Introducing Value Axiom for New Design Creations

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Abstract. This paper proposes "Value Axiom" that states "The larger the sum of Customer Attribute values, the better the design." A customer evaluates a design with the sum of the value produced by each Customer Attribute, expressing it with a monetary value such as Japanese yen. A designer can hardly estimate and express a perfect set of Customer Attributes at the early stage of a design. The designer writes down the design equation to visualize the entire design, and improves the sets of Design Parameters and Functional Requirements using the Independence Axiom and Information Axiom, and at the same time, it is also important to review the values of Customer Attributes using the Value Axiom.

1 Introduction

Axiomatic Design (AD) [1] is extremely effective in the design process of visualizing the definition of the design contents to understand the entire picture, and further in the process of decoupling interferences among Functional Requirements (FRs) when confronted with a problem with an existing design. Instead of improving an existing design, however, when it comes to "creative design" of a product that did not exist before, there are primarily 2 problems in applying AD.

The first problem is that the designer cannot analyse, estimate, or describe the necessary and minimum set of Customer Attributes (CAs), FRs and Constraints (Cs) in the early stage of the design. If the designer continues the design without supplementing the missing elements, the target values for CAs cannot be attained and the customers would not purchase the products or services when they are made available in the market. That means the design project ended up in a failure.

The new design without a former model is more difficult even for a skilled designer to describe all CAs, FRs, and Cs. The customer may come up with disturbances: for example, another CA way to use the product that the designer never thought of, or an unexpected natural disaster can cause a recession to cancel a CA value, or worker's strike at an overseas production site making a delay to lose customer's appetite for buying. In case of such drastic happenings, the only effective countermeasure for the designer is to flexibly and quickly modify the design equation with a new set of CAs, FRs, Cs, and Design Parameters (DPs).

The second problem is even if the designer reached a set of mutually exclusive and collectively exhaustive (MECE) FRs, the planned DPs to realize the FR set in an uncoupled manner may be unavailable for only purchase, or uninventable within budgets. Especially when there is no former model, combining existing technologies is often short in making a planned DP and the designer often has to invent it. The thinking process is inevitable for invention, however, AD does not provide a guide for supporting invention. Other supportive design tools, e.g., TRIZ may have advantages in this sense.

Our paper introduces a solution to the first problem by modifying CAs, FRs, Cs, and DPs so they can quickly approach the ideal set. Here, the sum of all CA values evaluate how close the elements are to the ideal set. In the early stage of a design, descriptions of CAs are insufficient and, as a result, the sum of all CAs values are small. However, through iteration of conceptual design, prototyping, testing, evaluation, design improvement, another prototyping, retesting, reevaluation the sum gradually increases its value and when all problems have been conquered, it is close to the ideal sum of CAs values. During this time, if the design leader can show the entire design process with the Design Equation (DE) to visualize the progress, the direction for the design to make advances are clarified and members of the design team can carry a unified vision.

The authors propose "Value Axiom" that "The larger the sum of Customer Attribute values, the better the design." A design improvement increases its value. The unit for customer values here is the monetary value. The list price of products and services is the balanced amount of what the customer is willing to spend and what the provider is hoping to sell at. If we identify all the CA elements and interview "At how much will you set the value of the CA element?," we can reach the rough monetary amount.

For example, if the design target is automobile for home use, CAs are, for example, "use it for the weekday commute (150,000 yen/year (y/y))," "use it for the weekend shopping (100,000 y/y)," or "use it for travel during vacation (100,000 y/y)." If the consumer, however, divides the sum (600,000 y/y) of purchase

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price, maintenance cost, insurance premium, and tax, with the number of travels, one would realize that it is less expensive if one uses a taxi or a rental car for every such needs. Thus, the CA with the biggest value is "immediately available without waiting (250,000 y/y)." Also, those with high-class cars maybe have value in "showing off (1,000,000 y/y)." Such kinds of non-engineering CA should be also accepted in the mature products.

The next section shows the CA value at the time of initial design and how it changed after introducing the product into the market with some design examples. Creative design projects is a trend at modern day universities to let the students build what they want to. For such projects, the instructors, together with the students, should lay down the DE, select DP to satisfy the Independence Axiom and Information Axiom, then check that the CA has increased with the Value Axiom, and if it is still insufficient, discuss what CA is missing from the design or coupled with the other CAs.

2 Case studies

2.1. Universal design for a spoon

Figure 1 shows the DEs for a spoon design based on one of the authors' colleague, Satoshi Nakagawa. He has an industrial designer's experience of designing a something for the elderlies.

As Fig. 1 (a) shows, the CAs identified were the original value of a spoon, "CA_1: pick up food," and one for the universal design, "CA_2: easy to hold for the elderly." The target values were 300 yen for the former CA and 500 yen for the latter. The total value was 800 yen, something a family member would consider as a gift.

The FRs for CA_2 were "FR_{21}: make the handle fat," and "FR_{22}: make the handle light." Fat handles for universal designs were in style with tooth brushes and mechanical pencils at the time. The first sketch in the figure shows the first design with the spoon bowl at the same level with the handle. This arrangement made it hard to scoop up food left at the end on plates because of the fat handle. In other words the "DP_2: constricted fat handle" coupled with "FR_1: scoop up with the bowl at tip." This was a violation of Independence Axiom, thus, an improved DP'_1 was made to offset the bowl lower from the handle level to make the scooping easier.

Fig. 1 (b) shows the spoon after it was placed in the market. The consumers that had perceived the initial design expensive now liked the improved design, approved by Value Axiom. The customer questionnaire showed that the most value was with "CA_3: floats in water and easy to find." This was a surprizing +500 yen value for the designer. Spoons made of stainless steel would sink in water and then can easily get flushed down the drain by accident.

The actual product was designed to be separable at the middle for use as a pill case. The customers, however, hardly saw any value in this function maybe because even if the caretaker placed the pills inside, the elderly would forget taking them.

2.2. CAD callus free mouse

Figure 2 shows the DE for a CAD callus free mouse by the same industrial designer, Nakagawa.

After 3D CAD spread in the industries, technicians started to work all day with computer mice in their hands. As a result, repeated moving of the mouse caused hardening of the wrist skin and eventually callus on the wrist. Young female technicians were especially concerned about them and a student that heard about the problem set "CA_1: prevent CAD callus", but at the same time the original value of the mouse "CA_2: same touch with regular mouse" was also a requirement.

The student came up with a design solution to place a plastic sheet between the wrist and the desk and glued the plastic sheet cut out to the shape of a torus around the mouse. The prototype satisfied the initial value with no rubbing of the wrist on the table. The plastic sheet, however, did not glide so smoothly over the desk and it interfered with "FR_{21}: move cursor." After all, the CA value looked just a piece of plastic sheet. The price of 1,000 yen, twice the regular price of 500 yen, gave the customers the conception that it was expensive.

Fig. 2 (b) shows the evaluation after a manufacturer introduced it in the market. The manufacturer hired an industrial designer to define the shape (FR_3), creating a "DP_3: aesthetic shape." The final design formed a beautiful streamline starting from the forward tilted nose to continue continuously to the wide sheet at the bottom. Also, a friction-free pad (improved DP'_1) was attached to the bottom of the sheet to remove the friction interference.

As a result, even with a sudden increase of the list price to 6,000 yen, the customer recognized the value and 100,000 units were sold within 1 month. The new "CA_3: shape attractively" is so valuable in 5000 yen.

This phenomenon is similar to the sales of bladeless fans. The single FR of invisible blades, added to the conventional set of FRs, lifted the price from 5,000 yen to its 10 times of 50,000 yen and made a big hit in 2009. For this fan, its aesthetic slim form was probably an important DP. A Japanese manufacturer had applied for a patent of a bladeless fan back in 1981, and had a head advantage with the acquired rights, however, the form in the patent application form was far from being aesthetic, giving doubts about its sales, and in fact, it was never developed into a product.

2.3. Instant noodle soup

Figure 3 shows the DE for the instant noodle soup invented by Momofuku Ando in 1958. When he started his development, he posted 5 CA targets of "good taste," "inexpensive," "convenient," "storable at room temperature," and "safe" on a wall in his experiment lab. These CAs were not declared by the customers, but predicted by Ando. He targeted the list price of 35 yen (FR_2), and distributed it to the CA elements for example,

15 yen to "good taste," 15 yen to "convenient," and 5 yen to "storable at room temperature." In 1958, only a few households had refrigerators, and food storable at room temperature had value back then.

Generally, the remaining "inexpensive" and "safe" did not have corresponding DPs, and they were calculated after selecting the DP sets, thus, in AD, they were constraints. The figure shows them as "constraint-like" CAs with 0 yen values. In other words, they were not explicit CAs declared by the customer, but they were implicit CAs the manufacturer prepared for the customer. The CA_2 of "inexpensive" should be rephrased to "perceived inexpensive," or "senses good cost performance". A conventional Japanese noodle product of Udon (soft fat wheat noodles) was only 6 yen, thus, the 35 yen he targeted must had been perceived highly priced for the consumers.

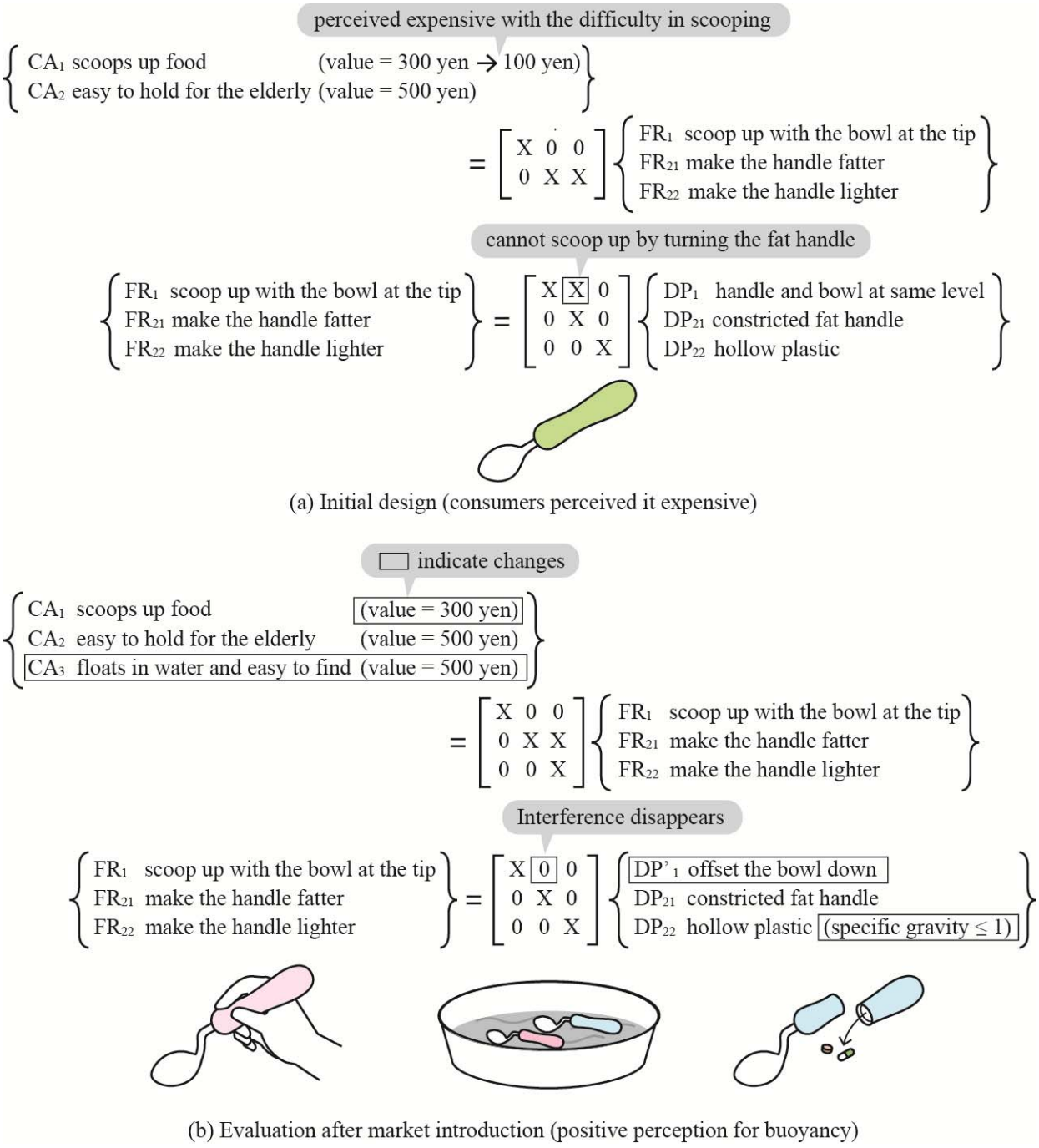
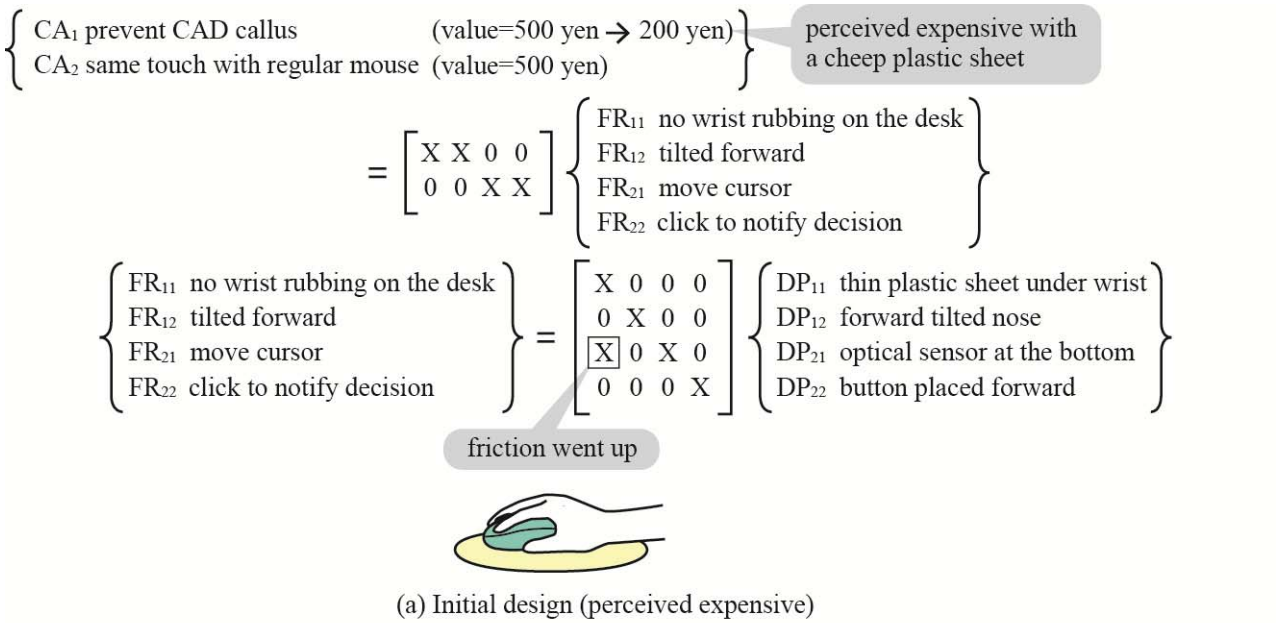
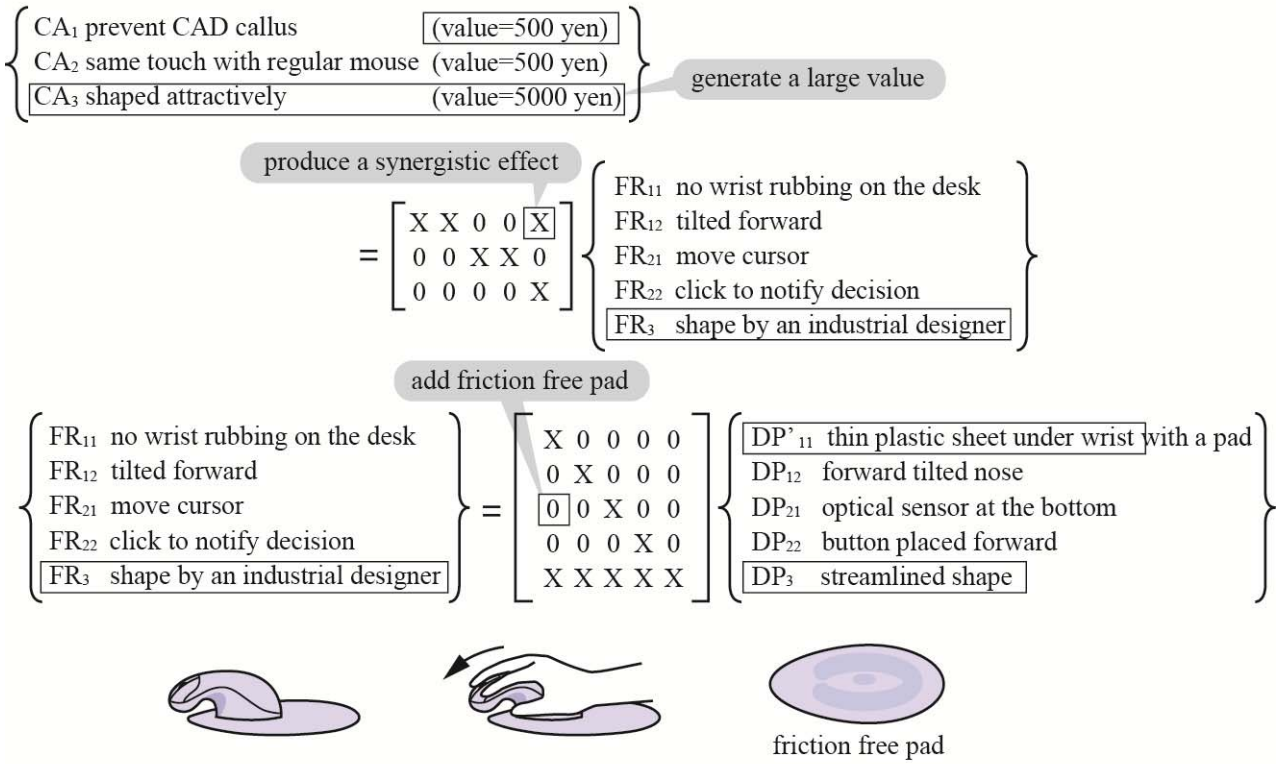


Fig. 1. Universal design for a spoon

Ando, for the CA of "tastes good" first developed "DP_1: chicken soup + curly noodles" easily. CA_4 of "storage at room temperature," however, gave him a hard time to reach a good solution for drying the noodles (FR_4). He tried heating, sun drying, and even freezing them but they all failed to meet the goal. One day, as he was watching his wife prepare deep fried "tempura," an idea suddenly hit him. After soaking noodles in chicken soup, he dipped them in high temperature oil evaporating only the water (DP_4). He could lift the noodles after all the moisture was completely evaporated. The technique produced an even unexpected effect of making the noodles porous with the explosive evaporation of water (DP_3). The hard lump of porous noodles in a bowl could loosen 3 minutes after pouring hot water over it (FR_3). That was the completion of his project.

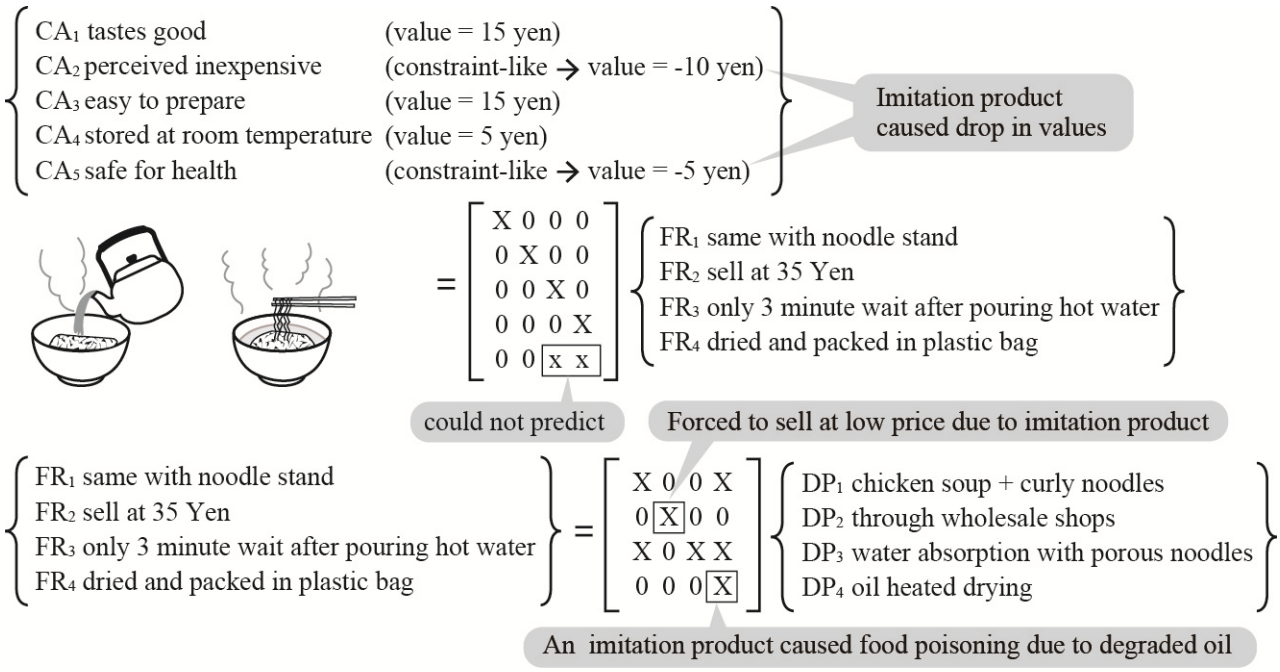


(a) Initial design (perceived expensive)

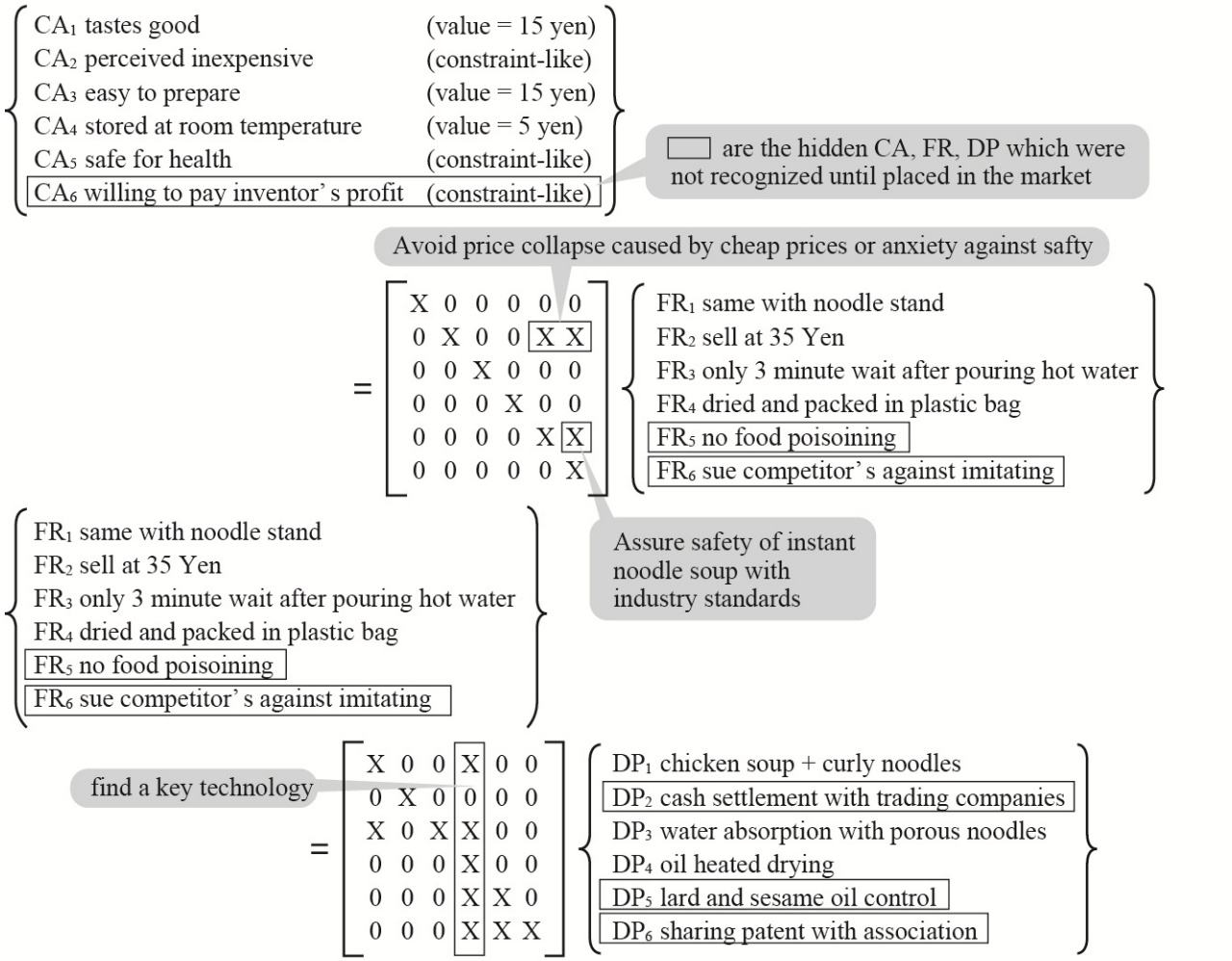


(b) Evaluation after market introduction (streamlined shape gave high-class looks)

Fig. 2. CAD callus free mouse

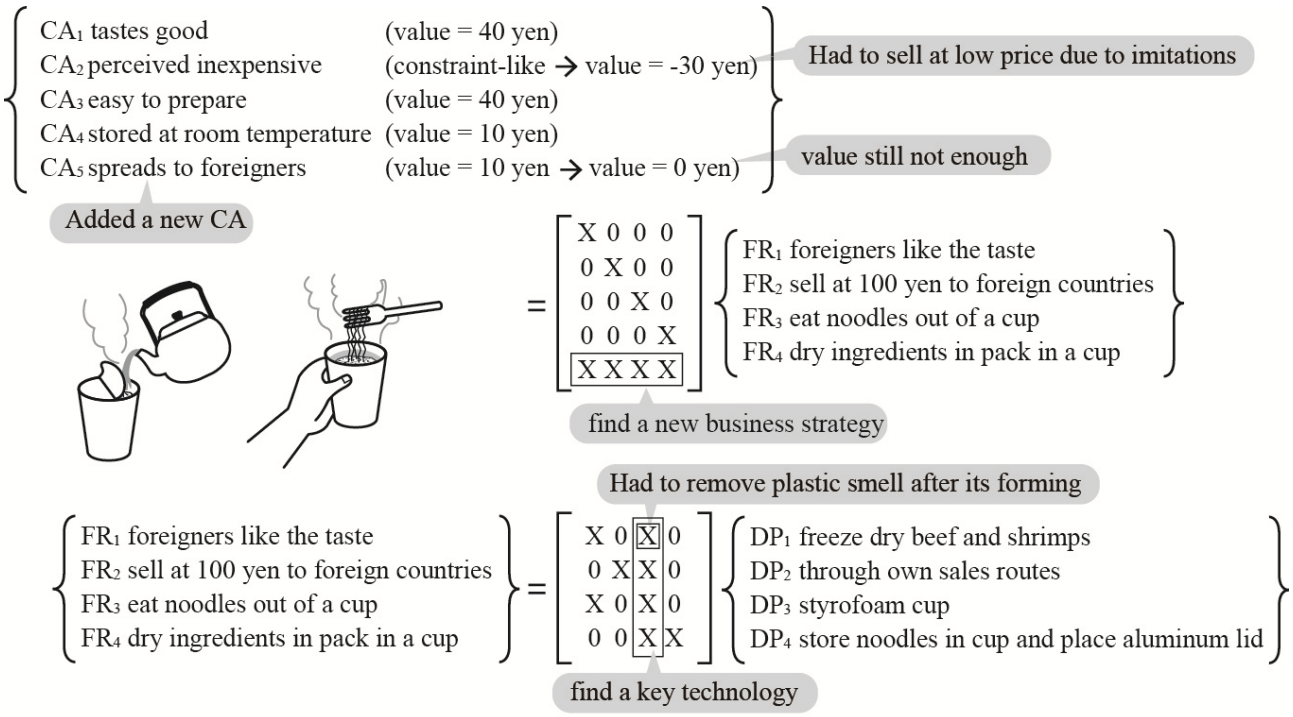


(a) Evaluation 3 months after market introduction (not a good business due to imitation and food poisoning)

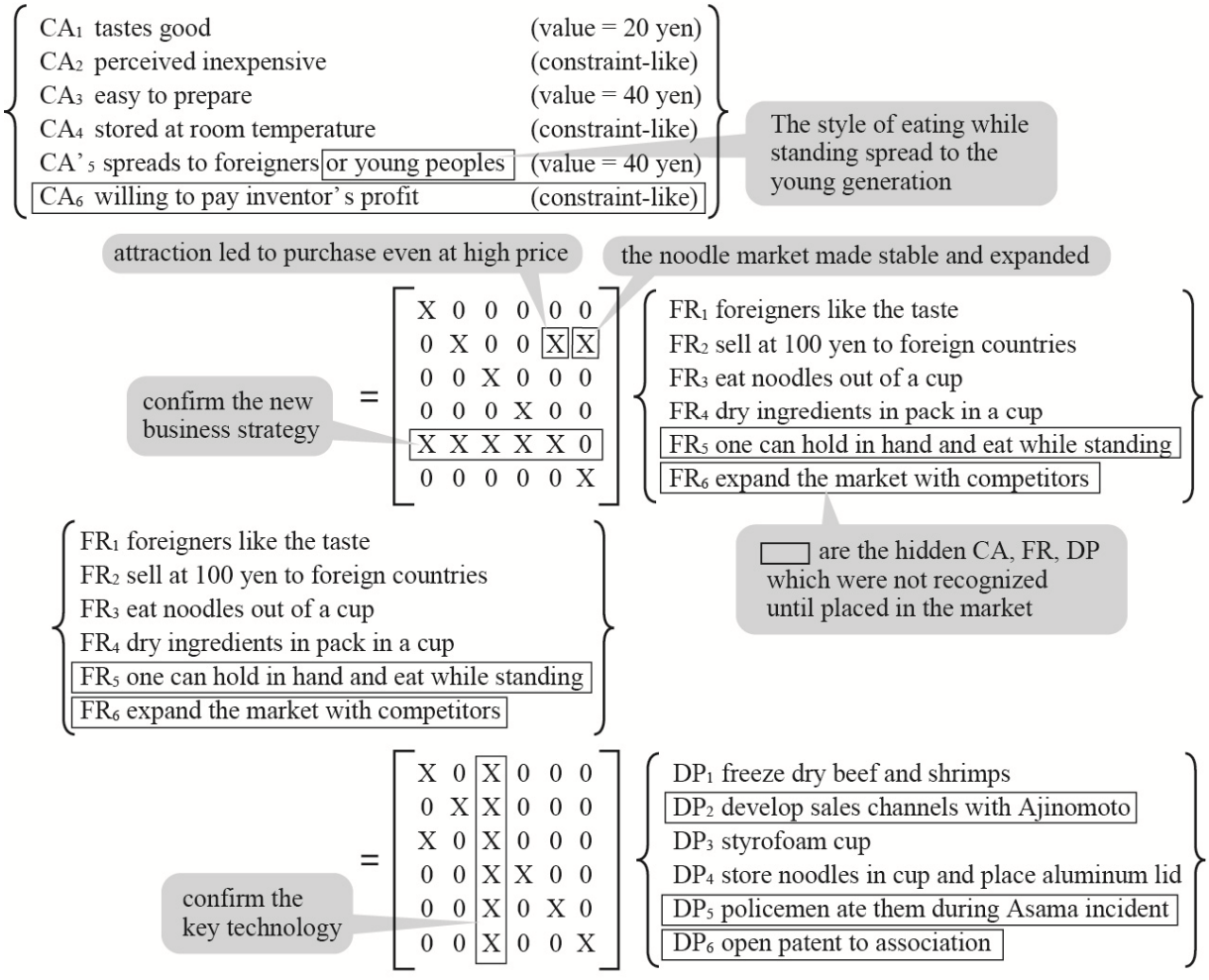


(b) Evaluation 1 year after market introduction (price collapse avoided by ousting low quality imitations)

Fig. 3. Momofuku Ando invented instant noodle soup (1958)



(a) Initial design (merely switching a noodle bowl to a cup was perceived expensive for the consumer)



(b) Evaluation 1 year after market introduction (sales increased with young culture of eating while standing)

Fig. 4. Momofuku Ando invented Cup Noodles (1971)

When he put the product in the market, however, it was met with so many imitation products within 3 months. Those imitations sold at cheap prices triggered price collapse of instant noodles. Also, a competitor kept using the same oil for oil heated drying and the oil degraded over time to cause a food poisoning and a rumour spread that instant noodles were not safe. In other words, Ando's "CA_2: inexpensive (-10 yen)" and "CA_5: safe (-5 yen)" drastically dropped to negative values and the consumers would shy away from the products. Naturally, sales started dropping.

Fig. 3 (b) is the DE at 1 year after the market introduction. Ando set a new CA_6 of "willing to pay the inventor's profit" and for FR_6, filed lawsuits against the competitors that were using his patent and trademarks without permission. He thought that the customers would accept that the inventor gets a proper royalty. This never-ending litigation with about 60 competitors, however, resulted in forming an industrial association and Ando acknowledged the rights for its members to use the patent. This move resulted in assuring safety of instant noodle soups and the entire industry lifted the sales. It also put a stop to the price collapse and Ando's company increased its sales and enjoyed a steady growth of profits.

Regrettably, Japanese industries and people in 1958 was not conscious about protecting intellectual properties and they were not afraid to imitate technologies of others. That was because large corporation in Europe and the US did not bother to file lawsuits against small companies in Japan in the far-east. That is why Ando had to set CA_6 of claiming "inventor's rights" in a hurry which was an unexpected value at the beginning of design. The FR-DP design matrix shows that "DP_4: oil heated drying" was the key technology obtained a patent of this instant noodles. The 4th column has many Xs, meaning the DP_4 affected to many FRs.

2.4. Cup Noodles

Figure 4 shows DEs for the 1971 Ando's new development of Cup Noodles.

He had a dream of "CA_5: spreads instant noodles to foreigners." He visited the US to have people try instant noodles, however, bowls for noodles were not readily available in America. So, the customers put the noodles in paper cups and poured hot water over them. That is when he realized to meet "CA_3: easy to prepare," he noticed the noodles selling with the container. He then adopted "DP_3: styrofoam cup" developed in the western world just before then. He also wanted Europeans and American to agree with "CA_1: tastes good," and he chose to apply "DP_1: freeze dry beef and shrimps," a technique that also just turned available around that time.

A prototype revealed that the key technology for this product was the cup container for DP_3. The cup was the container of the food, the pot for the cooking, and the package for transportation. Without it, the product could not exist. Figure 4 (b) shows this fact with the entire third column of the FR-DP design matrix filled with Xs, each indicating its effect on the corresponding FR. For example, the initial design had plastic smell remaining on the cup after its forming but steam heating removed it, decoupling the interference to the FR_1 taste.

The figure also shows that "CA_5: spreads to foreigners" was a business strategy for this product. The 5th row of the CA-FR design matrix also had almost all Xs. The remaining CA_1 to CA_4 were the same as those of instant noodle soup in Fig. 3.

Figure 4 (b) shows the design equation for Cup Noodles 1 year after its introduction to the market. Like the case with instant noodle soup, imitations entered the market even in 1971, and Ando again asked customers to "willing to pay his inventor's profit" (CA_6). This time, however, he quickly opened the patent to the industry association instead of filing suits. This act led the whole industry to grow and within a year, the industry sold 3 billion cups of noodle soups per year in the world.

Ando also recognized "FR_5: one can hold in hand and eat while standing" was an effective feature in meeting the CA'_5 of "spreads to foreigners and young peoples." Even the genius of Ando did not recognize what the FR_5 was to strongly support this CA'_5. According to Ando, what triggered the big hit of Cup Noodles was the Mount Asama incident of the Japanese Red Army in 1972. The TV broadcasts showed policemen on standby eating warm Cup Noodles while standing under the cold winter sky. In Japan, eating while standing was an indecent act, however, the young generation consumed Cup Noodles while standing, just like they would eat hamburgers while standing. That made an attraction for Cup Noodles and the price of 100 yen was well accepted.

3 Discussions

As the above 4 cases showed, whatever the product is, a new CA which was not recognized at the time of initial design works its way in. Consequently, it would push the sum of values higher, and the product turns into a stable selling product. At this time, the designers should modify a set of CAs, FRs or DPs flexibly and quickly.

There have been, of course, some products that did not make such sales. Ando, we introduced above, also developed rice cups of pilaf or dry curry that would cook by just pouring hot water into the cup, however, it hardly made any sales and was withdrawn from the market. Every household cooks rice daily, and a house person did not see the value in the CA of "perceived inexpensive" even though it could be stored as emergency food. His withdrawal was also a quick, flexible and proper decision to prevent increasing the loss.

4 Conclusion

Creative design without a previous model often results in the customer perceiving the product value different from what the designer originally intended in the early stages of design. In such cases, the designer should quickly recognize the missing or coupled CAs, FRs, and Cs as soon as possible to modify the DPs. This report explained the cases of a spoon for the elderly, CAD callus free mouse, instant noodle soup, and Cup Noodles

to explain this process. The above evaluations use as an indicator the whole sum of CA values expressed in a monetary number. After the CA reviews, the sum of CA values became larger.

The authors propose "Value Axiom" meaning "The bigger the sum of CA values, the better the design." There is hardly any designer that can estimate and describe the perfect set of CAs. The designer always should write out the design equation to visualize the entire picture of the design, improve the sets of FRs or DPs using the Independence Axiom and Information Axiom, and constantly review the set of CAs with the Value Axiom.

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