The Schme for Maximizing the Potential of Data Assets: D&A System Maturity Evaluation Model

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Abstract: In modern corporate management, data plays a vital role in corporate governance and business operations. The management of Data and analytics (D&A) system covers three main aspects: people, technologies, and processes. Establishing a D&A system maturity evaluation model is critical to measuring and improving system effectiveness. We developed a model that evaluates the D&A system to help ICM corporation executives make the right decisions pertaining to people, technology, and process.

1. Introduction

In the age of an information explosion, the importance and value of data is self-evident, and more and more companies regard them as strategic assets. However, effectively exploring and utilizing all kinds of data is not easy as we suppose .To this end, the enterprises need to establish integrated data and analysis (D&A) systems that use and manage the data through professional personnel, technology and processes to serve the company's strategic decisions and improve operational efficiency. Combined with relevant information and requirements provided by ICM, our team has developed a model to evaluate the D&A system, contributing to maximized economic benefits.

Overview of Our Work:

Analyze and select some key performance indicators that measure the success of their D&A people, technologies, and processes

Develop a model that evaluates the D&A system to help company executives make the right decisions pertaining to people, technology, and process.

Define the effectiveness of the model, establish the relationship between the effectiveness and maturity, and propose a protocol standard for establishing a effectiveness evalution model based on the maturity evaluation model.

Simulate the process of ship arrival and departure, and adjust the maturity evaluationmodel to propose improvement suggestions for corporate governance.

This paper analyzes the key differences between large and small ports in the application of the model, and points out the improvement methods.

2. Symbols and Notations

Notations that we use in the paper are shown in the following table 1:

Table 1

Symbols	Definition
C_i	Secondary performance indicators
B_i	Primary performance indicators
A	Maturity level of system
W_{ij}	element in row i ,c olumn j
ω	Number of ship arrivals per unit time
M	Number of berth equipment
λ	Work efficiency of single machine
T	Docking time of single ship
ε	System effectiveness
P^*	Cost of improvement that the company can afford
P_i	Marginal cost of firm's increase of C_i
τ	Accuracy of maturity evaluation model

3. Model I Design: Maturity Valuation Model of d&a System-Based on AHP

3.1 Problem Analysis: the Maturity Evaluation Indicators of the Data Analysis System

Reexamine ICM's D&A system from a big data perspective, we extracted typical features that reflect the maturity of the data analysis system according to the principle of hierarchical classification,. In the process, the skill level, business ability and adequacy of the personnel of the D & A system, as well as the technical characteristics such as IT support, technical stability, work efficiency, and product adequacy, and the process performance such as communication, coordination and data consistency are all taken into consideration.

We extracted the relevant factors as the primary performance indicators. Simultaneously, the three indicators were divided based on the principle of comprehensiveness and mutual independence, yielding nine secondary influencing factors. All the indicators of the D&A system and their definition measures are shown in Table 2 and 3:

Table 2 Performance Indicators Of d&a System Maturity Level

Target	Primary performance indicators	Secondary performance indicators
(A) Maturity level of D&A system	People B_1	Employee skill level
		C_1 Employee business ability
		C_2 Employee adequacy ratio
	Technology B_2	C_3 IT Support
		C_4 Technical stability
		C_5 System efficiency
		C_6 Product adequacy
	Process B_3	C_7 Communication and Coordination
		C_8 C_9 Data consistency

Table 3 Indicator Defination And Measurement

Indicators	Proxy metrics	Measurement
C_1	Personal training rate	$\frac{\text{number of trainings conducted per year}}{\text{number of total staff}}$
C_2	Employee value rate	$\frac{\text{Company average salary}}{\text{industry average salary}}$
C_3	Employment rate	$\frac{\frac{\text{employee number}}{\text{company valuation}}}{\frac{\text{Average company employee number of the industry}}{\text{average company valuation of the industry}}}$
C_4	IT adequacy ratio	$\frac{\text{Number of computers owned by the company}}{\text{total employee number}}$
C_5	System accuracy rate	$1-\frac{\text{Number of errors per unit time}}{\text{Number of operations per unit time}}$
C_6	Technical on-time completion rate	$\frac{\text{number of timely completion per unit time}}{\text{Number of operations per unit time}}$
C_7	Product Content	$\frac{\text{Total number of products}}{\text{Total number of technologies}}$
C_8	Data turnover rate	$\frac{24}{\text{hours of transmission between data departments}}$
C_9	Data accuracy rate	$1-\left\|1-\frac{\text{obtained value of data}}{\text{real value of data}}\right\|$

We take the data consistency and transmission speed as the main indicators of process. The calculation method is shown in the table 2.

3.2 AHP Model: a Metric to Measure the Current d&a System Maturity Level for ICM

3.2.1 Establish a Hierarchy Structure

This paper comprehensively evaluates the maturity level of current D&A system based on AHP model-Based on the above analysis, we take the system maturity level into the target layer, the primary influence factors (personnel performance, technical performance and process performance) as into criterion layer, the secondary influence factor into the index layer, and the D&A system which needs to be evaluated as the scheme layer.

3.2.2 Construct the Judgment Matrix

The relative importance of each element expressed by the judgment matrix is usually represented by a scale of 1, 2, ..., 9 and its reciprocal. The specific meanings are shown in Table 2. we use Table 4 to give the method of converting the initial value of the indicator score (percentage scale) into the elements of the judgment matrix (1-9 scale).

Table 4 Scale Determination And Conversion Method of the Matrix Elements

Scale	W_{ij}(the element in row i 、 column j)	Conversion method(raw value to scale)
1	W_i and W_j are equally important	Difference is less than 2.5%
3	W_i is slightly more important than W_j	Difference is of 5%~7.5%
5	W_i is obviously more important than W_j	Difference is of 10%~12.5%
7	W_i is highly more important than W_j	Difference is of 15%~17.5%
9	W_i is extremely more important tha W_j	Difference is more than 20%
2、4、6、8	The importance of W_i compared with W_j is between the median of two adjacent judgments.	Difference is of 2.5%~5%、7.5%~10%、12.5%~15%、17.5%~20%

For the judgment matrix of the criterion layer and the index layer as follows :

$$B_1=\begin{bmatrix} 1 & \frac{1}{7} & \frac{1}{1} \\ 7 & 1 & 2 \\ 3 & \frac{1}{2} & 1 \end{bmatrix} \quad B_2=\begin{bmatrix} 1 & \frac{1}{5} & \frac{1}{3} & 3 \\ 5 & 1 & 2 & 4 \\ 3 & \frac{1}{2} & 1 & 2 \\ \frac{1}{3} & \frac{1}{4} & \frac{1}{2} & 1 \end{bmatrix} \quad B_3=\begin{bmatrix} 1 & \frac{1}{5} \\ 5 & 1 \end{bmatrix} \quad A=\begin{bmatrix} 1 & 1 & 2 \\ 1 & 1 & 2 \\ \frac{1}{2} & \frac{1}{2} & 1 \end{bmatrix}$$

3.2.3 Consistency Test and Weight Calculation

Calculate the consistency index (CI)

$$C.I.=\frac{\lambda_{\max}-n}{n-1}$$ (λ is the matrix maximum eigenvalue, n is the matrix order)

Check the table to determine the corresponding average random consistency index(RI)

Matrix order	1	2	3	4	5
R.I	0	0	0.52	0.89	1.12

Calculate the consistency ratio (CR) and judge $C.R.=\frac{C.I.}{R.I.}$

When C.R. <0.1, the consistency of the judgment matrix is acceptable and C.R.> 0.1, the judgment matrix is not meeting the consistency requirements and needs recorrection.In our model, all the above four matrices passed the consistency test.

Weight calculation

People performance (B_1) $y_1=\sum_{i=1}^{3}W_{1i}C_i$ Technology performance(B_2) $y_2=\sum_{i=4}^{7}W_{2i}C_i$

Process performance(B_3) $y_3=\sum_{i=8}^{9}W_{3i}C_i$ D&A System Maturity(A) $y=\sum_{i=1}^{3}W_i y_i$

Index	Score by experts
C_1	W_{11}=0.0925
C_2	W_{12}=0.6153
C_3	W_{13}=0.2922
C_4	W_{21}=0.1436
C_5	W_{22}=0.4974
C_6	W_{23}=0.2655
C_7	W_{24}=0.0935
C_8	W_{31}=0.8333
C_9	W_{32}=0.1667
B_1	A_{11}=0.4
B_2	A_{12}=0.4
B_3	A_{13}=0.2

Membership function is introduced to initially divide the system maturity level: $\partial=\frac{y-y_{\min}}{y_{\max}-y_{\min}}$

∂	[0,0.25)	[0.25,0.5)	[0.5,0.75)	[0.75, 0.9)	[0.9,1]
maturity level	very poor	poor	medium	Mature	very mature

List of metric weights

Table 5 : Weights Of Performance Indicators

Target layer	Criterion layer	Criterion layer weight	Index layer	Index layer weight
(A) Maturity level of D&A system	People B_1	0.4000	Employee skill level C_1	0.0370
			Employee business ability C_2	0.2461
			Employee adequacy ratio C_3	0.1169
	Technology B_2	0.4000	IT Support C_4	0.0574
			Technical stability C_5	0.1990
			System efficiency C_6	0.1062
			Product adequacy C_7	0.0374
	Process B_3	0.2000	Communication and Coordination C_8	0.1667
			C_9 Data consistency	0.0333

Analyzing the List of metric weights, the success of personnel and technology on the maturity of D&A system is equally important, and the contribution of the process is lower than that of the former two indicators.It can be explained that Personnel and technology are the main factors in the D&A system maturity measurement model.Besides,C2 ,C5 ,C8 are the most important components of C1 ,C2 ,C3 (Criterion layer) respectively.Specifically, among the performance indicators of C1-C9, C2 has the largest success to the D&A system maturity, with a weight of 0.2461

4. Model Ii Design:d&a System Effectiveness Evaluation Model and Analogue Simulation

When a cargo ship pulls into the port, this movement of cargo generates a significant amount of data.

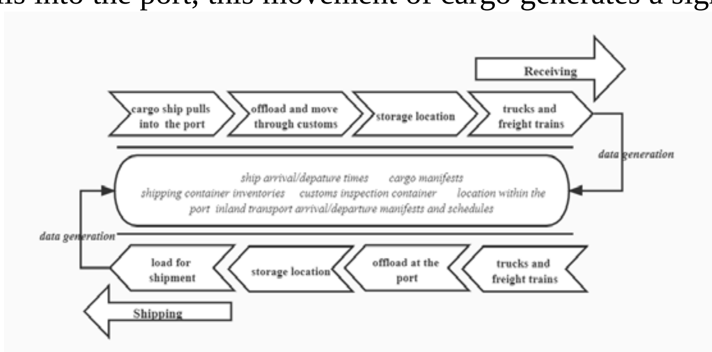

Fig.1 Flow Chart of Port Operation

4.1 Effectiveness Evaluation of Maturity Level Measurement Model &Recommendations of System Modification

4.1.1 Effectiveness Evaluation of Maturity Level Measurement Model

To maximize the potential of ICM corporation's data assets, effectiveness of D&A system should be promoted and time in port should be minimized.First, The improvement of the system through the maturity model can effectively shorten the ship time in port.

Model assumptions:All ships have the same model and the same cargo capacity; The number of ship arrivals per unit time obeys Poisson distribution; The operation time of land transportation and sea transportation is equal; The timetable is the optimal arrival time of land vehicles.Based on the aforementioned assumptions, we build a simplified effective evaluation model. The following calculation formulas are obtained:

$$T_S = T_{S1} + T_{S2} = T_{S1} + \frac{\omega}{M * \lambda} \quad (1) \qquad T_C = T_{C1} + T_{C2} = T_{C1} + \frac{\omega}{M * \lambda} \quad (2) \qquad T_T = T_{S1} + T_{C1} + \frac{2\omega}{M\lambda} \quad (3)$$

Ts/Tc is ships/trucks waiting period in port, Ts1/Tc1 is ships/trucks waiting period for working, Ts2/Tc2 is ships/trucks working period

Since the waiting times of ships/trucks are positively related to process performance, then:

$$T_{S1}+T_{C1}=\frac{A}{e^{B_3}-1} \quad (4)$$

The number of berth equipments M is an exogenous variable,influenced by port size and other indicators, which can be set as a constant.The determination of single-alone operation efficiency is a random event, which is directly affected by the people performance (B1) of D&A system , technology stability (C5) of data processing, system work efficiency (C6), process performance(B3), port scale, land transport punctuality θ , weather, we focused on the former five variables.According to the literature, the relationship between efficiency and performance can be measured by the exponential function, so the following equation is set to determine the single-machine operation efficiency:

$$\lambda = ae^{B_1}+be^{C_5}+ce^{C_6}+de^{B_3} \quad (5) \qquad T=\frac{A}{e^{B_3}-1}+\frac{2\omega}{M(ae^{B_1}+be^{C_5}+ce^{C_6}+de^{B_3})} \quad (6)$$

T is the total docking time of one single ship;a,b,c,d are all function parameter

4.1.2 Analogue Simulation Based on the Effectiveness Evaluation Model

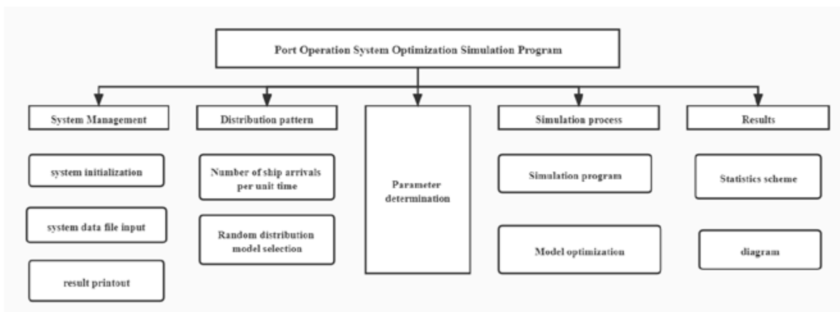

Fig.2 Process of Port Operation System Optimization Simulation Program

Based on the above effectiveness evaluation model, we conducted a simulation of the port ships.

Table 6 : Simulation Scores of Indicators Inmaturity Evaluation Model

Indicators	Proxy metrics	Measurement	Simulation score
C_1	Personal training rate	$\frac{\text{number of trainings conducted per year}}{\text{number of total staff}}$	0.73
C_2	Employee value rate	$\frac{\text{Company average salary}}{\text{industry average salary}}$	1
C_3	Employment rate	$\frac{\frac{\text{employee number}}{\text{company valuation}}}{\frac{\text{Average company employee number of the industry}}{\text{average company valuation of the industry}}}$	1
C_4	IT adequacy ratio	$\frac{\textit{Number of computers owned by the company}}{\text{total employee number}}$	0.5
C_5	System accuracy rate	$1-\frac{\text{Number of errors per unit time}}{\text{Number of operations per unit time}}$	0.95
C_6	Technical on-time completion rate	$\frac{\text{number of timely completion per unit time}}{\text{Number of operations per unit time}}$	0.75
C_7	Product Content	$\frac{\textit{Total number of products}}{\textit{Total number of technologies}}$	1.5
C_8	Data turnover rate	$\frac{24}{\text{hours of transmission between data departments}}$	1.5
C_9	Data accuracy rate	$1-\left\lvert 1-\frac{\text{obtained value of data}}{\text{real value of data}}\right\rvert$	0.5

4.1.3 Sensitivity Analysis of Effectiveness Evaluation Model

Table 7 :Sensitivity Analysis Results

	Initial result	Change of C_1		Change of C_2		Change of C_3	
		-10%	+10%	-10%	+10%	-10%	+10%
Mean of the total docking time of a ship	1.9511	1.9512	1.9511	1.9515	1.9507	1.9513	1.9509
Compared to the initial result (absolute value)		0.0001	<0.0001	0.0004	0.0004	0.0002	0.0002
Relative rate of change (absolute value)		<0.01%	<0.01%	0.02%	0.02%	0.01%	0.01%
	Change of C_5		Change of C_6		Change of C_8		Change of C_9	
	-10%	+10%	-10%	+10%	-10%	+10%	-10%	+10%
Compared to the initial result (absolute value)	0.0053	0.0053	0.0018	0.0018	0.2161	0.1789	0.0131	0.0129
Relative rate of change (absolute value)	0.27%	0.27%	0.09%	0.09%	11.07%	9.17%	0.67%	0.66%

Observing the table, it is obvious that the sensitivity of C8 is significantly higher than that of other variables. Therefore, C8 is modified from 1.5 to 4, The operating simulation results of using a computer program are shown in Figure 3 below. Effectiveness of The D&A system is improved.

Simulation times:365 Single unit efficiency:1.052

Frequency	Number of ships arriving at port per unit time	Total docking time per ship
1	3	1.85482
4	5	1.87383
4	6	1.88334
9	7	1.89285
17	8	1.90235
25	9	1.91186
34	10	1.92136
31	11	1.93087
40	12	1.94037
41	13	1.94988
40	14	1.95938
29	15	1.96889
24	16	1.97839
18	17	1.98790
14	18	1.99741
15	19	2.00691
10	20	2.01642
1	21	2.02592
4	22	2.03543
1	23	2.04493
1	24	2.05444
2	25	2.06394

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Simulation times:365 Single unit efficiency:1.1751

Frequency	Number of ships arriving at port per unit time	Total docking time per ship
1	3	0.59472
4	5	0.61174
4	6	0.62025
9	7	0.62876
17	8	0.63727
25	9	0.64578
34	10	0.65429
31	11	0.66280
40	12	0.67131
41	13	0.67982
40	14	0.68833
29	15	0.69684
24	16	0.70535
18	17	0.71386
14	18	0.72237
15	19	0.73088
10	20	0.73939
1	21	0.74790
4	22	0.75641
1	23	0.76492
1	24	0.77343
2	25	0.78194

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Fig.3 Simulation Results Before and after System Modification

4.1.4 Result Analysis and Modification Suggestions of d&a System

The sensitivity of C8 is the greatest and the weight is high as well, so the communication and coordination level of various departments in the process performance has positve effects on the system effectiveness.

4.2 Evaluation of System Effectiveness Based on Goal Planning

4.2.1 Assumptions

The company improves the people, technology and process performance,corresponding Ci increases Li on the original basis.The corresponding cost for each increase of 1 unit of A is Pi ,the number of equipment increases Qi , the number of personnel increases Hi, and the marginal cost remains unchangeICM Corporation faces cost and resource constraints as improving its performance. The maximum cost that the company can afford is P* ,the maximium number of equipments is Q* ,maximium number of employees is H*

4.2.2 Optimization Decision

The maturity score after improvement is

$$y' = \sum_{i=1}^{3} W_{1i} C_i (1+L_i) + \sum_{i=4}^{7} W_{2i} C_i (1+L_i) + \sum_{i=8}^{9} W_{3i} C_i (1+L_i) \quad (7)$$

The company's improvement system has cost restrictions, equipment quantity restrictions, and peoplel restrictions. The number of equipment P is related to location and infrastructure, and the variables that affect it are (C4 ,C5 ,C6 ,C7 ,C8), while the number of employees is related to management difficulty and personnel security. related to facilities, and the variables that have an impact on it are (C3 ,C6 ,C8). Using objective planning to maximize the improved maturity score, the following constraints need to be met at the same time:

$$\text{st.}\begin{cases} L_i \geq 0 \\ \sum_{i=1}^{9} P_i L_i \leq P^* \\ \sum_{i=4}^{9} Q_i L_i \leq Q^* \\ \sum_{i=1}^{3.6.8} H_i L_i \leq H^* \end{cases} \quad (8)$$

By consulting the data, we determined the marginal cost of improving each indicator score by 1 unit, when the C2 increase is 16.7% , the C5 increase is 100% , and the C8 increase is 100% , all the constraints are met, and the final maturity is increased to a maximum of 0.48 .

5. Model Iii Design:Protocol between Maturity and Effectiveness of d&a System

5.1 Based on the Maturity Evaluation Model

To quantify how accurately the maturity model measures system effectiveness , we recommend that ICM companies develop protocols that define system effectiveness and calculate how accurate the maturity model is.

Define $\tau = \left(\frac{1}{y - \frac{1}{E(T)}} \right)^2$ (9) Since $y = \sum_{i=1}^{3} W_{1i} C_i + \sum_{i=4}^{7} W_{2i} C_i + \sum_{i=8}^{9} W_{3i} C_i$; $T = \frac{A}{e^{B_3} - 1} + \frac{2\omega}{M(ae^{B_1} + be^{C_5} + ce^{C_6} + de^{B_3})}$ (τ is a nine-dimensional function of the indicator)

For each set of identified indicators, a unique maturity model accuracy can be calculated as τ . Therefore, the scope of application of the maturity evaluation model depends on the value of the indicators.

5.2 Based on the Goal Planning Model

In order to make the maturity evaluation model more feasible, we ignore the above-mentioned concerns about the accuracy bias of maturity evaluation. According to the traditional system evaluation theory, we assume that maturity A can directly represent the system effectiveness , and there is a relationship between it and the effectiveness. There is a definite functional relationship. Set to ε system availability.

According to the data, $f(\rho)$ is generally an exponential function, so that

$$\varepsilon = \begin{cases} 1, \rho \geq \xi_2 \\ ke^{\rho}, \rho \in [\xi_1, \xi_2] \\ 0, \rho \leq \xi_1 \end{cases} \quad (10)$$

If $\rho = \xi_2$, $\varepsilon = 1$, we can solve for $k = \left(\frac{1}{e}\right)^{S_2}$ therefore,

$$\varepsilon = \begin{cases} 1, \rho \geq \xi_2 \\ e^{\rho - \xi_2}, \rho \in [\xi_1, \xi_2] \\ 0, \rho \leq \xi_1 \end{cases} \quad (11)$$

The system effectiveness is calculated according to the maturity ε, when the maturity reaches a certain value, the system is considered to be effective, and when it exceeds a certain critical value, the effectiveness is considered to be the maximum value of 1.According to the actual situation of system operation and the specific requirements of business needs, let ξ_1 =0.1, ξ_2=0.75 . We recommend that ICM company develops the following protocols:When the system maturity is lower than 0.1, it is determined that the system is invalid;When the system maturity is between 0.1 and 0.75, it is considered that the system has a certain effectiveness;When the system maturity exceeds 0.75, it is considered that the system is always effective.

6. Conclusion

In our model, a method for measuring system maturity is established from three aspects: people, technology and process. We simulate the above model, and verify the feasibility of the above evaluation system through the relevant data of the industry status. The model is applicable in different situations, which further verifies the feasibility and practical value of the model. Therefore, managing D&A systems by using the maturity assessment model we developed can bring great value to the company. Rolling out the model to ICM's clients will also generate positive externalities for the maritime industry as a whole.

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