The Grammar of Technology Development for Value Creation

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From the Grammar of Science
as an Interface Between Statistics and Sciences
to The Grammar of Technology Development
as a one of the Interfaces Among Statistics, Relevant Methods and Engineering

INTRODUCTION:

Karl Pearson (1892) *The Grammar of Science*

- *A man gives a law to Nature*
  - Statistical Science
    as a new way to Scientific thinking in the 20th century.
    - **Systematic ways** to descript "a scientific law"
    - Not Scientific Objects but **Scientific Process**
      - Plan: Statistical Methods for Planning
        - » Careful and accurate classification of facts
        - » Observation of their correlation and sequence
      - Do: Constructing Scientific Laws
        - » Discovery of scientific laws by aid of creative imagination
      - Check: Checking the Laws
        - » Self-criticism and the final touchstone of equal validity for all normally constituted minds
    - Development of Statistical Methodology as the Supporting tools for the Scientists along the Grammar
      - **Probabilistic interpretation of cause and effect**
      - **Statistical description of a scientific law**

Historical Views of applied statistics

- *Biometrics* ***for Recognition***
  - Galton(1884)
    - **Statistical Sciences**
      - *Consensus through Discussion*
  - Pearson(1892, 1901, 1911)
    - ***The Grammar of Science***
      - *Man gives a law to Nature*
  - Fisher (1935)
    - **Design of Experiments**
      - **Effective Improvement of Characteristics**
- ***They used "scientific laws" estimated by statistical methods in order to improve their concerning characteristics***

- *Techonometrics* ***for Design***
  - **Shewhart(1931)**
    - ***Economic Control of Quality***
      - Process Control
        - » Continual Detection of Assignable Cause through Outlying Facts Detection
  - **Taguchi(1957, 1972, 1976)**
    - ***Systems of Experimental Design***
    - ***Parameter Design, 1984***
      - Effective Improvement of Function
        - » Robustness against Noise Factors
- *Man can improve the law for himself*
  - ***by finding phenomena beyond the current law or tuning the controllable parameters in the law***

Traditional TQM Methodology developed in Japan

- Problem Solving
  - Strategy: QC story,
  - Tools: Q7, SQC, N7, P7
- QC story
    - Problem Solving Procedure
    - Procedures for Solving Task-Achieving-Type Problems

Problem Solving Procedure since 1960s and Elementary Education in NZ

- Selecting a Theme
- Understanding the Current Situation and Setting Targets
- Creating a Plan of Action
- Analyzing the Factors
- Developing and Implementing Countermeasures
- Confirming Effectiveness
- Standardization and Establishing Control

Traditional Q7 for SQC

- Parato Diagram
  - To get a handle on the real problem among many
- Cause and Effect Diagram
  - To search out and Organize all Possible Factors
- Classification
  - Characterization of Objects
- Check Sheets
  - To take down data simply
- Histograms
  - To understand the form of a distribution and compare it to a standard
- Scatter Diagrams
  - To find the correlation
- Control Charts
  - To investigate whether a process is stable

N7: Qualitative Analysis P7: Process Oriented

- Relation Diagrams
- Affinity Diagrams
- System Diagrams
- Matrix Diagrams
- Matrix Data Analysis
- PDPC Method
- Arrow Diagram

Prof. Kanda (1994)

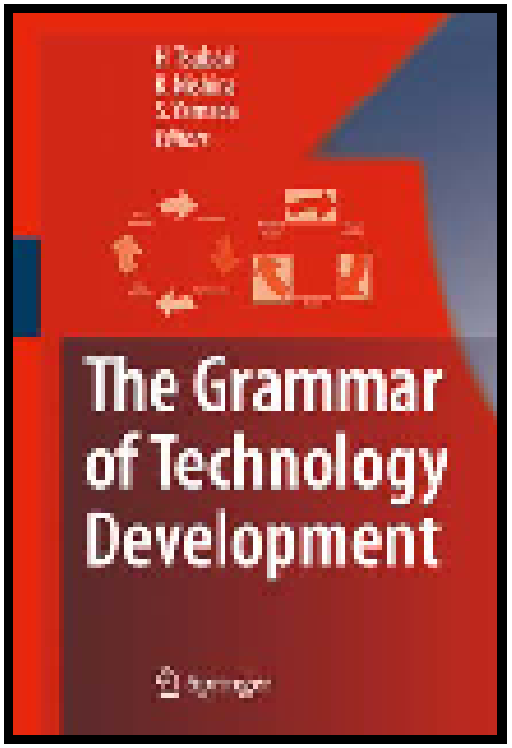
- Group Interview
  - **To Clarify Needs**
- Investigation by Questionnaire
  - **To Verify Needs**
- Positioning Analysis
  - **To Grasp positioning of various products in the market**
- Two Creative Thinking Methods
  - **To Clarify Concepts**
- Conjoint Analysis
  - **To Optimize Concept**
- QFD
  - **To Transform the Concept into Design**

Trans-disciplinary Engineering

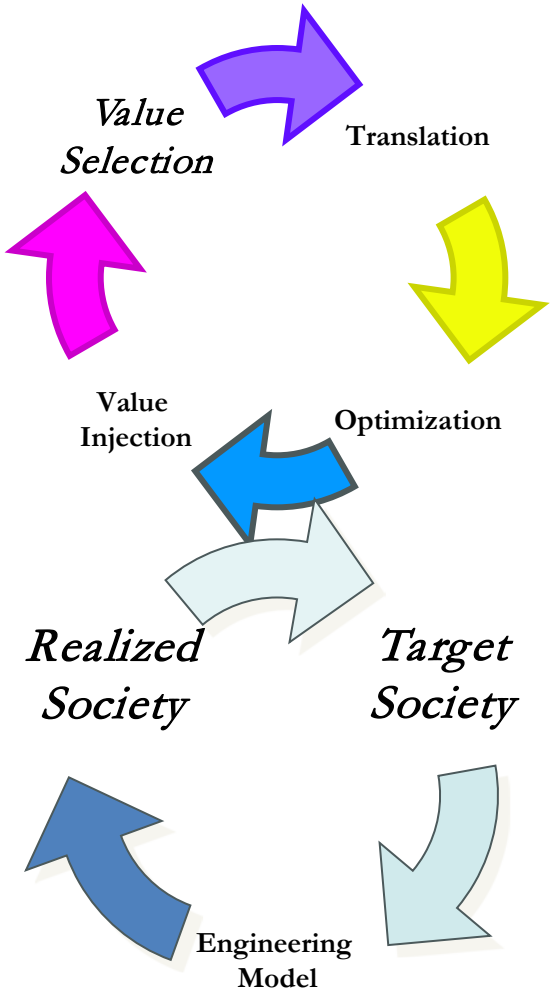
- Lecture by Dr. Gennich Taguchi, 1975/04/22
  - Effective Information Collection by Fisher
  - Effective Information Communication by Shannon
- Engineering for Design and Development Process (2002-, in Trans-disciplinary Federation of Science and Technology
  - Toshihiro Hayashi
    - TRIZ⇒QFD⇒Taguchi Method
- Tsubaki, Nishina and Yamada eds.(2008)
  - “The Grammar of Technology Development”

Springer
the language of science

The Grammar of Technology Development
by Tsubaki, Nishina and Yamada eds. (2008) , Springer.

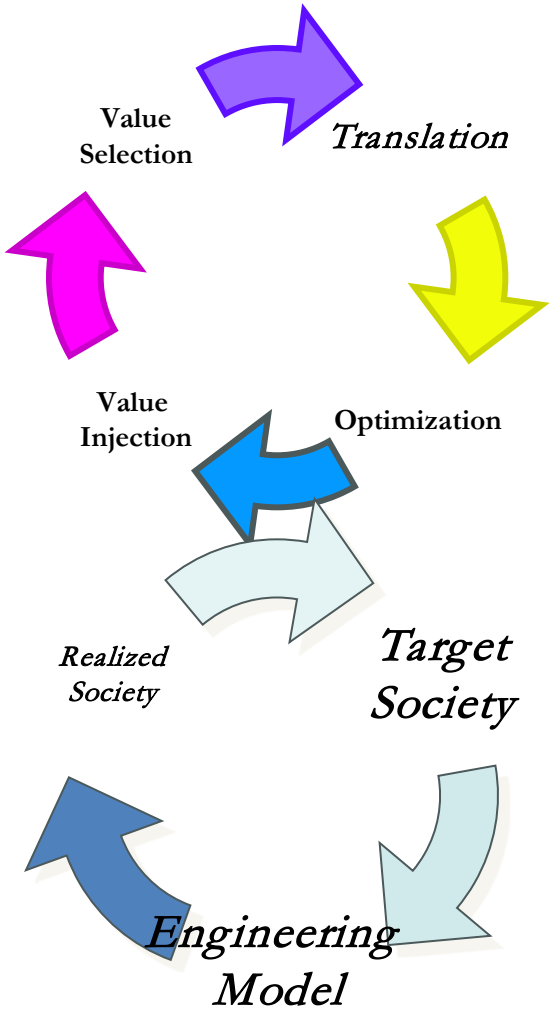


Step 1: Value Selection



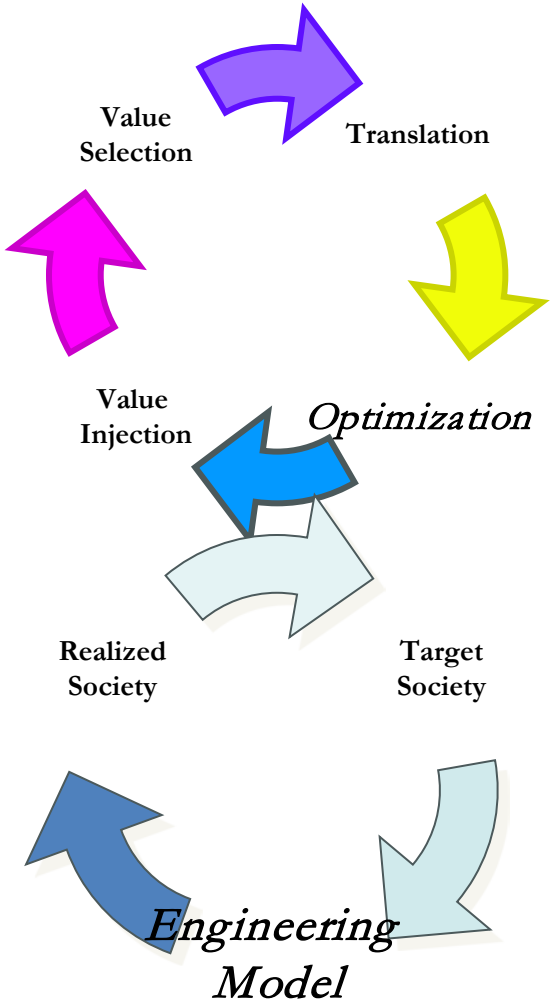
- **Objectives**
  - Selection of values with targets by defining expected VOC
- **Methods**
  - Predicting and analyzing the difference of user's performance between the real existing society and the virtual society affected by the designed technology
- Example: Useful Statistical Tools
  - **Sampling Survey**
  - Conjoint Analysis
  - Knowledge Discovery
    - Data Mining
    - Residual Analysis
    - Exploratory Classification

Step 2: Translation



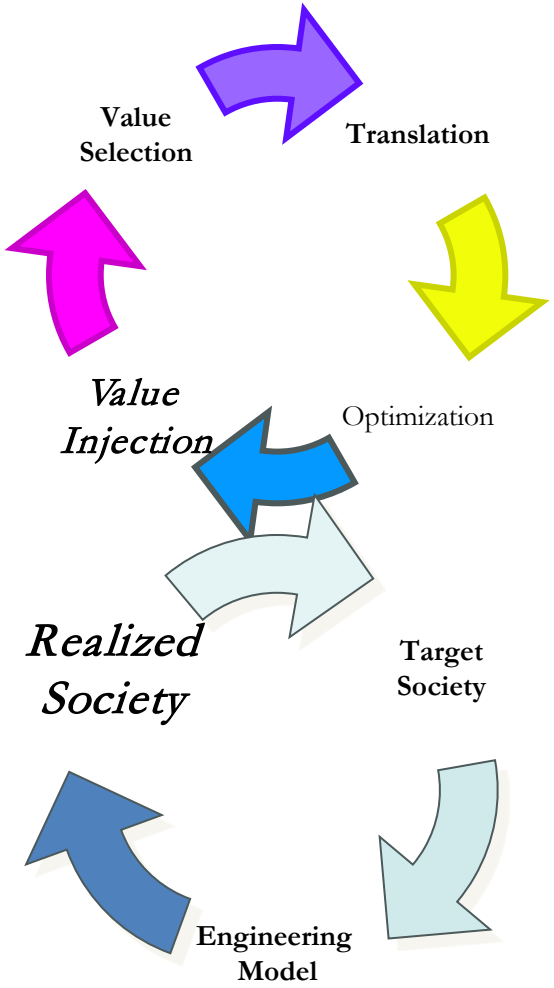
- Objectives
  - Translation of the Selected VOC into Functional Quality Elements (Voice of Engineers)
- Methods
  - Clarifying systems to attain the requirements from the society.
- Supporting Tools for Planning Engineering Models
  - **QFD**
  - **Cause and Effect Diagrams**

Step 3: Optimization



- Objectives
  - Attainment of usability by optimizing design parameters of the engineering models.
- Methods:
  - Designing the best performing systems against variation of uncontrollable factors.
- Tools
  - **DOE**
  - **Robust Parameter Design**

Step 4: Value Injection??



- **Objectives**: Value Realization
  - To attain the consistency between the realized functional qualities and the corresponding perceived quality in the real society.
- **Methods???**:
  - Communication and information management to make users notice the value of the designed technology

Japanese Typical Contributions to Design Oriented Quality Improvement

Not Recent But Since 1950s

- *Value Selection and Value Injection*
  - Methods for Concept Generation
    - ***New QC 7*** Tools by Prof. Nayatani (1983)
  - ***Non-linear Quality*** by Prof. Kano (1984)
- *Translation*
  - Concept Transformation to Design Parameters
    - ***QFD*** by Profs. Akao and Mizuno (1978)
- *Optimization*
  - ***Optimization of Design Parameters*** to Obtain Robustness against Noises
    - ***Taguchi Method since 1952?!***
      - Design of Experiment for Technology Assessment
      - ***Japanese Ways?!***

ACTIVITIES BY STATISTICIANS

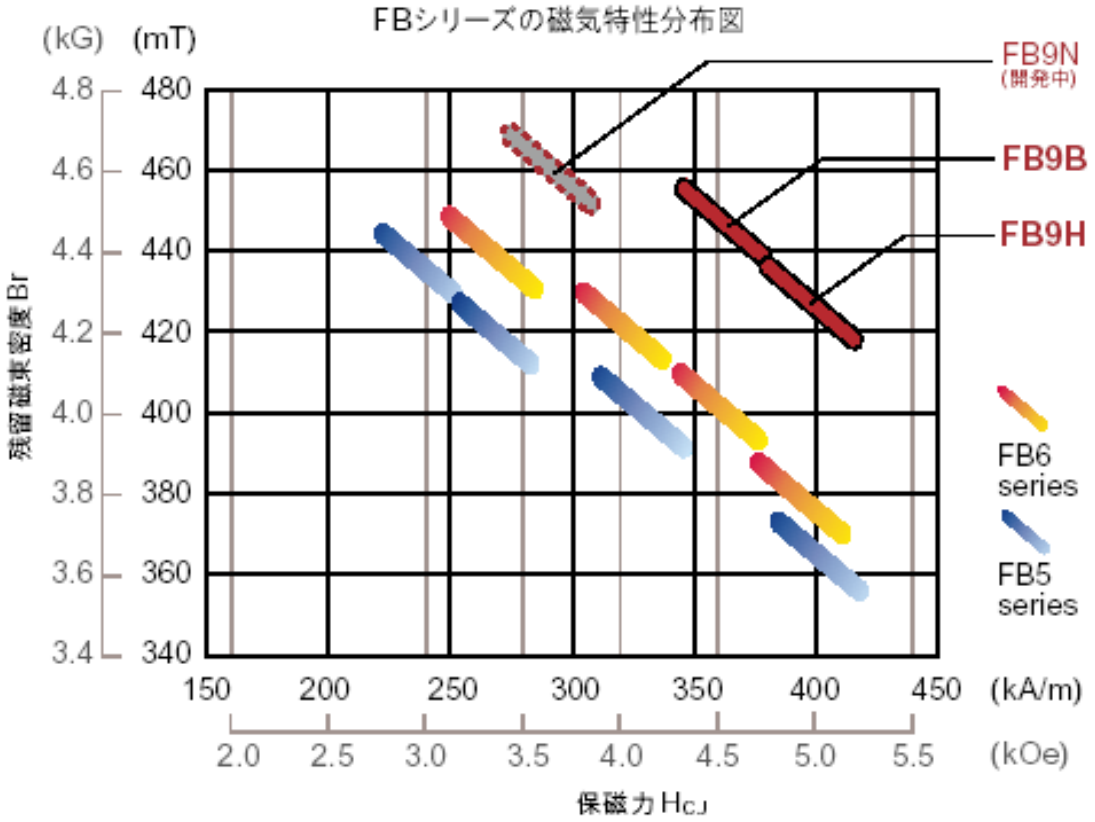
Graphical Modeling and SEM (Structural Equation Modeling)

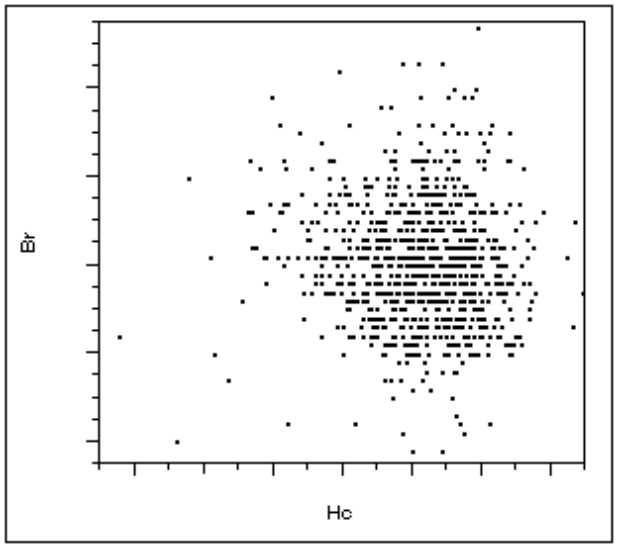
- Exploratory Causal Analysis since 1996
  - graphical modeling popularized by the JSQC technometrics research group (M. Miyakawa, T. Haga, K. Nishina, S. Yamada, M. Hirono et al.)
    - Haga and Hirono developed a software for conversational graphical modeling "***CGGM and CLGM***"
    - JSQC published "Practice of Graphical Modeling" in 1999 with several cases from Japanese industry.
- Confirmatory Causal Analysis since 1995
  - Japanese Industries have ***the largest number of users of SEM by AMOS***
    - SEM is commonly used *not at optimization or translation stages for quality improvement but* **at value selection stages** as recognizing the customers behaviors in marketing divisions.
  - In 2006 JUSE developed a new software **in which CGGM by and EQS are combined**
    - Graphical Modeling among latent factors
    - Regression Modeling with measurement uncertainties

*Case.1 Fusion of Physical laws and **SEM***

Lecture by Nonaka and Tsubaki (2004) in JUSE

- Theoretically suggested negative correlation between Br (magnetic flux density) and Hc (coercive force) and its observed correlation





Regression analysis to improve the Br and Hc

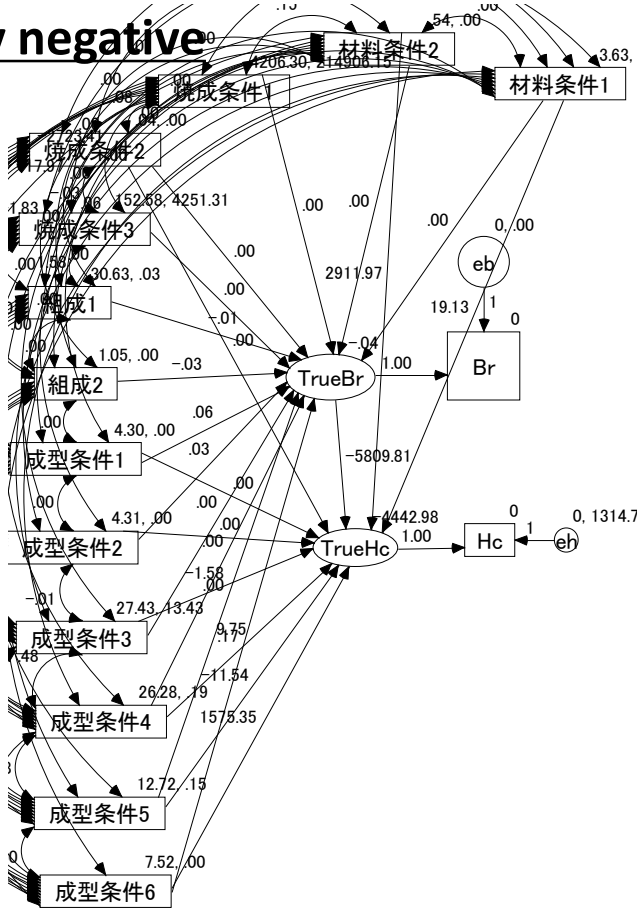
- 13 explanatory variables
  - 2 material conditions
  - 3 burning conditions
  - 2 composition conditions
  - 6 forming conditions
- The regression coefficients of Br becomes **positive** in multiple regression of Hc to 13 variables and Br.

Exact linear relation between true Br and true HC

Br and Hc are mainly affected composition and forming conditions, respectively.

⇒Association between true Br and true HC becomes **highly significantly negative**

			推定値	標準誤差	検定統計量	確率
TrueBr	<---	成型条件 6	.16512	.01547	10.67495	***
TrueBr	<---	成型条件 5	.00000			
TrueBr	<---	成型条件 4	.00110	.00051	2.15008	.03155
TrueBr	<---	成型条件 3	.00000			
TrueBr	<---	成型条件 2	.02605	.01068	2.43947	.01471
TrueBr	<---	成型条件 1	.06221	.00897	6.93502	***
TrueBr	<---	組成 2	−.02769	.00339	−8.17145	***
TrueBr	<---	組成 1	−.00668	.00092	−7.24790	***
TrueBr	<---	焼成条件 3	−.00002	.00000	−8.58302	***
TrueBr	<---	焼成条件 2	.00000			
TrueBr	<---	焼成条件 1	.00000	.00000	−5.50974	***
TrueBr	<---	材料条件 2	.00000			
TrueBr	<---	材料条件 1	.00000			
TrueHc	<---	TrueBr	−5809.81427	567.29868	−10.24119	***
TrueHc	<---	材料条件 2	2911.97084	531.49189	5.47886	***
TrueHc	<---	焼成条件 2	.00000			
TrueHc	<---	成型条件 4	9.74550	4.25063	2.29272	.02186
TrueHc	<---	成型条件 3	−1.58260	.36648	−4.31835	***
TrueHc	<---	材料条件 1	19.12662	11.09727	1.72354	.08479
TrueHc	<---	成型条件 1	.00000			
TrueHc	<---	成型条件 2	.00000			
TrueHc	<---	成型条件 5	−11.54235	3.72527	−3.09839	.00195
TrueHc	<---	成型条件 6	1575.35114	158.83846	9.91795	***
Br	<---	TrueBr	1.00000			
Hc	<---	TrueHc	1.00000			



Case.2 Modified Conjoint Analysis
Application of DOE for Value Selection

- Toya, Nishio and Tsubaki (2005)
- **Consumer's Sense of Value and Preference of Retail Financial Services**
  - Experimental design with rank logistic model fitting provide the evidence that customer preference has linear and non-linear relationship with their value.
  - The findings are useful for practical marketing strategy.
    - Customers those who want to enjoy their life prefer to have flexibility of deposit cancellation.
    - Customers those who have self-respect prefer to virtual channel.

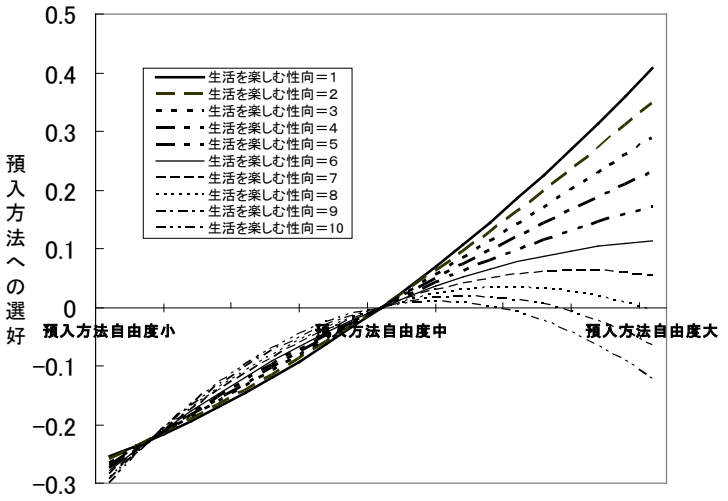
- Usual conjoint analysis using L8 or L9 cannot examine the effects of many important factors
- We assigned 7 factors to L27
  - one for assignments of **different conjoint survey sheets with 9 financial product profiles**.
  - Six controllable factors to design financial services
  - Individual structures on utility are not estimable so we measured several covariates possibly associating with "Financial Values" of customers
- **Estimate the interaction** between the covariates and the assigned factors

An Illustrative result

- The interaction between the level of the hedonic attitude and the degrees of freedom for deposit methods is significant .
  - For hedonic customers, a multi way for their deposit is a linear quality element.
  - For less hedonic customers it is a natural quality element.

Preference Level

High Hedonic Attitude



Low Hedonic Attitude

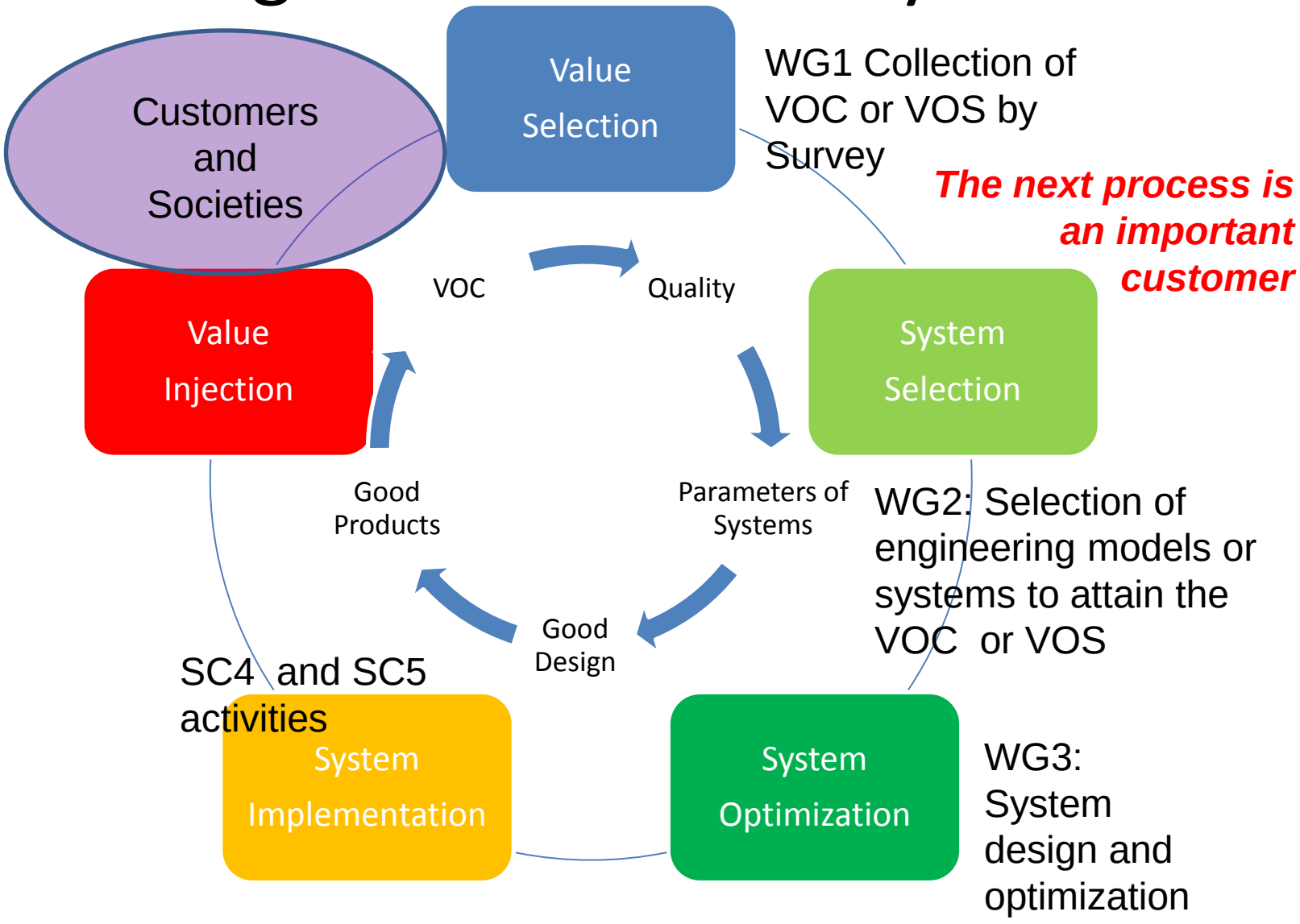
Degrees of Freedoms for Deposit Channels

INTERNATIONAL STANDARDIZATION IN ISO TC 69/ SC 8

TC 69 Standardization for Traditional Statistical Approaches to Quality Management *a-priori given by Functional Quality Characteristics*

- Output Control by Sampling Inspection (SC 5)
- Process Control by Control Charts etc (SC4)
- Process Improvement
  - Six-Sigma (SC 7), Kaizen, etc.
    - Adjustment of the average of Quality Characteristics
      - Improve the dispersion of the Quality Characteristics etc.

Statistical and related methods along the value chain cycle



What SC 8 will not do.

- Strategic guidelines for non-statisticians
  - What SC 8 will expect SC 7 relating to “Six Sigma” etc.
    - To publish process guidelines for engineers and managers including both statistical product and production process control or improvement (The Grammar of Statistical Quality Management) and further **the statistical technology development** (The Grammar of Technology Development)
- Standardization of methods to control or improve a current product or its production process

ISO TC 69 SC 8 ESTABLISHED IN 2009: "APPLICATION OF STATISTICAL AND RELATED METHODOLOGY FOR NEW TECHNOLOGY AND PRODUCT DEVELOPMENT "

Scope

- **The new SC will publish a series of technical standards on the application of statistical and related procedures for new technology and product including private or public services developments to optimize their values from the viewpoints of customers and/or societies.**

Three WGs for SC 8 (chair: Tsubaki) Activities

- **Value Selection Process（SC 8/WG 1）:**
  - **Selection of values from voices of customers or societies**
    - **By Mr. Marius Cronje from South Africa**
- **Transformation Process (SC 8/WG 2)**
  - **Transformation of the values into appropriate parameters defined in engineering systems**
    - **By Dr. Glenn Mazur from USA**
- **Optimization Process (SC 8/WG 3):**
  - **Optimization of performance of the engineering systems**
    - **By Masayoshi Koike from Japan**

Outlines of a Series of Standards

- ISO 16355 “Application of statistical and related methods to New technology and Product Development Process”,
- General Scope:
  - This Standard describes statistical and related procedures along QFD process for new technology and product development including private or public services developments to optimize their values from the viewpoints of customers and/or societies.

One standard with 8 parts

- 1. General Principle and Perspective of QFD Process
- 2. Acquisition of Non-quantitative VOC or VOS
- 3. Acquisition of Quantitative VOC or VOS
- 4. Analysis of Non-Quantitative and Quantitative VOC/VOS
- 5. Solution Strategy
- 6. Optimization – Robust parameter design
- 7. Optimization - Tolerance design and output to manufacturing
- 8. Guidelines for Commercialization

Part 1 General Principle and Perspective of QFD Process

- Part 1 describes the overall QFD process, its purpose, users, benefits, and lists of relevant statistical and related tools and methods
  - General Flow of QFD Process
  - Statistical and Related Tools and Methods for General Flow
    - Informative Annex: Illustrative Example of the best Practices

Part 2: Acquisition of Non-quantitative VOC or VOS

- Part 2 describes methods to acquire VOC and VOS using non-quantitative methods in order to develop questions for quantitative surveys
  - Non-quantitative VOC/VOS Process Flow
  - Statistical and Related Tools

Part 3: Acquisition of Quantitative VOC or VOS

- Part 3 describes methods to acquire VOC and VOS using quantitative methods
  - Objective of survey
    - Clarification of the objective
    - Clarification of targets
    - Assessment and accounting of costs and benefits
  - Quantitative VOC/VOS Process Flow
    - Definition of population
    - Survey design
    - Implementation of survey including data collection
    - Editing of results
    - Report of results
  - Sampling Methods
  - Stratification and Clustering
  - Evaluation of Accuracy of Results
    - Sampling error
    - Non- sampling error
  - Cost Effectiveness of Survey

Part 4: Analysis of Non-Quantitative and Quantitative VOC/VOS

- Part 4 describes methods to analyze non-quantitative VOC and VOS in order to understand how customers measure satisfaction from customer's perspective
  - Non-quantitative VOC/VOS Analysis Process Flow
  - Statistical and Related Tools for Non-quantitative VOC/VOS Analysis
  - Quantitative VOC/VOS Analysis Process Flow
  - Statistical and Related Methods for quantitative VOC/VOS Analysis

Part 5: Solution Strategy

- Part 5 describes statistical and related methods to translate VOC/VOS priorities and targets into product requirements such as functional requirements and target specifications
  - Solution Strategy Process Flow
  - Statistical and Related Tools

Part 6: Optimization – Robust parameter design

- ISO DIS 16336
- Part 6 describes a guidance of applying optimization method of parameter design, an effective methodology for optimization based on Taguchi Methods
  - Parameter design for robust products –overview
  - Evaluation of robustness by SN ratio
  - Procedure of parameter design
    - Informative Annex Example of application experiment

Part 7: Optimization - Tolerance design and output to manufacturing

- Part 7 gives a guidance of applying optimization method of tolerance design
  - Design process and output to manufacturing – overview
  - Tolerance design – basic concepts
  - Procedure of tolerance design
    - Informative ANNEX; Example of application experiment

Part 8: Guidelines for Commercialization

- Part 8 describes statistical and related methods to assure quality and customer satisfaction throughout the rest of the commercialization and product life cycle
  - Commercialization Process Flow
  - Statistical and Related Tools

Invitation to the Joint Research Activities of ROIS and JSA

VALUE CREATION PROCESS NETWORK

Objective of VCP-NET

- Our Environment
  - Varieties of Slogan and TIPS for Improvement, Innovation and Reconstruction
    - Explosion of Knowledge on Methods and Tools
    - Difficulties of Disclosure of Wisdom in Problem Solving Process in Japanese Industry
    - Inefficiency of Problem Finding for Value Creation
- Proposal
  - **Collection, Sharing and Autonomously Evolution of Wisdom on Effective Application of Knowledge**
  - **Constructing Network of Driven Engineers, Researchers and Managers to develop the Wisdom**
- Activities
  - **Developing "Wisdom Base" by Voluntary activities as Wikipedia**
  - Communication among academia and industries in the network
  - Standardized Collection of wisdom on the problem finding and solving processes and their supporting methods and tools for value creation in technology and product development

Activity of WG1

- Body of Knowledge
  - Standardized Description of Tools and their Organic Linkages for Value Creation
    - **Explicit Description of Tools from the viewpoints of their application activities.**
      - Input Information and its requirements
      - Output Information and its requirements
      - simplest description of Function and Procedures
      - Possible Tools to use the outputs
      - Possible Tools to supply the inputs
      - Similar tools

Activity of WG2

Standardized Process for Value Creation

- Standardized Description of Typical Problem Finding or Solving Processes in Value Chains
- Clarification of roles of methods and tools in the processes
- DPAM as Its pioneering activity in JEITA
  - Published in 2007/05
  - http://home.jeita.or.jp/is/committee/tech-std/sekkei-process/dpam/
  - Classification of design processes into 25 element processes with their concrete objectives to give their explicit evaluation viewpoints

New WG
Collection of Cases in Value Creation

- **Collection and Recording of Cases on Good Practices of Value Creation with Standardized Forms by WG 1 and WG 2**
  - **Problem Finding**
  - **Problem Solving**
  - **Implementing the Solution**
- **Survey Site to Attend VCP-Net**
  - https://codia2.heteml.jp/survey/index.php?sid=74185&lang=ja

Concluding Remarks

- Japan has developed several original methodologies for quality management activities by communications between academia and industries since 1950.
- ***Also in present and future?*** .
  - Design of Appropriate Communications in Academia
    - Between Sciences for Recognition and Design
    - Among Management Sciences as QM, Marketing, BSC, HRM etc.
    - Among Trans-Disciplinary Sciences as Statistics, IT and other Applied mathematics.
  - **Redesign of Communication between Industries and Academia**
- ***The perspective view points as the grammar would support these communications?!***