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Innovation activities based on s-curve analysis and patterns of technical evolution-"From the standpoint of engineers, what is innovation?" -

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Abstract

In the first half of this paper, I would like to introduce "The Diagram related to Innovation" based on "Affinity Diagramming" (It's called KJ Method in Japan). In order to collect "Language Data" for organizing the" Diagram", I asked engineers to answer a questionnaire about "what is innovation?" and respond on the answer sheet freely. The approaches are based on the Question asked engineers who took part in the pan-industry social events held by SANNO in September, October and November 2006. Total respondents are 45 engineers. This question was asked before starting the events. That is to say, I didn't reveal my intentions.

What "Organized Diagramming" makes clear is that a majority of engineers have images of "Innovation" as "the turning point of S-curve" focusing on the new generation products based on innovative technologies, as opposed to the conventional technologies. However, others have images of "Innovation" as "the integrated powers to create new ones, based on the conventional technologies, even utilized in previous the field. Moreover, some of them have images of "Innovation" as "something like a natural feeling ", "something like the power to keep organization control", and so on. For the results mentioned above, there is no doubt about the innovations having a variety of aspects.

To the images of innovation, I want to consider "the four types of Innovation activities" on S-curve, which are organized through our experimental studies focusing on future oriented strategies for new business. In the latter half of this paper, through one case example, I would like to introduce "The Future Prediction Technique based on the S-curve Template" developed by utilizing both "S-curve Theory "and "Pattern of Technical Evolutions" as one of the highly valued future prediction techniques, which is very useful to analyze the types of innovation activities.

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1. Introduction

The purpose of this paper is to propose the effective approaches to "Innovation Management Activities" from the points of view of both "S-curve theory" and "the Patterns of technical evolutions" in TRIZ field. This is due to the majority of companies recently recognizing the importance of "IMA". I derived some conclusions about Japanese manufacturers from the results of the questionnaire survey of 100 engineers, conducted in last year, which was presented at ETRIA2006 [1]. According to the results, most of them have confidence in both the "Structure of Manufacturing Stage" and the"Capability of Quality Management". However, they have no confidence in the enhancement of the "Structure of New Product Planning Stage". Therefore, I presume that they lack confidence in "Innovation Power" from results of the survey.

In the meantime, regardless of low self-esteem to "Innovation Power ", it's possible to confirm which "Brand Image" affected by "Innovation Power" is highly esteemed. That is to say, it looks likes a contradiction on the surface. However, according to Fig8 from the previous paper I wrote, I'm able to presume that both "Structure of Manufacturing Stage" and"Capability of Quality Management" with high self-esteem give "Brand Image "a higher score at this time. However, it can't be denied that self-evaluation to the "Brand Image "might be low in the not-so-distant future if self-evaluation to "Innovation Power" remains unchanged.

Therefore, in this article, with a focus on "Innovation", I will attempt to divide "Innovation" activities into four patterns through the survey's speculations based on responses to the questionnaire, "What Is Innovation?" which was conducted with 45 engineers as respondents.

In addition, in the latter half, I will introduce "The Future Prediction Technique based on the S-curve Template" as one of the effective techniques for "IMA". It's based on the categorization of "The Four Innovation Patterns".

This technique consists of two items, "S-curve Theory" and "Patterns of Technical Evolution". I intend to introduce one case example based on the utilization of this technique.

2. A questionaire about "what is innovation?"

2.1. A free response question about "innovation"

In order to make "The Diagram connected with Innovation" systematically, this survey is a series of attempts to put language data in order by utilizing Affinity Diagramming (called the KJ Method in Japan). As mentioned above, this data was collected through a questionnaire titled "What Is Innovation?".

This survey is based on the response of 45 engineers who took part in the pan-industry social events held by SANNO in September, October and November 2006．The 45 engineers came from 15 companies(2-3 per each company).This question was asked before starting the events. I did not reveal my intentions before asking questions.

The respondents (45 engineers) are a different sample to the 100 respondents from the previous survey (discussed in the paper at ETRIA2006). However, I have determined that I'm able to consider the results of this survey, correlating it with the previous survey, because the base attributes (Age, Task, Scale of the Business, Types of Products etc.) of respondents of both surveys have similarities.

2.2. How to make a diagram

I asked the 45 respondents to answer the questionnaire about "What Is Innovation?" They described the image of innovation on the answer sheet freely. After that, five faculties including my own, "Innovation Management Study Group", at SANNO checked these descriptive statements and eliminated several statements having no relevance to intent of the questionnaire. The rest of them were organized by the Affinity Diagramming approach. Therefore, the total number of statements (33) described on the card differ from the number of respondents (45).

2.3. Survey results and speculations about Innovation

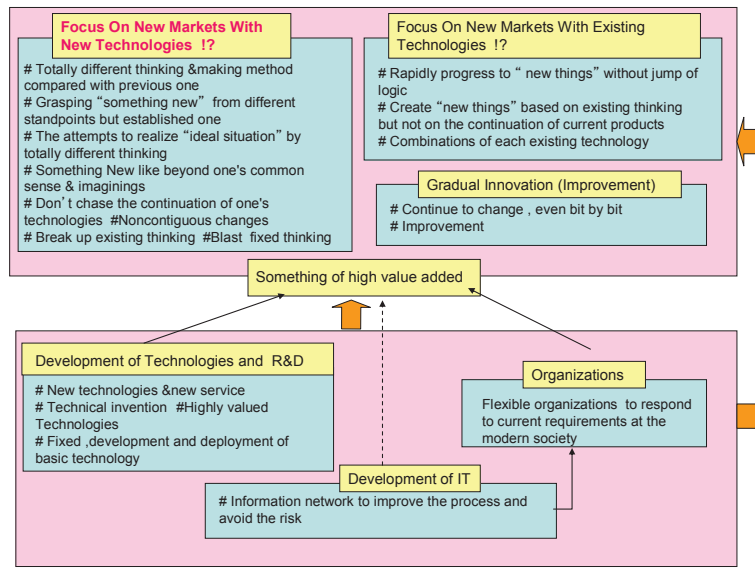"The diagrams" organized by the Affinity Diagramming approach appear in Figure1 and Figure2.
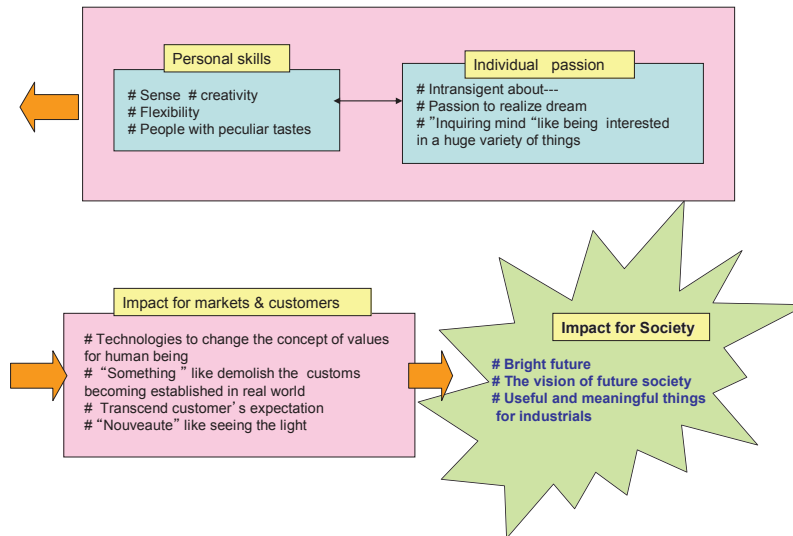
Figure1: Innovation Image (Left side)

Figure 2: Innovation Image (Right side)

The relationship between figures1 and 2 shows "one diagram" because the arrows on the right side in Figure1 link up with the arrows on the lift side in Figure2. In addition, Figure 3 focuses on a brief overview, omitting the detailed statements of the each group.
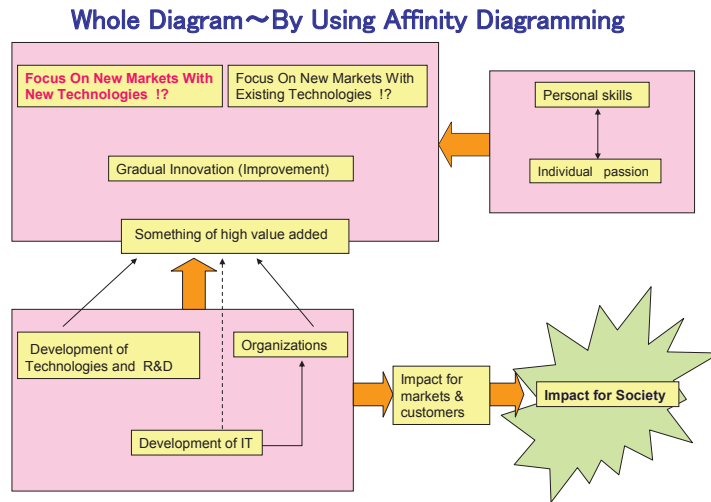
Whole Diagram〜By Using Affinity Diagramming

Figure 3: Innovation Image (brief overview)

Image of innovation (1)-"High value Added things"

As the result of the diagramming (see Figures1, 2 and 3), detailed statements related to "something of high valued added" are based on the viewpoint that statements indicate "strong and innovative image". The largest group of respondents focus on New Markets with New Technologies corresponds to a "strong and innovative Image". The second group indicated that a focus on New Markets with Existing Technologies was important. The third group favored "Gradual Innovation (Improvement)". Even if there are only 2 responses in the third group, we have to take heed of this fact that two respondents defined the image of innovation as "improvement".

Images of innovation (2)-"Flexible organizations, new technologies and Individual skills & passion"

We confirmed that there are two groups concerned with" Something of high value being added". Both groups defined the way to create "Something of high value added" as the "Development of Technologies and R&D" and "Organizations", respectively. On the other hand, some of the respondents defined the image of innovation as "Personal skills" or "Individual passion". (These groups could be defined as the means to have an impact on "Something of high value added".)

Superior images of innovation (3)-"Impact for markets &customers and impact society"

In addition, we confirmed that there are 4or 5respondents who believe that "a positive impact upon markets & customers" creates a superior image, conceptually, of the word "Innovation".

These two groups correspond to the results describing the image created by the realized results of" Something of high value added".

Others about images of innovation

As to the image of innovation, only one respondent described a need for an Information network to improve processes and avoid risk. This is based on the image of "Development of IT" and its influence on (Flexible) organizations and how they respond to modern society directly. However, I can't conclude that "Development of IT" has an influence on "Something of high value added" directly. Therefore, from the survey sheet, we didn't check responses related to the relationship between "Something of high value added (=next generation products)" and "Utilizing IT". In regard to this matter," Diagram of Cause –Effect Relationship Regarding Eleven Challenges (see Fig8 of my paper at ETRIA 2006) indicated that "as one of challenges, Utilization of IT Skill at R&D" was isolated from the whole diagram. I think the result I mentioned in my previous paper has a similarity to the above mentioned consideration about "Development of IT".

3. Four patterns of innovation

I tried to consider the images of Innovation through the previous chapter. We confirmed that the majority of responses are based on "something of high valued added" as "one of images of Innovation ". Although the summarized cards, which correspond to "something of high valued added" are indicated in less than 50 %(14/33=about44%) of cases, most of original responses indicate more than50 %(25/45=about 56%). Therefore, in this chapter, on the basis that "Innovation= something of high valued added (with reference to a product in this case)", I would like to consider "Innovation Patterns of Product Development".

From the aspects of technological novelty that embody a new product, it is possible to divide Innovation for Product Development into two main categories. The first demonstrates "Radical Innovation VS Incremental Innovation".

From the perspective of whether or not new technologies (or even existing technologies) destroy core companies in an existing market , we are able to confirm the existence of second of the two main categories, that being "Disruptive Innovation VS Sustaining Innovation".

These categories are based on Christensen's aspects of Innovation [2]. In addition, it's possible to organize the "Four Patterns of Innovation shown in Figure4 according to these categories.
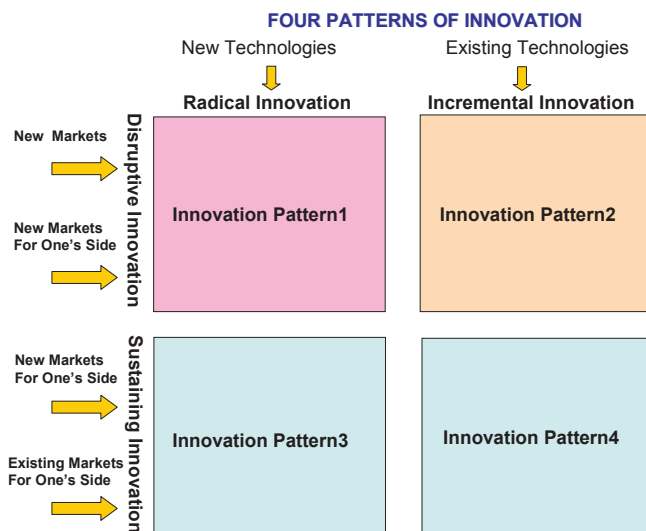

Figure 4: Four Patterns of Innovation

3.1. The relationship between "S-curve" and "Four innovation patterns"

To make the features of each Innovation pattern easier to understand, I have tried to describe in Figure5 the "Four Patterns of Innovation based on the S-curve Model".
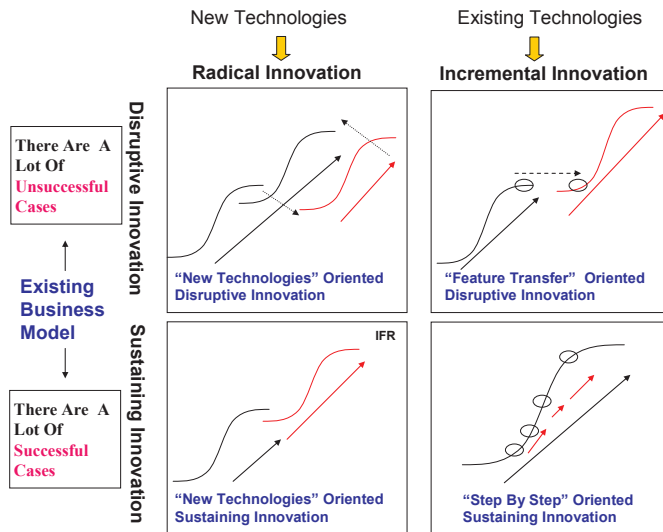
Figure 5: Four patterns of Innovation based on the S-curve

BY putting "customer's requirement" in Figure5, it's possible to organize as described (see Figure6).
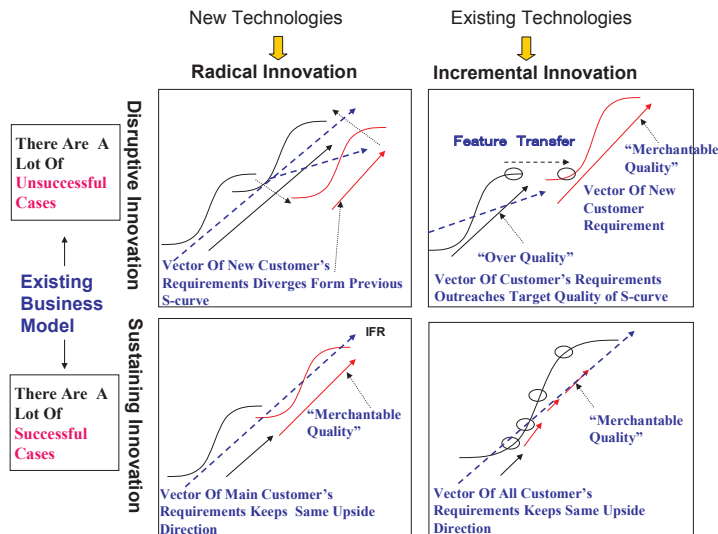

Figure 6: Customer's Requirements and Four patterns of Innovation

As shown in Figures 5 and 6, organizing each innovation pattern from the standpoints of both "S-curve" and "Customer Requirements" brings each innovation pattern's features into focus.

Innovation pattern 1 (disruptive × radical) innovation

The primary purpose of "Innovation Pattern 1" is to create new S-curve for the next generation product by utilizing new technologies. However, in the beginning, this Innovation has to focus on "Another Market (New Markets)" as the appropriate product for "Low End Customers", even with low performance and inferior quality compared to "High End" in existing markets. This is because, in the initial stages, this innovation can hardly realize "Customer's requirements (High End)" in existing markets. Therefore, returning to previous markets (existing markets) after long-awaited timing is a basic strategy of "Innovation Pattern 1".

"Innovation Pattern1" is the most powerful of the four patterns (see Figure4), because this strategy is finally designed to destroy the products of core companies in existing markets after new technologies were developed in other new markets. In addition, this innovation corresponds to "New Markets With New Technologies" in the "Innovation Image (see Figure3)".

Some examples applicable to "Innovation pattern 1" are given below.

> (Case examples about innovation pattern1)
> **Online Music Service**
> #CD-SHOP might be break down after Online music
> shops like iTunes becoming popular (ex. Tower
> record in U.S)
> **Suppliers Focusing On "Electric Vehicles" Or**
> **"Fuel Cell Vehicles**
> #Suppliers for gasoline-fueled vehicle might be break
> down after the appearance of suppliers for EV&FCV

Innovation pattern 2 (disruptive × incremental) innovation

If the core technologies (i.e. sophisticated technologies in established market) of this innovation are in the "maturity to deadline stage" and have exceeded the "Customer's requirements in established markets", this innovation actively "encourages companies to look to other markets" to create "new products". Consequently, "Innovation Pattern2" is based on the same powerful strategy as "Innovation Pattern1". This strategy is designed to destroy the products of "traditional companies" produced before those companies focus on new innovation, which will aid in the establishment of new markets.

In addition, this innovation corresponds to " Focus On New Markets With Existing Technologies " in "Innovation Image (see Figure3)". Some examples of "Innovation Pattern 2" are given below.

> (Case examples about innovation pattern2)
> **Refined Technologies Of Traditional Industrials in**
> **"Deadline Stage"**
> **#** Although **"**Deep draw work technique" for shaping the
> body of high class lighter stay in deadline stage, it
> become highly valued technique for shaping the
> rechargeable battery case of cell phone. Because it keeps
> high quality.

Innovation pattern 3 (sustaining × radical) innovations

This Innovation Pattern is based on new technologies which create the next S-curve after obsolescence of core technologies on a previous S-curve, but still chases the same existing markets. Therefore, industrial strength in previous markets is basically unchanged, even on a new S-curve. That is to say, traditional companies in a given market develop new technologies that cater to primary customers and their requirements for the higher quality. Some examples to "Innovation pattern 3" are given below.

(Case examples about innovation pattern3)
 Materials For Automobile Body
#After existing thin steel plate, high-tensional steel plate becomes main material for automobile body
Development Of Main Products
After gasoline-fueled vehicle, hybrid vehicle is expected to create next S-curve in the automobile industry.
B&W TV Color TV LCD TV

Innovation pattern 4 :(sustaining × incremental)innovation

The purpose of this Innovation Pattern is to utilize "the existing core technologies" comprehensively to extend an existing S-curve. Accordingly, this innovation is based on the detailed understanding of established customer requirements which enhance customer satisfaction.

Essentially, this innovation corresponds to "Gradual Innovation (Improvement)" in "Innovation Image (see Figure3)". Some examples to "Innovation pattern 4" are given below.

(Case examples about innovation pattern4)
 Usual Improved Products
Late-model car about hybrid vehicle
Late-model TV about LCD TV or
PDP TV etc.

3.2. The predictive paths about "innovation evolution"

As mentioned in the previous section, it is clear that innovation has four patterns. However, each innovation pattern is not independent, it evolves and develops itself while it's also influencing the other patterns.

In connecting the four innovation patterns comprehensively, I'd like to propose two "predictive paths for the evolution of an innovation" (see Figures 7 and 8).
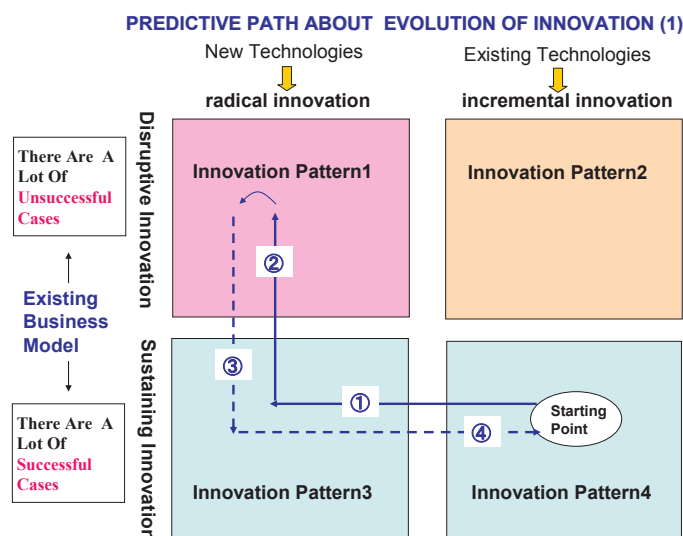

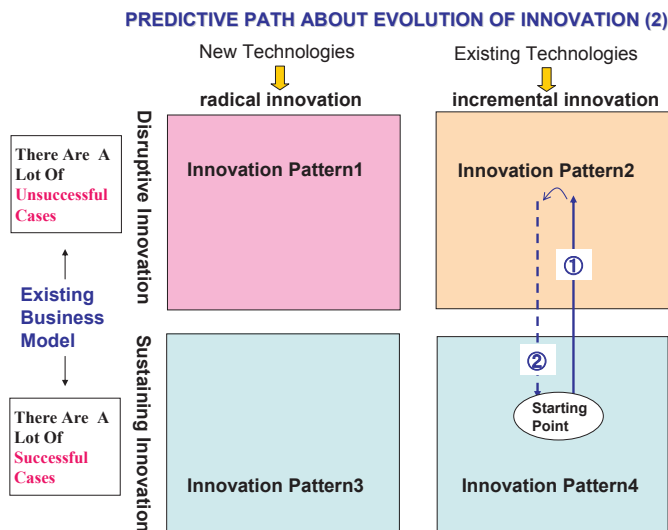Figure7: Predictive path about evolution of innovation(1)

PREDICTIVE PATH ABOUT EVOLUTION OF INNOVATION (2)

Figure 8: Predictive path about evolution of innovation (2)

"Predictive Path 1 "in Figure7 demonstrates that "an Innovation path (1)" proceeds in a cyclical manner from "Innovation pattern4", through "Innovation pattern3" and concluding with "Innovation Pattern1". It then returns through "Innovation pattern3" to "Innovation pattern 4". Needless to say, this path (1) is just one of the typical paths.

There are hardly any case examples where a company within the same industry has taken the "predictive path (1)" from beginning to end.

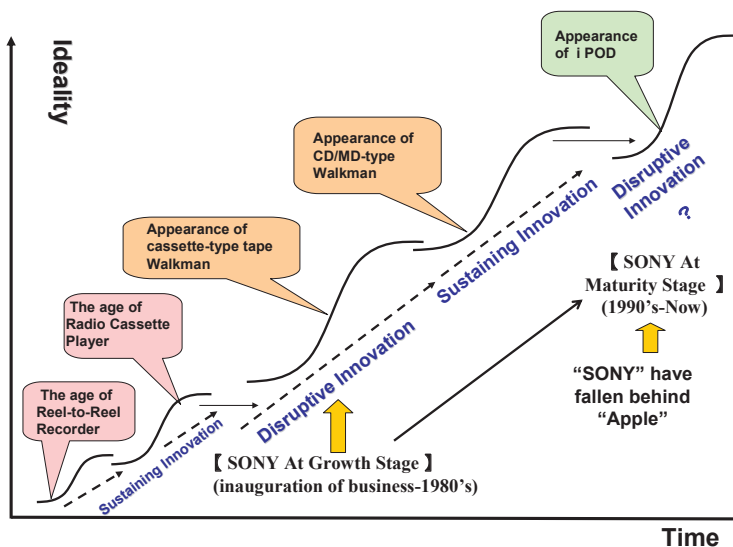Figure9 is one of the few examples that demonstrate the "predictive path (1)" in Figure7.

Figure 9: Case example about Innovation path (1)

This example shows that after the"Reel-to-Reel Recorder" appeared on the market, it underwent improvement according to "Innovation pattern4". The result was the "Radio Cassette Player" which was developed as new equipment based on new technologies instead of established technologies in established markets, which is

"Innovation pattern3". This was due to the fact that when converting to the "Radio Cassette Player", in new S-curve, it appealed to the existing market for the" Reel-to-Reel Recorder".

After the improvement activities ("Innovation pattern4") in this S-curve, the "Cassette-type Tape Walkman" was developed by SONY as new equipment after "Radio Cassette Player" and took the world by storm. To put it more succinctly, people wearing headphones rapidly increased and SONY created a new market with a "New Culture" of people who like to listen to music while walking. At the time, the "Walkman" was a realization of "Innovation pattern1".

Subsequently, "Walkman converted to the "CD/MD-type Walkman", a return to "Innovation pattern3". Needless to say, we'll notice that "Innovation pattern4" is a kind of "Starting Point "companies have to pass through after launching "innovation pattern1 ,2 or 3", because of the required improvement in each S-curve after launching.

After a long development, iPOD appeared and was expected to be a necessary complement to the coursework at universities in the U.S by utilizing a picture recording capability, unlike the more conventional "walkman", and the ability to download coursework from the net to the iPOD[3],[4].

It is clear that above mentioned examples regarding iPOD are in a new market. Moreover, these examples make it clear that in utilizing "IT", iPOD created a "New Business Model" that we've never seen before, if not entirely "new technologies" from a technical standpoint. Therefore, iPOD destroyed an existing market and its affiliated industries, it is an example of "Innovation pattern1".

4. The future prediction technique based on the s-curve templates

Through the previous chapter (see 3), what needs to be emphasized is that both "Innovation Paths (1) and (2)" finally get back to "Innovation pattern4"by necessity.

To put it another way, in order to predict when to proceed with another Innovation Pattern (1, 2, or3)", we can't ignore "Innovation pattern4".

Therefore, I would like to emphasize that we think the consideration of the features of the four stages on the S-curve is one of the most important required activities in "Innovation Management". If "S-curve Templates for Future Prediction at Innovation pattern 4(see Figure10)" are developed, it is clear that it's possible to predict the timing to "next Innovation pattern", in a more rational manner.
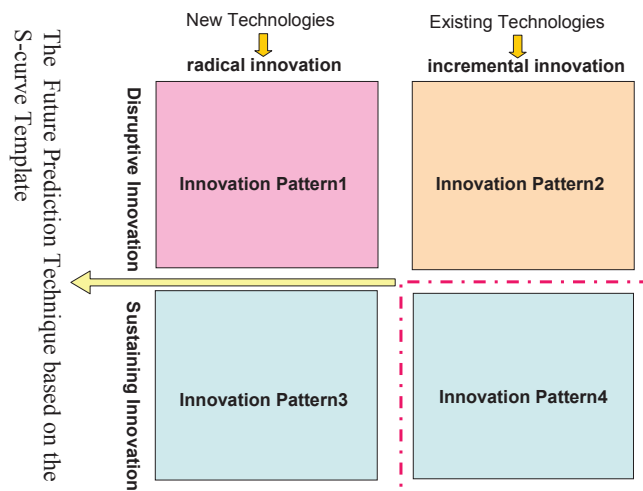

Figure 10: S-curve Templates for Future Prediction at Innovation pattern 4

Based on the above mentioned background of "Four innovation patterns", as one of "S-curve Templates for Future Prediction", using examples from Darrell Mann's S-curve[5], I tried to make simplistic one (see Figure11).

It's a kind of tool to indicate the features of product development on an S-curve from the aspect of function. It looks like "compass in mountain climb" and leads to the future according to some of "the Patterns of Technical Evolutions" in TRIZ, especially focusing around "Function Evolution". Moreover, predicting some challenges to work through at the stage of growth to maturity on an S-curve, I prepared other representative "patterns of Technical Evolutions" [6].
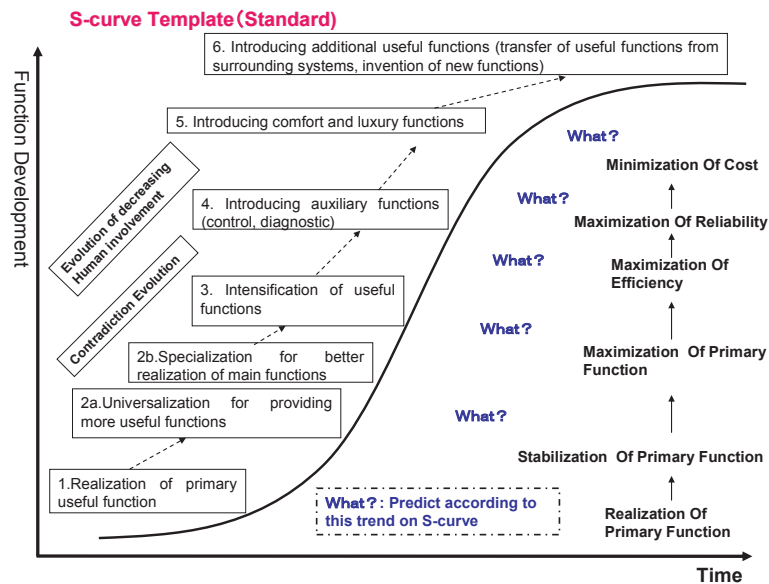
S-curve Template（Standard）

6. Introducing additional useful functions (transfer of useful functions from surrounding systems, invention of new functions)

5. Introducing comfort and luxury functions

4. Introducing auxiliary functions (control, diagnostic)

3. Intensification of useful functions

2b. Specialization for better realization of main functions

2a. Universalization for providing more useful functions

1. Realization of primary useful function

Evolution of decreasing Human involvement

Contradiction Evolution

Function Development

Time

What?: Predict according to this trend on S-curve

What? Minimization Of Cost

What? Maximization Of Reliability

What? Maximization Of Efficiency

What? Maximization Of Primary Function

What? Stabilization Of Primary Function

Realization Of Primary Function

Figure 11: S-curve Template (Standard)

"S-curve template shown at Figure11 is "a standard version" and I developed several "applied versions", which are based on the additional "patterns of Technical Evolutions", which predict a lot of challenges corresponding to each stage on S-curve more precisely. Therefore, using "several templates" concurrently depending on conditions, we are able to predict "Innovation in future". However, I will concentrate on "a standard version (see Figure11), as space is limited in this paper.

5. Case example according to the s-curve template

I tried to draw up the organized development history about "Cassette-type tape Walkman", (Figure9), which is one of symbols of SONY. This case example[7],[8] was organized by using "S-curve Template (Standard)" at Figure11.
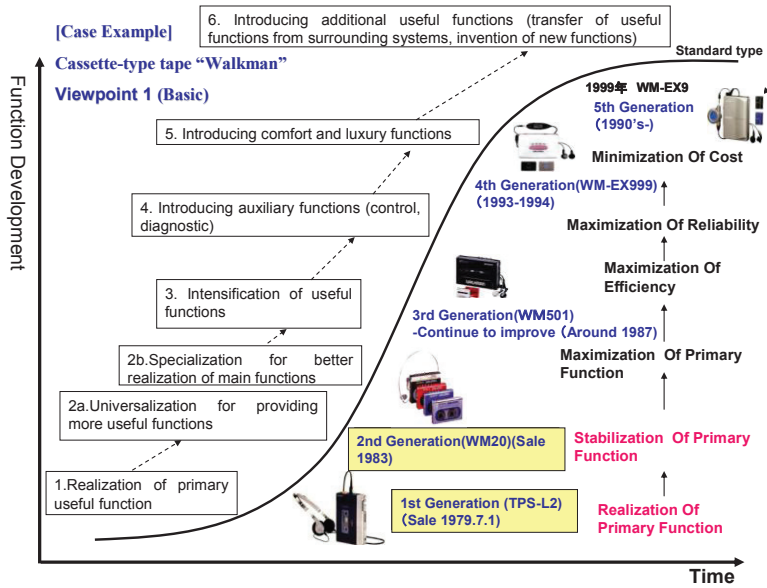
Figure 12: Cassette-type tape "Walkman" Viewpoint1 (Basic)

Figure 12 is the figure organized development history of "Cassette-type tape Walkman" from the viewpoint of "Function Evolution (basic view)". "Primary useful function" of "Walkman" was an innovative function at that time, because it created a "New Market". Especially, through the growth stage (2nd to 3rd generation Walkman), to enrich primary function, the attempt to reduce weight was continued. In addition, Figure13 is the "detailed version", organized with regards to the "development activities". On the way to the growth stage to realize weight saving, I confirmed the "Contradiction Evolution" and "Evolution of Decreasing Human Involvement". A case example for "Contradiction Evolution" is that the contradiction between motor performance and body weight was solved by converting "Pencil tape cylindrical motor" into" flattened motor". On the contrary, a case example for "Evolution of Decreasing Human Involvement" can be identified with the introduction of the auto reverse function of the cassette tape.
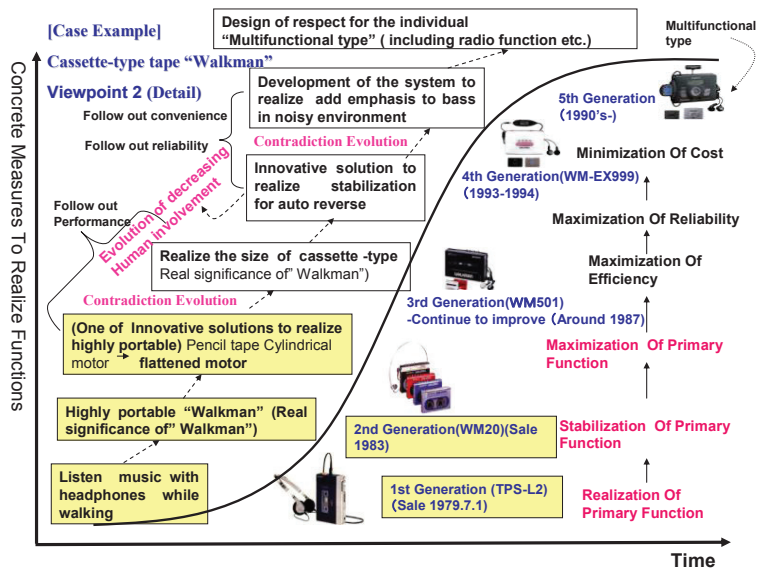

Figure 13: Cassette-type tape "Walkman" Viewpoint 2
(Detail)

"S-curve Template (Standard)" shows the" Realization of the enhancement and stabilization of Primary useful function (childhood to growth stage)";"Realization of the maximization of efficiency and reliability (maturity stage); and "Realization of the minimization of cost (maturity to decline stage)".

At first, I organized the history of "Walkman" from the Viewpoint 3(lightweight/weight saving), Figure 14, because the best way to realize the enhancement and stabilization of Primary useful function of "Walkman" was to reduce the body weight.
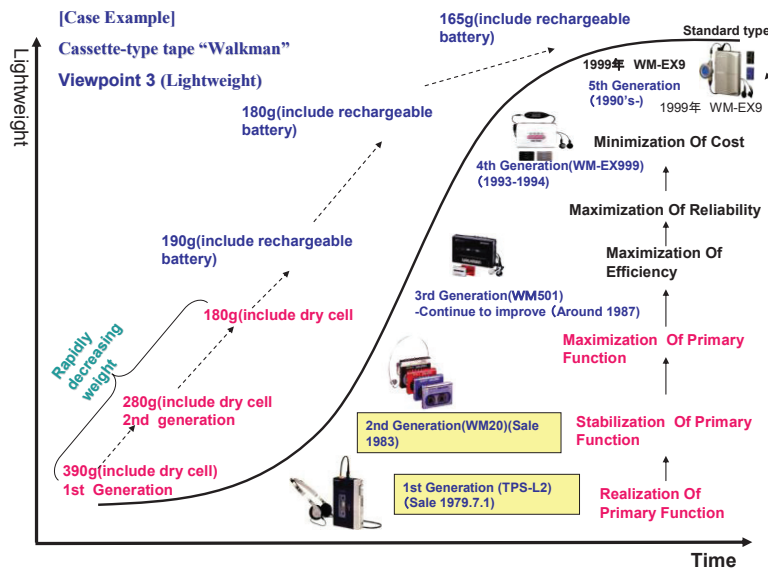

Figure 14: Cassette-type tape "Walkman" Viewpoint 3
(Lightweight)I

We can recognize from Figure 14 that body weight was rapidly reduced from 390g at childhood stage to 180g at growth stage and then finally reduced to 165g. Therefore, it is fair to say that the "Walkman" proceeded according to "S-curve Template (Standard)".

To check the process regarding" Realize the maximization of efficiency and reliability (maturity stage), I organized the history of "Walkman" from the Viewpoint 4(hour of use) at Figure 15. We can confirm that the hour of use was "alkaline dry cell 7.5H and rechargeable battery4H" at growth (3rd generation) and was improved significantly," alkaline dry cell 16H, rechargeable battery8.5H and alkaline dry cell with rechargeable battery 25H" at maturity (4th). A final improvement to "alkaline dry cell with rechargeable battery 100H"was made at this stage too. It is clear that improved efficiency was the goal for the "Walkman" during the maturity stage.

Consequently, it is fair to say that, mostly, "Walkman" proceeded according to "S-curve Template" from the viewpoint of efficiency, too.

Finally, to check the process regarding "Realize minimization of cost (maturity to decline stage)", I organized the history of "Walkman" from the viewpoint 5(price) at Figure 16. I used price (at the time) at Figure16 instead of product cost. It's very hard to grasp both cost of production and current market price.

We can recognize from Figure 16 that the price was reduced 33000 yen to 27000 yen in the intervening period between childhood and growth stage. However, it is clear that as compared with childhood stage, "Walkman" came down in price dramatically (33000yen to13000yen) at the latter half of maturity stage. This means a 60%cost reduction.

When it is compared to "Standard Type Walkman" at childhood stage, there is no doubt about the end result was an extremely low price. Further evidence that "Walkman" proceeded according to "S-curve Template" from the viewpoint of price.
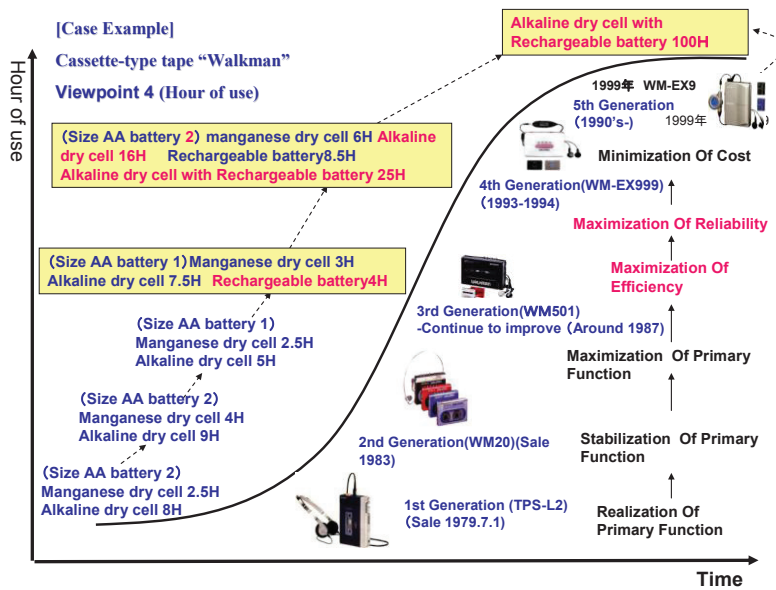
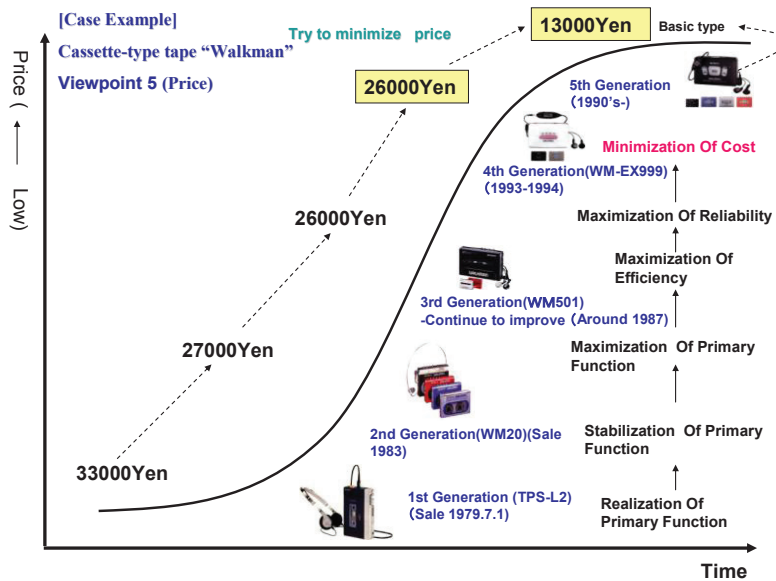Figure 15: Cassette-type tape "Walkman" Viewpoint 3
(Hour of use)

Figure 16: Cassette-type tape "Walkman" Viewpoint 4
(Price)

6. Summary

In the first half of this paper, what the survey about "the image of innovation" for engineers makes clear is that a multiple image of innovation exists. Additionally, using the possibility to develop a certain pattern focusing on "IMA", I proposed "The Four Innovation Patterns". These "Four Innovation Patterns" are connected with each

other organically. I indicated that their source can be poured into "Innovation pattern 4(Improvement activities)". If we can predict the near future based on "Innovation pattern 4", it's possible to predict the timing of the transfer to another of the Innovation patterns (1, 2, or 3)"more precisely. In the latter half, I proposed "S-curve Template (Standard) as a means to predict what target products (technologies) we should expect in the near future.

In addition, I tried to look into the effectiveness of "S-curve Template" through a case example ("Walkman").

Although I can't say definitively, based on only one case example, this technique is very useful to predict near the future of target products. I'm checking the effectiveness through other case examples, confirming that this template is a very effective tool that can be used to predict the life-cycle of in home electric appliances. I would like to utilize this template effectively to predict the "near future scenario" regarding next generation products.

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