



Research article

Insights on next-generation manufacturing of smart devices using text analytics

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ABSTRACT

With the mass expansion in technological user-friendly products, there is an increasing demand for smart devices, resulting in a highly competitive novel market. To ensure sustainable success, these products must remain robust and be perceived positively by customers. With the development of Web 2.0, individuals are able to make knowledgeable purchasing decisions, specifically with the availability of millions of online customer reviews. Companies manufacturing smart devices can utilize this unstructured data to analyze the customers' perceptions of their products and identify potential improvements. To the best of our knowledge, this paper is the first to propose next-generation manufacturing insights for companies producing smart devices by determining the current strengths, weaknesses, opportunities, and threats (SWOT) of these gadgets using text analytics. A three-stage methodology is utilized, consisting of bigram and trigram examination, topic identification, and SWOT analysis. After online review extraction, comments for each smart device are separated into positive, neutral, and negative categories, based on the customer ratings. Text analytic tools are then used to determine the most frequently occurring bigrams and trigrams to provide topics for conducting the SWOT analysis. Using the SWOT technique results, numerous next-generation smart device manufacturing recommendations are presented.

1. Introduction

During this technological age, consumers are regularly exposed to an abundance of innovative devices that continue to advance the boundaries of artificial intelligence. The introduction of smart devices has facilitated the communication and control of numerous products using the Internet of Things (IoT). Intelligent devices provide users with an interactive experience while assisting in basic tasks and managing their homes. These devices can understand simple commands sent by users via Bluetooth or button operations to create a more efficient and autonomous lifestyle. Consumers are inviting technology, like smart hubs and devices, into their homes at an extremely high rate. In a study conducted by Poushter (2016), a median of 87% reported smart device ownership across 11 countries.

Smart devices provide customers with a user-friendly, interactive experience in the comfort of their own home. With simple voice commands, manual operation using buttons, or virtual instructions through IoT, the user can control an entire IoT ecosystem within their home (Lazar et al., 2015). Everyday mundane tasks, such as setting the thermostat, can be performed automatically or standardized with scheduling

abilities. These smart products could add convenience to the users' daily lives in numerous ways that extend past house operations. Smartphones have revolutionized communication and the capabilities of the internet, including the collaboration of smart devices through smartphone applications, which is a conventional device feature.

The diversity of smart devices in the market also proves as an advantage for attracting a wide array of individuals. With a vast market for these devices, customers can find a product that is most suitable for their desired intent. Smart devices also often have customizable features (e.g., manual or automatic control options) to accommodate a broader market. These gadgets are created to provide an efficient experience for clients, while utilizing the expansive capacity of the internet.

Consequently, the expanding popularity of these smart devices demands a market analysis to assess and manage the existing faults of the products. Some may be attributed to the lack of knowledge of these devices, which can significantly disrupt a customer's individual experience. This ignorance also creates a low serviceability rate for smart devices (Chi, 2018). With new technology, it is crucial to provide adequate resources for understanding the product's capabilities, which has been a major downside for manufacturers. This weakness affects customer

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satisfaction and is only a single example among many others identified through this research.

The rise in Web 2.0 tools has altered the way companies and businesses gather information on their products' performances and the consumers' perceptions. Consumers can now communicate their personal opinions regarding the quality of products to a global audience as user-generated content persistently increases (Gao et al., 2017). The client experience and satisfaction levels posted online circulate as viable information for potential shoppers. The increased accessibility of the internet has provided individuals an opportunity to discuss a product's standard of quality. Although online customer reviews (OCRs) are purely based on specific experiences and are only a small component of the client population, they are still considered the second most reliable source of product information (Nielsen Holdings, 2012; Srinivas and Rajendran, 2019). OCRs could assist the technological market in increasing sales by providing insights into potential managerial recommendations that improve their product.

In this study, we provide next-generation manufacturing recommendations for smart devices by analyzing online customer reviews of several intelligent devices and identifying the key features that people prefer and dislike. Ten different smart devices are selected based on their price, intended usage, review volume, and rating distribution. A three-stage methodology is used consisting of bigram and trigram examination, topic mining, and SWOT analysis. Based on this approach, next-generation manufacturing recommendations are provided for smart device companies.

The remaining paper is organized as follows. Section 2 presents the review of smart devices, online customer reviews, and next-generation manufacturing in detail. Section 3 discusses the methodology, and Section 4 describes the data in-depth. The results are presented in Section 5, while the discussion based on the results is provided in Section 6. The conclusion and future work are given in Section 7.

2. Literature review

2.1. Smart devices

User-friendly technology, like smart devices, may assist in everyday mundane tasks in a customer's home or workplace. Ur et al. (2013) analyzed the ease of using three different smart items within a home based on three separate client's experiences. It was concluded that several features limited the adaptability of these intelligent devices, including network connectivity and accessibility to manual features. Although their research identified the current weaknesses of the smart devices, it only consisted of three customer's experiences rather than a large sample population, unlike the study mentioned in our paper. The current inadequacies of smart products were also discussed through research conducted by Lazar et al. (2015). After several customers purchased a gadget chosen by the researchers, information was collected regarding the advantages of using the product and the existing challenges. The authors found that individuals were unable to perform regular maintenance on devices due to their lack of product knowledge. However, their study established conclusions based only on one smart product rather than multiple.

Although smart devices possess several weaknesses that negatively impact a customer's satisfaction, the study by Mattern (2003) highlighted several potential advantages of intelligent devices. Mattern (2003) summarized many positive aspects, including their ability to communicate with one another via the Internet of Things. This feature is very marketable and encourages individuals to purchase several items rather than one. Characteristics like these that are well perceived by consumers may be transferrable to other products and are considered for managerial recommendations proposed in our study.

2.2. Online customer reviews

With the growing popularity of social media websites, consumers are now able to openly discuss about products online with acquaintances or

strangers. Erkan and Evans (2016) concluded that through the analysis of electronic word-of-mouth (eWOM), the influence of people's conversations on purchase intent could be examined. This influence is potentially crucial to sales, which has caused businesses to revolutionize marketing. Alongside the expansion of online ordering, companies are attempting to acclimate based on positive and negative consumer perceptions evaluated via reviews that have been posted to the internet. Fu et al. (2015) provided a better understanding of the motivations behind a consumer's decision to partake in eWOM communication, which has become more important as consumers begin to place more significance on eWOM while assessing a product.

Cheung and Lee (2012) identified the key factors that motivate consumers to propagate positive eWOM rather than negative feedback on social networking sites. With over 200 samples from a consumer review community, an empirical test was conducted to identify the multiple factors that contribute to a consumer's decision to participate in positive eWOM. The authors concluded that reputation, sense of belonging in a community, and the delight of helping other consumers significantly correlated to consumers' eWOM intention. The results of their research were also useful in understanding the behaviors and fluctuations of online consumer-opinion platforms members. It was shown through the conclusions of their study that this expanding form of communication, electronic word-of-mouth, represents a new and imperative marketing phenomenon.

Traditional (offline) word-of-mouth has shown to play a substantial role in customers' purchasing decisions (Balaji et al., 2016; Rajendran, 2020). The introduction of Web 2.0 has increased consumers' outlook for assembling unbiased item details from several individuals through eWOM rather than relying solely on a company's reputation. To further understand the complexity and implications of eWOM, Hennig-Thurau et al. (2004) used an online sample of 2,000 consumers to gather information on the structure and relevance of the motives of consumers' online expressions. The authors suggested that consumers' interest in social interaction, desire for economic incentives, personal concern for other individuals, and the potential to enhance their self-worth are the primary factors leading to eWOM behavior. By identifying these factors, businesses can modify their marketing strategies or product design to address the negative eWOM reactions.

2.3. Next-generation manufacturing

Manufacturing, alongside technology, has dramatically evolved and provoked an increase in market competition. Alvi and Labib (2001) examined the next generation of manufacturing methodologies to identify beneficial paradigms that help companies to remain robust and competitive. The authors also classified potentially harmful market behavior, such as introducing products to the public ahead of time and not allowing proper time for market research. They concluded that strategies like these often lead to a low serviceability rate that can negatively affect a customer's experience with the product.

The management of next-generation manufacturing with technology was analyzed by Soliman and Youssef (2001) to understand its impact further. An example of this evolving technology is the Internet of Things (IoT), which can serve as a communication path for devices connected to the internet. Their study assessed the implementation of IoT within manufacturing and found that it allowed companies to collect large amounts of valuable data that could be used to improve their process. Another technology that has shown to benefit next-generation manufacturing is virtual reality (Rubio et al., 2005; Chong et al., 2018; Karvouniari et al., 2018). Virtual reality revolutionizes process simulation and can identify potential machine faults that have financial paybacks (Rubio et al., 2005). These advancements in technology give manufacturing companies the opportunity to become more proactive and sustainable.

2.4. Contributions to the literature

We contribute to the existing literature multi-folds. Although analysis of the service sector has been widely discussed in the literature (e.g.,

Rajendran et al., 2015; Smith and Srinivas, 2019; Rajendran and Ravindran, 2019; Kambli et al., 2020; Srinivas, 2020), relatively fewer papers provide product examination and design recommendations. However, several articles in the literature highlight the necessity to consider proposing product design recommendations as these outcomes result in insights for better manufacturing (Singh and Tucker, 2017; Kim and Noh, 2019; Yang et al., 2019). In addition, prior research has proven a strong influence of customer opinion on the decision-making process of next-generation manufacturing (e.g., Gao et al., 2017; Lee, 2018; Zhu and Pham, 2020).

To the best of our knowledge, this study is the first to analyze online customer reviews of smart devices through text analytics and provide next-generation manufacturing insights based on the investigation. Next, despite several articles focusing on identifying the current weaknesses of the smart devices, most of them either considered limited client experiences (rather than a large sample population) or analyzed only the performance of one device. Whereas, in this paper, we examine more than 33,000 customer reviews of numerous smart gadgets, and evaluate ratings over an extended period that gives the smart gadget producers the ability to draw many conclusions.

Moreover, this research examines multiple products that are diverse with regard to their application, size, and price. Identifying the topics that individuals positively and negatively perceive in each product enables companies to potentially understand the key features that people prefer and dislike in each of these devices. Even though there are very limited papers on proposing managerial recommendations for the next generation of manufacturing, their findings did not capture the voice of the customers of other dissimilar products.

3. Methodology

The overview of the approach (Figure 1) displays the three main steps within this research. We extract the reviews related to different smart devices from several social networking sites, perform an in-depth customer review analysis, and then propose recommendations with a SWOT analysis. These managerial insights are based on text analytics performed during review analysis.

The overview of methodology (Figure 2) thoroughly outlines each step taken to complete the analysis of all customer reviews and the composition of managerial recommendations. To accurately assess the extracted online reviews, data pre-processing is conducted (Section 3.1), and the separation of reviews based on a rating scale is provided in Section 3.2. This categorization allows for more straightforward text analytics of the bigrams and trigrams found within the positive, negative, and neutral reviews. These bigrams and trigrams are then used to identify probable topics from client reviews that made an impact on the satisfaction level. After finding several topics, a SWOT analysis is conducted to determine the current strengths, weaknesses, opportunities and threats of each smart device. The strengths and weaknesses are attributed to

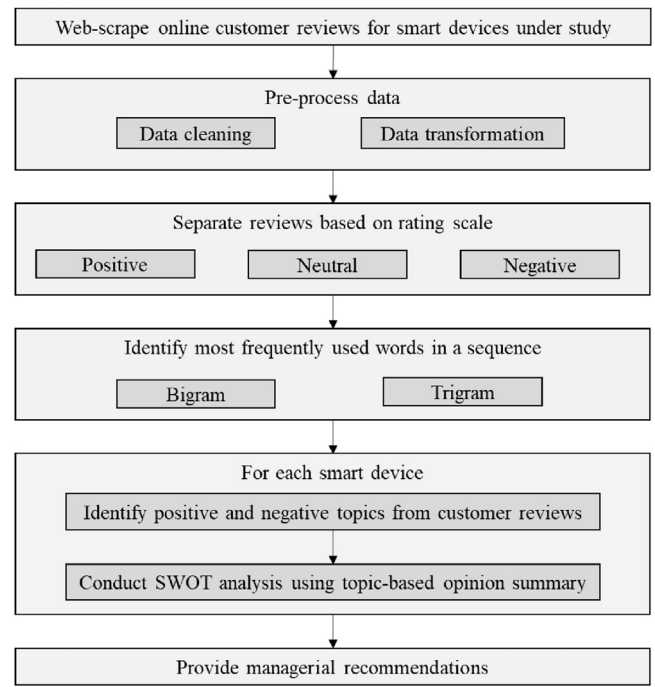


Figure 2. Overview of the methodology.

internal factors like Wi-Fi connectivity that affect customer's perception of quality, and the opportunities and threats are external factors like a competitive gadget's features. From the SWOT analysis, managerial recommendations are proposed to improve the overall quality of intelligent devices under study.

3.1. Web-scraping and data pre-processing

The proposed approach will begin by using a web scraper to extract over 33,000 publicly available online customer reviews from various online sources. This data will then be analyzed to identify the plausible subject matters using topic modeling. In this case, we extract the time of the online post, the given client rating from one to five, the review, and verification of purchase. Each review may not focus on a single aspect of the gadget. Therefore, each feedback is separated into individual sentences, and the statements are treated as independent comments. Following the extraction, Python® is used to condense the data by detecting and removing duplicate reviews. Subsequently, the sentences are further pre-processed for text analytics by tokenizing, removing unnecessary special characters and non-English words, stemming inflected words, converting all characters to lowercase, and removing stop words. This is accomplished through modules that are readily available in the

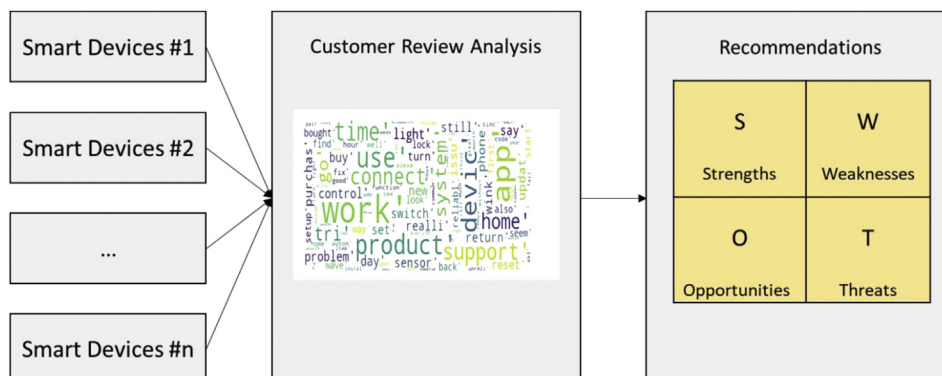


Figure 1. Overview of the approach.

Python® natural language toolkit (NLTK). Along with the default stop words provided in the NLTK, we also developed a set of custom stop words to filter unnecessary words that do not add value for the topic identification.

3.2. Separating reviews based on rating scale

After extracting and pre-processing the data, reviews for each product are separated based on the ratings established by the individual. These ratings are distributed between one and five and are dependent on the level of customer satisfaction. A rating scale is created to classify the topics associated with a positive or negative sentiment. Every 1–2 star rating is categorized as a negative review, a 3-rating as neutral, and 4–5 as positive. The categorization of reviews provides a clear divide in commonly occurring positive and negative topics based on the ratings.

3.3. Bigram and trigram analysis

The following section displays the bigram and trigram analysis discussed in Jurafsky and Martin (2014).

Suppose if R_1, R_2, \dots, R_N are set of any random words, the probability that these words are occurring in a sequence (i.e., $P(R_1 \dots R_N)$) is denoted by $P(R)$, as given using Eq. (1).

$$P(R) = P(R_1 \dots R_N) \quad (1)$$

The probability of occurrence of R_2 after R_1 in a sequence is given by Eqs. (2) and (3). Similarly, the likelihood of occurrence of R_3 after R_2 and R_1 consecutively is given by Eq. (4). Eq. (5) derives $P(R_1, R_2, R_3)$ using constraints (3) and (4).

$$P(R_2|R_1) = \frac{P(R_1, R_2)}{P(R_1)} \quad (2)$$

$$P(R_1, R_2) = P(R_2|R_1) \times P(R_1) \quad (3)$$

$$P(R_1, R_2, R_3) = P(R_3|R_1, R_2) \times P(R_1, R_2) \quad (4)$$

$$P(R_1, R_2, R_3) = P(R_1) \times P(R_2|R_1) \times P(R_3|R_1, R_2) \quad (5)$$

Applying this expression to N words, the probability of the occurrence of R_N immediately after the word sequence $R_1 \dots R_{N-1}$ is presented by Eqs. (6) and (7).

$$P(R_1 \dots R_N) = P(R_1) \times P(R_2|R_1) \times P(R_3|R_1, R_2) \dots P(R_N|R_1, R_2 \dots R_{N-1}) \quad (6)$$

$$P(R_1 \dots R_N) = \prod_{n=1}^N \Pr(R_n|R_1 \dots R_{n-1}) \quad (7)$$

Applying the chain rule of conditional probability to the word sequences under study, Eq. (9) gives the likelihood of the occurrence of N words in any sequence.

$$P(R_1 \dots R_N) = P(R_1) \times P(R_2|R_1) \times P(R_3|R_1^2) \dots P(R_N|R_1^{N-1}) \quad (8)$$

$$P(R_1 \dots R_N) = \prod_{i=1}^N P(R_i|R_1^{N-1}) \quad (9)$$

Alternatively, for the bigram model, the Markovian assumption previously discussed in Eq. (10) is considered.

$$P(R_N|R_1^{N-1}) = P(R_N|R_{N-1}) \quad (10)$$

where $P(R_N|R_{N-1})$ is estimated using the ratio of the bigram count of R_{N-1} and R_N (represented by $\nu(R_{N-1}R_N)$) to the sum of the frequency of all the bigrams containing only R_{N-1} ($\sum_r \nu(R_{N-1}R)$), as provided in Eq. (11).

$$P(R_N|R_{N-1}) = \frac{\nu(R_{N-1}R_N)}{\sum_r \nu(R_{N-1}R)} \quad (11)$$

Similarly, the trigram model to forecast the conditional probability of the N^{th} word in a sequence is given by constraint (12).

$$P(R_N|R_{N-1}, R_{N-2}) = \frac{\nu(R_{N-2}R_{N-1}R_N)}{\sum_r \nu(R_{N-2}R_{N-1}R)} \quad (12)$$

3.4. SWOT analysis

The SWOT analysis shown in Figure 3 briefly outlines the categorization of the identified strengths, weaknesses, opportunities and threats of the smart devices under study. The strengths and weaknesses of each product are internal factors that affect the perceived quality of the product, whereas opportunities and threats are external factors. External factors are often attributed to the current competitors' strengths. This analysis is used to create several managerial insights that, if implemented, would enhance the quality of the applicable smart gadgets.

4. Data

In total, 33,345 reviews of ten different intelligent devices and smart hubs posted by consumers from various online sources are extracted. The smart devices considered are Alexa Remote, Amazon Smart Plug, Logitech Harmony Hub, Nest Thermostat, Ring Alarm Kit, Samsung Smart Things, Schlage Connect, Sengled LED Lightbulb, Sonos Speaker, and WINK Hub.

As mentioned earlier, all online customer reviews extracted for each product are separated into positive, negative, and neutral reviews, based on a rating system out of five. To gather competitive intelligence, we identify the strengths and weaknesses of numerous smart devices and hubs and further analyze reviews pertaining to these traits. The strengths and weaknesses of the gadgets are respectively based on customer compliments and complaints, while the opportunities and threats are identified based on examining the online reviews of the many other existing competitors. After establishing the key topics, we put forth several managerial recommendations to the manufacturing companies that can aid them in their planning decisions to improve client satisfaction, product reputation, and sales.

Table 1 represents data fields that are obtained from the online customer reviews for all the ten smart devices under study. These fields are chosen based on relevance to the customer's perception of the quality and credibility of the review. The data points "rating" and "review" are essential when analyzing the overall perceived quality of each smart gadget. To draw conclusions regarding the intelligent device's performances over a period of time, the "date" record is also extracted.

4.1. Data analysis

Ten different products with varying abilities, prices, and lifetime on the market are chosen for this study. A diverse assortment of smart gadgets introduces additional features that can potentially be integrated with others. The selection of products is crucial in this study to provide well-informed managerial insights. The smart devices are labeled as SD#1 – SD#10 for the purpose of de-identification.

Table 2 displays the total number of reviews extracted for the ten smart devices under study, as well as the total number of negative, neutral, and positive reviews. It is clear that the majority of the reviews are positive (i.e., ≥ 4 stars). The percentage of authentic purchases is based on the classification of "verified purchase" displayed with each online customer review. Figure 4 outlines the total distribution of reviews as the percentage of negative, neutral, and positive reviews for each smart device under study. Through this figure, it is shown that most reviews for the gadgets under investigation are positive. Highly-rated

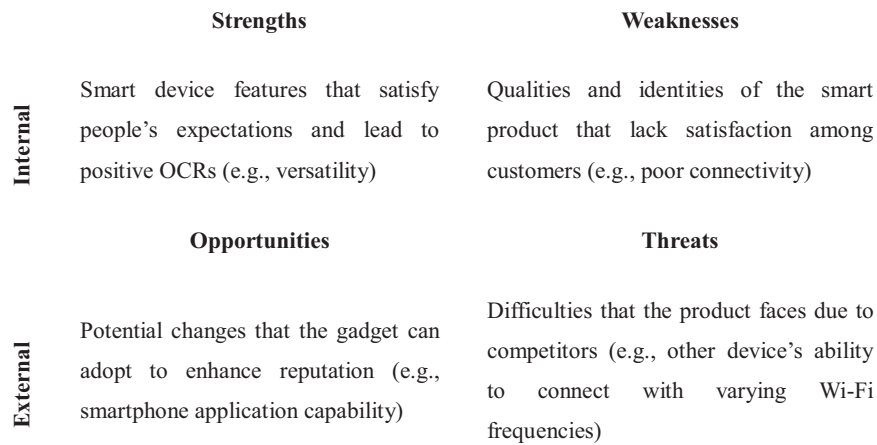


Figure 3. SWOT analysis framework.

Table 1. Extracted data description.

Field	Explanation
Date	Contains the date that review is posted online by the individual
Title	Contains a title of the client review, and in general, the overall feeling towards the product
Rating	Contains numerical value given by the customer regarding the product's perceived quality
Review	Contains the full review posted by individuals
Verified Purchase	States whether the review is posted by a customer whose purchase is verified by website

devices are further studied to establish all well-perceived qualities that are relevant to other competitive products.

Figure 5 represents the average rating across the four quarters of 2017, 2018, and 2019. Based on the trends identified in this graph, it is evident that the overall ratings decrease over time across all products. This steady decline could be attributed to the deteriorating long-term performance of smart devices that would have initially been highly commended due to many other factors. Often, smart gadgets require software updates that are meant to improve the performance of the device but may negatively affect the customer's experience. Table 3 presents the word and sentence statistics of the individual reviews for all ten smart devices under study. While observing the standard deviation values, it is evident that the average number of words in a sentence

Table 2. Review distribution.

Product	Number of Reviews				% of Authentic Reviews
	Positive (>=4)	Negative (<=2)	Neutral (=3)	Total	
SD#1	1056	460	187	1703	82.90
SD#2	1657	748	267	2672	91.54
SD#3	3166	740	206	4112	97.01
SD#4	766	643	123	1532	84.01
SD#5	3432	439	120	3991	99.97
SD#6	4909	231	635	5775	98.07
SD#7	3294	878	220	4392	99.54
SD#8	4976	452	226	5654	62.86
SD#9	1369	423	221	2013	97.98
SD#10	1291	150	60	1501	85.69

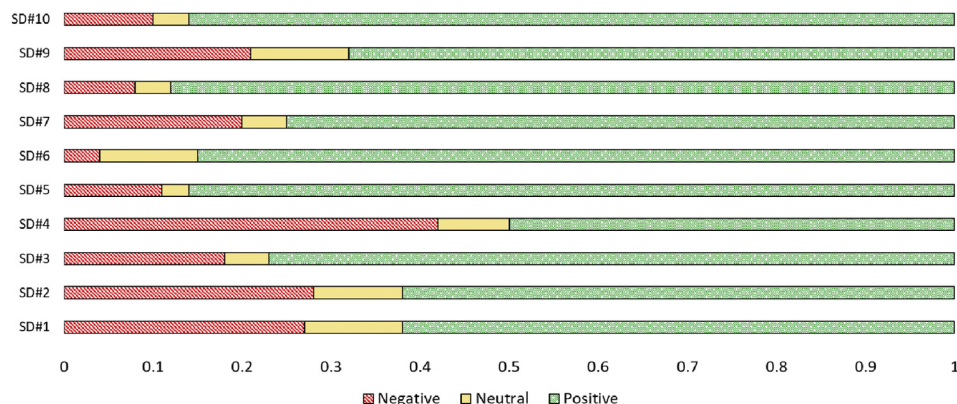


Figure 4. Distribution of reviews.

remains almost the same for all smart items. In contrast, the average sentences in each review fluctuate across products, with a range of more than four.

5. Results

5.1. Topics summary

Table 4 presents the topics identified for both positive and negative reviews for all ten smart products. These topics are inferred through the most common bigrams and trigrams found within the positive and negative online customer reviews.

5.2. SWOT analysis

The Fishbone diagram (Figure 6) outlines the five leading causes of customer dissatisfaction with smart gadgets that are considered in this study. Through text analytics, it appears that the capability, durability, connectivity, size dimensions, and serviceability of the products are mostly negatively perceived by customers. Problems with connectivity are most commonly associated with Wi-Fi and unreliable connection with other smart devices over IoT. Serviceability also poses issues for individuals due to the lack of technical support and product specialists. Some intelligent devices under study are newly introduced products, and hence, there is a lack of knowledge of their long-term performance, which negatively affects some customers' experience with the item. Many negative reviews possess content on the size dimensions of several products, which often cause mobility problems. Another factor of client dissatisfaction is the product's capabilities, including automatic control, sensor detection, and a lack of manual control. The device's durability also impacts customer satisfaction. In addition, people complain of inefficient battery life and short product relevance life.

The link analysis (see Figure 7) is created as a visual representation of the most commonly identified topics within positive customer reviews. These words are most relevant to the positive qualities of the smart devices under study. The size of the bubble directly correlates to the frequency of the topic within the individual reviews. From this figure, it is shown that versatility, installation, features, responsiveness, QR code availability, and sound quality all positively impact the customers' perception of quality of the gadgets under study. People compliment various features of the products like a microphone and Bluetooth options, which can be easily integrated into other smart products. The responsiveness of the voice control feature is also highly praised throughout the online reviews. Several of these devices contain speaker systems that have a high sound quality, as well.

After completing text analytics, we conduct the overall SWOT analysis for all the devices under study, as presented in Figure 8. The identified deficiencies violate several quality control standards, which negatively influence the reputation of the product. The following conclusions concerning the eight dimensions of quality are made after completion of the SWOT analysis.

Customers often complain about the smart device's unreliable connection to Wi-Fi routers, which may pose many issues in regards to product performance. This unreliability challenges the eighth dimension of quality – *conformance to standards*. Smart products often require a stable Wi-Fi connection to fulfill all their functions, so any interruption of this connection results in the nonconformance of standards and a negative perception of its quality. For example, some people experience connectivity and functioning issues with their smart door locks, due to which they are forced to hire a locksmith to enter into their house or break open the door, resulting in significant collateral damages.

Customers also criticize the insufficient battery life of smart items, which defies the third dimension of quality – *durability*. The smart device's inability to withstand time creates a negative perception of its strength. By increasing battery life, people would become more satisfied and relay their satisfaction via eWOM.

The incapability to move the device conveniently after installation pose problems for thousands of customers. Individuals regularly express their grievances about the size and weight of the product. If an individual chooses to relocate the device for any reason, their perception of its quality may be dependent on ease of reinstallation, so it is a critical aspect to consider when designing the product.

Another common complaint among clients is inadequate technical support for smart gadgets, which challenges the fourth dimension of quality – *serviceability*. Since smart devices are newly introduced to the technology market, sufficient technical support often does not exist. If these device manufacturers aspire to have success longevity, adequate support must be offered to customers in various forms to assure accessibility.

The last major weakness identified through the SWOT analysis is the lack of manual control, which violates the sixth dimension of quality – *features*. Although these devices are often meant to be fully automated, manual control is also expected by people for ease of use. By offering this additional feature, individuals can choose between automatic and manual depending on the desired outcome, which could positively impact their experience with the device and improve market appeal.

6. Discussions and managerial implications

Candi et al. (2017) categorized the product design aspects under three dimensions – functional, aesthetic, and symbolic. While the functional

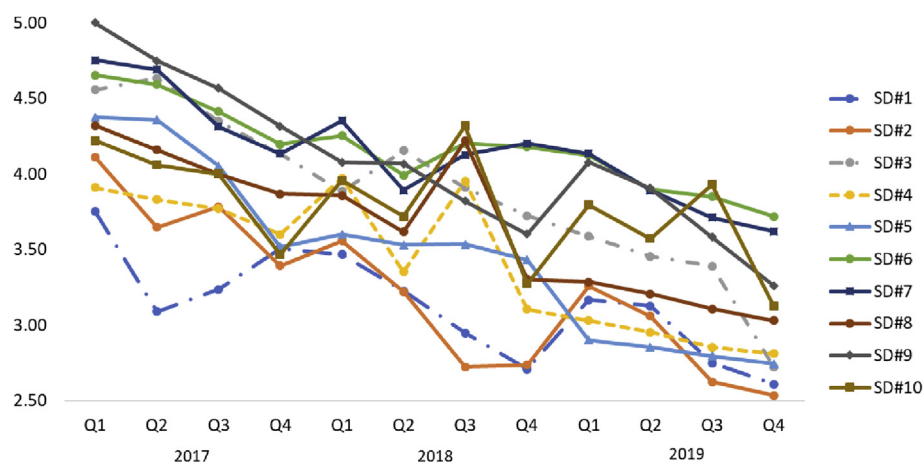


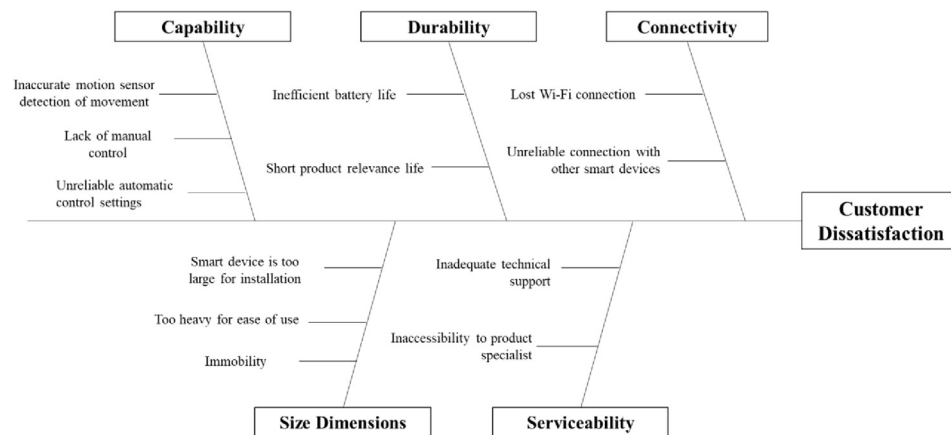
Figure 5. Average rating over time.

Table 3. Word and sentence statistics.

Product	Average Words per Sentence		Average Sentences per Review	
	Mean	STD	Mean	STD
SD#1	4.61	0.02	6.46	5.01
SD#2	5.27	0.02	5.21	5.02
SD#3	4.35	0.02	4.54	3.05
SD#4	4.51	0.03	5.01	4.01
SD#5	4.31	0.02	2.36	2.04
SD#6	4.39	0.04	4.32	3.16
SD#7	4.52	0.02	6.32	5.93
SD#8	4.62	0.02	6.74	4.12
SD#9	4.79	0.03	4.12	3.31
SD#10	4.41	0.05	5.27	4.13

Table 4. Summary of positive and negative topics.

Product	Topics from Positive Reviews	Topics from Negative Reviews
SD#1	IR blaster, capability of smartphone application, setup	Technical support, connectivity with smart device, cable box, large dimension
SD#2	Connectivity with other smart devices, setup, features, QR code	Product durability, automatic control, technical support, motion sensor
SD#3	Bluetooth, installation, connectivity to other smart hub and smart devices	Reliability, customer service, battery life, factory reset, large
SD#4	Setup, responsiveness, versatility, sound quality	Technical support, connectivity with smart devices, product specialist, heavy
SD#5	Microphone, connectivity with speakers, voice control, responsiveness	Battery life, customer service, automatic setting
SD#6	Installation, voice control, QR code scanning, accessories	Connectivity with Wi-Fi, customer service, responsiveness
SD#7	Temperature control, installation, money-saving, versatility	Customer service, connectivity with Wi-Fi, common wire – power source
SD#8	Sound quality, installation, accessories, security system, motion sensor	Customer service, security system, disarming alarm, extended ringing
SD#9	QR code, installation, price, connectivity with smart hubs	Customer service, connectivity with Wi-Fi, product specialist, motion sensor
SD#10	Setup, sound quality, Bluetooth connectivity, features	Technical support, access to online music libraries, heavy, automatic control, battery life

**Figure 6.** Fish bone diagram.

aspect focusses on whether the product does the intended task, the aesthetics is centered around the beauty of the device. The symbolic characteristic emphasizes on the self-image and value perceived by the customer as a result of using the gadget. The results obtained under the current study could also be categorized under one of these three dimensions. For instance, the topics “connectivity” and “capability” could be classified under product functionality, “size dimension” is related to the aesthetics, and “features” are associated with the symbolic attribute.

Hu and Liu (2004) suggested that online customer reviews description can be related to two aspects of a product; explicit and implicit. However, studies centered around the explicit feature portrayal of products are more extensive as they are easy to extract from the unstructured online data (Gao et al., 2017). This research contributes to the current body of the literature by analyzing both dimensions of the smart

devices. Even though factors, such as price, shape, and vendors, have been identified as key topics in prior studies (e.g., Candi et al., 2017; Gao et al., 2017; Singh and Tucker, 2017; Jiang et al., 2019), the reviews particularly associated with smart devices, focusses on features, durability, connectivity, and issues with automation.

Upon analysis, certain dimensions of quality are not currently satisfied by the products under study. Although automation is growing in popularity, many consumers are unfamiliar and uncomfortable with its capabilities. By providing the consumers with more manual control of scheduling, security preferences, and/or temperature fluctuations, they will feel more comfortable allowing devices to make changes in their homes when they are away. Smart products, like smart thermostats, can change the temperature of the user's home without command, which may lead to concern. Allowing consumers to choose the automatic or manual

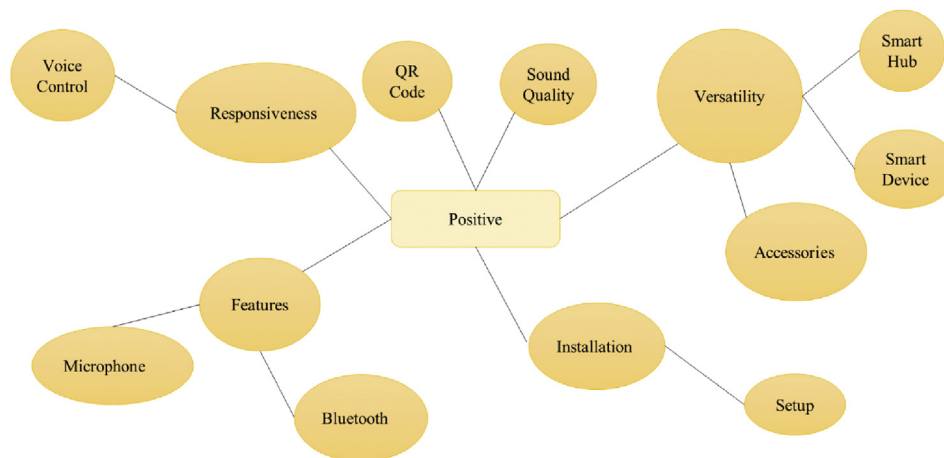


Figure 7. Positive link analysis.

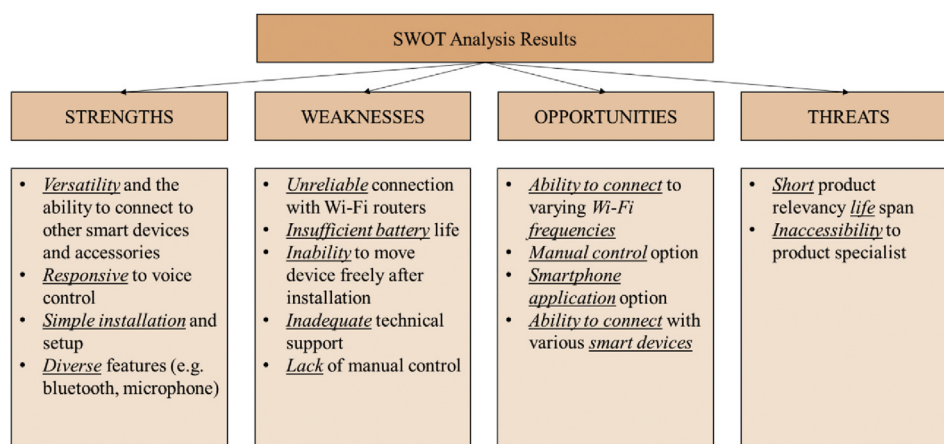


Figure 8. Summary of SWOT analysis.

state of the device might build people's confidence in the device's capabilities.

The product's characteristic of frequently disconnecting from the internet posed a concern to many individuals across every device in this study and results in thousands of negative ratings and reviews. The unreliability of this connection can affect the device's performance and dependability. For example, when owners are traveling, and their smart security system disconnects from the internet, they are unable to monitor their homes remotely. A solution would be to connect multiple routers within a home to increase Wi-Fi connections or install a hot spot connection within the device. If the device could consistently connect to the internet, its performance would improve.

To become more competitive, smart devices could increase versatility and connect to routers with different wireless frequencies, like 2.4 GHz and 5 GHz. This additional versatility will expand the product's market and result in increased sales. Moreover, a smart gadget that is compatible with multiple frequencies is more attractive to customers who have varying expectations, constraints, and needs.

Within this study, it is found that many consumers respond well to the smartphone application feature of certain products. This feature could be utilized virtually by any device connected to the internet. With the increased popularity of smartphones, an application gives consumers the freedom to control the devices from anywhere with limited effort. The smartphone application could also display data provided by the smart gadget, such as the current temperature of the home, security footage, or device status.

Many consumers complain about the low durability of products and insufficient battery life. With moderate to high prices, consumers expect a certain quality of products, so providing a long-lasting battery is necessary. Improving battery life will result in an increased life span, and therefore, could improve the customers' perception of its quality.

As new household smart devices emerge into the market, products could become more compatible with them and offer grouping and scheduling options. Through IoT, these devices could schedule on and off states to maximize energy efficiency within a home. This is especially useful with lighting and temperature, but has other applications as well.

The field of analyzing OCR for proposing next-generation manufacturing insights is still in the developmental stage. Although prior articles emphasize the need to consider OCRs for making product design recommendations (e.g., Candi et al., 2017; Gao et al., 2017; Jiang et al., 2019), manufacturing companies do need to explicitly specify the next-generation design changes that have been made as a result of the examining the OCRs. Discussing the implementation of the next-generation design insights would be helpful for academicians for validating their OCR analysis results.

7. Conclusions

Prior studies have repeatedly suggested that online customer reviews significantly affect an individual's purchasing decisions. eWOM also allows companies to understand further their customer's needs, preferences, and dislikes. To the best of our knowledge, this study is the first to provide next-generation manufacturing recommendations for existing

smart devices through online review analysis. We develop a three-stage methodology, consisting of bigram and trigram examination, topic identification, and SWOT analysis. Based on this approach, next-generation manufacturing recommendations are provided for companies making smart devices.

To begin this study, 33,345 online customer reviews for ten diverse smart gadgets are collected from several online sources. The reviews are then separated depending on star rating, and positive and negative topics are inferred through commonly occurring bigrams and trigrams. Upon completion, several meaningful topics are concluded, and a SWOT analysis is conducted to highlight the key factors that influence customer satisfaction. Numerous managerial recommendations with respect to durability, additional features, versatility, connectivity, and manual control are presented.

Declarations

Author contribution statement

Suchithra Rajendran: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Emily Pagel: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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The authors declare no conflict of interest.

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