

Systems Engineering Analysis of Reusable Cups to Increase the Reusable Cup Usage at ANU

ENGN2226 Systems Analysis

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1.0 Abstract

The reusable cup provides an environmentally friendly alternative to a conventional single-use paper cup. A sustainable campus at ANU can be achieved by increasing the usage of reusable cups and easing the landfill burden created by disposable coffee cups. The main focus of this portfolio is to suggest recommendations to inefficiencies in the system from various engineering perspectives. Recommendations suggested include optimising the sizes of reusable cup, making smarter material choice to reduce environmental impacts, energy losses and heat hazards, introducing economic incentive programs, a feedback system and storage shelves in stores to encourage and reinforce the behaviour of using reusable cups.

2.0 Introduction

Due to the massive amount of disposable cups contributed to landfill in Australia, this portfolio aims to increase the usage of reusable cups at the Australian National University (ANU) campus. The engineering approach is applied to suggest recommendations from different engineering perspectives toward the overarching objective. Currently, more than 1 billion single-use coffee cups are consumed each year in Australia, generating over 7,000 tonnes of waste goes to landfill which requires over 50 years to decompose (University of Queensland, 2013). As students and staff members at university become more dependent on caffeine in coffee for a boost of energy during the day to help increase their capacity to get more done in less time, there is an undeniable increase in consumption of single-use coffee cups. Although single-use coffee cups are getting more biodegradable and environmentally friendly, conventional paper cups made from cardboard with a thin layer of plastic are still widely used at ANU campus. In order to ease the landfill burden created by single-use coffee cups, increasing the usage of reusable cups is the ultimate solution for a more sustainable university campus.

2.1 Problem Scope

This portfolio analysed the most popular reusable cup designs in the market. Any disposable coffee cup, including 100% recyclable or biodegradable paper cup, is considered external of the system and hence excluded from the analysis. The portfolio focused on highlighting inefficiencies and underpinning problems that caused low reusable cup usage at ANU campus.

3.0 Qualitative and Quantitative Methods

Existing data and survey responses are gathered and analysed to understand the experiences and problems an ANU member has when ordering with a reusable cup. Information about the current practice of reusable cups and the potential criteria that determine one's choice of cup are also discovered and evaluated.

3.1 Qualitative Methods

A well-known report on reusable versus disposable cups conducted by Martin Hocking at the University of Victoria, Canada in 1994, suggested that one's choice between disposable and

reusable cups may be freely based on convenience and aesthetic criteria of the product rather than environmental or energy influences.

Based on the survey responses collected by Hocking, most coffee drinkers prefer disposable cups over reusable ones due to their attributes of convenience and lower unit cost (Hocking, 1994). The difference in the level of convenience between the two cup types made obvious in situations when the user commute to work by car or transport, or rushing between meetings or lectures. It definitely not the most attractive option to use a reusable cup that requires cleaning when the user is in a rush, regardless of the consumer's desires to be eco-friendly. Therefore the biggest problem with the reusable cups is that they do not fit within a coffee drinker's existing routine due to a lower level of convenience as compared to current practice of disposable coffee cups.

3.2 Turning Qualitative to Quantitative

Convenience is evidently contributed to system failure, however it is often undefined and difficult to measure. The level of convenience of a product is a subjective measurement. Since the underpinning notion of convenience is to make a task or activity better, easier, simpler, faster for consumers without sacrificing all favourable properties of the product, the level of convenience can be measured as the amount of time invested to successfully execute a task, number of executive steps involved in the process, and easiness and comfortability of the cup type (Anderson, 2013). Detailed analysis of the amount of time invested and the number of executive steps throughout the system are conducted in Time Analysis in section 7.0. It is important to highlight that all parties involved in the process of coffee production, delivery and consumption using a reusable cup are considered as part of the system, and hence the level of convenience should also be considered from their perspectives. Easiness and comfortability of a product is analysed in Human Factor, section 4.0.

3.3 BotE Estimation

According to Australian Bureau of Statistics, coffee is consumed by around one in three (34%) people aged 19 to 30 years; the median age range of population at ANU campus (Australian Bureau of Statistics, 2014; Australian National University, 2013). Assuming ANU has similar population as in 2013, there are 21,113 students and 3,753 staff members, which form a total population of 24,866 (Australian National University, 2013). Hence there are approximately 8,454 coffee drinkers at ANU. Of the coffee consumed by these coffee drinkers, on average one-third were made from ground coffee while the rest were made from instant coffee powder, however these two groups of coffee drinkers use their reusable cups in a similar way (Australian Bureau of Statistics, 2014).

3.4 Error

The average number of coffee drinkers at ANU are estimated using statistics provided by Australian Bureau of Statistics (ABS) in 2014, which may not perfectly represent the "true" value for the entire ANU population. However, it provides an initial insight into the size and general characteristics of the potential customer base and targeted audiences for which the analysis of this portfolio is focused on. Therefore the information provided by ABS remain valid and applicable to this portfolio.

3.5 Key Outcomes

Based on existing data and survey responses, the biggest problem with reusable cups is that they do not fit within a coffee drinker's existing routine due to a lower level of convenience as compared to current practice of disposable coffee cups. One way to increase the level of convenience is to make tasks and activities in the system easier, simpler and faster for customers without sacrificing all favourable properties of the product.

4.0 Human Factors

As the quality of a system is wholly determined by their ability to meet participants' needs and expectations, potential human-related issues of the system are explored and analysed in detail from the perspectives of ergonomics and human safety and comfortability.

4.1 Ergonomics

Reusable cups in the market come in various sizes, which made it difficult for the coffee makers to control the extraction time and the coffee-to-water ratio. Inconsistent size of reusable cups not only leads to frustrated baristas, but also increases the likelihood for the baristas to drop and break the cup if the cups are too big to fit under the coffee machines, causing undesired injuries.



Figure 1, available sizes of KeepCup mimicked the size of standard disposable coffee cups (KeepCup, 2013).

In order to reduce the interruption of a busy coffee maker's production line, reusable cup manufacturers such as KeepCup have mimicked the size of standard disposable coffee cups, as shown in Figure 1 above. Although the size of coffee cups varies slightly from coffee shops to coffee shops, conventional paper coffee cups are typically 4, 8, 12, 16 and sometimes 20oz (Australia Packaging, 2014). It is recommended that reusable cup producers manufacture their cup in similar sizes as the traditional paper coffee cups to reduce the potential conflicts with coffee drinkers' existing routine and the current practices adapted by coffee makers.

4.2 Human Safety and Comfort

To provide a satisfactory sensation and comfort to the customer, hot beverages such as tea and coffee often required to be served at high temperature, which requires the reusable cup designs to diminish the potential scald burn hazard and maintain an adequate product warmth (Brown & Diller 2007). The level of injury after 4 seconds for step changes in surface temperature of a human hand from 37.8 °C to 87.8 °C is shown in Figure 2, where 37.8 °C is the average temperature of a human body and 87.8 °C is the average serving temperature of a coffee (Brown & Diller, 2008). It is shown

in Figure 2 that the level of injury increases drastically if the surface temperature of a human hand reaches approximately 180 °F or 82 °C. Therefore, to make sure the surface of the cup does not exceed the hazard temperature of 82 °C while ensuring it maintains at the optimal temperature of about 60 °C as long as possible, thermal insulation is recommended to prevent or inhibit the transfer of thermal energy from the coffee to the outer layer of a reusable cup (Brown & Diller, 2008). Other than the commonly used vacuum-insulated or double-wall design, phase change materials (PCMs) and latent heat storage materials that absorb and release heat without rising in temperature themselves are also highly favourable (Zalba, et al., 2003).

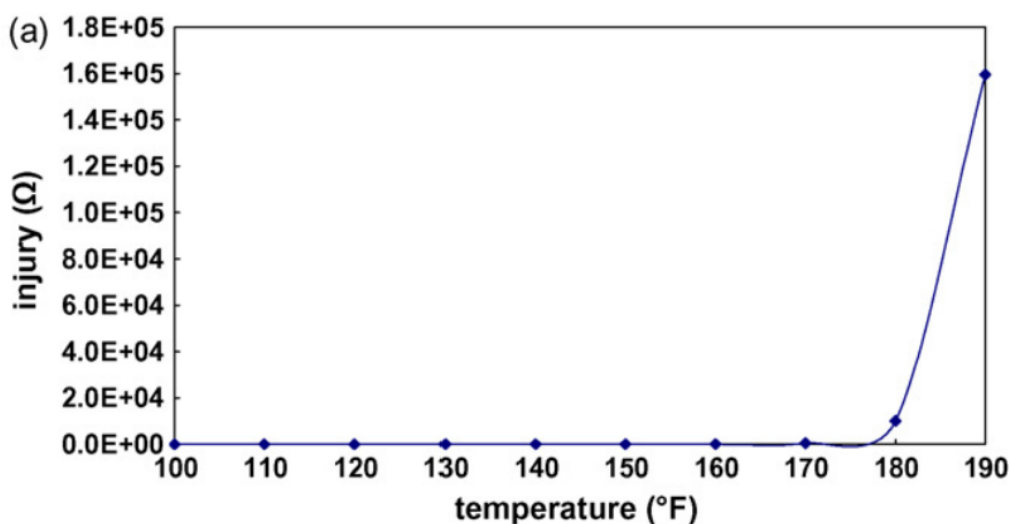


Figure 2, a linear scale of the level of injury after 4 seconds at depth of 0.1875 mm for step changes in surface temperature ranging from 37.8 - 87.8 Celsius (Brown & Diller, 2008).

4.3 Key Outcomes

The sizes of reusable cup are recommended to mimic the standard sizes of single-use paper cup, to reduce unnecessary interruption of a coffee maker's production line. From a human safety point of view, the reusable cup design needs to diminish the potential scald burn hazard and maintain an adequate product warmth.

5.0 Material Analysis

A material analysis is conducted to evaluate the benefits and consequences of commonly used materials on the life-cycle of the reusable cup. The analysis is conducted through comparing the mechanical and thermal properties of the selected materials, evaluating their embodied energy to identify which material provides the smallest environmental impact, and assessing the end-of-life issues related to these materials. The most commonly used materials to make the body of a reusable cup including glass, polypropylene, stainless steel and porcelain, examples are shown in Figure 3. For the following analysis, only the body of the cups are considered, whereas components such as lids, handles, thermal sleeves or other accessories are assumed to be constant for all designs with a capacity of 12oz or 355ml.

5.1 Properties of the Selected Materials

Of the selected materials and their representative designs, the mechanical as well as thermal properties are compared and evaluated. According to JOCO, their reusable cups are made from “high quality, non-porous, borosilicate glass”, which gives the cup characteristics of being lightweight, resistant to extreme change in temperature and microwave and dishwasher safe (JOCO, 2015). Reusable cup made with glass ensures the taste of the coffee is unaffected but increases the likelihood of breaking when it inevitably meets the ground. The Alchemy series of KeepCup as the most popular reusable cup in Australia used BPA and BPS free polypropylene #5 for its main body; this type of material is commonly known as thermoplastic polymer (KeepCup, 2015). The importance of using BPA and BPS free materials is discussed in the End-of-Life Issue in section 5.3. Polypropylene products are commonly stabilised with an antioxidant for them to be more durable, tough, and chemical resistant. Although polypropylene #5 is recyclable, it is generally not readily biodegradable and hence a relatively large amount of energy is required to recycle this type of products (Malpass & Band, 2012). Like most reusable cups that are made with stainless steel, Cheeki stainless steel coffee cup requires a double-wall insulation design to keep the coffee hot for longer, due to the relatively high thermal conductivity of 304 stainless steel used (Cheeki, 2013; Pitts & Sissom, 1991). The thermal conductivity of 304 stainless steel under 300 °C is approximately 15 W/m*K, approximately 15 time higher than borosilicate glass and porcelain, and 150 times higher than polypropylene (Pitts & Sissom, 1991). Conventional coffee mugs are typically made of glazed ceramic or porcelain that can withstand an extremely high temperature up to 1,400 °C, with a design of thick walls aims at thermal insulation (Corelle, 2015; Pitts & Sissom, 1991). The evaluation of general properties of these selected materials concluded that a reusable cup with a polypropylene body is, in general, more durable, tough and have the ability to keep the coffee hot for longer.



Figure 3, from the left: 12oz reusable cup made with glass, polypropylene, stainless steel and porcelain body, manufactured by JOCO, KeepCup, Cheeki and Corelle respectively (JOCO, 2015; KeepCup, 2015; Cheeki, 2013; Corelle, 2015).

5.2 Embodied Energy

The embodied energy of each selected reusable cup is summarised in Table 1. It is found that a reusable cup made of glass has a relatively low embodied energy value. It is important to highlight that only the body of cups are taken into account when calculating the embodied energy. In comparison, reusable cup that is made of porcelain has the lowest amount of embodied energy.

Hence it is recommended that coffee drinkers purchase and use reusable cups made with this type of material for the system to be more energy and material efficient.

Table 1, Material and Embodied Energy (EE) Audit of the body of the selected design (JOCO 2015; KeepCup 2015; Cheeki 2013; Corelle 2015; University of Victoria 1994; Cleveland and Morris 2013).

Brands	Material	Weight (g)	Coefficients (MJ/Kg)	EE (MJ)
JOCO	Borosilicate glass	311	10.5	3.27
KeepCup	Polypropylene	97	74	7.178
Cheeki	304 Stainless steel	214	26.5	5.67
Corelle	Porcelain	240	14	3.36

5.3 End-of-Life Issues

With the growing concern of global resource shortages, it is essential to apply a Cradle to Cradle approach to create systems that are not only safe and efficient, but also essentially waste-free. As mentioned in section 5.1, most of the reusable cups in the market are titled to be BPA and BPS free. BPA and BPS, short for Bisphenol A and Bisphenol S, are widely used as a monomer in manufacture of polycarbonates and polyepoxides. These chemicals are endocrine disrupting compounds that can interfere with the normal activity of hormones in human body and lead to adverse health effects (Grignard, et al., 2012). All manufacturers and reusable cup buyers are recommended to produce and purchase BPA and BPS free reusable cups. Although reusable cups are recycled at the end of their lives in most scenarios, using BPA and BPS free materials would reduce the chances of land or water contamination if the products are sent to landfill.

5.4 Key Outcomes

Coffee cup made with porcelain has the lowest embodied energy as compared to the rest of the selected materials, however, porcelain as a ceramic material is non-recyclable (City of Melbourne, 2014). By taking into account of the end-of-life issues associated with the products made of the selected materials, JOCO reusable cup made from borosilicate glass has the smallest environmental impact amongst all, represented by its low embodied energy and the fact that glass can be recycled forever. To summarise the analysis in the end-of-life issues and the material audit conducted above, borosilicate glass, stainless steel and polypropylene are the three most environmentally friendly materials that are 100% recyclable, promote a cradle-to-cradle approach.

6.0 Energy Analysis

It was suggested by Fredericka Brown and Kenneth R. Diller in 2007, hot beverage should retain at an optimum temperature of approximately 60°C as long as possible to provide the most satisfactory sensation to the customer (Brown & Diller, 2008). Energy analysis focus on evaluating the performance of heat retention of the selected designs as shown in Figure 3, and identifying which material has the highest energy efficiency.

6.1 Heat Retention and Energy Conservation

Newton's Law of Cooling is applied to investigate the heat flux at the boundary of a reusable cup and visualise the property of heat retention of the cup. This mechanism of heat removal at boundaries is represented as:

$$\Delta Q = h * A * (T_{inner} - T_{outer}) \quad 1)$$

Where ΔQ is the heat flow rate, h is the heat transfer coefficient, A the surface area, T_{inner} is the temperature of the coffee and T_{outer} is the room temperature surrounded the cup. The overall heat transfer coefficient U that incorporates the convective heat transfer coefficient h and the thermal conductivity of the medium would be much more convenient to work with, when boundary temperatures are unknown, represented by equation 3. Relationships between an overall heat transfer coefficient and the heat flow rate is represented by equation 2.

$$\Delta Q = U * A * \Delta T \quad 2)$$

$$U = \frac{1}{\frac{1}{h_i} + \frac{L_a}{k_a} + \frac{1}{h_o}} \quad 3)$$

Where \bar{h}_i and \bar{h}_o are the individual convection heat transfer coefficients for internal and external fluid respectively, with the unit of $W/m^2 \cdot K$. Internally, reusable cup contain coffee that has similar property as water. Hence the individual convection heat transfer coefficient for internal fluid is assumed to be the same as free convection water of $50 W/m^2 \cdot K$. Assume the coffee in a cup is served at $87.8^\circ C$ and exposed to air indoor at $20^\circ C$, the heat transfer coefficient for external fluid is $11.3 W/m^2 \cdot K$. L_a and K_a are the wall thickness and the thermal conductivity of the cup, respectively (Pitts & Sissom, 1991).

Table 2, wall thickness (L_a), the thermal conductivity (K_a) and the heat flow rate (ΔQ) of each selected cup, and their overall heat transfer coefficients calculated using conditions described above (Pitts & Sissom 1991).

Brand	Material	K_a (W/m ² *K)	L_a (mm)	U (W/m ² *K)
JOCO	Borosilicate glass	1.090	7	0.15313
KeepCup	Polypropylene	0.151	4.3	0.03498
Cheeki	304 Stainless steel	15.047	4	2.67145
Corelle	Porcelain	1.5	6	0.24340

With assuming the coffee is served at 87.8 degree Celsius and eventually dropped to room temperature of 20 degree Celsius, the change of temperate over time using different types of reusable cups is denoted in Figure 4. Since the detail dimensions of the selected designs are not available, based on the standard dimensions of a single-use paper cup with 60 mm base diameter, 111 mm height and 90 mm upper-base diameter, the surface area of a lid-less 12oz coffee cup is approximately 0.0655 square meter.

As shown in Figure 4, coffee in a reusable cup made with single-wall stainless steel reaches the room temperature as soon as 20 seconds after it was served, temperature decreases at a much slower rate when a reusable cup made of polypropylene is used. From the moment the coffee is being served in a polypropylene cup, it reaches room temperature after approximately 30mins, the longest amongst all popular designs in the market. It is important to take note that no accessories or lids are taken into consideration in the generation of Figure 4, and the top of the cup is assumed to be made of the same material as the body of the cup to simplify the mathematics.

Reusable cup made of polypropylene, porcelain, and borosilicate glass are microwaveable. If the coffee cooled before the consumer can finish it, most likely the user will reheat the coffee. Hence, potentially more energy is consumed if the reusable cup is made of material with high heat transfer coefficient. From the energy factors' point of view, reusable cups made from polypropylene are recommended, because of its high heat transfer coefficient. Polypropylene cups are more environmentally friendly, and energy efficient in long term, as compared to other types of popularly used materials.

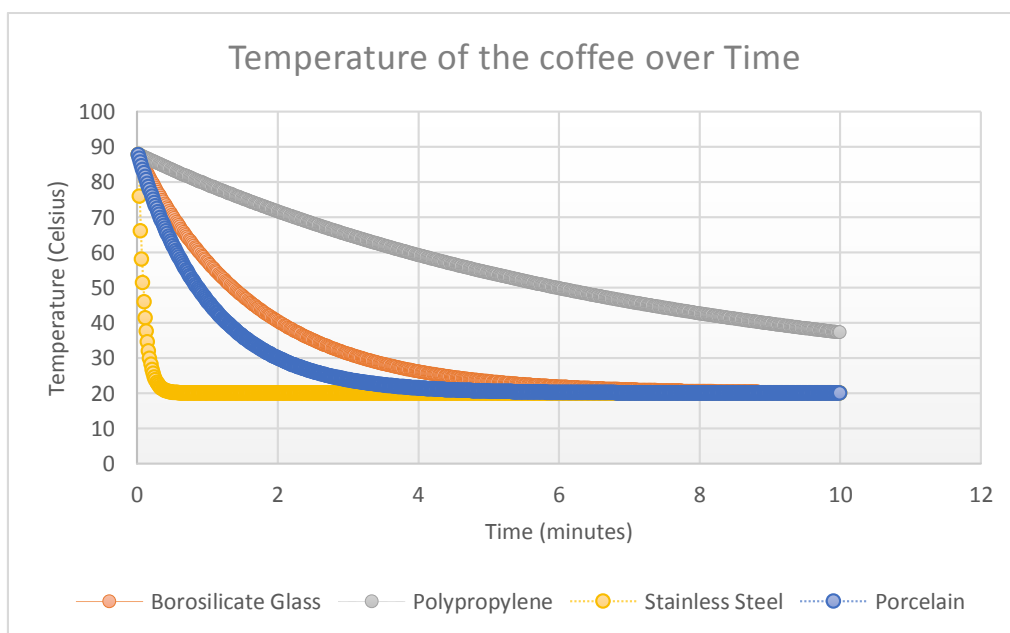


Figure 4, change of temperature of 355ml of coffee over time with reusable cups that are made of different materials.



Figure 5, EcoTOP lid comes with various sizes that fit over a range of existing coffee mug the user has (EcoTOP 2015).

In the theory of Convection, heated fluid including air and water carries energy and move away from the source of heat. Air above the coffee expand when heated, carries a large amount of energy from the coffee and rises into the colder areas above, causing heat loss. Hence, the lid design essentially important to keep the coffee hot for longer. A majority of the reusable cup designs in the market complement specially designed lids. For a conventional coffee mug made of porcelain cup users, universal cup lid that can be tailored over a range of cup sizes is recommended. Instead of replacing the porcelain coffee mug with an enclosed reusable cup, universal cup lid such as the EcoTOP shown in Figure 5 that provides a seamless fit to an existing mug or cup would be a more sustainable solution to reduce spills and to keep the coffee hot for longer in a cup the user already own (EcoTOP, 2015).

6.2 Key Outcomes

Conclusively, in order to improve the energy efficiency of the current system involving reusable cups made of various types of materials and to prolong the energy retention for the coffee to stay hot for longer, materials with low heat transfer coefficients and universal lids that fit to an existing coffee mug are recommended. In the long term, these recommendations allow reusable cup users to enjoy their coffee slowly without concerning about it getting cold or ruining the flavour by reheating it. Energy usage throughout the system be optimised as resources such as electricity and gas are used in a more efficient way that produce less waste.

7.0 Time Analysis

As mentioned in section 3.2, Time Analysis focus on evaluating the steps involved in the system and the time invested to successfully execute a task in each step, which aimed to increase the level of convenience of the system by making relevant tasks and steps easier, simpler and faster for consumers without sacrificing all favourable properties of the system. Systematic tools of a GANTT chart and a PERT chart are used to identify potential areas of improvement.

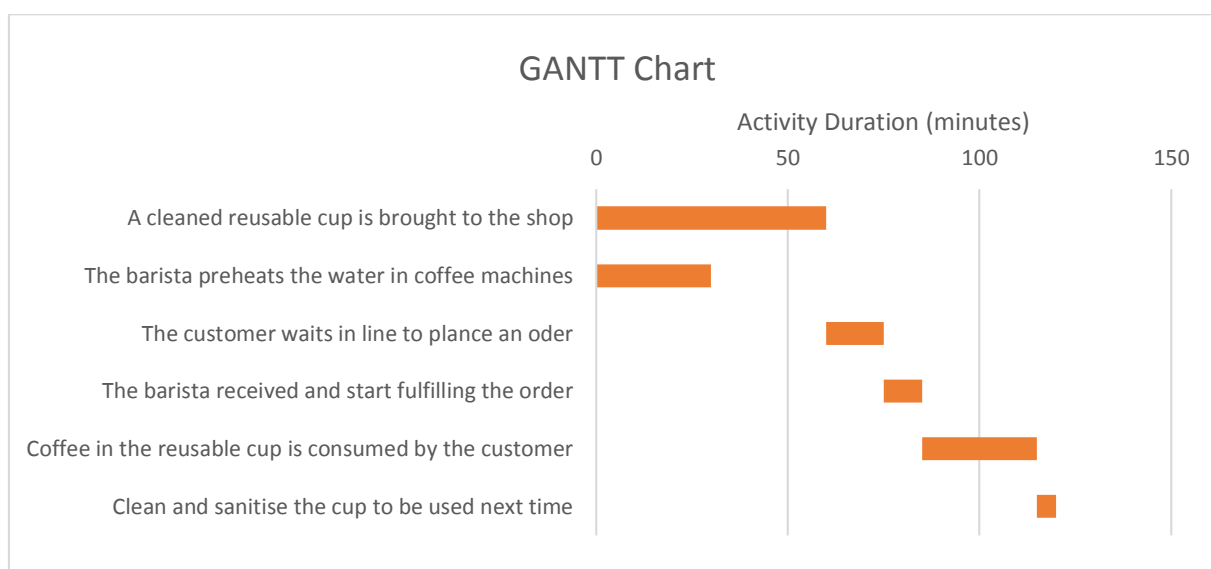


Figure 6, the amount of time required to complete each step in the system is illustrated in this GANTT chart.

7.1 GANTT Chart

A GANTT chart is generated to illustrate the schedule and amount of time required to complete each step in the system, as shown in Figure 6. By summarising the potential duration of each step and elements involved in the system, potential areas of improvement can be identified and recommendations from a Time Factors' perspective are then suggested.

Values in the GANTT chart are generated based upon personal experiences in purchasing coffee using a reusable cup at coffee shops within ANU campus. The GANTT chart showed that the most amount of time is spent on preparation and transportation before the user arrives to the university, approximately 1 hour is needed in this step. This includes the amount of time required for the user to get prepared and travel to the university. Depending on the time of the day, values in the GANTT chart above might fluctuate.

7.2 PERT Chart

A PERT chart is generated to differentiate the steps involved in the system and to gain a better insight into potential bottlenecks of that system that can be improved or modified in the future to increase the level of convenience. It is worthwhile to highlight again that the level of convenience of the system is concluded in section 3.0 to be one of the most important factors that determines the size of customer base and the overall usage of reusable cup at ANU campus.

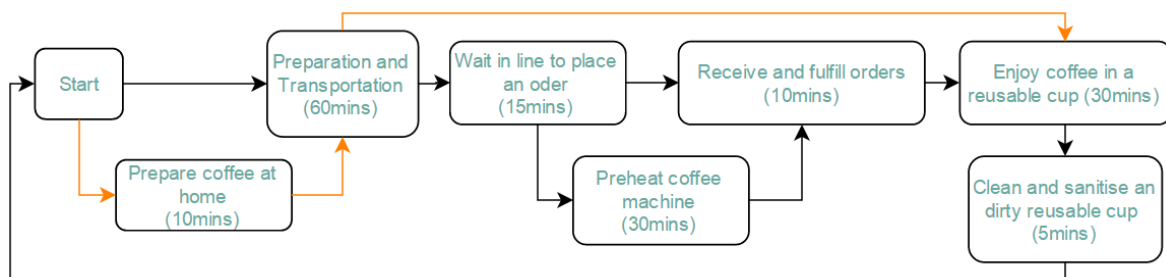


Figure 7, PERT chart illustrate the flow and interaction of steps in the system.

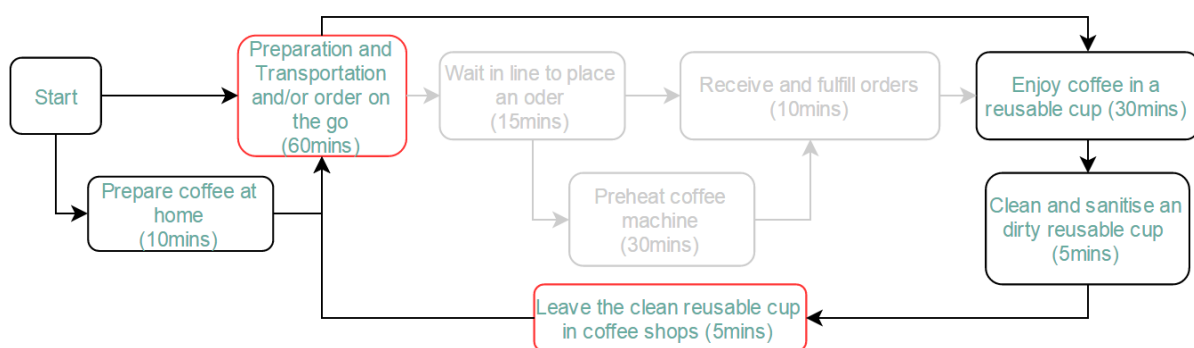


Figure 8, PERT chart of the optimised system.

The PERT chart shown in Figure 7 suggested that, reusable cup users would save up to 55 minutes daily as compared to users who purchase the items in stores. Steps in the second scenario that differ from those in the first scenario are connected by orange arrows. Similar to the findings from the GANTT chart in Figure 6, preparation and transportation requires the most amount of time.

For reusable cup user who prepare the coffee at home, essentially 4 steps are involved for them to pass through the system on a daily basis. For reusable cup user who order the coffee from a coffee shop, steps can be optimised in several ways to reduce the time consumption throughout the system. Waiting in a line for a coffee can be devastating for students or staff members who are running to and between meetings and lectures. An online ordering system or website that allow customers to order and paid for their coffee before arriving to the revenue would allow utilisation of the preparation and transportation time in the morning and diminishment of the amount of time required to spend waiting in a coffee shop. However, single-use paper cups are more likely to be used if customers order online. It is recommended that coffee shops at ANU campus provide small spaces for frequent reusable cup users to store their clean reusable cups at the end of every day. This would allow the users to continue using their reusable cups and order ahead with the online applications as recommended.

7.3 Key Outcomes

The system is optimised as shown in Figure 8, the step of “waiting in line to place an order” is merged with the step of “preparation and transportation”, and whereas the time spent waiting in the coffee shop is further reduced by introducing storage shelves for frequent reusable cup users to store their clean cups. Conclusively, recommendations suggested from a Time factors’ perspective allow reusable cup users to save up to 50 minutes a day and enable coffee shops to capture those customers whom do not have time to wait in the line.

8.0 Cost Analysis

A cost analysis is conducted to evaluate the cost-related aspects of the system by assessing the cost benefit model of the economic incentive program developed by ANUgreen and inspecting the payoff period of the selected designs in section 6.0 Energy Analysis for them to breakeven with conventional single-use paper cup.

8.1 Cost Benefit Analysis

In 2014, a cooperation between ANUgreen and coffee shops at campus with an aim to reduce the use of disposable cups conducted an economic incentive program, where customers would receive a 20 cents discount for bring in a reusable cup (ANU Sustainability, 2009). Unfortunately, the program was aborted at the end of 2014 due to low participation of coffee shops. A cost benefit analysis is conducted to evaluate the feasibility of this economic incentive program.

The average cost of a paper cup and a lid is approximately 29 cents. This value is estimated using the prices of 500 pack, 12oz Keji Paper Cups and 480 pack Ready Set Serve lids from the Officeworks, which cost \$109 and \$33 respectively (Officeworks, 2015). Excluding delivery fees and other costs associated with these disposable products, 9 cents is saved by the coffee shop for not using a disposable cup. Assume a coffee shop at ANU sells on average of 300 cups of coffee every weekday during teaching periods (total of 26 weeks), if 20% of the customers participate in the program and bring in their own reusable cups, a coffee shop would save up to 7,800 disposable cups and \$702 financially from the purchase of paper cups. Likewise, a reusable cup user who

purchase a coffee with 20 cents discount every weekday over the entire teaching period would save \$26 annually from the program.

8.2 Payback Period

With the fixed and running costs of owning a reusable cup, the total cost for 3 years is plotted against number of uses to determine the financial costs of disposable cup related to reusable products in the market, and to denote the breakeven point of the selected products with disposable cups. It is assumed that on average, a reusable cup is used 20 times in a month, approximately 2 litre of water is used to clean and sanitise the cup after each use and the water price in Canberra is approximately \$0.00297 per litre (Australian Bureau of Statistics, 2014). Compared to the price of a disposable paper coffee cup, the maintenance and operational costs of reusable cups are much lower, due to multiple uses of a reusable cup producing a lower overall environmental impact and on-going cost than a single use of a disposable cup for every serving. The total cost of the selected reusable cup designs is plotted over time as shown in Figure 9. The ongoing cost needed to purchase single-use paper cup is considered, whereas the ongoing cost required to buy coffee is assumed to be constant across all. As shown in Figure 9, reusable cups made with various types of materials have reached the breakeven point with disposable paper cup after approximately 6 months of purchase. Although the upfront cost of reusable cups are on average 20 times higher than a disposable cup, due to a low maintenance cost, reusable cup is a more financial effective solution in long term.

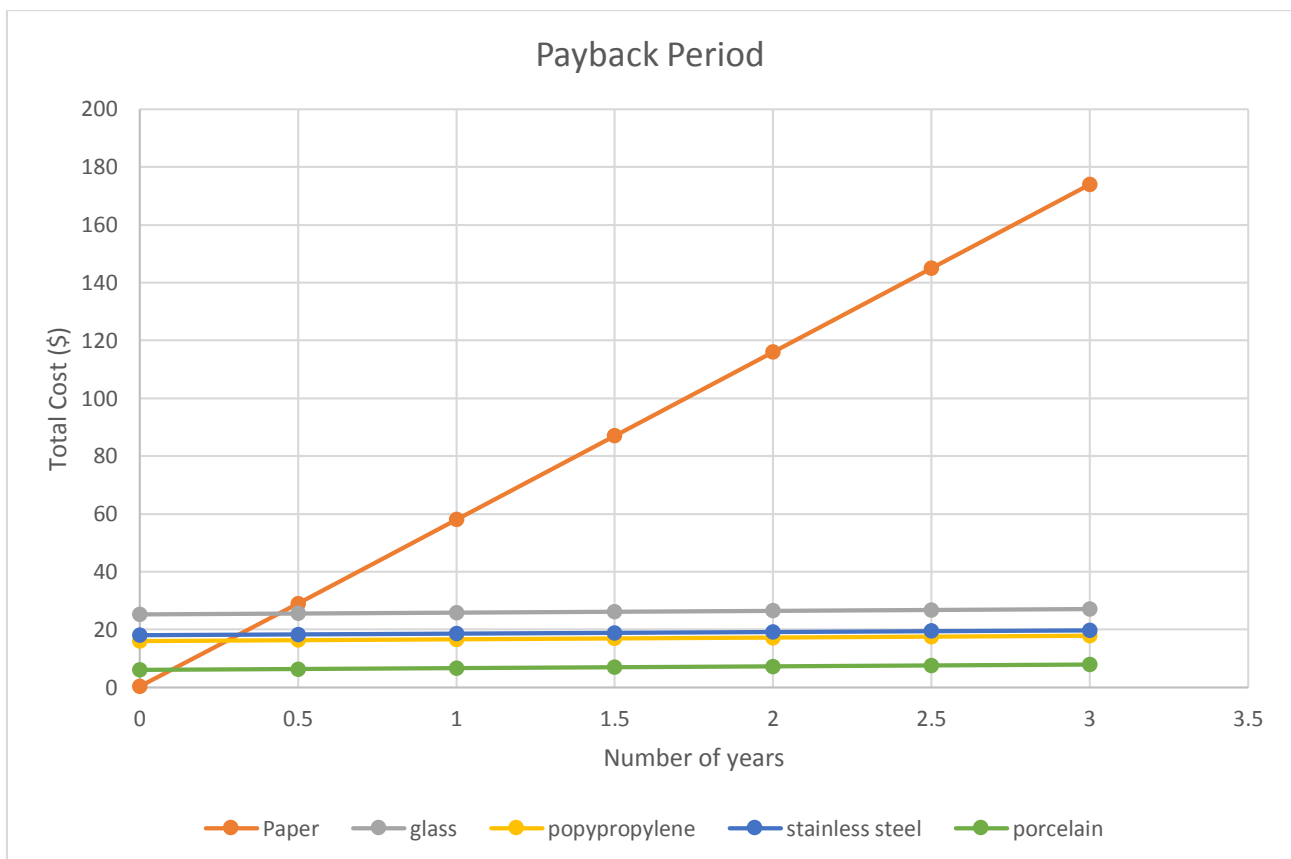


Figure 9, Payback period – total cost over time for selected cup types.

8.3 Key Outcomes

The economic incentive program led by ANUgreen in 2014 is highly feasible as all parties in the program are benefited financially. It is recommended that the program continues, while ANUgreen needs to provide sufficient statistics and information of potential costs and benefits when persuading coffee shops to participate. It is found in the evaluation of payback period of the selected designs, although the upfront cost of reusable cup is on average 20 times higher than a single-use paper cup, reusable cup is a more economical solution in long term (of approximately greater than 6 months) due to a low maintenance cost associated with the product.

9.0 Dynamics and Control

Dynamics and control of a system to design a control logic that can model, analyse and capture essential dynamics of the system, such that corrective actions can be carried out to achieve the desired changes or outcome (Astrom & Murray, 2008). With an overarching objective of increasing the use of reusable coffee cups at ANU campus, a feedback mechanism is suggested to the system to encourage and monitor the desired behaviour in the ANU population, while the desired behaviour is then reinforced by establishing system stability.

9.1 Feedback Structure

A feedback structure is suggested to gain insight into the level of convenience and satisfaction perceived by customers and the resulting behaviour of reusable cup usage in the system. A feedback mechanism that collects customer reviews about the reusable products in the market and the service gives a proxy of customer satisfaction level, level of convenience of a reusable product and an estimation of the quality of customer service delivered. Essentially, these information provides understanding of potential areas of improvement in the system which can be optimised to encourage the uses of reusable coffee cups at campus.

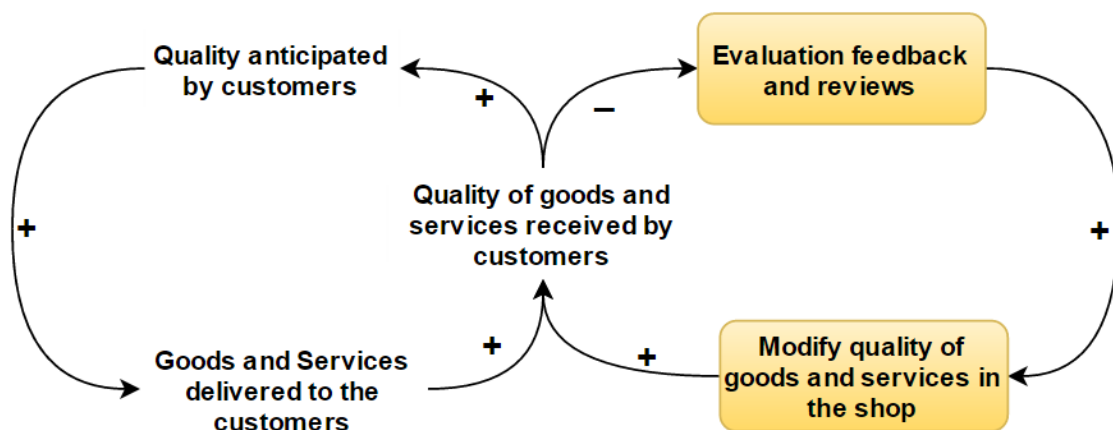


Figure 10, suggested feedback system to evaluate customer reviews and adjust the operation in coffee shops accordingly.

As shown in Figure 10 above, if the underpinning factors led to unsatisfied customers are identified by the coffee shops at ANU campus, the quality of goods and services can be modified and adjusted accordingly to ensure the quality delivered matches the quality anticipated by customers.

An online ordering system, website or application that allows customers to order and paid for their coffee before arriving to the revenue as suggested in Time Analysis would be an efficient medium to collect information about the customers' behaviour and their reusable cup usage.

9.2 System Stability

Considering different scenarios of the system as discussed in Time Analysis, demand of storage shelves for reusable cups and explicit loyalty program for reusable cup users are the two direct approaches to gather information about the reusable cup usage and to reinforce the behaviour of using reusable cups.

As discussed in section 7.2, coffee shops are recommended to provide storage shelves for customers to store their reusable cups overnight. Demand of the storage shelves would directly reflect the number of customers that is actively using their reusable cup and hence predict the overall reusable cup usage at ANU campus.

In a study published in the *European Journal of Social Psychology*, Phillippa Lally and her research team examined the habits of 96 people over a 12-week period and concluded that it takes anywhere from 2 months to 8 months before a new behaviour becomes automatic (Lally, et al., 2009). The process of balancing and reinforcing the behaviour of using reusable cups over time is represented by a general example of S-shaped growth in Figure 11. The S-shaped curve starts at less than the equilibrium or targeted amount. The usage experiences exponential growth when the incentive programs for reusable cup are widely promoted and encouraged or when using a reusable cup is a trend or norm at ANU campus. The exponential growth is the dominant behaviour of the S-shaped curve because coffee buyers start exploring and developing the new behaviour during this period. The amount of time required to reach the targeted level from the beginning is approximately the same as the time for a new behaviour becomes automatic. However, during this period of new behaviour formation, continuous practices is required and hence incentive programs are recommended to be conducted in a longer time frame.

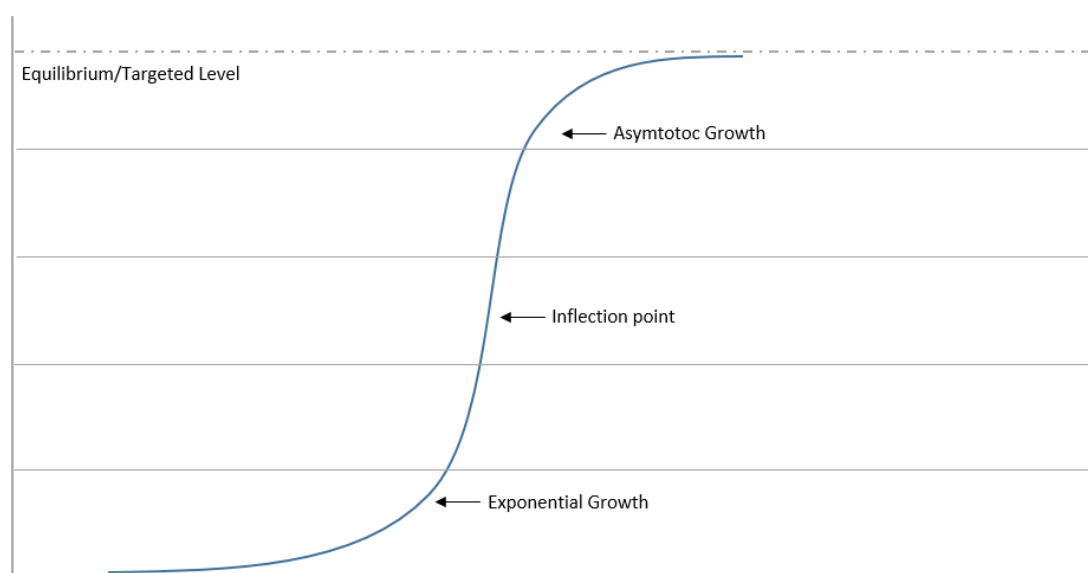


Figure 11, a general S-shaped growth of behaviour balancing and reinforcing reusable cup usage over time (Glick & Duhon, 2001).

9.3 Key Outcomes

Conclusively, a feedback mechanism is introduced to the original structure of the system to collect information customers' behaviour and their reusable cup usage which are essential for coffee shops to evaluate the quality of goods and services provided and to determine which incentive program is more effective at a given period.

10.0 Summary

With the aim of increasing the number of usage of reusable cup at ANU campus, recommendations are suggested toward the inefficiencies in the system from different engineering perspectives. The findings from existing data and survey responses provided supporting arguments to the recommendations made in other analysis methods. The recommendation suggested include mimicking the sizes of conventional paper cup to ensure there is no conflict with the current practices adapted by coffee makers and consumers, making smarter material choice to ensure the materials used contain low embodied energy and environmental impact, limiting heat hazards and heat losses by selecting materials with low heat transfer coefficients, introducing a feedback system and storage shelves in coffee shops to encourage and reinforce the behaviour changes from single-use coffee cup to reusable cups. In cost analysis, popular reusable cup designs in the market are found to financially breakeven with disposable paper cups after approximately 6 months of purchase, make it a more financial effective solution in both short term as well as long term. Overall, the system involving reusable cups becomes more energy efficient, reliable, stable and cost-effective at ANU campus if recommendations suggested in this portfolio are obeyed.

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