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KANO'S METHOD IN PRODUCT DESIGN: A STUDY OF DYNAMIC MODELS' RELIABILITY

Y. Borgianni

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1. Context and objectives of the paper

Many companies carry out New Product Development (NPD) initiatives by entrusting the so-called Voice of the Customer (VoC). Thus, the drivers of innovation tasks result in those product requirements that are attributed of greater importance by samples of customers. The literature illustrates several techniques tailored to deploy and value the data resulting from customer surveys in order to design products and services ensuring the maximum level of satisfaction. Among the most structured methods, the procedures introduced within Kano´s theory of attractive quality [Kano 1984] allow to analyse the relationship between the offering level of product attributes and the consequent customer satisfaction through the employment of ad-hoc questionnaires. In particular, it estimates how product requirements affect two nuances of customer satisfaction, namely the capability to avoid severe discontent and the possibility to make users excited. Thanks to these measures, the strategy represents an effective approach to help understand the potentiality of each product attribute [Matzler and Hinterhuber 1998], [Tan and Shen 2000] by emphasizing the asymmetric relationship between performance and perceived satisfaction and highlighting the different effects of poorly fulfilled customer requirements. A more accurate explanation of concepts, models and procedures introduced by Kano's theory is provided in Section 2.

As inferable from its infrequent presence among the topics of design courses [Ala et al. 2011], [Rizzuti 2011], [Liu and Lu 2013], Kano's model does not belong to the classical toolkit of engineering designers. However, it is gaining popularity as a valuable reference in light of the mentioned objective of aligning product development to customer expectations. Not surprisingly, Kwong et al. [2011] introduce Kano's toolkit to bridge marketing demands and engineering specifications in NPD undertakings. According to an articulated review of design methods, Horvath [2004] includes Kano's model within tools that support design quality. Indeed, in [Deubel et al. 2005], it is claimed as a suitable tool for ensuring a quality-oriented product development. In a broader perspective, Lindemann [2015] argues about the need of designers for grasping a better understanding of the environment in which they act; to this aim, Kano model is mentioned among the valuable supports for achieving a clearer grasp of society, customers and their emotional responses. From the same point of view, the integration of Kano's model in product development supports designers through handling functional fulfilment and emotional satisfaction appropriately [MacDonald et al. 2006].

On the other hand, in common design practice, Kano's model is not seldom employed as an instrument to enhance the usability of Quality Function Deployment (QFD) by specifying the potential impact that follows the improvement of certain product characteristics [van de Poel 2007]. Indeed, many applications and methodological refinements have followed the pioneering work of Matzler and Hinterhuber [1998], which originally combines QFD with Kano's underlying principles. In this sense,

designers exploit the latter's capabilities of ranking the attributes according to their relevance, which allows to individuate where to focus the engineering effort to maximize customer satisfaction and, consequently, market success [Wassenaar et al. 2005]. Saunders et al. [2011] claim that requirements identified as exciters by Kano's model are fundamental drivers for new products' success and creative content. Still within design, further contributions leverage Kano's power of identifying the main carriers of satisfaction and the supposed repercussions of improved or worsened performances. In [Jakobs et al. 2014] the use of Kano's model aims at determining differences among perceptions and attitudes of designers towards product characteristics. Similarly, Borgianni and Rotini [2015a] introduce Kano's concepts to remark the diverging perceptions of stakeholders that play a major role during the different stages of product lifecycle; the investigation urges to introduce means to manage these dissimilarities carefully.

In addition, Kano [2001] has explained regularities in the dynamics of the customer preferences, as widely discussed in [Löfgren et al. 2011]. Guidelines have been proposed to support the planning of new products, as it is possible to anticipate the transformations occurring to the perception of customer requirements, as it will be documented in Section 2. The intuition about a dynamic behaviour of preferences is viable to overcome some of the deficiencies of VoC-based innovation tools, as literature highlights the impact of customer preferences´ dynamics [Bacciotti et al. 2013]. This aspect calls into question the assumptions made at the beginning of NPD tasks, especially when much time elapses from the project start to the market launch [Chong and Chen 2010]. However, empirical validation is still required to prove the dynamic mechanisms that are a corollary of Kano's theory.

In order to enrich the knowledge about changes in customer preferences, the author performed an observational study of the results of customer surveys based on Kano's model and conducted in different years. In order to assess the role of time, the study neglected other factors potentially influencing the difference of customer preferences resulting from distinct surveys (e.g. demographical factors of respondents). More in detail, the study highlights the transformations that have taken place with respect to the perception of product requirements through the lenses of Kano´s theory. Thanks to literature sources, the study examined the alteration of 176 product requirements and service attributes. A statistical analysis of said changes allows to anticipate to which extent a product characteristic is expected to impact on customer satisfaction after a given amount of years by just knowing its present influence. The results partially put into discussion the mentioned dynamic models, which are fundamentally based on logic and scholars' intuition.

The paper is articulated as follows. Section 2 recalls the fundaments of Kano's theory and introduces the logic followed by dynamic Kano models. Section 3 presents the strategy followed by the present investigation in order to acquire statistic evidence of dynamic phenomena. Section 4 presents the results of the empirical analysis. These outcomes are further commented in Section 5, together with their expected repercussions in the design domain, future activities and final remarks.

2. An overview of Kano's theory of attractive quality

Within quality management and VoC-oriented design, the peculiarity of Kano's theory stands in challenging the idea of the linear relationship between the offering level of any product feature and the extent of customer satisfaction that is consequently generated. Thus, Kano's model is classically applied as a tool to analyse the perception of product attributes (often referred as customer requirements) and the resulting satisfaction of consumers ascribable to a given market segment.

With respect to the procedure that is generally followed, a certain number of customers is asked about their feelings when a given product attribute is fulfilled (functional question) or absent (dysfunctional question), as shown in the illustrative example reported in Figure 1.

The combination of answers provided by each potential customer gives rise to the designation of a Kano category (or quality attribute) for each investigated property, as suggested by Figure 2. Such quality attributes are:

- one-dimensional features, which generate excitement if the performance is high and cause dissatisfaction if unfulfilled;
- must-be features, which can just contribute to avoid dissatisfaction;
- attractive features, which are just capable of arousing excitement if fulfilled;

- indifferent features, playing a scarce role in determining customer satisfaction.

As reverse and questionable designations are considered the result of inaccurate definitions or wrong interpretations of questions, the present study focuses on the residual four above-listed quality attributes. The quality attributes describe, in a qualitative way, different curves depicting the relationships between performance and perceived satisfaction, as classically represented like in Figure 3.

Functional question Shoes can be worn regardless the external conditions, markedly the environment and the weather	☐ I really like it ☐ It must be this way ☐ I don't care/I'm neutral ☐ I can tolerate this/I can live with ☐ I dislike it
Dysfunctional question Shoes cannot be worn regardless the external conditions, markedly the environment and the weather	☐ I really like it ☐ It must be this way ☐ I don't care/I'm neutral ☐ I can tolerate this/I can live with ☐ I dislike it

Figure 1. Illustrative functional and dysfunctional questions of Kano surveys

Customer Survey Responses		Dysfunctional Question Answer				
		1. Like	**2. Must Be**	**3. Neutral**	**4. Live With**	**5. Dislike**
Functional Question Answer	**1. Like**	*Questionable*	Attractive	Attractive	Attractive	One-Dimensional
	2. Must Be	Reverse	Indifferent	Indifferent	Indifferent	Must-Be
	3. Neutral	Reverse	Indifferent	Indifferent	Indifferent	Must-Be
	4.. Live With	Reverse	Indifferent	Indifferent	Indifferent	Must-Be
	5. Dislike	Reverse	Reverse	Reverse	Reverse	One-Dimensional

Figure 2. Procedure to designate quality attributes according to the responses to functional and dysfunctional questions

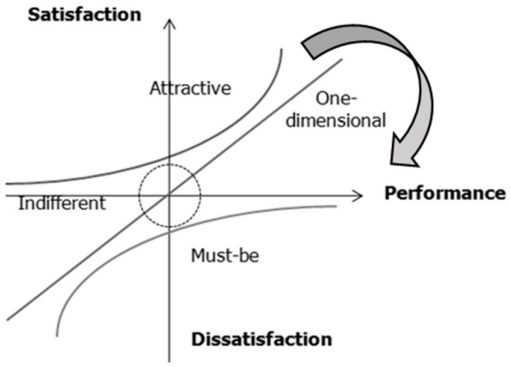

Figure 3. Quality attributes of Kano model and qualitative performance/satisfaction curves; the arrow represents the expected evolution of the categories

As already mentioned in Section 1, Kano [2001] hypothesizes the evolutionary nature of quality attributes. The nuances of different frameworks that accept the evolutionary behaviour is discussed in [Borgianni and Rotini 2015b]. The dynamic pattern foresees changes in customers' perception as they get used to benefitting from certain functions and properties (see the curved arrow in Figure 3). As appreciation for a customer requirement manifests first with an attractive quality attribute, this tends to switch towards one-dimensional and subsequently to must-be. In a certain sense, customer requirements tend to decrease their capability to generate satisfaction and their fulfilment is gradually more and more

devoted to avoid harm. According to certain keys of reading, customer requirements are classified as indifferent before turning into attractive features and/or after they can be characterized as must-be.

3. Methodological approach and description of the study

As introduced in Section 1, the scope of the paper is to assess the reliability of dynamic Kano models, which implicate cyclic transformations of quality attributes. Thus, the task consists of evaluating the actual effect of time on the alteration of customer preferences, or, more specifically, on the modifications occurring to product attributes in terms of their most represantitive Kano categories.
From a formal point of view, such an assessment should be performed through repeated-measures experiments. In the considered case, it would consist of re-administering Kano questionnaires about the features of a given product or service to identical samples of consumers. This would allow to reveal whether accumulated experience, elapsed time and routine to certain benefits have indisputably played a twisting effect on the perception of satisfaction and dissatisfaction. According to author's experience and results from the exploration of the literature, such a task has not been performed by any scholar. On the other hand, many research activities point out that different results are likely to be achieved by considering a large variety of criteria to discern classes of respondents, as outlined in [Borgianni and Rotini 2015a].
It is worth noticing that possible barriers can arise to conduct repeated-measures tasks concerning Kano's model, such as unavailability of subjects involved at a first stage and effects brought on by gaining confidence with this sort of questionnaire. With respect to the latter, it is useful to recall that the way questionnaires are administered, the subsequent extrapolation of quality attributes and their significance for decisions in product/service development have provoked much criticism. However, with regard to this issue, the review paper authored by Mikulić and Prebežac [2011] concludes that, despite correct objections, the approach proposed in the original Kano model (described in Section 2) outperforms procedures commonly employed for supporting decision-making or borrowed from different disciplines.

3.1 Approach to conduct the study

As the obstacles to carry out a repeated-measures experiment are clear and a not negligible amount of time and resources would be required to extract sound results, the author considered the opportunity of leveraging the abundant, although dispersed, literature about case studies conducted through Kano's model. The objective is extracting cases in which the same customer requirements have been surveyed in different research studies and, subsequently, to assess the effect of time on modifications of the quality attributes through statistical instruments. The methodological approach follows.
By using Google Scholar, as a rich collection of academicians' and practitioners' publications, the author individuated dozens of documents in which applications of Kano's model are reported. All the sources were classified according to the field of application, in order to identify products and services for which multiple Kano investigations have been performed. Within the sets of case studies characterized by akin domains, the lists of investigated customer requirements or product functionalities have been extracted. All the case studies have been compared in order to individuate multiple investigations of the same attributes evaluated through the lenses of Kano model. This has allowed to reveal the existence of different surveys concerning certain benefits that have been taken place in different years. Indeed, for the purpose of the present study, the author has not considered the cases in which the same customer requirements have been investigated more times in the same year. Some clarifications follow:

- the extraction of information has been limited to the results of Kano surveys; more clearly, although some sources were evaluated as poorly trustworthy from a scientific point of view, e.g. because of inaccurate review policies, the outcomes of Kano applications were considered reliable;
- the years in which surveys have been conducted are not declared in each publication; in the cases in which such an information is not available, the years of papers' first submission have been taken into account;
- as the focus of the investigation was the dynamics of Kano quality attributes, the author directly extracted this kind of data when available and when the definition of the categories has been performed through the classical procedure, i.e. by individuating the most diffused cluster in the

sample; in the cases in which different criteria have been employed, the author performed the definition of the quality attributes on the basis of available data; for what concerns publications reporting Kano surveys administered to different groups of respondents, data have been re-aggregated in order to individuate the most representative quality attribute for each customer requirement;

- in the cases in which the same authors report results of Kano investigation in multiple papers, the oldest one has been considered as a reference;
- when customer requirements have undergone Kano investigations more than twice, the author has considered the surveys in a sequential way; for example, in case of three investigations available, data of the first one against the second one and of the second one against the third one have been compared.

3.2 Description of the dataset gathered by the investigation in literature

The process described in the previous subsection has led to the identification of 176 couples of data, constituted by different results of Kano analyses for specific customer requirements. For each couple, the examination has considered the status of the designated quality attribute in a first and second Kano survey. The time difference (in years) between the two inquiries has been recorded as well. Table 1 describes the industrial fields in which such customer requirements are relevant and the number of couples that refers to each of said domains; conversely, the quantity of literature sources from which data have been extracted is omitted for space reasons.

Table 1. Dataset of different Kano surveys investigating akin customer requirements

Reference product or service	Number of couples	Number of sources
Apparel and textiles	4	2
Banking	33	5
E-learning	11	4
Healthcare	7	3
Hospitality	34	8
Methods for NPD and Product Lifecycle Management	3	2
Mobile telephones	6	2
Notebooks	6	2
Packaging	23	2
Ski resorts	2	2
Trains and railways	8	2
University education	35	7
Websites	4	3

3.3 Employed statistical tools: Criteria and choices

The core of the investigation consisted in determining whether statistical models can be extracted from real data that reflect the variations of Kano categories, as foreseen through dynamic frameworks. Still consistently with these transition models, it is worth noting that, according to the initial quality attribute, the appearing of certain dominant categories are initially probable and, subsequently, more and more unlikely. For example, if we consider an attractive customer requirement, the probability of its transformation into a one-dimensional one is high after a given amount of time, but, as time progresses, not particularly viable, as its designation as must-be is supposed to be the most likely. In this sense, a time-linear statistical model is insufficient to assess the robustness of dynamic hypotheses; thus, the author has included also the square of time within explanatory factors.

As well, the probability of facing a certain designation after a certain amount of time depends on the initial quality attributes. Consistently with this consideration, the author has built four independent statistical models, one for each initial quality attribute.

As Kano categories represent nominal variables, nominal logistic regressions were deemed as the most appropriate statistical models to be adopted. As a result, the whole task consisted in extrapolating four of such models with four possible responses (corresponding to the number of considered quality attributes) and two explanatory factors (time in years and its square). The task was carried out by using the software Stata MP13.

4. Outcomes of the statistical analysis

The outputs of the regressions are not easily readable, since the statistical models provide parameters and indexes related to odds ratios, which are proxies of the likelihood of turning into a given response (the quality attributes in this study) and which are influenced by the chosen explanatory factors (the time parameters in this case). Therefore, the author has elaborated the data further and built diagrams that express the expected trajectories of Kano categories' probability. The curves of Figures 4-7 describe the variation of the probability of observing the designation of each quality attribute after a given number of years according to the initial Kano category. The starting one is indicated in both each diagram and the caption of each Figure. The curves with the same colour are associated with the probability referred to the same quality attributes across the various illustrations. As well, such a colour-based association is recalled within each picture.

4.1 Suitability of existing evolutionary hypotheses in light of the empirical investigation

4.1.1 Trajectories of attractive customer requirements

The initial hypothesis about attractive attributes is turning into one-dimensional and then into must-be requirements. Figure 4 confirms this trend to a good extent, as the probability of one-dimensional designations grows distinctly at the beginning of the curve and then decreases, as must-be attributions become more and more likely. The (almost) steady decline of indifferent attributions complies with the discussed dynamic models. Conversely, the growing probability of new attractive designations results the most unexpected feature of the diagram.

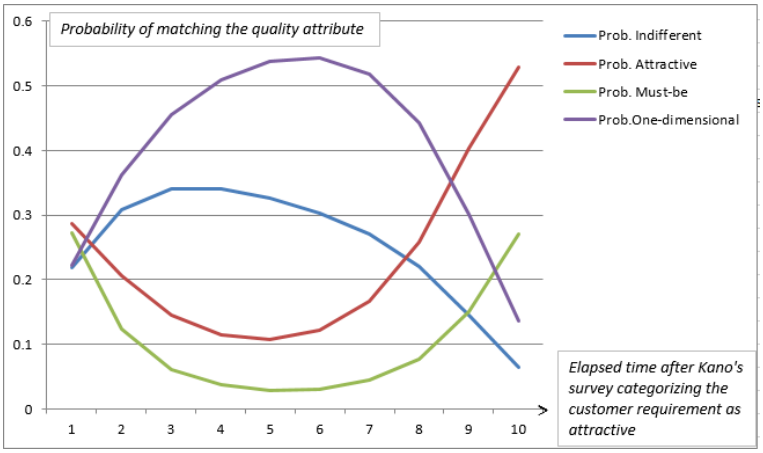

Figure 4. Expected trajectories of customer requirements designated as attractive

4.1.2 Trajectories of one-dimensional customer requirements

According to dynamic Kano models, it is expected that one-dimensional characteristics will become must-be as time progresses and customers' experience is accumulated. With respect to Figure 5, this phenomenon seems to be confirmed and, on the average, this should be observed 5-7 years after the initial Kano survey. Indeed, the ending parts of the curves remark the drop of likelihood of one-dimensional designations and an abrupt increase of must-be attributions' probability. The chance of observing transformations into attractive and (especially) indifferent quality attributes is quite low and this circumstance matches with dynamic Kano frameworks too.

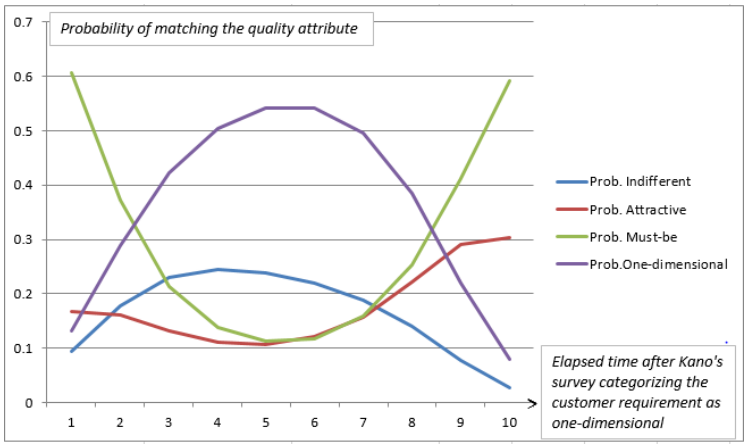

Figure 5. Expected trajectories of customer requirements designated as one-dimensional

4.1.3 Trajectories of must-be customer requirements

Evolutional Kano models postulate the consolidation of must-be attributions as time progresses. Transformations into indifferent requirements can be somehow expected with respect to certain functions that are not valued anymore by customers. However, we could argue that this does not hold if the customer requirement is expressed in terms of the benefit associated with the function, rather than with the function itself. Figure 6 does not confirm the initial hypothesis, at least qualitatively. While new must-be designations are overall the most probable in the future, transformations into one-dimensional requirements are not unlikely to take place. On the other hand, switches to attractive and indifferent quality attributes are rare.

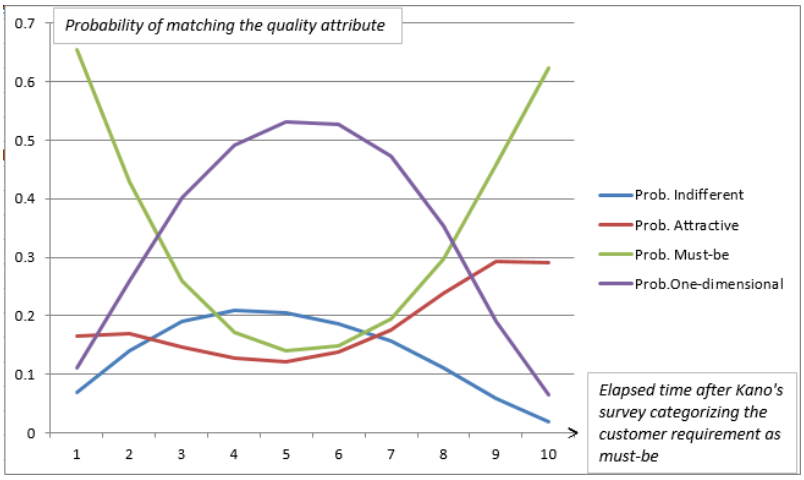

Figure 6. Expected trajectories of customer requirements designated as must-be

4.1.4 Trajectories of indifferent requirements

As Figure 7 suggests, the transformation of indifferent requirements is quite unpredictable according to the statistical model. Dynamic models do not pose particular emphasis on indifferent attributes, although it is supposed that either they will play a minor role throughout the whole historical product evolution or they will turn into attractive elements at a certain point in time and follows the trajectory of exciters subsequently. The diagram confirms such a hypothesis just partially.

4.2 Reliability of and notes about the statistical models

The above results are largely consistent with the dynamic frameworks of Kano's model and seem to confirm the role played by time in modifying quality attributes. As already highlighted, some specific

behaviours or some nuances of these evolutional models are, on the contrary, not compliant with the extracted data.

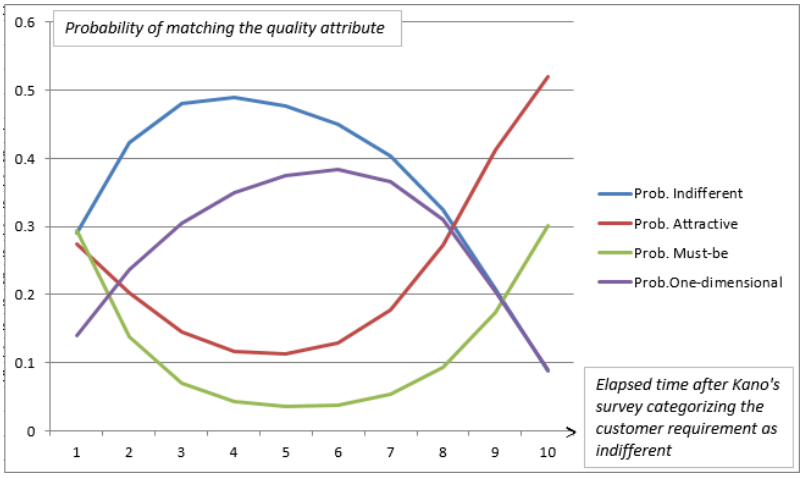

Figure 7. Expected trajectories of customer requirements designated as indifferent

The present subsection elucidates to which degree these outcomes are statistically reliable and, then, to which extent the validity of aforementioned conclusions can be claimed. As each statistical model is approximate and inexact, those that lead to Figures 4-7 clearly make no exception.

First, with respect to the regression model, it is worth noting that acknowledged nominal logistic models cannot be constrained to certain values (at least in author's knowledge). In the treated case, it would result useful to bind the outcomes of quality attributes' probabilities in terms of assigning 100% chance to the initial Kano category after 0 years. This datum cannot be extrapolated by any of the illustrated diagrams. This aspect clearly affects the accuracy of the curves. However, the utility of the graphs is limited for short-term forecasts, since product development teams can rely on extracted customer data after little time is elapsed. According to statistical rules, the most reliable indications refer to regions characterized by those regressors' values that are the most frequent in the dataset. For the sake of completeness, the average time difference between the 176 couples is about 4 years (the standard deviation equals roughly to 2.5 years). In other terms, the reliability of the forecasts diminishes as the difference between the abscissas' value and 4 increases. However, information from the literature [Bourgeon 2007] suggests that the most reliable region of the curves corresponds to the time elapsed from product design to market launch for medium- and long-term NPD strategies.

Second, the parameters connected to explanatory factors in the four regression functions are not all statistically relevant. This fact is not surprising, if we consider the limited extension of the dataset with respect to the outreach of this preliminary research, i.e. observing quality attributes' fluctuations for any kind of customer requirement and industry, moreover with a worldwide perspective, which, besides, corresponds to the claims of dynamic Kano models. A further factor complicating the matters could be represented by the rapidity of changes that are commonly associated with technology-intensive sectors if compared with traditional industries. Despite these difficulties, the functions associated to initial must-be and one-dimensional quality attributes show that almost all regression parameters are statistically relevant (p-value minor than 0.05, as a common rule of thumb). This means that the trajectories observed in Figures 5 and 6 are more reliable than the other ones. Further studies of the uncertainty associated to the curves are viable to provide a clearer and more truthful picture.

Third, the study has intentionally overlooked all factors other than time (e.g. geographic, demographic) that can have influenced the exploited results of Kano surveys. Through the values of goodness-of-fit associated with the regression functions, it is possible to assess the role played by time, or at least by the two explanatory factors used in the statistical analysis. To this regard, the values of Pseudo Square-R provided by the employed software ranges between 7 and 24% with respect to the four regression functions. These outcomes can be considered partially satisfactory, if we take into account the exploratory nature of the study and the supposedly great randomness connected with the individual

component, which is implied by the lack of customers' samples involved in repeated-measures investigations.

5. Final remarks and future work

The paper has presented a study of the reliability of dynamic models underpinning the evolutionary nature of Kano's quality attributes. The literature juxtaposes these transfomation patterns with Kano's theory of attractive quality, despite the fact that they have faced no scientific validation up to the present date. The topic is considered particularly relevant for engineering design as VoC-based NPD initiatives might greatly benefit from anticipating the capability of affecting customer satisfaction pertaining to single product and service requirements.

Despite methodological limitations that are recalled in the previous section, the statistical analysis of a plurality of Kano surveys provides partial verification of trends followed by customer requirements. Said trajectories foresee the increasing role of relevant characteristics in terms of avoiding customer dissatisfaction rather than working as exciters. Hence, according to illustrated results, designers can leverage the existence of this phenomenon in order to create products that have a greater chance to meet customer satisfaction at the end of NPD projects. In this sense, the findings of the paper help tackle the problems connected with changing customer preferences, which are considered as a significant unresolved issue in design and management literature.

However, because of the recalled weaknesses, some controversial results and high degrees of uncertainty, it could result extremely hazardous to rely on the presented curves rigidly. The author wills to clarify that, at the present stage of the research, the suggestions arising from the extracted statistical models can support the design process just from a qualitative point of view. In addition, the overwhelming majority of analysed case studies from the service industry can affect the applicability of the results within design and manufacturing of physical goods.

With the aim of enhancing the reliability of the presented models, future work is planned. On the one hand, the working dataset will be expanded as new surveys employing Kano's model will be divulgated (the search for data was interrupted in mid-2015), so as to exploit resources from the literature to the greatest extent. The construction of increasingly reliable statistical models will be accompanied by a specific consideration of uncertainty. On the other hand, as the definition and the usability of quality attributes is argued, the author will conduct further experiments with other parameters populating Kano's theory. Quantitative terms (such as indexes of customer satisfaction and dissatisfaction [Walden 1993]), as opposed to nominal values, lend themselves to the extrapolation of more controllable and more easily interpretable statistical models. Nevertheless, the sufficient availability of this kind of data should be checked beforehand.

In addition, Kano surveys on specific products and customer requirements will be conducted independently to observe the consistency of the outcomes with the findings of the paper.

Eventually, in order to strengthen the usability of the emerged results in the design field, future more robust results will be implemented in decision-making models for NPD, such as the dynamic framework developed by the author's research group [Borgianni and Rotini 2015c].

The author is available to share details about the mathematical functions underpinning the emerged statistical models, consulted sources and the customer requirements constituting the dataset and any sort of details that have been omitted in the paper for the sake of brevity.

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Dr.-Ing. Yuri Borgianni, Contract Researcher
Free University of Bozen, Faculty of Science and Technology
Piazza Università, 5, 39100 Bolzano, Italy
Email: yuri.borgianni@unibz.it