Design for Assembly
Retractable Pen

Abstract

An investigation into the assembly of a retractable ball point pen. The outcome of the project is a fully re-designed pen with minimal parts and a reduced assembly time.

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Table of Contents

1 Introduction 1
1.1 Aims 1
1.2 Assumptions 1
2 Current Design 2
2.1 Current components 2
2.2 Assembly sequence with operations 3
2.3 Manual Assembly of current design (Boothroyd) 3
2.4 Lucas DFA analysis 6
2.5 Comparison of Results 7
3 Redesign 8
3.1 Design 8
3.2 New assembly plan 10
3.3 Re-evaluation of new assembly plan 10
4 Issues with automation 11
5 Conclusion 11
6 Appendix 12

1 Introduction

In the UK the stationary market is estimated to be worth around £2.56 billion (1). With companies such as Bic selling on average 57 pens every second (2). To ensure maximum profits manufacturers are therefore challenged to design a pen that can be assembled in the most efficient way in order to remain competitive in this market. The reduction of costs even if they are minimal could give a company the leading edge in the market.

For this investigation a Schneider K20 retractable ball point pen will be analysed and re-designed using the conventional Design for Assembly (DFA) methods Boothroyd and Lucas.

1.1 Aims

- Reduce the assembly time of the retractable pen.
- Design parts for simplified assembly.
- Reduce the number of components required.
- Decrease estimated manufacturing costs as much as possible.
- Increase the efficiency of assembly.
- To propose a new and more efficient design than the one being analysed.

1.2 Objectives

- Assembly times and costs will be estimated using Boothroyd & Lucas analysis.
- Data will be obtained by software and worksheet Boothroyd analysis.
- A new pen will be designed using the results from the analysis.
- Concept pen designs will be illustrated with sketches and 3D modelling.

1.3 Assumptions

During the analysis and re-design the following assumptions will be made:

- The pen will be assessed for its manual assembled based on low volume production.
- The pen will retain its original function after the analysis (Retractable).
- The aesthetics of the pen will not be taken as priority (e.g. extra metal components for quality aesthetics).
- Components such as the refill will assume to be a standardised component across a range of pens therefore changes will not be made to this component.

2 Current Design

Initially the pens design was analysed for its current components, materials and assembly sequence.

2.1 Current components

The pen can be broken down into **9** components as shown in Table 1 and Figure 1:

Part No.	Part	Material	Dimensions (mm)	Rotational symmetry $\alpha + \beta$ (degrees)
1	Lower Body	Plastic	63.10 x 8.90	360
2	Ring	Metal	1.00 x 8.90	180
3	Spring	Metal	22.00 x 4.40	180
4	Refill	Plastic/Metal	3.10 x 107.00	360
5	Plastic Slider	Plastic	23.50 x 6.90	360
6	Plastic Push Button	Plastic	25.05 x 6.15	360
7	Silver End Cap	Metal	13.05 x 4.80	360
8	Upper Body	Plastic	74.00 x 8.90	360
9	Clip	Metal	44.70 x 4.20 x 3.90	720

Table 1 The components of the assembly with materials and dimensions.

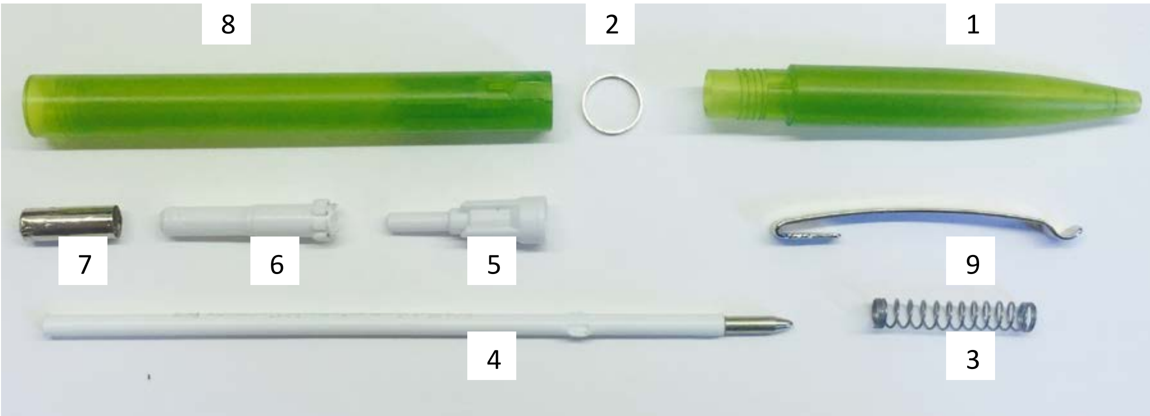

Figure 1 The 9 components that make up the pen assembly.

2.2 Assembly sequence with operations

The assembly of the pen was broken down into a main assembly, Upper body assembly and a sub assembly. The assembly process is described below:

Main Assembly:

- Place the Lower Body into the fixture so that the pointed end is at the bottom.
- Place the Ring on top of the lower body.
- Place the spring inside the lower body.
- Place the Refill into the lower body and inside the spring.

Upper Body Assembly:

- Place the Upper Body into the fixture so that the threaded sided is facing upwards.

  Push Button Sub Assembly

  - Place the plastic Push Button into the fixture
  - Place the Silver End Cap onto the Plastic Push Button.
  - Press fit.

- Insert the Plastic Slider into the Push Button Sub Assembly.
- Press the Push Button Sub Assembly into the upper body. (using tool or compressed air)
- Re-orientated the Upper body assembly so that the threaded side is facing downwards.
- Screw the Upper Body Assembly onto the Lower Body (which is still in fixture).
- Align the clip onto the assembly.
- Press Fit.

In an experiment the pen was assembled using one hand, this took roughly **50** seconds and this will be used for further comparison later.

2.3 Manual Assembly of current design (Boothroyd)

The Pen assembly was analysed using the Boothroyd method via software. This gave an estimation of **51.88** seconds assembly time, an assembly cost estimation of **$0.68 USD**, a theoretical minimum part criteria of **3** and a design efficiency of **19.87%**. The analysis is shown below in Table 2.

Name	Part No.	Minimum Items	Process Time (s)	Process cost ($)
Lower Body	1	1	3.22	0.04
Ring	2	0	4.24	0.06
Spring	3	1	4.01	0.05
Refill	4	1	3.22	0.04
Upper Body Assem			3.22	0.04
Upper Body	8	0	3.22	0.04
Push Button Assem			3.54	0.05
Plastic Push Button	6	0	3.22	0.04
Silver End Cap	7	0	4.17	0.05
Plastic Slider	5	0	3.22	0.04
(Snap Fitting)			2.26	0.03
(Reorientation)			3.54	0.05
(Thread Tightening)			6.50	0.08
Clip	9	0	4.30	0.06
Totals	**9**	**3**	**51.88**	**0.68**

Table 2 The Boothroyd software analysis.

A summation of the analysis is shown in Table 3; this highlights the assembly times of the parts which could be eliminated from the assembly.

Number	Assembly labour time
Parts meet minimum part criteria	10.45
Parts are candidates for elimination	22.37
Insertion of analysed sub-assemblies	6.76
Separate assembly operations	12.30
Total assembly labour time	**51.88**

Table 3 The assembly times of the pen.

The Boothroyd method has identified 6 parts of the pen for elimination as shown in Table 4; these parts exist as a separate part for no fundamental reasons.

Parts for elimination	Process Time
Clip	4.30
Ring	4.24
Plastic Slider	3.22
Silver Coloured End Cap	4.17
Upper Body	3.22
Plastic Push Button	3.22
Total Process Time	**22.37**

Table 4 The process times of the parts for elimination.

Excess process times were also estimated for elimination as shown in Table 5.

Process for elimination	Process Time
Thread Tightening	6.50
Reorientation of assembly	3.54
Snap/Push fitting	2.26
Total Process Time	**12.30**

Table 5 Recommended processes for elimination.

Handling difficulties during the assembly were also identified as shown in Table 6, it should be noted that the Ring has been identified as a part for elimination and for handling difficulties.

Handling Difficulties	Process Time
Spring (Nest & Tangle)	1.08
Ring (Slippery)	0.75
Total Process Time	**1.83**

Table 6 The handling difficulties of the assembly.

If all of these suggestions from the software were addressed in the re-design it is estimated that the manual assembly time could reduce from **51.88** to **15.38** seconds.

(Note: Boothroyd software analysis is available in appendix 7.1 for further reading)

A worksheet analysis using the Boothroyd method was used for the pen assembly shown below in Table 6. The assembly time was estimated at **55.78** seconds with a design efficiency of **22%** a theoretical number of minimum parts of **4** and an estimated cost of **$0.195 USD**.

Part ID No.	Number of times the operation is carried out consecutively	Two-digit manual handling code	Manual handling time per part	Two-digit manual insertion code	Manual insertion time per part	Operation time (seconds)	Operation costs (cents)	Figures for estimation of theoretical minimum parts	Pen assembly
1	1	10	1.50	00	1.50	3.00	1.20	1	**Lower Body**
2	1	03	1.69	00	1.50	3.19	1.28	0	**Ring**
3	1	05	1.84	00	1.50	3.34	1.34	1	**Spring**
4	1	10	1.50	00	1.50	3.00	1.20	1	**Refill**
8	1	10	1.50	00	1.50	3.00	1.20	0	**Upper Body**
6	1	10	1.50	00	1.50	3.00	1.20	1	**Plastic Push Button**
7	1	11	1.80	31	5.00	6.80	2.72	0	**Silver End Cap**
-	1	10	1.50	00	1.50	3.00	1.20	-	**(Insert sub assem)**
5	1	10	1.5	00	1.50	3.00	1.20	0	**plastic slider**
-	1	-	-	93	3.50	3.50	1.40	-	**(Push button in place)**
-	1	-	-	98	9.00	9.00	3.60	-	**(rotate sub assem)**
-	1	-	-	92	5.00	5.00	2.00	-	**(Screw thread)**
9	1	30	1.95	31	5.00	6.95	2.78	-	**Clip**
						55.78	**19.53**	**4**	**0.22**
						TM	***CM***	***NM***	***Design Efficiency***

Table 7 Worksheet analysis using the Boothroyd method.

2.4 Lucas DFA analysis

The Pen was next analysed using the Lucas method, the assembly flowchart is shown below in Table 6.

Company: Schneider	**Parts**	9	**Handling Score**	10.9	**Assem. score**	20.8
Assembly: Pen	**A parts**	4	**Handling Ratio**	2.7	**Assem. Ratio**	5.2
Version: 1	**Design Efficiency**	44%	**Handling Limit**	1.5	**Assem. Limit**	1.5

No.	Components	Component number	Functional analysis	Handling analysis
1	Lower Body	1	A	1.1
2	Ring	2	B	1.2
3	Spring	3	A	1.8
4	Refill	4	A	1.1
5	***Upper Body Assem***			
6	Upper Body	8	B	1.1
7	***Push Button Sub Assem***			
8	Push button	5	A	1.1
9	End cap	6	B	1.1
10	***Push Button Sub Assem***			
11	Plastic slider	7	B	1.1
12	**Upper Body Assem**			
13	Clip	9	B	1.3
	Totals	**9**	**4**	**10.9**

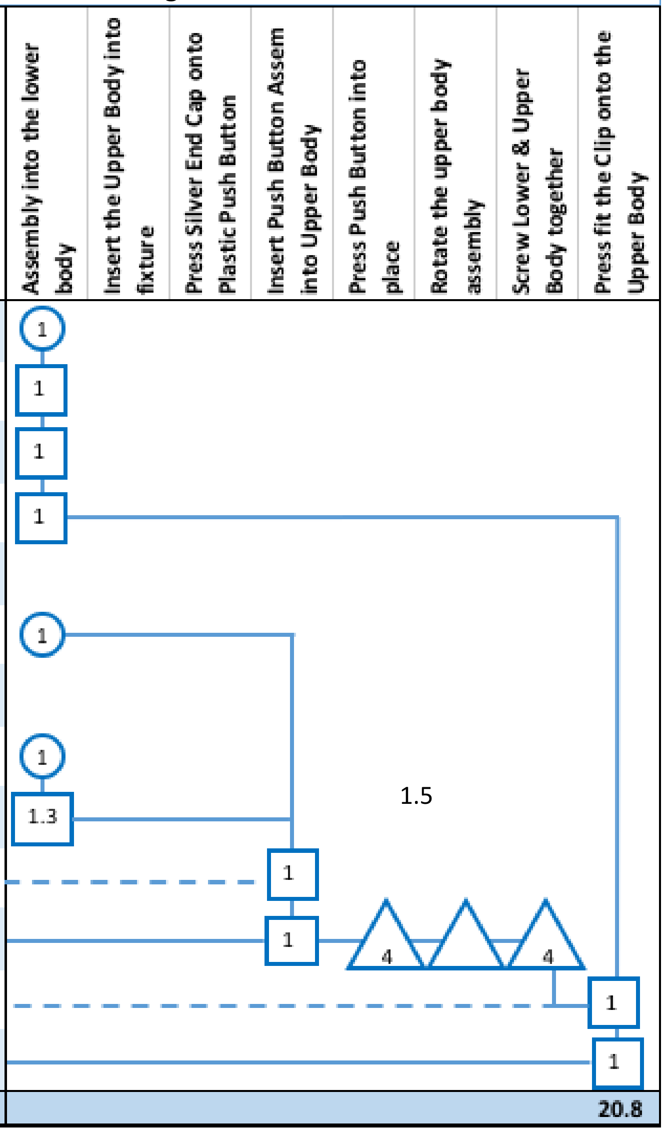

Table 8 Analysis of the pen using the Lucas method (assembly flowchart).

- The Handling Ratio of the pen was **2.73**, the Lucas method recommends that anything over 1.5 needs improvement with <2.5 being the target (3).
- The design efficiency was **44%**, an efficiency of 60% is suggested as a minimum based on a study of ‘good’ designs (3).
- The assembly ratio was **5.20** the suggested threshold is 2.5
- The Lucas analysis also highlights components which are not fundamental to the operation; these are listed in Table 8 as either A or B components. The results suggest that the theoretical minimum number of parts is **4**.

2.5 Comparison of Results

The analysis results of all 3 methods are summarised below in Table 8. **Note:** Lucas analysis cannot be directly compared to Boothroyd.

	Boothroyd software	Boothroyd Worksheet	Lucas
Assembly Time(s)	51.88	55.78	N/A
Theoretical no. of minimum parts	3	4	4
Assembly cost estimation ($USD)	0.68	0.20	N/A
Design Efficiency Boothroyd	19.87	22	N/A
Design Efficiency Lucas	N/A	N/A	44

Table 9 A comparison of the methods used to analyse the pen.

All of the methods identified the same parts in which could be removed in order to reduce the assembly time and costs and components. However, the Boothroyd software method also identified the push button as being removable; this is because the refill and the push button could technically be combined into one component, as they both share the same materials and relative movement. However, as the refill is a standardised component which in industry would be shared among many different pen designs this result will be ignored for the redesign.

Both of the Boothroyd methods gave similar results of assembly time (51.88 & 55.78 seconds) which was also similar experimental assembly time using one hand (50 second). However, the estimated assembly costs were fairly different to one another; this is most likely due to the software having more up to date cost estimations of assembly.

The results from the Boothroyd analysis are more in depth as they provide estimations for the assembly time and cost which could be used to compare to current manufacturing processes. The Lucas analysis can only be compared to another Lucas analysis; however the analysis is simpler to conduct due to the use of illustrations.

It is also important to note that both of the methods are a result of personal interpretation. This means that the results could potentially vary depending on who is doing the analysis.

3 Redesign

3.1 Design

As suggested by the DFA analysis 5 components could be removed from the current design of the pen. The new design of the pen is shown below in Figure 2; this design features just **4** components in the assembly.

Figure 2 The new design of the pen with only 4 components.

Relative movement:
The Plastic Push button, Plastic Slider and Silver End Cap all move together as one in the original pen. This suggests that if these components were made into one it would reduce the number of components by 2, therefore reducing the total components to 7.

Materials:
This pens design has multiple different materials for aesthetic purposes. The removal of the metal Ring and changing the Clip to plastic so that it is part of the click pen movement would remove a further 2 components. This reduces the assembly to 5 components.

Assembly:
Currently the pen is split into two sub-assemblies (Upper & lower body). This could be made into one component and have the entire assembly happen from one end of the pen. Not only would this reduce the orientation time but it could also open up possibilities for automatic assembly.

The current designs click mechanism has been altered and built into the pens body itself, the design takes inspiration from the locking mechanism of a bolt action rifle. However, the key difference here is that it relies on the materials deflection in order to remain in place until it is clicked again to return to its original position. Initially when the pen is first clicked it locks into position 2 as show in Figure 3. When clicked again the click mechanism deforms and goes out of the locking mechanism and inside the pens body to slide up a channel and return to its original position.

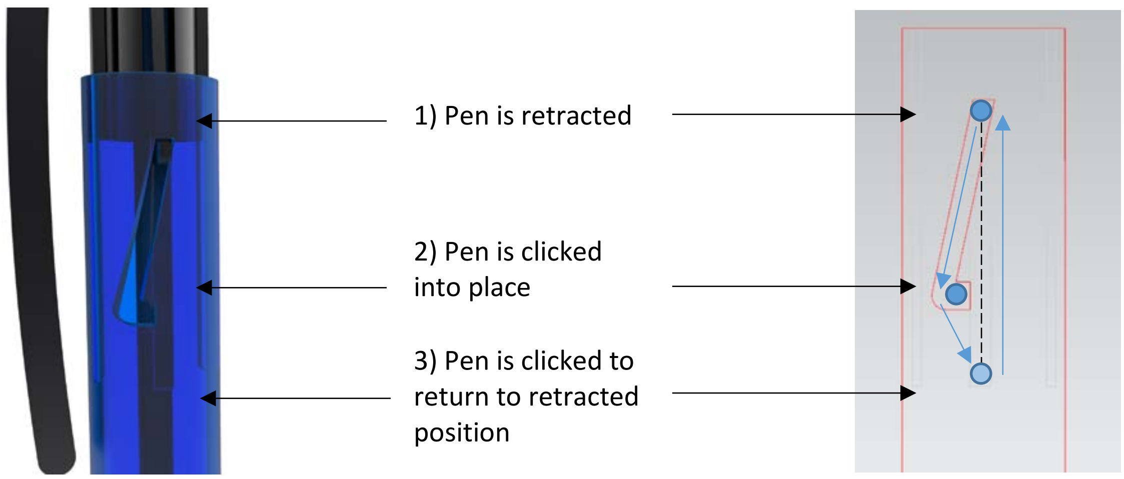

Figure 3 The click mechanism on the new design.

The new proposed parts list is also shown below in Table 7 along with the rotation symmetry of each component.

Part No.	Part	Material	Dimensions (mm)	Rotational symmetry $\alpha + \beta$ (degrees)
1	Body	Plastic	140.00 x 8.90	360
2	Spring	Metal	22.00 x 4.40	180
3	Refill	Plastic/Metal	3.10 x 120.00	360
4	Push Button	Plastic	36.50 x 8.90	720

Table 10 The new proposed parts list.

3.2 New assembly plan

The proposed assembly plan is as follows:

- Insert the Body into the fixture with the pointed end downwards.
- Place the Spring into the Body.
- Place the Refill into the Body with the writing end orientated downwards.
- Insert the Push Button into the top of the body.

The improvements made to this assembly include:

- Removal of press fitting operations.
- Removal of screw/threading operations.
- Reduced number of components in the assembly.
- Reduced the number of hard to handle components (Ring).
- Removal of sub-assemblies and extra fixtures.
- The assembly takes place in only one axis making it simpler for automated assembly.

3.3 Re-evaluation of new assembly plan

The new pen design and assembly plan was analysed using the Boothroyd software, this gave an estimate of **13.67** seconds assembly time (38.21 reduction), an estimated assembly cost of **$0.18 USD** ($0.50 reduction) and a new design efficiency of **75.42%**. The results are shown below in Table 11.

The software recommends still that the refill and push button could be combined in order to reduce the assembly time by a further **3.22** seconds. However, this would have to be analysed further as the costs of having a refill that is a moulded part of the click mechanism could potentially have further cost increases in comparison to leaving it as a standardised part across the range of pens.

Name	Part No	Minimum Items	Process Time (s)	Process Cost ($)
Main Body	1	1	3.22	0.04
Spring	2	1	4.01	0.05
Refill	3	1	3.22	0.04
Push Button	4	0	3.22	0.04
Totals		**3**	**13.67**	**0.18**

Table 11 the results of the new design using Boothroyd analysis.

(Note: Boothroyd software analysis is available in appendix 7.2 for further reading)

4 Issues with automation

By moving to an automated assembly line the company could reduce labour and energy costs required of the pen allowing them to have a more competitive edge in the market. The primary concern with investing in automated assembly is the initial investment costs in machinery and payback period. Another disadvantage of automated assembly is limited customisation, for example if any design changes were made after production had started it would increase the costs of production.

According to Boothroyd Assembly method selection chart 1-1, a pen assembly with 4 components based on a 4-year shift would require just over **400,000** annual units for a single st.one robot arm. For a 9 component pen like the original design, a production volume of roughly **700,000** would be required for a multi-station with robots.

Currently Bosch manufactures an automated pen assembly machine which can manufacture up to 180 pens per minute (4). The initial investment cost of machinery similar to this can cost in excess of **$900,000 USD** (5). With an estimated mark up value of 40% and re-sale value of around $1.00 per pen (6) it is possible to estimate that **565,500** pens would need to be manufactured per year in order to break even.

It would be recommended that the company would seek automation of the redesigned pen with 4 parts due to all the assembly being done in one axis, a shorter assembly time and also a shorter payback period (fewer units required).

5 Conclusion

Overall the analysis proved successful, the pen originally had an estimated assembly time of 51.88 seconds and 9 components, this was reduced to 13.67 seconds and 4 components. The analysis methods both proved to be useful by helping the designer identify unnecessary components in the assembly. Both Lucas & Boothroyd methods allowed the designer to think more about the assembly operations when designing.

The two methods Lucas & Boothroyd were fairly similar to one another, the Lucas method is more simplified and uses pictures in order to identify penalties in the analysis, whereas the Boothroyd method needs to be understood in order to programme into the software. However, the software can be adjusted to specific manufacturing processes so that companies can adjust timings to their own.

Both of the methods are down to personal preference as observed in the worksheet and software Boothroyd analysis. The pens refill was identified for elimination on the software analysis therefore estimating the minimum number of parts to be 3. Another disadvantage of both Lucas and Boothroyd is that they only give recommendations to the designer. It is then the designer's responsibility to redesign the assembly and re analyse. If software could be produced so that a CAD model could be submitted with its current assembly instructions and the software could re-design the component s it would potentially be industry changing.

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7 Appendix

7.1 Initial design Boothroyd Software

Name	Part number	Repeat count	Total count	Minimum items	Minimum part criteria
Pen Assembly			14	3	
Lower body		1	1	1	Base part
Ring		1	1	0	None
Spring		1	1	1	Movement
Refill		1	1	1	Movement
Upper Body Assem		1	1		
Upper Body		1	1	0	None
Push Button Assem		1	1		
Plastic Push Button		1	1	0	None
Silver Coloured End Cap		1	1	0	None
Plastic Slider		1	1	0	None
Snap/push fitting		1	1		
Reorientation of assembly		1	1		
Thread tightening		1	1		
Clip		1	1	0	None

Name	Process time per entry, s	Process time per product, s	Process cost per product, $	Piece part cost per item, $	Piece part cost per product
Pen Assembly		51.88	0.68		0.00
Lower body	0.00	3.22	0.04	0.00	0.00
Ring	0.00	4.24	0.06	0.00	0.00
Spring	0.00	4.01	0.05	0.00	0.00
Refill	0.00	3.22	0.04	0.00	0.00
Upper Body Assem	0.00	3.22	0.04	0.00	0.00
Upper Body	0.00	3.22	0.04	0.00	0.00
Push Button Assem	0.00	3.54	0.05	0.00	0.00
Plastic Push Button	0.00	3.22	0.04	0.00	0.00
Silver Coloured End Cap	0.00	4.17	0.05	0.00	0.00
Plastic Slider	0.00	3.22	0.04	0.00	0.00
Snap/push fitting	0.00	2.26	0.03		
Reorientation of assembly	0.00	3.54	0.05		
Thread tightening	0.00	6.50	0.08		
Clip	0.00	4.30	0.06	0.00	0.00

7.2 Re-design Boothroyd software

Name	Part number	Repeat count	Total count	Minimum items	Minimum part criteria
Pen Assembly			4	3	
Main Body		1	1	1	Base part
Spring		1	1	1	Movement
Refill		1	1	1	Movement
Push Button		1	1	0	None

Name	Process time per entry, s	Process time per product, s	Process cost per product, $	Piece part cost per item, $	Piece part cost per product
Pen Assembly		13.67	0.18		0.00
Main Body	0.00	3.22	0.04	0.00	0.00
Spring	0.00	4.01	0.05	0.00	0.00
Refill	0.00	3.22	0.04	0.00	0.00
Push Button	0.00	3.22	0.04	0.00	0.00

The potential role of DFA in the product development process

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Introduction

The aim of this report is to identify the potential role of Design for Manual Assembly (DFMA) in the product development process, in addition this report will also analyse current examples in industry where Design for Assembly (DFA) has benefitted and how major companies have developed products over time in order to implement DFA techniques.

Product Development Process

The life of a product begins with the product development process, as illustrated in Figure 1 there are 5 initial stages before a product is released. During these stages a product will be developed from a conceptual design to a manufactured product. It is suggested that a good understanding of the customer needs, environment and nature of the market are some of the crucial components for the success of the product (1); however these features only address the conceptual side of the product development process and not the importance of manufacture.

Figure 1 the product development process (2).

For the product design and development, it is suggested that 66%-80% of the products costs are already decided/committed in the concept design and detailed design phases; this is illustrated in Figure 2 (3) . It is therefore crucial that designers and manufacturers to get it right the first time as the costing of moulds and fixtures during manufacture are often too expensive to replace or change after committing to manufacture. For example tools and fixtures for injection moulding can cost in excess of £20,000 and take anywhere from 5-12 weeks to produce (3).

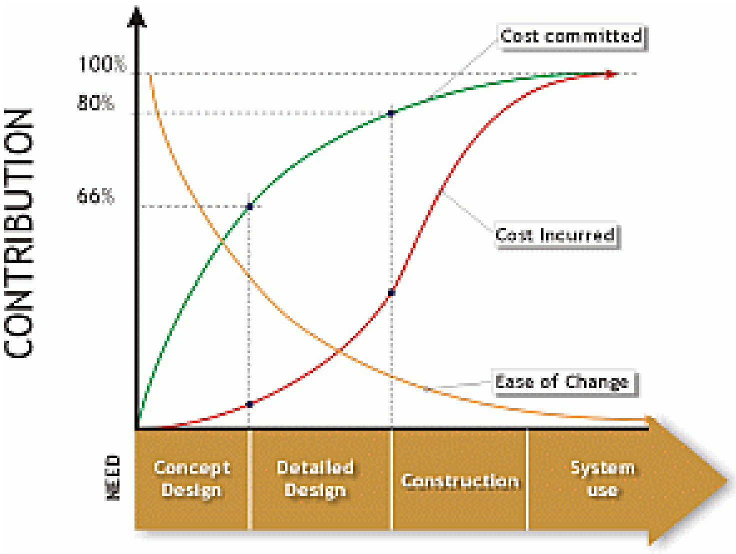

Figure 2 the cost of product development.

As part of the Product Development Process manufactures are constantly researching and discovering methods in order to push technological advances whilst also reducing the cost of the products to match customer needs and remain competitive against other manufactures in order to take the lead in the market. The assembly of a product can often be quite costly in the manufacture of products; therefore it is quite clear that there is a need for DFMA in the product development process.

The use of concurrent engineering has become crucial for manufactures and companies to reduce the product development time and also the time to market. As illustrated in Figure 6 , concurrent engineering allows product development processes to happen simultaneously to one another.

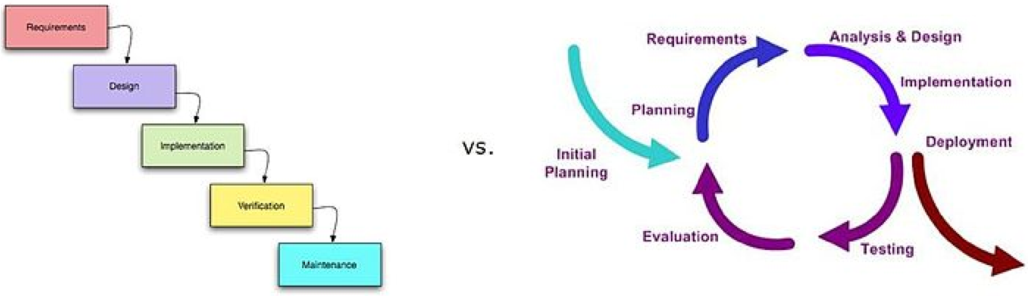

Figure 3 concurrent engineering vs traditional.

An advantage of concurrent engineering is that it allows individual engineers or designers to have more influence in the overall design process (11). The implementation of DFA should be initiated as soon as the product has been designed and before manufacture. By using DFA methods such as Boothroyd estimations of the production costs and assembly times can be quickly calculated before major costs of assembly have been committed to.

Case study – DFA in product development

A crucial factor when designing for assembly is implementing design for assembly techniques into an assembly without reducing the quality or functionality of a product. It is suggested successful DFA can be achieved in products that (5):

- Reduce part count & types.
- Modularise the design.
- Strive to eliminate adjustments.
- Design parts for ease of feeding or handling.
- Design parts to be self-aligning and locating.
- Ensure adequate access and unrestricted vision.
- Design parts that cannot be installed incorrectly.
- Use efficient fastening or fixing techniques.
- Minimise handling and reorientations.
- Maximise part symmetry.
- Good detail design for assembly.
- Use gravity.

The use of these DFA can be seen in the majority of modern companies, technology companies such as Apple & Samsung are constantly refining designs yearly to the latest smartphone devices. The challenge in this industry is to reduce/maintain costs while also increasing technology performance, the easiest way to reduce these costs is by the reduction in assembly costs & technology innovation.

Apple is currently the world's most valuable company with an estimated value of around $741.8 billion USD and annual turnover of 199.4 billion during 2015 (7). During quarter 4 of 2015 Apple sold roughly 48 million IPhone's which generated $32,209 billion USD in revenue (6). The latest IPhone 6 is manually assembled in China; the sheer volume of sales is a key reason why DFMA techniques are crucial for cost reductions. At the current production rate a saving of $0.01 USD during the assembly process could easily generate another $480,000 USD of revenue for the company.

The evolution of the IPhones design can be seen clearly by studying each generation of model releases. The first IPhone was released in 2007, since then the design has changed completely throughout. The original IPhone's design lacked crucial DFA techniques and featured multiple parts which were glued together along with inefficient use of material reduction and excess components. The assembly of the original IPhone is shown below in Figure 3 (7), although the majority of components are permanently glued to front display.

Figure 4 the assembly parts of the original IPhone.

The latest generation IPhone has been developed over 6 generations. It is clear to see the implementation of DFA techniques such as the standardisation of components, which can be seen in the components such as screen, battery, camera and microphone which are used on other apple devices.

The assembly has been efficiently revised so that the operation now happens in one orientation; this has been achieved by using the phones back cover as the main assembly body. The new design also shows examples of part reduction can be seen clearly with the frame of the IPhone. The original IPhone featured 3 components which made the body sub-assembly (illustrated previously in Figure 3) this design required handling orientations and gluing of components in order for the phone to be assembled. The latest design is illustrated in Figure 4 (8) in which the frame assembly is one component removing the need for excess screws and adhesion in the assembly.

Figure 5 the assembly parts of the IPhone 6.

Further examples of DFA techniques can be seen with the IPhone PCB assemblies, initially these were connected soldered components, these have since been replaced with standardised ribbon cable connectors, examples of this are shown below in Figure 5 (7) which illustrates the latest camera module featuring a ribbon cable. By using these efficient fastening techniques it is estimated that this feature alone would reduce manufacturing time by 4.5 seconds per soldered component (9).

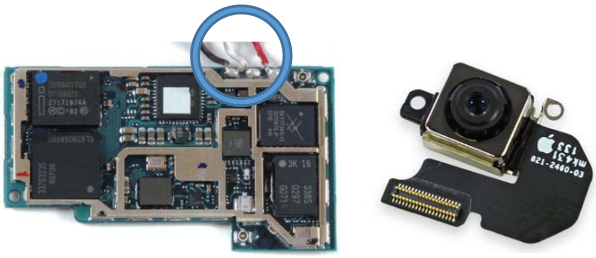

Figure 6 the soldered components on the original IPhone (Left), the ribbon cables used on the IPhone 6 (Right).

The current IPhone is manufactured in China in which reports suggest that the assembly cost is around $8.00 USD. By moving the assembly operations into the USA it would cost an extra $4.00 USD per unit which due to the volume of sales would cost the company roughly $600 million during one year of IPhone sales. (10).

Successful use of DFA techniques can result in weight and component reduction. The efficient use of space, materials and assembly techniques is crucial for technology advances. Table 1 shows a comparison of specifications between the two IPhone models used in this case study. The use of the design for assembly techniques highlighted in this case study has allowed for the latest IPhone to be thinner, larger and lighter than the original whilst remaining the same cost.

	Original IPhone 2007	**IPhone 6 2014**
Dimension	115 x 61 x 11.6 mm	138.1 x 67 x 6.9 mm
Weight	135g	129g
Display resolution	320 x 480 pixels	750 x 1334 pixels
Cost at launch	$399 - $599	$600
Processing power	412 MHz	Dual 1.4 GHz (6.8 times more powerful)

Table 1 a comparision of IPhone specifications (13).

It is therefore clear to see that a products design for assembly is perhaps even more crucial in companies which have very large product sales, as any reduction in costs during the assembly process could have the potential to save millions in manufacturing costs. The example used also illustrates the need for continual assessment and re-designs of components throughout each generation of a product.

Conclusion

In conclusion, it is clear to see that the role of design for assembly is important during the product development process. The earlier that DFA is introduced in the process the more cost efficient the product will be during manufacture. This was achieved by reducing costs and efficiently designing products so that they can be manufactured right first time. It was also found (from the case study) that even after a product has been successfully developed and launched, DFA analysis should be continually used for the assessment of each design iteration. The use of DFA analysis will allow room for advances in technology, reductions in costs and overall a higher quality product.

Design for Assembly is a technique with high potential that can be easily implemented into a company's product development process using concurrent engineering and suitable DFA software, companies which have a large production rate can greatly benefit from even the smallest savings. However it should also be noted that the simplicity of integrating DFA techniques in the development process should be used even by companies with low production rates.

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