# EVALUATION ON FLIGHT MANAGEMENT SKILL OF JET AIRLINER PILOTS - A CASE OF GO-AROUND

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**Keywords**: *Flight Management Skill, Crew Resource Management Decision making in normal operation, Experienced captains and novice co-pilots*

## Abstract

*In this paper the "Flight Management Skill" of jet airliner pilots is discussed. "Flight Management Skill" is one of many Crew Resource Management skills and is an experience-based skill that airline pilots should manage for flight safety, for economic fuel saving expenditure, for punctual flight operation and for passenger comfort. To evaluate this experience-based skill, the authors performed experiments using a full-flight simulator. The examinees who attended the experiment included 2 experienced captains and 2 novice co-pilots. The scenario used is one in which the pilots have to make a difficult decision during normal flight, i.e. going around due to a sudden runway closure by an earthquake. The measured items were their utterance, flight path, and the amount of remaining fuel. Interviews were also conducted with the pilots after the experiments. We analyzed their decision making in the form of a timeline, using decision trees. We also analyzed the test subjects' rationale and opinions for making the decisions they did. From these results, we compare the differences in "Flight Management Skill" between experienced captains and novice co-pilots. The results indicated the following conclusions; 1) Novice co-pilots try to minimize risk as soon as possible. Experienced captains are able to evaluate risks thoroughly and try to complete the original flight plan. 2) Novice co-pilots tend to obtain all the information which is related to the situation. Conversely, experienced captains obtain only the information which is necessary. Hence, the workload placed on experienced pilots is lower than that of the novice pilots.*

## 1 Introduction

### 1.1 Background

Recent advancements in flight- automation systems have drastically decreased the amount of pilot procedures required to fly aircraft, to navigate and to communicate with the air traffic control (ATC). These procedures have become automated and simplified; therefore, pilots can manage most normal flight situations without much difficult decision making [1]. Even in a non-normal situation such as an engine fire, pilots can solve the problem by simply following a non-normal checklist without excessively increasing the pilot's workload, as long as they focus their attention only on removing the non-normal situation [2].

It is often debated that the main reason for accidents involving aircraft is human error brought upon by the crew [3]. To decrease human error, Crew Resource Management (CRM) which is a non-technical flight operation skill, has become a significant issue on the forefront of air crew training[4]. There are several studies which have been done concerning human error in non-normal situations [5][6][7]. Line Oriented Flight Training (LOFT) [8] is a tool used primarily for training pilots to manage malfunctions by applying CRM skills. Trainees attending the LOFT use a full-flight simulator and operate under highly stressful conditions in which the workload is intense as several malfunctions occur.

As for daily normal flight, there are some cases where a pilots' mental workload is increased, for example, in an unexpected alteration in flight plan due to a sudden runway closure. Herein, the airline pilots have to exercise their flight management skill to resolve the problem, taking into consideration the amount of fuel remaining, weather, air traffic and many other factors. They have to re-construct the flight plan and fabricate, manage and execute a better solution for the benefit of the following four factors:

1) Flight safety,
2) Punctual flight operation,
3) Economic fuel usage (minimizing fuel consumption by optimal air route, altitude and aircraft configurations) and
4) Passenger comfort (avoiding air turbulence and rapid maneuvering).

If private pilots were involved in such a situation, they would divert to the alternate airport immediately. In their decision making, they try to choose the best solution from the perspective of flight safety. Airline pilots, however, make a comprehensive assessment of these solutions from the perspective of above mentioned four factors. Airline pilots evaluate each solution's risks and results, and make a decision to choose the solution that fulfills not only the requirements of flight safety, but also incorporating other factors into their decision as much as possible.

There have been only a few previous studies conducted which investigate how airline pilots manage situations under the condition of having to make difficult decisions during normal flight operation. Baker *et. al*. [9] developed PC-based training tools to learn CRM skills under normal conditions. Using this tool, the scenario used was one in which the pilots had to make a difficult decision during normal flight, i.e. a medical emergency involving a passenger while en route to the destination airport. The test subjects had to make a choice of which airports to land at. In the opinions of aircrews who had participated, this study elicited the conclusion that this PC-based training tool is a positive means in which to train aircrews' CRM skills. This study [9] focused on making decisions during normal flight, however, methods to provide quantitative and effective feedback for trainee pilots have not been considered. The management skill of an airline pilot who has to consider the four factors mentioned above is perceived as being a non-quantitative experience-based skill. It can be considered that the acquisition of this management skill mostly depends on individual pilots' own experience during actual flight.

Thus, there is a considerable need to clarify this experience-based skill so that the airline companies can improve their pilot training system.

### 1.2 Definition of Flight Management Skill and Purpose of the Paper

Authors define "Flight Management Skill" as an airline pilot's competence in managing any situation independently, without reliance on other flight crew, while tending to and balancing the four management factors. Flight Management Skill is different from CRM in the following way. While Flight Management Skill includes the four management factors, its primary focus is on each pilot's decision making ability without assistance from other flight crew.

This paper's purpose is to discuss the "Flight Management Skill" of both experienced captains and novice co-pilots during normal flight. Clarifying any differences in Flight Management Skill between experienced and novice pilots will help the less experienced airline pilot enhance their Flight Management Skill.

## 2 Experimental Details

To clarify and conceptualize the differences between the experienced captain and the novice co-pilot, the authors conducted a comparative experiment using a full-flight simulator. The scenario used in this paper is as follows: While shooting a normal ILS approach with an insufficient amount of fuel remaining and with marginal weather conditions, the runway suddenly closes due to an earthquake. The examinee has to make a decision whether to hold and wait for the runway to re-open or divert to another airport.

## 2.1 Test Subjects and Equipment

Examinees who attended the test included four set crews of Pilot Flying (PF) and Pilot Not Flying (PNF). PF test subjects were 2 novice co-pilots and 2 experienced captains. As for the novice pilot subjects, 1 and 2's total flight times were about 500 hours and 1500 hours, respectively. Conversely, for experienced pilot subjects, 3 and 4's total flight times were about 7000 hours and 12000 hours, respectively. Novice co-pilots (examinees 1 and 2), had no experience as a Pilot In Command (PIC) of a transport aircraft. PNF pilots were experienced co-pilots or experienced captains. PNFs were asked not to advise PF's decision. They simply followed PF's decision and conducted standard operation procedure. A full-flight simulator of a Boeing 767, (250 passengers, 2 person crew, glass cockpit aircraft) was used for the experiments (Figure.1).

## 2.2 Scenario Settings

Details of scenario settings are as follows:

1) The scenario starts from 5 nautical miles out on final approach into HND (RJTT, Tokyo Japan) ILS Runway (RWY) 34R procedure (Figure 2). Original destination being HND, first alternate airport being NRT (RJAA, Narita Japan). Two other airports, NGO (RJGG, Nagoya Japan) and SDJ (RJSS, Sendai Japan), were considered as second alternate airports. The upper part of Table 1 shows the estimated flight times for a diversion from HND in addition to the estimated amount of fuel necessary to divert. NRT is the nearest alternate airport. NGO and SDJ are relatively far from NRT.
2) Examinees were assumed to be a PF and also be a PIC. Although a PNF performed the normal operation procedures, he was asked not to express his opinion regarding decisions made by the PF. Air traffic Control (ATC) and company radio performed just like in actual operation. However, only information requested by the examinees was offered. A pilot instructor who operates the flight simulator also worked as the ATC and as company radio.
3) At the beginning of the scenario, the amount of remaining fuel was 18,000 lbs and gross weight was 240,000 lbs. This amount of remaining fuel is appropriate for operation in fine weather conditions. However, considering bad weather, such as in this scenario (see scenario setting 5), the pilot must load much more fuel before departure in anticipation of unforeseen fuel requirements due to the weather. However, in this scenario, it was assumed that the weather suddenly became worse after the plane took off, hence the insufficient amount of remaining fuel for the present weather setting when the plane approaches the final destination at HND.
4) Table 1 shows the amount of fuel necessary to divert to the alternate airport that company radio advises to the examinees upon their request. The amount of fuel necessary to divert to the alternate airport was assumed to be constant regardless of weather and the aircraft's weight. The plane consumes about 2,000 lbs to maintain holding for 30mins.
5) The assumed weather at each airport is also shown in Table 1. HND's Runway Visual Range (RVR) is 1,200 meters and is above the prescribed RVR value for ILS approach (As for test subjects 1 and 2, the RVR was 550 meters before making a go-around and recovered to 1200 after making the go-around). However, if a glide slope is un-serviced and if the plane is forced to

shoot a localizer approach, this length of RVR 1200 meters would correspond to that which is called a "Just Minimum" condition where the plane may land or may be forced to go-around. NRT, the first alternate airport, has relatively fine weather conditions. The other alternate airports (NGO and SDJ) are in a "Ceiling and Visibility OK" (CAVOK) condition, which means there is no problem concerning weather conditions for these airports.

6) The earthquake occurs when the plane is at about the Decision Height The examinee conducts a normal missed approach procedure when the ATC instructs the plane to go-around as shown in Table 2.
   Within 10 minutes from the occurrence of the earthquake, company radio relays to the pilot examinee the following information upon request.
   - HND and NRT are in runway check for 10-15 minutes due to the earthquake.
   - NGO and SDJ are not influenced by the earthquake.
   After 10 minutes from the occurrence of the earthquake, company radio advises the examinees on following information.
   - HND and NRT will re-open soon.
   - However, HND has been damaged and Glide Slope RWY34R is not in service. Other runways at HND are also not in service.
7) There is air turbulence at a holding altitude of 3,000ft.
8) Figure 3 shows the location of the alternate airports and summarizes each airports scenario settings. Experiments finish when the examinee makes a decision where to land.

### 2.3 Measured Items

The measured items were latitude and longitude of aircraft position, altitude and the amount of remaining fuel. The utterance record of PF and PNF, and communication logs among ATC and company radio were recorded by a video camera. After the experiments, interviews were also made and examinees were asked the reasons which affected their decision during the flight, such as the remaining fuel, weather and alternate airports.

## 3 Results

### 3.1 Flight Paths

Figure 4 shows lateral flight path of examinee 1 and Figure 5 shows vertical flight record of examinee 1. Dotted marks indicate aircraft location and are colored in red every 2 minutes.

Every examinee entered in the holding pattern after the go-around and made the decision in the holding pattern. Other examinees, with the exception of examinee 1, stayed at 3,000 feet holding altitude. However, examinee 1 requested an altitude change to 5,000 feet considering air turbulence as shown in Figure 5.

### 3.2 Timelines

Through the use of the pilot's utterance record, communication logs and the amount of remaining fuel, the results were sorted out in a form of timelines (Figure 6). Figure 6a) shows results of examinee 1 together with an explanation of these timelines. The timeline of fuel remaining is shown in row i). The origin of the time coordinate starts at the time of go-around. Both the information acquired and the examinees' decision making are shown in row ii) such as weather, airport damage by the earthquake and fuel levels necessary to divert. Row iii) illustrates a list of possible airports to land at or divert to. In this row, dotted lines are airport options that examinees were taking into consideration. The solid line indicates an airport at which a particular examinee decided to land at or divert to. The beginning of these lines is defined as the time at which the examinees acquired information on each airport from company radio. The end of a line indicates the point at which an examinee expressed his intention to the PNF that he was going to exclude the options or that he decided to choose other options.

When examinee 1 (Fig.6a)) obtained earthquake information at HND and NRT, he excluded HND and NRT as possible destinations (3:15) and began to collect information for NGO and SDJ. After the company radio confirmed both NGO and SDJ were acceptable landing locations, he asked company radio "which airport is better to divert to?"(6:51) Company radio answered "It depends on your intention.", upon which he finally made the decision to divert to NGO (7:33). Row iii) illustrates that he excluded HND and NRT from his decision making process at an early stage.

Examinee 2 (Fig.6b)) obtained earthquake, weather and traffic information at HND, NRT, NGO and SDJ (4:30-6:00), then made the decision to divert to NGO because he was not certain of the extent of the damage caused to HND and NRT by the earthquake. While requesting information on the amount of fuel required for diverting, he was informed of the re-opening of HND within 5 mins (8:30). Afraid of the earthquake happening repeatedly at HND, he took this aftershock into consideration and decided to continue diverting to NGO (10:18).

Examinee 3 (Fig.6c) made the decision to hold at HND for a while after acquiring information from HND (7:15). When he was advised that HND's runway was damaged (11:32), he made the decision to divert to NGO, considering the possibility that NRT was also damaged by the earthquake(12:45). (However, he mentioned during the interview that he would have made an alternate decision considering the aircraft's position had NRT re-opened during the experiments). Row iii) illustrates that he was considering three options (HND, NRT and NGO) for a long period before making a final decision.

After obtaining runway information for HND and NRT, examinee 4 continued to hold at HND and collect information from the company radio (Fig.6d). When he was advised that HND was damaged, he made the decision to divert to NRT, maintaining an option to land at HND in the event that HND re-opened suddenly (7:47). Thereafter, he kept holding at HND waiting for NRT's re-opening. When he was advised of HND's condition being at "Just Minimum" (11:00), he excluded HND as a possibility and finally decided to divert to NRT. Row iii) illustrates that he was considering HND and NRT at the same time for a long time (2:30-11:30).

In summary, novice co-pilot examinees (1 & 2) made decisions at an early stage to divert to NGO. Conversely, experienced captain examinees (3 & 4) tried to land at HND. Row iii) in Fig.6 illustrates that novice co-pilot examinees tried to reduce the number of options they had as fast as possible and selected one airport option in a short period. Conversely, experienced captains considered several options for a long period and selected what they considered to be the best option.

### 3.3 Results of Interview

Interviews were conducted for each examinee after the experiments. The results of examinee 1's interview are summarized as follows.

Examinee 1: "First, I thought about the possibility of landing at HND or NRT for the benefit of passenger convenience. However, I considered that the amount of remaining fuel was severe, that HND's weather was at the just minimum condition and that NRT's runway was going to be closed for at least 10-15 minutes. I chose to select from NGO or SDJ where the weather was fine and we were assured a chance to land. The reason I chose NGO was passengers' accessibility to Tokyo, though I would chose SDJ if company radio had recommended it. I didn't request NRT's weather, because I thought the effect of earthquake at NRT was severe. Since company radio didn't inform me of air traffic congestion at NGO or SDJ, I thought that there would be no risk factor involved in selecting from NGO or SDJ."

Other examinees' interviews were also conducted. These results were analyzed and will be used in the following sections.

### 3.4 Decision Trees

Based on the dialogue in the timelines and interview results, decision trees were made (Figure 7). In the present scenario there are two significant periods where examinees have to make critical decisions. The first being when runway checks commenced in HND and NRT just after the earthquake (decision making point A), and the second is when HND and NRT re-opened, although some of the navigation aids at HND had been damaged (decision making point B). In bracket i) in Figure 7a), black arrows represent options which examinees considered and red ones represent the options which each examinee actually chose. Tables in Figure 7 (bracket ii)) represent the state of information acquired at each decision making period, i.e. the symbol "+" indicates information which the examinee obtained and a blank column indicates information which the examinee pilot did not obtain. Tables in bracket iii) show the details of the information in ii).

For decision making point A, these figures clearly illustrate that novice co-pilot examinees chose to divert to NGO immediately (Figs. 7a and 7b) and experienced captain examinees chose to hold at HND (Figs. 7c and 7d). One common similarity between the novice co-pilot examinees was that they did not acquire information on NRT's weather (row ii) in Figs. 7a and 7b. For examinee 1, he excluded NRT as an option because of the presumption that the effect of earthquake was considerable there, thus the lack of inquiry about the weather. For examinee 2, the miss-acquisition of NRT's weather resulted from the heavy workload as a result of requesting a lot information of every airport in a very short time from company radio. Both of the experienced captain examinees acquired all the information on HND, NRT and NGO, and didn't obtain information on SDJ as it was not necessary information for them.

For decision making point B, the results between experienced captains are different, i.e. examinee 3 chose NGO and not NRT, although the information acquired by both pilots was similar (Figs. 7c and 7d).

### 3.5 Reasons for Decision Makings

Reasons for the decisions made by the examinees were sorted out as Table 3 from the results of timelines and interviews. The symbol "+" is an item assumed as being an examinees' reason for making a particular decision. An empty column is assumed as being representative of where examinees did not consider rationale for making a decision. The slash indicates an irrelevant item not affecting an examinee's decision choices.

Among the items of I), within the "Reason" column, there are differences between the experienced captain examinees reactions concerning how they rationalized the damage of earthquake and considered the required fuel to divert.

Among items of II), for the two experienced captain examinees, the reasons for making certain decisions were analogous. When the reasons regarding the selection of decisions of novice co-pilot examinees in these items are compared to that of experienced captains, it becomes apparent that the novice co-pilot examinees considered various matters relating to the earthquake as motives for decision making. The items of IV) show that one of the novice co-pilots (examinee 2) considered matters relating to the earthquake as his primary reason for the decisions he made. Within items of V), we see that although examinee 3 thought NGO's air traffic might be heavy, examinee 1 pressumed that there was no traffic problem because the company radio did not mention anything about it.

### 3.6 Different Opinions for Decision Makings

There are several differences in opinion among the examinee subjects for why decisions were made. Table 4 indicates the different opinions regarding decision makings elucidated from the results of the timelines and interviews. The numbers in the column of each examinee, i.e. 1, 2 and 3, correspond to the classification number written on the right hand side of Table 4. Empty columns indicate unidentified items which were not distinguishable from the results of interviews or timelines. The slash sign is an irrelevant item for examinees' decision makings. The items at the lower part of Table 4 show each examinee's planning concerning remaining fuel. Item A) indicates the amount of fuel remaining when the examinees made their final decisions. Item B) indicates the amount of fuel equivalent to that consumed by the aircraft when holding for 30 minutes. According to the airline company's policy, examinees have to declare an emergency in the event that the remaining fuel becomes less than the amount of B). Item C) indicates the amount of fuel required to divert. Therefore, item D), i.e. D) = A) – B) - C), indicates auxiliary, redundant fuel for use in the event of other problematic factors arising. At the bottom of Table 4, these problematic factors that may be included within item D) are listed.

According to Table 4, the only item which differentiating experienced captain examinees 3 and 4 is the concern regarding damage to facilities at the airports. They share the same opinions for all other items. Therefore, it is suggested that experienced captains would generally share a similar pattern of thinking, as is observable through the differences and similarities in the choices made which led them to near identical results; i.e. examinee 3 held at HND then diverted to NGO and examinee 4 also held at HND but diverted to NRT.

In the items of planning pertaining to the issue of remaining fuel presented at the lower part of Table 4, the experienced captains' proposed use of redundant fuel (D)) is very clear, while the same cannot be said for the novice co-pilots. The experienced captains' intention for D) considers the uncertainty of air traffic while maintaining enough fuel for holding.

The results in the last column for HND airport listed in Table 4 can be summarized as follows: Examinee 1 changed altitude to avoid air turbulence to improve passenger comfort. Examinee 2 tried to concentrate on trouble shooting related to the earthquake to improve flight safety rather than considering passenger comfort. Examinees 3 and 4 considered the air turbulence to be within a permissible range and tried to maintain approach sequence priority without changing altitude to maintain operational punctuality and preserve fuel. The examinees all had priority to land at HND as they were the first planes forced to go-around due to the earthquake. Thus, it becomes clear that there are differences among the four factors' separating the novice co-pilot and experienced captain examinees.

## 4 Discussion

As discussed in Figures 6a and 6b, novice co-pilots are only capable of coping with a limited number of risks simultaneously. They cannot properly evaluate risks for factors they have not experienced or expected. Hence, their tendency to make decisions as soon as possible in order to minimize the risks. Conversely, experienced captains can evaluate uncertain risk factors and can determine the extent to which they can take risks to improve the punctuality of flight operation in addition to saving fuel (Figs. 6c and 6d).

Novice co-pilots consider many options at the same time and make decisions within a short time span. Experienced captains tend to consider fewer options simultaneously but consider their options longer. It is thought the reason for this difference can be derived from the fact that novice co-pilots try to develop a solution after collecting all the information, while experienced captains mentally construct a scenario to solve the problem by collecting only the information necessary. They can choose from several potential solutions being considered by setting a priority. They can change and reconstruct solutions based on priority at any time when new and more complete information is acquired. Therefore, the workload taken on by experienced captains is suppressed to a low level by avoiding extra and unnecessary information. In contrast, novice co-pilots can not formulate solutions by themselves, hence their dependency on advice obtained from the outside, and their common tendency to obtain more information than is necessary. Therefore, the workload of novice co-pilots tends to be high.

In applying the present evaluation method, the amount of data to analyze was enormous including video-recorded results in a full-flight simulator and interview results. Therefore, the number of examinees used in these experiments was limited to four. In the future, it will be necessary to develop a method in which data analysis can be done more quickly and economically, accommodating the participation of more examinees.

## 5 Conclusions

In this paper, decision making skills during normal flight operation were discussed. Flight Management Skill was defined by four factors which were taken into consideration; flight safety, fuel saving economy, punctuality of flight operation and passenger comfort. The scenario used to evaluate Flight Management Skill is one in which the pilots had to make a difficult decision while in flight. Evaluation methods employing figures and tables as visual aids were constructed.

Using these evaluation methods, the differences in Flight Management Skill of pilots with different levels of experience were made clear as summarized in the following:

1) Novice co-pilots tend to try to minimize risks as fast as possible. Conversely, experienced captains evaluate risks thoroughly and try to adhere to the original flight plan as closely as possible.
2) Experienced captains think about possible solutions before collecting information and acquire only the necessary information. In contrast, novice co-pilots consider solutions only after collecting a lot of information that may or may not be necessary, leading to a large volume of information collected and consequently, a higher workload.
3) Experienced captains have similar patterns of thinking and similar reasons for making certain decisions, in spite of the final results of the present scenario being slightly different based on contrasting situational understanding.

## Acknowledgements

The authors would like to express their gratitude to Captain Hiroshi Takahara for his advice and to the examinees who attended the experiments.

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Table 1 Scenario settings of destination/alternate airports

| Scenario settings | | HND | NRT | NGO | SDJ |
|---|---|---|---|---|---|
| Alternate airport | Approximate time to divert | / | 35min. | 50min. | 55min. |
| | Approximate amount of fuel required | / | 7,000lbs | 9,000lbs | 10,000lbs |
| Damage due to earthquake | | 10-15 min. runway check. Then, glide slope un-service and localizer approach | 10-15min. runway check | No damage | No damage |
| Weather | Wind | 340deg/10kt | 350deg/15kt | Calm | Calm |
| | Visibility | 1,200m | 5,000m | CAVOK* | CAVOK |
| | RVR | 1,200m**, *** | 5,000m | CAVOK | CAVOK |
| | Ceiling | 500ft | 1,500ft | CAVOK | CAVOK |

*Ceiling and Visibility OK: **550 meters for examinee 1 and 2 ***Just Minimum value when Glide Slope is un-service

Table 2 Scenario settings

| Timing | Instruction from ATC | Information from company radio |
|---|---|---|
| at decision height | Go Around due to earthquake | |
| Within 10 min. after Go Around | | Huge earthquake happened<br>HND and NRT are in runway check for 10-15min. |
| After 10 min from Go Around | | HND and NRT will re-open soon. NRT: No damage<br>HND: RWY34R LOC APP, other RWY un-service |
| About 15 min. after Go Around | | HND and NRT runway re-open |

Table 3 Four examinees' reasons for decision making (Ex.1 & 2: novice co-pilots, 3 & 4 experienced captains)

| Airports | Reason | Reasons for Decision Making | Ex 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|
| HND | I) The reason to hold at HND | Original destination | / | / | + | + |
| | | To maintain approach sequence priority at HND | / | / | + | + |
| | | Earthquake damage might not be severe for this earthquake scale | / | / | | + |
| | | Using radar vector, it consumes less than 7000 lbs to NRT | / | / | | + |
| | II) The reason not to try to approach HND again | Unknown whether runway will re-open or not. | + | + | | |
| | | Runway check will continue for 10-15 min. | + | | | |
| | | Possibility of aftershock (earthquakes happen repeatedly) | | + | | |
| | | Bad weather : Just Minimum condition | + | + | + | + |
| | | Severe remaining fuel | + | + | + | + |
| | | Possibility of heavy air traffic | | + | + | + |
| NRT | III) The reason to divert to NRT | Unknown whether runway will re-open or not at HND. | / | / | / | + |
| | | NRT is usually the alternate airport under normal flight circumstances | / | / | / | + |
| | | Fine weather | / | / | / | + |
| | IV) The reason not to divert to NRT | Unknown whether runway will re-open or not at NRT. | + | + | + | / |
| | | Runway check continues for 10-15 min. | + | | | / |
| | | Possibility of aftershock (earthquakes happen repeatedly) | | + | | / |
| | | Possibility of heavy air traffic at NRT (many aircraft will divert to NRT) | | + | + | / |
| | | Other aircraft diverting to NRT are also in severe remaining fuel. Possibility of priority of approach sequence at NRT and to hold long time to approach | | | + | / |
| | | Severe remaining fuel | + | + | + | / |
| NGO | V) The reason to divert to NGO | Closer than any other airport except NRT | + | + | + | / |
| | | Fine weather and no effect from earthquake. No uncertain factors to land | + | + | + | / |
| | | -: No problem regarding air traffic +: Possibility of heavy air traffic diverting from HND | - | | + | / |
| | | Length of runway is longer than SDJ | + | + | | / |

+: Examinees considered these items when they made decisions.
Blank: Examinees did not consider Slash(/): Irrelevant to examinees' decision making

Table 4 Different opinions of examinees for decision making

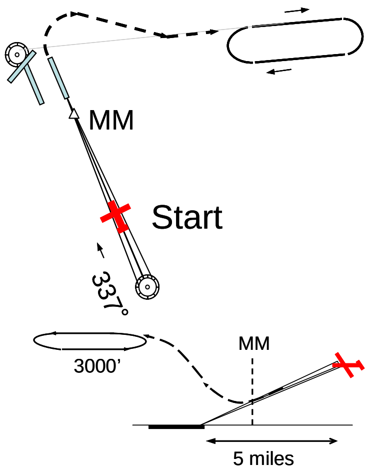
| Airports | | Ex. 1 | 2 | 3 | 4 | Opinion 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|---|
| HND | Damage of airport facilities considering the scale of earthquake | 2 | 2 | 2 | 1 | There might be no severe damage. | There might be severe damage. | |
| | After shock (earthquake happens repeatedly) | 2 | 1 | 2 | 2 | Considered | Not considered | |
| | Bad weather (Just Minimum) | 2 | 2 | 2 | 2 | Possible to try once | Uncertain enough to try | |
| | Air traffic | / | 1 | 1 | 1 | Expedite to make decision in case of heavy air traffic. | Hold at HND as long as possible | |
| | Approach sequence | 2 | 2 | 1 | 1 | Want to continue holding at HND to keep priority of approach sequence to HND | Want to divert to alternate airports as soon as possible | |
| | Air Turbulence at holding altitude | 2 | 1 | 3 | 3 | Want to concentrate on troubleshooting due to earth quake | Problematic. Request altitude change | Want to Keep approach sequence priority |
| NRT | Damage of airport facilities considering the scale of earthquake | 2 | 2 | 2 | 1 | There might be no severe damage. | There might be severe damage. | |
| | After shock (earthquake happens repeatedly) | / | 1 | 2 | 2 | Considered | Not Considered | |
| | Holding at HND until NRT re-opens completely | / | / | 1 | 1 | Holding at HND until NRT re-opens completely | Divert to NRT immediately before NRT re-opens and try to land earlier | |
| | Weather tendency | / | 2 | | 1 | Visibility 5000m at NRT is enough to divert | NRT' s weather might become worse just like HND | |
| | Planning of alternate fuel to NRT | / | / | | 2 | 7000 lbs | Less than 7000 lbs using radar vectoring by ATC | |
| | Air Traffic | / | / | 1 | 1 | The later, the more heavy traffic. Expedite to divert | Hold at HND as long as possible | |
| NGO | Planning of alternate fuel to NGO | 1 | 1 | 1 | / | 9000 lbs | Less than 9000 lbs using radar vector | More than 9000lbs considering uncertainty |
| | Air traffic | 3 | 1 | 1 | / | The later, the more heavy traffic. Expedite to divert | Hold at HND as long as possible | Ask for company radio |
| Planning of remaining fuel [lbs] | Declare emergency | | 1 | 1 | 1 | This situation is not appropriate to declare emergency | This situation is appropriate to declare emergency | |
| | A) Remaining fuel when made final decision | 16200 | 15800 | 15500 | 15700 | | | |
| | B) Holding for 30 min. | 4000 | 4000 | 4000 | 4000 | | | |
| | C) Alternate Fuel | 9000 | 9000 | 9000 | 7000 | | | |
| | D) Redundancy D) = A)−B)−C) | 3200 | 2800 | 2500 | 4700 | | | |
| | Uncertainty of air traffic | 2 | | 1 | 1 | Included in D) | Not Included in D) | |
| | Uncertainty of fuel calculation by company | 2 | 2 | 2 | 2 | Included in D) | Not Included in D) | |
| | Sufficient holding time | | | 1 | 1 | Included in D) | Not Included in D) | |
| | Go Around once | 2 | 2 | 2 | 2 | Included in D) | Not Included in D) | |
| | Alternate fuel in case of diverting once more | 2 | 2 | 2 | 2 | Included in D) | Not Included in D) | |

Slash(/): Irrelevant to examinees' decision making :


a) Full-flight simulator

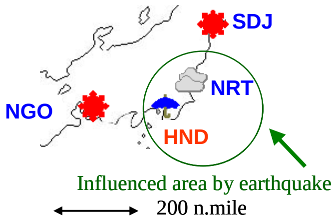

b) Picture of experiment

Fig.1 Equipment and experiments




| STRAIGHT-IN LANDING RWY 34R | |
|---|---|
| ILS<br>*DA* 222' *(200')* | LOC (GS out)<br>*MDA* 440' *(418')* |
| FULL | |
| RVR *550m*<br>VIS *800m* | RVR *1200m*<br>VIS *1200m* |

Fig.2 HND ILS RWY 34R approach chart




HND: Original Destination
Bad weather
Uncertainty due to earthquake
NRT: Near
Uncertainty due to earthquake
NGO&SDJ: Far from HND
Good weather
No damage

Fig.3 Image of scenario settings of original destination and possible alternate airports

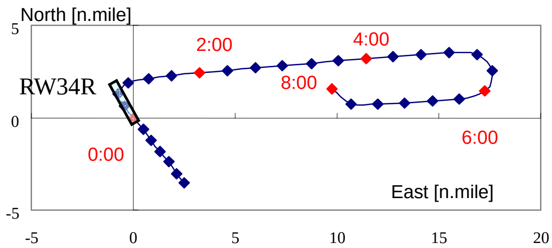



Fig.4 Example of lateral flight path (examinee 1)

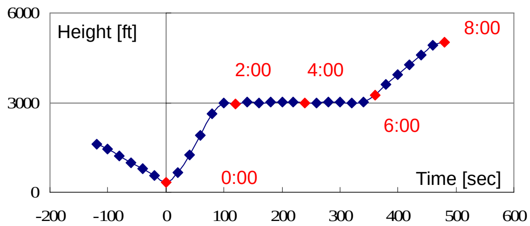
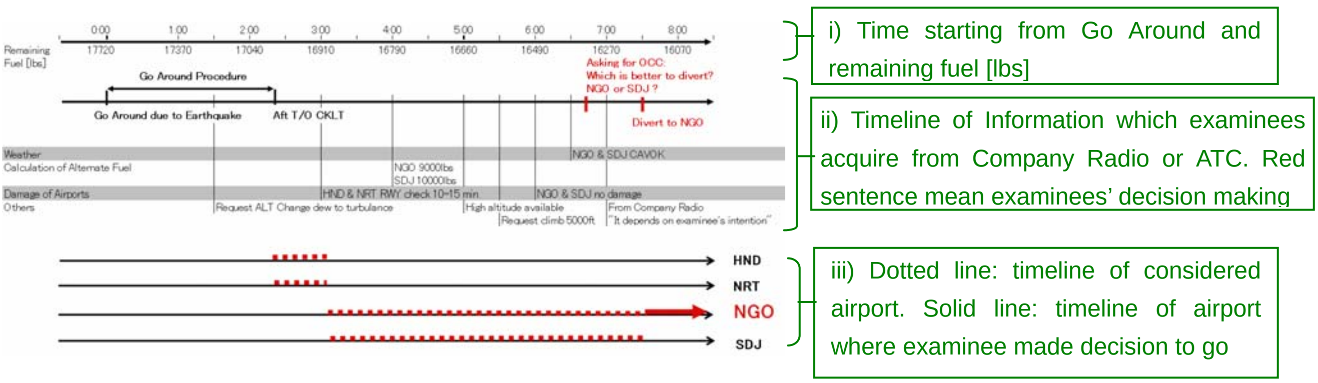
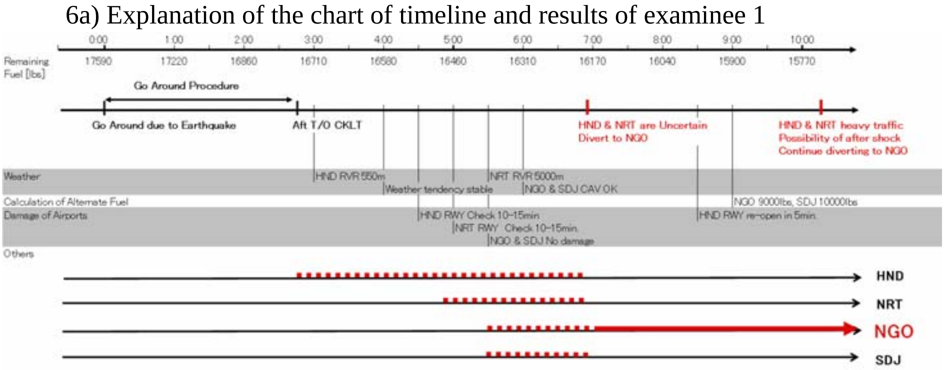


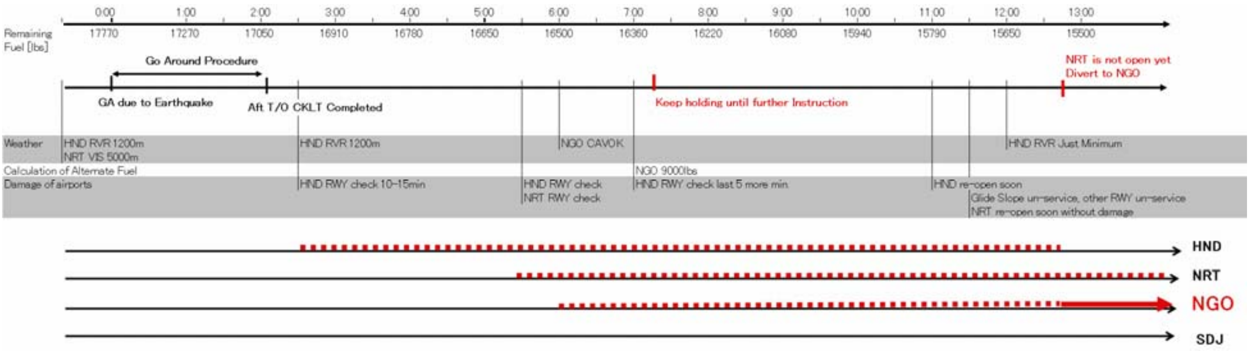

Fig.5 Example of vertical flight record (examinee 1)



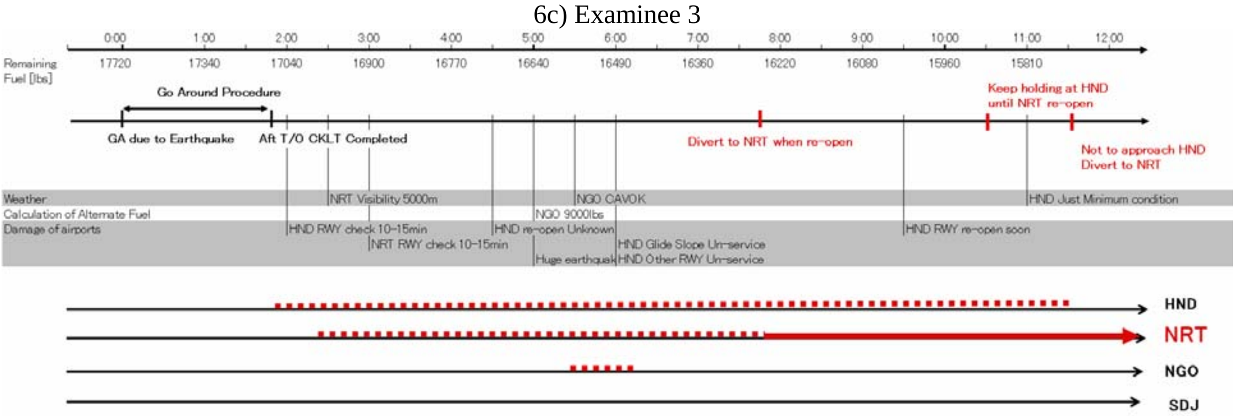

6a) Explanation of the chart of timeline and results of examinee 1




6b) Examinee 2

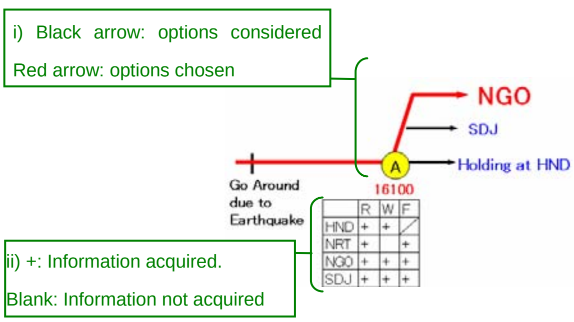



6c) Examinee 3

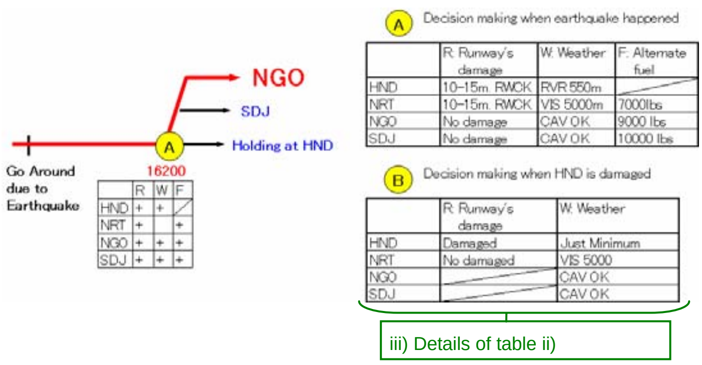



6d) Examinee 4

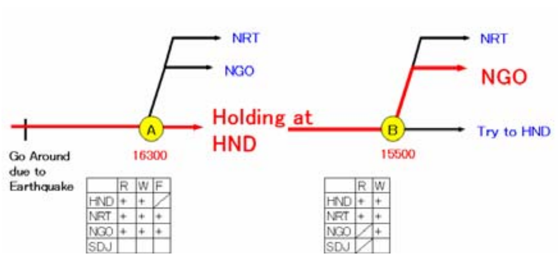
Fig.6 Results in a form of timelines



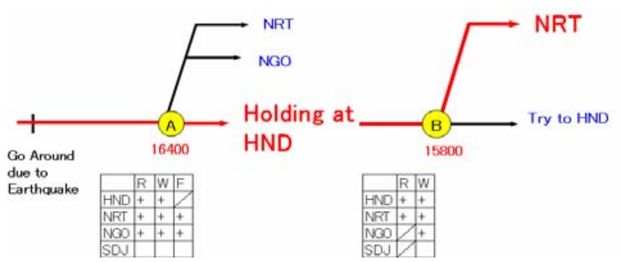

7a) Examinee 1




7b) Examinee 2




7c) Examinee 3




7d) Examinee 4

Fig.7 Results in a form of decision trees