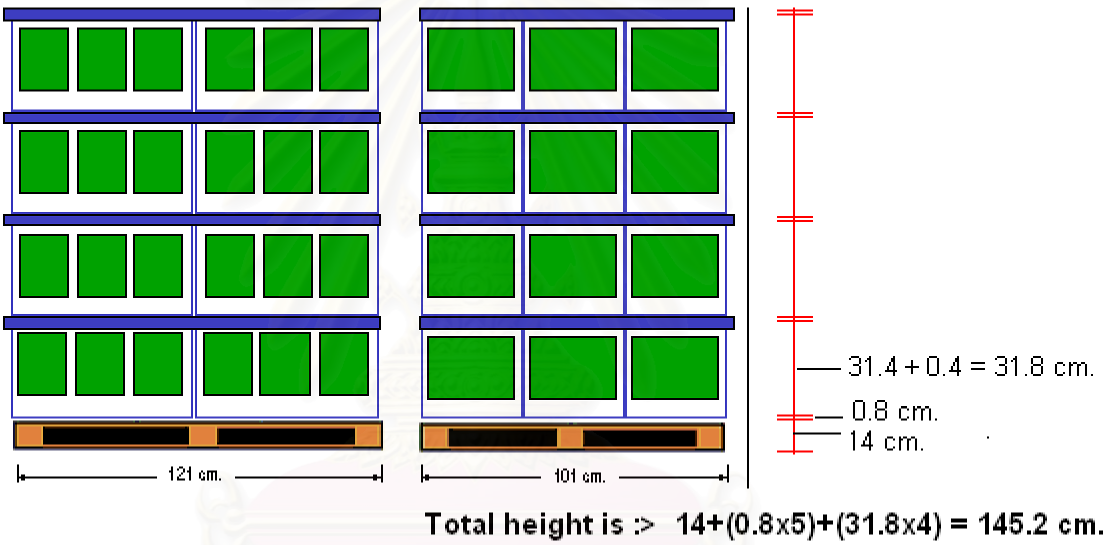


Figure 5.30 Total Stacked Height *(own creation)*

The box is design to have the thicker cushion on the bottom and thinner cushion of the top. This is because we found that bottom cushion is more critical to HSA than top cushion. And with this concept, we will able to increase the shipping capacity per pallet from 1,200 HSAs to be 2,880 HSAs per pallet.

In the detail design of packaging, we can use the computer software to help us shorten the development time. There are many kinds of software that is available in the market. In this packaging improvement project, the packaging designer also uses the software to test that the new packaging has utilised the shipping pallet space effectively or not.

TOPS Pro is the computer that we used for testing our packaging design. The output from software can help us to select the design that has the most efficiency the shipping pallet space. The result from the software shows that the new packaging design can achieve the percent utilisation of shipping pallet at 99.54% (for area efficiency) and 89.24% (for cubic efficiency). And it is the highest percent utilisation when compares with the other designs.

Computer software is the very power tool that we can use to design the cushion, box and others. In the packaging improvement project, we also try to use the finite element simulation to estimate the performance of new packaging also. And because of percent confidence of the simulation analysis for dynamic impact is not good enough. We have decided to validate the new packaging by actual packaging qualification test.

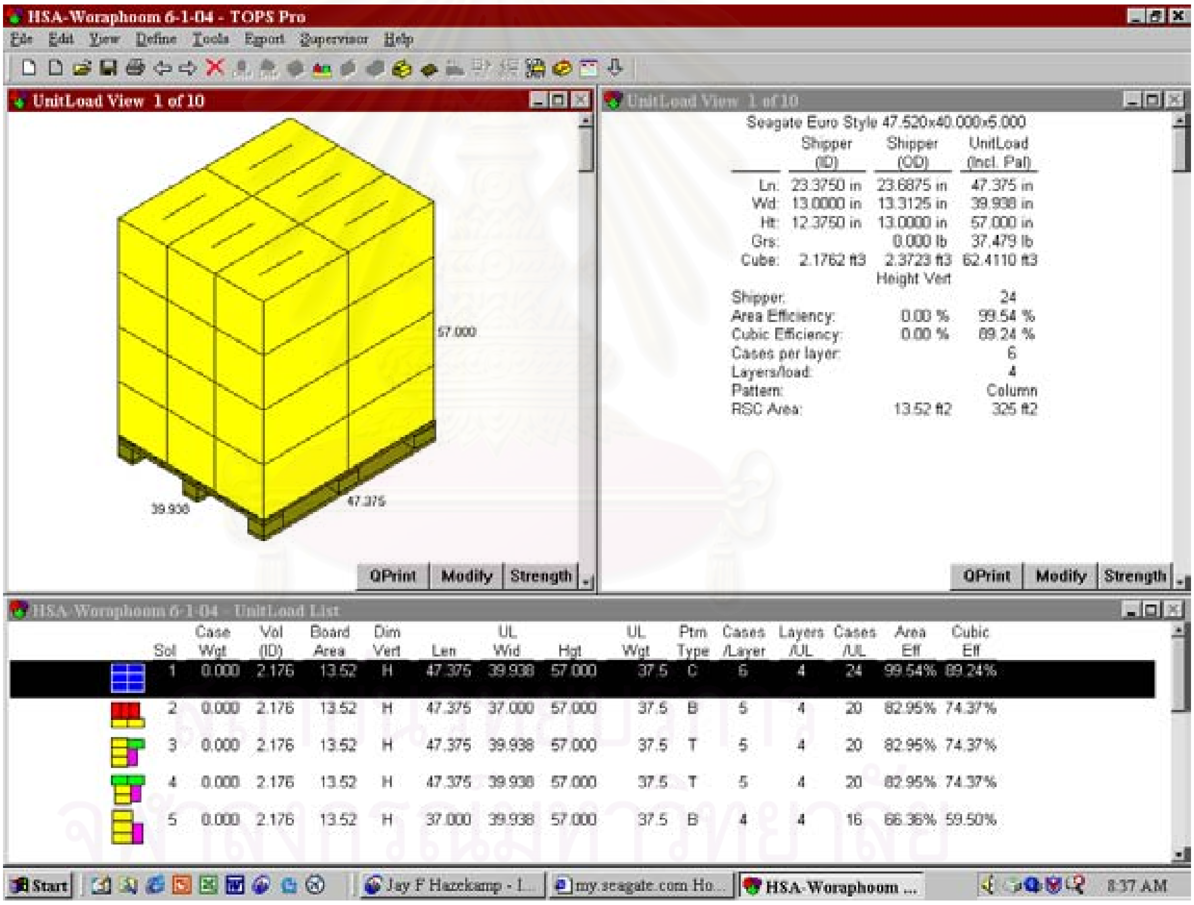
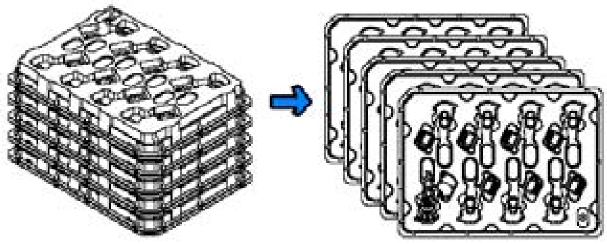
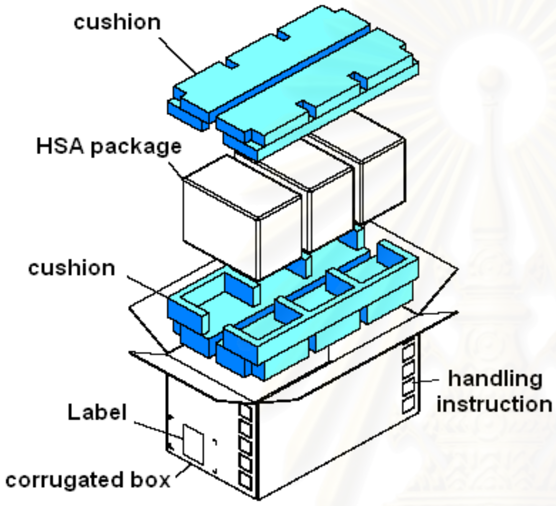
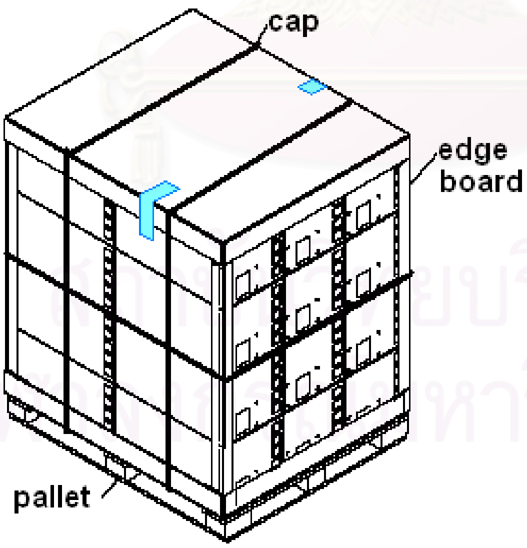


Figure 5.31 The output from TOPS Pro Software *(Hazekamp & Woraphoom)*

When we have combined all components together. The new packaging that is design for transport packaging can be summarised in the following table.

Table 5.9 : New Concept Packaging

Tray 	• Increased the number of cavities per tray from 6 to be 8 cavities. • Tray profile is reduced. So we can increase number of stack tray from 4 to be 5 trays.
Box and Cushion  	• Weight of each HSA package is 1.69 kg. • Reduce top cushion thickness and increase the bottom cushion to maximise number of stacked box per pallet. • HSA is oriented in vertical. • Total weight of box includes HSA package is 6.27 kg that is not too heavy for operator.
Pallet Assembly  	• Utilise area on shipping pallet at 99.54%. • Has top and bottom cap to hold all boxes together during transport. • Attach warrantee tape to make sure that package is not disassembly before arrive customer warehouse. • Capacity per pallet **2,880 units.**

5.1.5 Verify Phase

5.1.5.1 Validation of the new packaging design

After we get the new packaging, we have tested it with the normal packaging qualification. The condition of drop test has been changed to Mechanical Handling Test (ASTM D1083) that is more appropriate for Transport Packaging.

After we have done all drop test and vibration test, we did visual inspection and measured gram-load again. The result of our qualification is shown below.

Visual inspection:

There is no any mechanical failure after we dropped and vibrate the package. The package passes the head damage defect criteria.

HSA Gram-load analysis:

The qualification criteria requires that the new packaging need to perform equally or better than the baseline packaging. In this case, we will use the statistical analysis to do the comparison. The data analysis has been done step by step as following.

- **Normality Test.**

To select the appropriate statistical tool, we need to analyse that the data follows the normal distribution or not. If it is normal distribution, we can use parametric tool for analysis. If it does not follow the normal distribution, we should select non-parametric tool for analysis.

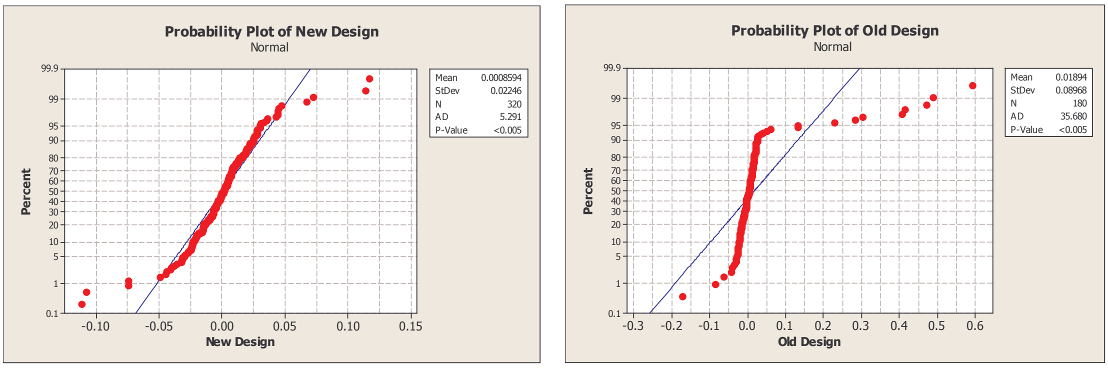


Figure 5.32 Normality plot *(with MINITAB)*

The result of normality test shows that we should use non-parametric tool to test the different between old HSA package with the new HSA package.

- **Two-sample T for New Design vs Old Design** *(with MINITAB)*

```
                N     Mean    StDev   SE Mean
New Design    320   0.0009   0.0225    0.0013
Old Design    180   0.0189   0.0897    0.0067

Difference = mu (New Design) - mu (Old Design)
Estimate for difference:   -0.018080
95% CI for difference:   (-0.031494, -0.004665)
T-Test of difference = 0 (vs not =): T-Value = -2.66
P-Value = 0.009          DF = 191
```

- **Mood Median Comparison between New Design vs. Old Design** *(with MINITAB)*

```
Mood Median Test: Delta-gram versus Design

Mood median test for Delta-gram
Chi-Square = 2.11     DF = 1     P = 0.146

                                              Individual 95.0% CIs
Design       N<=   N>    Median     Q3-Q1    ----+---------+---------+---------+--
New Design   171   149   0.00100   0.02000   (-------*-------)
Old Design    84    96   0.00500   0.02600   (--------------------*-----)
                                             ----+---------+---------+---------+--
                                               0.0000    0.0025    0.0050    0.0075

Overall median = 0.00200


A 95.0% CI for median(New Design) - median(Old Design): (-0.00600,0.00202)
```

We also test for equal variance of gram-load difference between old and new packaging design. The result is shown below.

➢ **Test for Equal Variances**

```
Test for Equal Variances: Delta-gram versus Design

95% Bonferroni confidence intervals for standard deviations

    Design    N      Lower      StDev     Upper
New Design  312  0.0207609  0.0226313  0.024857
Old Design  180  0.0801549  0.0896786  0.101659


F-Test (normal distribution)
Test statistic = 0.06, p-value = 0.000


Levene's Test (any continuous distribution)
Test statistic = 13.90, p-value = 0.000
```

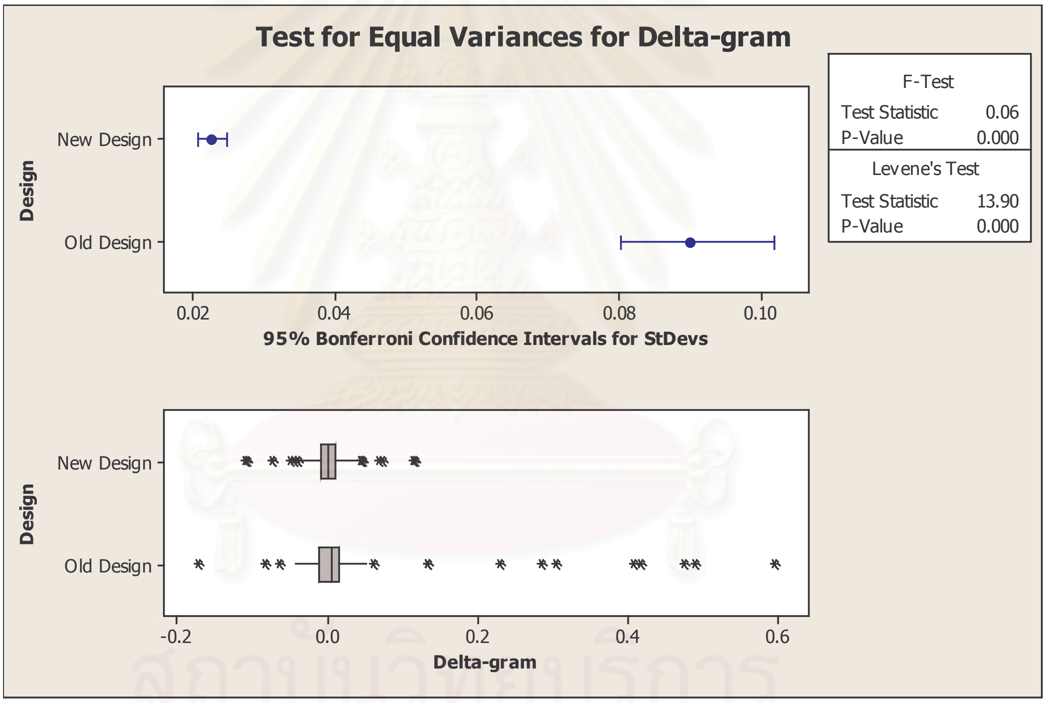


Figure 5.33 Box Plot of variances *(with MINITAB)*

The F-Test analysis shows that New Design can reduce the variation of gram-load difference significantly.

Summary of packaging design conclusion:

The result from statistical analysis shows that new package performs better than the baseline packaging. Both Mode and Median analysis and Variance analysis shows that new packaging has lower gram-load change and has smaller variation.

So, the new package design is qualified.

5.1.5.2 Compare improvement with the goals

Cost Saving Analysis from the new design

The new package design concept can increase the number of HSA per pallet from 1,080 HSA per pallet to be 2,880 HSA per pallet. This is the breakthrough improvement.

The new packaging cost and new freight cost is calculated below.

- **Package cost:**

Table 5.10 : Cost of New Concept Packaging

		Cost/set	Cost/pallet
Pallet Cost	1	8.5	8.5
Wrap +Belt +Edge Board	1	16	16
Carton box & Cushion	24	6.5	156
Tray (set)	24	11.2	268.8
Number of HSA per pallet	2880		
Packaging Cost per HSA		**=> US$**	**0.156**

The packaging cost is reduced from 0.598 dollar to be 0.156 dollar per HSA And we can compare the cost from new package with the other designs as the graph below.

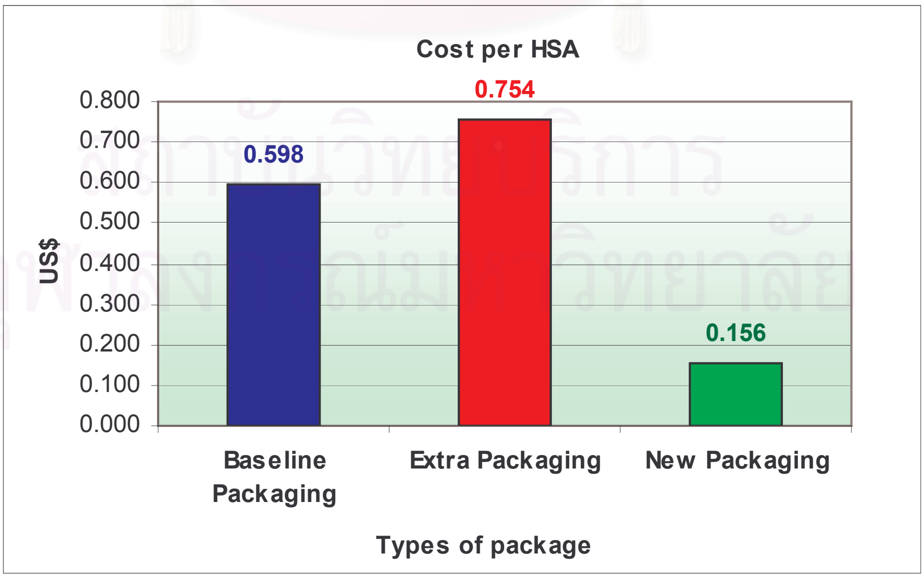


Figure 5.34 Packaging cost comparison

Packaging cost has been reduced obviously from new packaging design. Packaging is been reduced 0.442 US$ per HSA.

➢ **Freight Cost:**

The new design has outer dimension and detail per pallet as shown below.

Maximum Width	=	104 cm.
Maximum Length	=	124 cm.
Total Height	=	150 cm.
Capacity per pallet	=	2880 HSA.

(Base on airfreight from Thailand to China)

1. Freight charge	=	58 Baht per kg.	(Variable cost)
2. Custom charge	=	1,400 Baht per shipment	(Fixed cost)
3. Destination charge	=	6 Baht per kg.	(Variable cost)
4. Crisis charge	=	2 Baht per kg.	(Variable cost)
5. Fuel charge	=	3 Baht per kg.	(Variable cost)

Calculation method of chargeable weight:

1 Full pallet dimension = 104 x 124 x 150

= 1,934,400 cubic centimetres

(6000 is international coefficient to calculate chargeable weight)

Chargeable weight = 1,934,400 / 6000 = 322.4 kg.

Total freight cost per pallet = [322.4 x (58 + 2 + 3 + 6)] + 1400

= 23,645.6 Baht

= 591.14 US$. *(Convert to US$)*

Freight Cost per pallet	591.14	US$
Number of HSA per pallet	2880	HSA
Freight cost per HSA	**0.205**	**US$**

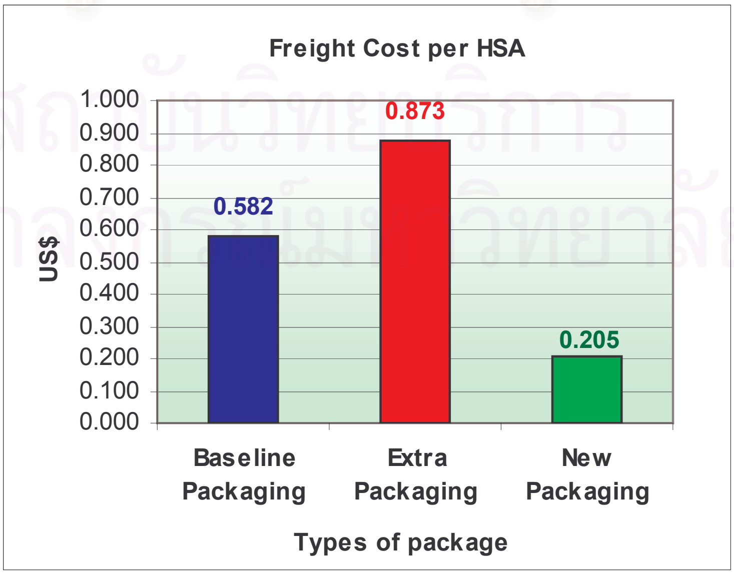


Figure 5.35 Freight cost comparison

5.1.5.3 Assess the quality impact from new packaging

We also prove that new packaging has the impact to quality of HSA or not. In the quality assessment test, we had decided to use Two Proportions for this hypothesis test. We decided to compare percentage of HSA yield between shipping with old packaging and new packaging.

The sample size of hypothesis test is calculated with alpha-error at 5 percents and power of test at 99 percents. With Minitab software, we should have sample size at least 1796 HSAs for each group. The output from software is shown below.

```
Power and Sample Size
Test for Two Proportions

Testing proportion 1 = proportion 2 (versus not =)
Calculating power for proportion 2 = 0.99 Alpha = 0.05

               Sample  Target
Proportion 1     Size   Power  Actual Power
        0.97     1796    0.99      0.990015
The sample size is for each group.
```

The hypothesis statement is, percent yield of HSA at receiving site from new packaging is the same as percent yield of HSA from old packaging.

The Two Proportions analysis shows that with confident level at 95 percents, HSA yield from new packaging has no significant different from HSA from old packaging. This is because P-Value is 0.083 that is higher than 0.05. The output from Minitab software is shown below.

```
Test and CI for Two Proportions
Sample         X     N  Sample p
New Package 1910  1920  0.994792
Old Package 1980  2000  0.990000

Difference = p (1) - p (2)
Estimate for difference:  0.00479167
95% CI for difference:  (-0.000628810, 0.0102121)
Test for difference = 0 (vs not = 0):  Z = 1.73
P-Value = 0.083
```

This quality assessment test proves that new packaging has no negative impact to quality of HSA at receiving site. Actually, it may improve quality of HSA but the percentage of improvement is not significant.

5.1.6 Control Phase

To maintain and has continuous improvement, we need to have the appropriated control system. Firstly, we need to create the document that states all specifications and all design requirements that we have studied to be the reference. And this document will be used to develop packaging in the future also.

We have updated all the specification in our QFD part-planning matrix. The specification is summarised as shown in the table below.

Table 5.11 : Specification of Tray

HOWs / Inputs \ WHATs / Outputs	Tray										
	Liquid Particle count (LPC)	Out-gassing requirement	Surface resistivity	Has stacking feature	Total Height of stacked tray	Perimeter of tray (width)	Perimeter of tray (Length)	Quantity of HSA per tray	Weight of tray	Dimension not change after use or clean	Recycle material
Direction of Improvement	↓	↓	✖	✖	✖	✖	✖	↑	↓	✖	✖
Units	paritcle/cm2	ng/cm2	ohm.	Include	inch.	inch.	inch.	unit	kg.	%	Include
Target					6.5	8.3	11.3				Y
Lower Limit				Y	6.3	8.0	11.0	8			
Upper Limit	500	770	10^5		6.5	8.6	11.6		0.2	10	

Table 5.12 : Specification of Cushion & Box

HOWs / Inputs \ WHATs / Outputs	Cushion									Box					
	Cushion density	Cushion thickness	Cushion Elongation	Dampening feature	Number of cushion parts	Weight of cushion	Dimension not change after use	Recycle material	Hold HSA in the vertical direction	No open gap on the box	Weight of box	% utilisation of Shipping space	Readable barcode & symbol	Dimension not change after use	Recycle material
Direction of Improvement	✖	✖	✖	✖	↓	↓	✖	✖	✖	✖	↓	↑	✖	✖	✖
Units	Lbs/ft3	inch.	%	Include	unit	kg.	%	Include	Include	kg.	kg.	%	Include	%	Include
Target	1.5	2.5	70	Y		1.0		Y	Y						Y
Lower Limit	1.35	2.63	63			0.9						80	Y		
Upper Limit	1.65	2.37	77		5	1.1	10			3	1			10	

Each component will have its specification. The quality of each component will have an effect to the quality and the performance of packaging also. We need to set up the system that can control the quality of each critical item.

In Six-Sigma, it is recommended that we should control the KPIV (x) to maintain the KPOV (y). *[y= f(x)]*

In this case, we can use the statistical process control chart (SPC) to maintain the quality of our packaging component.

There are many types of SPC. We need to select the right type to control each KPIV. We have selected the parameter that is related to the quality of packaging for SPC control chart. In this packaging improvement, we have selected to control the parameter that is shown below.

Cushion & box: Cushion density, cushion thickness and cushion elongation.

Tray: Liquid Particle count, Total Out-gassing, and dimension of tray.

All of these items are the continuous data (variable data). We need to select the SPC control chart that is appropriate with them.

At the vendor site, they have built cushion, box, and tray by batch build. Cushion, box, and tray will be formed by mould and die. Actually, we have to qualify the dimension of the mould before vendor use it to produce cushion, box and tray.

Anyway we have foresee that when they use mould or die for long-times. The mould or die could be worn out and the dimension of cushion and tray can be changed.

If the dimension of cushion or tray changes, it will have an effect to the packaging performance also.

In this packaging improvement project, we have decided to use X-bar R chart to control the quality of cushion, box, and tray.

About the tray, the parameters that are critical to HSA quality, such as LPC and Out-gassing are need to be control. We also use X-bar R chart to control its quality since the supplier site.

There are many types of control chart, and each of them will be appropriate for the different type of data. We have to select the one that is appropriate for each of them. Rath & Strong have summarised the flow to select the type of control chart in their book. It can help to select the type of SPC chart correctly.

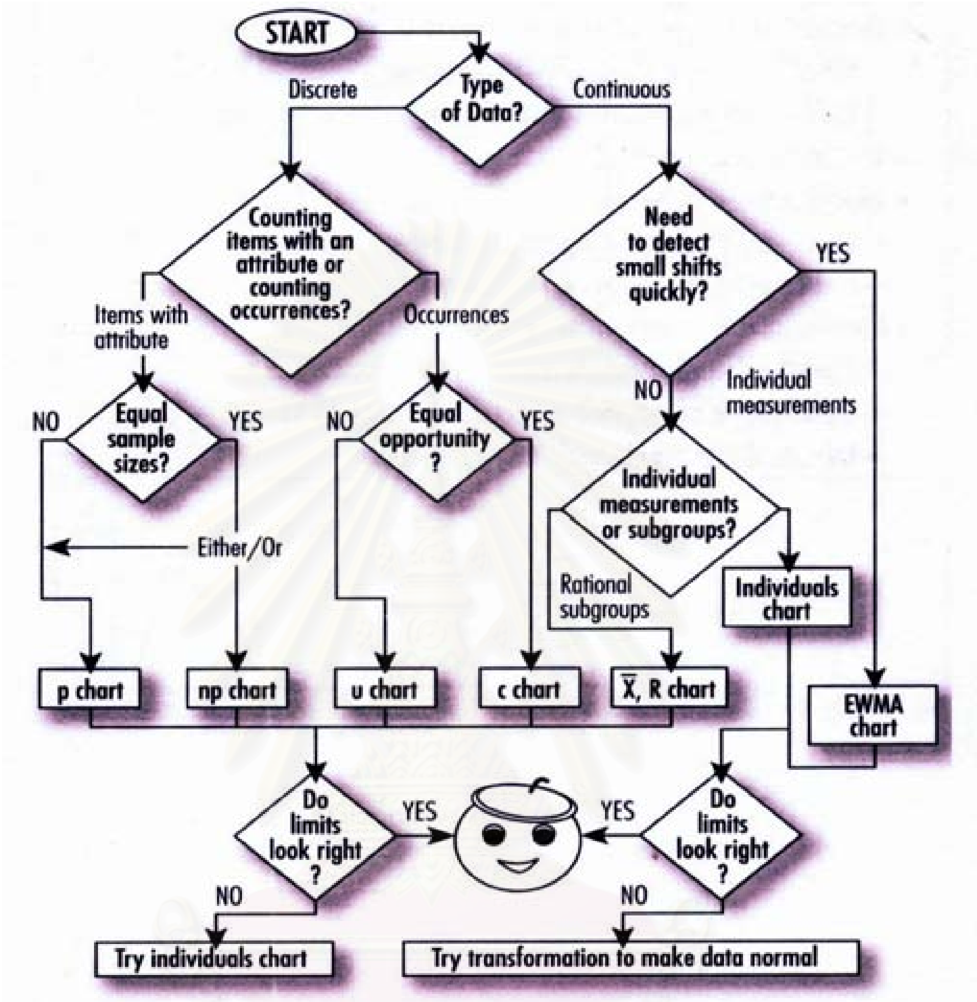


Figure 5.36 Decision tree of SPC selection (From Rath&Strong, 2001: 184)

The most important thing in control phase is the document. We have to document all packaging instruction and specification to be the reference. For the documentation, we need to be aware that the document has to be approved by all of concerned people. It has to be available anytime to be the reference. And it has to be updated. For the example, the QFD that we have generated since the beginning of study, it has to be update periodically.

The appropriate period for update may be the next time when we need to improve the packaging. Or it can be updated when we discover the new important criteria or specification.

There are some comments that we should aware when creating new document.

- **Keep the document simple**

The complicated and long sentences of wording can makes the people ignore that document. Keeping the document simple by changing it to be the picture as the process flow or process diagram is very effective. People can understand our document within short time, and they willing to train the subordinate or their staff easily. In our packaging improvement project, we had to work with many people from the different country. Language is one of the barriers that had an impacted to our project. Process Diagram and Quality Function Deployment table can help us a lot in communicating and convincing the people from different countries.

- **Document should be available any time when is needed**

The authorised people should able to access and see the document easily and quickly. This is important because if our document is difficult to reach, our process will be deviated easily. Document that is easy to find and easy to be distributed also helps us to expand our knowledge to the other in the organisation.

- **Have a process for updates and revisions.**

Nowadays technology is changed quickly. There is new technology that can help us improve packaging design quickly and effectively. The new sponge that has better cushioning factor or new material that can make packaging lighter than before may be presented. We need to prepare document for that change also. The document should be revised and updated all the times. Anyway we also need to aware that we should have the system that allow only the authorise people to make that change.

The document and process control system is very important thing to sustain the gain of any improvement project.

CHAPTER 6

EXPAND AND INTEGRATED INTO THE ORGANISATION

In implementation phase of the project, we can found that there are a lot of problems. Many problems are about the complaints from the people that do not want to change their work. Many times the problem that was occurred can be solved by the sample solution, such as training or explain how our project help them.

To deal with this kind of the problem, we can use the Lewin's Force-Field Model to be the guidance for finding the appropriate solution.

Lewin's Force-Field Model

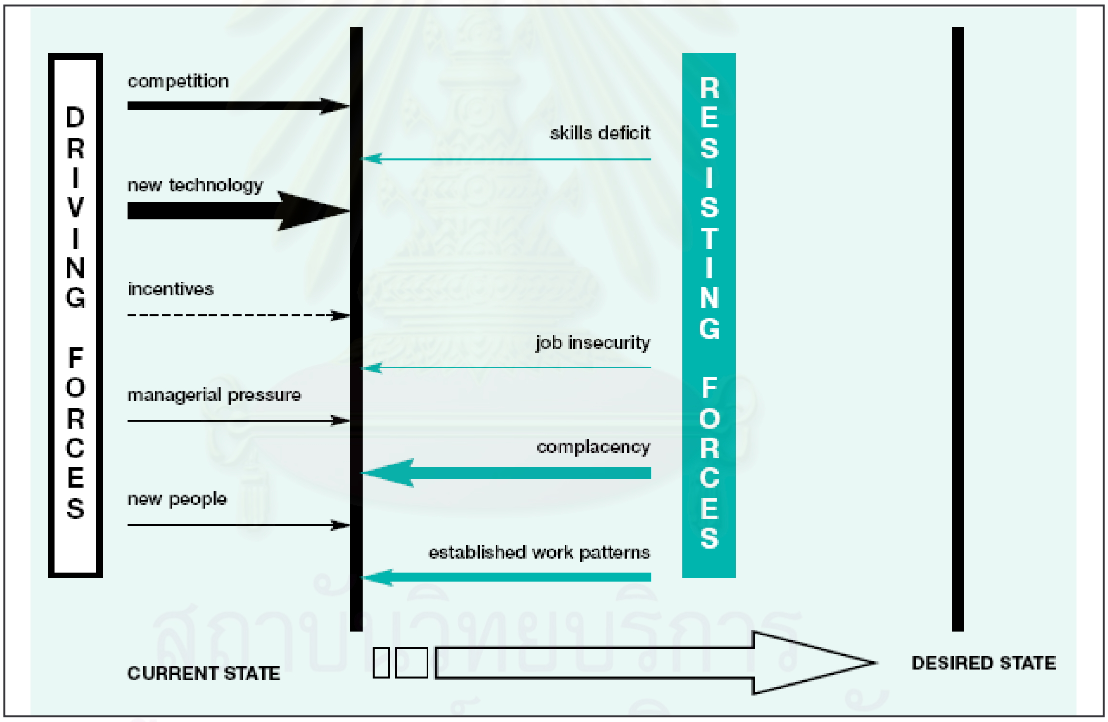


Figure 6.1 (Iles, 2001)

To implement project successfully, we need to reduce resisting force and try to increase the driving force as much as we can.

In our packaging improvement project, there are a lot of people that has been working in packaging area for many years. And they never see the big change in packaging. This group of people has resisting force to our project.

We have tried to reduce the resisting force and increase driving force as following.

6.1 Reduce Resisting Forces

- **Skill Deficit:**

We have presented and trained all concerned people about how we have designed and analysed new packaging. We also trained them how to interpret the output from statistical analysis. During the training and presentation we have opened for their recommendations also.

Training and sharing our knowledge to the other people can generate tremendous benefit. This is because we also have a chance to gather more information from the experts. The discussion session in the training or presentation can help us to get more ideas and more feedback about our new packaging also.

- **Job Insecurity:**

Job insecurity is a very big concern in our project. This is because there are a lot of problem when we start design the packaging. In the beginning of design phase, we had tried to present our conceptual design but designer had rejected it all the times. Eventually, we found that they had worried about job security. So we have changed our approach. We request them to design the packaging for us but we can purpose our design to them as the alternative. We have presented to everybody who works in packaging improvement project that we try to help him or her and all credits from the project will belong to the area owner. This approach can help us get more co-operations from them.

- **Complacency:**

The complacency is not the big issue for packaging improvement project because the problem or freight cost and packaging cost is existing. And it makes traffic and logistic department searching for help. The department that had this resisting force is the quality engineer. They worried that our project will have impact to the quality of product. We have reduced their resisting force by showing them the data from our analysis. Making the decision with the data is very useful for convincing the complacency people.

- **Established work patterns**

Established work patterns, this resisting force was occurred when we worked with the experts. We have deal with this resisting force by accept for their idea first. We let them think about the current issue in their working area. Most of times, we can found that it is matched with our project. We can show them how project work, and how it can helps solving their issue. This activity can also reduce resisting force.

6.2 Increase Driving Forces

(lles, 2001)

Addressing the resisting forces need to be creative, many practising managers will be able to reflect on occasions in their own experience when they have aimed to increase the driving forces, rather than reduce the resisting ones, they have increased the resistance and the tension as a result.

Driving force is important in implementing new packaging. We have increased the driving force as described below.

- **Competition**

In our packaging improvement, we also apply the driving force from the competition. The company has HSA and HDA factories in Thailand, Singapore and China. We have presented the benchmarking comparison between each site. This presentation is very useful because each site try to reduce their packaging and freight cost as the competition. The performance of each site will be benchmarked by monthly and quarterly basis.

- **New technology**

Bringing the new concept or new method to use in packaging improvement project is very useful. For the example, Six-Sigma and statistical analysis can help us a lot in convincing the people to accept for implementation. The new tool that we never use before such as QFD may need a lot of effort for training but it is the powerful tool for increasing the driving force.

- **Managerial pressure**

In packaging improvement project, we have tried to create the managerial pressure from multilevel of manager. We have got the support from top management since we presented the factory spending cost and factory benchmarking. Moreover, we also request co-operation from shop floor manager. This approach is very helpful to increase managerial pressure for shop floor staff.

There is a technique to present our project to management and it can be illustrated with the figure below.

(Russell, 2001)

Paul presented that the huge and difficult project should be presented and realised the benefit with the strategy. Implement too much change and quickly may make management understand that we do project carelessly and may make the wrong decision. Implement too slow or too late may make management doesn't see the progress and cancel the project.

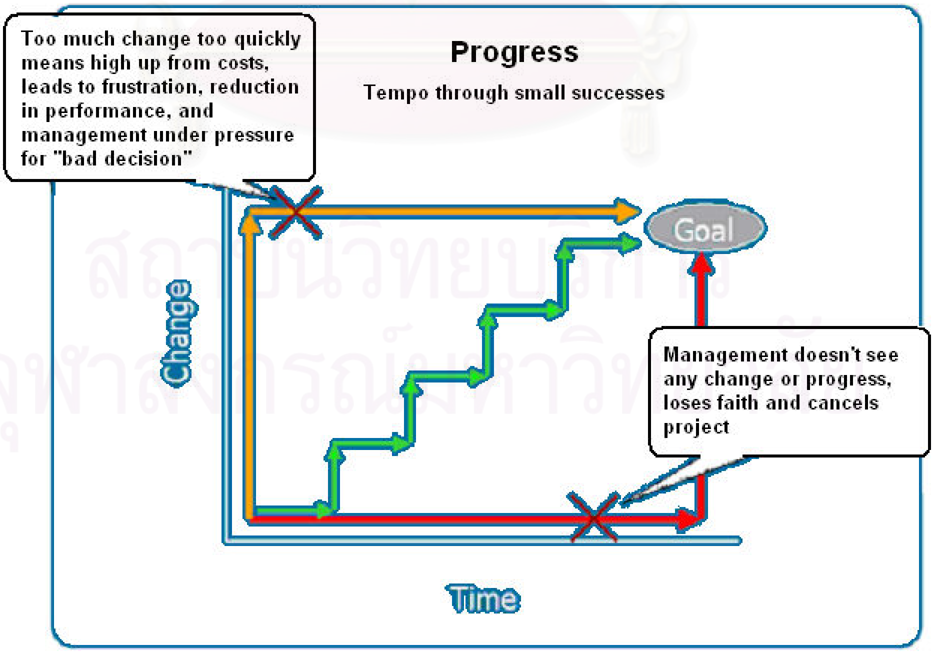


Figure 6.2 Tempo through small successes (Russell, 2001: 38)

- **Reward and Recognition**

During packaging development, we have tried to realise the benefit from our improvement team all the times. We had not waited until we implement the whole project. If we found something that can deliver the benefit to the company, we will implement it immediately. The presentation of these benefits can be realised and the supporting team can also get the credit from it. During our packaging improvement, we also get the award from management. After we share the award and prize with the team, our team power has been increased dramatically.

- **New people**

In our packaging improvement project, we have tried to have new people in our team all the times. New member can help us increase enthusiasm of team member also. More people will also help us to communicate and announce our project widely.

Summary:

Many good quality improvement projects have been keep on the shelf and never been expand to the others. The best practice should be announced and sustained to be the new baseline for improving the organisation for better quality level.

One of the reasons that project was not deployed to other programs is, it is too difficult and too complicate for the others. Force Field is one of the effective tools that we can use to implement and expand our packaging improvement project.

CHAPTER 7

CONCLUSION AND RECOMMENDATION

7.1 Conclusions

In this packaging improvement project, we have started with creating the Six-Sigma process step. The Six-Sigma process diagram that has been created can be used to tackle the problem in all business levels. That is included business transformation, strategic improvement, and problem solving.

We had analysed the packaging problem in both macro level and micro level. The process mapping is the first tool that has been used to understand the big picture and see the actual practice of packaging process.

After we understand the purpose of HSA packaging clearly, we have changed the type of packaging from secondary packaging (group packaging) to be tertiary packaging (transportation packaging). Selecting the correct type of packaging can help us design the packaging that match with customer requirements.

We had gathered the customer requirements from the theory of packaging and from brainstorming with the customer. The tool for brainstorming such as process mapping, affinity diagram, and fish bone diagram had been used in this step.

The customer requirements were ranked the priorities by using FMEA and QFD. FMEA can be used to approach the problem in detail or when we try to analyse the root cause for only one objective. QFD is more useful when we try to deliver the solutions that meet all customer requirements.

Before we start the project, we also need to measure the current performance to be the baseline for comparison. This is very important because the baseline and historical data can be the good guidance for us to set the reasonable goal and objective.

In design phase, benchmarking analysis is the simple tool but it is really powerful to get alternative design concept for further improvement. Computer Aid Design is also the important tool that we can use to reduce the packaging development cycle time. The Finite Element Analysis can be used to verify our assumption before the physical testing. This is a powerful and cheapest way in engineer evaluation.

In hypothesis testing, firstly we need to make sure that our measurement system is capable enough to detect the difference or not. If it is not, we need to improve it before use. The poor measurement system can lead us to get the wrong conclusion.

The data from evaluation should be analysed with the statistical analysis. We can use the statistical software to reduce the time and error from calculation.

The packaging requirements can be transferred to the packaging design engineer with the QFD deployment process.

After we get the completed packaging design, we can not implement it immediately until we have proved and validated that design. The validation is very necessary phase to detect the problem that may be overlooked during the design process.

In control phase, the documentation is very important. The document has to be created appropriately. The complicated and difficult reading document can cause abandon of that document. The document can be simplified with the table or the picture of process diagram.

In the implementation phase, dealing with the people is very important. To dealing with these difficulties in implementing the project, we can use force field to analyse and solve the problem. Reducing the resisting force is more effective way to let the people change more than increasing the driving forces.

After we had finished the packaging improvement project. If that project is success, we should expand that project to the others as the case study. Sharing our knowledge with other people can help us gathering useful information for more improvement in the future.

7.2 Recommendations

Packaging design is concerned with many people both inside and outside company. To improve packaging, we need to have inputs and requirements from all concerned people. The concern people are not only our customer. They are included the staffs in our organisation and supporting organisation also.

Improvement of packaging design can deliver the huge benefit to the company in term of cost and quality of the product.

Packaging Designer and packaging developer need to be aware of getting all requirements from internal customer and external customer before working on it. Poor packaging design can cost increasing in product return rate that can effect to company image but over-packaging can increase the cost of product also. The design engineer needs to balance of these factors appropriately.

The research study shows us that the design engineer should utilise and check efficiency of shipping pallet space before launches the design. In this packaging validation phase computer software can be the powerful tool to help engineer shorten the development time.

From the study, we found that the most important factor that really effective to the cost of transport packaging is the shipping capacity of each pallet. If we can understand customer requirement and use it for designing the product, trade off some requirements that are critical to packaging design but customer can loosen it or change it. We will get the new design that can generate value much more than before.

Six-Sigma methodology and statistical calculation seem to be a very complicated improvement process, but we can make it is more simple by using the statistical software.

7.3 Recommendations for Further Study

When we share our practice with the other people from both inside and outside company, we also found that our packaging is useful for the supplier of HSA raw material also. This is because the supplier packaging is more expensive than our packaging, and they have requested to use our packaging for their product also.

This is very interesting because if we can have the common packaging with the supplier, we can let them buy the prime packaging and when we receive their package, we can use it to ship our finish product also.

With this concept, we can see the opportunity to reduce our packaging spending about 89 percent.

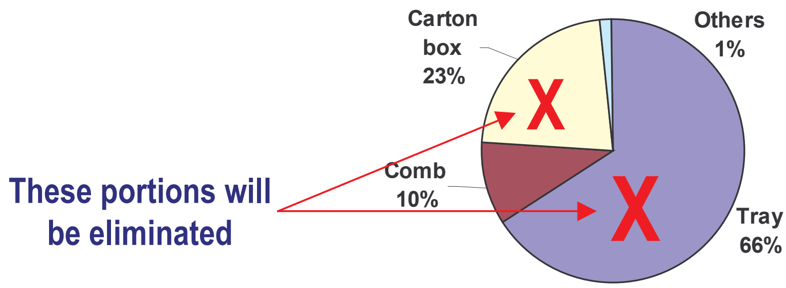


Figure 7.1 Pie chart of packaging spending

The vendor also willing to reduce the price of raw material because they can reduce their transportation cost and handling cost also.

We have realised that the packaging improvement is very useful and can help company reduce the product cost very effectively.

In the next packaging development program, we have decided to expand the scope of packaging improvement to suppliers. We should consider the packaging with the whole product life-cycle perspective. The scope for future packaging improvement can be illustrated as the figure below.

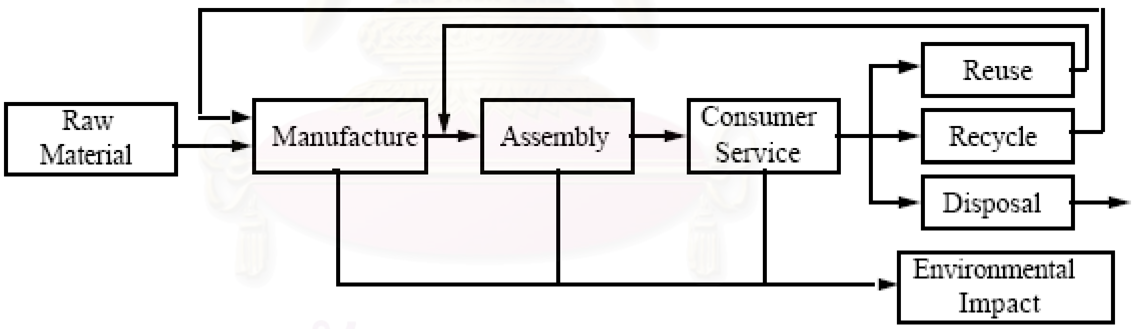


Figure 7.2 Product Life-cycle (Ishii, 2004)

The packaging can be treated as a product, if we can reuse it since the raw material of our HSA, we can use it as the free packaging. The company that has high bargaining power to the supplier should take a look at the opportunity to reduce their packaging cost with this concept also.

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APPENDICES

APPENDIX A

PACKAGING TESTING DESCRIPTION

VEHICLE VIBRATION

The test levels and the test methods for this element of the distribution cycle are intended to determine the ability of the shipping unit to withstand the vertical vibration environment during transportation.

Reference Specification: ASTM D 999, Method B.

Special Instructions:

Perform the test for bottom surface of the shipping unit (shipping orientation). An input acceleration of 0.5 g (0-peak) is applied and a sine sweep from 2-200Hz is performed. The resonant peak is identified, and a 15 minutes dwell at the resonant peal is performed.

LOOSE LOAD VIBRATION

The test levels and the test methods for this element of the distribution cycle are intended to determine the ability of the shipping unit to withstand the repetitive shocks occurring during transportation of bulk or loose loads.

Reference Specification: ASTM D 4728

Special Instruction:

The shipping unit is placed loosely on the vibration table and a random vibration (truck-air) spectrum is applied. Total dwell time is one hour, along the bottom surface. The container is then examined for any physical damage and the pre-tested test specimen (product) is re-tested to determine if any damage occurred during random vibration.

MECHANICAL HANDLING

The test levels and the test method for this element of the distribution cycle are intended to determine the ability of large and heavy shipping units and unitized loads to withstand the mechanical handling hazards that occur during loading, unloading, sorting, or stacking. The main hazards during these operations are the impacts caused by dropping the shipping unit from a forklift, crane sling, or hook.

Reference Specification: ASTM D 1083

Special Instructions:

Use specified drop height only, not successively increasing as specified in Method D 1083. Support shipping unit on opposite edges with supports of specified drop height. Remove one for rotational drop and remove the second support for a flat drop.

FREE FALL IMPACT:

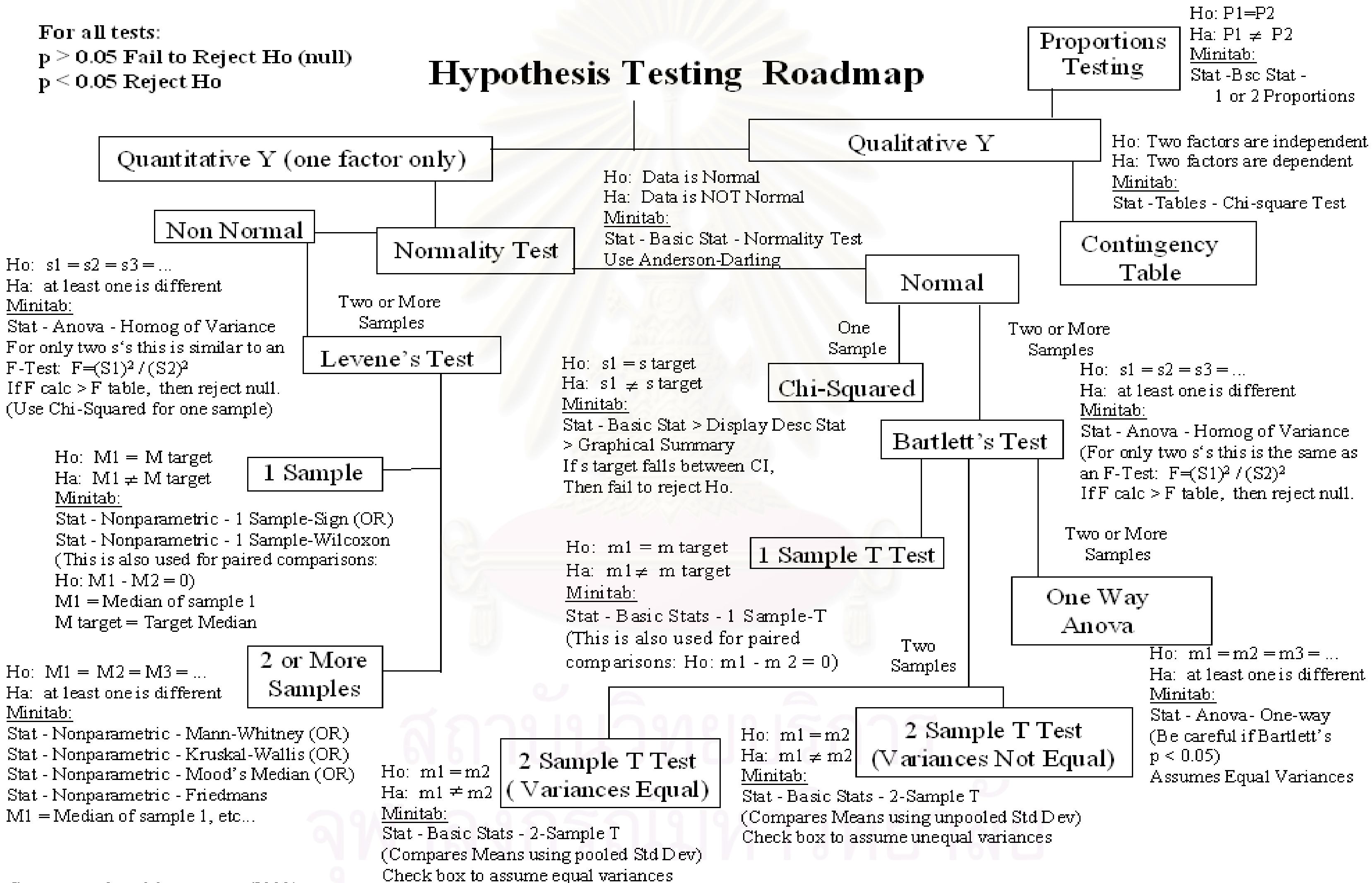
The test levels and the test methods for this element of the distribution cycle are intended to determine the ability of the shipping units to withstand the hazards ociiring during manual handling such as loading, unloading, stacking, sorting or palletizing. The main hazards from these operations are the impacts caused by dropping or throwing. Size, weight, and shape of the shipping unit will affect the intensity of these hazards.

For purpose of this procedure, the bottom of a small parcel is the surface on which the parcel tests in its most stable configuration.

Reference Specifications: ASTM D 5276 and ISTA 1A.

APPENDIX B

HYPOTHESIS TESTING ROADMAP



Summarize from Montgomery (1999)

BIOGRAPHY

Woraphoom Jatuworaphat was born on January 4, 1973 in Ratchaburi, Thailand. He obtained his Bachelor's degree of Electrical Engineering from Assumption University in 1996. He has started working at Seagate Technology since 1997 up to present time. During 8 years in Seagate, his responsibilities are related to HSA process engineering, new product development, HSA packaging development, and Six-Sigma Blackbelt. In 2002, he continues to study post-graduate for master degree of Engineering Management at The Regional Centre for Manufacturing Systems Engineering, Chulalongkorn University and University of Warwick (UK).