Evaluation of a City Snow Removal Program by Quality Function Deployment

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Abstract
In Sapporo (Japan), annual snowfall often exceeds 5 meters. Residents identified snow removal as their leading concern for the past 26 years, and their overall satisfaction with it is low despite the great sums the city spends on snow removal. Budget constraints prevent the city from raising expenditures on snow removal. Consequently, more efficient and effective removal is required if the city is to improve its residents' satisfaction. The authors considered the low satisfaction to arise from a discrepancy between snow removal service provided and that needed by the residents, i.e., the snow removal items and quality do not address user needs. We examined the application of Quality Function Deployment (QFD) to the design of snow removal that could incorporate customer perspectives. QFD, a design method extensively used in manufacturing, services and other industries, is based on the philosophy of designing a product by converting market needs into the technical aspects required for the product to meet those needs. A transportation behavior survey of businesses located in the city evaluated how businesses regard the current snow removal services. Analysis enabled us to identify snow removal items that are not provided, and certain snow removal levels of service that need to be changed. QFD successfully converted the needs of residents into items and qualities of snow removal that could be used in the design of a snow-removal program and in evaluation of the current snow removal's ability to meet resident needs.

I. INTRODUCTION

Sapporo is one of the snowiest cities of its size in the world. The capital of Hokkaido, Japan's northernmost prefecture, Sapporo often records annual snowfall in excess of 5 meters (Figure 1) (*1*).
In the three decades from 1965, the population more than doubled from 82 thousand to 1.75 million. Vehicle ownership jumped from 83 thousand vehicles in 1995 to 94 thousand vehicles in 2000 and continues to grow. However since peaking in 1997, the gross product of the city has been declining. Both local tax revenue and central government funding are expected to shrink, despite growing demands for various social services and overall growth of the city's fiscal obligations.

Despite the great sums spent on snow removal (US$15.2 billion in FY 2002 (Figure 1)), overall satisfaction with snow removal is low. Residents identified it as the leading concern for the past 26 years in the city's annual opinion poll *(2)*. Budget constraints do now allow the city to raise expenditures on snow removal toward improving overall service levels. Consequently, more efficient and effective snow removal is required if the city is to improve the residents' satisfaction.

The authors attributed the low satisfaction to a discrepancy between snow removal service and snow removal needs. We examined the feasibility of applying Quality Function Deployment (QFD) *(3)* to the design of snow removal that would incorporate the customers' perspective.

QFD is a design method extensively used in manufacturing, services and other industries. It is based on the philosophy of designing a final product by converting market needs into the technical aspects required for the product to meet those needs. Because snow removal is a service, albeit a public sector one, QFD has the potential to be applied in a manner similar to its use in evaluating private sector services.

In designing a new product, the focus is put on a specific market segment, the "expected customers." We followed that custom, focusing on "businesses" as the target market segment. A transportation behavior survey was made of businesses located in the city, to evaluate how businesses regard current snow removal services. We report our attempt to use QFD to convert the needs of residents into items and qualities of snow removal toward designing a snow-removal program and evaluating how well the current snow removal meets resident needs.

II. QFD

(1) History and Outline

After the Second World War, statistical quality control (SQC) was used extensively in the chemical industry in Japan. In that case, QC focused on the production process, because once a plant is established, the quality of its products is secured by SQC of production. From the 1960s onward, manufacturing industries represented by the automotive sector grew rapidly. New models were introduced in rapid succession, and QC shifted from SQC to total quality control (TQC).

These were the formative years of applying quality deployment (QD) to product development. Bridgestone Tire was one of many companies that attempted to use QD for this purpose. When Shigeru Mizuno and Yuji Akao published *Quality Function Deployment* in 1978, it provided a groundbreaking theoretical framework for QFD. They advocated using QFD to secure product quality at every phase of production, from the earliest stages of design through the final phases of development. Since then, many companies have been using QFD, including Mitsubishi Heavy Industries, Komatsu and Panasonic. QFD has been registered in Japan Industrial Standard (JIS 9-9025) as a recommended QC tool. Japan Science and Technology Association and Japanese Standard Association host regular educational seminars and publish textbooks and computer software on QFD. In addition, numerous private consultants host QFD seminars and publish QFD software, including dedicated software, for each business category.

In the U.S., QFD gained widespread attention when presented in *The Journal of Quality Control* in 1983. QFD has been widely used by U.S. businesses, such as 3M, Boeing, Hewlett Packard and IBM. Even the Big Three automakers selected QFD as a standard QC tool *(4)*. In the U.K., the University of Sheffield has been studying QFD. Businesses that have introduced QFD include Rover *(5)*. In Brazil, Marcio Tavares of Global Transporte Oceanico S.A. has used QFD for Environmental Strategy Management.

These examples show how widespread QFD has become. It has been established as a rational tool for product development planning in which the final product reflects customer needs. Services can be considered one such "product."

(2) Definitions

QFD is defined as the conversion of customer needs into the technical features of a product such that the product realizes customer requirements, and the systematic deployment of relationships between qualities of various

parts/phases *(3)*. Unlike SQC, data used in QFD are described as "language." (For definitions of other important QFD terms, refer to this paper's glossary.)

In Figure 2, the left triangle indicates the "customer." It is a "Deployment Diagram of Quality Requirements" that clarifies the Quality Requirements of customers based on the voices of customers (VOC). The triangle at the top indicates "technology." It is a "Deployment Diagram of Technical Elements." The Quality Table converts Quality Requirements to Technical Elements and is often called House of Quality (HOQ), from its shape.

One of the benefits of using QFD is that it provides a quality assurance system that includes the development phase of a new product, thereby reducing the development lead-time of a new product by designing it such that the quality addresses the VOC. This allows QFD users to take adequate product liability measures and to meet requirements of the ISO 9000 series and ISO 14000.

(3) QFD Procedures

Figure 2 shows a HOQ, which is a visual presentation of QFD procedures and their flow.

1) Identify the Services to be Provided

This is self-explanatory.

2) Collect VOC

Data on VOC and attributes of the customers are collected by descriptive user questionnaire or interview survey from company records, claim reports and opinions by sales personnel.

3) Develop a Scenario

Through various combinations of "WHO", "WHEN" and "WHERE," use of the product is imagined.

4) Convert VOC into Required Items

Analyze the "true requirements" of customers using a VOC breakdown, and then integrate them with each other.

5) Convert Required Items into Quality Requirements

Find a clear (unambiguous) expression of quality to describe a Required Item.

6) Deploy Quality Requirements

Break down the customer's Quality Requirements and integrate them using the KJ Method or other affinity method. Develop a Deployment Diagram of Quality Requirements.

7) Determine the Weight for Each Quality Requirement

Obtain weights by questionnaire (5-level evaluation of Quality Requirements, AHP, etc.) or by duplication of frequencies of the item in VOC. Assign them 5 or 9 weights.

8) Plan Quality Levels for Each Quality Requirement.

Select "sales points" of the new products from Quality Requirements. Set "Planning Quality Levels." Calculate the "Level-up ratio" by dividing "Planning Quality Levels" with "Current Quality Level."

9) Convert Quality Requirements into Quality Elements

Determine what technical elements satisfy the Quality Requirements of the customer (or the market).

10) Deploy Quality Elements.

Group the Quality Elements by KJ Method or other affinity method. Develop a Deployment Diagram of Quality Elements.

11) Make a Matrix of Quality Requirements vs. Quality Elements (Quality Table)

Make a matrix to convert weights of Quality Requirements to those of Quality Elements. Compare the strength of relationship between each Quality Requirement and Quality Element. Assign the strengths of the relationships between each Quality Requirement and Quality Element with double circle (strength of 5), single circle (strength of 3), triangle (strength of 1), or nothing (strength of 0).

12) Check the Quality Table

Determine whether there are any Quality Requirements that have no corresponding Quality Element.

12) Convert the Weights of Quality Requirements into the Weights of Quality Elements
The weights given to Quality Requirements in 7) above are converted to the weights of Quality Elements and are shown at the bottom of the table.

III. QFD OF A CITY'S SNOW REMOVAL PROGRAM

(1) Survey Outline

In collecting VOC data, we focused on the transportation behavior of businesses, because they are central to the economic well being of the community.

A Winter Transportation Behavior Survey was given to the person in each business who is responsible for traveling to the bank and to the client to collect money and make payments. The survey day was Feb. 25, 2004 (Thursday). Such personnel were selected because in Japan, the 25th is second-busiest day of the month (after the last day of the month) for personnel in charge of money matters, so their transportation behavior is expected to remain largely unchanged from season to season, and because every business has such personnel.

Questionnaires (Figure 3) were posted (45 questionnaires) or handed out (568 questionnaires) to businesses in Sapporo from Feb. 20 to 23, 2004. Respondents numbered 259, for a response rate of 45.6% (Table 2).

(2) Collection of VOC

The survey asked the respondents to record their transportation behavior on a trip-by-trip basis. A trip that took longer on the survey date than in summer was said to incur a "winter delay." Respondents who reported such delay were asked to write down the reasons, which were used as the VOC.

Our previous winter transportation survey of businesses (2002) clarified that "efficiency reduction of business activities due to winter delay" is the second most problematic winter traffic issue for businesses, after "increased danger of traffic accident." Therefore, we selected "reasons for winter delay" as the key in identifying winter traffic issues. The written reasons for delay on each delayed trip were taken as the winter traffic problems. Our survey's VOC is "reasons for delay," Required Items are "conditions required to prevent the delay," and Quality Requirements are quality-related expressions of those items.

The frequency of duplication in VOC for each "reason for delay" was calculated on a trip-by-trip basis to obtain the weight of each item. Respondents reported making a total of 777 trips. Of these, there were complete responses for 705 trips. Winter delay occurred on 348 trips (49.4%). Reasons for delay were written for 302 trips, for which weights of Required Items were calculated. Figure 4 shows the numbers and percentages of trips for which winter delay occurred by transportation mode.

(3) QFD Procedure for Snow Removal

Figure 5 (a) is the flow of QFD conducted for snow removal in this study. The procedure follows the general procedure for services described above. Figure 5 (b) also shows phases of QFD corresponding to the numbers in the following process. In this paper we used QFD software developed by Shindo et al. *(6)*.

1) Identify the Services to be Provided
The service to be provided is "snow removal that secures the traffic flow of vehicles and people in the city."

2) Collecting VOC from Road Users
Data were collected in the Winter Transportation Behavior Survey conducted on Feb. 25, 2004. Respondents' notes on "reasons for winter delay" were used as VOC. Therefore, in our survey, the WHO is the person in charge of money matter, the WHERE is a road in Sapporo, and the WHEN is the time specified on the survey sheet on Feb. 25, 2004.

3) Develop a Scenario
The collected VOCs consist of every reason for winter delay. They should be read as reasons for the trip taking longer on the winter survey date than in summer. Many of the notes were not complete sentences. To understand the circumstances of a delayed trip, weather data and snow removal data on Feb. 23, 24 and 25 were collected. The written notes were analyzed using keywords to indicate each "reason for delay."

4) Convert VOC into Required Items of Snow Removal
Using the keyword analysis, "road conditions under which winter delay occurred" were identified (Figure 6). Required Items are the road conditions that caused the delay, as given in the "reasons for delay" (Figure 7).

5*) Convert Required Items into Quality Requirements*
Quality Requirements are defined as road conditions that would prevent delay, each corresponding to a "reason for delay" (Figure 8). Quality Requirements were selected by transportation mode and then combined.

6) Deploy Quality Requirements
All the Quality Requirement items were used.

7) Find the Weight for Each Quality Requirement
Frequency was calculated for each of the reasons for delay given in VOC (Figure 9). The weights were given in 8 levels at increments of 5%. Because there were many items under 5%, an additional category of less than 2.5% was set to make 9 levels in total (Figure 10). Weights were given to Quality Requirements in 9 levels in the "Weights of Quality Requirements" of the Quality Planning Table (Figure 10). "Taken-for-Granted" Quality was examined. These were taken for granted: absence of rutting, adequate road surface friction, absence of newly fallen snow on roads, and sufficient road width. The weights for Quality Requirements related to these were set two levels higher than those of the frequency-based calculation.

8) Plan Quality Levels (LOS for Winter Road) for Each Quality Requirement
In completing the Quality Planning Table, values for "the city's current levels" were given based on the snow removal expenditures for Fiscal 2002. For some Quality Requirements, there is no corresponding snow removal provided by the city. In such case, we assigned a value of 1 to "the city's current level," because a value of 0 would prevent further calculation. No comparative analysis was made.

Based on conventional policies of the city, "securing road width," "maintaining adequate road surface friction," and "completing the removal of freshly fallen snow from roads" were selected as Sales Points and the Quality Planning Table was completed. In the table, a double circle indicates that the weight should be multiplied by 1.5 and a single circle indicates it should be multiplied by 1.3. Based on the survey, a double circle was given to "securing punctual operation of the mass transit system," and a single circle was given to "addressing increased traffic needs."

Planning Quality Levels were given. "Reduction in number of lanes" and "insufficient road width" had high weights among VOC. This suggests reduced traffic capacity. Improving traffic capacity at intersections is more efficient in improving overall traffic capacity than is increasing the road width, because the former entails less snow removal amount. For road width-related and intersection-related Quality Requirements, we set Planning Quality Levels one to two levels higher than "the city's current levels".

9) Convert Quality Requirements into Quality Elements
The engineering aspects that satisfy the Quality Requirements specified by the road users were selected as Quality Elements (Figure 11(a)).

10) Deploy Quality Elements
All the Quality Elements selected were used in this study.

11) Mak a Matrix of Quality Requirements vs. Quality Elements (Quality Table)
A matrix was made for converting "road user needs" into "snow removal items"(Figure 11(b)). The strengths of the relationships between each Quality Requirement and Quality Element were given by double circle (strength of 5), single circle (strength of 3), triangle (strength of 1), or no mark (strength of 0). City government officials who had experience working in snow removal divisions assisted in rating the relationships.

12) Check the Quality Table
Absence of a Quality Element that satisfies the Quality Requirements indicates that current snow removal by the city does not address the road users' Quality Requirements.

13) Convert the Weights of Quality Requirements to the Weights of Quality Elements
The weights given to Quality Requirements in 7) above were converted to the weights of Quality Elements, and they are at the bottom of the table (Figure 11). The calculated weights of Quality Elements were compared to the state of snow removal by the city government to see how well they corresponded. Little or no difference indicates fulfillment of road users' requirements.

(4) Weather and Road Conditions on the Survey Day, and "Taken-for-Granted" Quality

1) Absence of Deep Freshly Fallen Snow or Slush on Arterial Roads

a) Weather data
There was heavy snowfall (max. 30 cm) on Feb. 23, two days before the survey. On Feb. 24, some parts of the city received over 10 cm of snowfall early in the morning. Because the city is big enough for snowfall to vary by location, road conditions also varied. On the survey day (Feb. 25), rising temperatures and rainfall were forecasted, and the temperature reached 5℃.

b) Snow removal records
Road conditions were estimated from snow removal records. Because the snowfall on Feb. 24 was in the early morning, removal of fresh snow had not been completed on some road sections by the morning rush hour. A comparison of fresh snow removal lengths of arterial roads on the 24th and 25th in wards that had snowfall on the 24th and the lengths of arterial roads in those wards shows that much of the arterial road length was not plowed on the 24th or 25th. We can attribute this lack of plowing to the high forecasted temperature. The VOC suggests that some road sections had much snow.

c) "Taken-for-Granted" Quality
The current city snow removal standards require that compacted snow on arterial roads be kept to less than 5 cm depth. In our survey, a high percentage of respondents (36.8%) reported snow on roadways as a problem. This indicates that road users in Sapporo expect deep fresh snow to be completely cleared from the roadway, i.e., "absence of deep freshly fallen snow on the roadway" is a "Taken-for-Granted" Quality.

2) Rutting and Unevenness
No respondent identified rutting as a problem. This is attributed to the compacted snow on roadways not being deep enough for ruts to form. However, many did identify considerable unevenness in the road surface as a problem. Before tires studded with metal pins were banned in the city, rutting made winter driving very difficult on all categories of road. Since then, the absence of rutting has become a "Taken-for-Granted" Quality. On the survey day, rutting was indeed absent.

(5) VOC Not Addressed by Current Snow-Removal Policy
The Quality Requirements of road users for winter roads that are not addressed by the current policy are regarded as the "mismatch" between the needs of customers (or residents) and the snow removal provided by the city. Mismatch means the lack of a Quality Element corresponding to a Quality Requirement, i.e., the absence of a double-circle, circle or triangle for such Quality Requirements in the Quality Table. In this way, QFD evaluates whether current snow removal policy addresses all needs of road users, and identifies any needs that are not being addressed. The following are road user needs that were identified as not being addressed.

1) Slush Removal on Sidewalks

2) Snow Removal Standards Tailored to Expected Traffic Volumes
The 25th is the second-busiest day for businesses, but the snow removal standard on such days is the same as on other days including holidays and weekends.)

3) Effective Measures against Parking and Stopping at the Roadside
2.6% percentage of respondents pointed out that there are road sections narrowed by snow left on the roadway as a result of vehicles having parked on the road during nighttime snow removal. Identifying such narrowed road sections is effective in increasing the traffic capacity without greatly increasing the volume of snow to be hauled. Although the city has an ordinance prohibiting such parking, it is largely unenforced. A more effective measure, such as public awareness raising, should be considered.

4) Reserving Space for Loading and Unloading of Merchandise

5) Higher Snow Removal LOS for Streetcar Routes and Bus Routes
City policy places high emphasis on maintaining the road width on bus routes through narrow roads. However, such efforts are not enough, and the road width of streetcar routes is not maintained.

(6) Survey Results
The following were pointed out as requirements by businesses on Feb. 25, 2004.

1) Improved Trip Efficiency in Winter for All Modes

Trips made by businesses use various modes: not only company vehicles, but also public transit. Private transportation necessitates walking as part of the trip. Thus, snow removal programs should address the needs of mass transit users, especially bus and streetcar riders, and those of pedestrians. VOC identified such user needs. Bus and streetcar routes require a high LOS. Efficient operation of buses and streetcars encourages ridership, promoting better traffic conditions through traffic reduction.

2) Improved Intersection Traffic Capacity Rather Than Securing of the Effective Road Width
Many respondents pointed out that reduced road width caused them a delay. In terms of engineering road design, traffic capacity can be efficiently increased by improving the intersection capacity. Snow removal standards in Finland and Norway require that snow piles at intersection corners be removed within one day of formation. Removing snow piles from intersections appears to be effective in maintaining capacity, but it is not carried out by Sapporo. Additional necessary measures are maintaining right- and left-turn lanes so as to secure the flow of vehicles that are not turning, use of a phase-separation signal between pedestrians and vehicles to keep left-turning vehicles from being blocked by pedestrians, and other measures to improve intersection capacity.

3) Lack of Snow Hauling on Residential Roads on Busy Days
Businesses are located not only in the CBD but throughout the city. Four respondents pointed out that their trip was delayed by snow hauling. Snow removal records show that 199,000 m^3 of snow was hauled from residential roads on the survey day, versus 36,000 m^3 hauled on the 23rd. It does not cost the city anything to forgo snow hauling on the 25th and the last day of the month. Thus, consideration should be given to this need by businesses.

IV. CONCLUSION

This research found benefits of applying QFD to snow removal in Sapporo.

1) VOC collected in the QFD procedure from "language" data revealed road user needs that were unknown to the road administrator. The importance of such needs could be calculated from the frequencies at which certain expressions appeared.
2) QFD allows the items and qualities of snow removal to be designed in a way that addresses user needs. Snow removal policy can be evaluated by comparing the importance placed on snow removal items under the current policies versus those determined by QFD.

QFD identified issues that are not addressed by current policy, despite customer requirements regarding such issues. However, QFD did not clarify the Planning Quality Levels or target values of quality requirements. These can be estimated based on QFD participants' opinions. For higher accuracy, other tools, such as analysis of experimental design, is needed. Nevertheless, QFD can be used to evaluate current government services and policies from the customer's perspective, and it is a useful tool for the design of user-oriented snow-removal programs and other public services.

Our future study will aim to use other phases of QFD for snow removal, and to develop methods that effectively apply QFD to other public services.

QFD GLOSSARY

Quality Function Deployment (QFD): Includes Quality Deployment (QD) and Job Function Deployment (JFD). In the strict sense, JFD is also regarded as QFD. This study follows the JIS practice of referring to QFD as JFD. QFD is used to clarify the qualities required of products and services, and to construct a system to achieve such qualities.

Quality Deployment (QD): Used to clarify the qualities of products and services required by customers. This in turn, clarifies the production items that require special attention.

Job Function Deployment (JFD): Used to clarify systems in which qualities that have been identified by QD are secured in product planning, product design, procurement, process planning, process control planning, etc.

Voice of Customer (VOC): Obtained by survey of customers or observation of customer behavior. It is qualitative data. It is not possible to obtain quantitative data directly.

Required Items: Requirements of products/services obtained from Voice of Customer.

Quality Requirements: Those Required Items that relate to quality.

Quality Elements: Technology terms that express the customer's quality requirements.

Measurable Quality Elements: Those Quality Elements that can be expressed in measurable units.

Quality Table: A matrix of Quality Requirements and Quality Elements. The customer's perceptions are converted into technological aspects. Also called House of Quality, because of the shape of the table.

Deployment: A term that in QFD can mean either a breakdown of abstract demands of customers, or use of a conversion matrix (e.g., converting quality requirement weights to quality element weights). In JIS, use of such a conversion matrix is called "conversion."

"Taken-for-Granted" Quality: Quality Items of conventional products/services so fundamental that they are expected to be achieved as a matter of course. For example, it is assumed that the foundation of a prefab house must be solid. All customers expect this, even though they might not explicitly specify it. If "Taken-for-Granted Quality is not satisfied, dissatisfaction can be great.

Planning Quality Levels: Target values of Quality Requirements

REFERENCES

REFERENCES
1. Website of The City of Sapporo at "http://www.city.sapporo.jp/kensetsu/yuki/" (partly in English)
2. "FY 2003 Opinion Survey", City of Sapporo, 2004 (in Japanese)
3. "Quality Function Deployment (1) & (2) ", Tadasjo Ofuji, Michiteru Ono, Yuji Akao, Nikkagiken Publishing, 1997 (in Japanese)
4. Website of QFD Institute at "http://www.qfdi.org/"
5. Website of University of Sheffield at "http://www.shef.ac.uk/~ibberson/qfd.html"
6. Shindo, et.al., "Statistical Problem Solving", Nikkagiken Publishing, 2001(in Japanese)

List of tables and figures

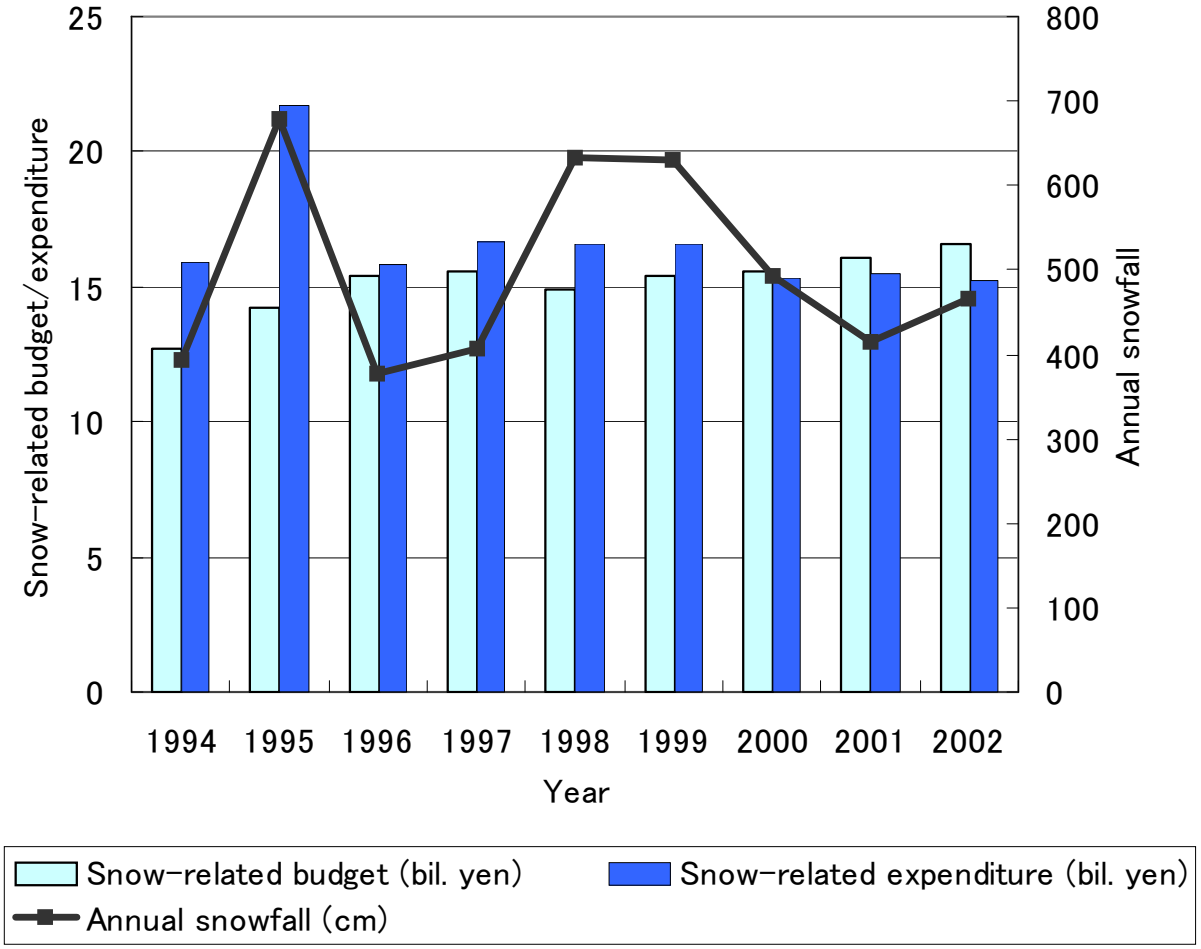


FIGURE 1 Snow and ice control outlays and annual snowfall.

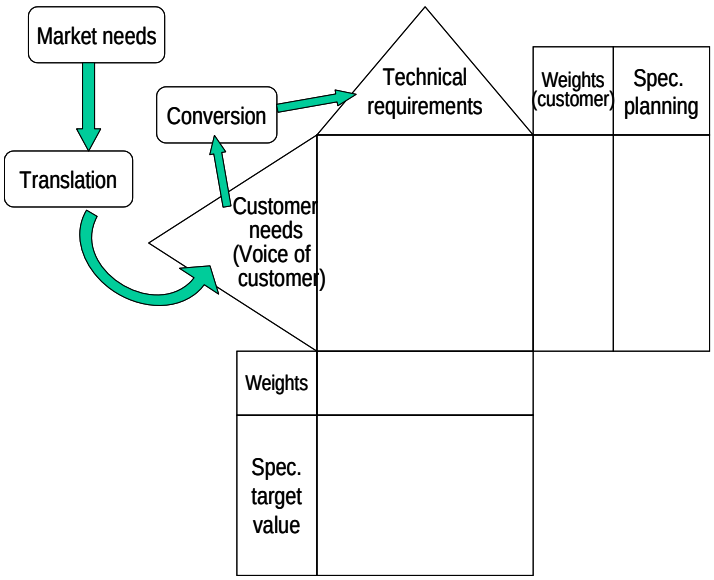


FIGURE 2 (a) Visual presentation of QFD.

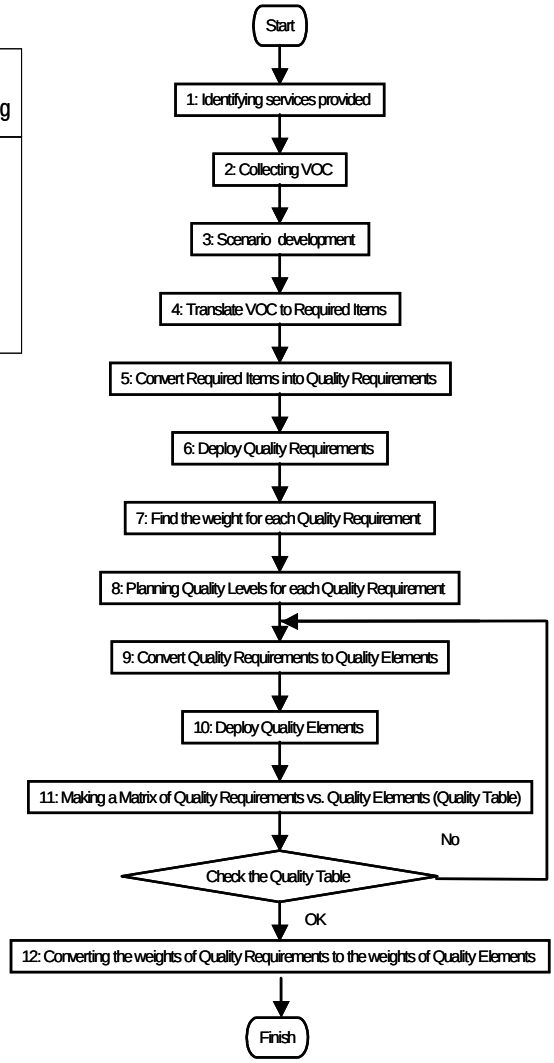


FIGURE 2 (b) Flow of QFD.

FIGURE 2 Visual presentation and flow of QFD procedures.

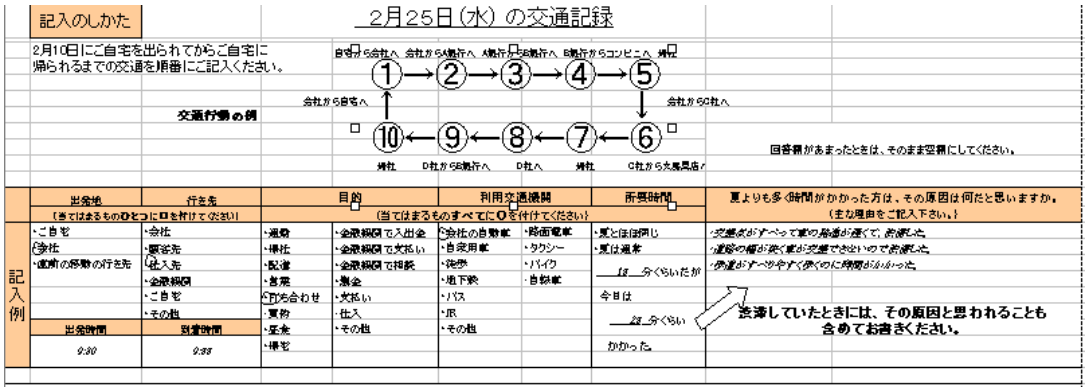


FIGURE 3 Questionnaires.

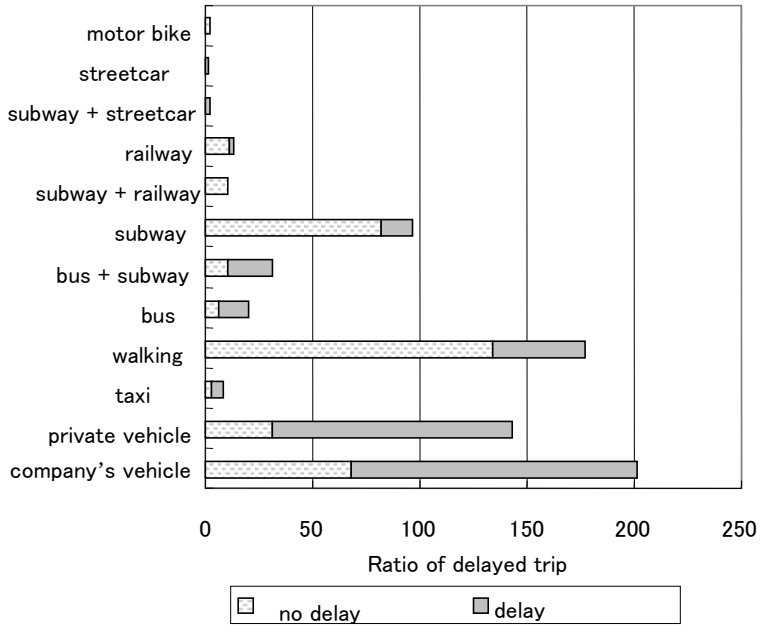
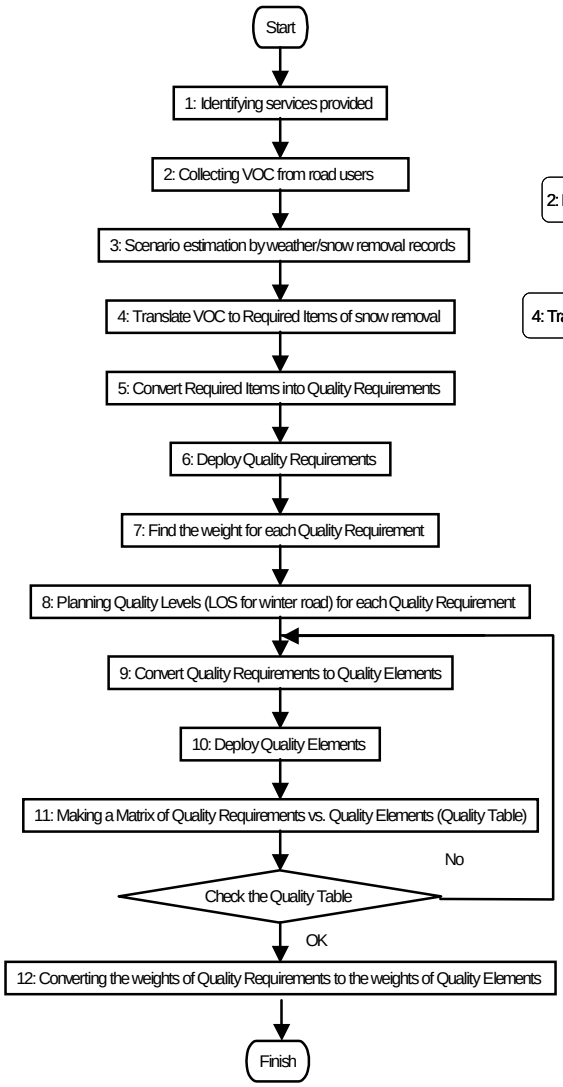


FIGURE 4 Percentages of winter delay by transportation mode.



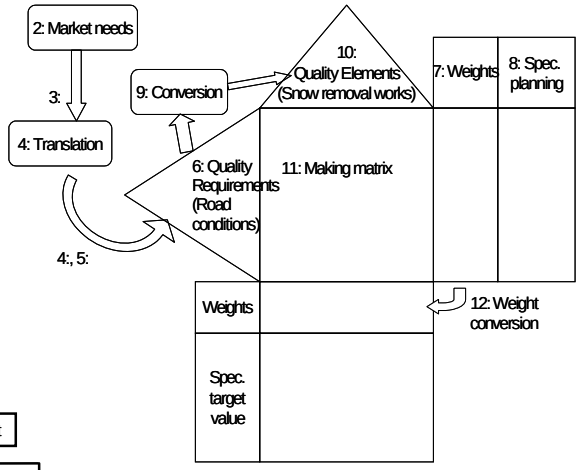


FIGURE 5 (b) Phases of QFD conducted for snow removal.

FIGURE 5 (a) Flow of QFD conducted for snow removal.

FIGURE 5 Phases and flow of QFD conducted for snow removal.

Required Items	Increased traffic	Congestion in CBD	Parking vehicles on roadsides	Improper width	Reduced No. of lanes	Snow piles	Narrowed road sections	Hard to pass each other	Slippery intersections	No dedicated lanes for right/left turn	Snow and ice on road	Remaining snow after plowing	Slush	Unevenness	Slippery road	Snow hauling operation	Reduced visibility	Crowded parking lots	Delay of bus/streetcar	Intersections and roadsides hard to	Snow on side walks	Slush on side walks	Slippery side walks	Water pools
No. of trips	34	6	13	98	31	10	9	14	5	10	128	73	4	4	65	3	2	2	40	2	23	7	20	3
Ratio over total trips	4.8	0.9	1.8	13.9	4.4	1.4	1.3	2.0	0.7	1.4	18.2	10.4	0.6	0.6	9.2	0.4	0.3	0.3	33.0	0.3	3.3	1.0	2.8	0.4
Ratio over delayed trips	9.8	1.7	3.7	28.2	8.9	2.9	2.6	4.0	1.4	2.9	36.8	21.0	1.1	1.1	18.7	0.9	0.6	0.6	11.5	0.6	6.6	2.0	5.7	0.9
Ranking	6	16	11	2	7	13	14	10	17	12	1	3	18	18	4	19	20	20	5	20	8	15	9	18
Weight	3	1	2	7	3	2	2	2	1	2	9	6	1	1	5	1	1	1	4	1	3	1	2	1
"Taken-for-Granted" Quality				○								○		○	○									

FIGURE 6 VOC by keyword analysis.

Required Items

1. Road capacity insufficient to accommodate increased traffic on busy days
2. Smooth flow of traffic in the CBD
3. Vehicles parked that hinder traffic flow
4. Inadequate road width
5. In adequate number of lanes
6. Reduced sight visibility
7. Existence of road sections narrowed by snow remaining after plowing
8. Insufficient width of narrow roads that vehicles can pass by each other
9. Intersections at which it is not easy to stop and start
10. Intersections where vehicles are hindered from going straight
11. Driving hindrance by snow on the road
12. Incomplete removal of freshly fallen snow on roads
13. Slush on roadways
14. Rutting and great unevenness
15. Inadequate surface friction
16. No consideration for snow-hauling timing
17. Reduced visibility on roads during snowfall
18. Delayed operation of mass transport
19. Sufficient information on parking not available
20. Walkability not achieved at intersections and on roadways
21. Newly fallen snow on sidewalks
22. Slush on sidewalks
23. Inadequate friction on sidewalks
24. Pooled water at roadsides and intersections

FIGURE 7 Required Items

Quality Requirements

1. Addressing increased traffic needs
2. Smoothing traffic flow in the CBD
3. Eliminating vehicles parked such as to hinder traffic flow
4. Securing road width
5. Securing necessary numbers of lanes
6. Securing sight visibility
7. Ensuring that snow remaining after plowing does not narrow any road sections
8. Securing two-way road width at narrow road sections
9. Stopping and starting easily at intersections
10. Ensuring vehicles are not hindered from going straight at intersections
11. Ensuring that driving is not hindered by snow and ice on roadway
12. Completing the plowing of freshly fallen snow on roadways
13. Completing the removal of slush from roadways
14. Securing road surfaces that are neither rutted nor greatly uneven
15. Maintaining adequate road surface friction
16. Conducting snow hauling only during hours in which companies are not busy
17. Securing visibility even during snowfall
18. Securing punctual operations of the mass transport system
19. Providing information on vacant parking lots
20. Maintaining walkability at intersections and roadsides
21. Completing the removal of freshly fallen snow from sidewalks
22. Eliminating slush and melted snow on sidewalks
23. Maintaining adequate sidewalk surface friction
24. Ensuring that water does not pool at intersections or on roadways

FIGURE 8 Quality Requirements

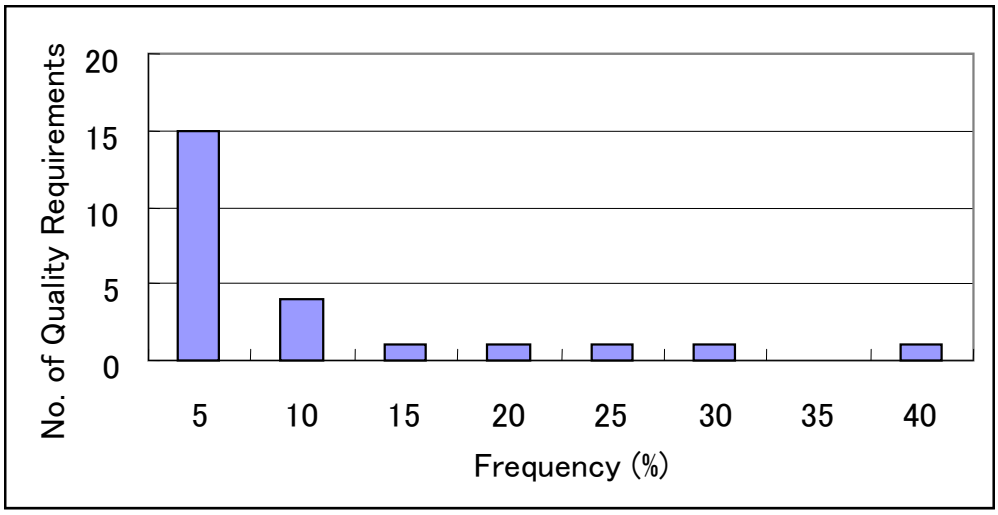


FIGURE 9 Duplication of frequency in VOC.

		Weight	比較分析 Comparative analysis	自社 Current quality levels	他社	X社	Y社	Z社	企画	Planning Quality levels	Level up ratio	(1.x)		Absolute weight	Relative weight (%)
1. Addressing increase	1	3		1						3	3.0	○		10.8	8.2
2. Smoothing traffic flc	2	1		2						2	1.0			1.0	0.8
3. Eliminating vehicles	3	2		1						3	3.0			6.0	4.6
4. Securing road width	4	7		6						7	1.2	◎		12.3	9.3
5. Securing necessary	5	3		3						4	1.3			4.0	3.1
6. Securing sight visib	6	2		3						3	1.0			2.0	1.5
7. Ensuring that snow	7	2		2						3	1.5			3.0	2.3
8. Securing two-way rc	8	2		2						3	1.5			3.0	2.3
9. Stopping and startin	9	1		5						6	1.2			1.2	0.9
10. Ensuring vehicles a	10	2		3						3	1.0			2.0	1.5
11. Ensuring that drivin	11	9		4						4	1.0			9.0	6.9
12. Completing the plov	12	8		3						4	1.3	◎		16.0	12.2
13. Completing the rem	13	1		2						2	1.0			1.0	0.8
14. Securing road surfa	14	3		5						8	1.6	◎		7.2	5.5
15. Maintaining adequat	15	7		4						8	2.0	◎		21.0	16.0
16. Conducting snow ha	16	1		1						2	2.0	○		2.4	1.8
17. Securing visibility e	17	1		2						1	0.5			0.5	0.4
18. Securing punctual o	18	4		3						8	2.7	◎		16.0	12.2
19. Providing informatic	19	1		2						2	1.0			1.0	0.8
20. Maintaining walkabi	20	1		3						5	1.7			1.7	1.3
21. Completing the rem	21	3		4						5	1.3			3.8	2.9
22. Eliminating slush ar	22	1		1						2	2.0			2.0	1.5
23. Maintaining adequat	23	2		3						5	1.7			3.3	2.5
24. Ensuring that water	24	1		2						2	1.0			1.0	0.8

FIGURE 10 Quality Planning Table.

FIGURE 11 (a) Quality Elements

要求品質 \ 品質要素		1 Width	2 Friction & rutting, unevenness	3 Traffic info. provision	4 Pedestrian envirionment	5 Safe and smooth intersection traffic	6 Measures against roadside parking vehicles	7 Timing and site of snow removal operation	重要度 Absolute weight	ウェイト (%) Weight (%)
1. Addressing increased traffic needs	1	◎		△		○		◎	3.0	8.2
2. Smoothing traffic flow in the CBD	2	◎	◎	○		◎	◎		1.0	0.8
3. Eliminating vehicles parked such as to hinder traffic flow	3	△			△		◎	○	2.0	4.6
4. Securing road width	4	◎				◎	△		7.0	9.3
5. Securing necessary numbers of lanes	5	◎				◎	△		3.0	3.1
6. Securing sight visibility	6	◎			△				2.0	1.5
7. Ensuring that snow remaining after plowing does not narrow any road sections	7	◎			○	○	○		2.0	2.3
8. Securing two-way road width at narrow road sections	8	◎	○		△	○			2.0	2.3
9. Stopping and starting easily at intersections	9	○	◎			◎			1.0	0.9
10. Ensuring vehicles are not hindered from going straight at intersections	10	◎	◎			○			2.0	1.5
11. Ensuring that driving is not hindered by snow and ice on roadway	11	○	◎			○			9.0	6.9
12. Completing the plowing of freshly fallen snow on roadways	12	○	○		○	△			8.0	12.2
13. Completing the removal of slush from roadways	13		○		○	△			1.0	0.8
14. Securing road surfaces that are neither rutted nor greatly uneven	14		◎		△	○			3.0	5.5
15. Maintaining adequate road surface friction	15		◎		◎	◎			7.0	16.0
16. Conducting snow hauling only during hours in which companies are not busy	16	○		△			△	◎	1.0	1.8
17. Securing visibility even during snowfall	17			◎		△			1.0	0.4
18. Securing punctual operations of the mass transport system	18	◎	◎	△		◎	○		4.0	12.2
19. Providing information on vacant parking lots	19			◎			○		1.0	0.8
20. Maintaining walkability at intersections and roadsides	20	△	◎		◎	○	△		1.0	1.3
21. Completing the removal of freshly fallen snow from sidewalks	21	○	○		◎	△			3.0	2.9
22. Eliminating slush and melted snow on sidewalks	22		○		◎	△			1.0	1.5
23. Maintaining adequate sidewalk surface friction	23		◎		◎	○			2.0	2.5
24. Ensuring that water does not pool at intersections or on roadways	24				◎	◎			1.0	0.8
重要度 Absolute weight		16.7	16.3	1.8	9.8	17.3	4.0	2.2		
ウェイト (%) Weight (%)		22.4	23.3	2.4	14.5	25.5	6.9	5.0		

FIGURE 11 (b) Quality Table (Matrix of Quality Requirements vs. Quality Elements.)

FIGURE 11 Quality Elements and Quality Table.ss