Design Strategy for Interior Space in High Speed Rail: A Case Study of the Kyushu Shinkansen Tsubame

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Abstract: This report focuses on the design strategy for interior space in the Shinkansen Tsubame Series 800 in Kyusyu, Japan and describes the challenges and solutions as obtained from an interview survey of the companies engaged in producing the products used in the train. With regard to construction of the Tsubame Series 800 trains, the companies involved encountered many challenges. The following two solutions contributed greatly to overcoming these challenges: 1)The "building up experiences" were used effectively, including the continuous improvements made in technologies, the effective use of knowledge accumulated in departments in the companies other than those directly related to product production, and the contributions of their research laboratories. 2)A flexible production system was established, including the accumulated experiences and knowledge mutually shared by other related departments in the companies, and the manual assembly processes added to the automatic production lines.

Key Words: *High Speed Rail, Interior Design Strategy, Interview Survey*

1. INTORODUCTION

In 2004, the Kyushu Shinkansen railway train Tsubame (Swallow) Series 800 started operation. This is the first train that ran on the Shinkansen railway line in the Kyushu region. The interior spaces of cars in this train express the enthusiasm of JR Kyushu. An abundance of timbers produced in Kyushu are used in the car rooms with white as the basic color. In each passenger room, the seats covered with colored textiles in the Japanese style have an attractive arrangement creating a luxurious impression. In each toilet room, the rush-worked split curtain conveys a mildness specific to the natural material of the room, and is a complete change from the image of the interior spaces in the public traffic which pursue functionality and comfort. The car rooms where traditional craftworks produced from materials in the Kyushu region are used suggest that a specific design strategy should be introduced into future means of public transport.

The authors anticipate that such a design strategy will create a new value in the limited or required time of transport and the limited space, especially in means of public transport which are predominantly used for tourist trips, and will have beneficial influences not only on the passengers and operators of these traffic means but also on the development of areas along

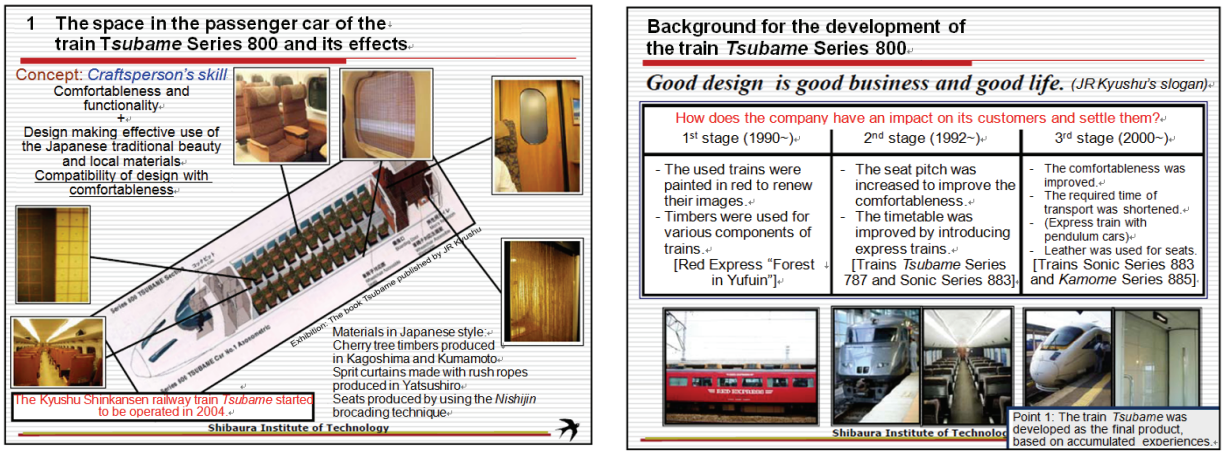

Figure 1 Effects and background for the development of the Shinkansen Tubame 800

railways. If local colors are introduced into the key components of trains, the passengers will probably have a naturally excited feeling of "I'm traveling," and railway operators will most likely be able to improve their corporate brands. We also expect that the development of this design strategy will contribute to the use of traditional craftwork technologies which are gradually decreasing in our country.

In this research, we interviewed the representatives of the related companies and analyzed the problems and solutions regarding the manufacture of the Kyushu Shinkansen railway train Tsubame in order to search for a method of introducing an optimum design strategy adaptable to the local climate into the interior spaces of the means of public transport. The "traditional craftworks" covered by our research include those using local materials.

2. BACKGROUND FOR THE INTRODUCTION OF TRADITINAL CRAFTWORKS INTO THE TUBAME

The background for the introduction of traditional craftworks in the Tsubame Series 800 train will be described here based on interviews of the representatives of JR Kyushu as well as published papers. When the Japan National Railways was privatized, motor vehicles accounted for more than 70% of all the over land transport in the Kyushu region. JR Kyushu was competing with other public transport companies to obtain a large share of the remaining 30% (1). To emphasize its sensibility value compared to those of its rivals (2) JR Kyushu implemented a joint train development project with Mr. Eiji Mitooka, consulting designer at Done Design Research Laboratory.

As shown in Fig. 1, JR Kyushu has had an impact on the users of its railway through its train designs and has made efforts in responding to their demand since the Japan National Railways was privatized. An abundance of timber was used for the floors, walls, handrails, and tables in event trains such as “Forest in Yufuin.” Cowhides were used for all the seats in the *kamome* (Seagull) train. JR Kyushu has enhanced the beauty and functionality of its trains for 20 years by actively developing characteristic coloring and train designs, through continual reviews even while making occasional blunders (3) The *Tsubame* Series 800 train was developed as the final product under the train design strategy of using local materials produced in the Kyushu region and the traditional craftworks in Japan, as described in Fig. 1.

Table 1 Answer items to Questions

Sense of spaciousness	Feel the passenger room is very large and spacious.
Natural materials	The atmosphere is good because natural materials are used, like wooden chairs.
Large seats	The seats are large.
Careful	I would like to use the clean passenger room and seats carefully.
Japanese style	The atmosphere is good in the passenger rooms and in the Japanese style.
Private compartment	The seats have high backrests. So I feel as if I sit in my seat in a private compartment.
Sense of high quality	My ordinary car appears to have as high a quality as the green car.
Appearance	The design appearance is refined.

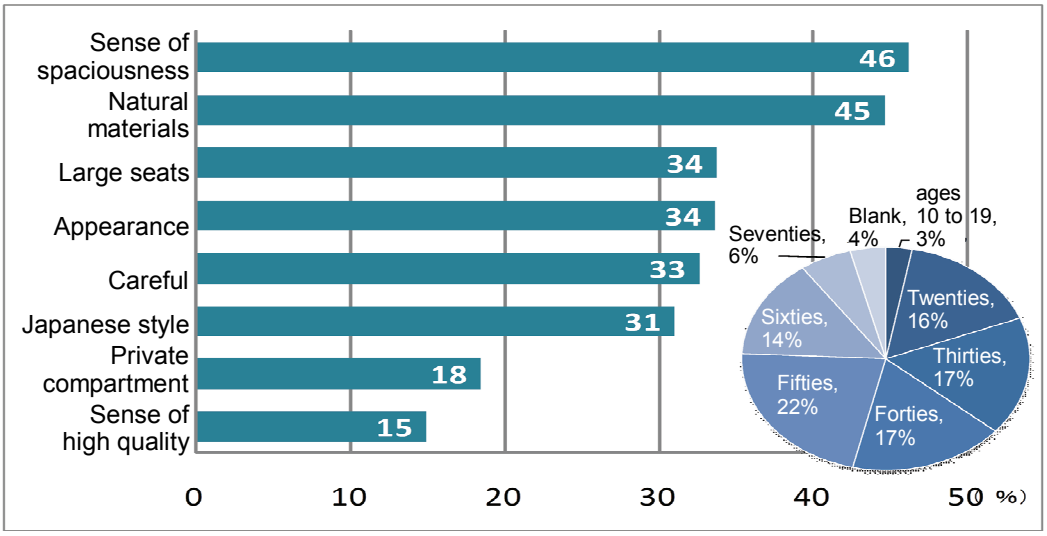

Figure 2 Image survey conducted by the questionnaires sent to the users of Shinkansen trains

The interior decoration of the Tsubame Series 800 train follows the principle of "compatibility of design with comfort," uses white as the basic color, and increased the seat pitch to create a comfortable interior space with the 2 + 2 array of seats in the train.

3. USERS' EVALUATION OF THE INTERIOR DESIGNS OF TUBAME

3.1. Outline of survey

In the 2008 fiscal year, the Institute for Transport Policy Studies (Foundation) sent questionnaires to the users of Shinkansen railways as a part of the post-assessment made on the Kyushu Shinkansen railway. Several assessment items proposed by the current authors also were adopted as questions about the train design images. The assessment report summarizes all the concepts and design policies as keywords as described in the papers and books written on the Kyushu Shinkansen railway.

Table 1 gives the answers to item questions. The questionnaire asked each of the Shinkansen train *Tsubame* users to check multiple answer items that they selected. The number of effective answers was 1,807, with about 60% given by men and about 38% given by women.

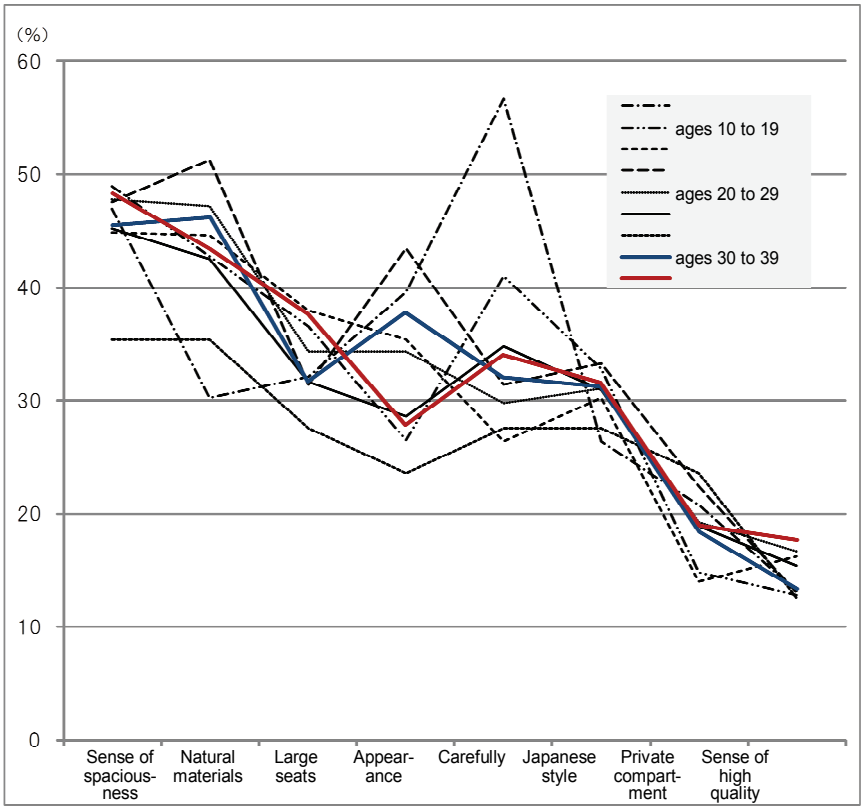

Figure 3 Appraisals by sex and age bracket

3.2. Results of survey on the designs of the trains running on Kyushu Shinkansen railway

a)Trend of all the effective answers

Figure 2 shows the results of the appraisals made by all the effective answerers. The "sense of spaciousness," "natural materials," and "large seats" had the highest percentages among all the answer items.

b)Trends by sex and age bracket

Figure 3 shows the results of the appraisals made by sex and age bracket. The trend in the 10 to 19 age is obviously much different from that of all the effective answerers. The answer item "careful" accounted for the highest percentage in the 10 to 19 age bracket, while the answer items "sense of spaciousness" and "natural materials" were regarded highly by all the responders. Differences were observed between men and women in the answer items "large seats," "appearance" and "sense of high class." The "appearance" was more highly appreciated by men, while the "large seats" and "high quality" by women.

The answer item "natural materials" was highly appreciated by responders in their thirties to fifties, and especially by 50% of all the responders in their forties and seventies. The item "large seats" was more highly supported by women than men in all age brackets, probably because of the general differences in body sizes between men and women. The item "private compartment" was supported by about 15% of all the responders in their twenties and thirties and by 27% of all the responders in their seventies. The item "sense of high quality" was selected by 23% of all the women in their fifties and about 15 % of all the women in their twenties to sixties.

3.3. Considerations

Responders using the Kyushu Shinkansen railway line supported the answer items, "sense of spaciousness," "natural materials," and "large seats," which are directly related to comfort. The other answer items were answered differently depending on age brackets and where they were living. Therefore, it can be said that a design concept strategy targeting the users will contribute to future development of spaces in cars.

4. SURVEY BY INTERVIEWING THE REPRESENTATIVES OF INTERIOR DECORATION-RELATED COMPANIES

4.1 Outline of survey

JR Kyushu had adopted the policy of limiting the operating cost for the Shinkansen train *Tsubame* to a lower value than that for conventional trains. To implement cost reduction measures, therefore, JR Kyushu entrusted Mr. Mitooka with all the works ranging from design to the selection of materials, while it retained the responsibility for checking the functions of the train and purchasing the great quantities of materials. Mr. Mitooka gave first priority to the "use of natural materials." Although an abundance of timber was used in the *Tsubame* Series 800 train, he reduced the production costs by using materials that might normally be disposed of as waste. Mr. Mitooka decided that he wanted to use natural woods rather than beautiful timbers and that timbers with nodes were natural. This know-how was applied to the leather-covered seats in the express train Series 885 before the *Tsubame* Series 800 train was constructed. Thus, it seems that the past experiences were used effectively.

However, it will significantly increase production costs to achieve such high-quality spaces in cars while producing a relatively small number of trains. In this research, therefore, we conducted the interview surveys not only on the technical and cost problems that interior decoration related companies encountered when they introduced the traditional craftworks into their products but also on the solutions that they adopted to solve these problems. In the interview surveys, we asked the following three questions of the interviewees:

- Questions -

1) What problems were caused by using new materials for trains? (Technical problems)
2) You said that "the trains "*Tsubame* Series 800" had been produced without increasing production cost." However, the increase in production cost should have been inevitable if new materials were used to meet the different standards. How did you solve this problem? (Cost problem)
3) What influences did the development and production of the train *Tsubame* Series 800 have on your company and other companies? (Delivery influence)

4.2 Challenges and keys to solutions in production process

The answers provided by the 6 companies that were engaged in the production of the Tsubame train are given in Table 3. In terms of the production process, the Tsubame Series 800 train presents unique characteristics as follows: (1) It needed to have not only the express speed required for Shinkansen trains but also be able to accommodate tourists because the Kyushu region is dependent on tourism; (2) the companies had to produce small lots because

the Kyushu Shinkansen railway was only partially opened, and because the daily number of operations was lower for the Tsubame train than for other trains; (3) the use of natural materials caused technical and maintenance problems; and (4) sophisticated designs were required. These characteristics had a great influence on the production process.

Table 2 Interior decoration-related companies and the materials and characteristics of interior decorations

Product and manufacturer	Materials and characteristics
Split curtains Inoue Industry	Split curtains made by the rush ropes produced in Yatsushiro
Blinds Kyowa kogyo	Cherry tree (produced in Kagoshima) blinds like bamboo screens
Chairs (seats) Suminoe Textile	Textiles (in lapis lazuli blue, bluish green, and antique lacquer color) woven using the Nishiin brocading technique effectively and having the original patterns modeled on the antique patterns in Japan
Chairs (design and production) Suminoe Industry	Cherry tree timbers (produced in Hokkaido)
Benches, handrails, tables, and picture frames Nittax	Cherry tree timbers (produced in Kumamoto) [Timbers for benches in Persimmon tannin color, light pink, and laurel leaf color]
Gable walls and wooden sheets for sliding doors Hoxan	Camphor tree timbers (produced in Kagoshima)
Floors	PVC (thermally deformable) White sheets with Japanese traditional grid patterns

4.2.1 Technical challenges

Technical challenges were encountered by the introduction of new materials necessary to comply with the train design standards. The products to be used for the interior decorations in the Shinkansen trains are required to meet high standards such as light weight, flame resistance and incombustibility, and durability.

1) Weight reduction

Efforts were made to reduce the weight of delivered products, and suppliers were required to make such efforts for each item delivered. For example, Lonseal Corp. was required to submit its floor materials to fire resistance and anti-slip processing while under the constraint of weight reduction. Since Mr. Mitooka adopted the policy of using timbers to produce seats, Suminoe Industry also was required to further reduce the weight of its chairs, which were already lighter than those of conventional products. To satisfy this requirement, the company manufactured test products balancing the product's strength and weight. These challenges were solved by establishing a flexible system that included the effective use of knowledge accumulated in their research laboratories as well as the formation of special project teams.

2) Flame resistance and incombustibility

The companies used their own technologies to process their products in order to make them flame resistant and incombustible.

Table 3 Challenges and keys to solutions in production process

Company	Challenges	Keys to Solutions
Inoue Industry	A. Technical challenge Thinner ropes than the ordinary ones had to be developed.	- Our techniques were repeatedly improved. - We had many skillful artisans. - We had an incentive for spreading rush-made products. - We expected to receive subsequent orders.
Kyowa Kogyo	A. Technical challenge Wooden blinds for train cars had to be manufactured. B. Cost problems The wooden blinds had a minor mass-production effect.	- Our experiences in introducing our wooden blinds into train cars were effectively used in the event train operated by JR Kyushu. - Our building division's knowledge was effectively used. - The manual work permitted us to flexibly respond to the demand. - A lumbering company gave us its cooperation. - Our employees were conscious as artisans. - We were proud of our products delivered to Shinkansen Trains.
Suminoe Textile	A. Technical challenges The wear resistance of textiles had to be improved. (The wear resistance of moquette is low.) The balance between the quantity, weight and strength of threads had to be adjusted. B. Cost problem A small lot of seats was produced so that the initial production cost was relatively a little higher.	- The knowledge accumulated in related and other divisions was effectively used. - Because we had developed many products we could develop techniques for the products in use for the *Tsubame* train and make an effort in reducing the development cost.
Suminoe Industry	A. Technical challenges The weights of our products had to be decreased.(The weights of our products were decreased by using wooden material, but a further decrease in weight was required by the customer.)	- The parts that did not affect the strength of our products were removed through experiments. - Small quantities of many items could be produced for a shot period because of our flexible production lines. - Two designers were used, though one designer was usually in charge. - Our company established a back-up system. - Our experience in developing new type chairs (for the *Kamome* Series 885 train) was effectively used. - Our employees adopted their good ideas by a consensus. - We had a stable technical base (automobile division). - We expected to receive further orders.
Hoxan	B. Cost problem Our products have a small effect on mass production.	- We could supply good products because JR Kyushu insisted on the use of natural materials without concern for their nodes. - Our experiences in developing a wide range of new wooden products was used effectively. - We could make a small effort in reducing the production cost for our products in use for the *Tsubame* train because we had developed many products.
Lonseal Corp.	A. Technical challenges The characteristics of material (It was difficult to print geometric patterns on PVC sheets having a thermal deformability.) Design (A little deformation or a few stains may be very noticeable on a white floor of 20m in length with grid patterns.) Weight reduction (The values such as incombustibility, anti-stain and anti-slip had to be added to thin PVC sheets.) B. Cost problems Our products did not have any mass production effect so that the initial production cost was increased. The production cost was increased by producing a small quantity of products. The producing speed was lowered. Our products involved the copy right of a designer.	- We have established a flexible system to process the order for any quantity of products. - Our research laboratory could be effectively used to develop new products. - We were aware that these technical challenges might contribute to improving our technologies. - We were aware that these technical challenges might contribute to improving the publicity effect of our products. - We have accumulated experiences for many years. - We formed a special team for the *Tusbame* train.

3) Durability
Durability was important because the *Tsubame* train targeted tourists rather than business passengers. The interior decorations of Shinkansen trains are generally replaced after 7 to 8 years of operation. If textiles are used in interior decorations of the business trains requiring durability, these textiles may have an unreasonable influence on the service lives of the interior decorations. Moquette is generally used for the seats in railway cars. However, Suminoe Textile used textiles which are inferior to moquette in several properties such as durability, strength, and service life. Therefore, the challenge to the company was to develop the technology for improving the strength and wear resistance of textiles such as silk used for curtains. Suminoe Textile has operated a polytechnic center for research in textile technologies, and the center's knowledge was effectively used to produce the seats for the Shinkansen trains.

4) Sophisticated design
Lonseal Corp. that produced the floor sheets for the Shinkansen trains was required to adopt the Japanese traditional design of grid and dot patterns on a white sheet. However, it was very difficult for the company to paint the PVC floor material sheets white and draw the geometric grid patterns on them, because of the requirement that no stain was allowed to stick on them. A PVC sheet roll of 20 m and 140 kg may expand and shrink due to its weight and thermally deformability. Therefore, the products were repeatedly checked with decreasing production speed. Some people noted that there was a difference in the production span between Lonseal and the train manufacturer so that the floor sheet production process did not have any effect on mass production. Based on its experiences accumulated over many years, however, Lonseal's products contributed to improving their public image via their own technologies.

4.2.2 Cost problems

The companies encountered problems of increasing costs because of the new high quality products being developed and the small number of trains being produced. The rate of losses was slightly increased by producing a small quantity of products. However, the companies made efforts in reducing the production costs for their products, expecting that the product delivery effect might offset the higher producing cost. The cost reduction techniques adopted can be roughly divided into two categories: (1) Flexible production lines could respond to orders of small quantities of many items (Inoue Industry, Kyowa Kogyo, Suminoe Industry, and Lonseal Corp.) and (2) A small effort could be made in reducing production costs for the products used in the *Tsubame* train, because many new products are developed annually and because departments other than the affected ones were stable in the companies (Suminoe Textile and Hoxan).

4.2.3 Maintenance

As regards the maintenance challenge, it was supposed that the production cost might be increased by defects in the natural materials. However, the interviewees answered that "the products of high quality designs were carefully used" (JR Kyushu), and that "spare parts were stocked for maintenance, but little delivered" (Kyowa kogyo). This means that the higher quality of the interior decorations in the trains limited the rise of maintenance costs.
The representative of JR Kyushu reported that although it was very difficult to clean the white body of the "Tsubame," train, the train manufacturer had improved on this problem through the production of high quality trains and come to consider that "it was natural to maintain the

clean environment."

4.2.4 Cooperative system

In the hearing, many participants gave the same comment that "they have established a cooperative system to produce their products for the Tsubame Series 800" train. They were not only profoundly impressed with and supported JR Kyushu's and Mr. Mitooka's intentions of "providing artisan's skill," "using natural materials," and "producing the unique Shinkansen trains reflecting the local features of Kyushu 4)" but also they expected**,** with pride**,** that they would "produce the best Shinkansen trains." It can be said that the production of the high quality trains improved the employees' consciousness as "artisans" in the companies.

4.3 Delivery effects

The challenges provided by the companies were beneficial to them through delivery of a quality product. As shown in Table 4, the interviewers' answers such as "the delivery of their products to the Shinkansen trains was seen by many people as producing a great publicity effect," and "the number of customers was increased by this publicity effect" revealed that the delivery of their products had a great appeal to outsiders. In addition, their answer "their technological levels were improved" suggested that they positively appreciated the efforts made in developing new technologies and reducing their production costs.

4.4 Reactions made by local industries

After the Kyushu Shinkansen railway line was opened, various industries showed their reactions. Suminoe Textile reported that "it had given a lecture on the development of its textiles (and its physical standards) to meet the request made from the Hakata textile manufacturers in Kyushu region" and that the manufacturers had had the intention of introducing their products into the trains running in their local areas. Hoxan also reported that such requests had been made not only from the parties related to the *Tsubame* Series 800 train but also from other public facilities including the prefecture governments.

5. CONCLUSION

This research focused on the design strategy for the interior space in Shinkansen *Tsubame* Series 800 and described the challenges and solutions which were clarified by making the audio survey on the companies engaged in producing the products for use in the train.
With regard to the construction of the *Tsubame* Series 800 trains, the supplying companies were presented with many challenges. The following two solutions made a great contribution to solving these challenges:

1) The "building up experiences" were effectively used, including the continuous improvements made in technologies, the effective use of the knowledge accumulated in the departments directly involved and other departments in the companies, and the presence of their research laboratories.

2) A flexible production system was established, including accumulated experiences and knowledge mutually shared by the departments directly involved and other departments in the companies and the manual assembly processes added to the automatic production lines.

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