At JR East, “safety” has been identified as the most important issue in management and safety measures have been undertaken to achieve zero injury or death of passengers and zero fatal accidents among the staff. In order to enhance this safety further in addition to obtaining an accurate assessment of “accidents and the ‘seeds’ of accidents,” lessons must be extracted from past accidents without fail in an attempt to prevent accidents and the recurrence of accidents. The “phenomena that require attention” (phenomena that have the risk of leading to accidents in railway operations; hereafter referred to simply as “phenomenon or phenomena”) that are the “seeds” of accidents for JR East are for the most part caused by human error and for this reason, in order to prevent accidents, it is indispensable that the “phenomena” be analyzed in detail from the perspective of the human factor.

“4M4E analysis” is a multifaceted method of analysis on the causes that induce human errors. This method utilizes the concept of the method of accident investigation used by the National Transportation Safety Board (NTSB) and rather than constituting mere guidelines on procedures, it is a method on how an accident should be viewed and what lessons should be drawn from accidents. The method has been widely adopted in a variety of industries and used in reviewing measures having to do with human error. This research initiative involves the development of JR East’s version of “4M4E analysis” that may be used by staff in the field or in branches who are the subjects of the analysis of “accidents” and “phenomena that require attention” in order to analyze contributing factors that induce errors from the perspective of the human factor and measures to deal with such errors in an appropriate manner. This paper explains the objectives and overview of such a research initiative.

**Introduction**

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**2 Objectives of Adoption of 4M4E Analysis**

2.1 Problems in the Current Method of Accident Investigation

In order to analyze “phenomena that require attention” that constitute the “seeds” of accidents for JR East in an appropriate manner and to take effective measures to prevent accidents and the recurrence of accidents, knowledge of the human factor is required and if this knowledge is inadequate, there is the tendency for a situation in which “the human error itself is considered to be the cause and the investigation does not cover the elements that induced the error” to arise. Moreover, even when analyzing the error, the viewpoint with respect to human error becomes cosmetic and rigid and there is a tendency to think in terms of “the cause of the error is slackness and so the only thing that can be done is initiate a shake up.” For this reason, important factors are overlooked and similar accidents recur frequently. Moreover, “human error” is looked upon as something “shameful” in the field and true lessons are not accumulated. As a result, in order to extract appropriate lessons from an accident and to adapt this to the prevention of accidents and the recurrence of accidents, a method of analyzing human errors and accidents from the perspective of the human factor is indispensable.
2.2 Objective of the Adoption of 4M4E Analysis

As explained above, 4M4E analysis is a method of analysis that addresses the contributing factors that induce human errors or accidents that are generated from the perspective of the human factor in a multifaceted manner and that also allows review of measures from a far-reaching perspective. Moreover, it can be said to be a method that is easy for field staff to understand. For this reason, the 4M4E method of analysis has been adopted as the base for the development of a new method of accident analysis.

The name “4M4E” originates from the initial “M” of the four causes that induce error and the initial “E” of the four measures that may be taken.

Table 1: Origin of the Name 4M4E

<table>
<thead>
<tr>
<th>4M</th>
<th>Man (humans)</th>
<th>Machine (things)</th>
<th>Media (environment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4E</td>
<td>Education (humans)</td>
<td>Engineering (things)</td>
<td>Environment (media)</td>
</tr>
</tbody>
</table>

It is the general practice to allocate “Example (model)” to “Environment (media)” in Table 1 but in order to provide for integration with the 4M, JR East has adopted “Environment (media).” Moreover, with respect to the content of work, procedures for work and manual for work, while the categorization is generally under “Media (environment),” since in many cases rules are categorized under “Management (control),” such a categorization is difficult to understand for the staff in the field. For this reason, “Media (environment)” includes only the limitation of work space, inclement weather, darkness of the work space, noise, and other conditions of the working environment while manuals and other such factors are considered management factors. (The expressions in parentheses are provided to enhance the clarity of the meaning of each category and to point out the matrix relationship between the 4Ms and the 4Es.)

Table 2 shows the concrete perspectives of the 4M in JR East’s version of 4M4E analysis and Table 3 shows the concrete perspectives of 4E.

Table 2: Perspectives of the Causes of Induction “4M”

<table>
<thead>
<tr>
<th>Man (humans)</th>
<th>Machine (things)</th>
<th>Media (environment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inadequacy of knowledge, experience, and skills</td>
<td>Inadequacy of sensitivity to danger and of alertness</td>
<td>Poor visibility of signals and signposts, etc.</td>
</tr>
<tr>
<td>Physical problems, physiological problems, etc.</td>
<td>Difficulty of grasping the work, equipment, and machines</td>
<td>Difficulty of the work and operation of machines</td>
</tr>
<tr>
<td>Management (control)</td>
<td>Environment (media)</td>
<td>Media (environment)</td>
</tr>
<tr>
<td>Inadequacy of instructions, notices, or human signals</td>
<td>Limitation of work space</td>
<td>Limitation of work space</td>
</tr>
<tr>
<td>Defective system of cooperation in the organization and among work places</td>
<td>Poor working environment such as lighting and noise</td>
<td>Inclement weather, etc.</td>
</tr>
<tr>
<td>Inappropriateness of the work manual</td>
<td>Inappropriateness of working hours, staffing, etc.</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Preventive Measures from the “4E” Perspective

<table>
<thead>
<tr>
<th>Education (humans)</th>
<th>Engineering (things)</th>
<th>Environment (media)</th>
<th>Enforcement (control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education on the procedures such as the work standards</td>
<td>Enhancement of the functions of trains, equipment, and machines</td>
<td>Improvement of lighting and noise abatement</td>
<td>Review of the working system and allocation of work</td>
</tr>
<tr>
<td>Education and training in order to master skills</td>
<td>Improvement of the machine interface</td>
<td>Improvement of footing and flooring</td>
<td>Review of the working procedures and forms of work and manuals, etc.</td>
</tr>
<tr>
<td>Enhancement of awareness with respect to safety, etc.</td>
<td>Improvement of the dependence of the work in which work is performed, etc.</td>
<td>Improvement of the dependence of the work in which work is performed, etc.</td>
<td></td>
</tr>
</tbody>
</table>

3 Method of Implementation and Procedures for 4M4E Analysis

3.1 Problems in the Current 4M4E Analysis Method

From before this research initiative commenced, 4M4E analysis had been implemented by certain branches as independent efforts. For this reason, interview surveys were conducted among branches that had been using the 4M4E analysis in the field and the issues that needed to be addressed in implementing the analysis in JR East were
collected. As a result of this, the following facts were ascertained.

(1) Unfamiliarity with analysis of contributing factors inducing errors
In analyzing the “contributing factors inducing” errors, there are many cases in which the perspective on which focus ought to be placed is not known and the depth in the study of the contributing factors that induce errors is inadequate. Moreover, measures are determined intuitively and the analysis of the contributing factors inducing errors merely follows in order to provide the rationale.

(2) Prioritization of measures is difficult. Moreover, the substantiation of measures is often inadequate.
Measures that are proposed as a result of the analysis may, as represented in the strict enforcement of fundamental actions, be inadequate in terms of substantiation of the content of implementation of the measures. Moreover, since numerous measures to deal with errors are identified from a multifaceted perspective, the determination of priorities becomes difficult.

3.2 Implementation Procedures for the New 4M4E
In order to resolve the problems mentioned above, with the JR East version of the 4M4E analysis, a method of analysis has been formulated that is undertaken in three steps, “time series analysis,” “contributing factor analysis,” and “establishment of measures” and within each step, with final measures to be implemented being determined after undergoing the three procedures of “increasing the extent,” “increasing the depth,” and “making an evaluation” (refer to Figure 1). In this section, each of these steps will be explained.

3.2.1 Time Series Analysis
Accidents often occur due to a combination of errors. For this reason, in order to take steps to prevent accidents and the recurrence of accidents, it is necessary to discern the entire process leading to the generation of the “phenomenon.” As a means of making this possible, time series analysis is undertaken using the following three procedures (increasing the extent, increasing the depth, and making an evaluation).

“Increasing the extent”: The phenomena that have occurred are described in time series and the problem areas (errors or actions that may not be actual errors but are lacking in consideration in terms of safety; hereafter simply referred to as error or errors) are extracted.

“Increasing the depth”: The overall structure of the accident is analyzed such as through analysis of the relationship among multiple errors or the factors that are common to the errors.

“Making an evaluation”: The seriousness of the error is analyzed.
As seen above, in order to extract errors related to the occurrence of the “phenomena” without omission, time series analysis traces back the phenomena to the extent possible and places emphasis on extracting all errors that led to the generation of the “phenomena.”

3.2.2 Analysis of Contributing Factors that Induce Errors
(4M why-why analysis)
As with the time series analysis, in order to take appropriate measures to deal with errors, “cosmetic analysis of errors” should be overcome so as to clarify the true contributing factors in the error or accident. To this end, a decision was made to implement the “4M why-why analysis” using the following three procedures (increasing the extent, increasing the depth, making an evaluation).

“Increasing the extent”: Making reference to the type of error (more on this in a later section) the contributing factors that induce errors are extracted extensively from the perspective of 4M.

“Increasing the depth”: Through the “why-why analysis” that repeatedly asks why with respect to contributing factors that have a large impact, the intrinsic contributing factors are elucidated.

“Making an evaluation”: The impact is evaluated of the intrinsic contributing factors extracted upon the occurrence of an error.
One of the basic principles of the “Kaizen” (improvement) initiatives of Toyota Motors is “repeating the query ‘why’ five times.” Through this, it is said that intrinsic contributing factors (root causes) may be identified rather than being limited to mere cosmetic analysis of causes. A similar “why-why analysis” method exists as a method of
investigating accidents in which the phenomenon that has occurred is studied in depth through repeatedly asking why and this targets achieving understanding of the intrinsic contributing factors. JR East will adopt the “why-why analysis” method in depth in order to study contributing factors extracted through 4M analysis and elucidate the intrinsic contributing factors in an attempt to break away from cosmetic analysis.

3.2.3 Formulation of Measures to Deal with Errors
(4E so what analysis)
In order to prevent accidents, it is necessary to cast off formalistic measures and to form effective measures to deal with errors in a substantive manner. As with the “4M why-why analysis,” the procedures for undertaking “4E so what analysis” to this end have been determined to be the following three procedures (increasing the extent, increasing the depth, and making an evaluation).

“Increasing the extent”: Comprehensive review is made of measures to prevent the recurrence of accidents from the perspective of 4E with respect to the contributing factors that are extracted.

“Increasing the depth”: Measures are substantiated through the “so what analysis” with particular emphasis on measures that have to do with important contributing factors.

“Making an evaluation”: The priorities for taking the various measures are evaluated.

Review of measures using only 4E is prone to become abstract and the effectiveness is not clear. For this reason, by repeating “so what” with respect to measures extracted through 4E, a procedure has been adopted for deriving a concrete action base from the measures. Through this, it will be possible to forecast the effect of measures and to take such measures speedily.

3.2.4 Determination of the Measures to be Taken
The “4M why-why analysis” and the “4E so what analysis” are undertaken for each error that occurs in a phenomenon. For this reason, in order to determine the actual measure to be taken, the measures reviewed for each error need to be evaluated in a comprehensive manner and the measures to be taken need to be prioritized. This is the final procedure leading to the determination of the measures to be taken.

3.3 Analysis Sheet used in 4M 4E Analysis
Analysis using the 4M4E system employs the three analysis sheets, “time series analysis sheet,” “structural analysis sheet,” and “detailed analysis sheet by problem groups,” described below.

3.3.1 Time Series Analysis Sheet
This is a sheet for stating the process leading to the occurrence of a “phenomenon” in time series and extracting all errors that lead to the “phenomenon” without any omissions. Figure 2 shows an example of a filled out time series analysis sheet.

![Fig2: Time Series Analysis Sheet (Hypothetical Example)](image)

Fig2: Time Series Analysis Sheet (Hypothetical Example)
3.3.2 Structural Analysis Sheet

In addition to analyzing the structure of an accident such as through extracting the relationship among and the common contributing factors in multiple errors, the structural analysis sheet is used for “4M why-why analysis” and “4E so what analysis” in order to perform analysis in an effort to determine appropriate measures to deal with errors. Figure 3 shows an example of the use of the “4M why-why analysis” and the “4E so what analysis” using the structural analysis sheet for an error that is generated through a “phenomenon.”

3.3.3 Detailed Analysis Sheet by Problem Groups

This is a sheet for undertaking detailed “4M why-why analysis” or “4E so what analysis” with emphasis on errors that are identified as being important in the structural analysis as well as for describing the “concrete action based measures” that have been decided.

3.4 Guide to Analysis utilizing the Error Type

In order to analyze the contributing factors that induce errors and to review measures to deal with such errors in an appropriate manner, it is effective to take into consideration the type of error that is involved. This is because the contributing factors on which focus should be placed and the measures that are effective in error prevention differ according to the type of error involved. At JR East, reference has been made to the error model of Reason and Rasmussen and review of error type using the 4M4E analysis has been undertaken and a decision was made to use the categories shown in Table 4.

Moreover, a 4M4E analysis guide was produced (Table 5) that allows compilation of contributing factors that induce errors and measures that are considered to be effective which should focus on each error type to be used to support those who are unfamiliar with analysis from the perspective of the human factor.

The following is an example of the identification of contributing factors from the error type. For example, if the error that is generated is identified as a “judgment error,” the issue is “Why did the error occur despite the fact that there has normally been no problem?” In this case, guidance is provided to extract and analyze contributing factors on which focus should be placed from the perspectives of “Is there any influence of having become too familiar?,” “Is the design prone to inducing illusion and misunderstanding?,” “Were there any anomalous conditions that were different from the usual circumstances that induced illusion or misunderstanding?,” and “Was..."
there any ambiguity in the provision of information or instructions? in line with the 4M4E analysis guide.

3.5 Checklist for the 4M4E Analysis
Since this analysis method assumes implementation in the field and by staff of branches, a checklist has been produced to confirm that the analysis is undertaken from the perspective of the human factor in an appropriate manner. These items may be termed the essentials of the 4M4E analysis. The check items are comprised of the basic check items and check items for each step of the analysis. Table 6 shows the checklist that has been produced.

Table 6: 4M4E Checklist

4 Effectiveness of the 4M4E Analysis
For example, assume the generation of a "phenomenon" whereby "through an error in transcription of the original drawing, a decision is made that a section that fundamentally requires a change in the circuit diagram does not need such a change." Unless the contributing factors are studied in depth, the causes of the error are prone to being analyzed as "inadvertent error in transcribing the original drawing" and such a measure as "when transcribing an original drawing, confirmation shall be made without fail after the transcription is complete" is often identified as a measure to prevent such an error, although this is a mere reversal of the statement of the cause.

On the other hand, when using the 4M4E analysis method, analysis such as shown in Table 7 will also be possible.
As can be seen, the adoption of 4M4E analysis avoids viewing human error cosmetically and ensures understanding of the process by which the error occurred and extracts the intrinsic contributing factors that induced the error thus allowing the formation of measures to eliminate or reduce errors substantively and in an efficient manner. Moreover, in the field, awareness of the human factor and accidents will change and understanding will be obtained on the intrinsic contributing factors that induce an error rather than cosmetic factors and in addition to the accumulation of true lessons on “phenomena,” it is expected that the perspectives for addressing activities and lessons designed to prevent accidents will become more diversified.

Formulation of Measures to Deal with Errors
- Obtain understanding based on examples that suspension of work is a typical contributing factor that induces errors (Education).
- Establish a scheme whereby instructions are issued or awareness is obtained without fail when a task is outside the norm (Enforcement).
- When producing a circuit diagram, change the procedures to include a requirement that the original drawing must be retained in the CAD as the work progresses (Enforcement).
- Incorporate a logical check function in the CAD (Engineering).

While this method of analysis is still under development, the intention is to achieve the prevention of accidents and the recurrence of accidents by enhancing the completeness of the method of analysis and entrenching it as the analysis method to be used for JR East’s "phenomena that require attention" towards full adoption in the coming fiscal year.

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Conclusions

The procedures for 4M4E analysis described above have been compiled in the form of a manual and from fiscal 2004, education on 4M4E is being provided at each branch. Since it may be said that analysis skills will improve as the number of analyses using 4M4E increase, emphasis is on “OJT”.

On the other hand, obtaining adequate understanding on the knowledge and fundamental concept of the human factor which is the basis for 4M4E analysis internalizes some difficulties. For this reason, in order to improve the level of the staff conducting the analysis and enhance the precision of the content of the analysis, training and support tools for 4M4E are currently being developed.