IT’S JUST PACKING
Packages doesn’t matter in manufacturing?

Ylemmän ammattikorkeakoulututkinnon opinnäytetyö
Teknologiaosaamisen johtaminen
Visamäki spring 2018

Katja Sivonen
TIIVISTELMÄ

Tekijä
Katja Sivonen

Vuosi
2018

Työn nimi
It’s just packing - Packages doesn’t matter in manufacturing?

TIIVISTELMÄ

Tämä työ on tehty ICT-alalla toimivalle matkapuhelinvalmistajalle Huawei Technologies Co.,Ltd:lle. Yhtiö työllistää globaalisti yli 180 000 henkilöä, joista 80 000 työskentelee R&D:ssä.

Matkapuhelin markkinat ovat hyvin dynaaminen ja kilpailtu ala, jossa muutokset ovat nopeita ja katteet pieniä. Kun kilpailu on kovaa täytyy valmistajien löytää koko ajan uusia keinoja tehostaa toimiaan ja kasvattaa kateosuuttaan pysyäkseen mukana.

Design for manufacturing, Design for assembly ja Lean periaatteet ovat olleet mukana tuotekehityksessä jo useita vuosikymmeniä ja niiden hyödyt tuotannon ja kokonaiskustannusten optimoinnissa ovat testattu ja verifioitu useilla eri toimialoilla. Niiden käyttö tuotteen myyntipakkauksen optimoinnissa on ollut vähäistä, lähinnä siksi ettei pakkauskseen tehokkuuteen ole kiinnitetty paljoa huomiota sen kustannuksen ollessa pieni osa tuotteen kokonaiskustannusta. Tämän työn tavoitteena on esittää tapa ottaa näitä teorioita käyttöön Huawein myyntipakkauksien kehityksessä, selvittää mitä on Design for packing guideline sekä luoda sen sisältö ja mitata sen käyttöönoton tehokkuus. Tutkimusmetodi on toimintatutkimus, jossa käytetään sekä kvalitatiivisia että kvantitatiivisia periaatteita, sekä tutkijan omaa tietotaitoa aihealueesta. Tutkimusmetodi on osoittaa yhden tavan määritellä ja luoda guideline sekä todistaa valittujen teoreettisten viitekehyksen soveltuvuuden sekä hyödyt myyntipakkauksen kehityksessä kokonpanon tehokkuuden kasvuna.

Tutkimuksen aikana esiin nousi käyttöönoton haasteet sekä eri organisaatioiden strategia ja manageri tason sitoutumisen tärkeyks, jotta työn tulokset voitaisiin ottaa laajemmin käyttöön. Tärkeäksi kysymyksksi nousi: Voiko sitoutumista olla ennen todennettuja hyötyjä ja voiko todentamista tapahtua ilman sitoutumista?

Avainsanat
Design for manufacturing, Design for assembly, Lean, pakkaus, valmistettavuus

Sivut
50 s. + liitteet 65 s.
ABSTRACT

This thesis is done for Huawei Technologies Co.Ltd., a growing ICT business company that manufactures mobile phones. Company has globally over 180 000 employees, from which 80 000 work for R&D.

Mobile phone market is dynamic and highly competitive environment, where changes are fast and profits are thin. To stay in competition manufacturers need to find new ways to improve efficiency and increase profit.

Design for manufacturing, Design for assembly and Lean principles have been in use for decades and the benefits have been proven in multiple industries. In sales package development the usage is not same level due to attention put into it as it is only small part of total cost of product. Target for this study is to present a way to implement theories in Huawei mobile phone package development and clarify meaning of design for packing guideline and its content and verify the change effect to assembly efficiency. Theoretical frame is based on mentioned principles and researchers own experience. Research method is actions research that uses both qualitative and quantitative methods.

Study defines one way to define and create guideline and verifies the suitability of chosen theories in packing context and implementation benefits in assembly efficiency increase.

Challenges in implementation and importance of strategy and manager level commitment between organizations for further deployment came to the fore during the research. It raised on question: Can there be commitment before some verification of benefits and can verification happened before commitment?

Keywords

Design for manufacturing, Design for assembly, Lean, packaging, manufacturability

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INTRODUCTION

Packaging is most times the forgotten part of product development in the manufacturing / supply chain point of view. Many times it is considered as “It’s just packing, not rocket science”, something that one product manager once mentioned to me. On the other hand the designers are focusing on the look and feel of design, logistic efficiency or sustainability. But what if we would take it as seriously as rocket science and start studying and improving the designs?

To deep dive into packaging has taught me, that there are many factors effecting to E2E cost of package, which are many times not discovered, because of lack of analyzing and development. This also supported by study of Betancur-Muñoz, Osorio-Gómeza, Martínez-Cadavida & Duque-Lombanab (2014) “Integrating Design for Assembly guidelines in packaging design with a context-based approach”. In study they made literature study of 115 articles with same identification, that none of them was combining all packaging aspects into one analyzing method. This is now considered in their development of design guideline and showing the opportunity for efficiency improvement by choices made in design.

Overall there has been happening giant leap in the consumer electronics industry within the last decades. Globalization has bring own challenges to support more customers in local way, it has also made information to competitors more easily available through internet. This has tighten the competition, which means that products need to be developed and delivered faster. (Huhtala 2009, 26-31) Similar changes has been happening in the sales package fabrication area. Shorter development time is identified there also and new priority of design intent is not anymore the protection or transportation, but more the visual aspect and branding through packaging. (Stora Enso, 2014) All of the changes has led to situation that in order companies to survive with lower margins and scattered product volumes, they need to able to optimize all functions and reduce the cost.

Design for assembly (DFA) is method for optimizing the design of assembly parts, mainly focusing on reducing parts and improving the part manufacturing. Design for Manufacturing (DFM) is more focusing on integrating design and assembly process optimization based on similar principles. In addition to manufacturing efficiency it also includes how to design in quality and reliability. Many companies are using these principles and created design guideline to ease the communication between manufacturing engineers and mechanical engineers to design manufacturable products. Guideline is also used as a learning center for not making the same mistakes again in next product with new people.

Target for this research is to optimize and improve the sales packaging efficiency and cost in Huawei mobile phone production by creating a design for packing guideline and implementing its principle to one product’s sales package design. Make changes to design according to guideline, then measure and verify the effects of changes.
Currently the design is done by ID (Industrial design department) and manufacturing department is included into design process in very late phase (verification before product ramp up), which leads to situation that no major changes to design can be made to support manufacturing better. One point of having guideline is to have early involvement, as in DFA method is highlighting.

Huawei sales have grown rapidly in last years and this has led to noticing also the non-efficiency in packing area of manufacturing. Capacity of manufacturing could be the bottle neck for delivering customers the wanted products, if nothing is made for this issue.

Researcher has worked in this area in another company for several years and has experience of similar activity with good results which is used as reference. Guideline is created based on DFM/DFFA and lean principles and translating them into packaging area and co-operation between ID design, manufacturing engineers in Huawei factory and researcher to learn from current design and manufacturability issues.

This works theoretical background is based on Design for manufacturing, Design for Assembly and lean. Study method is action study, which includes both quantitative and qualitative methods. There is plenty of research made related to DFM/DFA guidelines creation for the product assembly, but only few related to sales package guidelines and especially the implementation into real case company.
2 CONTEXT

2.1. Mobile phone industry

“From clunky luxury items to integral parts of daily life, cell phones now fuel an industry touching all corners of the globe.” This sentence clearly defines the evolution of mobile phone history. From first “mobile” phones that weighted 5 kilo’s, to smaller handheld devices, which could make calls and later short text messages, to today's all around tool in everyday life, business and communications. This development has been happening only in few years, as just in 1994 cell phones became more popular. Even the cell phones rise from the western world, it is today used heavily in many developing countries as access to outside world, like money transfers, access to internet and place business orders, even in places were running water and electricity is not available to the masses. The cell phone industry is the fastest growing sector in the communication industry and it is concentrating on moving forward technologically. (Sheth 2017)

Mobile phone industry key character is the dynamic fast moving and changing environment. Beside technology also the physical designs has been going through changes and makeovers by shape, size and weight. (Sheth 2017) In tight competition new products needs to be developed in faster cycle. What makes this challenging is more complicated products with bigger variant amount. Fast cycle of product lifetime means also that there is less and less time to do quality and efficiency improvement during development. (Huhtala 2009, 26-31)

Different vendors has had rise and falls due to technology, form or trend development. The markets has been dividing into smaller parts, which means that product variants are increasing and beside this also the product itself is variating more. Change in the top vendor and the market share between many vendors, especially the high share of the others portion can be seen in the chart below showing the sales volumes by vendors from 2010 to 2015. (Huhtala 2009, 26-31)

![Figure 1 Global mobile phone sales per quarter 2010-2015, by vendor (Statista 2015a)](image-url)
“Making money in the mobile industry is not an easy task”. Comparing to old industries, like oil etc., profit margin is relatively thin. Only exception has been Apple that has been able to achieve 40% profit. Apple profitability is due to its capability to prepaying supplier, loaning them money for special equipment’s and achieving the component market rock bottom prices. Only issue they have is the limited capacity, due to complex product which is difficult to manufacture. Operating profit is not telling the whole picture of market situation as it is only description of how much profit we get from revenue after reduction of cost of goods sold, labor and other general and other administration cost and therefore it is good to compare to sales. Average selling price is giving more reflection of market situation. Smartphone retail prices often are divided into three price categories: low-end (less than 150 US dollars), mid-range (from 150 to 550 US dollars) and high-end (above 550 US dollars). Over the last few years, mid-range smartphones accounted for about 40 to 50 percent of all smartphone shipments, while low-end’s share varied between 26 and 34 percent and high-end held from 20 to 28 percent of the share. During the last years the average selling price has been dropping so that from 2010 average selling price of 440 it was 2016 only 283. (Daniel 2011) (Investing answers 2017) (Statista 2016b)

![Figure 2 Smartphone average selling price worldwide (Statista 2016b)](image)

New technologies comes in fast cycles which means that products are coming more complex. That increase the needs for new manufacturing technologies and assembly difficulties. Competition between suppliers is fierce and because of smartphone market change, the average selling price has dropped. Only Apple has been able to keep the selling price in high level, which is partly also explained by fact that they only produce high end phones. (Richter 2016)
Saturation of market in highly developed regions, as North America and Europe means less people buying the products. Much of growth comes from emerging markets, where price is much more of an issue that can be also seen in average selling price decrease. (Richter 2016) Saturation is not anymore in western countries, but same can be also seen in China. Comparison of shipment units by regions from 2013 forward shows that actually only emerging APAC and Middle East & Africa is still having meaningful growth comparing the units and % increase. (Appendix 1). Within few years the growth has been slowing from 22% increase to 4% yearly increase. (Statista 2017c)
Mobile phone forecast by Gartner (2017) states the same little growth, which is expected to continue over next five years and seeing next positive growth in 2020 as arrival of 5G technology.

Researcher studied future analysis from different sources that had used for example PESTEL and SWOT analysis, to make summary. Based on those market situation is as shown in charts on stable status, but with some increase in volume. Markets drivers are decrease in phone pricing, increased standard of living, providing unique experiences and evolving environment. In the challenges area most effecting is low penetration in rural areas, which should be the region with most opportunity for sales increase, and increased labor cost in China effecting to profitability, as almost all manufacturing is in China. Other challenges are related to security and privacy concerns and customer loyalty, which is more related to western world and effecting the competition there. One general aspect for all regions is the issues with battery charge cycles, as today’s products are having features that use a lot of power and battery technology hasn’t been developing to serve this need. Collection of trends shows that form of phone as product is going to be evolving in the future, as is technologies related to display, sound, photographing. This may be the differentiation between vendors in the future. One main point is the increase in cloud-based services and apps that changes the perspective of not only to be mobile phone manufacturer, but to offer the whole ecosystem around it, with multiple supporting devices and services. To be top future vendors they need to be leading innovators, have high brand recognition and also effective marketing team. (Appendix 2).

2.2. Manufacturing

Industrial revolution, began in the 18th century, had big impact on how items were manufactured. Before the revolution items were hand made at home, since that it has overcome the hole industry of making everything people need by machines to produce bigger quantities in less time and cost. First assembly line was developed by Henry Ford in 1908 to build cars fast and efficiently. This has been stated as age for mass production (The Economist 2012). Next big change happened when Toyota Motor Corporation developed lean concept in 1948. In 1990’s concept spread outside automobile industry and today it’s used in every process, not only in manufacturing. Robotics came into manufacturing already in 1960’s when General Motor started to use them in assembly line. (Mancini 2009)

Packaging automation has traditionally been fixed automation, supplemented by manual labor. For high volume, low mix products this has been suitable option. Globalization and technological development has changed company’s operational environment in last decades towards lower volume product and wider product mix, where using fixed automation comes un-beneficial or un-useful due to short runs and normally long change over time from product to another. This has led to change of the packaging process to totally manual or some assisting small automation equipment processes. In the tightening competition new less-costly and more-flexible solutions are needed. This might be the next revolutionary thing in packaging automation. Next still coming packaging
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automation is small assembly robots with flexibility to do wider variety of tasks like material handling, pick and place, loading/unloading, package forming, product insertion. (Huhtala 2009, 26-31) (Denso 2014)

2.3. Packaging

Consumer electronics products has changed to be commodity, rather than big investment. This change has also effected to purpose of package. Earlier main purpose has been the protection of product during transportation. Nowadays it’s more like silent salesman of products on the shelves of supermarket and from the other hand as a communication tool of brand experience. (Järvi-Kääriäinen & Leppänen-Turkula 2002, 15-31.)

Packaging designers faced with such challenges often increase packaging volume to fulfill such sales functionalities. As demonstrated in a study The Commoditization of Consumer Electronics Products and its Influence on Packaging Design by Wever, Boks, & Stevels (2008). This can lead to packaging that is 20 to 40 times as voluminous as the product contained within, and fully loaded sea containers, of which the volume percentage actually occupied by products is as low as 4%.”

In packaging design the idea of what is good design can be very different on depending of what organization point of view we are looking at it. Many times the ID design is looking from marketing and look and feel point of view, that manufacturing engineers may not understand in the same way. When trying to change something in the outlook of design to support better manufacturability, we need to understand what a good package is and make compromises in decision to fulfill each point.

The Finnish Packaging Association has made a very good overview of good package with context of considering all the different aspects. The first priority of package is to protect the product from damages during transportation and handling. Required durability properties are defined by the distribution route, method and handling times. Total stress is also affected by transportation length, temperature and moisture. Temperature and moisture are mostly effecting to strength and shock absorber features. Beside outer effects to package durability also laudability is one point to test and this should also be considered when designing the secondary and tertiary packages and loading to pallet. Package needs to works in logistic and retail environment, which can be from internet shopping to shipping or selling in supermarket shelf. After this is confirmed we can start focus on other aspects like thinking that package serves the consumer. In this meaning, the designers needs to consider the consumer experience of opening the package and how package guides consumer to get started with the product. According to Jeff Davis (2016), Vice President, Account Director at branding and design agency Davis the change of package size or format to meet the customer needs is relevant for succeeding and one key point in list of seven strategies for cross channeling. (Järvi-Kääriäinen & Leppänen-Turkula 2002, 15-31) (Mohan 2016)
Environmental awareness has been one key issue in the packaging area in last years. This means considering ecological materials, re-use of package after transportation and retail, disposal of package at the end of life, so it needs to be recyclable and overall it needs to be cost efficient. Environmental and sustainability investments and initiatives are resulting also as good PR for marketing team, even though they are driven by the need to improve efficiency and reduce cost. (Wever, Boks et al.., 2007) (Smithers 2014)

Efficient in production is also mentioned point in Finnish Packaging Association overview. Meaning that design is supported by production technologies and processes and is easily packed. This is many times a point not considered by designers or is not aligned with other aspects like consumer experience. This is also recognized by package suppliers, as Stora Enso (Finnish paper manufacturer) has stated that “Brand owners do not just need a box, they need a reliable and high performance packaging operation.” (Järvi-Kääriäinen & Leppänen-Turkula 2002, 15-31) (Stora Enso 2014)

In competitive market environment the vendors need to have strong brand image and package has become essential part of this. Visual appearance has become very important for consumers and this has led to new printing technologies for suppliers and to package that has identifiable brand image and product authenticity. (Smithers 2014)

From researcher experience another new point designers need to consider is the tampering. They need to make sure that parts are not stolen or changed to fake products from package. Solutions for this may vary, but can lead to un-efficiency in packaging volume, manufacturing efficiency or customer opening experience.

Even todays packaging trend are changing to creating always something new, finally it needs to be optimized for its purpose, which means evaluating all of these items and they importance for certain product, product category or vendor. To combine these in one sentence package should serve distribution, storage, selling and usage. (Järvi-Kääriäinen & Leppänen-Turkula 2002, 15-31.) (Stora Enso 2014)

The future trends in the packaging area are very similar than in the overall consumer electronics environment. Products are coming in faster cycle and development time is short for new package. Mike Ferrari, founder of Ferrari Innovation Solutions, advices in the PAC conference 2016 that brand owners, suppliers and printers should consider based on 2025 packaging trend: 1. Reinvent your business, focus on harmonizing packaging across all the channels, 2. Reduce complexity and 3. Create a master plan and an all-digital workflow. (Mohan 2016)

2.4. HUAWEI

Huawei was founded in 1987 by Ren Zhengfei. In that time it was providing consulting and operational services to enterprises in China. It was formed at private company and is still. Today Huawei is leading global information and
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communication technology (ICT) solutions provider. Its solutions, products and services are used in more than 170 countries, serving one-third of world’s population. Huawei has 180,000 employees, from which 80,000 work in R&D. It has 18 R&D institute and centers. Finland’s R&D center in Helsinki, where researcher is employed, has around 260 employees. In 2015 sales revenue was 395 billion CNY and estimation for 2016 is 520 billion, an increase of 32% year-on-year. (Success Story 2017) (Huawei 2017a)

In July 2003 Huawei established its handset department and in 2004 first phone C300 was shipped. First Android based smartphone was published in 2009. In 2011 Huawei had strengthen mobile phone sales and over one million C8500 smartphones was sold in China within 100 days of launch. Today Huawei product range is from consumer products, like PC’s & tablets, wearable’s, mobile broadband, smart home and other accessories to business solution for enterprises and carriers varying from WLAN and server products to wireless network and cloud solutions. (Huawei 2017b)

Huawei values are under statement of “Building of better connected world and continuously create value for customers and society”. Which means that they are providing future-oriented information pipes through open partnership and continuing to innovate around customer needs, focusing on the development of leading technology that meets those needs. Huawei believes that staying customer centric, innovating at the crossroads of customer needs and leading technology by building an industry ecosystem that thrives on shared success they can become the top smart device brand that consumers prefer and trust. Since starting of mobile phone offering Huawei has taken a huge step in presence in mobile phone industry, as being today number 3 by smartphone market share and shipping 139 million units in 2016, by increasing the sales with 30%, a growth that has significantly outperformed the market. Huawei focus is on premium products, differentiating innovation, achieving technological breakthroughs and bringing the latest technology to consumers. To accomplish this target they are offering mobile phone products in different categories; D-series for the "Ultimate Technology", the P-series for the "Ultimate Fashion"; the G-series for the "Ultimate Value", and the Y-series for the "Ultimate Accessibility" and this relates to price range also, which is typical offering for vendors, except Apple that is only focusing on high level category. (Huawei 2017c) (Huawei 2017a) (Huawei 2017d)

Huawei Consumer Business Group Chief Executive Officer Richard Yu stated in the business results of 2016 “We have continued to maintain healthy growth within the highly competitive smartphone market, which is testament to Huawei’s long-term commitment to innovation, anticipation of consumer trend and dual strategy of focusing on both domestic and international markets”. This is differencing them from other China vendors, which are focusing more in domestic market and has also been key thing to Huawei’s overseas growth surpassing domestic growth. Mr. Yu also said “We saw particularly fast growth in traditionally high-end smartphone markets such as Europe and emerging markets including North Africa, Central Asia & Latin America.”, which is also interesting as compared to overall mobile phone markets, these are the areas that have difficulties in growth. (Huawei 2017e)
2.5. Thesis structure and research methodology

Thesis has critical-realism paradigm, as theory is applied within context. Meta-theoretical approach is qualitative, but is uses both qualitative and quantitative materials. Researcher is part of related organization, so approach to study is mostly subjective. Action research was chosen as methodology, as target is to make research and make changes. Researcher as part of process also support this methodology. (KvantiMOTV 2016) In the end we get information/results about effects of changes made. Research theoretical framework is based on Design for manufacturing, Design for Assembly, concurrent engineering and Lean theories.

First researcher introduces the operational environment of this research. Due to special features of implementing theories into area where it has not been used as much this part contains multiple aspects to be able to get full view of the environment. Even there is lot of theory material available researcher decided to handle main theories only by parts that are meaningful for this study. Research plan and empirical part is covered in details. In the end researcher reflects the research including contribution and further study proposals.

2.6. Conclusions

From introduction and context we can pick up some key highlights. Mobile phone industry is fast moving and changing environment with heavy competition between vendors. Profits are very thin and to compete with other vendors even small benefits create huge effect when multiplied by selling volumes. Manufacturing of mobile phones has then turned to be more complex and it is even more decreasing the profits as manufacturing cost are higher than before. New technologies are needed to assembly the phones and they are not anymore just to increase the efficiency as earlier days. In the sales package design area the development has been changing from bulk transportation to marketing material and important selling feature. This may effect also the efficiency in manufacturing, as design need to have the WOW effect and support the brand image and it increase the variation in designs.

Huawei as a company is fairly new vendor in mobile phone industry and has been rising very fast. Without the historical experience of manufacturing mobile phones it needs to find new ways to increase the efficiency to gain bigger profits. From Huawei values the customer centricity is one key point to be highlighted for making successful mobile phone products. They have also been able to increase sales in the areas that are considered as saturated.

Overall all aspects are heading to same direction of diversity and complexity. By implementation of DFM/DFFA theories we can assume to have benefits in the competition against other vendors. For this research it is important to understand the consumer electronics market and its effect to sales package design requirements, but same time try to make compromises to improve the efficiency and profit.
3 THEORY

3.1. Design for manufacturability

"Design for manufacturability (DFM) is the process for proactively designing the products to (1) optimize all the manufacturing functions: fabrication, assembly, test, procurement, shipping, service and repair” (Anderson 2014, 3).

In introducing the DFM process we must understand this wide range of expertise needed. This means a lot of resources (people) and time to do the actual work related. In this project it was clear that we are not able to focus on all aspects nor it was necessary. To prove the method benefits we started from optimizing the parts that had the biggest lack of manufacturability.

In packaging fabrication (when using experienced supplier) the producing of packaging and materials are quite well optimized based on researcher experience. Therefore it was not included into guideline or optimization for this study. Most times shipping is considered also well. Packages are tested against hits and vibration and efficiency is considered in pallet level. Based on these, focus is put mainly into assembly, testing (in this case quality control), procurement and repair. These items are focus of guideline first release.

"Design for manufacturability (DFM) is the process for proactively designing the products to (2) ensure best cost, quality, reliability, regulatory compliance, safety, time-to-market and customer satisfaction; and (3) ensure that lack of manufacturability does not compromise functionality, styling, new product introduction, product delivery, improvement programs, or strategic initiatives and make it difficult to respond to unexpected surges in product demand or limit growth.” (Anderson 2014, 3.)

This sentence is describing how huge task it is to do DFM. We need to have expertise in multiple areas, have analyzing capability for each benefits and finally, need to make design decision that fulfills all design development organizations targets. Work is making improvement proposals based on knowledge, proof the benefits and then convince the whole team to support. Or then compromising in some part of benefits with better gains in other.

By DFM method companies are able to design products that are manufacturable the first time with low-cost, high quality and satisfying customer needs. Reason for not achieving these targets is mainly due to skipping the critical concept phase and focus on schedule and cost, doing individual work efforts instead of team work. If full DFM method is followed it is not only the total cost effect but also the later work effort reduction by having less change orders and firefighting activities. DFM is tied to two other theories: Concurrent engineering and Lean.
3.2. Concurrent engineering

"Concurrent engineering is proactive practice of designing products in multifunctional teams, with all the specialties working together from the earliest stages” (Anderson 2014, 3). This is essential part of doing DFM for packing. Package design development is many times started in the later phase of product development and has also very short time for development. Many times the conceptual design is developed within few months. After the conceptual design is freeze and only smaller fitting changes can be done. This means that we need to have very clear structure how and what to do to support manufacturability. This is where guideline comes to play an important role. We have based on the DFM theory what to consider or to avoid in design, we have the information about current / past designs problems and we have the manufacturing requirements i.e. machinery or process restrictions, in one place to get fast the information needed for analyzing the design and make design decisions based on facts.

3.3. Lean

Basic idea of Lean is ability to accomplish more with less. It’s systematic method for eliminating waste, defined into 7 categories; (1) Transport (moving products that are not actually required to perform the processing), (2) Inventory (all components, work in process, and finished product not being processed), (3) Motion (people or equipment moving or walking more than is required to perform the processing), (4) Waiting (waiting for the next production step, interruptions of production during shift change), (5) Overproduction (production ahead of demand), (6) Over Processing (resulting from poor tool or product design creating activity), (7) Defects (the effort involved in inspecting for and fixing defects). These same principles can be used in package design analyses and make changes to design to avoid these wastes in manufacturing. (Sayer & Williams, 2007)

3.4. Design for assembly

Design for assembly (DFA) is many times thought to be same as DFM and for sure they can be. But in DFA the view is more focusing on the product assembly cost reduction as DFM is looking more widely to also part fabrication production cost. There are many different methods under the DFA from different sources. Differences are within how they handle manufacturability. In researcher experience Boothroyd method has been working in mobile phone industry and therefore mostly followed they method. (Huhtala 2009, 232)

Design for assembly (DFA) is term for designing the product for ease of assembly, as Design for manufacturing (DFMA) is combination of DFA and DFM (Design for manufacturing; meaning the ease of manufacturing of parts and will form product after assembly). Original method development started in the 1960’s on automatic handling and in the mid-1970s it was extended to general areas of DFM and DFA. Same time first study around this issue was performed. Study proved the two basic principles of design for ease assembly: Reduce the number of assembly operations by reducing the number of parts and make
assembly operations easier to perform. In the late 1970’s the DFA time standards for small mechanical products was published in handbook form and success of application of DFA were reported. Major breakthrough happened in 1988 when Ford Motor Company reported savings of using the DFA software created earlier. After this General Motors (GM) studied the differences between GM and Ford production plants. Based on gap of 41% GM executive stated that DFM/DFA is a primary driver of quality and cost improvement and it provides technical improvement to both product and process. After method for analyzing assembly difficulties were developed, it was found that following the principle of reducing the number of parts is not only reducing the assembly cost, but also even greater savings in cost of the parts. The ability to estimate these both (assembly and part manufacturing cost) at the earliest stages of product design is essential of DFMA. To avoid large number of design changes, or delays due to manufacturing issues in design it is very important to take manufacture and assembly into consideration as early as possible in the design cycle. Another reason for early consideration is fact that over 70% of final product cost are determined during design. (Boothroyd, Dewhurst & Knight 2002)

Design for assembly aim is to reduce total product cost and improve reliability, without compromising products functionality. Even that from typical product cost breakdown assembly might be only 4% of total cost, it may be that focusing to the easy assembly we can actually reduce the other costs as well.

**TYPICAL PRODUCT COST BREAKDOWN**

- **Part Costs 72%**
- **Assembly Labor 4%**
- **Overhead 24%**

*Figure 5 Typical product cost breakdown (BOOTHROYD DEWHURST Inc. 2017)*

Focusing only for other cost elements may increase the actual assembly cost by increasing the part count and therefore all the other elements cost increases also in repair, supplier, part cost and so on. By Boothroyd and etc. Surveys have shown that instead of reduction in manufacturing cost the reduced time to market an improved quality is seen more important in the development. Another benefits come through the procedure. Results are simpler and more reliable products. This also effect to cost reduction in drawings, specifications, vendors, inventory as we can reduce the amount of them. Overhead forms the largest portion of total cost
of product and this way we can effect on it. (Boothroyd, Dewhurst & Knight 2002) (BOOTHROYD DEWHURST Inc. 2017)

DFA principle is to reduce the part count, but it also considers other aspects. In DFA Guidelines focus should be put into firstly reduce the number of parts and part types and by this we get standardization of parts and reduce the number of assembly parts. This leads reduction of different assembly processes and total handling time/product. Second point is to design for easy assembly, including less fasteners, designing self-locating features, minimizing the reorientation by using symmetry in design, and easy part handling by optimizing the part size, slipperiness, sharpness and flexibility. By this we can reduce the assembly time of each part. Third point is to ensure the access and visibility and top-down assembly direction. All of these combines makes assembly process faster, more error free and inspection capability is better. (Kumar 2015)

As mentioned DFA is based on simplification of products by reducing the number of separate parts. For guidance how to reduce the number of parts there is three criteria against which each part must be examined.
1. Does the part move relative to all other parts already assembled.
2. Must the part be different material
3. Must the part be separated from already assembled parts because of assembly or disassembly

By this analyses we get theoretical minimum number of parts without any practical limitations. Based on practical, technical or economic considerations any extra part need to be justified. Before considering alternative design it is necessary to have estimates of assembly cost, these can be done without having the final detail or drawings pf parts available and then later make estimates for the part and associated tooling cost. To measure the design in comparable way, assembly design index can be used. The figure is calculated by comparing the estimated assembly time with theoretical minimum part count multiplied by minimum time of assembly of each part of 3 seconds. Index can be used to compare new and old design, but it can also refer to presentation of good design. Normally the higher the index number is the easier the assembly is. In packing using this type of evaluation was not seen as beneficial as it not as complex and also there are many other factors effecting to total part count, i.e. accessories like charger, headset, cables and other material used by consumer and it is very difficult to analyze the theoretical minimum part count. In comparison purposes there was made similar comparison index including evaluating part count, packing density, assembly easiness, error proofing etc… but in this phase it was not yet seen valuable tool. (Appendix 3)

DFMA method includes several steps. First action is to make DFA analyses to get current state and also to simplify the product structure. Then using DFMA, cost estimates for the parts can be made for original and new design. During this the best materials and processes are considered. Once final material selections are done more detail analysis for DFM can be done. (Boothroyd, Dewhurst & Knight 2002, 8-11).
3.5. Design for packing

There is no official description of what Design for Packing (DFP) is. It can be considered as sub-discipline of DFM/DFA. Or as Anderson (2014, 126) is putting packaging under Design for Everything (DFX). He is touching the subject lightly and in very high level. This shows the level of focus put into design for packing activities and possible benefits. Researcher’s definition is that DFP purpose is to analyze and simplify a package concept or product specific package design based on specific drivers for manufacturing efficiency. These drivers can be functionality, cost, materials, quality, manufacturing and logistics, as it describes the actions to improve the design and different aspects to consider while doing this. These are also the common cost elements of packaging as part of total cost. If we compare DFP to other DFM disciples, it is not driven as so complex and small technical details, but it contains same basic elements like “poka yoke”, minimizing part count, using standard components, minimize assembly directions etc. Difference is in the wider scope of analyzing. To fully capture DFP potential, specialist need to understand also the material manufacturing, branding, variation effects, logistic and balance those, to meet customer requirements.

3.6. Guideline

Before starting to build guideline we also need to understand what guideline is. Researcher collected some statements of what guideline in from various sources.

"Recommended practice that allows some discretion or leeway in its interpretation, implementation, or use" (Business dictionary 2016).

"Information intended to advise people on how something should be done or what something should be” (Cambridge Dictionary 2016).

"Firstly we need to understand that guideline is not same as specification. It will include some specifications like automation requirements, but manual assembly is always to be analyzed and considered in each case separately and understanding the total cost effect, before making the decisions just based on assembly efficiency. Second point of guideline is to be interpretation between ID designers and manufacturing engineers. It will include process and machine or tooling capabilities and specifications. Example cases of current good and bad designs in assembly view and ideas of manufacturing parts more efficiently” (Hamidi & Farahmand 2008).

In this study researcher uses these statements to create basis for content of guideline. Researcher made statement about what this DFP guideline is and created a baseline content. As the purpose of Design For Packing is to analyze and simplify a package concept or product specific package design based on the specific drivers for manufacturing efficiency, the design for packing guideline is a tool for that development and communication between groups or organizations to realize these targets into design. This take into account the nature of guideline described in the earlier statements, not to be restrictions or requirements only. It
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offers company possibility for overall cost reduction, better quality and simplified processes. Even though supply chain logistic is significant cost element, in this case to funnel the information to intended group, it was not included as main item to be developed in the first release of guideline.

Guideline will include:
- Equipment and machine restrictions/limitation
- Design for assembly principles
- Design examples of good and bad designs in component specific content

Guideline is always living document that should be updated based on new findings or new requirements. Therefore there should an owner for document that is following up these updates and also process to give the feedback or learnings on new product’s development.

3.7. China culture

Culture illustrates the accepted norms and values and traditional behavior of a group and it can be defined as an evolving set of collective beliefs, values and attitudes. Culture influences management, decisions and all business functions from accounting to production. (Business culture 2017)

As Huawei has been privately owned Chinese company most of its workers are mostly from China it is important to understand the cultural differences. To prepare for the interviews and discussions researcher needed to understand and focus into these special features. First and most important is the indirectness of Chinese versus directness of Finns. Researcher needs keep in mind that losing the face has been traditionally and still is very upsetting for Chinese. This may be seen in answers, where they might withholding information, color the answer or avoid answering if the reply is not in their best interest. No and yes has also multiple meaning in Chinese culture. I.e. “No” is not used most times at all and “Yes” can mean anything between yes, maybe or I don’t understand or know. In the interviews confronting problems directly should be avoided, as it is also “loosing face” situation. This might be frustrating for Finns. To avoid any uncomfortable situation researcher (as a woman) needs to also consider how to dress as in Chinese business dressing is conservative and traditional (Peng 2009)

Beside national cultural differences, there might be also special company business culture that researcher is not familiar with. As a new employee this was not well known and researcher needed to learn the culture during the research and adopt accordingly. Business culture as culture in general is also evolving all the time. Business culture includes same characteristics as culture, but is also includes more about management, meeting procedures, hierarchy. It defines how decisions are made and how to effect best way to have open communication and information sharing. These differences between workers from different culture may results into conflicts, if not considered and adopted into. (Wikipedia 2015a)
3.8. Conclusions

Based on theories there is possibility to use the DMF, DFFA, Lean theories in packaging context to improve the efficiency by implementing the optimization principles to package design. These theories have been utilized multiple times in assembly of different kind of products. There is lot of literature about these theories and examples of implementation of those by creating guideline and optimization of design. Theory also highlights the possible obstacles that implementation may run into and that is something that should be considered during the planning and empirical part.
4 RESEARCH METHODOLOGY

4.1. Research purpose

Purpose for this project is to create guideline for Huawei package ID designers, manufacturing engineers and product development engineers to consider manufacturing efficiency in early package design development phase. Show the current issues in designs and improvement benefits. Project target was to make changes in Huawei mobile phone package design and by this improve UPPH (units produced per hour per operator) by 20%.

Research questions are:
- What is Design for Packing guideline?
- How to build DFP guideline?
- What are benefits of DFP guideline?

4.2. Action research as a method

In action research the goal is to study and change the current way of working. Research focus on solving “real life” problem. Essential is that people working around the issue are actively participating into research. Typical features of action research is practice orientated, problem based, researcher and participants are actively involved in change process and co-operation between researcher and participants that is based on their relationship. The aim of action research is to create changes. Basic steps in action research includes: problem statement and target for research, literature review about similar issues, plan process and steps for research, define the evaluation criteria, analyzing the information and evaluating results. Action research founder is presented Kurt Lewin. In he’s research he made description of field test basic model. It includes baseline mapping, intervention description, and result evaluation. He also defined the spiral principle of action research. It goes through phases: action planning, change execution, tracking and evaluating change effects and starting the cycle again from new action planning. Action research proceeds in cycles and every new cycle gives possibility to improve the results. (Kuula 2017)
Reflection is basis for action research. It means that researcher gives input and all participants evaluate and give feedback based on each phase success and results. This can be used as input for designing of next phase actions. Constant reflection is happening during action research, but still there is needed to have final reflection. It shows that action research has been able to develop the research subject and the participants. As results new plan of how to continue and what is needed to develop further. Target is to consider and re-evaluate action targets and procedures. (Virtuaali ammattikorkeakoulu 2007) (Suojanen 2004)

Action research has been chosen as a method as it supports best the nature of this study and allows to do changes based on findings and situation changes, as more traditional experimental research method can actually inhibit effective change due to hypothesis restrictions. (Dick 2000)

4.3. Need analysis and target

Competitive environment in mobile phone industry has let also Huawei to notice that in order to keep up with the competition of being one of the leading vendors they need to focus on the efficiency of packing. Based on theories it can be estimated that implementing DFP could improve the efficiency and profit.

Target for this research is to create DFP guideline and implement it to one product to evaluate the actual benefits. Based on results Huawei can then evaluate if there
is value to implement the DFP into new product development process and have benefits across product categories. During the research main targets are to create the actual guideline and create knowledge to related participants about DFP and how the optimization is happening.

4.4. Research execution

Research uses both qualitative and quantitative methods. In the beginning the researcher uses secondary data to make presentation material about DFP that is shared to participants. This is first intervention as it already opens the door about DFP thinking of participating persons. After this current status of package design is studied based on observations, interviews and process analysis. Based on the already existing secondary data and now collected primary data and competitor analyses the draft of DFP guideline is build. After guideline existing it is then implemented to one product and change effects are then measured against the original design efficiency. If results are good and review group accepts the guideline is released to be used in the new product design development.

Figure 7 Research execution

4.5. Study method Benchmarking

Benchmarking is process to help companies overcome challenges in continuous and fast development and answer questions like; in which matters company can become better, how much better, how good they can be and how to achieve this change. Benchmarking origin is in Japan, as many other development technics. In Europe the pioneer has been Rank Xerox, followed by many other companies like Motorola, AT&T, General electric and so on. Benchmarking is not just copy-paste process. It means detail understanding of process and ability to change and adapt learnings to your company environment. (Tuominen, 1993, 11; Tuominen, 1993, 17)
There is 3 different benchmarking types; strategic, performance and process benchmarking. In this study we use the performance benchmarking method, because it measures company products or process performance and compares it other companies, which gives us current status baseline and improvement ideas. Choosing this method is also supported by S.G Lee and S.W Lye study of design for manual packaging (2002), where they conclusion was that study showed how the best packaging features of similar products may be adopted from different companies to improve packaging efficiency (Lee & Lye 2003) (Tuominen 1993, 18)

Used information is from generally available sources, like product packages in the shops, internet pages, and by this information we are able to make handtime analysis and comparison of effect to process performance that were also the key performance indicator.

By Tuominen (1993, 21) benchmarking includes 8 process steps.
1. Define the benchmarking target
   - Study focus on sales package design and manufacturing process in DFM/DFA perspective
2. Search for best corresponding target company/companies
   Benchmarking companies can be divided into groups: internal, competitor, within the industry, best possible (Tuominen, 1993, 22). In this study competitors were chosen as a group of interest.
   - 3 main competitors in mobile phone industry was chosen: iPhone, Samsung and Nokia.
3. Learn your own process
   - Observation
   - Current documentation
   - Interviews
   - Hand time analysis
   - Manufacturing process analysis
   - Design analysis
   By these we get comparable performance indicators and understanding of preconditions effecting to better targets.
4. Learn chosen best process
   - Hand time analysis based on design
   - Manufacturing process set-up
   - Design analysis
   - DFP (DFM) usage in design elements
   By this we get comparison data, process learnings, and design competitiveness
5. Define the performance indicator differences and reasons
   - Comparison of analysis
6. Define target
   - Define ideas that can be take into use 1) immediately 2) short term development targets

7. Apply and take into use
   - Transfer the best practices into your own process

8. Establish and develop further
   - Define long term target and develop further

By comparing Huawei design and analyzed efficiency figures to other companies, we get information of what we can learn from others and also help us identify our own weaknesses and make then development plan accordingly. This can be use also as efficiency comparison of where Huawei stand within the consumer electronics industry.

4.6. Interview

Interview is most commonly used information collection method. Interviews target is to get primary data that researcher did not have. Interviews can be classify based on how structured the interview plan is. Theme interview is not proceeding with exact before prepared questions, but it is open communication within predefined themes. These themes are collected from earlier studies or subjects based on familiarizing to related study material. Which means that researcher needs to throughout study the materials and consider the individual situations. Interviewer aims to discuss all the themes with each in interviewee, even though they need to consider to give space for free speech. To support this interviewer can have notebook with bullet point of themes. Beside the questions also the interviewee’s need to be chosen accurately, so that researcher gets enough material from them. Interviews analyzing is happening by categorization based on themes and continue by further analyzing the typical topics that raised from interviews. (Saaranen-Kauppinen & Puustniekka 2006)

4.7. Observation

In observation target is to create information that is not possible to gain with literature basis by using knowledge and skills. Observation can be used in all kind of material collection but is working best in process studies. Observations are made in real environment and preparation beforehand is needed to be able to create reliable and accurate. Researcher performing observation should also have background knowledge to be able to make interpretations of what she is seeing. Observation is divided into two main categories: direct and participating observation and they both can be structured and un-structured in the way to collect material. Direct observation means that participants are not aware of observatory. In participating observation researcher can influence the target of observation when it is active participating observation. If researcher is part of the observation environment but not effecting to it, it is passive participating observation. In both ways the researcher needs to define her role and its effect to
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occasion, so that she can evaluate the research reliability. In structured observation researcher needs to define the problems before hand and create classifications. Un-structured observation is used when target is find us much information as possible. In this type of observation there needs to be also pre-
knowledge to make estimation of what is going to be happening and make list of key words that can be used in analyze of observation. Research reliability is depended on the right way of doing observation. Examples are mistakes in making notes or making notes by delay. Due to this researcher needs to consider if some other information collection method is also used for triangulation. (Virtuaali ammattikorkeakoulu 2007)

4.8. Process analysis

Process analysis will give understanding of how current packages are supporting the process. Each process step is described and handtime for each action is measured. There are multiple ways to measure the efficiency in production like FSP (Floor space productivity), manufacturing cost etc... But as Huawei is using UPPH (unit’s produced per operator per hour) for efficiency measurement it was chosen also to be one key measurement for this project and not to consider any new measurements. UPPH can be calculated by having produced amount per hour and divide that with amount of operator.

As DFP should not only considered design optimization we also can use the analysis of current process and DFP based design effect to possible process changes to improve the efficiency even more. This also included the needed floor space in current and new design (process). Cost of packing operation per package can also be calculated from UPPH, when we know the cost of one operator per hour.

When doing the measuring of design change effect to UPPH the learning curve must be considered. Learning curve relates to repetitive task and presents the relationship between experience and productivity. Research has shown that process time per unit decreases until 140th units. After this standard time can be developed. (Krajewski 2016)

![Figure 8 Learning curve, Showing the learning period and time when standards are calculated (Krajewski 2016)](image-url)
5 EMPIRICAL PART

Study frame is built on Huawei development process, which includes five (5) stages and four (4) check points. Project charter, Project charter approval check point, Requirement analyses and solution design, Plan Decision Check Point (PDCP), Development and verification, Technology Decision Check Point (TDPC), Technology migration, End Decision Check Point (End-DCP) and Technology maintenance stage.

![Diagram of Huawei Technology development process](Huawei 2016f)

Using the Huawei development process is supported by the chosen method of action research, where development happens in cycles and in every cycle reflection is happening and it gives opportunity to improve the results or change the plan.

In each check point there is 2 reviews. First one is TMG (technology management group) review where all analysis and action details is presented and TMG makes decision if project is mature enough to go to TMT (Technology management team) review and they can also make adjustment or change request. In TMT the actual phase approval is reviewed and they can also make adjustment or change request for the plan in the next phase. (Huawei 2016f)

5.1. Project charter phase

Before the actual project is approved, project charter needed to be created. This included project goal, scope, schedule, possible investment and resources needed (money and people). Presentation of project defines the solution, estimated benefits and benchmarking to other companies.

![Diagram of Charter phase schedule plan](Huawei 2016f)
Project charter phase includes steps 1-4 from benchmarking process. To start building the frame for the project charter, researcher started to build information based on benchmarking method, theory and own experience.

5.1.1. Using theory to create base line

Based on theories researcher created DFP startup material (Appendix 4). Material started by explanation why packages are important part of whole product experience and what are the purpose of packages. This gives manufacturing engineers wider view of packaging that they may have not considered earlier. It also opens the perspective from where ID sees the package and why in design some things may not seem necessary from manufacturing view. The basic process of DFM was introduced and how DFP may differ from other DFX disciples. This gives input of where and when to do DFP work during product program and understanding of what DFP is. DFM and DFA principles and examples of use cases in packing context are presented to give manufacturing engineers idea of what kind of things to focus and what effect they may have on the efficiency. Definition of different aspects that effect to packing cost efficiency besides manufacturing, i.e. variation, logistics and total volumes are presented, even though they may not be in the scope of first version of guideline. In the end researcher raised questions that would need be clarified during current state analysis.

5.1.2. Huawei current state analysis

Based on theories researcher created a plan for analyzing the current status of Huawei package design, manufacturing and processes. As researcher herself was a new employee of Huawei and did not have any earlier experience of Huawei sales package design and processes, she decided to use triangulation by using multiple different methods to get as wide range of information as possible. After the method’s decisions, researcher prepared a visit to Huawei HQ in China Shenzhen to meet and interview people, visit the factory for observation and analyze process and designs.

5.1.3. Interviews

For interview method researcher had chosen theme interview, as it supports best the diversity of group to be interviewed. Before the interview researcher had prepared a bullet line of key questions or themes raised by theories and earlier created DFP startup document for each interview (Appendix 4). Otherwise interview was un-structured. Interviewee’s were selected based on DFP startup document raised questions by senior Huawei manufacturability engineer. In the list of categories was variation/customization in sales packages, cost analysis and sourcing, ID Design/ Product development process and alignment with manufacturing. Interviews were arranged as colleague meeting and DFP startup material was shared with each interviewee beforehand. Timing of each meeting was scheduled before researcher came to China. The length of meeting was not defined, to give the interviewees possibility to fully engage with interview and
also the language barrier made estimation of time needed difficult. Interviews were not recorded due to restrictions of taking any recording device into China office. Researcher was making notes of each interview by pen and paper. Due to language barriers some of the interviews were translated by Chinese colleague between Chinese and English. This created a challenge for researcher to make sure that questions were understood correctly and that everything was translated correctly. In the beginning of each interview researcher presented herself and project targets and reason for meeting. During the meeting researcher tried to keep an open atmosphere and consider the Chinese culture. After the meetings researcher stored the notes to word format for further analyses (Appendix 5). Interviews were analyzed by using content analyzing method by themes to find out key points that should be focused in the guideline based on interviews. (Appendix 6)

Conclusions:

After the meetings researcher had feeling that interviews were successful in the way that each interviewee was openly sharing the information. From these interview analyses researcher has raised few main topics. In highest priority and most potential for improvement is the dis-continuity of sales package design’s between products. Each product had they individual design and materials. This can create difficulties in designing and balancing the assembly line, which should be studied more in the observation and competitor analyses using available efficiency figures. It creates excess work in sourcing by supplier selection, capacity& quality control and cost level. During the product development creating each time totally new design takes resources and time in ID design and customization team. If using the same design for multiple products we could reduce this workload. This relates theory of DFM/DFFA in the context of standardization and modularity between products.

Second major issue that raised from interviews was the missing co-operation between organizations. This lead to situation that issues raised in sourcing or manufacturing departments, never got any feedback loop back to ID design. Customization team was working better with co-operation to manufacturing engineers. DFM method implementation helps on this as one main step is early involvement and co-operation. Guideline will also be good communication tool to share ideas/issues between organizations.

Variation inside one product interviewee’s did not see an issue. Customization was also considered as late as possible, like using sticker to variate the text in the sales package graphics. Reason variation and customization is not an issue may be due to that Huawei has been focusing on China market and abroad variants are not so big in volumes. This is still something that should be considered in the future, if the variation between local and abroad product selling volumes shift.

Two factors raised in the theory parts were also visible in the interviews. First one was the short development time. Package development start time is in later than actual product development time, which means that packages need to be designed in fast cycle. There is no much time to use for testing and so on.
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This development time picture also shows the important point for package design development the OOBE. It is the phase when the design is freeze and no big changes are possible after that. It means that time when co-operation and optimization should be done is very short and manufacturing has not seen the package at all to give feedback about design efficiency.

Some issues may not been covered in the interviews as deep as they could have been due to language barrier and no pre connection to interviewee before. This may be seen in some hesitation about problem sharing in ID design especially. Researcher did not use preliminary interviews to check the content before actual interviews. The material shared before the meeting still helped to have enough conversations and material from the interviews. Because of these researcher planned to use triangulation in next phases to deepen the information.

Reporting:

The analyses of interviews were used for guideline creation to raise items that were discovered from them. Results were presented in the project charter presentation for Huawei TMG (Technology Management Group) review as content of guideline.

5.1.4. Observation

Target for observation is to have information about current production process, possible problems or good solutions in there and sales package design suitability and to find opportunities for improvements based on design changes to process or sales package. As researcher is in the factory floor and attendants are aware of it, but she is not making any changes observation method is passive participating observation. Researcher will use un-structured observations and has prepared excel sheet based on theories and experience for things to look into during observation. (Appendix 7)

During observation researcher used 7 lean principles to make findings.
1. Overproduction
2. Waiting for something to happen, material to come, missing information
3. Transportation delays, resources, management
4. Waste in process, no standardization, sub-optimization set-up
5. Inventory, floor space, quality concerns, obsolescence, cash, management
6. Excess motion in walking/lifting, positioning, turning
7. Scrap and rework in material/time, labor, and space.
(Appendix 8)

For sales package design analyses researcher uses list of assembly tasks: storing, handling, positioning, joining, adjusting, securing, inspection. In observation all of these were analyzed. (Appendix 9)

During observation researcher used paper and pen to make notes mark those on printed checklist sheet. For hand time measuring researcher used stop watch and marked results by paper and pen. Taking pictures or recording was restricted, this may have some influence on how much details researcher was able to obtain during the observation. Researcher was trying to keep observation as passive participating observation and not to effect on activities persons were doing. Still being present in the situation researcher might have effect that operators followed the process more accurately and put a lot of focus on “looking good” and being more efficient than normally. In discussions or questions during observations researcher had local Chinese people to translate and ask questions from the staff, as many of them did not speak English. In discussions researcher needed to make sure that questions and answers were translated and understood correctly. Researcher needed to also be sure that she did not effect to activities operators were doing by asking questions about details or purpose of certain issues. During the observation researcher made description of process, including operator activities and work place space and part placements and measured the handling time of 2 products packing process, to use information later for efficiency improvement target creation. (Appendix 10)

Conclusions:
Sales package design in process analyses key items that raised up where part count variation between products, lot of re-orientation during packing, part insertion and top-down assembly where not considered. In the Process list improvement the incoming material packages design raised up, as there was a lot of over packing which means lot of money used in transportation protection and increase the preparation time and waste material. Materials design did not support any certain dividable amount, like for example each package would include 20 pc’s of parts. Another point was the material handling as when doing hand time calculations operators were using 22% of time for handling the packing material instead of using that time for productive work. Third point in process was that there was lot of quality assurance done online, which could be reduced and efficiency could be higher.

For the keyword from Lean principles researcher made notice that over-production was not issue, as all production was based on customer orders. Waiting was more issue as there was not certain amount of material in the packing line and when material ended operator needed to contact material delivery person and wait for them to deliver the new material. This is also related to inventory levels as there was lot of material in packing lines, but no control how much in each one.
Overall the process observation showed that there was multiple handling for same parts during the process this could lead to quality issues like scratches on the package and mainly it is non-value added work that reduces the efficiency. Reasoning for using this type of process was the variation between products and difficult line design to support all designs in standard line.

Based on these focus should be put into design of incoming material of packaging parts and how they are delivered to packing line. To make packing process more efficient all material handling should be removed from packing operator. For the sales package design key findings were related to quality controls and excess turnings. If design supports visibility to all packing parts we need less work for quality control, as they can be visually checked. Interior design needs to support better top-down assembly and same orientation insertion of packing parts. Unification of designs creates possibility to of optimization of process flow and cycle time.

During the observation the production process was also analyzed. This information was used to calculate UPPH (Units produced per operator per hour). As a comparison researcher uses earlier knowledge about similar products process figures. Comparison shows that with similar type of product and packages the UPPH of Huawei is 50 % lower than what could be estimated to be achieved. (Appendix 11)

5.1.5. Competitor analyses

For competitor analyses researcher has chosen 3 companies; Apple, Samsung and Nokia. Competitor analyses were done based on generally available information like box opening videos in YouTube, company information shared on web pages, other reviews about companies packages and researcher own experience within one of the company. (Appendix 12)

Reason to choose the mentioned companies was that Apple has been able to achieve iconic status also in design of sales package, therefore being the consumer view of outstanding opening experience. Samsung has been the leader in sales globally, therefore leader in the industry. Nokia has been leader in DFP and supply chain and also some time ago still leader in sales of all mobile phones, from Nokia researcher can learn the best way to optimize the design and process.

Based on each company findings researcher made listing of raised themes and rated each company on those themes. (Appendix 13) Lot of similarities was found between companies. Main difference was Apple having significantly less products and customization/ variation in sales package graphics and also design is very minimum. Each company had strong strategy for package design and that can be seen in designs. Design followed product categorization and had modularity and standardization in sales package design between products. This was especially seen in the Samsung sales packages. Nokia had also the product categorization and also the optimization of packing process in manufacturing. Packages was built so that even variation between customer designs, they were able to be balanced with handtimes in manufacturing. Nokia’s view on packaging
development was throughout the chain from material fabrication and cost, manufacturing and shipping to end customer opening experience. Considering the logistics efficiency was also highlighted by Apple that had created a new smaller package in 2014. (Apple 2014)

Comparing to Huawei biggest gaps are in design continuation. With standardized design manufacturing can improved by shortening the new product learning curve. During mass production operators can change between products without excess training for each product packing process. Even if going further materials could be shared between products, which saves money as supplier can do bigger batches and reduces inventory needs. It has also big effect to hole manufacturing concept as it enables process optimization in longer run and between products.

Detail level learning are in the manufacturability of packages design. Especially Apple has example of easy top-down assembly, which is one requirements for easy assembly operation. The actions to improve would be in high level make design strategy and plan that continues for yearly basis. Another point is designs based on product categories. As low cost products have very different needs and requirements than the high end products, they should be also evaluated and designed in different aspect as top priority. This requires a lot of co-operation in high level management and is not a short time action to create. The immediate actions that can be take are considering the details on design that would support better the manufacturing and its processes.

5.1.6. Guideline content

Based on theory, earlier studies, interviews and observation in Huawei environment researcher build content of guideline. It included 10 parts:

1. Introduction of what packing is
2. Purpose of the document
3. Scope of the document
4. Basic principles of packing explaining the aspects that good package needs to fulfill
5. Packaging types explaining the target of sales package of product and categorization of packages into 3 layers and different standards for packages designs
6. Part design section to explain details of each part to consider in designing phase
7. Design for packing theory
8. KPI’s (key performance indicators) for package development explaining how different measurements can be used to measure the target and success of design
9. Process description for DFP
10. Optimization part to highlight aspects that effect to design cost efficiency.
5.1.7. Charter preparation

After finishing these activities researcher started to prepare for the TMT (Technology management team) review meeting and build charter material. For material preparation researcher used Chinese sub-project manager to assist and also project mentor to evaluate and give inputs for material preparation. This was necessary that content is within Huawei practices.

In charter phase the researcher makes the schedule for Huawei process steps, research activities and result estimations. In Huawei process steps schedule is planned in phases of charter in April, 2016, PDCP in June, TDCP in September and END-CP in January 2017. These steps were also aligned with research methods.

Research activities include continuation of current status analysis by studying current materials, communication with manufacturing engineers, new product package analysis. These are needed to deepen the information received by interviews and observation. After finishing the current status analysis new product sales package design is developed based on DFP guideline and implementation of improvement to new product package.

Charter review material included project goal statement (establish guideline and increase UPPH by 20%), scope of project (all Huawei mobile phone products), problem statement (low efficiency), explanation of DFP guideline and example of its content, agreed product to be used as implementation and evaluation, competitor benchmarking results, milestones, project approval targets, resource plan, risk list.

5.1.8. Conclusions and charter review

In first review (TMG at 18.02.16) comment was that project is ready for TMT review after few additions. It needs more defining in what roles and who would be key resources to project. TMG highlighted that communication plan and organizing is needed between project manager and senior adviser and other important roles. Before the TMT review meeting the roles and responsibilities were clarified between researcher and support members. New weekly meeting was agreed for communication. In second review (TMT at 13.03.16) project charter was approved. Some modifications were made to project schedule. Comment was also to change the name from guideline to specification.

Conclusions:
After the first phase of process the researcher made conclusions about what are major issues regarding the design and manufacturing process. Guideline content should highlight the continuity of sales package design between products, detail level improvement in construction to be more efficient and big effort to be put into material handling and incoming packaging of components. By this manufacturing process can be optimized for more efficiency. There is no cooperation between manufacturing and design team during development phase, which can be seen in the efficiency level in packing process and also in the variation. There was existing manufacturing guideline, but main items in this was
related to equipment restrictions. There was no common practice to use DFM/ DFFA methods for packaging in the product development.

5.2. Requirement analysis and solution design phase

Objective for stage 1&2 is to specify the development requirements, formulate the business and resource plan, ensure risk can be managed and define the objectives and activities based on development project. In these stages the cooperation with other teams was started. DFP guideline content is defined more in detail level. More details about current requirements from manufacturing, current issues / problems in manufacturing /in package design development within product development are studied.

For PDCP review the current issues in manufacturing, sales package design and solution how to solve those issues with guideline needs to be presented. Detail benefits with proposed solution for new product needs to be shown. Schedule is defined in task level and aligned with product development of new product.

After the project charter was approved researcher started to act on closer cooperation with manufacturing engineers to deeper the knowledge about current issues and possible solutions. In project charter review the new product to implement guideline was chosen and researcher started to analyze the design, find possible improvement opportunities and effect to UPPH of that. This phase continues on stages 3-4 and includes stages 5-6 in benchmarking process.

5.2.1. Weekly meeting

Weekly meeting was agreed and arranged with supporting project manager and project supporting TMG leaders. Plan was to go through done activities and discuss any issues that may require more support. This worked well as lot of communication was on Chinese and it was difficult for researcher to follow up. Also the Chinese supporting project manager was supporting on creating more understanding of Huawei company culture and way of working, which researcher was not familiar, and was different from any earlier experience. Understanding of new culture was essential in the whole process, as it can create many miss-leading points if not understood properly.

5.2.2. New product package analyses

For new product hand time analyses researcher used tool from sub-contractor to analyze the handling time of concept. There are many tools/methods to analyze the design. In this case Huawei had already project on going to use tool for analyzing assembly handling times before trials and mass production and it was reasonable to use the same tool. Researcher received PowerPoint presentation of sales package concept pictures and few samples for analysis. After reviewing the design, researcher made some changes to sales package design based on DFA principles and made a new hand time analyses. In comparison the difference between old design and new one 9% improvement for hand time may be possible.
Researcher also made process analyses and used lean principles to optimize the packing process. Based on these the current packing operation UPPH increase 14% and new process even UPPH 50%. (Appendix 14)

5.2.3. Communication

After visit to factory and observation analyze sharing manufacturing engineers are asked to send information about current problems with package design. This will give valuable information about what kind of issues they see we should focus on and get more content to guideline about what kind of issues to avoid in future designs especially in Huawei sales packages. This will give opportunity to generalize the results of observations and test theory. This will also increase the co-operation, as they knowledge is seen as valuable input for project.

In manufacturing engineer’s presentation they communicated issues with design differences between products, sales package design details (like tray for accessories), issue with multiple assembly directions and assembly easiness differences between different designs. These were all driven also by DFFA principles and are used as examples in guideline.

After charter approval researcher planned a new visit to Shenzhen to have formal kick off meeting with local engineers and have more communication with them, as now they had idea about what is DFP, what kind of issues guideline is trying to fix and they can better share they experiences. Visit included a new observation and communication in manufacturing line more as active participating observation, as analyses from earlier observation were now as proposals for improvement. Review of new product design change proposal was arranged with product sales package ID designer. Meeting with manufacturing engineer’s was arranged before ID meeting to make sure they had change to comment and make proposal beside researcher ideas.

5.2.4. Current documentation

By current guidelines, current process description and sales package testing processes we get understanding of how Huawei is considering the manufacturability in current status. This will help to build guideline based on current knowledge level. This way we can create guideline that is easily understandable and useful and not too wide range of issues included. Local supporting project manager shared the material in Chinese, which was then translated by translation tool to English. In existing guideline all the references were for technology restrictions like minimum and maximum sizes of packages that wrapping machine can handle. This is mainly giving designers input about size of packages and not details helping for assembly easiness.
5.2.5. Task list creation

To make clearer activities and timelines researcher created task list to show the activities and milestones for each item for all participants. This was to ease the communication and keep on track what is happening in different areas of research.

5.2.6. Change request meeting with ID designer

Meeting with ID design was arranged to discuss details about design change proposals (28.4.2016). Before meeting researcher had made presentation about changes to design and improvement benefits. Each item was gone through with ID designer. Most of them was rejected by designer as they would not create the same quality in the outlook of package or designer had some doubt about solution working in details. In the meeting it was sometimes difficult to understand if some proposals were not accepted based on real facts. Later on it was found out, that actually the change proposals made were too late and would have created already overloaded designer extra work that she did not have time to do. This shows how important it is to have full commitment from all the parties design is affected. In this study the design department had been communicated, but not fully understand or engaged the development process. Another point that effected to co-operation was company culture that is somewhat isolated between different organizations. They all have they own targets and are measured only against those. That’s why they focus on what is set for they individual target instead of having larger view and looking what is actually beneficial for the company.

5.2.7. OOBE review

Plan was to participate in the final decision making review OOBE (opening of box experience). Even lot of communication by local Chinese project manager and researcher by emailing, chatting and so on, and the review meeting was arranged without manufacturing participation or input in decision making. After OOBE review no big changes to design can be made anymore. This meant that DFP guideline testing with this new product was not possible to verify, because the changes proposed and possible benefits were not included into OOBE meeting. This lead to situation that to verify the guideline, new plan needed to create. After discussions with supporting TMG members, it was decided that proposed changes for this new product were made as samples and effects would be tested by trial instead of real production model.

5.2.8. New design trial

Based on earlier analysis new sales package design that would best support the manufacturing efficiency improvement was made. Design used top load assembly direction and all the excess small boxes was removed from the design. Based on created sales package design, a set of 10 pc’s samples was fabricated by supplier. Those samples were then used in current manufacturing line set-up to measure the effect to handtime and UPPH calculations (27.6.2016).
trial the design changes improved the UPPH by 19%. (Appendix 15) In trial a new improvement opportunity was found in design. SIM slot opening PIN placement was difficult and to improve new solution needs to be created.

5.2.9. Guideline

During this phase researcher analyzed the level of Huawei current status and re-defined the content in guideline based on learnings from research activities. Plan for guideline content creation and reviews are set into plan.

Lot of detail level information about different structures of package design that were not used in Huawei was removed, as they might be just confusing and too much information to handle. Instead more details are added about key design solutions identified in manufacturing engineer’s communication, current manufacturing equipment specifications and requirements and trial with new sales package design.

5.2.10. Conclusions and PDCP review

First review (TMG in 7.7.2016) made recommendations to highlight first the competitor’s analysis before the Huawei new solution. New bigger verification of new sales package design was also requested in next phase and communication with ID about these new design trials. Researcher notified in TMG that for optimizing sales packages in optimum way, it cannot be done by focusing one product at time, bigger changes would be needed how sales package design is road mapped and unified and standardized in longer term. This would need communication in higher level of ID design leaders, as it cannot be done through product sales package designer. Based in TMG review meeting researcher modified the plan for trial with bigger amount and modified the review presentation.

In second review (TMT 13.7.2016) implementation for new product was agreed and action plan based on recommendation in TMG was checked. TMT approved the new plan. This phase showed that DFP guideline has effect to design efficiency in small scale, but major issues are with how DFP is implemented and how much commitment we get from other organizations besides manufacturing.

Complexity of sales package design is effecting to long handtime, low UPPH and visual quality control also difficult. These items will be added in the guideline. Proposal is to use more top-down assembly directions and reduce package inside package designs. Variation in packages is effecting to un-balanced manufacturing line and use of pre-packing process to have balance in the final assembly and packing line combination. Variation between products makes also automation implementation inefficient or complex. Incoming material packages is seen one
major item to be developed. It creates a lot of handling time for operator, in this case even 20% of total packing time is used for material handling and preparation for packing. Proposal is to remove un-necessary protection bags for each part and use more tray design’s instead of transportation bags. Second point was to change the handling process of materials, so that operator does not need to handle any material, but logistic operator would handle all the needed preparations. This will give operator fluent flow in packing process and also the time used by operator is only beneficial time. Design work is happening in very short cycle during the product development. This leads to situation that not much time is for trialing and improving the design efficiency. This is also seen in the workload of ID designer and they possibility to do changes and trials of proposals during development. Design feedback in current process is only given after OOBE in verification trials of product, which is too late to make any modifications to design. Timing early enough should be highlighted in the DFP process and in guideline. In this point guideline content is including the introduction to packaging and packaging design, sales package part design examples and proposals, basic principles and theory for design for packing, product and design categorization and continuity/standardization and short process description.

5.3. Development and verification phase

Objective for stage 3 is to complete the development activities and prepare for release of standard. In this phase the guideline is maturing and new sales package design based on guideline is verified. The results are then verifying the benefits of DFP guideline. Benchmarking process stage 7 is fulfilled in this step.

5.3.1. New bigger trial plan and execution

As small trial did not convince the TMG members, a new bigger trial was planned. For new design researcher and team decided to fix the issues raised in earlier trial sales package design. This new design improvements were added to guideline part specific details. Trial amount was agreed to be 150 pc, as that takes also into account the possible learning curve of operator for new process to make study reliable. Learning curve means that after certain repetition the time used for assembly is stabilizing to optimum level. (Krajewski 2016)

Trial was done in normal production environment. One operator was trained for new packing process and sales package design. Researcher was in place during trial and had some inputs for how operator was doing the activities, so that it would be as designed to be the most optimum working process. Operator continued packing until 140 units and after that time was measured for 10 pc.

Same operator was also doing packing for the “old” or current design of sales package, so that we get reliable comparison data. As different operator normal speed and skills may effect otherwise to results. Operator was already familiar and had been doing this product packing so no learning time was needed before measurement. New trial verified that with changes to design we could have been able to increase the UPPH 22, 9 %. (Appendix 16)
5.3.2. Second new product for implementation

As first agreed product implementation was not successful TMG members make request that even guideline verification was done with good results in trial, there needs to be real product before approval of TDCP phase. New product sales package design was analyzed in same process as earlier. Improvement proposals and learnings was used from earlier study.

Researcher had same issue in participating to OOBE, even though the team this time put even more focus on communication and highlighting the importance of participation to this review. After some radio silence ID designer shared that they had had the OOBE review and showed the final design. This time the new efficient innerpart proposals were accepted and top down assembly was included. But outside of sales package was totally new. Which is against the wish for continuation and standardization.

New design was analyzed and compared against old design. As design had not been used in manufacturing same UPPH measurement was not available at this point. Researcher used measured handling time as comparison measurement. Handling time of new design based on guideline was 25.52% faster than earlier design. (Appendix 17) It was again proof of guideline itself is improving the efficiency, but still major issues in how to implement in next product and especially how to have co-operation in creating continuity and standardization between products.

5.3.3. Guideline

Guideline content was supplemented based on learnings in sales packing design at this phase. During the weekly meetings researcher got feedback that incoming material related part should be removed from sales package design guideline, as there would be separate document for incoming material packaging guideline. Automation of packing was item that was raised as an issue. Researcher made part of how to design for automation, even though total automation of packing process was not existing.

Guideline was translated into Chinese and set into Huawei review system for open commenting and official review. Based on comments from different organizations some details were modified, but major change into guideline content came from review request that guideline should be more like specification that designers need to follow. This was against how researcher had described the guideline purpose in the beginning. Therefore the content needed a big change. Researcher together with supporting project manager modified content so that all material that could not be specified in such details or were more like recommendations was removed. In the part related section all design proposals were rated as option 1, option2, etc... so that designer had a path to follow when making design decisions. After modifications new version of guideline was put into Huawei document review system for second review and commenting. This version was then approved by persons from different organizations. (Appendix 18)
5.3.4. Conclusions and TDCP review

First review (TMG 22.12.16) was delayed from original schedule as new trial arrangements took un-expected time. This was because of changes made to sales package design, purchasing process un-clarity and delay of materials. Other delay reason was change in guideline scope. Change from communication material into specification to “must” and “suggestion” delayed the review and approval of guideline.

In review meeting researcher presented the delay reasons, project deliveries, meaning the guideline and guideline implementation into product. The change in the design was presented. Project achievements were UPPH increase of 22, 9% in trial of new design and 25% handtime reduction in implementation product and monetary savings. In TMG the material cost of new design was requested. Quotation from supplier with new design showed that it was also lower in material cost. Co-operation with ID is still very difficult in the decision making point. Participating to final decision review to show the effects to manufacturing was almost impossible. With following the guideline the improvement opportunities are within created target of 20% improvement. Researcher also made analysis of packing process and with new design and new process the benefits would be even higher.

In the review the commenting about results was positive. Mr, Wan Jun, the chief supply chain officer, recommended to implement guideline to further products. Mr. Wan Ziyu from Device manufacturing department agreed about guideline proposal to use standardize designs as it helps utilization of current machinery, improves the efficiency and sets solid foundation for packing automation plans.

5.4. Technology migration and maintenance phase

Objective of technology maintenance phase is to use the results/ outcomes of development so far into target users. In this phase also continue verification activities by users. This phase includes the plan for longer term development activities included in stage 8 of benchmarking process. Tasks for maintenance phase is to assist using of guideline, establish outcomes sharing channels. During this phase researcher followed the production of guideline implemented product design manufacturability. Researcher made training plan for one specialist in each R&D center to use the guideline in the future products. During writing this thesis this phase is still waiting to be happened. During this phase researcher will continue with spreading the learnings and teaching the guideline to other team members and support in their implementation activities within new product development projects.

5.4.1. Training plan for new specialist

Three specialist were agreed as resource for DFP development for next products from each R&D center and implementation of guideline. Researcher created a training plan for DFP guideline, DFP process for development and also the feedback and support after the training and during the product development. After
the training specialist continued implementation and researcher supported, when needed.
6 CONCLUSIONS

Research results show that DFM/DFFA theories can be applied into sales package design development. Theories based guideline can be created using the methods used in this research and guideline can be implemented to products with benefits to increase the assembly efficiency of packing process. Research targets for increase efficiency improvement 20% was achieved. Research showed that definition and actual content of DFP guideline can vary based on current status and company definitions and it should be considered as living document that is updated from time to time.

Interesting finding during the implementation of DFP guideline based design was the difficulties implementing design changes. This challenge is also highlighted in the theories and solution to overcome this is to create strategy of DFP implementation and management level commitment. In future the company should focus on creating this strategy and commitment between organizations, keep updating the guideline based on current situations and new design improvement ideas and to increase the scope of DFP to include also other major cost elements of packing, like the logistic cost and possible efficiency improvement to this cost. To support the manufacturing better the sales package design department should create portfolio and roadmap that is shared with other teams, so that they can design new standardized packing lines based on Lean principles and reduce the non-value added work.

How well those benefits are then captured depends then implementation of DFM method and resources put into it. In this case first target is to show one of the benefits to team that is currently having the most issues with the packaging designs. The road further ahead is then endless path of developing and going deeper and deeper into details of each aspects of total cost.

This study can also be beneficial to other companies to provide information about package design effects to manufacturing and how to start improving the efficiency and total cost in packaging area and maybe use the money saved into the actual end product itself. The actual benefits are depended on the current status of company and how well DFP principles can be implemented.

6.1. Research success and results effecting factors

Researchers 10 years’ experience in the sales package design optimization based on DFFA/DFM theories and complex sales package design used by company had effect to find solutions to increase the efficiency this much without changing other factors like process. With some more simple design the effect may not been as big only by changing the design, but changing both the design and the process results could be even higher.
6.2. Validity

Research questions were able to be answered through chosen methods. Quantitative measures validity was in good level, as they have taken into account learning curve of operator and same operator was also used to make analysis from comparison design during short time between measurements. The actual analysis of final test were done same way as other mass production analysis in Huawei production, which makes the results as good as the mass production measures.

Question raised is that is UPPH the right measurement for design efficiency evaluation? In this research the process itself did not effect to UPPH as much as there was only 1 operator used, but if there was even 2 operators the results might have been different as then the UPPH may not been as high as the handtime improvement would indicate due to un-stable process where operators workload is not balanced. In these type of process the higher workload is bottle neck and determine the output of line. Researcher proposal is to use handtime as comparison target in this type of study to eliminate the process effects.

This research target was not be generalization, but it can be assumed that similar benefits can be found in companies in similar situation where design has not been evaluated in early design phase by manufacturing efficiency as target. Based on this research there is now one perspective of what DFP guideline is and validity of this definition is depended on the environment, researcher and the team involved.

6.3. Reliability

Reliability of this study is in acceptable level. Study can be repeated base on attachment materials and detail practical part. What lowers the reliability is the researcher and other participating engineers input and knowledge to translate DFFA/DFM principles into packing context and is in this point unique. The actual improvement level is not reliable as start phase design, the knowledge and experience base of research group effect to content of guideline and therefore results of improvement. Guideline content can be very different based on these facts. Overall the results of this study shows one type of way to create DFP guideline and its content and assume to have benefits when implemented to mass production products sales package.

6.4. Reflection

In the beginning of research researcher had experience of using these theories in the packaging context and also implementation and effect of different cost elements to overall cost. Researcher view lead to thinking of too wide scope within the new environment and during the current status analysis the scope needed to narrow down to only focus on the design and its effect to manufacturing cost. If the strategy level pre/study would be conducted the results may have been in wider scope and taken the total cost as reference value of results. It was important point for this study to get results that would be answering to research
questions. In the following research this total cost point of view can be taken into consideration and widen the scope with aspects that researcher has highlighted in the study. Important but sometimes painful point of this process was intermediate reviews with TMG that guided researcher to make changes to plans and actions from the original plan. This could lead to frustration if not understood to be integral part of action study. During empirical part the implementation challenges realized and those were solved in the manner that supported this research target. These challenges could be avoided by having the same strategy work done. Even the challenges this research was able to show the benefits of using DFFA, DFM and Lean principles in the sales package design assembly efficiency.
7 CONSIDERATION AND CONTRIBUTION

7.1. Consideration

Let’s create an example case of what DFM/DFFA can mean for packing and its development. We have vendor that is developing a consumer electronics product and its package assembly cost is 0.1 €/pc. By implementing DFFA principles, so implementing DFP, to its design we get 22% savings in the assembly cost. Based on this we get savings of 0.022 €/package. Vendor sells 10M pc’s during the product lifetime, so it means that company can save 220 000 €. They will further implement the strategy plan of having standardization across categories and having modular design. They have totally 10 different products in the product line each with 10M volume. After this they have achieved savings of 2,2M €. Considerable amount of money to be used in the product itself or to improve the profitability.

By implementing the new strategy they are not only having benefits in the assembly cost, but due to standardization also the package manufacturer is able to improve the efficiency of production by producing in larger quantities having less tooling’s and changeovers. Also by implementing DFP they have been able to reduce over packing and have less material overall. By this they are able to offer better pricing. Let’s assume that they can offer 10% decrease in price and cost per package has been 0,5€. Savings in the material cost is then totally 50M€.

That is still not all the savings they get. By having standard design the actual design work is also reduced. They do not need to design a new construction for each new products and graphical design can use standard layout and just change the product information on the graphics. This is not just the money savings by needing less designers, but it is also faster way, which is essential when trying to compete in such rapidly evolving environment.

Even though they have been able to achieve savings more than 50 M it still not all the savings. As we have not yet analyzed the biggest cost element in packing that is logistics. Normally the logistic cost is about 70% of the total cost. Earlier company has been paying on average 1€/ package for shipping. This figure varies between the transportation method and route. In air transfer they pay by the weight and in road and sea by the volume. Based on DFP the size of package was reduced and due to less materials also the weight. From these benefits they are able to reduce the logistic cost by 5% which has created a savings of 5M€.

So in totally the company would be able to save more than 60 M€, as all the benefits, like quality improvements and so on is difficult to evaluate with money. But after implementation to first product they are not able to continue the development. Why is this? In beginning of starting to implement DFP they have started from engineering level and from one product. They have connected the designer, manufacturing and the DFP champion to create a team to make these changes and after the first product they lose the connection to designers. Designers think that they should have the design freedom and they focus is purely on the visual aspect and material cost. As discussion in engineer level is not going further at some point each party will give up as changes are almost impossible to
It’s just packing

do. What they should have done to collect the savings? Have management level commitment and all beneficial departments involved in the beginning. If this company would have had also the logistic, product cost manager involved they would have more power to influence the decision making.

Story is imaginary, but reflects very well the real situation in the companies. By focusing on one aspect we may lose in other and the one department having the power to make decision is always winning. If the evaluation and decision making would be made in the total cost level where all of the aspects would be considered and based on what is seen most beneficial is winning and others will need to make compromises, we would be making decisions that benefit the whole company. What raises from these thoughts can be referred as chicken or egg dilemma. Can company commit to strategy level for implementation before they have some proof of concept in their environment and can some proof of concept be implemented before upper level commitment?

7.2. Contribution

As packaging is many times seen as transportation tool, this research shows the actual wide range of scope and requirements that good package needs to fulfill. Research can be used as example how to create design for packing guideline and what kind of benefits can be expected when implementing it to real products. It shows the importance of strategy level pre study and management commitment from all the related organizations in order to make good implementation possible.
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It’s just packing


It’s just packing


It’s just packing

YouTube. (2017c). iPhone 6 Unboxing (Gold + Space Gray). Read 23.1.2017 from https://www.youtube.com/watch?v=KmOQmJNRAy8


Global smartphone unit shipments by region 2013-2017

<table>
<thead>
<tr>
<th>Year</th>
<th>Latin America</th>
<th>Central &amp; Eastern Europe</th>
<th>North America</th>
<th>Emerging APAC</th>
<th>Middle East &amp; Africa</th>
<th>Western Europe</th>
<th>China</th>
<th>Developed APAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>68.7</td>
<td>36.14931238</td>
<td>139.1</td>
<td>27.38036964</td>
<td>96.9</td>
<td>36.07214429</td>
<td>115.4</td>
<td>9.415041783</td>
</tr>
<tr>
<td>2014</td>
<td>108.5</td>
<td>68.32165986</td>
<td>71.5</td>
<td>7.76791034</td>
<td>148.6</td>
<td>15.97390114</td>
<td>127.9</td>
<td>6.899895216</td>
</tr>
<tr>
<td>2015</td>
<td>110.4</td>
<td>9.00090911</td>
<td>19.1</td>
<td>3.9269701571</td>
<td>197.8</td>
<td>7.230091236</td>
<td>135.4</td>
<td>-3.249630724</td>
</tr>
<tr>
<td>2016</td>
<td>105.9</td>
<td>8.970727101</td>
<td>19.5</td>
<td>1.308923678</td>
<td>214.5</td>
<td>4.67723986</td>
<td>131</td>
<td>-2.328424748</td>
</tr>
<tr>
<td>2017</td>
<td>115.4</td>
<td>85.2</td>
<td>20.1</td>
<td>238.6</td>
<td>176.8</td>
<td>464.3</td>
<td>-100</td>
<td>70.1</td>
</tr>
</tbody>
</table>
Mobile phone market summary

<table>
<thead>
<tr>
<th>Market</th>
<th>Volume in 2016: 1500 million</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sales are still increasing but not as fast as in 2013-2014: 22%, in 2015-2016 only 4%</td>
</tr>
<tr>
<td></td>
<td>By regions China is leader, but clear saturation is happening in there also</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease in mobile phone pricing</td>
</tr>
<tr>
<td>Increased standard of living and buying behavior of consumers</td>
</tr>
<tr>
<td>Providing unique experiences</td>
</tr>
<tr>
<td>The evolving environment of electronic communication</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low penetration in rural areas</td>
</tr>
<tr>
<td>Security and privacy concerns</td>
</tr>
<tr>
<td>Customer loyalty</td>
</tr>
<tr>
<td>Battery charge cycle</td>
</tr>
<tr>
<td>Increasing labor cost in China</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trends</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing popularity in large display phones</td>
</tr>
<tr>
<td>Trend of Android OS</td>
</tr>
<tr>
<td>Multicore processor</td>
</tr>
<tr>
<td>High resolution touchscreen display</td>
</tr>
<tr>
<td>Better photos</td>
</tr>
<tr>
<td>Clearer-sounding music</td>
</tr>
<tr>
<td>No more buttons</td>
</tr>
<tr>
<td>Virtual reality</td>
</tr>
<tr>
<td>Foldable phones</td>
</tr>
<tr>
<td>Ultra HD</td>
</tr>
<tr>
<td>Usage of internet</td>
</tr>
<tr>
<td>Increased Cloud-based services</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major Players</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung 23.2%</td>
</tr>
<tr>
<td>Apple 14.8%</td>
</tr>
<tr>
<td>Huawei 8.3%</td>
</tr>
<tr>
<td>Oppo 4.6%</td>
</tr>
<tr>
<td>Xiaomi 4.2%</td>
</tr>
<tr>
<td>Others 44.8%</td>
</tr>
</tbody>
</table>

(Swarnakar 2013) (O2 2016) (CTIMES 2016) (Baidya 2016) (Nave 2016)
DFP analyze tool

Analyse tool is to record data for efficiency of sales package design based on facts chosen to be important.

Handtime: Total packing time is divided by the number of parts. This handtime/part is compared to estimated theoretical handling time/part and efficiency number is given for comparison. Theoretical handtime / part is based on analysis done in Nokia packaging study. Efficiency number calculation is based on assumption: If HT/part is <1.8 =1, <2.1=2, <3.9=3 if >3.9=5.

Number of parts, Material Cost, weight of package, Volume (W x D x H), pc's/pallet, Packing time

Error proofing: Assembly wrong part, Assembly wrong part, Assembly part wrong way

Handling: Tangle/Nest/stick together, Flexible/Slippery/Sharp/Fragile, Insertion: Difficult to align/Locate, (how many items identified), Holding down required, Resistance to insertion, Poor visibility/access (top down assembly principle), Secondary operations: Re-orientated work piece, Twist/Bend, Glue/adhesive tape, clean/heat/other additional operations, parts are easy to pick from bulk, test/measure/adjustment needed

DFP Principles: is there possibility to remove some parts? (Number of parts), is there self-locating features, is standardize parts used, can current production equipment be used, risks identified (how many risks identified)

Specialist if analyzing all the above items and by ranking system the calculator is summarizing the DFP figure, the lower the figure is the better the design is based on these facts. This way company can evaluate different designs and overall development of efficiency based on longer term data.
<table>
<thead>
<tr>
<th>Part Error proofing</th>
<th>Handling</th>
<th>DFP Principles</th>
<th>Insertion</th>
<th>Secondary operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight of package</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume (W x D x H)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pallet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packing time</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly wrong part</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly part wrong way</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tangle/Nest/stick together</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexible/Slippery/Sharp/Fragile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficult to align/locate, (how many items identified)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holding down required</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance to insertion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor visibility/ access (top down assembly principle)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Re-orientated work piece</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paste/Bend</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wax/ adhesive tape</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sharp/heat/other additional operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parts are easy to pick from bulk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test/Measure/adjustment needed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there possibility to remove some parts? (Number of parts)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is there self locating features</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Are standardize parts used</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can current production equipment be used</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risks identified (how many risks identified)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packing score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
It’s just packing!
Reasons why to focus on package design

- When looking and thinking of packages from manufacturing perspective, it easily seems very simple and many time it is the last thing to consider in product development and most of time left without attention.

- But if we look at other angle we see the importance:
  - It is the first thing end user sees when buying the product
    - What feeling would you get if you got your expensive product in brown ugly carton box?
  - It protects the product during transportation
    - Or if your product would be already be broken when you receive it?
  - It informs the user about product
    - You know what you have received
  - It reflects the brand and product image
    - Last connection point from brand owner to consumer
What is a good package?

- It serves the consumer
  - Experience, easy opening, helps to get started with product
- Is part of today’s delivery chain
  - Works in logistic, retail environment
- Is sustainable
  - Ecological, re-usable, recyclable, cost efficient
- Protects the product
  - Is durable in transportation and prevents from theft
- Is efficient in production
  - Supported by production technologies and process, easily packed
- Identifies brand image and product authenticity
- Is optimize for it’s purpose

It serves DISTRIBUTION, STORAGE, SELLING & USAGE!

How DFP differs from other DFX

- If we compare DFP to other DFM disciples it is not so driven by complex and small technical details, but it contains some basic elements like “poka yoke”, minimizing part count, using standard components, minimize assembly directions etc...
- In DFP the scope of analyzing is much wider and you need to understand more than just own manufacturing process. To fully capture DFP potential, specialist need to understand also the material manufacturing, branding, variation effects, logistic and balance those, to meet customer requirements.
- Team involved in packaging is much wider than just the designer and DFP specialist and to make proper analysis it should be done in good cooperation between parties, so that everyone understands each others requirements and can make truly E2E analysis based on commonly agreed targets.
Variation / Customisation

- In packaging you can use the 80/20 rule almost everywhere.
- For example in high end products:
  - 80% of variants create 20% of total volume
  - 80% of volume consist of small orders.
- This creates then high cost for varying parts that could be reduced by making last phase customisation in-house. This way we would be buying modular components that can be used for multiple variants, customise those in last phase and create a lower cost part.
- In packing almost biggest cost comes from the material itself, that’s why by focusing on design that can be automated and then lower material cost and using that profit to invest in automation is a good example of DFP work.

Design for Assembly Principles

- Minimize part count
- Design parts with self-locating features
- Design parts with self-fastening features
- Minimize reorientation of parts during assembly
- Design parts for picking, handling, & insertion
- Emphasize ‘Top Down’ assemblies
- Standardize parts...minimum use of fasteners.
- Encourage modular design
- Design for a base part to locate other components
- Design for component symmetry for insertion
DFA Guidelines

- In order of importance:
  - Reduce part count & types
  - Ensure parts cannot be installed incorrectly
  - Strive to eliminate adjustments
  - Ensure parts self-align & self-locate
  - Ensure adequate access & unrestricted vision
  - Ensure parts are easily handled from bulk
  - Minimize reorientation (assemble in Z axis) & secondary operations during assembly
  - Make parts symmetrical or obviously asymmetrical

Cost analysis

Understanding Product Costs

Consideration of True Production costs and the Bill of Material Costs,

Typical Costing

<table>
<thead>
<tr>
<th>Pareto by Part Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Castings $5</td>
<td>5</td>
</tr>
<tr>
<td>2: Forging $1</td>
<td>7</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>n: Fasteners</td>
<td>1</td>
</tr>
</tbody>
</table>

Pareto by Total Cost

<table>
<thead>
<tr>
<th>Pareto by Total Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Castings $555</td>
<td>555</td>
</tr>
<tr>
<td>2: Forging $10</td>
<td>10</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>n: Fasteners</td>
<td>1</td>
</tr>
</tbody>
</table>
Example of package cost break down

- **Cost separation**
  - Operational cost 6-9%
  - Logistic cost 72-57%
  - Material cost 22-34%

<table>
<thead>
<tr>
<th></th>
<th>Material cost</th>
<th>% of total manufacturing cost</th>
<th>% of total outbound logistic</th>
<th>% of total total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old design</td>
<td>10</td>
<td>33%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>New design</td>
<td>7.8</td>
<td>26%</td>
<td>1%</td>
<td>21%</td>
</tr>
<tr>
<td>Difference</td>
<td>-2.2</td>
<td>27%</td>
<td>1%</td>
<td>19%</td>
</tr>
</tbody>
</table>

Old design is in use and manufacturing equipment is already paid. Material cost include all package parts material cost, manufacturing cost includes equipment cost and IT cost, outbound cost based on weight of package and pallet usage. New design is created where material cost is able to cut down 27%, but it needs new equipment in manufacturing and is slower to pack, therefore manufacturing cost is increasing 27%, also the outbound logistic cost is increasing due to less pcs/pallet. Therefore after analysing we reduce the total cost only by 2%
It’s just packing

- **Analysis Tool**
  - Process Flow Chart and Value Stream Mapping
- **Economies of Scale**
  - As production volume increases, manufacturing costs usually decrease.
  - Fixed costs divided among more units
  - Variable costs are lower since the firm can use more efficient processes and equipment

- **Selection of Manufacturing Method**
  - Have we selected the Best Technology or Process to fabricate the parts?
  - Have we selected the best Material needed for function and cost?
Design for Packing work

- Gathering DFM Information
  - Sketches, drawings, product specifications, and design alternatives.
  - A detailed understanding of production and assembly processes
  - Estimates of manufacturing costs, production volumes, and ramp-up timing
- DFM Method
  - Estimate the manufacturing costs.
  - Reduce the costs of components.
  - Reduce the costs of assembly.
  - Reduce the costs of supporting production.
  - Consider the impact of DFM decisions on other factors.

Design for Production
General Principles

1. Use Common Sense
2. Plan and Define
3. Consider Available Facilities
4. Consider Available Tools
5. Consider Available Worker Skills
6. Employ Simplicity
7. Standardize
Design for Production Guidelines

1. Minimize Total Number of Parts
2. Develop a Modular Design
3. Minimize Part Variations
4. Design Parts to be Multifunctional
5. Design Parts for Multiuse
6. Design Parts for Ease of Fabrication
7. Avoid Separate Fasteners
8. Minimize Assembly Direction (Top Down Direction Preferred)
9. Maximize Compliance in Assembly
10. Minimize Handling in Assembly
11. Minimize Complexity of Design
12. Maximize common Jigs and Fixtures
13. Optimize Work Position
14. Ease Access

DFP guideline, the handbook

It includes: process capabilities and specifications, machinery and tooling capabilities in various manufacturing modules, guidelines for helping the designers understand the manufacturing challenges presented as a result of not well thought out design, and the various design examples or shortcuts that would enable the manufacturing of parts and products efficiently and at lower cost, faster time, and best quality approach. The procedures followed include: visiting workshops and interviewing operators and supervisors; gathering data documentation; discussing issues with engineers, managers, and operators; and making recommendations.
Decision criteria

- Cost (Implementation)
- Cost (Recurring)
- Schedule
- Risk (Technical, schedule, cost)
- Performance

Better than baseline: Worse than baseline: Same as baseline

---

HT/line balancing/cycle time

- Increased capacity with 79%
- Increased pc/operator 34% compared to current design

- Increased capacity with 178%
- Increased pc/operator 19%

- Increased capacity with 28%
- Increased pc/operator 28%
Design For Packing in Huawei?

- What is DFP in Huawei?
- What are focus areas now/in the future?
- What metrics we should use?
  - HT
  - UPPH
  - Cycle times
  - Line balancing
  - Logistic efficiency, pc's/pallet,
  - E2E Cost
  - Number of parts
  - Offline/subassembly work amount
  - Number of operators
  - Quality
- Who are in the team that DFP work should be conducted?
- Process for DFP work?
- What analysing tools we should be using?

Set target

1. Takt time(next page), quality etc..
2. Value Stream Map
Takt Calculation Example

- Your process has two main products
  - Product 'A' currently has demand for 350 a month
  - Product 'B' currently has demand for 525 a month
  - Total demand is 875/month
- One shift operation, 5 days/week, 4.2 weeks/month
  - 5 days × 4.2 weeks = 21 available days
  - 21 days × 8 hours = 168 hours
  - Monthly available time is 168 hours × 60 minutes = 10,080 minutes

\[
\text{Takt} = \frac{\text{Available Time}}{\text{Demand}} = \frac{10,080}{875} \approx 12 \text{ minutes / unit}
\]

In order to meet customer demand, the process must complete one unit every 12 minutes!

CSA of packing 1/3

- Current packing process?
- How we measure efficiency in packing process?
- How we measure quality in packing?
- What technologies we have in use? Problems with those?
- What are biggest problems in packing?
- Warehouse (inbound/outbound) and incoming material handling?
- Order handling process?
- Order sizes?
- Production test/ inspections?
- Rework?

- Production process improvements
- DFP guideline
**CSA of packing 2/3**

- Packaging suppliers, co-operation with them? Design, sourcing, product development team?
- Current package design development process
- Package testing during development?
- Package roadmap?
- Special customer requirements?
- Logistics handling and measuring?

**CSA of packing 3/3**

- Security in packages? Security seals, theft protection?
- Variation/customisation in packages? How much, where, to whom...?
- Secondary / tertiary packages design? (master carton/pallets)
- Competitor analysis
- End user experience
- Environmental considerations
Thoughts of DFM

- The Best Design is the Simplest one that works!
  ~ A. Einstein

- Minimize product cost through design and process improvement

- Reduce material, overhead & labor cost

- “ELIMINATE, MINIMIZE, STANDARDIZE -> PRODUCTIONIZE”
Outcomes

- Current process and design improvement proposals
- DFP work principles
- DFP guideline basis
- Package design process and product development process basis
- Incoming packages basis and improvement proposals

The purpose of Design for Packing is to analyse and simplify a package concept or product specific package design based on the specific drivers for manufacturing efficiency.

- Package (mechanical) design drivers and targets are well defined.
  - Functionality
  - Cost
  - Materials
  - Quality
  - Manufacturing
  - Logistics
  - Handtime
  - Part count
  - Material cost
  - Quality
  - Logistic efficiency (pcs/pallet)
• **What we get from building DFP guideline?**
  - Overall cost reduction → lower cost for creating and using packages
  - Better quality
  - Simplified processes

  - Guideline is tool for development of new package
Design and manufacturing

Basically, there are three manufacturing models:
(with a different approach from DFM point of view for each)

- **Adaptive** manufacturing model
  The manufacturing process is adjusted to fit the product

- **Efficient** manufacturing model
  Optimisation of product and manufacturing model to achieve the best overall solution

- **Lowest cost** manufacturing model
  The product has to fit the manufacturing process

<table>
<thead>
<tr>
<th>Strategic Intent</th>
<th>Adaptive</th>
<th>Efficient</th>
<th>Lowest Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Cost</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Flexibility</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Scalability</td>
<td>++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Customisation</td>
<td>++</td>
<td>+++</td>
<td>+</td>
</tr>
</tbody>
</table>

+++ is extremely important
++ is important
+ is relevant
Design roadmap

- Based on what manufacturing model package belongs to we can start building package design roadmap.
- By this we can make detail guideline for each model to support manufacturing

Optimising Part Count

<table>
<thead>
<tr>
<th>Requirement / issue</th>
<th>Drivers / benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce the number of parts to simplify the packing process.</td>
<td>Power process savings in packaging</td>
</tr>
<tr>
<td>- Eliminate unnecessary parts</td>
<td>Shorter packing time</td>
</tr>
<tr>
<td>- Integrate parts that can be made of same material</td>
<td>Simplified material placement in working environment, better ergonomics</td>
</tr>
<tr>
<td>- Combine parts coming from one supplier in the supply chain</td>
<td>Less parts to be designed or considered in the design</td>
</tr>
<tr>
<td></td>
<td>Less assembly equipment, smaller packing lines</td>
</tr>
<tr>
<td></td>
<td>Fewer suppliers</td>
</tr>
<tr>
<td></td>
<td>Less material order to be managed, replenished and stored</td>
</tr>
<tr>
<td></td>
<td>Less logistics and buffering</td>
</tr>
<tr>
<td></td>
<td>Less material obsolescence</td>
</tr>
</tbody>
</table>
## Easy material handling

<table>
<thead>
<tr>
<th>Requirement / issue</th>
<th>Drivers / benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packing Operations is basically a pick and place process.</td>
<td>Easy packing of components (enhancements)</td>
</tr>
<tr>
<td>Packing process efficiency is heavily dependent on incoming material packaging and part configuration.</td>
<td>Easy assembly of components</td>
</tr>
<tr>
<td>Ensure that component incoming material packing (IMP) format and component configuration in package are aligned with the relative components location in final sales package design.</td>
<td>Minimized component re-configuration during packing operations</td>
</tr>
<tr>
<td></td>
<td>Minimized additional material handling during packing operations</td>
</tr>
<tr>
<td></td>
<td>(removal of waste, carton opening, ...)</td>
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## Enhancements and Package Components

<table>
<thead>
<tr>
<th>Requirement / issue</th>
<th>Drivers / benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment of enhancement. Incoming format with package design or vice versa.</td>
<td>Packing hand time reduction</td>
</tr>
<tr>
<td>Incoming Material/Packaging configuration of enhancements is specific and known by IMP</td>
<td>Elimination of part m configuration</td>
</tr>
<tr>
<td>Specifying product specific enhancement IMP</td>
<td>• Change of shape</td>
</tr>
<tr>
<td>• Component specific operations</td>
<td>• Correcting shape (odd shaped parts)</td>
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<td>• Requirement implementation to suppliers process or sales package design</td>
<td>• Removal of bags, etc.</td>
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<tr>
<td></td>
<td>• Elimination of re-grasping due to picking access or orientation in sales package</td>
</tr>
<tr>
<td></td>
<td>• Component cosmetic quality</td>
</tr>
<tr>
<td></td>
<td>• Specified protective measures for operations and components</td>
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Interviews
It's just packing
It’s just packing
It’s just packing
Interview analysis

<table>
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<tr>
<th>Themes</th>
<th>ID</th>
<th>Customization</th>
<th>Sourcing</th>
<th>Variation</th>
<th>Product Range</th>
<th>Standardization</th>
<th>Modularity</th>
<th>Environmental Friendliness</th>
<th>Design Strategy</th>
<th>Categorization of Design</th>
<th>Assembly Easiness</th>
<th>Co-operation</th>
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<td>Yes</td>
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<td>Not in use</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Major</td>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Not in use</td>
<td>Not in use</td>
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<td>Yes</td>
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<tr>
<td>Major</td>
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<td>Not in use</td>
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<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Major</td>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Not in use</td>
<td>Not in use</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
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</table>
## Appendix 7.

### List of items to be checked during observation

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<thead>
<tr>
<th>Item/suppliers:</th>
<th>Check</th>
<th>Feedback</th>
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<tr>
<td>part count</td>
<td>x</td>
<td>varies between products</td>
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<tr>
<td>self-locating features</td>
<td>x</td>
<td>Manhattan has small box marked of which item to be placed, product label has placement marks</td>
</tr>
<tr>
<td>reorientation during assembly</td>
<td>x</td>
<td>needed many times</td>
</tr>
<tr>
<td>picking packing parts from shelf</td>
<td>x</td>
<td>optimized, but operator need to prepare material for packing</td>
</tr>
<tr>
<td>part handling</td>
<td>x</td>
<td>ok</td>
</tr>
<tr>
<td>part insertion</td>
<td>x</td>
<td>not optimized</td>
</tr>
<tr>
<td>top-down assembly</td>
<td>x</td>
<td>not optimized</td>
</tr>
<tr>
<td>base part design for other components</td>
<td>x</td>
<td>ok</td>
</tr>
<tr>
<td>component symmetry for insertion</td>
<td>x</td>
<td>some have</td>
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<tr>
<td>phone protection method</td>
<td>x</td>
<td>protection foil used</td>
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<tr>
<td>security</td>
<td>x</td>
<td>sealing with plastic wrapping</td>
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<tr>
<td>part count</td>
<td>x</td>
<td>varies between products</td>
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<tr>
<td>self-locating features</td>
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</tr>
<tr>
<td>security</td>
<td>x</td>
<td>sealing with plastic wrapping</td>
</tr>
</tbody>
</table>
Lean principles based findings

- Over production is not big issue as all the sub-assembly packing is done based on production orders
- Waiting is sometimes issues, when material is ending and there is no feedback to material operator automatically, but operator needs to call for material
- Transportation is heavily an issue as there is material feeding in sub-assembly packing and also then un-finished goods are transported to storage and then finally to main line for final packing and after that to warehouse.
- In Process there is lot of waste for operator in material handling. Calculations show that 20% of operator time is used for material preparation. In total process there is issue with sub-optimizing the packing process to sub-process and main line. This is due to every product have different design and that leads to different hand time and therefore the process to be in main line would create un-balanced line.
- Inventory is also an issue, there is material inventory in warehouse, in sub-packing area, in packing cell, un-finished goods storage, material in main line and finally material in outgoing warehouse. This creates waste in floor space, management of goods.
- Excess motion, in packing itself the process is designed in small space with optimal distances for operator, but material handling and preparation creates lot of turning and lifting actions, that reduces the efficiency. In design of package has also many details that makes packing less efficient as there is turnings and positioning that could be avoided.
- Scrap and rework, lot of handlings can create scratches to outer box, otherwise the quality control was done by reading the 2D barcode to make sure right items are put inside the package, based on customer order. Scale is also used to verify the right content based on weight. Parts are easily identified with these codes.
Appendix 9.

Assembly task observations
It’s just packing
Appendix 10.

Process steps in pre-packing
It’s just packing
Appendix 11.

Process data comparison of Nokia and Huawei
Competitor analyses

**Samsung:**
Samsung was founded in 1938 Byung-Chull Lee in Korea. In the beginning it was a small export business and has now grown into one of world’s leading electronics companies. Samsung has started in smartphone business in 2001 with Samsung I300. But it took some years until they break out with Galaxy S II in 2009. This success has led to Samsung becoming the leader in mobile phone sales and having 20-30% of global market share until last year. Samsung has product in different categories. Last year they have had 3 main categories (S, A and J) in smartphones. The packaging between different categories varies, but several product inside the category uses the same design for several generations. (Samsung 2017a) (Segan 2017) (Statista 2017d) (Samsung 2017b)

![Samsung Galaxy S III](Maisto 2012)

Even though Samsung uses same design they are having lot of variation in graphics between regions or operator variants.

![Samsung Galaxy SII](Flickr 2011)
Samsung Galaxy J Max (Saurabh 2016)

Samsung Galaxy J (Samsung Galaxy J 2017)

Samsung (2014b) has made a strong statement in 2014 that packaging development will focus on environmental friendliness. This has meant that they are focusing not only on the material selection, but also on the energy use and recycling of unused resources. This is especially for Galaxy series. In 2015 Samsung launched products with new packaging they called smart. Packaging has been part of a new strategy, where they are designing with a new aspect of end to end view. Design now reflects a minimalist approach in packaging. (Corbin 2015)

Samsung package analysis

Samsung Galaxy A3:
Galaxy A3 uses rigid 2 part package construction. Rigid box means that package domes to phone manufacturing in 3D format. This makes logistics of incoming material un–efficient. Cost of rigid box is also high compared to foldable constructions. Benefit of rigid box is the carton material printability. By this we can print on fine materials that makes printing quality higher, than in normal corrugated carton. Another aspect is the quality of outlook of package. Corners are sharper and box construction is fixed, as in foldable it can be more flexible and make package look not so nice finished. Variation is made with stickers including color and country information. Which means there is no variation in printing process, reduces the cost of package. Sealing of package for theft protection is done with 2 IMEI (International Mobile Equipment Identity) label, which means that they have been able to reduce the separate sealing labels, which effects to handtime and material cost reduction. Labels are also pre-printed, which means that they need less time and less ink cost in production and can benefit of using more suitable printing method as mass production of stabile content and print only the varying information in-house. (YouTube 2017a)

Sealing is done with IMEI label multipurpose use for required item (YouTube 2017a)

Sealing is done with IMEI label, multipurpose use for required item (YouTube 2017a)

In the innerpart design Samsung is not using separate phone insert but using the construction of innerpart as phone placement. This way they can reduce the number of parts. Box inside box for innerpart. Space is minimized. (YouTube 2017a)

Galaxy J7:

Galaxy J7 is using so called end load construction, without phone insert. They are using over packing as they have box inside box construction with opening to left, with cavity for parts (charger, cable, headset), paper material on top. (YouTube 2017f)
Endload construction means that package is foldable in packing process. It can be glued or having manual locking. This is not visible in video. Material cost is less than in rigid construction due to less material required and is efficient in incoming logistics, as it comes to factory as flat and not in 3D format as rigid box. Box has mostly top-down assembly, which is efficient in inserting parts and in quality control. Cavities are different sizes for all parts which ensures that parts cannot be installed incorrectly and assembly of them is having self-aligning and locating feature. Some sliding is needed in assembly due to pins of charger need to slide inside cavity and also cable has small top cover, which makes assembly in sliding mode. This is creating more assembly time as it increases the adjustments needed.
Sealing of box is done using the information label, same way as in A3 model. This means they have standardization between products, also the product information label is pre-printed. In this video you can also see that they have guiding feature for placement of label, which is self-aligning feature.

Galaxy SIII:

Galaxy SIII is rigid box with top and bottom part with additional sleeve on top. Samsung is using the same basic design, but added the sleeve. The reason may be the marketing of this product and by adding the sleeve they do not need to variate the more expensive part. (YouTube 2017g)

In this design they are using separate sealing sticker, which differs from other models. Phone is also having separate insert, which increases the part amount. Box inside of box solution is used as insert for other accessories, with opening flap. This increases the handling time in manufacturing. Construction is from one foldable piece, which is good solution from part count point of view. (YouTube 2017g)
In space consumption view, the part fittings are tight, which may on the other hand increase the handling time as inserted parts needs to align accurately but it also gives lot of benefits in logistics as there is no waste space. (YouTube 2017g)

Conclusion:
In every category the innerpart construction is same, even though the outer box varies. This is efficient and easily packed in production as packing time for this part is always the same and takes same amount of time and standardize process can be used for several models. Interesting is that they are using the carton material for phone innerpart or no separate innerpart at all, which may be a quality issue if not tested in transportation test and have enough protection for phone not moving in the package during transportation. Commonly for phone insert molded pulp is used. This makes recycling easy, material and supplier can be the same. If using pulp innerpart, it might require a different supplier, when sub-assembly in carton package supplier is needed. This may lead to delay in delivery is sub-supplier has some issues or delivery problems.

Samsung has considered the optimization in tight fitting of packing items to minimize space that reduces the transportation and material cost. Using pre-printed sticker to reduce printing time and cost on-line and using information sticker as sealing stickers to optimize the space in package that reduces the cost of labels and handling time. They have markings for placement of sticker to ease the assembly and make quality of label assembly.

They have combined/integrated parts when possible/feasible. Like no separate innerpart for phone or one foldable innerpart for all other packing parts. This means they have standardization and modularity between products.

Apple

Apple is a multinational corporation that creates consumer electronics, personal computers, servers, and computer software, and is a digital distributor of media content. It was founded by Steve Jobs and Steve Wozniak in 1976 as Apple computer. In 2001 they introduced iPod, The music player, and has been known for its recognizable products and simple design. Apple history with mobile phones has started from co-operation with Motorola, when they integrated iTunes to be available for ROKR E1. Steve Jobs, the inventor of Apple was not satisfied and they started to develop own product. First iPhone was released on June, 2007. Phone had only touch screen and no keyboard and after this it became to standard for smart phones. Apple has been leader in the industry in design, and one of the biggest vendors by 15-20% global market share. Apple product category differentiates from other vendors, so that they only have one product category and release updates to this phone on yearly basis. (Wikipedia 2017b)
Timeline of release years of iPhone models (Wikipedia 2017c)

They have the basic design, which they have not varied in graphical element.

Until year 2013, when they introduced also colors to phone with iPhone 5C and also changed the packaging concept for this product to hard plastic box. (Dickson 2013)

Figure 13 iPhones 5C package (Dickson 2013)

Apple is known for designing the products to finest details. This is also how they design they packages. They have used many hours and materials just to test the opening feeling of package. Apple highlight packages in the environmental report. They have considered materials to be recyclable and use more recycled materials. Apple has also put focus on the shipping efficiency, as result 50% more
capacity in airplane than the first generation iPhone. This is due to optimizing the size for pallet and minimizing the package size. It is not only environmental benefit, but also it reduces the cost of shipping and materials. Which are the 2 main cost elements in packaging. (Heisler 2012) (Apple 2014)

Apple package analysis

iPhone 4, unboxing video analyze:

Package is wrapped in shrink plastic, function can be protection in transportation and also theft protection in retail or logistics. Package construction is rigid box with top and bottom. Phone has separate insert from molded pulp and separate folder for manuals, which has multifunctional purpose, as it helps to lift the phone insert from package.

iPhone 4 multifunctional phone insert and manual folder (YouTube 2017b)

Own cavity with different size for each accessory, which is supporting self-locating and ensuring parts will be placed in right place. It also supports top-down assembly that is efficient in manufacturing and quality control view. Not optimized space utilization, as there is some free space in the cavities, this size reduction may not be possible due to phone size is bigger than the space needed for accessories and phone is specifying the outer size of package.

iPhone 4 accessory cavities (YouTube 2017b)

Variation of box text to country variants by languages is done by sticker. This makes printing cost lower as there is no variation in the carton printing process. Sticker variation is lot easier and cheaper solution. (YouTube 2017b)
It’s just packing

iPhone 6:

Product is using same package construction as in iPhone 4. Headset uses special case inside package. This might be also the selling package for headsets sold as accessory separately. Then this is standardization and no not need to separate the material that is for accessory selling and for phone package.

iPhone 6 interior design (YouTube 2017c)

Innerpart material change to pulp from carton to create the round design for cavities. In iPhone 6 they also started variation in graphics based on product color. This was also the first time they had more than black & white in the selection, except iPhone 5S).

Graphic variation in iPhone 6 (DHgate 2017)

iPhone 7:

As other models also the iPhone 7 has plastic wrapping as protection. For this model they have change the way of opening this plastic wrap so that it has peel off opening slit. It makes the opening experience better for consumer, but for manufacturing it means new technology implementation. In the un-boxing video this new feature is still left n-noticed and the person in the video is still using knife. So this means that even it has been targeted to improve the opening it was not designed so that people would actually notice this feature. (YouTube 2017d)
The interior layout design has changed so that phone is not on top, but first one is the user manuals folder. Phone has no separate insert, as not in earlier models. This reduces material cost and assembly time. Layout design of accessories has also changed so that charging cable is placed under the headset and headset adapter placement is integrated to headset insert. This reduces the needed space and makes package more efficient in logistics and also might lead to using less material, which makes package cheaper. (Youtube 2017d)
iPhone 7 interior design, cable under headset (YouTube 2017d)

iPhone 7 headset adapter integrated to headset insert (YouTube 2017d)

 Innerpart material seems to be changed to plastic. Which can be considered environmentally not so positive thing, reasons for this can be the design restrictions of carton material, but also the carton material price increase in the recent years. (Lin 2016)

Conclusion:
Apple has put effort for consistency and design details, all from materials to consumer opening the package. Apple has been benchmark for other company’s packages for years. Apple has put also focus on environmental responsibility in the marketing aspect, but how much is considered actually in materials etc. is question marks, as they have started to use plastic in recent models. Apple package design has also been developing trough the evolution of phones and markets, but having sill consistency by each model following the same design principles. Packages are mostly easily packed (top down assembly) and consistency helps in production planning and process design or automation implementation. All phones has had very little customization or variation in graphics, which also is benefit in manufacturing as there is less stock and material handling. (Wroblewski 2012)

Nokia

Nokia has a long history from 1865 starting in wood pulp mill industry and through cables and networks, they ended up of producing mobile phones. The Mobira Talkman, launched in 1984, was one of the world's first transportable
phones and through development from NMT to GSM network Nokia launched the Nokia 3310 in 2000. It has become one of the most popular devices of all time. Nokia 7650, released in 2002, was considered first Nokia smartphone and after that they have released more than hundred different models. Nokia’s wide range of products and categories in the early 2010 lead also to huge variation in the sales package design. This created a complexity to manufacturing, but also the cost of sales packages. (Wikipedia 2017d) (Wikipedia 2017e)

Within few years, as selling volumes decreased this was put focus on. Nokia aligned the product roadmap and same time also the sales package design roadmap, by cutting the variation between products, both in design and graphical elements. Leading into last year to only one graphical outlook (still having variation in the language of sales package) and 3-5 different sales package designs, with option for modularity to change the size of package based on product size and sales package content. This means that new product design is always optimized as they have been going through intensive concept design phase without limitation to product development schedules.

As researcher has been part of DFP team in Nokia for last 10 years, she knows the manufacturability of those and did not do analyses as for the other vendor’s package. Based on this researcher highlights the main points in new design development. Design decision is done by analyzing the end to end cost. In this cost they have elements from material cost, manufacturing cost and logistic cost. The manufacturing is guiding the design based on different product categories, where in lowest cost products package design the manufacturability must be considered in the design and not much freedom is given to design to reduce the efficiency. In the middle range product the freedom for design is more and in high end category design must be manufacturable, but it’s not the key driver and based on customer experience manufacturing can accept less efficiency in assembly. (Grontpunkt 2017)

Conclusions:

Nokia put lot of focus to optimize the full end to end sales package effect. This was done by standardization, size optimization, material optimization, logistic optimization and variation decrease and manufacturing optimization. All of the actions has led to optimized solution in all aspects. Based on category the cost and materials vary only for the outlook purposes.
Competitor analyses by themes

<table>
<thead>
<tr>
<th></th>
<th>Apple</th>
<th>Samsung</th>
<th>Nokia</th>
<th>Huawei</th>
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It’s just packing

Appendix 14.

Sales package design from ID
It’s just packing
Appendix 15.

1st trial handtime analysis comparison
It’s just packing
It’s just packing

Appendix 16.

2nd trial handtime analysis comparison,
Appendix 17.

New design change and handtime analysis
Design For Packing Guideline.

Appendix 18.
It's just packing
It’s just packing
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