

## EXTRACTION OF COGNITION RESULTS OF TRAVEL ROUTES FROM OPEN-ENDED QUESTIONNAIRE TEXTS

Kazutaka TAKAO

Doctoral Student

Graduate School of Science & Technology  
Kobe University

1-1 Rokkodai-cho, Nada-ku, Kobe,  
657-8501 Japan

Fax: +81-78-803-6360

E-mail: 003d912n@y02.kobe-u.ac.jp

Yasuo ASAKURA

Professor

Graduate School of Science & Technology  
Kobe University

1-1 Rokkodai-cho, Nada-ku, Kobe,  
657-8501 Japan

Fax: +81-78-803-6208

E-mail: asakura@kobe-u.ac.jp

**Abstract:** We are studying to model route choice behaviour with words because travelers' psychological states are observed directly and clearly by words from a bottom-up viewpoint. Route choice behaviour is expressed in two stages: "recognize" and "choose" stages. Their thinking processes are clearly described by placing "cognition results" between the two stages. Cognition results are their impressions and feelings of each travel route. This paper shows a method that extracts cognition results out of open-ended questionnaire texts. Once we collect the linguistic knowledge, cognition results can be extracted from texts even if they are unseen. Not only simply extracting words that express cognition results, the extraction of denial is also reported to interpret properly as cognition results. Finally, an experiment on the extraction of cognition results from unseen texts is reported.

**Key Words:** route choice behaviour, words, open-ended questionnaire, elimination-by-aspects, bottom-up viewpoint

### 1. INTRODUCTION

#### 1.1 Background

One of the major topics of travel engineering in Japan has been to meet the traffic demand quantitatively which is increasing with the rapid development of the economy. Accordingly, many of the existing studies on travel engineering have analyzed travel route choice behaviour with an economical model in order to estimate traffic demand and economical effects. These analyses are mainly done only from the viewpoint of planners, namely the top-down viewpoint. These studies are more interested in the results of travel behaviour rather than the travelers' psychological state. Many have used numerical equations to explain behaviour quantitatively, and psychological factors are often expressed with internal variables.

However, Japan has reached the same stage of the mature society as the Western countries, therefore, it is required to improve countries and cities qualitatively and attract travelers' flow. When a company develops a new product, it is important to analyze customers' consciousness, namely the bottom-up viewpoint. In the same way, it is also important for us

to analyze from the bottom-up viewpoint, that is, to observe travelers' psychological state about travel routes as much as the top-down viewpoint.

We are attempting to model travel route choice behaviour by words in order to describe thinking process of travelers. Words can handle human psychological states directly and clearly. The objective of this paper is to show a method to extract cognition results of travel routes from open-ended questionnaire texts; cognition results are the feeling and impression of travelers. We expect our approach to be applied generally rather than to terminate in a case study. Therefore, we treat this extraction as a task of information processing, especially the natural language processing (NLP). In other words, this paper shows that once we build the linguistic knowledge, we can extract cognition results from open-ended texts even if they are unseen.

Many of the top-down viewpoint studies use numerical data that can be collected with observation equipment, whereas this study handles linguistic data. Availability of handling linguistic data has the following advantages: First, linguistic resources exist widely around us that can be collected as data, for example, in conversation, meetings, Web, E-mail, etc. Second, new knowledge may be acquired because words reflect human psychological state more directly than observation equipment.

Travelers' cognition is the main theme in this study. Therefore, this paper does not mention numerical demand estimation, nor replaces it because the objective is different from it.

## **1.2 Related Studies**

Some studies have attempted to analyze human psychological states from open-ended questionnaire texts. Inui (2004) analyzed open-ended questionnaire texts about roads focusing on the classification of the intention behind answers. However, this paper focuses on the contents of cognition.

Tateishi *et al.* (2002) and Kobayashi *et al.* (2004) extracted evaluations of specific products from the large quantity of language resources that exist on the Web. They easily found language resources using product names as keywords. However, large language resources do not always exist in our study. Moreover, evaluations of cognition results are analyzed from texts as priority orders rather than their method that used a previously made dictionary.

## **2. MODELING OF TRAVEL ROUTE CHOICE BEHAVIOUR**

### **2.1 Route Choice Process**

Route choice behaviour is expressed as follows: a traveler "recognizes" the characteristics of the alternatives (i.e. travel routes) in a choice set and "chooses" one route. Therefore, route choice behaviour can be expressed as a two-stage process that places the "cognition result" between the travel route and the behaviour as shown with solid line in Figure 1. The first stage recognizes the characteristics, feelings, and impressions of each route in the

choice set, i.e., cognition results. The second stage chooses a route by evaluating cognition results. Many of the existing top-down approaches analyze the relationship between the travel route and the behaviour directly with numerical equations as shown with broken line. However, this paper places the cognition result in order to trace the thinking process.

These two stages are analyzed with open-ended questionnaire texts. The "recognize" stage is to extract the cognition results themselves of each travel route from the texts. The "choose" stage is to extract the choice strategy that is described as priority order of cognition results. This paper describes the first stage, i.e., the "recognize" stage whose objective is to extract enough cognition results to handle the travel route choosing process in the second stage. This paper introduces a process to extract cognition results from open-ended questionnaire texts.

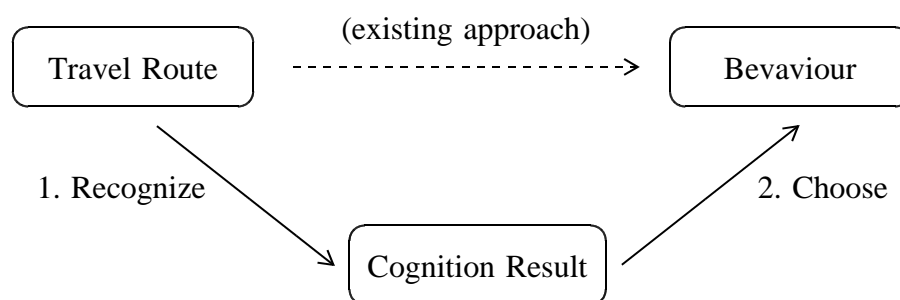


Figure 1. Route Choice Process

## 2.2 Noncompensatory Decision-Making Model EBA

Extracted cognition results are handled in the second stage. Therefore, we have to see the second stage to clarify the requirements of the first stage. The second stage is the stage of decision-making that can be expressed by noncompensatory decision-making models such as the Elimination-By-Aspects (EBA) model in Tversky (1972). Decision-making models are classified into compensatory models and noncompensatory models (see Payne (1976) for details). Compensatory models are expressed as the additive sum of score such as utility function, whereas noncompensatory models are expressed as selection of alternatives with certain attributes. Noncompensatory models are appropriate for handling the logical thinking process of each traveler and clarifying the reason of the choice unlike compensatory models that are appropriate for grasping perspective demand.

An "aspect" is a feature of a situation that appears among several alternatives, such as "bright" and "comfortable." The cognition results in our study correspond to aspects. In the EBA model, a decision is made by eliminating alternatives and judging whether each alternative includes the aspect in question. For example, when a traveler wants to choose a "comfortable" route, the routes that do not have the cognition result "comfortable" are eliminated from the choice set. If more than one route remains, the traveler considers another aspect in the next priority order. In this way, a final route is chosen by eliminating routes according to the priority order of aspects.

For example, suppose that there are three alternatives to travel between a certain OD pair and the cognition results are as follows:

Alternative 1: get wet, fast, annoying

Alternative 2: not get wet

Alternative 3: not get wet, fast, easy, expensive

If a traveler thinks "I don't want to get wet," Alternative 1 is eliminated because it gets wet. Next, if he thinks "I want to go fast," Alternative 2 is eliminated and Alternative 3 remains and is chosen.

In this way, the two stages of route choice can be expressed clearly with cognition results. Therefore, the cognition results should be extracted appropriately from open-ended questionnaire texts. Consequently, the requirements of extraction are as follows. First, cognition results should be extracted as expressions of aspects. Therefore, we have to handle the meanings of words by considering what the questionnaire texts want to say rather than simply handling the words grammatically. Second, cognition results should be categorized easily because aspects indicate the categories of the meaning of words rather than external appearance.

### **3. TRAINING AND EXTRACTION PROCESS**

#### **3.1 Training the Knowledge**

Once we collect linguistic knowledge by some texts, we can extract cognition results from other texts even if they are unseen. It is convenient to use a thesaurus-dictionary to handle unseen texts. A thesaurus is the dictionary that classifies words hierarchically according to their meaning. We used the Kadokawa New Thesaurus released by Oono and Hamanishi (1989) as a thesaurus-dictionary. The classification of a Kadokawa dictionary is indicated with semantic codes. The collection of linguistic knowledge is called "training", the texts used for training are called "training texts", and the texts that are not used for training are called "unseen texts". We also used ChaSen and CaboCha as tools for analyzing the linguistic structures of sentences.

The method of training is as follows (see Figure 2): Give the semantic code to each word by looking up the thesaurus-dictionary: for example, the Kadokawa semantic code of "irritate" is 694b <annoyance>. Besides, extract the cognition result of the sentence by hand: for example, "irritate" is the cognition result. Consequently, the knowledge of the relationship between the semantic code and cognition result is obtained: for example, the semantic code 694b <annoyance> indicates the category of a cognition result.

Then, we can extract cognition results from unseen texts automatically with the knowledge, i.e., judge which word is the cognition result. Figure 3 shows an example. First, give the semantic codes to the words in the text by looking up the thesaurus-dictionary. Note that a lot of words appear at this stage. Next, by referring to the knowledge that code 694b indicates a cognition result, we can judge "annoy" as the cognition result.

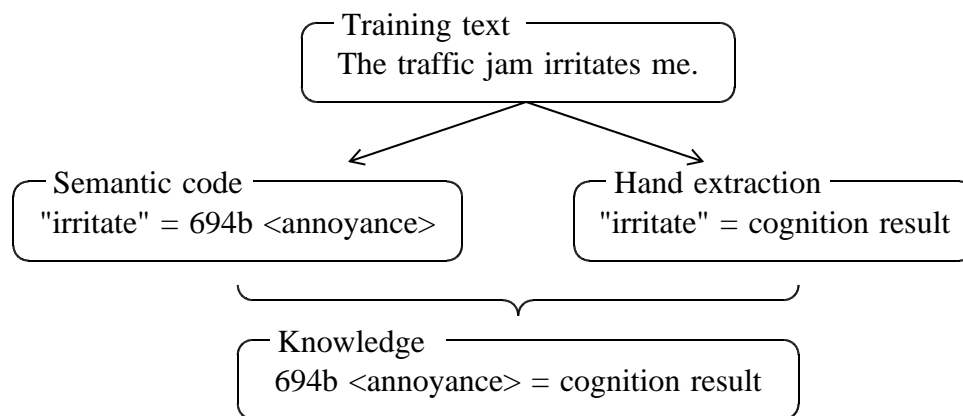


Figure 2. Training of Relationship as Knowledge

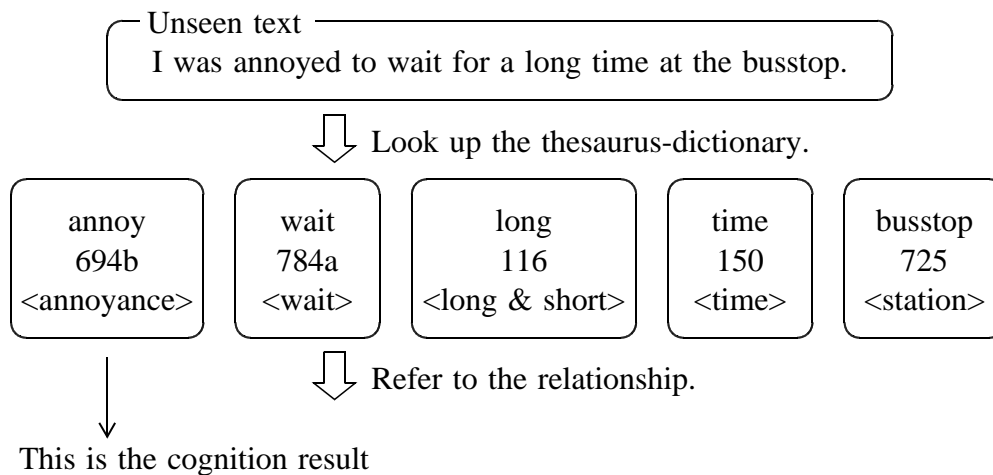


Figure 3. Extraction by Referring to the Knowledge

### 3.2 Extraction Procedure of Cognition Result

Using a thesaurus-dictionary to extract cognition results from open-ended questionnaire texts has the following advantages: First, we can use the wealth of vocabulary covered in the dictionary even if it does not appear in training texts. This is advantageous for obtaining high vocabulary coverage without collecting large amounts of training texts. Second, extracted cognition results can easily correspond to categories of the thesaurus-dictionary to be classified into aspects. However, some considerations are required for the actual extraction. The procedure of extraction is as follows:

- Step 1: Give the semantic code to each word by looking up the thesaurus-dictionary.
- Step 2: Extract cognition results using the relationship.
- Step 3: Judge the expression patterns to filter out incorrect cognition results.

- Step 4: Analyze the denial of the extracted cognition results.

We need to filter out incorrect extractions by considering the structure of sentence. Besides, not only simply extracting the cognition results, denial of them should be extracted correctly to interpret them as the aspects. Thus, we have to train the following contents:

- (a) Vocabulary knowledge for Step 1.
- (b) Relationship between the semantic codes and cognition results for Step 2.
- (c) Expression patterns to avoid extracting incorrect cognition words for Step 3.
- (d) Structures of denial onto the cognition results for Step 4.

#### **4. COLLECTION OF DATA**

Subjects are required to write actively what they feel about travel routes in this study. Many existing studies that analyze travel behaviour have used observation equipment to collect numerical data. In such cases, the data is collected automatically even if the subjects are not conscious of the collection. On the other hand, subjects are required to be active in our study. Therefore, we must realize that the amount of linguistic resources in our case is not large because of the difficulty of collection.

We conducted a questionnaire about going from a certain place to Kyoto City Hall (See Takao and Asakura (2004-a) for details). Four routes were shown as the choice set; bicycle, subway, bus, and taxi. Scenarios were presented in which such spatial conditions as season, weather, and time were different. The subjects were asked to write freely what they thought about each route and each scenario in open-ended texts. They were also asked to write their choice and the reason. This is a questionnaire about transport mode choice in the narrow meaning. However, it can be treated within the travel route choice in the wide meaning because its process is also expressed as "recognize" and "choose."

1209 valid sentences are collected. 200 sentences were separated at random as the test set for unseen texts. 1009 sentences were used for training.

#### **5. TRAINED KNOWLEDGE**

##### **5.1 Vocabulary**

###### **5.1.1 Complex Words**

One word is sometimes too short to understand as a cognition result. For example, the word "time" in the sentence "Waiting takes time." is too short to be understood as an aspect. Therefore, we allowed complex words that consist of more than one word as cognition results. Moreover, synonyms or antonyms of complex words are sometimes covered in the thesaurus-dictionary. Therefore, it is coherent to regard these complex words as cognition results just like simple words that are already covered in the thesaurus-dictionary.

Example (Japanese words are shown in italics):

Covered: *tsukareru* (tired).

Allowed: *tairyoku ga shoumou suru* (drain one's strength).

Cognition results are clarified as aspects by the allowance of complex words. However, complex words are usually not covered in a thesaurus-dictionary. Hence, we have to collect the vocabularies ourselves, i.e., from training texts. A collection of complex words means the combination of nouns, verbs, particles, etc. Therefore, many expressions have the same meaning. For example, the following words that mean "distinctness" are collected from the training texts as shown in Table 1.

Table 1. Collected Words that Mean Distinctness

	(p.: particle)
• <i>jikan</i> (time) <i>doori</i> (exactly)	
• <i>jikan</i> (time) <i>ga</i> (p.) <i>hakareru</i> (can estimate)	
• <i>jikan</i> (time) <i>ga</i> (p.) <i>yomeru</i> (readable)	
• <i>machi-jikan</i> (waiting time) <i>ga</i> (p.) <i>wakaru</i> (know)	
• <i>ryokou-jikan</i> (travel time) <i>no</i> (p.) <i>yosou</i> (expectation) <i>ga</i> (p.) <i>tate</i> (plan) <i>yasui</i> (with ease)	
• <i>shoyou-jikan</i> (required time) <i>ga</i> (p.) <i>yomeru</i> (can be read)	
• <i>shoyou-jikan</i> (required time) <i>no</i> (p.) <i>mikomi</i> (expectation) <i>ga</i> (p.) <i>tate</i> (plan) <i>yasui</i> (easy)	
• <i>touchaku-jikan</i> (arrival time) <i>ga</i> (p.) <i>keisan</i> (calculate) <i>dekiru</i> (can)	

### 5.1.2 Uncovered Words

Existing dictionaries are made for wide use, i.e., not targeted at travel behaviour. Therefore, some basic words of travel behaviour are not covered in the thesaurus-dictionary. Moreover, some colloquial words are also missing. We collected the vocabularies of uncovered words from training texts whose semantic codes were also trained by hand.

Examples:

<i>gotoobi</i> (every 5th and 10th day):	019c <days in month>
<i>doatsuudoa</i> (door-to-door):	108c <near & far place>
<i>byuun</i> (mimetic word; fast):	155a <fast>
<i>iratsuku</i> (annoying):	694b <annoyance>

### 5.1.3 Semantic Codes

In the same way, the semantic codes of some words that are already covered in the thesaurus-dictionary are inappropriate for expressing travel route choice behaviour. For example, the semantic code of "*toomawari* (roundabout)" reads 212b <progress>. However, the purport of this word is "far" when it is used for expressing travel route choice behaviour, hence code 108a <far> is appropriate.

Moreover, the semantic codes of wide meaning words should be limited into a travel route choice task in order to filter out extra noise. For example, "*sayuu*" has three meanings:

"right and left", "nearby", and "dependent". If this word is used as the meaning of "influenced by weather" the semantic code should be limited to "dependent", otherwise, such an inaccurate cognition result as "nearby" would be extracted.

#### 5.1.4 Indirect Expressions

Sometimes, cognition results do not appear directly. In everyday conversations, feeling or impression words are often hidden by common sense and tacit understandings. In this paper, indirect expressions are treated as cognition results by interpreting them with common sense into direct expressions covered in the thesaurus-dictionary and estimating those semantic codes. Some examples are shown in Table 2.

Table 2. Interpretation and Semantic Codes of Indirect Expressions

Indirect expression	Interpretation	Semantic code
<i>kyori</i> (distance) <i>ga</i> (particle) <i>nagai</i> (long)	<i>tooi</i> (far)	108a <far>
<i>nimotsu</i> (baggage) <i>ga</i> (particle) <i>heru</i> (decrease)	<i>migaru</i> (agile)	693 <easy>
<i>suwareru</i> (can sit)	<i>raku</i> (easy)	693 <easy>

#### 5.2 Relationship

The Kadokawa dictionary consists of 2814 categories. 109 categories were judged as the categories of cognition results. Table 3 shows the 10 topmost categories that appeared frequently in the training texts. Their total count of appearance and examples are also shown.

Table 3. 10 Topmost Categories of Cognition Results

Semantic code	Count	Examples
691a <unpleasant>	59	<i>taihen</i> (hard), <i>mendou</i> (troublesome), <i>uttoushii</i> (annoying)
171a <price>	58	<i>takai</i> (expensive), <i>hiyou ga kakaru</i> (cost), <i>yasui</i> (cheap)
155b <slow>	56	<i>osoi</i> (slow), <i>jikan ga kakaru</i> (time-consuming)
252a <wet>	55	<i>nureru</i> (get wet)
693 <easy>	42	<i>raku</i> (easy), <i>rakuchin</i> (easy)
166b <distinct>	42	<i>kakujitsu</i> (certain), <i>seikaku</i> (accurate)
691 <pleasant>	41	<i>kaiteki</i> (comfortable), <i>kimochi ga yoi</i> (comfortable)
146a <hot>	38	<i>atsui</i> (hot), <i>mushiatsui</i> (muggy), <i>ataakai</i> (warm)
146b <cold>	37	<i>samui</i> (cold), <i>tsumetai</i> (cold), <i>suzushii</i> (cool)
156c <early & late>	36	<i>hayai</i> (early), <i>osoi</i> (late)

#### 5.3 Expression Patterns

Incorrect cognition results would be extracted from some expressions without filtering out noises. For example, "can sit" would be extracted as a cognition result from the sentence:

"I feel anxious about traffic jams even if I can sit."

But this is wrong. The words in the expression "even if" should be ignored. In this way, we should consider the structure of sentence and judge whether a word is a cognition result or not by expression patterns. We collected 14 expression patterns from the training texts.

#### 5.4 Denial

The denial of cognition results can be expressed as a modifier of cognition result. In some cases, cognition results were denied directly:

"It is not hot" → Cognition result: "not hot"

However, in other cases, the action verb is denied, and the cognition result modifies the verb. In both cases, the extraction should be in the form of the "denial of the cognition result."

"I cannot arrive there easily" → Cognition result: "not easily"

Therefore, we treat this as the passage of the effect scope of denial, i.e., the effect of "cannot" passes the verb "arrive" and reaches to "easily". This can be considered that the effect scope of denial reaches to the first content word (adjective, adverb, and verb) and we should collect the knowledge of words that pass the denial. However, the next example shows that the effect scope of denial should stop at a certain word:

"I cannot go by bicycle in a rainy day because it is dangerous."  
→ Cognition result: "dangerous"

In this example, "cannot" only denies "go", whereas "dangerous" is not denied. The scope should be stopped at "because". Note that the original texts are written in Japanese, hence it is not convenient to judge this by the appearance of another subject "it" or another verb "is" because they are often omitted in Japanese. Consequently, we should collect the knowledge of both the words that pass the denial and the words that stop the denial:

- Effect scope of denial reaches at content word(s).
- Knowledge of content words that pass the denial is required (ex. arrive).
- Knowledge of non-content words that stop the denial is also required (ex. because).

See Takao and Asakura (2005) for details. Table 4 and Table 5 show the collected words.

Table 4. Example of Words that Pass the Denial

<i>iku</i> (go), <i>tsukamaru</i> (can catch), <i>naru</i> (become), <i>ugoku</i> (move), <i>kuru</i> (come), <i>idou</i> (move), <i>hashireru</i> (can run), <i>ikeru</i> (can go), <i>koto</i> (matter)
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Table 5. Example of Words that Stop the Denial

<i>node</i> (because), <i>tara</i> (in case), <i>ka</i> (whether)
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## 6. EXPERIMENT OF EXTRACTION FROM UNSEEN TEXTS

### 6.1 Extraction of Cognition Results

We carried out an experiment that extracted cognition results from unseen texts. 117 sentences different from training texts were selected out of the separated 200 sentences. Some sentences are the same because some cognition results are common regardless of scenario. Only different sentences were chosen for this experiment to see the availability of extraction from absolutely unseen texts. The results are as follows:

Table 6. Experiment Results (Extraction of Cognition Results, count)

Result	Count of words (cause of failure)
Success	119
Failure	
Partly extracted	9 (complex word: 9)
Extra noise	6 (expression pattern: 3, complex word: 2, semantic code: 1)
Missing	9 (complex word: 7, uncovered word: 1, other: 1)

Table 6 shows the number of extracted or missing cognition results. The causes of the failure are also shown. The recall, which indicates the rate of unmissing, is 86.9% ( $=119/(119+9+9)$ ,  $=[\text{successful extraction}]/[\text{required extraction}]$ ); the precision, which indicates the rate of unmixture of extra noises, is 88.8% ( $=119/(119+9+6)$ ,  $=[\text{successful extraction}]/[\text{actual extraction}]$ ). "Partly extracted" means that some words were extracted but they were too short to be understood as aspects, hence they were treated as failure. (We also carried out the extraction on the whole 200 sentences; the recall is 92.8% and the precision is 93.5%).

Only one failure is caused by the insufficiency of training uncovered words. Many of the unseen simple words are covered in the thesaurus-dictionary. Therefore, even if they do not appear in the training texts, cognition results have been correctly extracted by referring to the thesaurus-dictionary. This means that the proposed method of using the thesaurus-dictionary is effective. On the other hand, many of the failure are caused by the insufficiency of training complex words because these vocabularies are collected only by training texts.

### 6.2 Extraction of Denial

Table 7. Experiment Results (Extraction of Denial, count)

Total	46
Success	44
Failure	2 (missing: 2, extra: 0)

We also evaluated the extraction of the denial. We chose 46 cognition results which are extracted from the sentences with at least one denial word or whose correct cognition results are denial out of 119 successfully extracted cognition results. Table 7 shows the result. The result is with high accuracy because many sentences have the simple structure:

*xxx node yyy nai* (I do not yyy because xxx).

However, the next example terminated in failure:

*jikan-doori ni touchaku suru ka shinpai* (I am afraid whether it arrives on time).

This sentence has no denial word. However, the traveler is worrying that it does not arrive on time. Therefore, the cognition result should be "not *jikan-doori* (not on time)". The expression "*ka shinpai* (be afraid whether)" has already been trained as an expression of the denial. However, the vocabulary of "*touchaku* (arrive)" as a word that passes the denial was insufficient, causing the failure.

## 7. HOW THE COGNITION RESULTS ARE USED IN "CHOOSE" STAGE

The second stage "choose" is expressed by Elimination-By-Aspects (EBA) as described in 2.2, i.e., it is expressed as the choice strategy of aspects among alternatives in the choice set. Concretely, elimination and selection by focusing on particular aspects according to their priority order. This stage starts with the state in which the cognition results of each alternative are obtained. Cognition results correspond to aspects in using EBA. The choice strategy can be classified into three types: Positive, Negative, and Indifferent.

Positive strategy indicates that an aspect is attractive. It selects alternatives that have the aspect in question and eliminates other alternatives. For example, the following sentence expresses the positive strategy about the aspect "comfortable":

I like bicycle because it is comfortable.

Negative strategy indicates that the traveler dislikes an aspect. It eliminates alternatives that have the aspect in question and leaves other alternatives. For example, the following sentence expresses the negative strategy about the aspect "get wet":

I don't want to get wet.

Indifferent strategy indicates that an aspect is not important. For example, the following sentence expresses the indifferent strategy about the aspect "expensive":

I went there by taxi although it is expensive

The priority order of elimination or selection by aspects is expressed by tracing the appearance of aspects with judging these types. Therefore, the second stage requires the judgement of these types and the judgement of denial with correctly extracting aspects.

Finally, the process of "choose" can be expressed as shown in Table 8.

Table 8. Example of "Choose" Process

Order	Aspect	Denial	Strategy
1	comfortable	-	Positive
2	get wet	-	Negative
3	expensive	-	Indifferent
4	hot	not	Positive
...	...	...	...

## 8. CONCLUSION

We extracted cognition results of travel routes from open-ended questionnaire texts. The accomplishments of this paper are briefly summarized as follows:

- (a) Travelers' psychological states of route choice behaviour are expressed clearly with words as the two stage process: "recognize" and "choose".
- (b) We extracted cognition results of travel routes from open-ended questionnaire texts with high accuracy by collecting linguistic knowledge.
- (c) It is convenient to use a thesaurus-dictionary to extract cognition results out of unseen texts.
- (d) Complex words are also allowed as cognition results, however, the collection of them was insufficient because they are not covered in existing thesauri nor dictionaries.
- (e) The denial of cognition results are also extracted with high accuracy.

This paper has shown the extraction of cognition results. In the same way, static attributes of travel routes, such as facilities, and the dynamic conditions of travel space, such as weather, season, time, etc. can be also extracted. Thus, the causality of generating cognition results can be extracted as rules (See Takao and Asakura (2004-c) for details). For example, the following text brings the following rule, which is useful for infrastructure planners to get hints for modifying travel spaces:

Text: "It is bright at night because of the street lights."

Rule: Street light & night → bright.

The extraction of cognition results reported in this paper is also necessary for the second stage, i.e., the "choose" stage. See Takao and Asakura (2004-b) for details.

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