A New Prediction Method of Transportation Demand of Fast Passenger-Car Ferry, Using a Benefit-Cost-Risk Model *1

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In the present study, a new prediction method of transportation demand based on a benefit-cost-risk model for users is developed, and the results are economically evaluated by a net present value and an internal rate of return for operators. The benefit-cost-risk model is deduced based on the utility theory in which users are assumed to behave like an investor in choosing a transportation system among many alternatives using the following factors, traveling fare, and time as cost, comfort, convenience, and safety as benefit, and motion sickness, and exhaustion as risk. The model assumes that the users always choose the transportation system, which has the maximum benefit-cost-risk ratio. Results by the model are compared to those by a generalized cost model that was proposed by one of the authors in the previous paper. In order to assess the present method, a feasibility study of fast passenger-car ferries in Osaka-Tokushima route is carried out. The results by these two models show that when routes are relatively short, fast passenger-car ferries of 40-50 knots are highly competitive with other transportation systems even with channel-bridges.

Keywords: Transportation Demand, Prediction Fast Passenger-Car Ferry, Benefit-Cost-Risk model, Generalized Cost model, Feasibility Study

1. Introduction

For these twelve years, more than eighty conventional ferry services have been closed due to the openings of new bridges and new underwater tunnels in Japan. On the other hand, highway transportation systems such as express buses and private cars have been increasing their demand. This may be because most of users prefer to a fast and convenient transportation system.

One of the authors investigated the performances of newly developed fast passenger-car ferries and carried out economical evaluations of them in 19981), and pointed out that fast passenger-car ferries are probably one of promising alternative solutions for establishing a future marine transportation.

Many types of fast passenger-car ferries have been developed around the world for these ten years, and they are successfully operated in many routes in Europe, South America, Korea etc. In Japan, however, the introduction of such fast car ferries to regular ferry services does not proceed well, because of some social and economical obstacles.

In order to break these barriers, it is necessary to create a prediction method of transportation demands of fast passenger-car ferries in competition with other transportations, and to show the feasibility of them.

In respond to this subject, one of the authors has developed a prediction method of transportation demand of fast passenger-car ferries on the basis of a new generalized cost analysis for users and a profit analysis for operators2). Following the previous work, the authors develop a new prediction method of transportation demands based on a benefit-cost-risk analysis for users, and evaluate the economical results by a net present value, NPV, and an internal rate of return, IRR, for operators. The present benefit-cost-risk model is developed by applying the basic concept of finance to a demand function. The difference between two methods is; the share estimations are based on the minimum cost of each users for the generalized cost model and the maximum benefit-cost-risk ratio for the benefit-cost-risk model.

In this research, the new model for predicting trans-
portation demand is applied to the ferry service between Osaka and Tokushima using passenger-car ferries of 40-50 knots, and the results are compared with those by using the generalized cost model.

The outcomes of the feasibility study from both two methods show that fast passenger-car ferries of 40-50 knots are highly competitive with other means of transportation systems in the route.

2. Hierarchy of Evaluation of Transportation Systems

The evaluation of a transportation system is derived from three different points of views as follows: users, operators and societies as shown in Fig.1. The users usually tend to choose a transportation system that is quick, convenient, cheap, safe, and less exhaustion and motion sickness. Profit and return on investment are the most important factor for the operators. Societies consider environmental impacts, public profits, infrastructures of transportation systems and social welfare.

3. Share Calculation and Project Evaluation

A benefit-cost-risk model is used to predict the share of fast passenger-car ferries. The model includes factors of comfort, convenience, and safety as benefit, total required fare and time as cost, and motion sickness and exhaustion as risk. A break-even fare analysis is applied to determine the fare of the ferries using components of operating cost, and the time is calculated by summing up sailing hour and access time. Level of importance of each factor is determined using the Analytical Hierarchy Process, AHP, method.

Using the share estimation as mentioned above, both a net present value analysis and an internal rate of return analysis are applied to the evaluation of the project.

3.1 Fare of Fast Passenger-Car Ferries

For the share calculation of a fast passenger-car ferry it is necessary to determine the fare of it. The fare is obtained by adding the fare at break-even point and appropriate profit of operators.

The estimation of each component in the operating cost of a fast passenger-car ferry is shown in Table 1.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed cost</td>
<td></td>
</tr>
<tr>
<td>1. Crew cost</td>
<td>8 million/crew</td>
</tr>
<tr>
<td>2. Maintenance cost</td>
<td>3% of building cost</td>
</tr>
<tr>
<td>3. Insurance cost</td>
<td>1% of building cost</td>
</tr>
<tr>
<td>4. Property tax</td>
<td>0.7% of building cost</td>
</tr>
<tr>
<td>5. Depreciation cost</td>
<td>90% of building cost/10</td>
</tr>
<tr>
<td>6. Interest</td>
<td>6% of building cost</td>
</tr>
<tr>
<td>7. Additional cost</td>
<td>4 million</td>
</tr>
<tr>
<td>8. Office cost</td>
<td>100 million/year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable cost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fuel cost</td>
<td>9.5/kW/hour</td>
</tr>
<tr>
<td>2. Port charge</td>
<td>0.2 million/day</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Service speed and Loa (76 m - 96 m)</th>
<th>Building cost (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 knots</td>
<td>3000 million</td>
</tr>
<tr>
<td>50 knots</td>
<td>4000 million</td>
</tr>
</tbody>
</table>

As shown in Table 1 the cost is classified into two kinds of costs. The first one is called Fixed cost for every year, including crew, $C_C$, maintenance, $C_M$, insurance, $C_{IS}$, property tax, $C_T$, depreciation, $C_D$, additional, $C_A$, interest, $C_{IT}$, and office, $C_O$, costs. The fixed cost depends on the number of crews and building cost. The building cost is assumed to vary according to speed and size of the ferries as shown in Table 2. The second one is Variable cost for ship operations, including fuel cost, $C_F$, and port charge, $C_P$. The cost depends significantly on speed or power of the ship and the level of activities of the ferry such as frequency and operating time.

The operating cost of the fast passenger-car ferry is calculated by summing up the fixed cost, $C_{Fixed}$ and the variable cost, $C_{Variable}$. Therefore, the operating cost can be expressed as

$$ O_C = C_{Fixed} + C_{Variable} $$

For the fare estimation of fast passenger-car ferries, a break-even analysis where the operating cost is just equal to the income of the operator is needed. In the analysis, it is assumed that the break-even fare of a
car, $F_{CBEP}$, is $n$-th times of that of a passenger as follows.

$$F_{CBEP} = nF_{PBEp}$$ (2)

When $N$ is the number of the fast passenger-car ferries operated in a market, $S_P$ is the share of the fast passenger-car ferries in total demand of passengers, $S_C$ is the share of the fast passenger-car ferries in total demand of cars, and $D_P$ and $D_C$ are total numbers of passengers and cars in the market, respectively, then, Eq.2 can be rewritten as follows.

$$F_{PBEp} = \frac{NOC}{S_P D_P + n S_C D_C}$$ (3)

When the operating cost and the demands are constant, a break-even fare analysis of the fast passenger-car ferries can be expressed as shown in Fig.2. The figure shows that when the shares decrease from X to Y, then, the break-even fare increases from Fare X to Fare Y.

If the profit margin or mark-up percentage of the operator is assumed to be $M$, the fare for a passenger of the ferries, $F_P$, can be expressed as

$$F_P = F_{PBEp}(1 + M)$$ (4)

Similarly, the fare for a car, $F_C$, can be expressed as

$$F_C = nF_{PBEp}(1 + M)$$ (5)

### 3.2 Total Fare and Required Time by Users

Fig.3 shows an example of distance and required time by users to travel. In the figure, $D_S$ denotes the distance from the departing port to the arrival port, $T_A$ is total access time by an user from starting point to the departing port and the arrival port to the final destination including waiting time and $V_S$ is speed of fast passenger-car ferries, then, total required time by the user to travel can be expressed as follow.

$$T_T = \frac{D_S}{V_S} + T_A$$ (6)

Similarly, total required fare by the user to travel can be written by summing up the fare of the fast
passenger-car ferries, $F_F$, from Eq.4 or Eq.5, and an access fare to and from port, $F_A$, as

$$F_T = F_F + F_A$$  \hspace{1cm} (7)$$

The access fare and time normally depends on distance from and to the ports, and kinds of access transportation. For other transportation systems similar estimations of required time to travel are done.

3.3 Benefit-Cost-Risk Model

In the present study, a model for predicting the demand of a fast passenger-car ferry is deduced on the bases of the utility theory. The utility theory, that is a theoretical measurement of satisfaction level, is widely used in the share prediction of demand in any marketing research. The theory asserts that the users can rank possible alternatives in order preference according to their utility. From the alternatives, the users will always choose the option that they considers most desirable, given them tastes and the relevant constraints placed on their decision-making$^3)$. For the optimization of the decision, the users usually make value comparison among the alternatives based on many factors.

Since there are various ways in the utility theory, an appropriate method for predicting the share of the fast passenger-car ferries must be deduced. The new generalized cost model, that was proposed by one of the authors$^2$), is one of methods for doing it. In the present study, the authors propose a benefit-cost-risk model in which users are assumed to behave like an investor in choosing an option among many alternatives.

![Fig. 3 Total required time by users to travel.](image)

**Fig. 3** Total required time by users to travel.

When an investor wants to choose a profitable project, then, three basic questions may be put into his considerations in order: how much profit of each project is, how long the investment will return and how the level of risk of each project is.

In order to answer these three questions, he firstly should be able to estimate cost and revenue of each project, then, he will estimate ratio of rate of return on investment of the projects. When two projects offer the same ratio, another determinant component possibility is by the level of risk. Then, the investor should predict the risk of the projects. Finally, he makes a decision based on his analysis.

Similar to the behavior of an investor mentioned above, an user of transportation is assumed to choose a suitable transportation system. In the choosing process, many factors should be considered in his mind as follows: required fare and time, comfort, convenience, safety, and so on. In the present study, seven factors, total fare, total required time to travel, comfort, safety, convenience, motion sickness and exhaustion, are taken into account, and they are categorized as benefit, cost and risk for users.

The elements of benefit contain three factors such as convenience, safety, and comfort. Convenience means the level of convenience to use transportation systems such as frequency. Safety means the possibility of oc-
currence of accident that it is determined based on accidental statistics. Comfort can be measured by the space that the users can use. The reason that the factors are considered as the elements of the benefit, the factors are positive factors.

The elements of cost contain as follows: the required fare and time. The traveling time is converted into value of money by multiplying it by the time value of each user.

The elements of risk contain two factors such as motion sickness and exhaustion. Motion sickness means sick resulting from the acceleration of transportation systems. Exhaustion means feeling of exhausted consequence due to use transportation systems. The factors are classified into risk because they are negative factors.

The evaluation of hierarchy of predicting share of each transportation system based on the elements of the benefit, the cost, and the risk can be derived into several stages as shown in Fig.4.

Using benefit, cost and risk components, a benefit-cost-risk model used here will be deduced as follows.

The return value to users can be expressed as follows\(^4\).

\[ U_K = V_B - V_C \]  \(8\)

where \( V_B \) and \( V_C \) denote benefit and cost in term of value of money, respectively. Then, the rate of return to users can be obtained by dividing the return value by fare as follows.

\[ R_{BC} = \frac{V_B - V_{Fare} - V_{Time}}{V_{Fare}} \]  \(9\)

where \( V_{Fare} \) and \( V_{Time} \) denote fare and time, respectively.

Dividing the rate of return by the risk component, \( V_R \), the ratio of benefit-cost-risk can be expressed as follows.

\[ R_{BCR} = \left( \frac{1}{V_R} \right) \left( \frac{V_B - V_{Fare} - V_{Time}}{V_{Fare}} \right) \]  \(10\)

In order to calculate the ratio of benefit-cost-risk, the components of benefit and cost should be converted in term of money, and the components of risk should be in term of non-unit factors. All components are converted to the same unit by multiplying each one by a weight determined by the Analytical Hierar-

Chy Process, \( AHP \), method. Then, the ratio can be expressed as follows.

\[ R_{BCR} = \frac{1}{\sum W_R E_R} \left( \sum W_B E_B - (W_F F + W_T R_T) \right) \]  \(11\)

where \( W_B \) is weight of the components of the benefit that consists of weights of comfort, convenience and safety, \( E_B \) is Eigen value of transportation systems for the components of the benefit such as Eigen values of comfort, convenience and safety, \( F \) is the required fare of the users to travel, \( W_F \) is weight of the required fare, \( W_T \) is weight of the traveling time, \( R \) is time value, \( T \) is total required time to travel, \( W_R \) is weight of the components of the risk that consists of weights of motion sickness and exhaustion, \( E_R \) is Eigen value of transportation systems for the components of the risk such as Eigen values of motion sickness and exhaustion.

The benefit-cost-risk model assumes that users always choose the transportation system, which has the maximum benefit-cost-risk ratio. The basic concept of the shares calculation is shown in Fig.5. In the figure two possible alternatives, transportation X and Y, are considered. The figure above shows the ratio of benefit-cost-risk of each system, and the figure below shows density of distribution of the users with time value. The figure above shows that value of \( R_{BCR} \) decreases when time value increases. Methodology of share estimation for each transportation system is calculated according to the maximum value of \( R_{BCR} \) at each time value. For example, the share taken by transportation system Y can be obtained by the area of the density function where value of \( R_{BCR} \) for transportation system Y is larger than that for transportation system X.

3.4 New Generalized Cost Model

The new generalized cost model which was proposed by one of the authors\(^2\), assumes that the users always choose the transportation system which has the minimum generalized cost. The model is expressed in linear superposition of the same factors, which are taken into account in the present benefit-cost-risk model in previous section, as follows\(^3\).

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The model, as an example, calculation cost is shown in Fig.6.

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\[ C_k = W_1 F_k + W_2 RT_{kt} + W_3 \sum_{i=1}^{5} w_{ki} F_{ki} \quad (12) \]

where \( k \) is the number identifying each transportation system in a certain route, \( C_k \) is the generalized cost of \( k \)-th transportation system, \( W_1 \) is weight of the transportation fare, \( F_k \) is transportation fare of the \( k \)-th transportation system, \( W_2 \) is weight of the time required to travel, \( R \) is time value for each user, \( T_{kt} \) is total time required by the traveler by the \( k \)-th transportation system, \( W_3 \) is weight of the third element, \( w_{ki} \) is weight of each factor in the third element and \( F_{ki} \) is value of evaluation of each factor in the third element of transportation system.

Fig.6 is generalized costs of two different transportation systems, X and Y. Below is density distribution of travelers with time value. The figure shows that each transportation system has different general cost. As mentioned before, the methodology of share calculation is according to minimum general cost. For example, the share taken by the transportation system Y is obtained by the area of the density function in Fig.6 where \( C_k \) for the transportation system Y is lower than that for transportation system X.

As shown in Fig.5 and Fig.6, the methodology of share estimation by using the benefit-cost-risk model is the same as that by using the new generalized cost model, but evaluation function, \( R_{B\!C\!R} \) and \( C_k \), are in reciprocal relation.

3.5 Project Evaluation of Fast Passenger-Car Ferries

In order to evaluate a project of fast passenger-car ferries, a net present value, \( NPV \), and an internal rate of return, \( IRR \), are used in this research. The net present value is equal to difference between the net cash flows generated by a project and the initial cash outlay. The net present value of the project is calculated as follows\(^4\).

\[ NPV = \sum_{t=1}^{n} \frac{C_t}{(1+k)^t} - C_0 \quad (13) \]

where \( C_0 \) is the initial outlay on the project, \( C_t \) is net cash flow generated by the project at time \( t \), \( t \) is life of the project and \( k \) is the required rate of return.

It is known that a net present value analysis is complex. In order to make the analysis easy, it is assumed that the initial outlay refers only to the building cost of the fast passenger-car ferries and that the net cash flow refers to the profit of the fast passenger-car ferries.

Profit can be defined as the remainder of funds available to the proprietor after deducting all costs and expenses from total sales revenue\(^4\). The profit function of the fast passenger-car ferries can be expressed as

\[ Phi = ((F_P S_P D_P) + (F_C S_C D_C)) - (NOC) \quad (14) \]
where \( \Phi_i \) is profit of the ferries. The equation consists of two terms that the first one is total sales revenue, and the last one is total operating cost of the fast passenger-car ferries.

Using Eq.4 and Eq.5, the profit function can be rewritten as

\[
\Phi_i = F_P((S_P D_P) + (nS_C D_C)) - (NO_C)
\]  

(15)

By applying Eq.15 into Eq.13, then, the net present value can be expressed as

\[
NPV = \sum_{t=1}^{n} \frac{F_P((S_P D_P) + (nS_C D_C)) - (NO_C)}{(1 + k)^t} + C_O
\]

(16)

Fig.7 shows the basic concept of the net present value analysis for a project using fast passenger-car ferries. When the present value of ship 1 continuously increases until higher than its initial outlay, the project of the ship will be accepted where its NPV is zero or higher than zero or in the accepted area.

The second method used in the project evaluation is the internal rate of return. The internal rate of return can be calculated if the net present value is zero or the present value is equal to the outlay of the project. Then, Eq.16 can be written as

\[
C_O = \sum_{t=1}^{n} \frac{F_P((S_P D_P) + (nS_C D_C)) - (NO_C)}{(1 + k)^t}
\]

(17)

Methodology of estimation of the internal rate of return is shown in Fig.8. Reciprocal from Fig.7, if the present value of ship 1 continuously decreases until lower than its initial outlay, then the project will be accepted if its IRR is greater than its expected rate of return, ERR.

In the calculation of the net present value and the internal rate of return, it is assumed that the life of the project is 10 years, and the required rate of return is 10 percent.

4. Feasibility Study of Fast Passenger-Car Ferries in Osaka-Tokushima Route

In order to assess the present prediction method of transportation demand of the fast passenger-car ferries, the feasibility study for Osaka-Tokushima route is carried out.

4.1 Distribution of Demand

Under the circumstance that area of distribution of the demands is very wide, it is assumed that the
demands are distributed in each sub-area. In order to make the calculation easy, area of the distribution of the demands in Osaka Prefecture can be divided into eight market segments as shown in Fig.9.

The total traveler demands between Osaka and Tokushima are assumed to be two million passengers and a million cars. The density of the demands of each segment in Osaka is assumed as shown in Table 3 based on population of each segment.

### 4.2 Weight and Eigen Values

Weight of each factor in the benefit-cost-risk model and Eigen value of each transportation system are the same as those which one of the authors used in previous paper\(^2\). Table 4 shows weight of each factor for leisure and business travelers. Weight of each factor was determined by using the Analytical Hierarchy Process, AHP, model, and mean value of each factor was calculated. The results show that weight of the factors significantly depends on travel purposes. For example, for the business travelers, time is more important, because they have to arrive at the final destination on time.

Eigen value of each transportation systems was also determined by using the Analytical Hierarchy Process, AHP, model, as shown in Table 5.

### 4.3 Time Value

Total required time to make travel is evaluated in amount of money by multiplying it by time value of each user. The time value is usually determined according to earning of the users in an hour. Ikeda et.al\(^3\), however, pointed out that the time value depends on the purpose of travel, and assumed that the time values for the leisure and the business travelers as shown in Fig.10. The time value of the business traveler is higher than the leisure. This may be because companies pay travel expenses for the business travelers.

### 4.4 Alternative Transportation Systems

Table 6 shows an example of the total required time to travel, and fare of various transportation systems operated between one of the segments in Osaka Prefecture and Tokushima. There are seven kinds of alternative transportation systems operated between Osaka-Tokushima. As mentioned in the introduction, after the opening of Akashi Bridge, express buses and private cars became a dominant transportation system. The traditional car-ferries between Osaka and Tokushima disappeared, and the fast passenger ship service met very critical situation due to decrease number of passengers.

### 4.5 Flow Chart of Shares Calculation

Fig.11 is a flow chart of calculation of shares and projects evaluation. In the shares calculation, total passengers and cars are assumed to be two million and one million, respectively. Firstly, in order, we give initial value of the share, \(I\), and other data such as number of ferry, \(N\), length of overall, \(Loa\), speed, \(Vs\), distance, \(DS\), frequency of the ferries, \(V\), and ratio of fare of a passenger to a car, \(n\). The operating cost of the fast passenger-car ferries can be calculated using the operating cost analysis from Eq.1. Then, using the break-even fare and the profit analyses, we can calculate the fare of the fast passenger-car ferries.
Table 4  Weight of each factor.

<table>
<thead>
<tr>
<th></th>
<th>Fare</th>
<th>Time</th>
<th>Comfort</th>
<th>Convenience</th>
<th>Safety</th>
<th>Exhaustion</th>
<th>Motion sickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business</td>
<td>0.32</td>
<td>0.30</td>
<td>0.051</td>
<td>0.096</td>
<td>0.106</td>
<td>0.086</td>
<td>0.038</td>
</tr>
<tr>
<td>Leisure</td>
<td>0.33</td>
<td>0.16</td>
<td>0.106</td>
<td>0.112</td>
<td>0.122</td>
<td>0.099</td>
<td>0.076</td>
</tr>
</tbody>
</table>

Table 5  Eigen values of transportation systems for each factor.

<table>
<thead>
<tr>
<th>Transport</th>
<th>Comfort</th>
<th>Convenience</th>
<th>Safety</th>
<th>Exhaustion</th>
<th>Motion sickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airplane</td>
<td>0.12</td>
<td>0.10</td>
<td>0.17</td>
<td>0.09</td>
<td>0.12</td>
</tr>
<tr>
<td>Bus</td>
<td>0.06</td>
<td>0.17</td>
<td>0.14</td>
<td>0.22</td>
<td>0.15</td>
</tr>
<tr>
<td>Train</td>
<td>0.15</td>
<td>0.29</td>
<td>0.30</td>
<td>0.12</td>
<td>0.07</td>
</tr>
<tr>
<td>Small ship</td>
<td>0.08</td>
<td>0.04</td>
<td>0.04</td>
<td>0.31</td>
<td>0.45</td>
</tr>
<tr>
<td>Large ship</td>
<td>0.25</td>
<td>0.20</td>
<td>0.26</td>
<td>0.06</td>
<td>0.15</td>
</tr>
<tr>
<td>Private car</td>
<td>0.34</td>
<td>0.36</td>
<td>0.09</td>
<td>0.20</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Table 6  An example of time and fare of each transportation system between Osaka-Tokushima.

<table>
<thead>
<tr>
<th>Routes</th>
<th>Time</th>
<th>Fare (Yen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Airplane</td>
<td>3H32 Min</td>
<td>11,480</td>
</tr>
<tr>
<td>2 Express bus</td>
<td>3H57 Min</td>
<td>3,920</td>
</tr>
<tr>
<td>3 Train (via Seto bridge)</td>
<td>4H24 Min</td>
<td>10,810</td>
</tr>
<tr>
<td>4 Fast passenger ship (Osaka – Tokushima)</td>
<td>4H25 Min</td>
<td>5,290</td>
</tr>
<tr>
<td>5 Private car using car ferry (Wakayama – Komatsujima)</td>
<td>5H08 Min</td>
<td>11,480</td>
</tr>
<tr>
<td>6 Passenger using car-ferry (Wakayama – Komatsujima)</td>
<td>6H21 Min</td>
<td>2,850</td>
</tr>
<tr>
<td>7 Private car via Akashi bridge</td>
<td>2H30 Min</td>
<td>9,578</td>
</tr>
</tbody>
</table>

Fig. 11  Flow chart of calculation of prediction demand of the fast passenger-car ferries.
for passengers and cars. After that, the fare and the required time to travel by the users are calculated using Eq.7 and Eq.6, respectively. Finally, the shares of the ferries are calculated by using Eq.11 and Eq.12. These shares, \( S \), do not coincide with the initial value of share, \( I \). Therefore, iteration is necessary in calculation. The shares of the ferries are obtained when the obtained shares, \( S \), are equal to the initial share, \( I \).

In order to evaluate the project of fast passenger-car ferries, the net present values, \( NPV \), and the internal rate of returns, \( IRR \), are calculated using Eq.16 and 17, respectively. The project will be accepted if \( NPV \) is greater than zero and \( IRR \) is greater than the expected rate of return, \( ERR \).

4.6 Results and Analysis

Table 7 shows eight solutions of share estimation of the fast passenger-car ferries with speed of 40-50 knots using the benefit-cost-risk model. Furthermore, Table 8 explains seven solutions of shares estimation of the fast passenger-car ferries with speed of 40-50 knots using the new generalized cost model. The results by both two models show that the shares, the profits, the net present values, and the internal rate of returns increase when speed increases. Therefore, the fast passenger-car ferries with speed of 50 knots may be preferable for passenger and operator because of the highest in ratio and profit among others solutions.

However, the shares estimated by these two models show different in quantity, but, qualitatively suggest that the fast passenger-car ferries of 40-50 knots can be adopted in Osaka-Tokushima route. It means that the fast passenger-car ferries have a great promising new marine transport in Japanese sea route.

5. Conclusion

Following conclusions have been obtained:

1. The evaluation of transportation system has been analyzed based on two viewpoints as follows: users and operators in total evaluation.
2. A prediction method of transportation demand including factors of total required fare and time, comfort, convenience, safety, exhaustion, and motion sickness has been developed by applying a benefit-cost-risk model. The method gives us shares of any transportation systems.
3. Using the predicted shares, a project can be evaluated using a net present value and an internal rate of return analyses.
4. The method is applied to a feasibility study of fast passenger-car ferries operated between Osaka and Tokushima.
5. The results are different in quantity from those by using a generalized cost model, but both results suggest that fast passenger-car ferries of 40-50 knots can be adopted for Osaka-Tokushima sea route.

References

Table 7 Eight solutions of shares of fast passenger-car ferries with speed of 40-50 knots obtained using benefit-cost-risk model.

<table>
<thead>
<tr>
<th>No. of ship</th>
<th>Vs (knots)</th>
<th>L oa (m)</th>
<th>V No. of voyage per day</th>
<th>Fare of passenger (¥)</th>
<th>Fare of vehicle (¥)</th>
<th>Share of passenger (¥)</th>
<th>Share of vehicle (¥)</th>
<th>Profit (million ¥)</th>
<th>NPV (million ¥)</th>
<th>IRR (%)</th>
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Table 8 Seven solutions of shares of fast passenger-car ferries with speed of 40-50 knots obtained using the new generalized cost model.

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<th>V No. of voyage per day</th>
<th>Fare of passenger (¥)</th>
<th>Fare of vehicle (¥)</th>
<th>Share of passenger (¥)</th>
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