

**ANALYZING CONSUMER DEMANDS TO DETERMINE THE BEST SMART
TECHNOLOGIES FOR THE NEXT GENERATION DISHWASHERS**

**THE INFLUENCE OF CONSUMER DEMAND ON DISHWASHER FUNCTIONALITY
FOR TOP RATED DISHWASHER PRODUCTION COMPANIES**

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Systems Engineering

By
Khin Kyaw

November 2, 2020

Technical Project Team Members
Alexander Hu, Laura Gustad, Soumya Chappidi

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

TECHNICAL ADVISOR

Sara L. Riggs, Department of Engineering Systems and Environment

STS ADVISOR

Catherine D. Baritaud, Department of Engineering and Society

Mass production and the widespread availability of electricity initially enabled the average American household to obtain time-saving appliances such as the dishwasher (Cowan, 1983, pp. 93-101). The invention of the dishwasher decreased the amount of time people spent doing their dishes, because of the switch from hand-washing to automation. Over time, dishwashers have become an integral part of most American households. A survey done by the U. S. Energy Information Administration found that three out of four American households own a dishwasher (McNary, n.d.).

The popularity and widespread adoption of artificial intelligence and the Internet of Things (IoT) completely altered the way that people live their daily lives (“IoT has quietly and quickly changed our lives,” 2019). This shifted the expectations of household appliances to adapt to each user's necessities, within a timely manner, through an intuitive user interface. To keep up with the latest technological developments, dishwasher manufacturing companies have produced a variety of dishwashers equipped with smart sensors and IoT technologies, including automatic detergent dispensers within dishwasher applications. The project will be divided into two phases: discovery and research in the first-semester and concept development in the second-semester, shown in Figure 3 and Figure 5 on pages 4 and 5. At the conclusion of this project, we intend on providing a list of key functionalities for the next-generation dishwasher.

Today, technology appears to be essential in everyone’s busy daily routines. The capabilities of technology alleviate consumers from performing dreaded tasks such as dishwashing. As technology integrates into everyday lives, there are numerous requests from consumers for technology to accommodate their individual needs. The focus of my STS topic is to examine the evolution of these demands over time and its impact on the operational

alterations of dishwashers. This interaction will be identified through reviewing previous research studies and data from top-rated dishwasher companies. At the completion of my research, the goal is to produce a research article assessing the progression of consumer demands and dishwasher functionality.

My technical and STS topics are tightly coupled because my STS research will provide insight on common trends in consumer demands and challenges manufacturers face when addressing these requests. An enhanced understanding of the relationship between the consumer and manufacturer from my STS topic will enable me to determine a list of the appropriate sensors necessary for the design of next-generation dishwasher in my technical project.

OPTIMAL SMART TECHNOLOGIES FOR DISHWASHERS

As technology rapidly expands in the 21st century, the societal expectations for the abilities and usability of technology increases. Specifically, smart and automatic household appliances have become increasingly popular and affordable. People expect their technology to operate instantaneously while preserving system capability. The objective of this project is to optimize the user interaction experience through the use of the latest technology with dishwasher appliances without sacrificing the functionality of the product.

To create the optimal user interface, it is important to consider factors that influence user behavior ranging from the size of the household to personal characteristics like religion (Assadi, 2003, p. 3). A balance between technology and usability of a user interface (UI) is extremely important for a consumer because a UI that is too technologically advanced can become unusable, and a UI without adequate functionality would result in consumer dissatisfaction. An overview of the influence of usability factors is shown below in Figure 1. Within the four dishwasher components, five factors that have the largest weights on consumer influence: label

icon, exterior size, rack size, the shape of the knob, and LCD size. Figure 2, on page 4, provides a visualization of the primary components referenced in Figure 1.

Component of Dishwasher	Physical Design Factor	Degree of Influence (%)
Exterior	Label icon	21.50
	Size	21.64
	Button shape	15.82
	Color	10.44
	Panel size	9.95
	Button color	8.23
Interior	Rack size	41.47
	Bar	32.11
	Strength of bar	17.95
	Distance between racks	8.47
Doorknob	Shape of knob	67.40
	Thickness	32.60
Display	LCD size	26.56
	Display font type	22.16
	Color	20.47
	Control sound	14.91
	LCD font size	9.02

Figure 1: Generated Dishwasher’s Physical Design Factors and the Degree of Influence. Table of the four main dishwasher components with a percentage breakdown of each physical design factor and its influence on consumer behavior (Jin et al., 2009, p. 191)

A study of 200 in-house consumer surveys showed that 20% of dishwasher cycles were not fully loaded and some households preferred higher temperatures, so the value of energy consumption would be higher than the value listed on the appliance label (Richter, 2011, p. 186). This study shows that most users do not fully comprehend the capabilities and user interface of their dishwashers. Therefore, this project aims to ensure that the user interface is up to date with the latest technology and is intuitive for the consumer while achieving their desired operational capabilities.

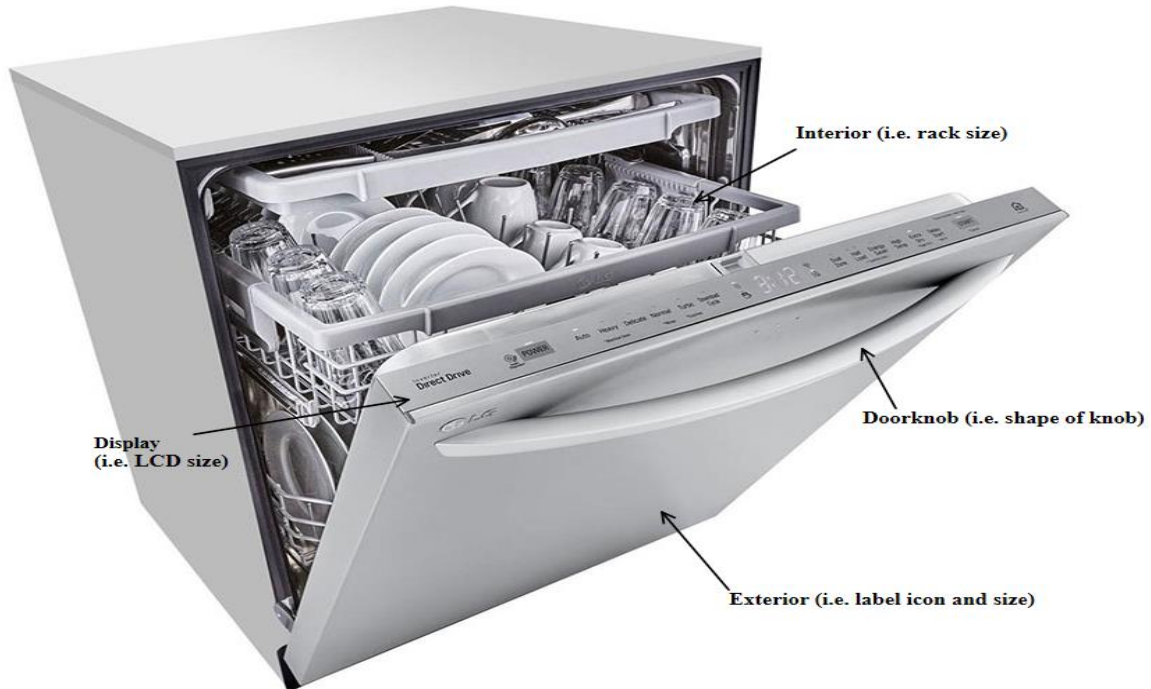


Figure 2: Visualization of Dishwasher Component Terms. The labeled depiction of a dishwasher identifies the primary physical counterpart to the terms used to describe influencing features which contribute to consumer behavior (Chappidi, 2020).

The U.S. Energy Information Administration found that, out of 80 million households in the United States with dishwashers, 54% of households utilize it at least once a week (McNary, n.d.). Given dishwashers are a technology used daily by a large number of people around the world, having more streamlining and optimizing the experience for users would be a great benefit. The next generation of consumers are comfortable with technology and therefore, expect certain features like real-time feedback and automation, to be present in their devices. This new acceptance of technology and these rapid advancements can create an influx of integration of smart home technology.

Smart technologies have been rapidly emerging throughout a multitude of industries such as the automotive industry, home connect device industry, and now, the household appliance industry. The rapidly growing demographic of tech-savvy consumers requires a new approach to daily tasks that are often taken for granted. Through our research, we intend to find what users

believe would best improve their dishwashing experience. By looking into how smart technologies, particularly sensors, connectivity, and autonomous features, change the way users interact with dishwashers, we aspire to develop a UI that would provide the features and experience that addresses current problems in the dishwashing process, improves usability, and offers features that are expected by consumers for a 21st-century technology.

From: 09/22/20 - 12/11/20	09/22- 10/05	10/06 - 10/19	10/20 - 11/2	11/3 - 11/16	11/17 - 11/30
Research current dishwasher landscape and research similar markets					
User interviews completed					
Map insights, hypotheses and unmet needs					
User diaries completed					
Surveys of potential users sent out					
Interim Report					

Figure 3: Timeline of Project Phase I. Goal dates for milestones in interviews, research, designs, and testing divided by semester into Phase I (Kyaw, 2020).

The approach for the technical project was divided by semester into two main phases, which is shown in Figure 3 on page 4 and Figure 5 on page 4. The first-semester approach, illustrated in Figure 3, is centered around gathering information about user experience and problems with their current dishwasher. Semi-structured interviews were used to collect user accounts of frustrations in the process of loading and unloading, as well as to gain an understanding of how users interact with the dishwasher interface. More specifically, conversations and questions were developed to delve into how users comprehend the different cycle options, the reason why capabilities and cycles are most used, and the anticipated level of use for an app to operate the dishwasher remotely. A histogram of the age of interviewees for the interviews completed through October 22, 2020, is shown below in Figure 4. Diary studies were

also conducted to gain insight into the more immediate frustrations with the loading and unloading routine that may not be revealed during a phone interview.

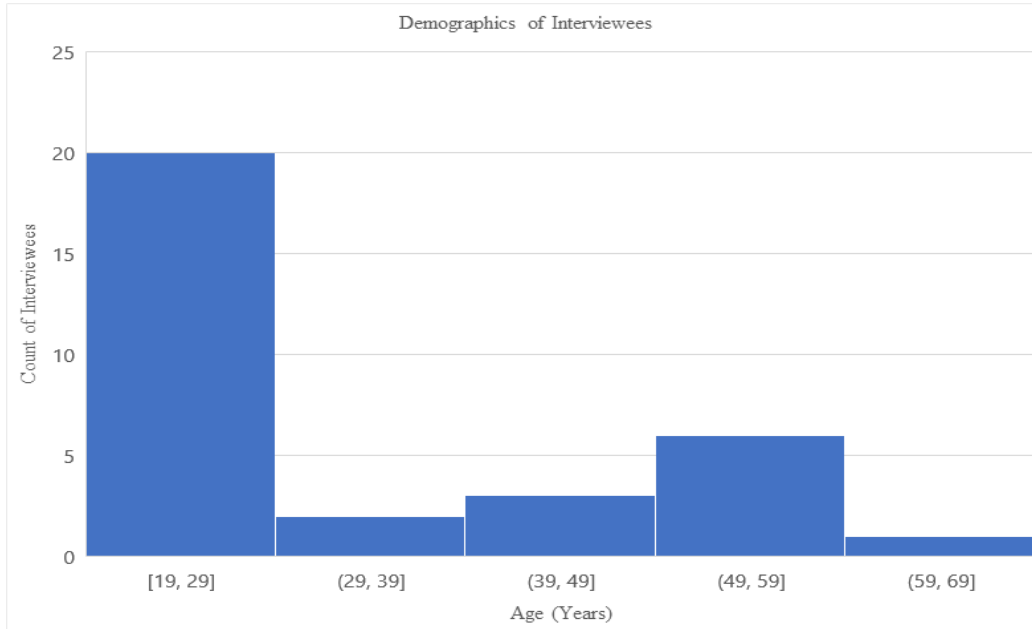


Figure 4: Histogram of Ages of Interviewees. Representation of the age distribution of the sample population interviewed (Chappidi, 2020).

From: 02/01/21 - 05/04/21	02/01 - 02/15	02/16 - 03/01	03/02 - 03/15	03/16 - 03/29	03/30-04/12	04/13 - 04/26	04/27 - 05/04
Brainstorm concepts based on research							
Narrow down concepts based on technical feasibility and cost							
Create initial designs							
First round user testing							
Use first round user testing and iterate design process							
Second round user testing							
Use second round user testing and iterate design process							
Third round user testing							
Present final designs							

Figure 5: Timeline of Project Phase II. Goal dates for milestones in interviews, research, designs, and testing divided by semester into Phase II (Gustad, 2020).

The second-semester, illustrated in Figure 5, will be focused on developing new designs for dishwashers’ user interface. The preliminary designs will be developed based on the data collected in the first-semester research and tested iteratively on potential users. The feedback from user testing will be used in improving the usability of the initial prototype for the final designs. To improve user experience, our findings will aid a major home appliance corporation

in their decision making and design process by determining which key features to include in their next-generation dishwasher.

The overarching goal of this technical project is to work with a major home appliance corporation to design the next generation dishwasher for their North American Market in 2030. The technical project team consists of myself and three other undergraduate engineering students Alexander Hu, Laura Gustad, and Soumya Chappidi. This technical project will span two- semesters and will be supervised by Professor Sara Riggs in the Department of Engineering Systems and Environment. We intend to collect consumer data through interviews and surveys, but will also rely on researching the current capabilities of competitor dishwasher companies through their appliance advertisements. Our findings will be summarized in a Systems and Information Engineering Design Symposium (SIEDS) conference paper at the conclusion of this project.

IMPACT OF CONSUMER DEMANDS ON DISHWASHER FUNCTIONALITY

20th-century dishwasher manufacturers were not focused on improving usability because the technology that existed at the time failed to clean dishes well enough to meet societal standards of cleanliness. The first dishwasher, patented in 1850, was a complete failure because it was inefficient and failed to properly clean the dishes (“History of Dishwashers,” 2017). The drying feature, which is an essential function for sanitation and a feature of every dishwasher today, was not a component of dishwashers until the 1940s (“How the dishwasher has changed our world,” 2018). Current dishwasher designs are the result of decades of design iterations to optimize cleaning while minimizing effort.

According to studies performed by Bosch (n.d.), not only are dishwashers time-saving appliances, but they are also devices that eliminate harmful bacteria such as E. coli and

Salmonella through high-temperature antibacterial cleaning techniques that cannot be achieved through handwashing (“Four reasons why you should use a dishwasher,” n.d.). E. coli and Salmonella can cause food poisoning, kidney failure, and even death, so it is critical to consumers that the dishwashing processes eliminates these types of bacteria. Consumers instill a level of trust into their dishwashers to efficiently complete a commonly dreaded household chore while providing a level of sanitation that cannot be achieved through handwashing.

As the dishwasher market becomes more competitive, companies are trying to manufacture the most desirable dishwasher for consumers by adding new features such as Wi-Fi connectivity and artificially intelligent sensors. Even with the shift in the market focus to enhance usability, it is critical to facilitate a strong relationship between new functions and consumer trust in these new technologies. These iteration and redesign cycles will continue indefinitely so that the dishwasher can successfully appease the societal demands of that time.

A study performed by the U.S. Energy Information Administration provides the visualization, shown in Figure 6, of the breakdown of household appliance ownership and usage. Figure 6 shows that about 20% of dishwasher owners did not use their dishwashers in 2015 (McNary, n.d.). Additionally, Figure 6 highlights that dishwashers have the highest proportion of consumers that own the appliance, but did not use it (McNary, n.d.). This statistic reflects a disparity between the consumer’s desires and the current dishwasher design. Therefore, it is important to analyze the interaction between consumer demands and dishwasher functionality so manufacturers can obtain a better understanding of the consumer’s perspective of the technology.

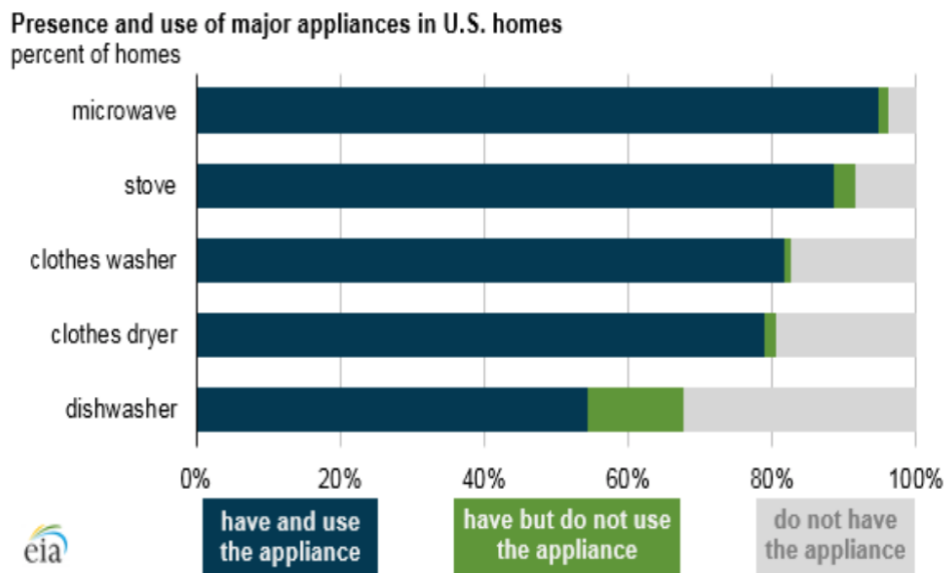


Figure 6: Segmented Bar Plot of Household Appliances. Visualization from U.S. Energy Information Administration household appliance usage and ownership survey results (McNary, n.d.).

This STS project, under the guidance of Professor Catherine Baritaud in the Department of Engineering and Society, will compare various top-rated consumer dishwasher manufacturing companies within the United States to determine the role that consumers’ expectations have played in the evolution of dishwasher capabilities.

EVOLUTION OF DISHWASHER TECHNOLOGY

The first dishwasher, patented in 1850 by Joel Houghton, consisted of a wooden hand-turned wheel that sprayed water on dishes, cleaning them ineffectively (“History of Dishwashers,” 2017). A more successful dishwasher was created by Josephine Cochrane, in 1886, to prevent her servants from breaking expensive dishes (Bellis, 2019). She created the first automatic dishwasher by using a wooden wheel that was laid flat against a copper boiler (Bellis, 2019). Dishwashers then became widely available and popular for families after the Second World War. Cochrane’s invention laid the foundation for the start of the first dishwashing company: KitchenAid (“History of Dishwashers,” 2017). The capabilities of dishwashers have now been drastically enhanced since the first patent of the dishwasher.

Some consumers' expectations for dishwasher performance can be rooted in their misconceptions. A national survey performed for Bosch by Impulse Reach determined that there are two major consumer misconceptions about dishwashers: they are the loudest item in the house and require more water than hand washing (Wolf, 2011, p. 64). To combat these misconceptions, companies such as Bosch have designed dishwashers that attempt to address consumer misunderstandings of the appliance. Shortly after completion of the Impulse Reach survey, the Bosch 800 plus dishwasher was released. This dishwasher was virtually silent, at 39 decibels, due to 18 sound reducing technologies (Wolf, 2011, p. 64). Bosch's rapid response to address consumer misconceptions by creating a new, virtually silent appliance demonstrates the extent of influence that consumers have on dishwasher design.

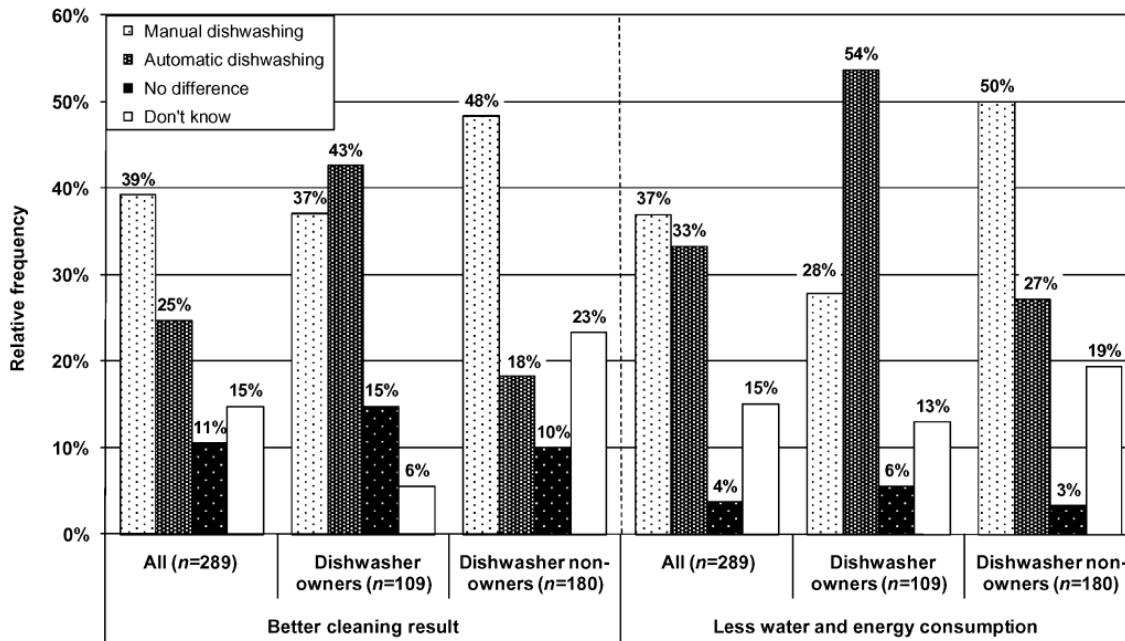


Figure 7: Bar Graph of Consumer Perceptions of Dishwashers. Graphical comparison of consumer beliefs on resource consumption and cleanness of dishwashers versus manual washing (Berkholz et al., 2010, p. 54).

Figure 7 features the results of a study performed by the University of Bonn and provides insight into the public's understanding of resource consumption and cleanness for handwashing

versus dishwashers. As shown in Figure 7, 37% of participants believed that manual dishwashing saves more energy and water and 39% of participants thought that it would provide better cleaning results. The finding that dishwasher resource consumption was perceived higher than handwashing was consistent in both the University of Bonn study and the Impulse Reach national survey.

In reality, manual dishwashing is less sanitary and requires more energy and water than a dishwasher. A study by Berkholz et al. (2010) found that all dishwashing machines only require 9.6 L to 26.7 L of water per cycle while manual dishwashing ranged from 34.7 L to 160.1 L. Ultimately, this study concluded that dishwashers were the superior choice because they require less resource consumption while delivering clean dishes (Berkholz et al., 2010, pp. 46-51). Most dishwashers today exceed consumer expectations and are now able to kill 99.9% of germs through high-temperature cleaning, of up to 158 degrees Fahrenheit (“Four reasons why you should use a dishwasher,” n.d.). Not all new generations of the dishwasher are successful in accommodating consumer requirements. In 2007, Bosch released their Integra Dishwashers that featured a load sensor for cycle customization and reduced energy consumption through a Half Load feature (“Bosch Bows New Evolution, Integra Dishwashers,” 2007, p. 71). However, the statistics from Figure 7 show how dishwasher manufacturers such as Bosch failed to produce a dishwasher that convinced consumers that dishwashers decreased their overall water and energy consumption.

Today, dishwasher designs have become more complex due to the high demand for the latest, newest technology that enables consumers to complete tasks with minimal effort. Fisher and Paykel created the DishDrawer which allows users to run two independent loads at different times (“History of Dishwashers,” 2017). Meanwhile, Bosch was one of the first companies to

create stainless steel tubs and self-cleaning filtration for dishwasher durability (“History of Dishwashers,” 2017). More recently, in September 2020, Miele was the first company to release a new line of dishwashers that automatically dispense a certain amount of detergent depending on how dirty the dishes are (Bird, 2020, p. 23). Popular appliance companies like Fisher and Paykel, Bosch, Kenmore, and Maytag have all contributed novelties to the essential components and capabilities that we see in dishwashers today and continue to include the latest technologies in their devices.

However, not every attempt to implement improvements to the dishwasher is successful. Whirlpool had to recall 1.7 million dishwashers in 2010 due to an electrical failure in the heating component, which resulted in 12 house fires (Wolf, 2010, p. 72). This represents a case where rushing to meet consumer demands within a competitive market, without proper testing, can fail and ultimately hinder the reputability of the company.

This STS topic will highlight the capabilities and analyze the success of the improvements that top-rated dishwasher companies have implemented, as well as analyze the fluctuation of consumer expectations through the Social Construction of Technology (SCOT) approach (Pinch, T. J., & Bijker, W. E., 1984, pp. 399–441). A SCOT approach enables a full grasp of the relationships between relevant social groups. As shown in Figure 8, to ensure the success of the next generation dishwasher through SCOT, the manufacturers must be able to integrate the latest technology that will facilitate consumer satisfaction while meeting all governmental regulations.

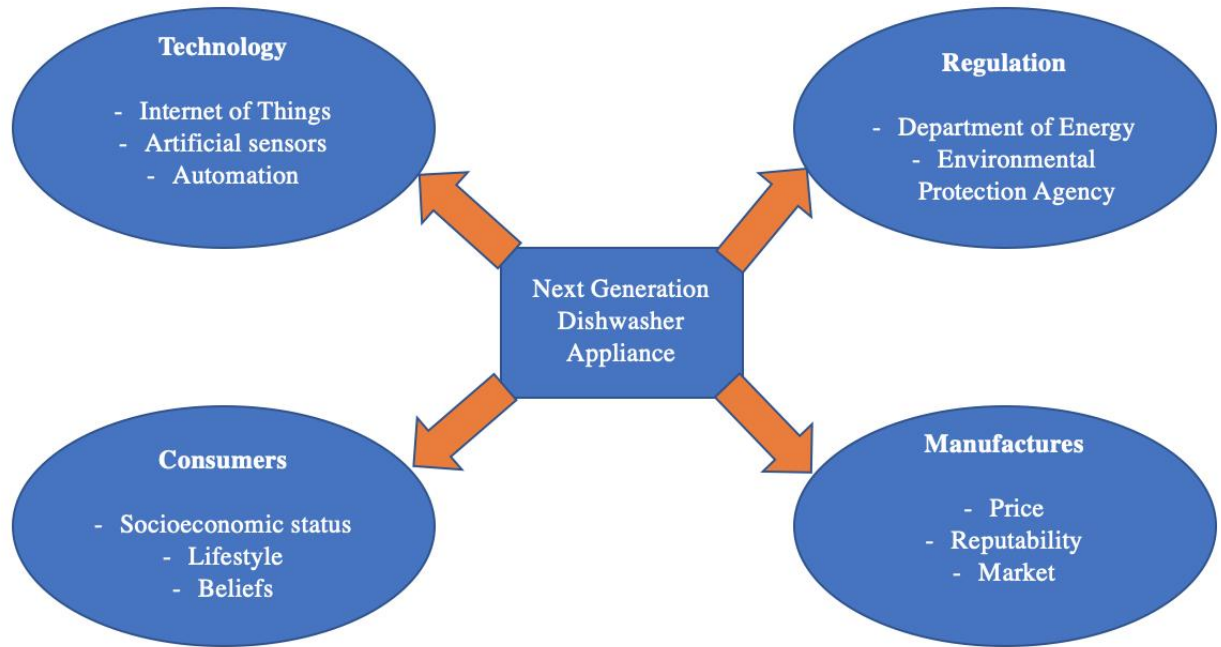


Figure 8: Dishwasher appliance SCOT model. A successful design of the next generation dishwasher is dependent on the ability to balance these four key actors (Kyaw, 2020).

The research for the STS project will be performed by collecting consumer reports from research studies and the characteristics of various generations of dishwashers from well-known dishwasher companies. This data will be contextualized to identify key patterns in consumer demands to establish a list of meaningful consumer values and to analyze the effectiveness of various dishwasher manufacturing companies in adapting to these demands. There will be a specific focus on data regarding consumer opinions and ideals. For example, we will consider the logic behind consumers' decisions to purchase, or not purchase, a dishwasher, as well as whether they are dissatisfied with handwashing. After determining consumer requirements, the dishwasher generations released, after the publication of the study, will be examined.

Additionally, my STS topic will enable me to diagnose the disparity between the ideal consumer product and the one provided by manufacturers. My STS topic will be tightly coupled with the topic of my technical project because the information obtained through the STS research

project will help me determine which dishwasher features are most desired by customers. I will then be able to create the type of sensors necessary to accommodate consumer demands in my technical project.

Preliminary research has revealed that the two important reasons that consumers use a dishwasher, beyond the time-saving component, are for hygienic aspects and the ability to wash loads of various sizes (Berkholz et al., 2013, p. 51). As the range of technological capability rapidly advances, it is critical for dishwasher manufacturers to understand the needs and desires of their consumer market. Therefore, an understanding of consumer trends must be achieved to properly and successfully design the next generation dishwasher that will reinforce consumers' daily aspirations.

Reviewing literature that ranges from trusted manufacturers to federal consumer studies will provide a comprehensive understanding of the interaction between the demand for specific dishwasher capabilities and the dishwasher products that are produced. Ultimately, the objective of my STS research project is to produce a scholarly article analyzing the impact that consumer demands have on dishwasher functionality over time.

NEXT STEPS FOR DISHWASHER TECHNOLOGY

A thorough understanding of the evolution of the dishwasher is necessary to determine which features are essential for the next generation dishwasher. Learning from the successes and failures of previous manufacturers will contribute to the understanding of consumer trends. The information obtained on the relationship between the user and manufacturer will provide a foundation to determine the key discrepancies between these two actors. By using the STS research as a guideline, the technical project will perform a detailed analysis and provide possible solutions to these issues. The ultimate goal for dishwashers remains the same: to have

clean dishes after you run a cycle. Constantly-evolving societal expectations impact people's standards for the functionalities and convenience of their dishwashers.

REFERENCES

- Assadi, D. (2003). Do religions influence customer behavior? confronting religious rules and marketing concepts. *Databases*, 22(10). https://www.researchgate.net/profile/Djamchid_Assadi/publication/242109368_Do_Religions_Influence_Customer_Behavior_Confronting_religious_rules_and_marketing_concepts/links/549db7ab0cf2fedbc311989d.pdf
- Bellis, M. (2019, July 3). You can thank this woman for inventing the dishwasher. *ThoughtCo*. <https://www.thoughtco.com/josephine-cochran-dishwasher-4071171>
- Berkholz, P., Stamminger, R., Wnuk, G., Owens, J., & Bernarde, S. (2010, March 1). Manual dishwashing habits: an empirical analysis of UK consumers. *International Journal of Consumer Studies*, 34(2), 235 - 242.
- Berkholz, P., Kobersky, V., & Stamminger, R. (2013). Comparative analysis of global consumer behaviour in the context of different manual dishwashing methods. *International Journal of Consumer Studies*, 37(1), 46-58. doi: 10.1111/j.1470-6431.2011.01051.x
- Chappidi, S. (2020). *Histogram of ages of interviewees*. [Figure 4]. *Prospectus* (unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.
- Chappidi, S. (2020). *Visualization of dishwasher component terms*. [Figure 2]. *Prospectus* (unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.
- Cowan, R. S. (1983). *More work for mother*. Basic Books. <https://huntersocfamilies.files.wordpress.com/2016/07/ruth-schwartz-cowan-more-work-for-mother.pdf>
- Darby, S. J. (2018). Smart technology in the home: Time for more clarity. *Building Research & Information*, 46(1), 140–147. <https://doi.org/10.1080/09613218.2017.1301707>
- Four reasons why you should use a dishwasher. (n.d.). *BOSCH*. <https://www.bosch-home.com.sg/experience-bosch/living-with-bosch/fresh-reads/4-reasons-why-you-should-use-a-dishwasher>
- Gustad, L. (2020). *Timeline of project phase II* [Figure 5]. *Prospectus* (unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.
- History of dishwashers. (2017, December 1). *Appliances Connection*. <https://www.appliancesconnection.com/blog/dishwasher-history>
- How the dishwasher has changed our world. (2018, June 21). *Universal Appliance and Kitchen Center*. <https://uakc.net/blog/dishwasher-changed-world/>

- IoT has quietly and quickly changed our lives. (2019, February 1). *NCTA — The Internet & Television Association*. <https://www.ncta.com/whats-new/iot-has-quietly-and-quickly-changed-our-lives>
- Jin, B. S., Ji, Y. S., Choi, K., & Cho, G. (2009). Development of usability evaluation framework with quality function deployment: From customer sensibility to product design. *Human Factors and Ergonomics in Manufacturing*, 19(2), 177-194. doi: 10.1002/hfm.20145
- Khin, K. (2020). *Dishwasher SCOT model*. [Figure 8]. *Prospectus* (unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.
- Khin, K. (2020). *Timeline of project phase I*. [Figure 3]. *Prospectus* (unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.
- McNary, B. (n.d.). Dishwashers are among the least-used appliances in American homes. *Today in energy U. S. Energy information administration*. <https://www.eia.gov/todayinenergy/detail.php?id=31692>
- Pinch, T. J., & Bijker, W. E. (1984). The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology might Benefit Each Other. *Social Studies of Science*, 14(3), 399–441. <https://doi.org/10.1177/030631284014003004>
- Richter, C. P. (2011). Usage of dishwashers: Observation of consumer habits in the domestic environment. *International journal of consumer studies*, 35(2), 180-186. doi: 10.1111/j.1470-6431.2010.00973.x