Investigation of Different Perspectives between Developers and Customers: Robotic Vacuum Cleaners

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***Abstract*--The literature on high-technology marketing frequently observes that the perspectives of managers in cutting-edge product development are often at odds with the perspectives of consumers, leading to products that do not fit into consumer values, force behavioral changes upon them, are difficult to use, or do not meet needs at all. A possible case-in-point is robotic vacuum cleaners (RVC) for home use. In 2001, their market introduction was accompanied by optimistic forecasts, but the pace of market penetration has been slow and over 10 years after their initial launch, RVC still only account for 4.1% of the vacuum cleaner market in 2012 in the United States.**

This paper investigates if there is a mismatch between product developers' perspectives and actual customer needs that can provide a possible explanation why RVCs are facing difficulties in expanding market share in the home cleaning device market. To do so, it uses fuzzy cognitive mapping (FCM) to capture and quantitatively model the perceptions of RVC developers and RVC customers. The developer model shows the causal links between product features and presumed product attractiveness; the customer model shows causal links between product features and perceived product desirability. The models are used to investigate how developers and customers value alternative product improvements and two what extent their perspectives are aligned. Results show that there are distinct gaps between both perspectives, causing product developers to favor product improvements with little pay-off for perceived product desirability.

I. INTRODUCTION

Since the 1920s, when Karel Čapek first coined the term robot in his theater play R.U.R. (Rossum's Universal Robots), robots are a mainstay of popular fiction, where they wait on people, save users from unpleasant chores, share their emotions, and even function as friends. In industrial settings, these predictions have - to some extend - become a reality: since the 1960s robots are deployed in a wide variety of automation systems for mass-production, where they replace humans' physical functions, and do repetitive functions. In contrast and despite countless efforts to bring robotic technology into our home, so called "Consumer Robotics" or "Domestic Robotics" are slow to be adopted by the public and dominantly used as high-tech toys. One notable exception is floor cleaning robots. In particular, robotic vacuum cleaners (RCVs) have been developed with the idea of reducing the human work for cleaning the floor and to replace typical manual vacuum cleaners. Usually, RVCs are built with low cost components for competitiveness of price. In addition, these robots are small enough to move freely even under furniture and enough light for people to carry more easily. Some RVCs have intuitive user interfaces for convenient control. With these advantages, RVCs are showing faster growth than traditional vacuum cleaners: in 2012, sales volumes increased by 3.4% to 698,600 units, while the typical vacuum cleaner market achieved 1.7% growth to 41,460,100 units in the United States [1]. However, RVCs still only constitute a very small share of the total market.

In spite of this distinctive growth, according to the 2012 annual report of iRobot, a dominant producer in robotic cleaning devices, RVCs developed as supplements are competing with typical manual vacuum cleaners[2]. According to the interview by Forlizzi and DiSalvo, current commercial products such as the Roomba series have not matched customers' expectation [3]. Though the use of RVCs is now becoming more acceptable due to the technology improvement and the decline of price, still, the performance of RVCs seems to fall short of customers' expectation.

The literature on high-technology marketing provides a possible explanation and observes that the perspectives of managers in product development are often at odds with the perspectives of consumers, leading to products that do not fit into consumer values, force behavioral changes upon them, are difficult to use, or do not meet needs at all [4]. Table 1 shows cognitive differences about new products between customers and managers.

TABLE 1 CUSTOMER FOCUS VERSUS MANAGERIAL FOCUS

Customer Focus	Managerial Focus
Features	Design
Consequences, values	Cost
Ease of operation	Ease of production
Unique qualities	Unique technologies
Consumption	Production

Source: Rosen et al. [4]

This paper investigates a mismatch between product developers' perspectives and actual customer needs as a possible explanation why RVCs are facing difficulties in expanding market share in the home cleaning device market. To do so, it uses fuzzy cognitive mapping (FCM) to capture and quantitatively model the perceptions of RVC developers and RVC customers. The developer model shows the causal links between product features and presumed product attractiveness; the customer model shows causal links between product features and perceived product desirability. The models are used to investigate how developers and customers value alternative product improvements and two what extent their perspectives are aligned.

Including this introduction, the paper is organized in six sections. Section II provides a brief overview over relevant literature on domestic robots. In the section III, the theoretical foundations of the FCM research method employed in this paper is introduced. Section IV employs FCM to the RVC case and presents the developer and customer model, and presents the results of simulating different product design alternatives in both models. And, Section V compares the conclusions drawn by developers and customers. Section VI contains the direction of this paper and directions for further studies.

II. LITERATURE REVIEW

A. Development of Robotic Vacuum Cleaners

Several specific analyses of the main technologies for cleaning robots exist. They discuss the link between technology, product performance and customers' expectations from the viewpoint of developers. Fiorini and Prassler suggested several main technology areas which are required in developing cleaning robots [5]. And, one of developers in the iRobot Corporation described the developing process of the first Roomba robot, the first commercially successful RVCs [6]. In developing the first Roomba, the developers focused on making well-functioned and inexpensive robots. Since the Roomba's success, lots of companies have introduced commercial RVCs. To respond to needs of establishing industrial standards such as IEC 60312-3 (Draft) and IEC 60335-2-2, several researchers proposed test methodologies for RVCs [7]. In these efforts of researchers and developers, differing perspective on developing RVCs can be captured. Therefore, in this paper, the analysis of developers' perspective is conducted based on these efforts.

B. Social Expectation on RVCs

Another approach to capture customer needs is to investigate social expectation about RVCs. Identification of customers' expectation on RVCs is one of the main important aspects for this study. There are several studies describing the social factors such as the usage and adoption of robots and analyzing people's expectations about robotic technology for daily life of the public. There are many studies regarding the psychological attitudes of customers about robots. Forlizzi and DiSalvo explain the adaptation cycle of a consumer robot from introduction and adaption of robotic products to the importance of the interaction of human-machine for the robot acceptance [3]. Some papers analyze the perspective and expectations of customers on robotics in the future from economical and physical perspectives [8]–[10]. These papers analyze the human behavior and attitudes when they live with robots. The analysis includes gender perspective, gender attitudes, and economical perspectives. Many of the studies are made by surveys and ethnographic analysis. Also, most these studies analyze the behavior of customers, needs, and the interaction considering many technological factors such as language, noise, and shape of the robots. In addition, there are some studies specifically about vacuum robot cleaning and the customers' interactions [11], [12]. With these studies, basic concepts for customer needs can be captured to provide background knowledge for contributors who participate in building a fuzzy cognitive map.

C. Fuzzy Cognitive Maps

Causal cognitive mapping, as a tool to capture unique perspectives of individuals' world, is useful to understand causalities of various concepts visually. However, causal mapping is limited to reflect vague relationships between each concept in a model. Also, a complicated and large size model tends to cause difficulty to analyze. Therefore, some alternative methods, such as clustering analysis and system grid analysis, have been proposed. However, these methods do not provide any forecast of the whole system behavior. In addition, because most of the concepts and relationships in causal cognitive maps are obtained from qualitative data, such as verbal or written data from specific views of subjects, it is difficult or impossible to quantify those data [13].

In this regard, Kosko suggested one solution for these problems, Fuzzy Cognitive Map (FCM) as a way of developing qualitative cognitive maps in order to improve the understanding of uncertain causal knowledge with adopting the neural network theory [14], [15]. In particular, FCM was applied to extract, integrate and analyze stakeholders' understanding on products in new product development (NPD) [16].

III. METHODOLOGY

The process of FCMs is divided into six steps [17]. First of all, what are model objectives and information needs should be clarified. The next step is to plan how collect relevant information. To do this, it is required to identify knowledge sources (e.g. experts or literature) and methodology for collecting knowledge (e.g. interviews or text mining). With this plan, main concepts from knowledge are captured, and expected dynamic behavior of the system is investigated. The fourth and fifth steps are to develop FCMs from conceptual to detailed design. Simultaneously, reasonable squashing function and initial state vectors need to be identified in these steps. Finally, after testing, the result of FCMs is interpreted and validated. Figure 1 shows a brief example of a FCM. In Figure 1, if the concept B increases when the concept A increases, the relationship is assigned as a positive sign. And, if the concept D decreases when the concept C increases, the relationship is assigned as a negative.

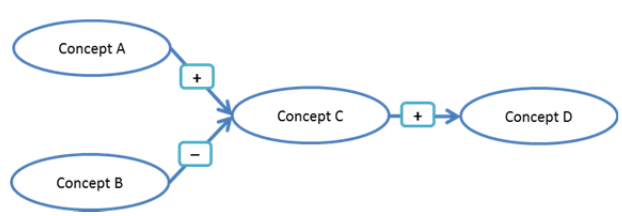

Figure 1. Basic rule for a causal cognitive map

A FCM model is built by synthesizing causal maps from participants. And, in the synthesized model, a value of each relationship can be calculated as a mean value of each corresponding number of signs, or assigned by consensus of participants. The range of these values is from -1 to 1. Based on this model, an adjacency matrix, or a square connection matrix, consists of relationship values between each corresponding concept. Therefore, if n is the number of concepts in a FCM, the size of an adjacency matrix has n rows and n columns. For example, the adjacency matrix corresponding to the causal map in the Fig. 1 is represented like below;

$$\mathrm{E} = \begin{bmatrix} 0 & 0 & +1 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & +1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \qquad (1)$$

To investigate the change of each concept by inducting a type of specific changes of concepts, an initial state vector with one row and n columns is multiplied by the adjacency matrix. For instance, if the concept A is only activated while others are turned off in Figure 1, the initial state vector is like below;

$$\mathrm{S} = [1 \quad 0 \quad 0 \quad 0] \qquad (2)$$

Each element in the matrix (one by n) by the multiplication of the initial state vector and the adjacency matrix is converted by a squashing function which can be of various types, such as binary, linear and hyperbolic tangent function according to the type of a system. These squashing functions are depicted like below;

- Binary function: $S(x) = \begin{cases} -1 & for\ x < 0 \\ 0 & for\ x = 0 \\ 1 & for\ x > 0 \end{cases}$ (3)
- Linear function: $S(x) = \begin{cases} -1 & for\ x \le -1 \\ x & for -1 < x < 1 \\ 1 & for\ x \ge 1 \end{cases}$ (4)
- Hyperbolic tangent function: $S(x) = \tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}}$ (5)

Then, the new state vector is multiplied by the adjacency matrix again until reaching stable status or a stop criterion [16]. Lastly, the last state vector to reach stable status or a stop criterion can be used to investigate how the change of each element in the last state vector can be interpreted.

IV. RESULTS OF MODEL BUILDING AND TESTING

In this paper, FCM is applied to investigate two different points of view; perspective of developers in NPD and expectation of customers on robotic vacuum cleaners. After building two different FCMs based on literature and interviews with general customers and developers, common concepts between both models are identified. And then, the common concepts, as elements of an initial state vector, are integrated into the FCMs, and the results of the last state vectors which reach a stable status or a regular repetition are compared. For this investigation, binary, linear and hyperbolic tangent functions are applied to calculation of both FCMs.

A. Perspective of Developers

As mentioned above briefly, a FCM on designing a RVC with perspective of developers is modeled, based on literature review and an interactive group session with experts who have experience in developing robotic products. Above all, the fundamental concepts were elicited from the literature related to perspective of developers which described in the section II. With these fundamental concepts, two experts, who have researched and developed some robotic products for over 10 years, organized a cognitive map with discussion. And then, the experts assigned relationships between concepts and weights on the relationships. Figure 2 is the causal cognitive map related to designing a robotic vacuum cleaner. This map includes fifteen concepts defined in Table 1. And, each relationship has corresponding value assigned by experts in the interactive group session and within a range between -1 to 1, which is shown in the adjacency matrix in Table 2. This matrix shows information of quantitative relationships between each concept and is used investigate how the change of each element in the last state vector can be interpreted.

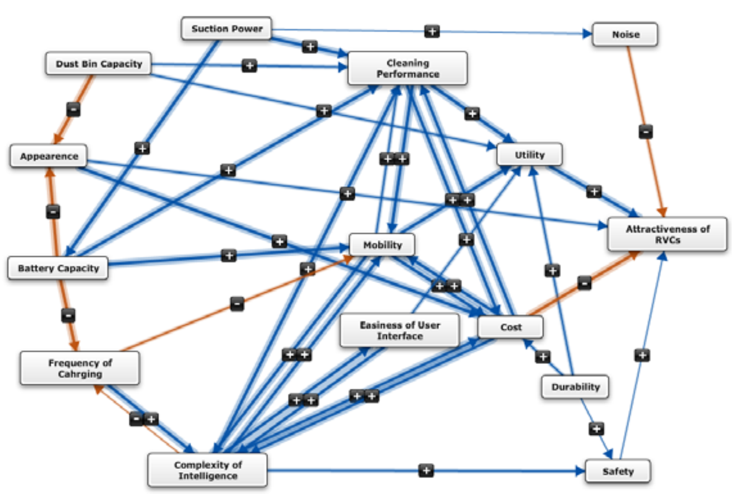

Figure 2. The causal cognitive map of developers

TABLE 2. DEFINITION OF EACH CONCEPT IN THE COGNITIVE MAP OF DEVELOPERS

No.	Concepts	Definition
1	Attractiveness of RVCs	the degree of attractiveness which stimulate customers to buy a RVC
2	Utility	the degree of usefulness which make a RVC convenient for users
3	Cost	the amount of money that have to be spent for developing a RVC
4	Safety	the state of not being dangerous or harmful in using a RVC
5	Noise	the degree of loudness or unpleasant sound in using a RVC
6	Cleaning Performance	the degree of performance how well a RVC can clean a specific location
7	Mobility	the degree of capability of moving for cleaning and charging
8	Easiness of User Interface	the degree of ease of use in inputting specific commands or recognizing status of a RVC
9	Durability	the degree of staying good condition in usual usage of a RVC
10	Suction Power	the maximum pressure difference that the pump can create for cleaning
11	Complexity of Intelligence	the quality or state of being complex in controlling a RVC with artificial intelligence or control algorithms
12	Frequency of Charging	the number of times that a RVC have to charge its battery to clean a specific area
13	Battery Capacity	a measure of the charge stored by the battery in a RVC
14	Appearance	the way that RVC looks
15	Dust Bin Capacity	the maximum volume where a RVC can store dust or debris

TABLE 3. THE ADJACENCY MATRIX CORRESPONDING TO THE COGNITIVE MAP OF DEVELOPERS

	Attractiveness of RVCs	Utility	Cost	Safety	Noise	Cleaning Performance	Mobility	Easiness of User Interface	Durability	Suction Power	Complexity of Intelligence	Frequency of Charging	Battery Capacity	Appearance	Dust Bin Capacity
Attractiveness of RVCs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Utility	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cost	**-1.00**	0.00	0.00	0.00	0.00	**1.00**	**1.00**	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00
Safety	**0.25**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Noise	**-0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cleaning Performance	0.00	**1.00**	**1.00**	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mobility	0.00	**1.00**	**1.00**	0.00	0.00	**0.50**	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00
Easiness of User Interface	0.00	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00
Durability	0.00	**0.50**	**0.50**	**0.25**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suction Power	0.00	0.00	0.00	0.00	**0.25**	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00
Complexity of Intelligence	0.00	0.00	**1.00**	**0.50**	0.00	**1.00**	**1.00**	**1.00**	0.00	0.00	0.00	**-0.25**	0.00	0.00	0.00
Frequency of Charging	0.00	0.00	0.00	0.00	0.00	0.00	**-0.50**	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00
Battery Capacity	0.00	0.00	0.00	0.00	0.00	**1.00**	**1.00**	0.00	0.00	0.00	0.00	**-1.00**	0.00	**-1.00**	0.00
Appearance	**0.50**	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dust Bin Capacity	0.00	**0.50**	0.00	0.00	0.00	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-1.00**	0.00

B. Expectation of Customers

Another FCM on customer expectation in purchasing a RVC is developed by literature review and an interactive group session with general customers who have various backgrounds regardless of whether anyone has experiences in RVCs or not. Like the FCM of developers, basic concepts are elicited from two interviewees and literature related to customer needs which described in the section II. With providing these concepts, five contributors built a conceptual cognitive map and assigned relationships similar with experts for the FCM of developers' perspective. Figure 3 is the causal cognitive map related to expectation of customers in purchasing a RVC. This map includes twenty two concepts defined in Table 3. And, each relationship has corresponding value assigned by the interactive group session and within a range between -1 to 1, which is shown in the adjacency matrix in Table 4.

V. DISCUSSION

In comparing two causal cognitive maps, the developers' causal cognitive map shows a more complicated structure but includes fewer concepts than the customers' cognitive map. In particular, in the developers' causal cognitive map, there are several mutual relationships between some concepts such as between cleaning performance and cost, between cleaning performance and mobility, between mobility and cost, between mobility and complexity of intelligence, and between complexity of intelligence and cost. Also, there are some feedback loops. For example, increase of mobility augments complexity of intelligence. If complexity of intelligence increases, frequency of charging will be decreased and affect mobility. On the other hand, the causal cognitive map of customers is relatively intuitive. Particularly, while all concepts are directly connected with

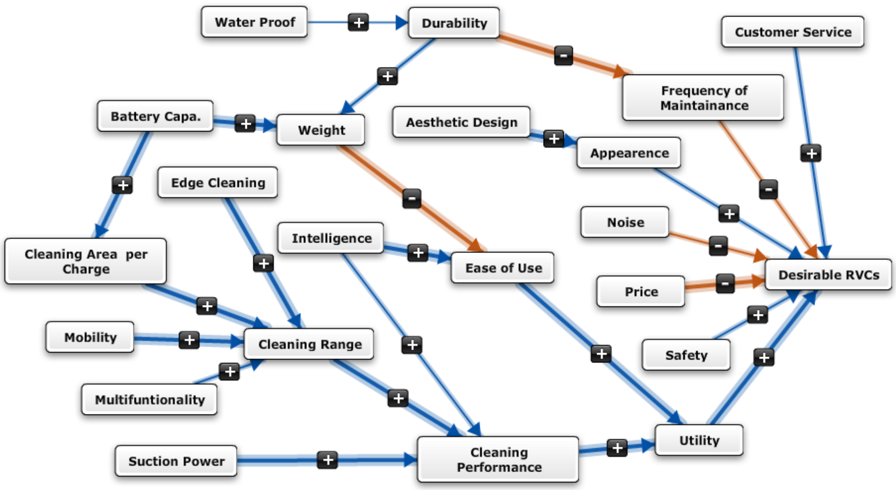

Figure 3. The causal cognitive causal map of customers

TABLE 4. DEFINITION OF EACH CONCEPT IN THE COGNITIVE MAP OF CUSTOMERS

No.	Concepts	Definition
1	Desirable RVCs	the degree of desirability that customers want to buy a RVC
2	Customer Service	the degree of how much customers satisfy customer service of a RVC
3	Frequency of Maintenance	the number of times that a RVC need maintenance for keeping normal condition
4	Appearance	the external show of a RVC
5	Noise	the degree of loudness or unpleasant sound in using a RVC
6	Price	the amount of money that customers pay for a RVC
7	Safety	the state of not being dangerous or harmful in using a RVC
8	Utility	the degree of usefulness which make a RVC convenient for users
9	Durability	the degree of staying good condition in usual usage of a RVC
10	Aesthetic Design	the design that customers appreciate beauty of a RVC
11	Ease of Use	the ability of a customer to readily and successfully perform a task with a RVC
12	Cleaning Performance	the degree of performance how well a RVC can clean a specific location
13	Weight	a measurement that indicates how heavy a RVC is
14	Intelligence	the ability of a RVC to deal with given situation with its artificial intelligence or programmed algorithms
15	Cleaning Range	the range of area that a RVC can move and clean
16	Water Proof	a special design to prevent water from entering into the body of a RVC
17	Battery Capacity	a measure of the charge stored by the battery in a RVC
18	Edge Cleaning	the ability of a RVC to access edges or corners for cleaning
19	Cleaning Area per Charge	the rage of area that a RVC can move and clean after charging its battery fully
20	Mobility	the degree of capability of moving for cleaning and charging
21	Multifunctionality	the ability of a RVC that can clean various environment with variety of functions
22	Suction Power	the maximum pressure difference that the pump can create for cleaning

TABLE 5. THE ADJACENCY MATRIX CORRESPONDING TO THE COGNITIVE MAP OF CUSTOMERS

	Desirable RVCs	Customer Service	Frequency of Maintainance	Appearance	Noise	Price	Safety	Utility	Durability	Aesthetic Design	Ease of Use	Cleaning Performance	Weight	Intelligence	Cleaning Range	Water Proof	Battery Capacity	Edge Cleaning	Cleaning Area per Charge	Mobility	Multifunctionality	Suction Power
Desirable RVCs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Customer Service	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frequency of Maintainance	**-0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Appearance	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Noise	**-0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Price	**-1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Safety	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Utility	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Durability	0.00	0.00	**-1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aesthetic Design	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ease of Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cleaning Performance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weight	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**-1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Intelligence	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cleaning Range	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Proof	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.25**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Battery Capacity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00
Edge Cleaning	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cleaning Area per Charge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mobility	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Multifunctionality	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.50**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Suction Power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

the attractiveness of RVCs, such as cost, utility, safety and noise, are influenced by other concepts in the causal cognitive map of developers, some concepts connected with the desirable RVCs, such as price, noise, safety and customer service, in the causal cognitive map of customers are not affected by any concepts. And, in this causal cognitive map, there is no feedback loop.

From the two causal cognitive maps, three common concepts such as durability, suction power and battery capacity, which are rarely influenced by other concepts, are identified as design parameters. These design parameters are used to investigate how the two goal concepts, “attractiveness of RVCs” and “desirable RVCs,” are affected by individual or multiple activations of design parameters. Table 5 shows the final states of the two goal concepts that are affected by activation of the design parameters in both models. Also, the table includes impacts of squashing functions described above on the two goal concepts, “attractiveness of RVCs” and “desirable RVCs.”

The “Attractiveness of RVCs” concept in the developers’ cognitive map is negatively affected by activated design parameters in all cases except the case 1, in which only durability is activated. In all of these cases, activated parameters have positive or neutral impact on the “Desirable RVCs” concept in the customers’ FCM. On the other hand, activation of the durability parameter as the case 1 positively influences the “Attractiveness of RVCs” concept but negatively influences the “Desirable RVCs” concept. However, the impact of this case is relatively weaker than other cases. It implies that durability of RVCs, only itself, is a less important concept to increase attractiveness and preference of RVCs in both of views. Also, activating only the concept of battery capacity affects only perspective of developers while it has neutral or very weak influence on the customers’ expectation. In other word, battery capacity of RVCs is considered as a meaningful performance element in view of developers' perspective while customers do not show a meaningful response to the activation of it. If only one of design parameters can be activated, suction power impacts positively and meaningfully on customer expectation while it affects the attractiveness of RVCs relatively strongly and negatively in a view of developers.

Simultaneous activation both durability and suction power as the case 4 affects customer expectation most strongly and positively, but its difference with the case 2, activation of the suction power, is relatively small. And, except the case 3, activation of the battery capacity, in calculating the two FCMs with the tangents hyperbolic squashing function, the two goal concepts are in opposite sides each other. Therefore, between perspective of developers and expectation of customers, there is a distinctive gap.

VI. CONCLUSION

The purpose of this paper is whether there are perspective gaps between developers and customers on RVCs. For this purpose, two different FCMs are developed from perspective of developers and expectation of customers on robotic vacuum cleaning devices. By comparing both maps, this paper shows that developers have totally different perspective view with customers. In addition, the map developed by developers is more complicated than the other. The calculation of both FCMs also traced apparent difference between perspectives of both sides. With these results, managers in product development projects can attempt to trade off each conflicting requirements in ways that lead to appealing products. Also, this comparison of both FCMs provides a good opportunity in terms of communication between multidisciplinary teams.

However, this paper has some limitations in spite of confirming the gap between both perspectives. The relationships between concepts in both models are assigned quantitatively by concurrence and intuitions of participants rather than by analytical quantification such as desirability curve or utility curve. Moreover, it is difficult to make a judgment which of squashing functions used in this research is proper to make these models more credible. Therefore, more insightful studies about which type of squashing function is appropriate for developing more close to a real model are required. Also, this study did not include impact of enterprise characteristics in the developers’ model. Though this study focuses on developers’ perspective in developing a new product, if expanding the focus to other parts in new product development process, more practical results can be expected. Therefore, this study will be continued in the future. Lastly, based on this research, a novel framework can be adopted for capturing customers’ potential expectation in new product development on consumer robotic devices.

TABLE 6. IMPACTS OF DESIGN PARAMETERS AND SQUASHING FUNCTIONS

Case No.	Activated Design Parameters			Binary Squashing Function		Linear Squashing Function		Tangents Hyperbolic Squashing Function	
	Durability	Suction Power	Battery Capacity	Attractiveness of RVCs	Desirable RVCs	Attractiveness of RVCs	Desirable RVCs	Attractiveness of RVCs	Desirable RVCs
1	1	0	0	1	-1	0.19	0	0.15	-0.03
2	0	1	0	-1	1	-0.5	1	-0.3	0.57
3	0	0	1	-1	0	-0.4	0	-0.3	-0.08
4	1	1	0	-1	1	-0.4	1	-0.3	0.6
5	1	0	1	-1	1	-0.3	0.5	-0.2	0.23
6	0	1	1	-1	0	-0.5	0	-0.4	0.27
7	1	1	1	-1	1	-0.4	0.5	-0.3	0.53

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