Product Design and Development

Project 2

Design and Development of Automatic Toilet Seat Cleaner

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SECTION 1

INTRODUCTION

Public toilets are easy to find every where in cities, and one seldom needs to look very hard when nature calls. Restrooms can be found in department stores, supermarkets, book stores, CD shops, parks, most convenience stores, trian stations, etc. However clean, dry and germ free toilet seat in public toilets is hard to find. Beginning in the recent past, there has been a movement to make toilet seats cleaner and more germ free than they had been in the past.

No one can deny the importance of dry, clean and germ free toilet seat due to health and safety factors associated with its use. After all who wants to sit on a wet toilet seat?. The use of dry and clean toilet seat is increasing day by day due to awareness among general public about health and clean sanitation. However, low cost and easy to use toilet seat cleaners are not easily available in the market. This factor has discouraged the use of automatic toilet seat cleaner in our societies at large.

The current project aims to solve this problem by designing a low cost and simple to use automatic toilet seat cleaner. In this project, the team will design and develop the automatic toilet seat cleaner by considering the following key phases of product development.

1) Developing Mission Statement for the product to be designed and developed
2) Identifying customer needs
3) Converting voice of customer (VOC) into customer needs

4) Developing metrics (product characteristics) to address customer needs in engineering terms
5) Develop Need-metric relationship
6) Using Quality Function Deployment as a tool to build the House of quality
7) Generate Concepts
8) Select Concepts using Concept Scoring Matrix
9) Process Driven Design
10) Product Architecture
11) Design for Manufacture
12) Reflect on the result and process

The design and development of Automatic Toilet seat cleaner is explained in this report with reference to all the above mentioned steps involved in product design and development.

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SECTION 2

MISSION STATEMENT

2.1 General

In order to provide guidance during product development phases, the team usually formulates a detailed definition of the product, target market and assumptions under which product will be developed. These decisions are highlighted in the product mission statement which includes the following [1]:

a. Brief description of the product
b. Key business goals
c. Target Markets
d. Assumptions and Constraints
e. Stake Holders

2.2 Mission Statement for Design of Automatic Toilet Seat Cleaner

Based on the guidelines mentioned above and referred in reference [1], the following mission statement of the project was formulated:

Product Description:	Automatic Toilet Seat Cleaning System.
Key Business Goals:	• Introduce in the market in the fourth quarter of 2006. • 50% gross margin • 25% share of product market by the 1st quarter of 2007.
Primary market :	Hotels, Restaurants, Towers, Residential apartments, Corporate offices
Secondary market :	Villas, Luxury Flats, Housing Schemes developers

SECTION 3

IDENTIFYING CUSTOMER NEEDS

3.1 General

The process of identifying customer needs is an integral part of product development process [1] and is related to concept generation, concept selection, bench marking and establishing target specifications [2]. Identifying customer needs is a process divided into the following phases [1]:

1) Gather raw data from customers (VOC)
2) Interpret raw data in terms of customer needs
3) Establish relative importance of needs
4) Reflect on the result and process

3.2 Identifying Customer Needs for Toilet Seat Cleaner

To identify customer needs, the project team started by gathering raw data from ordinary people belonging to different walks of life. The team used one to one interview method for collecting data. The total number of customers interviewed were 44 (Male = 23, Female = 21). The interviews were conducted at Suranaree University of Technology and the focus group belonged to 3rd year undergraduate students in Industrial Engineering and at the Asian Institute of Technology, AIT. The average age of the customers was 25 years. The customer survey is shown in Table 3.1.

Total = 44 (Male = 23, Female = 21) Age average = 25

Voice of Customer	Number of votes
1) I would like to have a push button for cleaning before sit down (show the cleaning process before use)	10 votes
2) Have a water supply for cleaning the seat	12 votes
3) Have a disinfectant seat	6 votes
4) Have a automatic wipe system	11votes
5) Have a drier system (Seat should be dry)	14 votes
6) Can adjust temperature?	1 votes
7) Easy to use	7 votes
8) Look nice	2 vote
9) Good Ergonomics (Comfortable seat)	2 votes
10) Fast Operate	2 votes
11) When I flush the toilet it should simultaneously clean seat	1 vote
12) I can operate the mechanism using automatic control after use	12 votes

Table 3.1 Voice of Customer

3.3 Conversion of VOC into Customer Needs

After getting voice of customers, the data was translated in terms of customer requirements. For conversion from VOC to customer needs, the team followed the basic guidelines such as use of positive phrases, avoiding use of must and should, expressing the needs in terms of product attributes, etc [1] .

Table 3.2 presents each voice of customer interpreted in terms of customer needs.

Voice of Customer	Needs
1) I would like to have a push button for cleaning before sit down (show the cleaning process before use)	Provision to operate the Cleaning mechanism before sitting on the toilet seat
2) Have a water supply for cleaning the seat	Water supply for cleaning
3) Have a disinfectant seat	Disinfectant seat
4) Have a automatic wipe system	Incorporate automatic wipe system
5) Have a drier system (Seat should be dry)	Dry seat after cleaning
6) Can adjust temperature?	Provision of temperature control
7) Easy to use	Simple Design
8) Look nice	Attractive appearance
9) Good Ergonomics (Comfortable seat)	Good Ergonomics
10) Fast Operate	Short operation time
11) When I flush the toilet it should simultaneously clean seat	Simultaneous operation of flushing the bowl and cleaning the seat
12) I can operate the mechanism using automatic control after use	Operate automatically after use

Table 3.2 Customer needs

3.4 Establish relative importance of needs

Relative importance is a value that is subjectively allocated to customer needs on a scale 1-5 (5 most important) or 1-10 (10 most important). The team selected a range from 1 to 5 to rank the customer needs where 5 indicating the most important need and 1 indicating the least important need.

The relative importance of needs is shown in Table 3.3

Needs	Importance
1) Provision to operate the Cleaning mechanism before sitting on the toilet seat	3
2) Water supply for cleaning	4
3) Disinfectant seat	3
4) Incorporate automatic wipe system	4
5) Dry seat after cleaning	5
6) Provision of temperature control	1
7) Simple Design	3
8) Attractive appearance	2
9) Good Ergonomics	2
10) Short operation time	2
11) Simultaneous operation of flushing the bowl and cleaning the seat	1
12) Operate automatically after use	4

Table 3.3 Relative Importance of Customer needs

3.5 Reflect upon the results and the process

The final step in identifying customer needs is to reflect upon the results and the process [1]. The process of identifying customer needs is not an exact science, and methods of gathering and identifying customer needs vary from product to product and also depend on the thinking approach of the team members. Therefore the team did a brain storming session to challenge the data gathered from customers to highlight any discrepancies in the data. After thorough deliberations, the team finally agreed that the customer needs mentioned in table 3.3 are comprehensive enough to proceed to next product development stage mention in Section 4.

SECTION 4

BUILDING THE HOUSE OF QUALITY

4.1 General

For producing sustainable products, effective communication between all parties is necessary and human needs have to be taken into consideration. A structured process is required to match human needs (ergonomics) with the product specifications. One way of achieving this structured process is by using quality function deployment (QFD) [3]. One of the key objectives is to ensure that the needs of the customer (the so-called “Voice of the Customer” or VOC) are incorporated into the design [4].

QFD is based around a series of standard matrices. The most commonly applied is the House of Quality (HOQ – so-called because its resemblance to a house). The HOQ relates the requirements of a design to the means by which those requirements will be met. In this way, it allows priorities to be defined before applying engineering effort. At the simplest level, the HOQ is a matrix which defines the relationship between the requirements of the design (stated from the customer’s point of view) and the product characteristic (in engineering terms). The strength of the relationship is defined in subjective terms on a simple scale (this varies in different applications of QFD). In practice, the HOQ matrix is more detailed. The core of the matrix is the same is that discussed previously. There are, however, some key additions:-

1. **Customer Perceptions.** This box indicates customer perceptions on a scale 1-5 (5 = highly positive perception). Perceptions of competitors are superimposed on the chart.

2. **Roof Matrix.** This indicates the relationship between different product design characteristics. These can be positively or negatively related.

3. **Importance.** This is a value that is subjectively allocated to customer requirements on a scale 1-10 (10 most important) or 1-5 (5 most important).

4. **Technical Assessment and Target Values.** This section provides technical information relating to the product characteristics. This section also provides target values for the product characteristics as a focus for further improvement.

4.2 House of Quality for Automatic Toilet Seat Cleaner

As a first step to build the House of Quality, the team developed a list of metrices for each of the customer needs to establish the relationship between the requirements of the design (stated from the customer's point of view) and the product characteristic (in engineering terms).

These metrices are generally referred to as the preliminary specifications which are established after identifying customer needs and before concept generation. The list of metrices for toilet seat cleaner are shown in Table 4.1 and need metric relationship is shown in Fig 4.1

Need No:	Metric No	Metric	Units
1,9	1	Access time to push button	Seconds
2,4	2	Cleaning Surface area of the seat	mm^2
3	3	Bacteria test	Pass/Fail
3,4,5	4	Dry test	Pass/Fail
1,7,8,9	5	Position of System	Subjective
7,8,9	6	Dimension	mm
7,8	7	No of Parts	No
4,10	8	Cycle Time	Seconds
10,11,12	9	Starting Time of both the operations	Seconds
6	10	Difference between ambient & seat temperature	Deg Celsius

Table 4.1 List of Metrices for Toilet Seat Cleaner

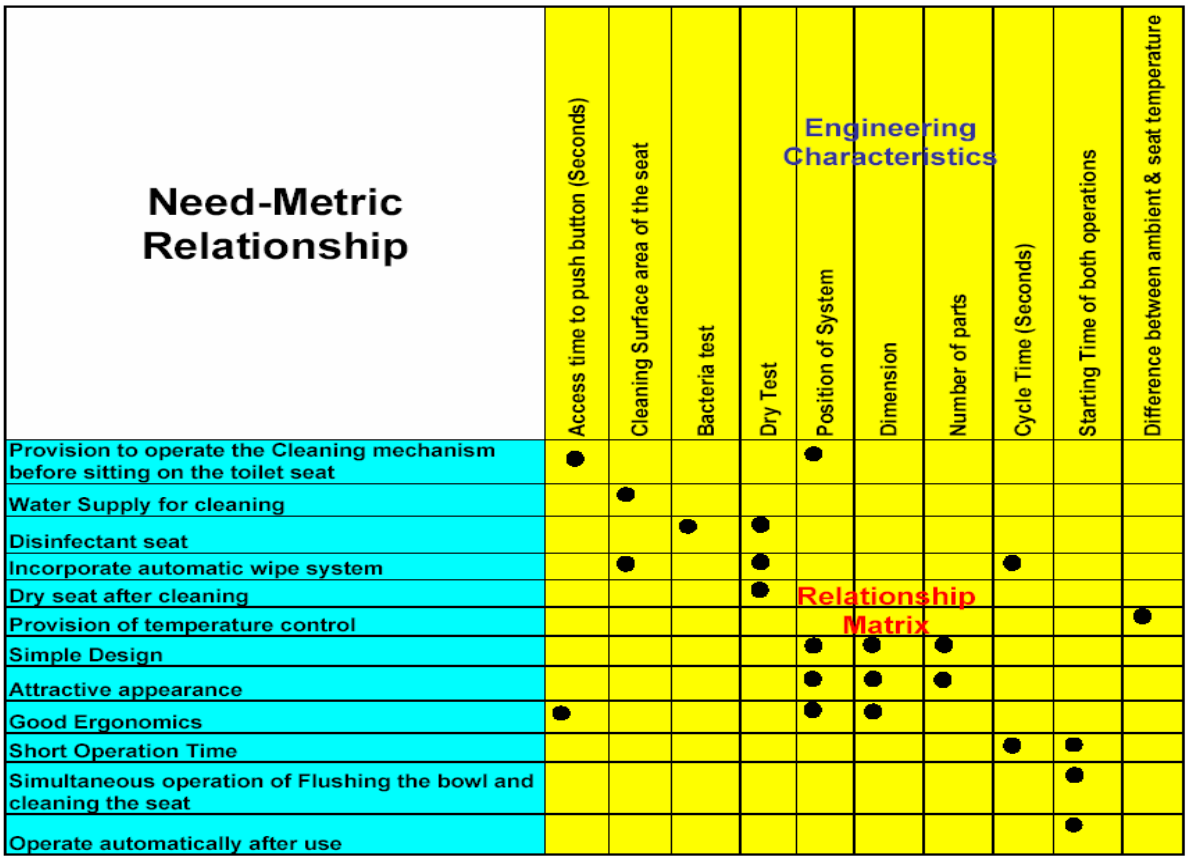


Fig. 4.1 Need Metric Relationship

The list of metrics mentioned in Table 4.1 were used to develop need-metrics relationship Matrix for the House of Quality. The Complete house of quality for automatic toilet seat cleaner is shown in Fig 4.3

The team also identified whether or not there was a relationship between each need and each Engineering Characteristic, and also determined how strong that relation was. Following symbols and numerical values were used to express the relationships:

△ **Weakly Related [1]**

○ **Strongly Related [3]**

◉ **Very Strongly Related [9]**

The influence of each specification in terms of score was calculated by multiplying its numerical value with the corresponding need percent score.

The team also built the roof Matrix and identified whether or not there was a positive or negative correlation among specifications.

The competitive benching marking was carried out by considering the following competitors' products.

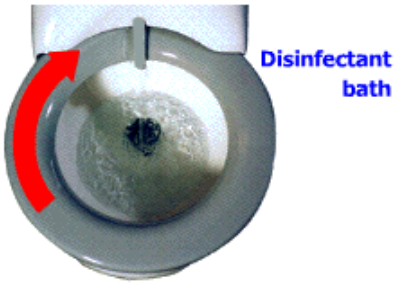


Fig 4.2 A Company-A Product

Fig 4.2B Company B Product

The improvement ratios were calculated based on competitive bench marking for this project. In order to compete with the competitors and be cost effective at the same time, an improvement ration of 1.5 was given to "**provision to operate the mechanism before sitting on the toilet seat**", "**automatic wipe system"** and "**good ergonomics"**.

The project team evaluated the impact of the improvement to the sale using values of 1, 1.2, 1.5 respectively. Sale point of 1.5 was given to "**provision to operate the mechanism before sitting on the toilet seat**", "**short cycle time**" and "**automatic operation after use**". The score of each need was computed by multiplying its importance, improvement ratio, and sale point and the value was later normalized as shown in Fig 4.3

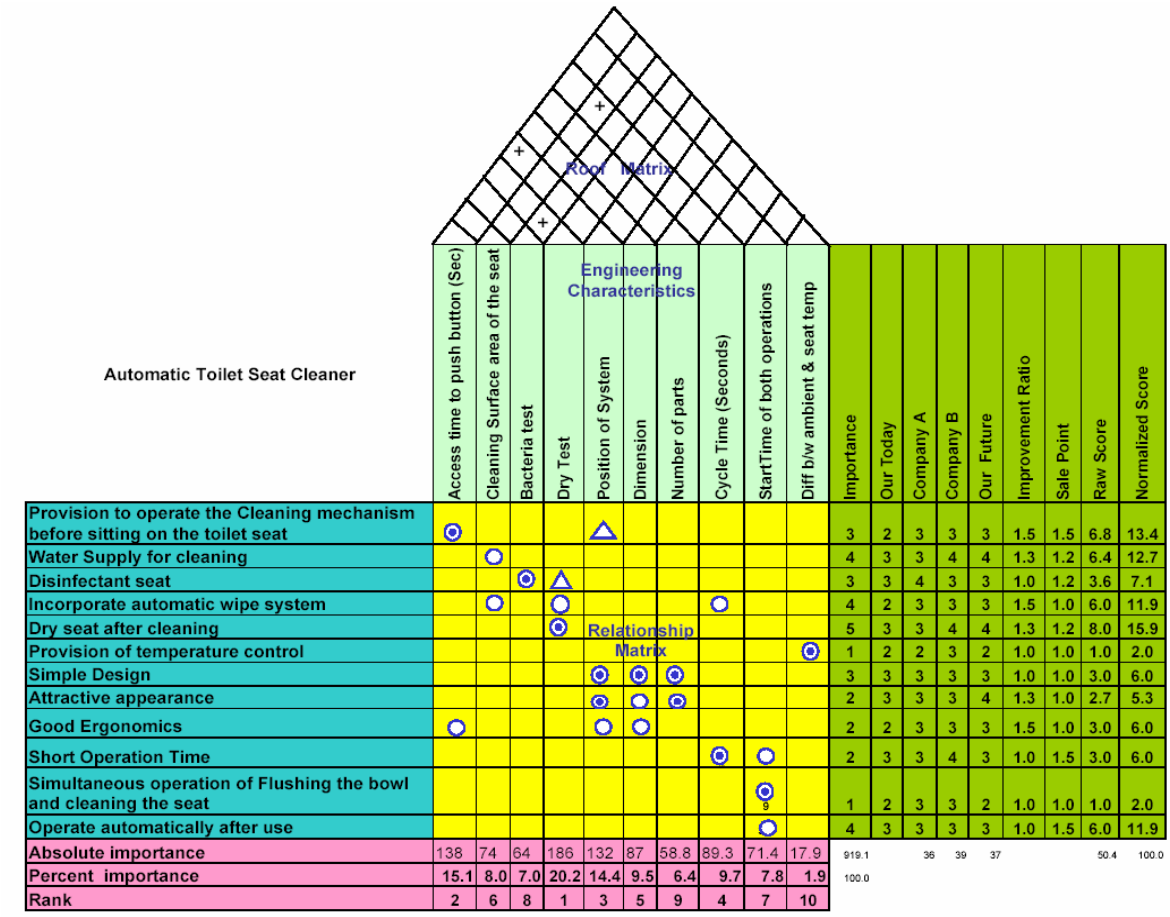


Fig 4.3 House of Quality for Automatic Toilet Seat Cleaner

4.3 Results of House of Quality for Automatic Toilet Seat Cleaner

The HOQ for automatic toilet seat cleaner shows that the characteristics of "**dry test**" received the highest score of **186**. The dry test is related to the following customer needs:

a. Disinfectant seat
b. Automatic wipe system and
c. Dry seat after cleaning.

The second highest characteristic was "**access time to push**" button which received the second highest weighting of **138**. The access time to push button is related to the following customer needs:

a. provision to operate the operate cleaning mechanism before sitting on the toilet seat and
b. good ergonomics.

The third highest characteristic was "**position of the system**" which received a score of **132**. The position of the system is related to the following customer needs:

a. Provision to operate the mechanism before sitting on the toilet seat
b. Simple design
c. Attractive appearance and
d. Good ergonomics.

Therefore improving these three major characteristics would lead to customer satisfaction. There is a positive correlation between "**Position of the system**" and "**Access time to push button**". Similarly there is a positive relationship between "**dry test**" and "**bacteria test**". Also there is a positive correlation between "**cycle time**" and "**cleaning surface area of the seat**". The above analysis reflects the usefulness of the QFD analysis in identifying those product characteristics that should be changed in order to offer a compact design for automatic toilet seat cleaner that meets the demands of the customers. The analysis has shown that position and mechanism of automatic toilet seat cleaner should be chosen so as to provide dry seat, good ergonomics and simple and attractive design. Based on the results of the QFD analysis, the concept generation and selection automatic toilet seat cleaner are discussed in the next sections

SECTION 5

CONCEPT GENERATION

5.1 General

A product concept is a general description of the working principal and form of the product. It is usually expressed as a sketch or as a rough three dimensional model with some brief description [1].

The concept generation process begins with a set of customer needs and target specifications and results in a set of product concepts from which the final concept is chosen. The structured approach to concept generation consists of the following five steps [1]:

1. Clarify the problem
2. Search externally
3. Search internally
4. Explore systematically
5. Reflect upon the results and the process

This section deals with concept generation for automatic toilet seat cleaner with reference to some of the steps mentioned above:

5.2 Concept generation for Automatic Toilet seat Cleaner

As a first step to concept generation for automatic toilet seat cleaner, the team's first task was to clarify the problem by any suitable functional decomposition. The functional decomposition is shown in Fig. 5.1

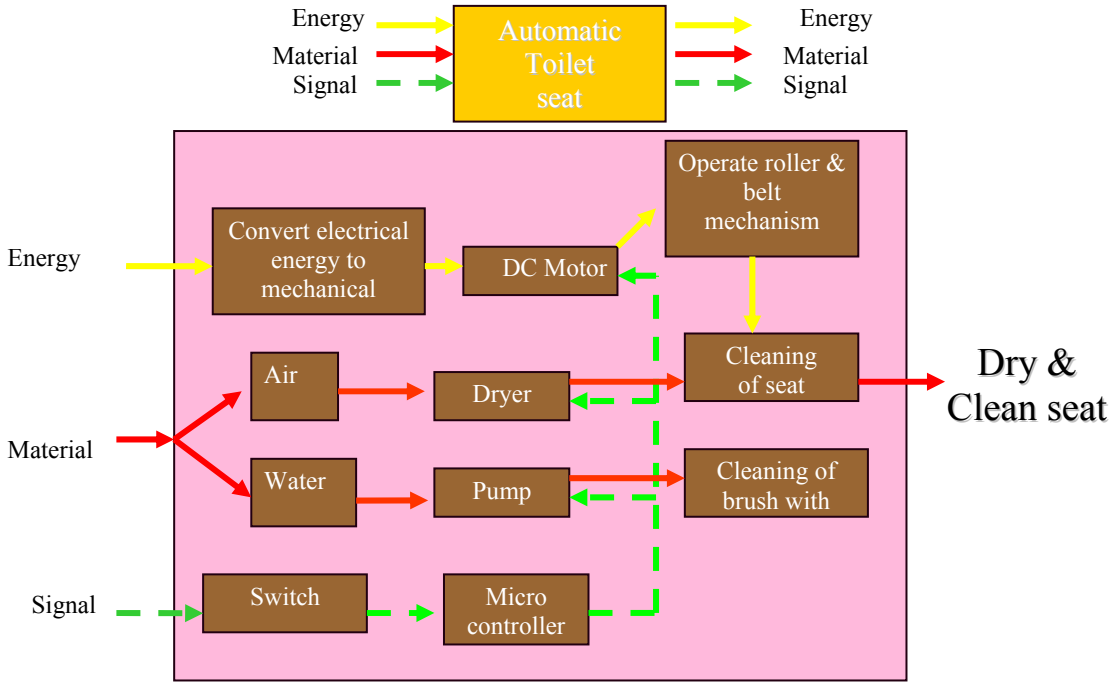


Fig. 5.1 Functional Decomposition of toilet seat cleaner

The functional decomposition involved first representing the automatic toilet seat cleaning mechanism as a single black box operating on energy, material and signal flows as shown in Fig 5.1. The black box was later subdivided into sub functions to create a more specific description of what the elements of the toilet seat cleaner might do in order to implement the overall product function as shown in Fig 5.1

The next step involved internal search within the team members. Various individual and group sessions were held to discuss a range of ideas for Automatic toilet seat cleaner. The most promising concepts were further investigated within the team members.

The team finally came up with the five design concepts and concept combination table for systematic exploration of different design concepts was developed as shown in Fig. 5.2

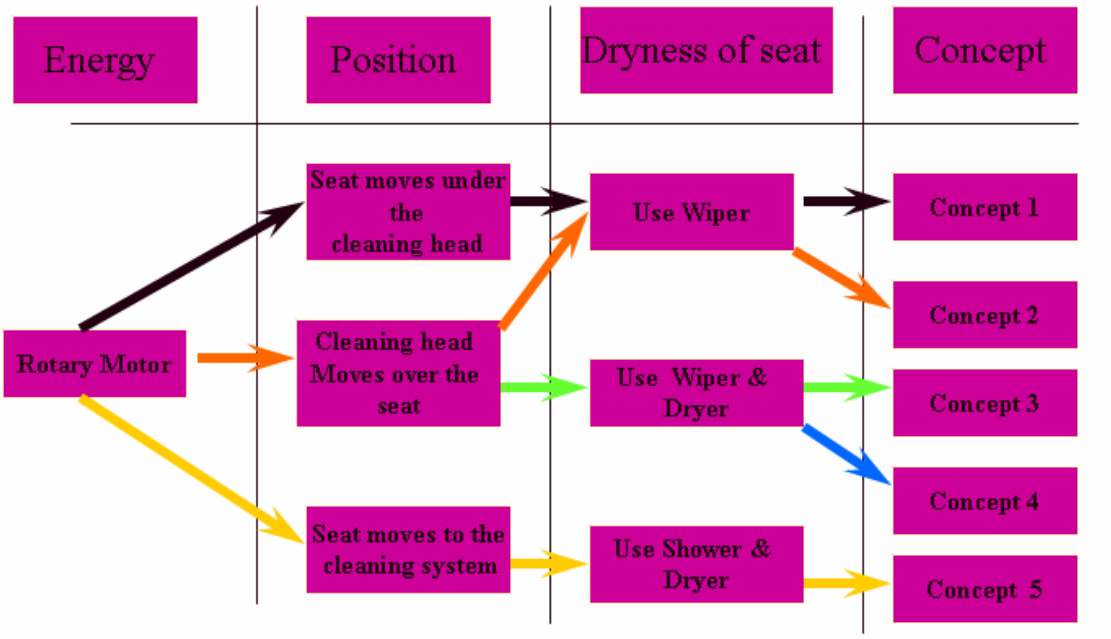


Fig. 5.2 Concept Combination Table for Automatic Toilet Seat Cleaner

The concept combination table provided a way to consider combination of solution fragments systematically.[1]. The columns in the table make reference to the sub problems mentioned in functional decomposition of the product as shown in Fig 5.1. The five design concepts considered for final selection for automatic toilet seat cleaner are shown below:

CONCEPT 1

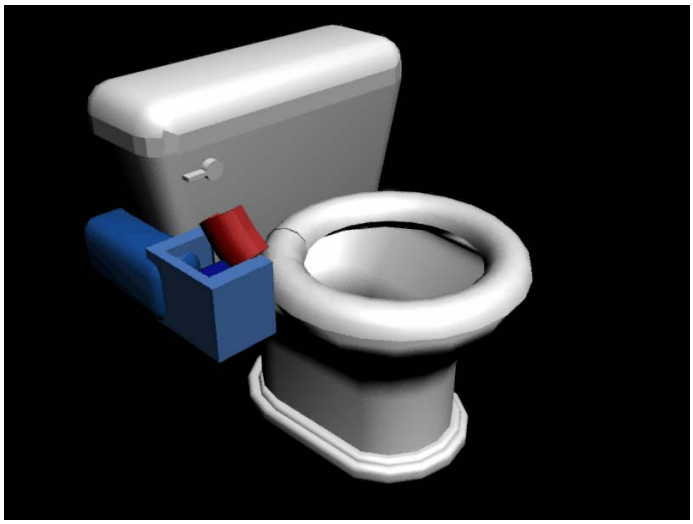


Fig. 5.3 Concept 1 “Seat moves under the cleaning head”

CONCEPT 2

Fig. 5.4 Concept 2 “Cleaning head moves over the seat”

CONCEPT 3

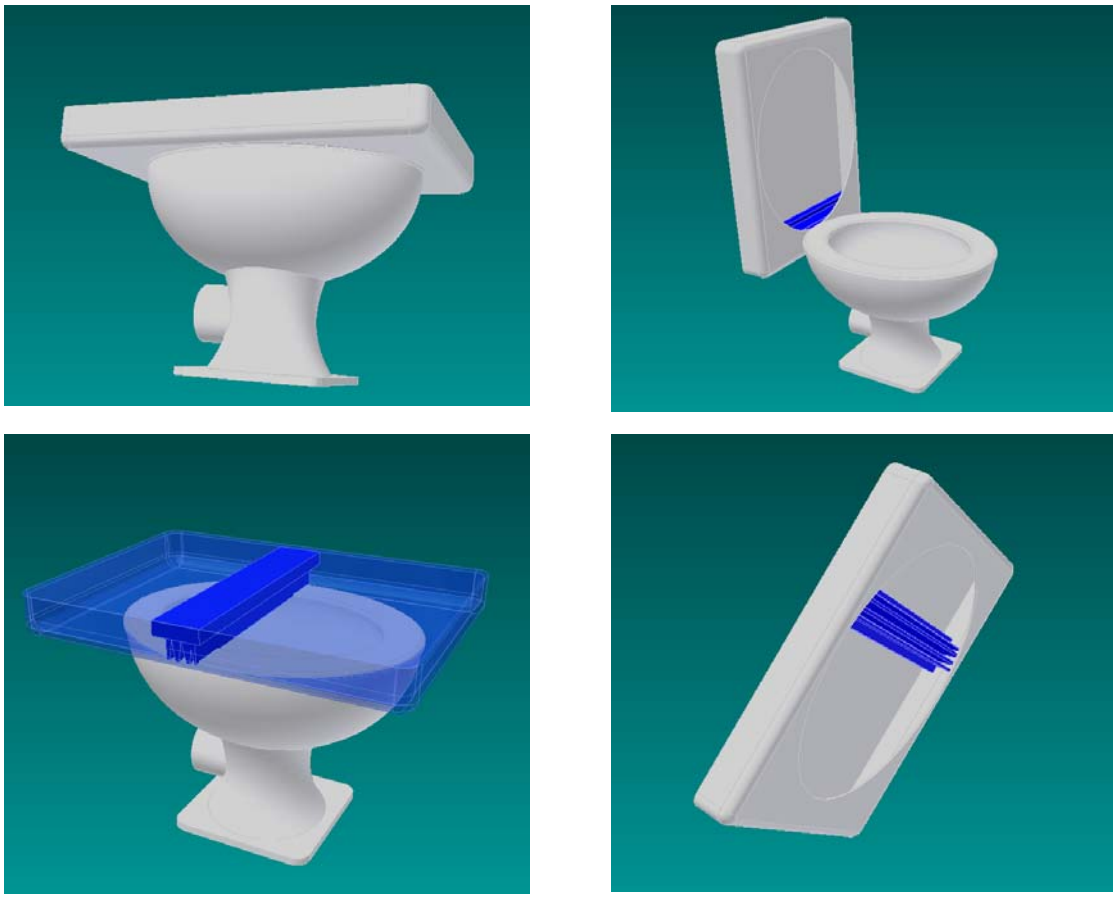


Fig. 5.5 Concept 3 “Cleaning head moves over the seat”
(Uses wiper and dryer)

CONCEPT 4

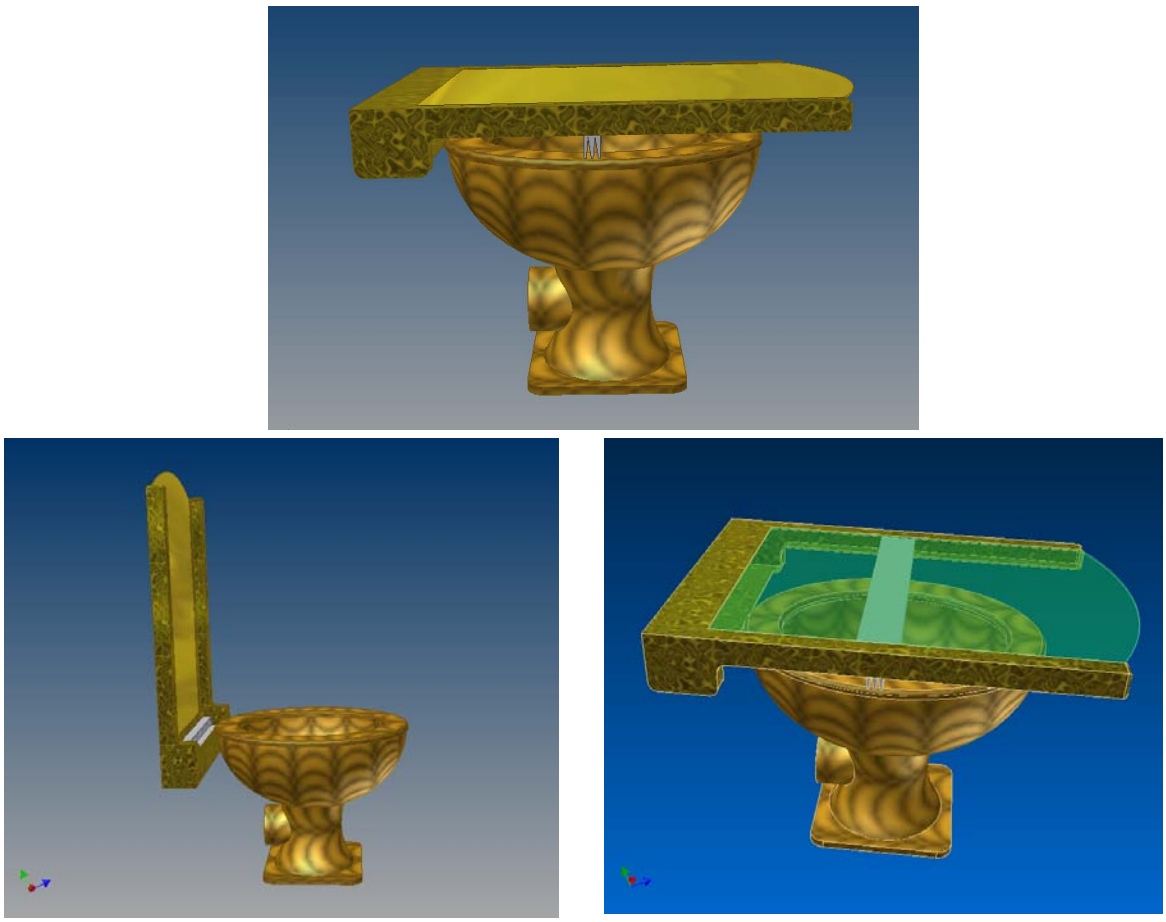
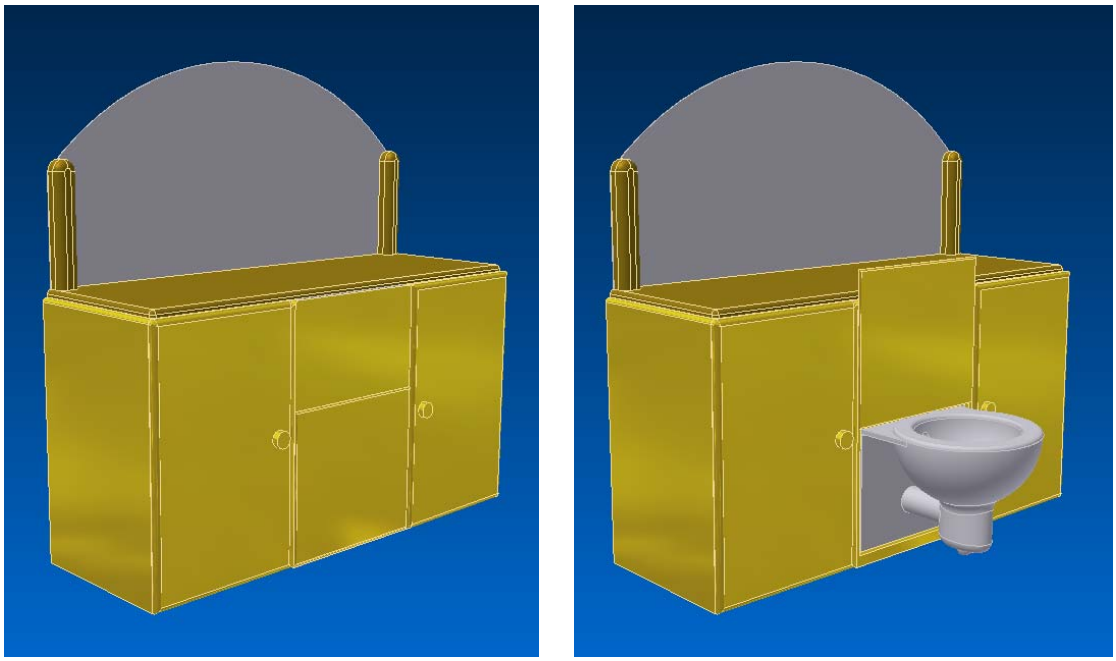


Fig. 5.6 Concept 4 “Cleaning head moves over the seat”
(Uses wiper and dryer)

CONCEPT 5



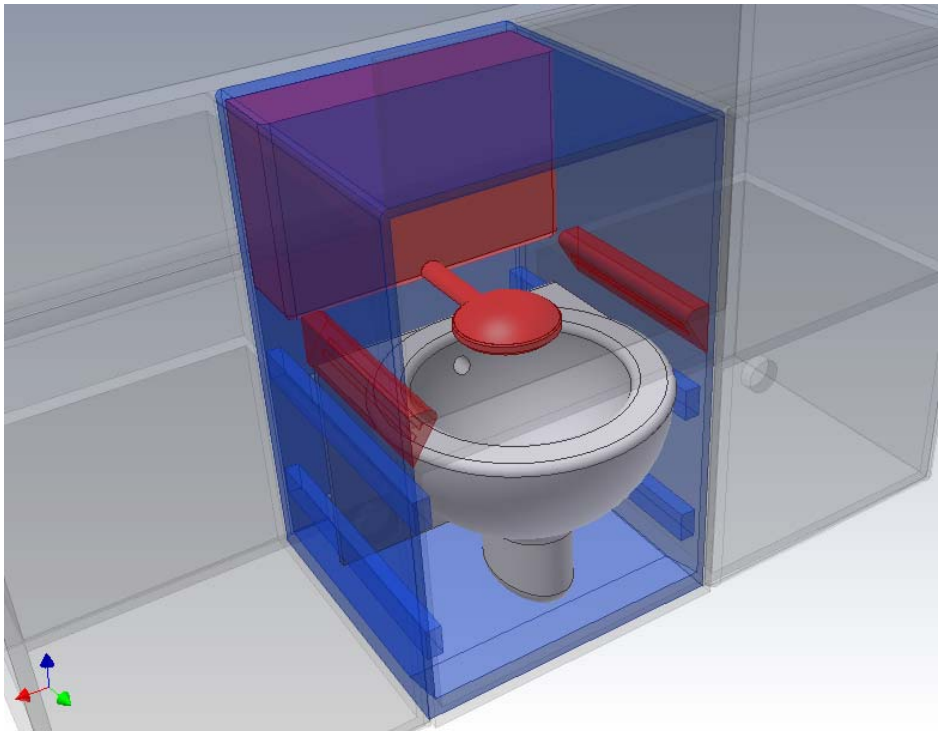


Fig. 5.7 Concept 5 “Seat moves to the cleaning system” (Uses shower and dryer)

SECTION 6
CONCEPT SELECTION

6.1 General

Concept generation is a process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts and selection of one or more for futher investigation, testing or development [1].

The concept selection method in this section is build around the use of decision matrix for evaluating each concept for toilet seat cleaner with respect to a set of selection criteria.

6.2 Concept selection for Automatic Toilet Seat Cleaner using Concept Scoring Matrix

The generic steps involved in concept selection using concept scoring matrix are[1]:

1. Develop evaluation criteria
2. Assign importance rate to each criterion
3. Rate each concept with respect to each evaluation criterion
4. Rank the concepts
5. Combine and improve the concepts
6. Select one or more concepts
7. Reflect on the results and process

The following selection criteria for automatic toilet seat cleaner was finalized by taking into consideration the customer needs:

1. Performance
2. Inexpensive
3. Easy to operate
4. Compact
5. Ergonomic
6. Simple Design
7. Appearance Rain Proof
8. Easy of Manufacture
9. Short Cycle Time

The next task was assigning weights to each selection criteria in the scoring matrix. Several different schemes can be used to weight the criteria such as assigning the importance value from 1 to 5 or allocating 100% points among them [1]. For the purpose of concept selection for toilet seat cleaner, the weights were determined subjectively by the team members.

Rating of all the concepts for toilet seat cleaner with respect to selection criteria was done on a scale of 1-5 with following definitions for each scale [1]:

Relative performance	**Rating**
Much verse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

The concept scoring matrix for automatic toilet seat cleaner is shown in Table 6.1. The method uses a weighted sum of the ratings to determine concept ranking. The reference points for each criteria are signified by bold rating values in red colour.

CUSTOMER REQUIREMENTS	WEIGHTS	CONCEPTS									
		Concept 1		Concept 2		Concept 3		Concept 4		Concept 5	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Performance	15	4	60	3	45	4	60	3	45	3	45
Inexpensive	10	3	30	2	20	3	30	3	30	3	30
Easy to operate	14	3	42	3	42	4	56	4	56	3	42
Compact	8	3	24	2	16	3	24	3	24	3	24
Ergonomic	10	4	40	3	30	3	30	3	30	3	30
Simple Design	13	3	39	2	26	4	52	4	52	3	39
Appearance	10	**3**	30	2	20	5	50	4	40	4	40
Ease of Manufacture	10	3	30	2	20	4	40	3	30	3	30
Short Cycle Time	10	3	30	3	30	3	30	3	30	3	30
Total Score			**325**		**249**		**372**		**337**		**310**
Rank			**3**		**5**		**1**		**2**		**4**
Continue			**No**		**No**		**Yes**		**No**		**No**

Table 6.1 Concept Scoring Matrix for Automatic Toilet seat cleaner

The concept scoring matrix indicates that Concept 3 (Fig 5.5) in which "Cleaning head moves over the seat and use a wiper and dryer received the highest score of **372**. All other concepts remained below the score of concept no 1. Therefore, Concept 3 was finally chosen as the best design for automatic toilet seat cleaner. The chosen concept is shown in Fig 6.1

SELECTED CONCEPT

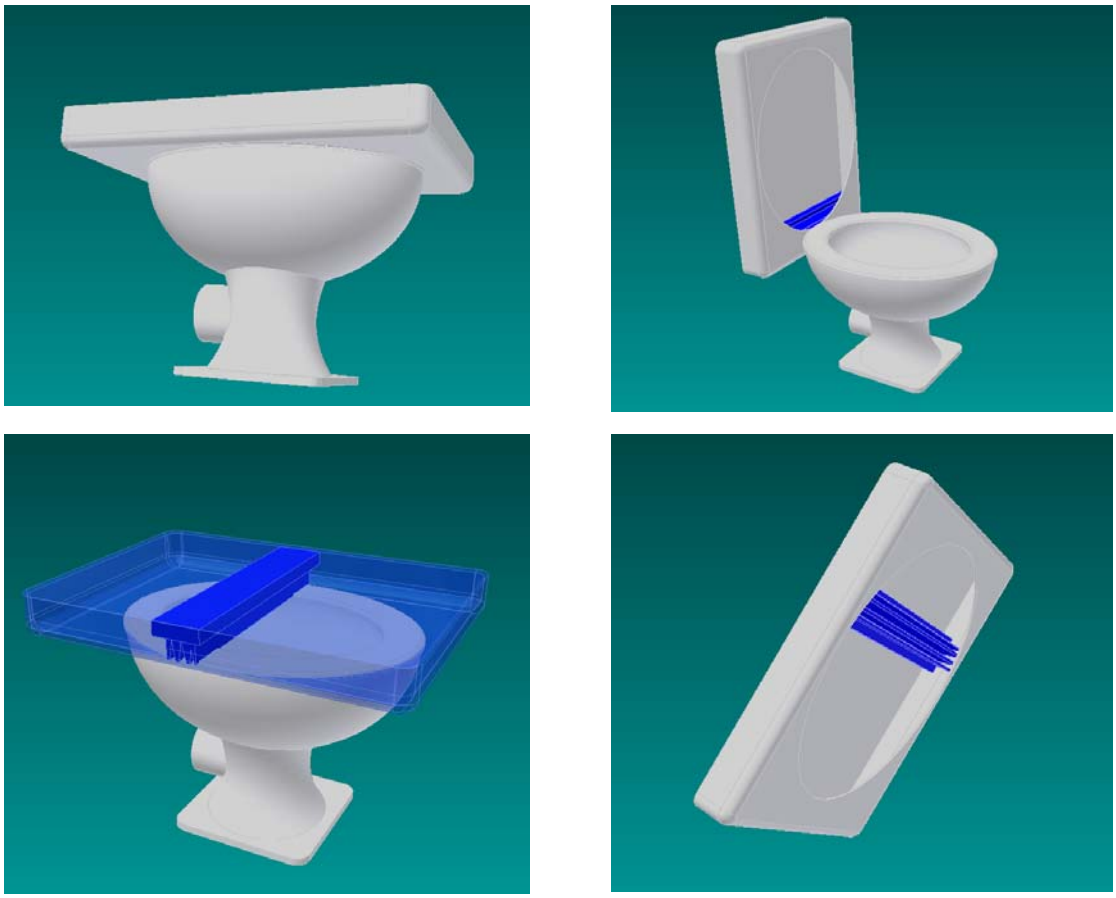


Fig. 6.1 Concept 3 “Cleaning head moves over the seat” (Uses wiper and dryer)

SECTION 7

PROCESS DRIVEN DESIGN

7.1 General

The goal of the process driven design approach is to ensure the development of best possible part decomposition from a functional, manufacturing, support and business point of view [2].

The process driven design involves the following six step procedure [2]:

a. Develop the manufacturability design goals
b. Develop a product and process plan
c. Design components for ease of Assembly
d. Consider redesign of components for ease of fabrication
e. Optimize and refin the design.

For the design and developemnt of Automatic toilet seat cleaner, the team mainly focussed on developing a product and process plan and conducted the following activities:

- Material and Process class for key component
- Product architecture.
- Assembly Concept

Material and Process classes for Key Components

Selecting the right material and process for major components can be a key consideration in developing a successful product and process plan. Process first or material first approach can be adopted for product development [2.]

In the case of automatic toilet seat cleaner, the team adopted the process first approach as the main objective was to develop a first working prototype for concept demonstration. The process first approach for automatic toilet seat cleaner is shown in Fig. 7.1

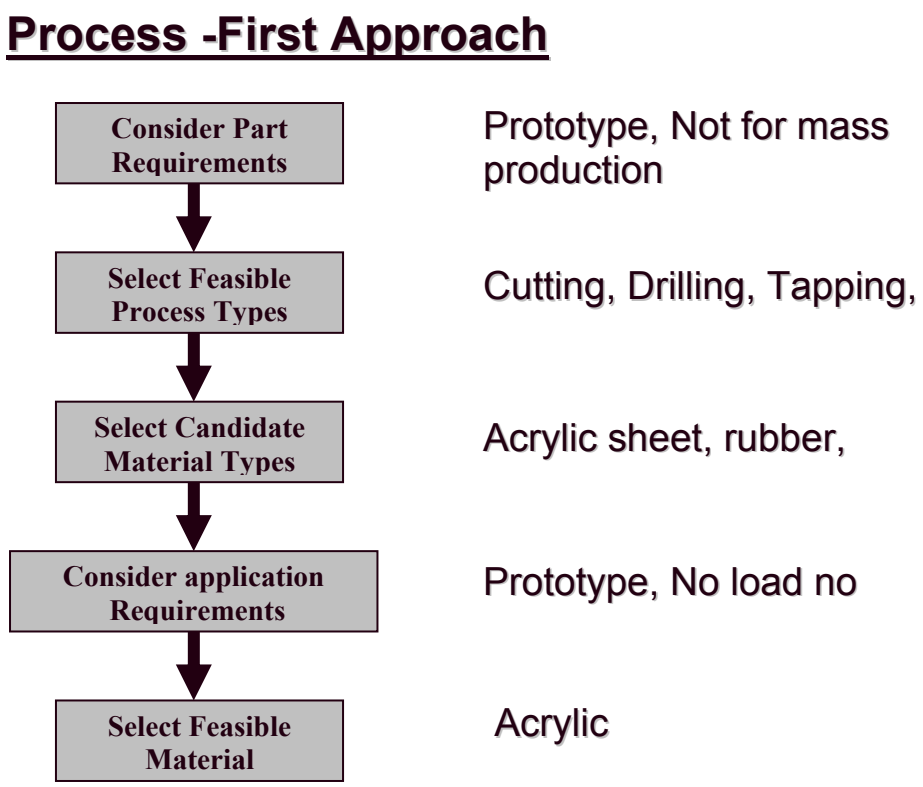


Fig. 7.1 Process first approach for Toilet seat Cleaner

Product Architecture

Product architecture is a scheme by which functional elements of the product are arranged into logical groupings of physical elements called chunks [1]. Functional elements are the individual operations and transformations that contribute to the overall performance of the product. Physical elements are the standard and designed parts that that implement the product function. A carefully planned product structure makes it possible to easily customize and evolve the product to meet the customer requirements.

The product architecture consists of the following steps:

a. Create a schematic of the product
b. Cluster the elements of the Schematic
c. Create a rough geometric lay out
d. Identify fundamental and incidental interactions

The product architecture for automatic toilet seat cleaner is shown below.

Step 1: create a schematic of the product

A schematic is a diagram which represents the team's understanding of the constituents elements of the product [1].

Schematic of Toilet Seat Cleaner is shown in Fig.7.2.

The schematic shown in Fig. 7.2 shows the team's best understanding of the product but it does not contain detail information of the sequence of operation and shows only the broad out line of how the product will function.

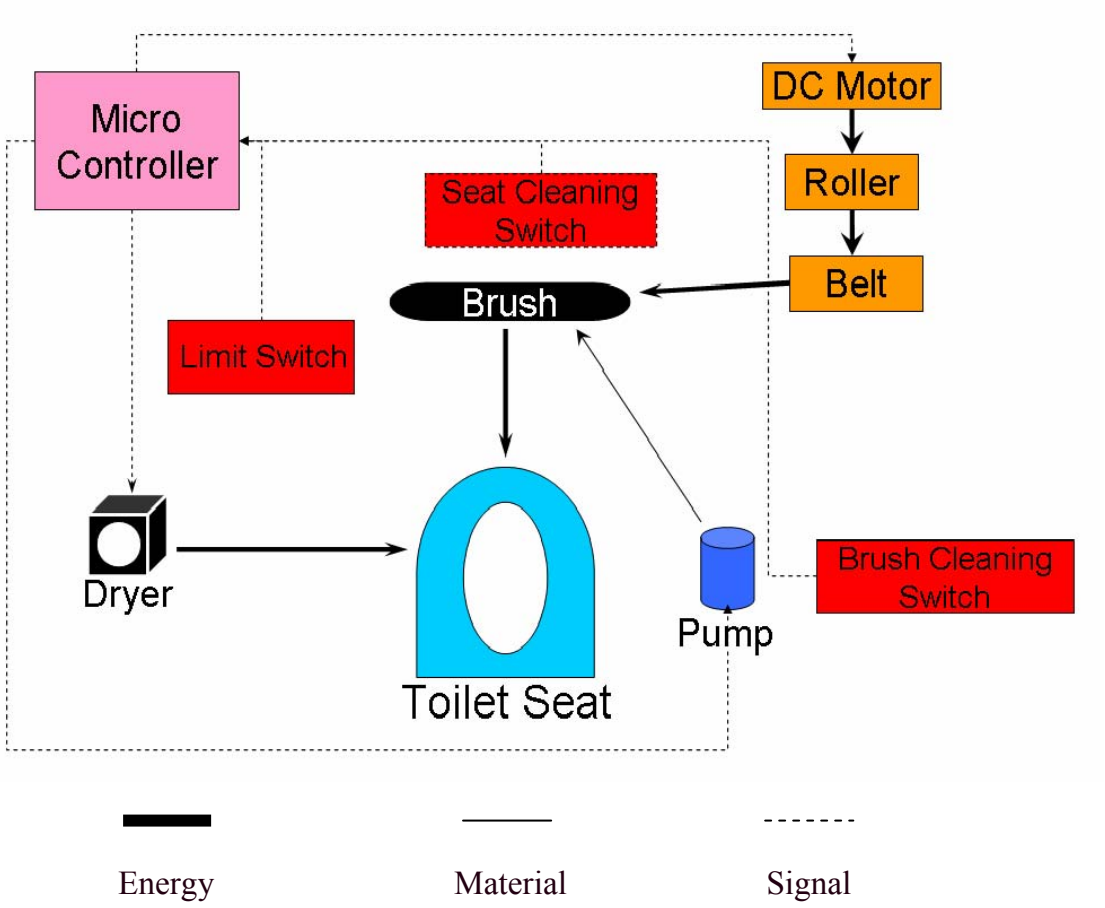


Fig. 7.2 Schematic of Toilet seat Cleaner

The sequence of operation of the toilet seat cleaner starts automatically when the cover assembly covers the toilet seat. At this stage, the DC motor drives the brush on belt mechanism to clean the toilet seat. After that, the belt mechanism will stop when the brush touches the limit switch. Then dryers operate for five seconds automatically to dry the toilet seat. In the final operation, when the cove assembly is lifted to its initial position, the brush cleaning system operates automatically to clean the brush.

Step 2: Cluster the elements of the Schematic

Clustering of the elements is shown in Fig 7.3. The clustering of the elements for toilet seat cleaner is based on:

a. Function sharing
b. Similarity of production technology
c. Portability of interfaces

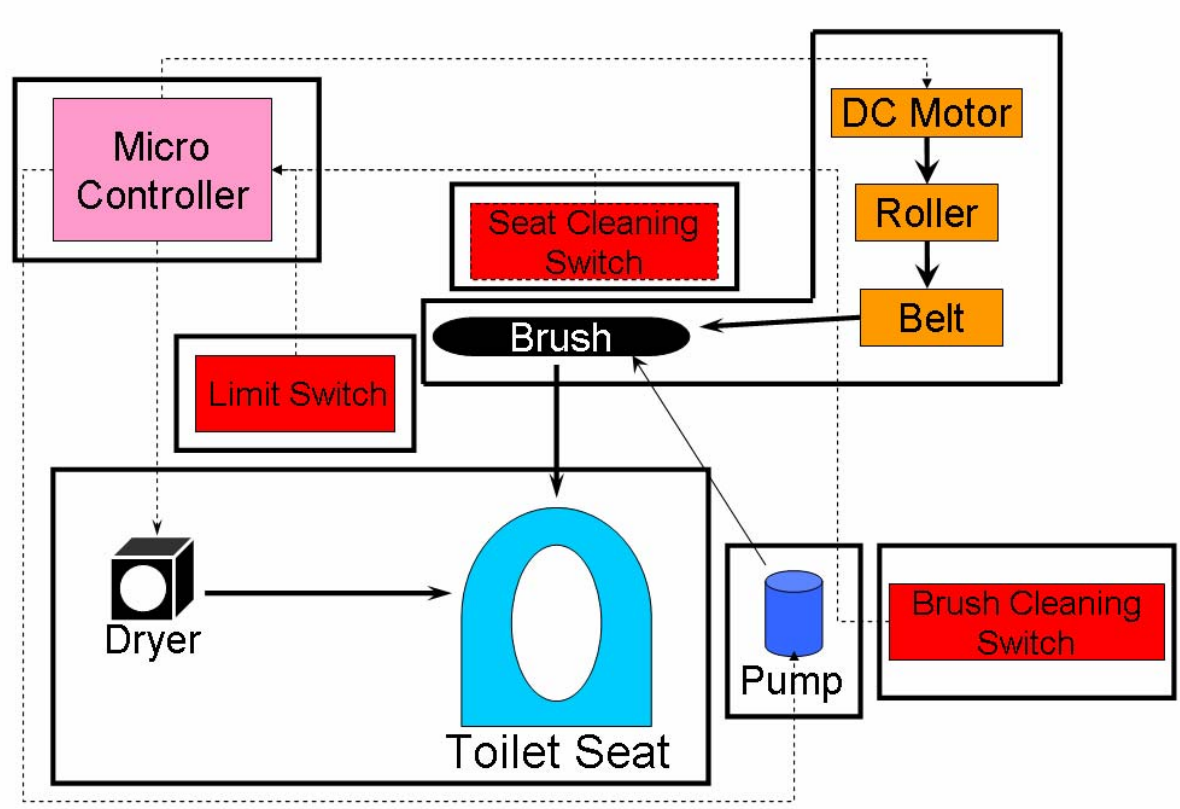


Fig. 7.3 Schematic of Toilet seat Cleaner

Step 3: Create a rough Geometric layout

A geometric layout was created to work out the basic feasible relationships among chunks.

The rough geometric layout is shown in Fig. 7.4

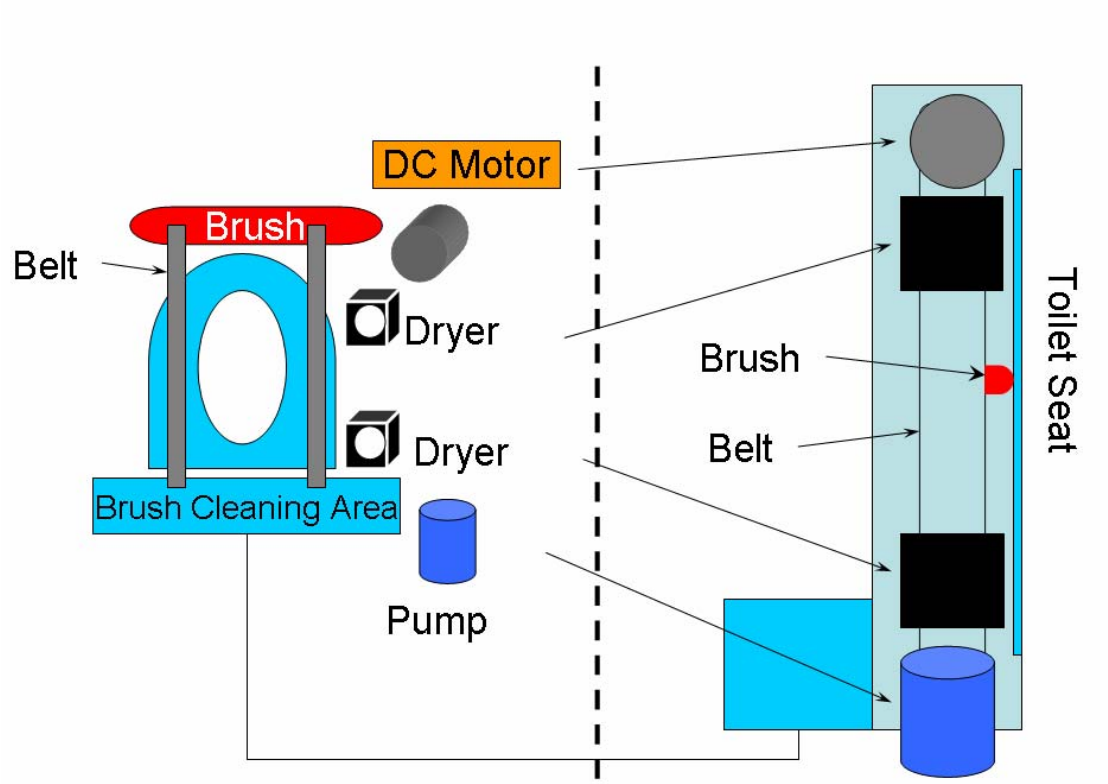


Fig. 7.4 Rough Geometric Layout Toilet seat Cleaner

Step 4: Identify Fundamental and incidental interactions

The fundamental interactions are those corresponding to the lines on the schematic that connect the chunks to one another [1]. The complete computer program compiled in Basic Stamp 2 for controlling the operations of the toilet seat cleaner is mentioned in Appendix-A [5].

The incidental interactions are those that arise because of the physical implementation of functional elements or because of the geometric arrangement of the chunks. The incidental interaction graph of the toilet seat cleaner is shown in Fig 7.5. For example, the brush moving mechanism may

malfunction and the moving force to move the brush may not be enough. The force on the limit switch may not be enough to stop the brush at the right position for cleaning with water. The pump may not produce enough pressure to adequately clean the brush, etc. The incidental interactions shown in Fig. 7.4 helped the team to understand the challenges in the development of the prototype toilet seat cleaner.

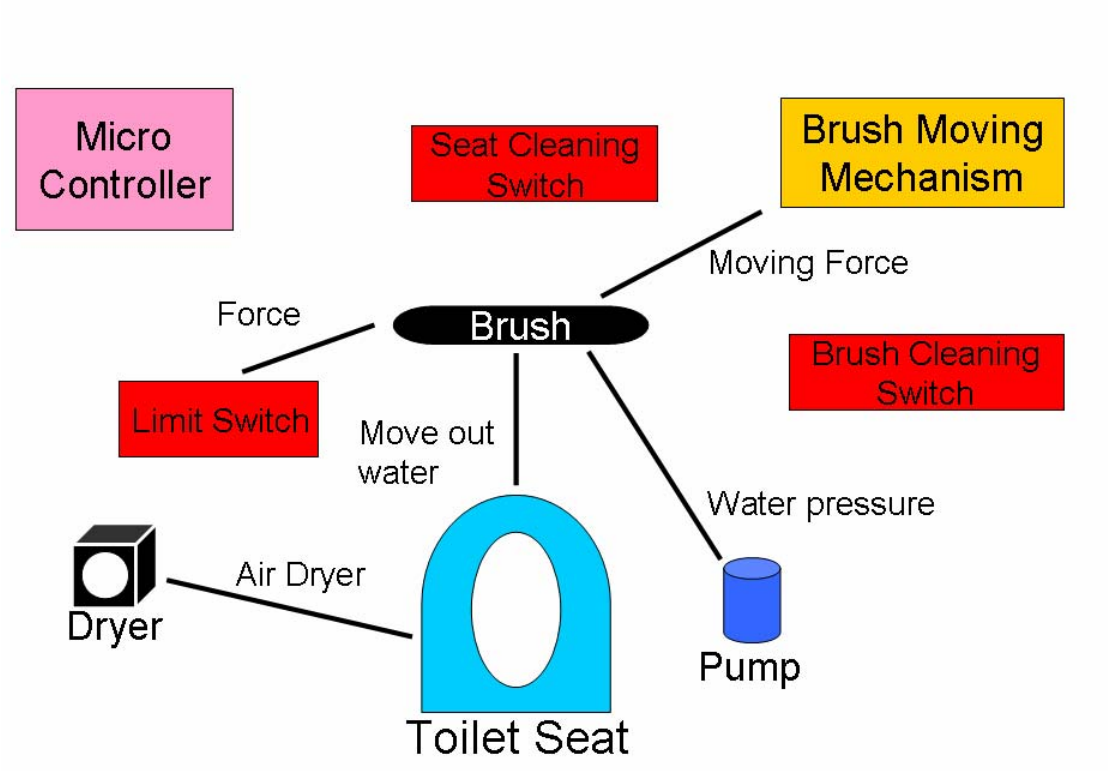


Fig. 7.5 Incidental interactions Graph of Toilet seat Cleaner

Assembly Concept

The way the components are assembled together to form the final product is determined by the assembly concept [2]. An assembly comprises of two parts

a. Assembly structure
b. Assembly Plan

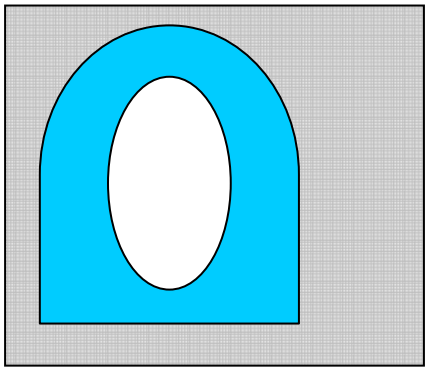
Assembly structures include frame based assembly structure, base component construction, stacked construction and building block construction, etc.

In case of automatic toilet seat cleaner, Assembly structure is frame based assembly structure because first frame is made from the acrylic sheet and then components are installed on this frame .

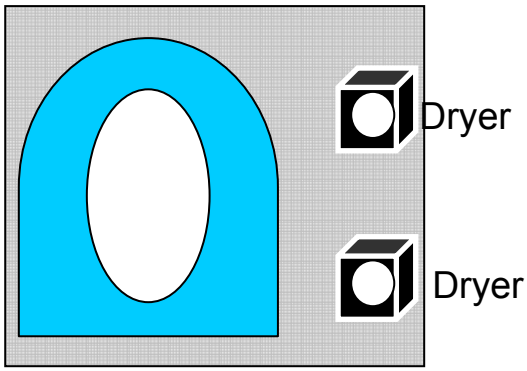
Assembly plan specifies the sequence in which the components/ chunks are assembled and how the components are to be handled, inserted, retained and inspected during assembly [2].

The assembly sequence of Toilet seta cleaner is as follows:

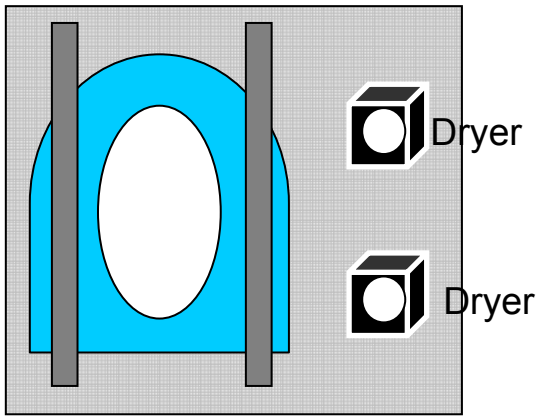
Step 1: Cut toilet seat and Cover plate for cover Assembly from Acrylic sheet



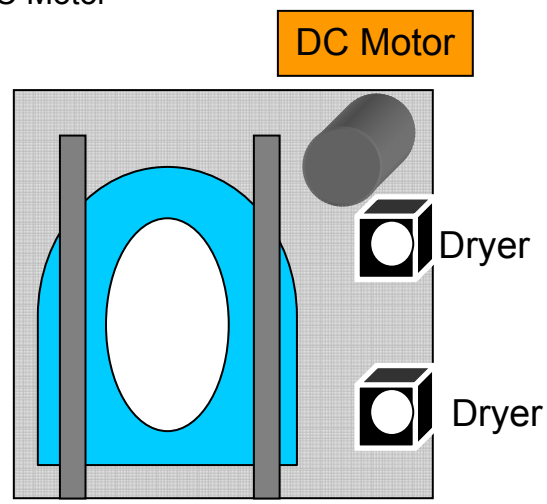
Step 2: Install Dryers



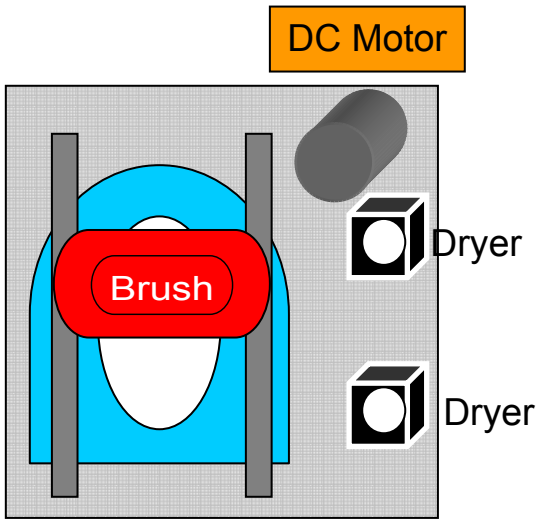
Step 3: Install belt driver mechanism



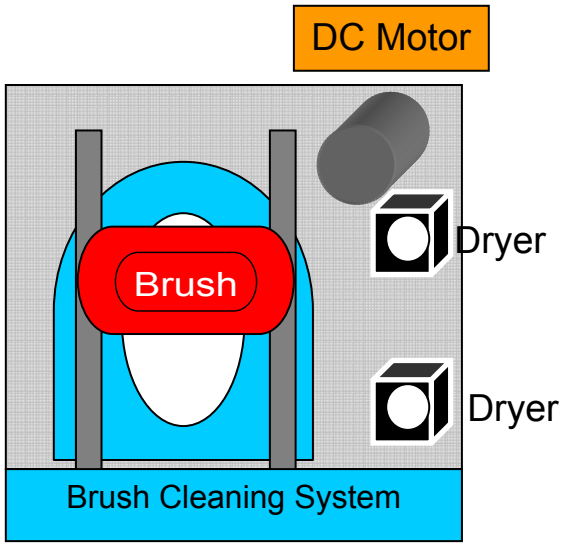
Step 4: Install DC Motor



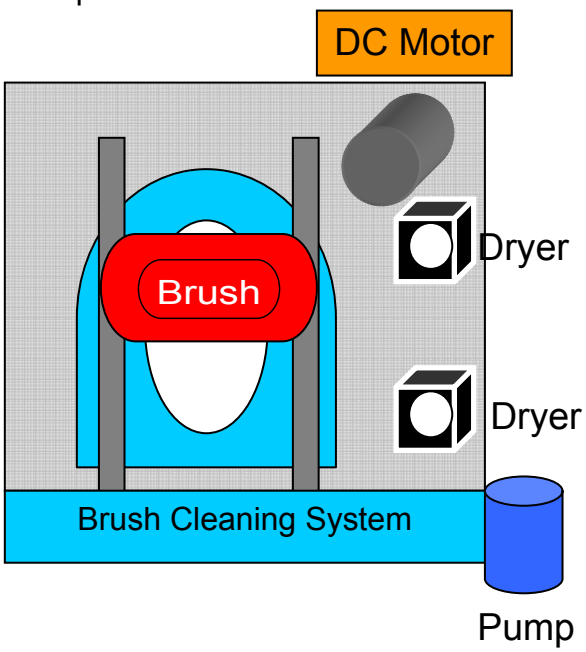
Step 5: Install Brush



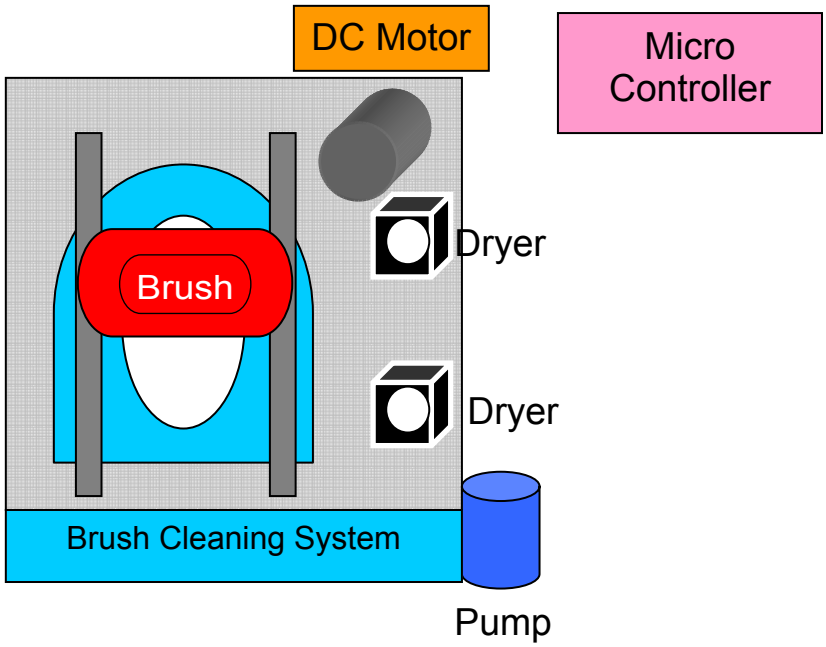
Step 6: Install Brush Cleaning System



Step 7: Install Pump



Step 8: Connect DC motor, Dryer and Pump to Micro Controller and install limit switch



SECTION 8

MANUFACTURABILITY IMPROVEMENT ANALYSIS

8.1 General

This is a systematic approach for seeking to eliminate parts and processes, simplifying the parts and processes that remain, and standardizing where possible to improve the existing product or proposed design [2].

The manufactuability improvement method involves the following four step procedure [2]:

1. Gather Information: Obtain information
2. Analyze: Determine improvement opportunities
3. Create: Redesign the product
4. Refine and Optimize: Developed improved concepts

8.2 Manufacturability analysis worksheet for Automatic Toilet seat cleaner

The complete part list of the toilet seat cleaner is shown in table 8.1

Sr. No	Nomenclature	Qty
1.	Cover Box Assembly	7 plastic sheets
2.	Toilet seat	1 plastic sheet
3.	Screws for Cover Box Assembly	25
4.	Hinges for Cover Box	2
5.	Screws for assembling toilet seat with the cover box	4 Screws
6	Hinges for assembling toilet seat with the cover box	1
7	Locking system	4 Screws+2 Locking system items
8	A 12Vdc Pump assembly set+2 Screws for install with cover box	1 + 2 screws
9.	Connector set between motor and belt driving system	2
10	Belt driving mechanism (2 Belts+4 Roller sets+2 Crank shafts	-
11	Set of Bearing system	3
12	Dryer systems (Including 4 Screws for installation)	2
13	Brush Slot (Including 2 cable ties for installing with the belt)	1
14	Brush	1
15	Limit Switch (1 Screws and 2 Supporting Items)	1
16	Brush Cleaning system (1 Slot+1 Tube+ 2 Set of Installing item with the cover box)	1
17	Tube for supply the water	1
18	Tube for drain water	1
19	Switches (one for start clean toilet seat and one for Brush Cleaning system)	2
20	Resistors (10K Ohm)	3
21	Parallax Micro controller Science Box Set	(1 Set)
22	Adapter(220 VAC - 12 VDC)	4

Table 8.1 Part list for Toilet Seat Cleaner

The manufacturability analysis worksheet is shown below

			Assembly				Part Elimination				Assessment			
1	2	3	4	5	6	7	8				9	10	11	12
Part name	**Quantity**	**Type**	**H**	**I**	**S**	**C**	**Motion**	**Material**	**Assembly**	**CFE**	**V**	**M**	**UI**	**Notes**
Cover Box Assembly	1	3	0	0	0	0	N	N	Y	0	0	+	0	
Toilet seat	1	2	+	+	+	-	Y	N	Y	0	1	+	0	
Placement of Dryer systems	2	3	0	0	0	0	N	Y	Y	0	2	0	0	
Screws for installation of dryers	4	1								**4**				
Placement of Belt mechanism	1	3	-	-	0	-	Y	Y	Y	0	3	0	-	
Placement of DC Motor	1	2	0	0	0	0	N	Y	Y	0	2	0	0	
Screws for Cover Box Assy	25	1								**25**				
Assemble side walls	1	0								**1**				
Hinges for Cover Box	2	1								**2**				
Screws for assembling toilet seat	4	1								**4**				
Hinges for assembling toilet seat	1	1								**1**				
Mount Brush on Belt System	1													
Install cleaning system Assy	1	3	-	-	-	-	N	Y	Y	0	3	-	0	
Place back and Top Plates	2	2	0	0	-	0	N	Y	Y	0				
Locking system Assy	1	3	0	0	0	0	N	N	N	**1**	2	0	0	
A 12VDC Pump assembly	1	3	0	0	0	-	N	Y	Y	0	2	0	0	
Screws to install 12VDC Pump	2	1								**2**				
Limit Switch	1	2	0	0	0	-	N	Y	Y	0	2	0	0	
Switches	2	2	0	0	0	-	N	Y	Y	0	2	0	0	
Parallax Micro controller Box Assy	1	3	0	0	0	-	N	Y	Y	0	2	0	0	
Adapter(220 VAC - 12 VDC)	4	3	0	0	0	-	N	Y	Y	0	2	0	0	

Fig. 8.1 Manufacturability Analysis Worksheet

$$\text{Count ratio} = \frac{\sum Qty - \sum CFE}{\sum Qty} = \frac{59 - 40}{59} = 0.32$$

Separate Fastener Ratio $= \frac{\sum Type1}{\sum Qty} = \frac{6}{59} = 0.10$

Separate Operation Ratio = $\frac{\sum Type0}{\sum Qty} = \frac{1}{59} = 0.01$

Value Ratio = $\frac{\sum (2\ \&\ 3 ValueRatings)}{\sum Qty} = \frac{10}{59} = 0.169$

From the manufacturability analysis, it can be seen that all fasterners and separate operations are candidate for elimination.

In the case of making toilet seat cleaner, the fastenenrs and screws were not eliminated since it was first prototype and the intended purpose in mind of the team was to siccessfully dempnstrate the concept. Nontheless, the manufacturability ananlysis will be useful during industrialization and production phase of the toilet seat cleaner.

SECTION 9

PROTOTYPING

9.1 General

Prototype is defined as the approximation of the product along one or more dimensions of interest. [1].

Prototypes are used for four purposes [1]:

1. Learning : Will it work
5. Communication: Look and feel
6. Integration: Components work together
7. Milestone: Achievement

9.2 First prototype of Automatic Toilet seat cleaner

The first and foremost purpose of making the first prototype of toilet seat cleaner was learning. The team wanted to know

a. will it work
b. How well does it meets the customer needs

Virtual Prototyping

As a first step, virtual modeling of the prototype was done. The virtual prototype of toilet seat cleaner with accessories is shown below:

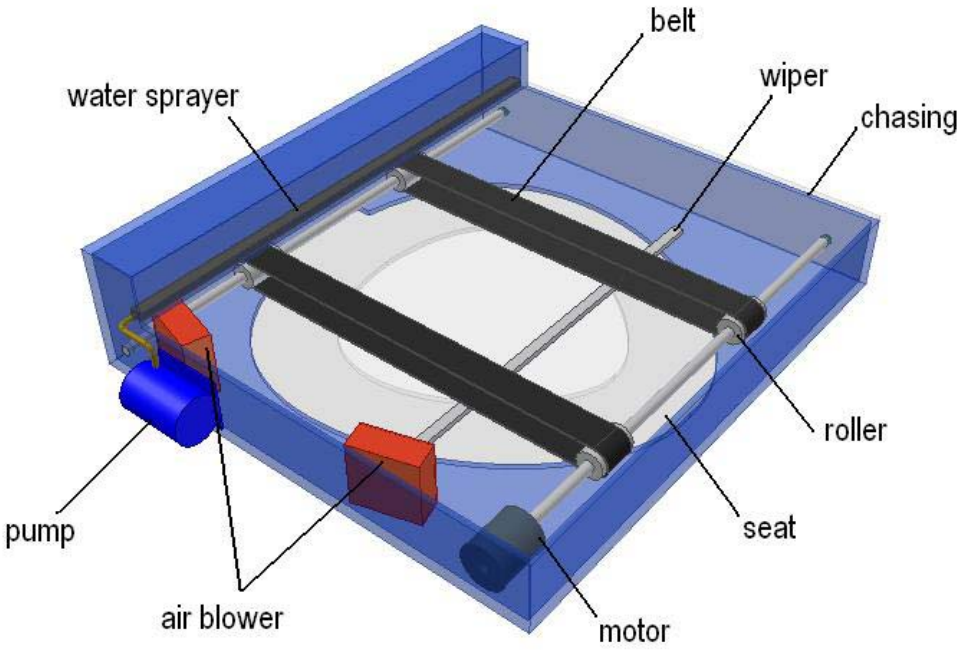


Fig. 9.1A Virtual Prototype Toilet seat Cleaner

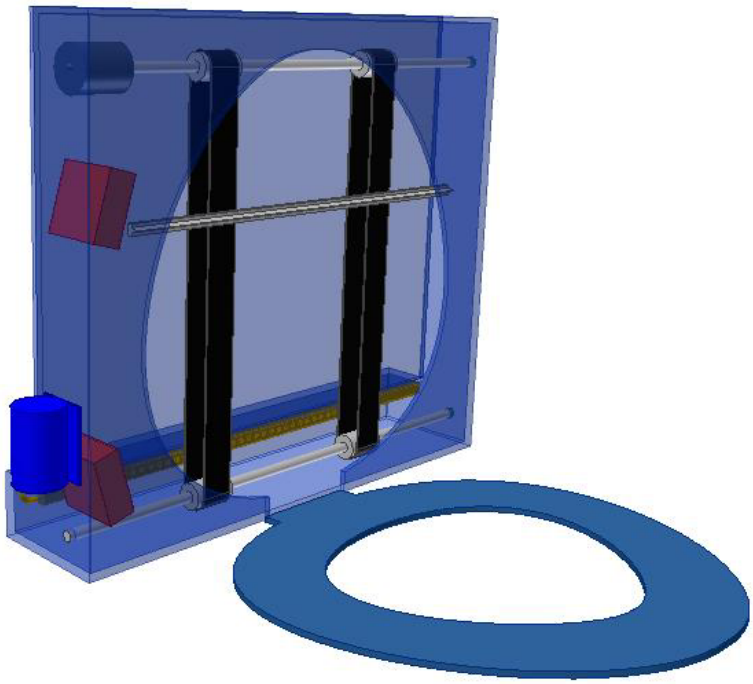


Fig. 9.1B Virtual Prototype Toilet seat Cleaner

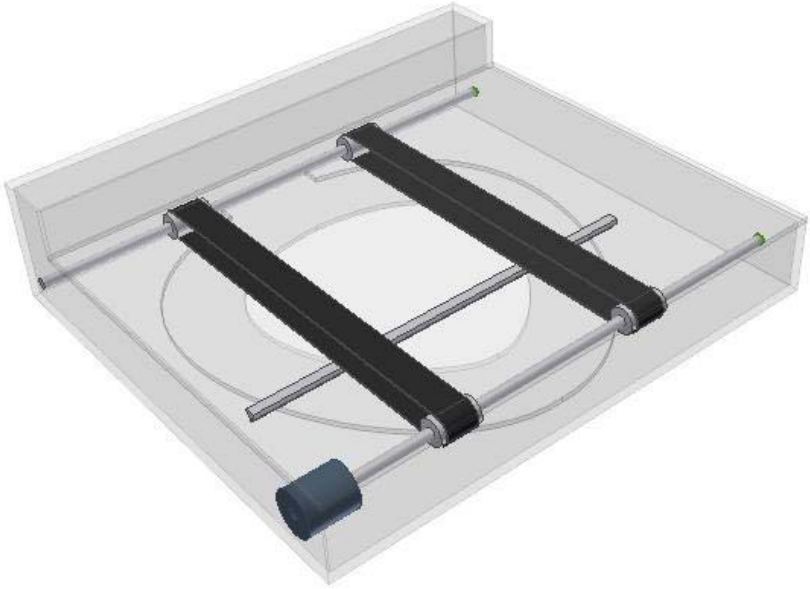


Fig. 9.2 Cleaning Mechanism

Fig. 9.3 Belt Drive mechanism

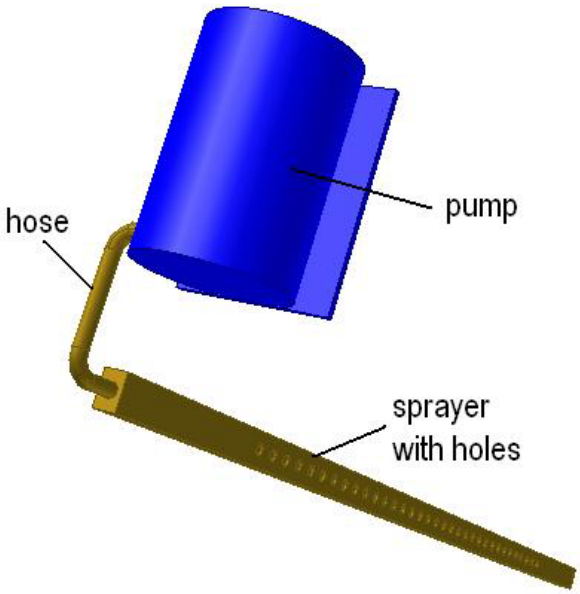


Fig. 9.4A Water Sprayer

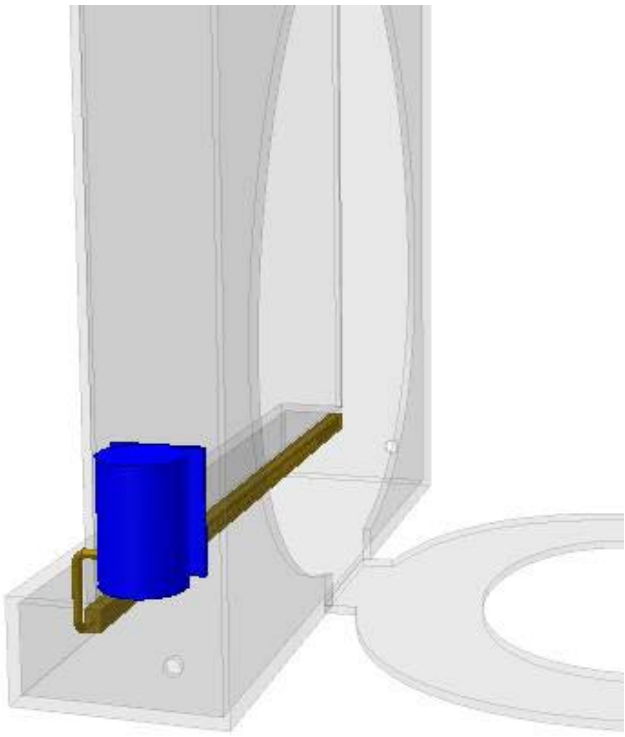
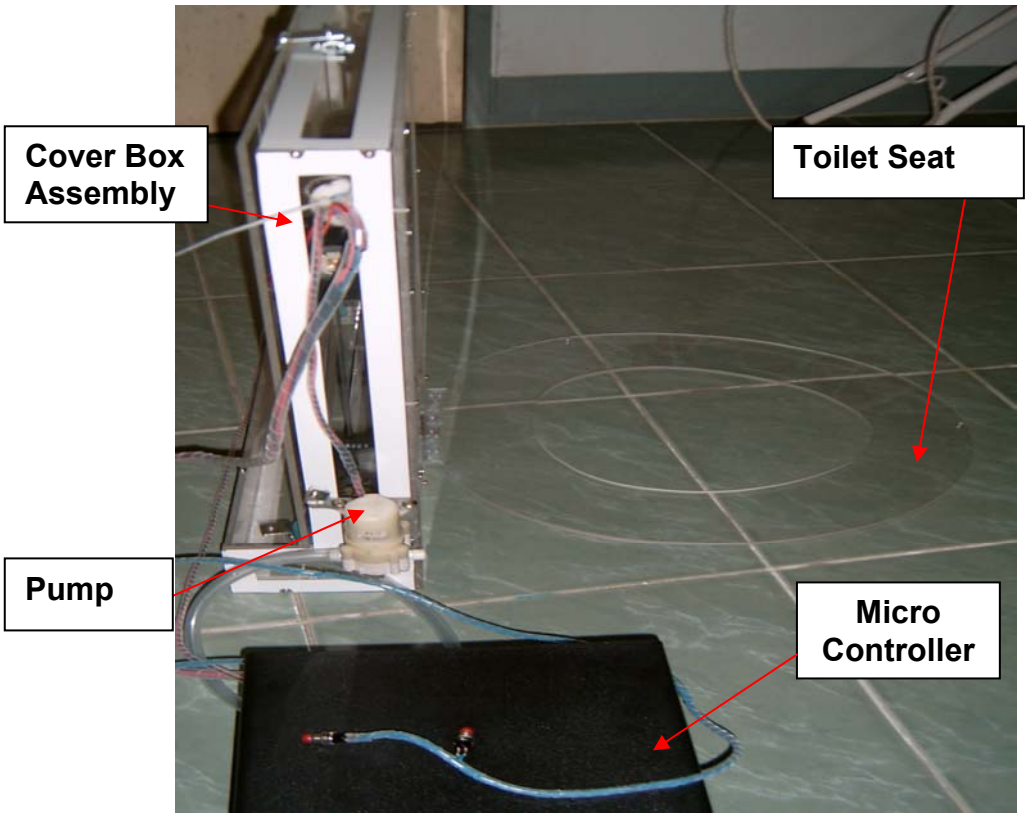


Fig. 9.4B Water sprayer

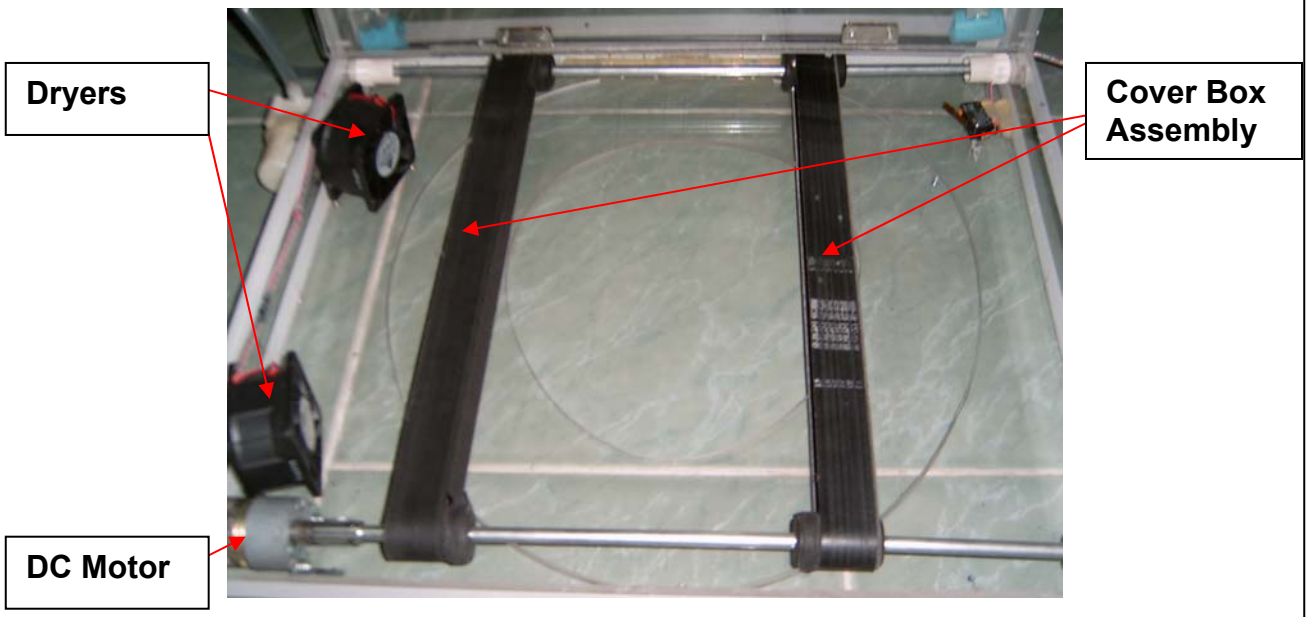
The 2-D drawing of cover and toilet seat is shown in Appendix- “B”.

Physical Prototyping

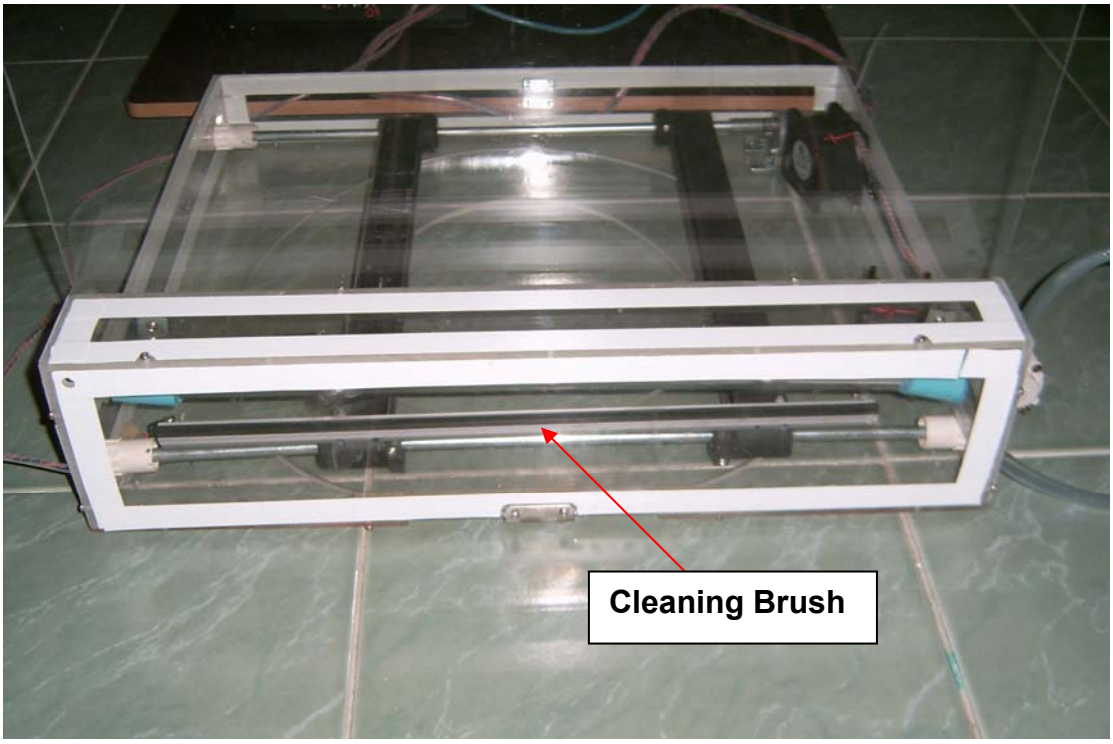
The photographs of the first working prototype toilet seat cleaner are shown as under:



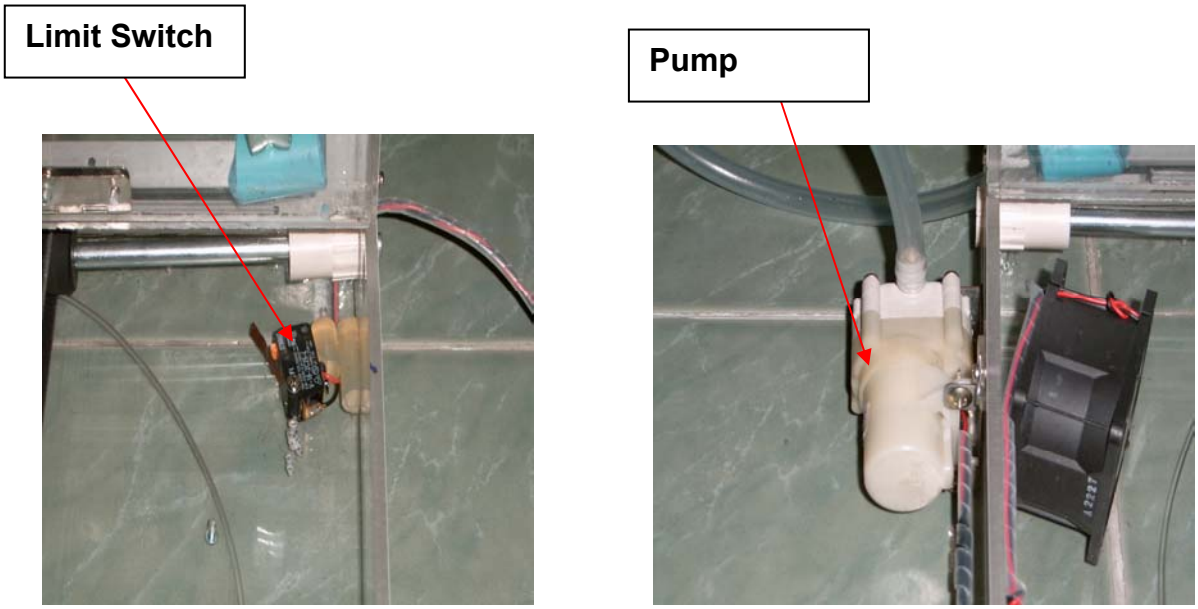
Photograph 1 – Prototype Toilet seat Cleaner



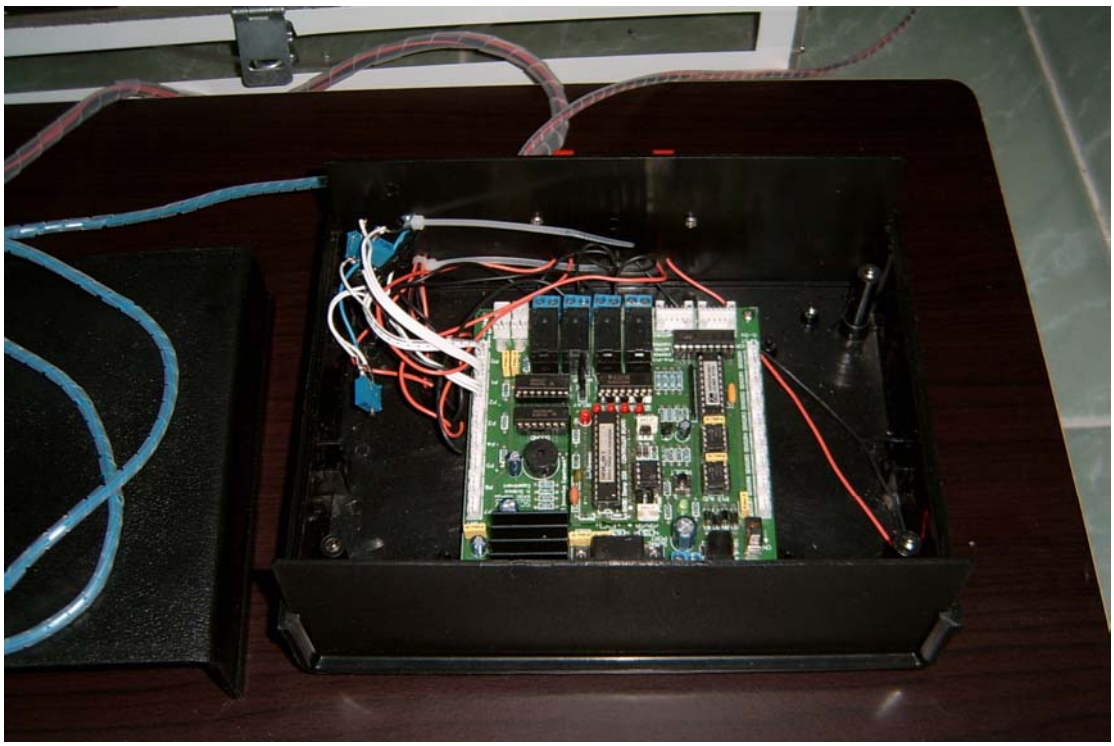
Photograph 2 – Prototype Toilet seat Cleaner



Photograph 3 – Prototype Toilet seat Cleaner



Photograph 4 & 5 – Prototype Toilet seat Cleaner



Photograph 6 – Micro Controller for Prototype Toilet seat Cleaner

SECTION 10

CONCLUSIONS

In this project, the team developed the design and development of automatic toilet seat cleaner by considering the generic phases of product development mentioned in section 1 and referred in reference [1]. The mission statement of the project was defined first to serve as a guide line during product development phases. To identify customer needs, the project team started by gathering raw data from customers. After getting voice of customers, the data was translated in terms of customer requirements. The relative importance of needs was appropriately allocated to each need on a scale of 1-5. To build the House of Quality, the team developed a list of metrices for each of the customer needs to establish the relationship between the needs of the customers and the product characteristic (in engineering terms). The HOQ for automatic toilet seat cleaner showed that the characteristics of “dry test” received the highest overall weighting of 186 followed by “provision to operate the cleaning system sitting on the toilet seat” characteristic which received the second highest weighting of 138. The third highest characteristic was “position of the system” which received an overall rating of 132. Therefore it was concluded that improving these three characteristics would lead to customer satisfaction. For concept generation, the team came up with the five design concepts. Concept combination table was used for systematic exploration of different design concepts. Finally the concept scoring matrix was used for concept selection in which concept 3 (**Cleaning head moves over the seat and use a wiper and dryer)** received the highest score of **372**. All other concepts remained below the score of concept no 1. Therefore, Concept 3 was finally chosen as the best design for automatic toilet seat cleaner.

For the design and developemnt of Automatic toilet seat cleaner, the team mainly focussed on developing a product and process plan and conducted the following activities:

- Material and Process class for key component
- Product architecture.
- Assembly Concept

In manufacturability analysis, manufacturability analysis work sheet was prepared for systematic approach to eliminate parts and processes to simplify the parts.

In the final phase, the prototype toilet seat cleaner was prepared and successfully demonstrated in the lab.

SECTION 11

RECOMMENDATIONS FOR IMPROVEMENT

The prototype automatic toilet seat cleaner is a frist attempt to successfully demonstrate its functioning to meet key customer need mentioned in section 3 and 4.

Within the budget and time constraints, the team successfully came up with a working prototype of the toilet seat cleaner for concept demonstration. However the existing prototype has some inherent limitations which can be improved in future work. The main area of improvement are:

a. Use of stepper motor in instead of DC motor to control the movement of cleaning head.

b. Use of timing belt for precision movement and position control of the cleaning head.

c. Eliminate fasteners for ease of assembly. Consider one or two piece plastic injection moulding for cover assembly.

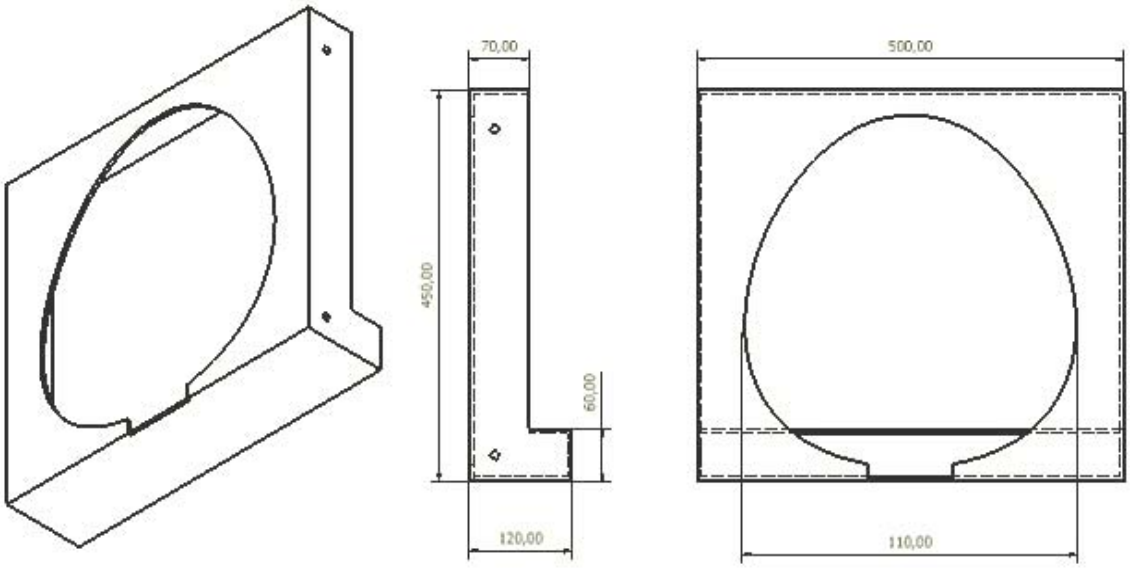
APPENDIX -A

COMPUTER PROGRAM FOR CONTROLLING THE SYSTEM

```
' {$STAMP BS2sx}
' {$PBASIC 2.5}
' {$PORT COM4}

SWITCH01    CON 0           'Connect SWITCH at P0
SWITCH02    CON 1           'Connect SWITCH at P1
SWITCH03    CON 2           'Connect SWITCH at P2
SW_VAR01    VAR Byte        'Switch variable for BUTTON command
SW_VAR02    VAR Byte        'Switch variable for BUTTON command
SW_VAR03    VAR Byte        'Switch variable for BUTTON command

PAUSE 500                   'Delay 0.5s for pheripheral initialize
DIRC=%1111                  'Force P8-P11 as OUTPUT

LOOP1:
BUTTON SWITCH01,1,255,0,SW_VAR01,0,LOOP1    'Get switch01 , one time
LOOP2:
OUTC=%0001                                  'On the DC motor
BUTTON SWITCH02,1,255,0,SW_VAR02,0,LOOP2    'Waiting signal from limit switch
OUTC=%0000                                  'Of the DC motor
PAUSE 100                                   'Delay for some time
OUTC=%0010                                  'On the Drying system
PAUSE 5000                                  'Duration of the Drying system
OUTC=%0000                                  'Off Drying system
LOOP3:
BUTTON SWITCH03,1,255,0,SW_VAR03,0,LOOP3    'Waiting the signal from Wiper
                                            cleaning switch
OUTC=%0100                                  'On the Wiper cleaning system
PAUSE 5000                                  'Duration of Wiper cleaning system
OUTC=%0000                                  'Stop the Wiper cleaning system
GOTO LOOP1                                  'Go to the first step
```

APPENDIX -B

2-D DRAWING OF COVER & TOILET SEAT



References

[1] K.T. Ulrich, and S.D. Eppinger, Product Design and Development, McGraw-Hill, 2004

[2] H. W. Stoll, Product Design Methods and Practices, Marcel Dekker, 1999

[3] Karin Bergquist, John Abeysekera , Quality Function Deployment- A means of producing sustainable products, Division of Industrial Ergonomics, Luleh University of Technology, S-971 87 Lulea, Sweden, International Journal of Industrial Ergonomics 18 (1996) 269-275

[4]M. L. Shillito, Advanced QFD Linking Technology to Market and Company Needs, John Wiley&Sons, 1995

[5] Vorapot K., Chaiwat L., SCI-BOX Microcontroller in science experiment, Innovative Experiment, 2001