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Development of the Speed Limit Model for Harbour and Waterway(Ⅱ) - The Method of Speed Limit Decision and Application -

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Abstract : *This research is the result on calculating the logical speed limit through certain process which some elements must be considered on selecting the speed limit of harbour and waterway. The suggested speed limit select model on this research is processed from 1~6 steps by forming a professional group of experts. Each step has its information which 1st step(water division), 2nd step(selecting the model vessel and vessel applied with speed limit.), 3rd step(selecting the maximum and minimum speed range on each section), 4th step(evaluation on the safeness of traffic), 5th step(suggesting the appropriate speed limit), 6th step(execution and evaluation.). The appropriate speed limit was decided on consideration of the safety of maritime traffic on the range of the maximum speed and the minimum speed. This model was used to derive the appropriate speed limit on the harbour water and Busan harbour entrance waterway. As the result, the harbour water was calculated to be 6.9 knots, the appropriate speed limit of Busan entrance harbour was 9.3 knots. The present calculation of the speed limit on the approaching channel area is 10 knots, inner harbour area is 7 knots, which are similar to the result of the speed limit. This research is the first research on selecting the speed limit model and has its limits on finding the perfect speed limit result. More detailed standards on the safeness of traffic evaluation must be found and additional study is necessary on discriminating consideration of the elements. This research has its value which it provides instances of aboard cases on guidelines of selecting the speed limit.*

Key Words : *Speed limit, Maximum speed, Maritime traffic, Traffic evaluation, Speed limit decision*

1. Background of the research

The speed limit not only has the purpose to simply reduce speed, it is a method to prevent accidents and to have efficient traffic flow with constant speed of transition for cars and vessels in a speed restricted areas. Also in sea, it is a method used for increasing the calmness of the harbour by reducing the size of the sailing wave caused from the moving vessel and not to forget, it is also a guide for efficient traffic flow and prevention of marine accidents.

In korea, out of 31 commerce harbours, 21 harbours use the appointed speed limits. As the vessel gets greater and faster, the vessel operators and people in marine industries are requesting the improvement of the speed limit, but there are request of reducing the speed limit regulation from the skippers around the harbour and around the entrance of the harbour who are associated in fishing industries. But the reality is cruel, where both industries are unsatisfied due to having a different approach to the speed limit. And the reason for this is because we do not have a standard for an average model needed for selecting the speed limit(Kim et al., 2012).

Speed limit is not only decided on the safety of the vessel, but the economical aspect and efficiency of the operation of harbour. The effects that were caused around the harbour and waterway are to be considered as well. So, it can't be decided with emphasizing on just one aspect.

In this research, certain aspects are to be considered when deciding on the speed limit. The main focus is to deduct on the speed limit logically through a certain method, where a model should be developed that can decide the speed limit.

2. Method of research

The research was processed as following to make the speed limit select model of waterway and harbour.

(1) To find out the reasons for selecting the speed limit and the speed limit standard that are presently selected in the country's harbour, a survey was done with phone call with each regional marine harbour station's civil servant and

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VTSO(Vessel Traffic Service Operator).

(2) To find out the real situation of traffic within the vessels and to speculate on the speed limit, the vessel's speed was investigated and analyzed from data obtained for 10 days with AIS(Automatic Identification System).

(3) The speed limit standard and selecting method of world's major harbours were analyzed.

(4) When deciding on the speed limit, the AHP(Analytic Hierachy Process) survey and survey using Delphi method was processed with group of experts to find out the consideration factors. The Delphi method was used to discriminate the 23 consideration factors which are heavily related with speed limit, and the AHP method was used for the discriminated consideration factors. The priorities(weight) for each consideration factor was derived.

(5) To come up with logical speed limit, a speed limit select model was suggested in 1~6 steps. The speed limit select model used the traffic safeness evaluation, weight and consideration factors from above. The traffic safeness evaluation only considers factors that are heavily related to the speed limit. The traffic safeness evaluation standard is based on the evaluation standard which includes the marine safety law, country's law, harbour and fishery design criteria, PIANC(Permanent International Association of Navigation Congresses) rule, marine traffic engineering, experts' opinion.

(6) The appropriate speed limit was decided with consideration of marine traffic safeness within the range of max. speed and mini. speed a vessel can have within its water.

(7) This model was used to derive the appropriate speed limit of inner harbour water and approaching channel area of Busan port.

The results of the research processed (1)~(4) are same as Kim et al.(2012) and Kim et al.(2015) and this research is the result of (5)~(7).

3. Proposal of speed limit model

The speed limit model(SL model) is accomplished through 1st step to 6th step, by gathering a group of professionals who are related to the vessel operation and management of the harbour. when the group of professionals present their opinions on each step, they deduct and present the final appropriate speed limit cost by accomplishing the task of evaluation, survey and other method. the SL model at last, is the process model that finds the speed that the user and operator thinks it is logical, using the harbour facilities directly or indirectly. the fig. 1 shows the operating process of the SL model.

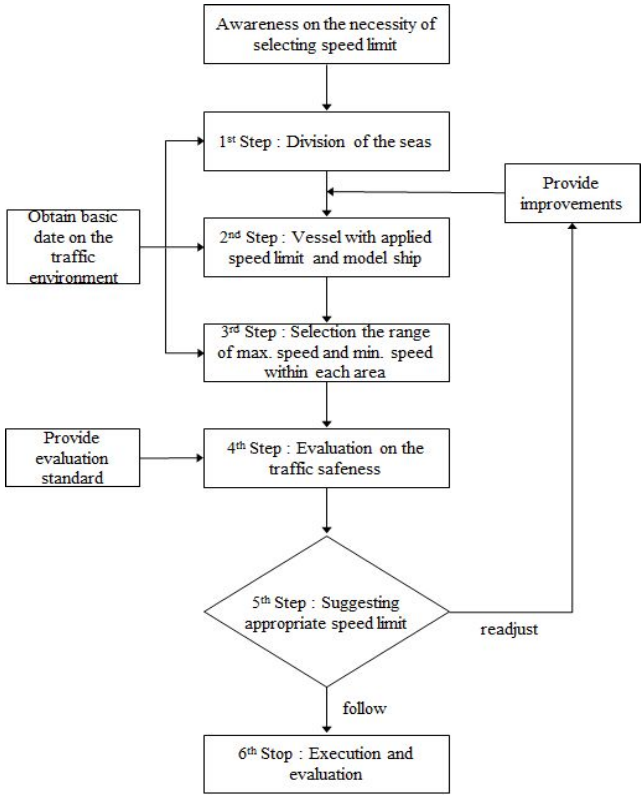

Fig. 1. Procedures of the speed limit model.

3.1 Division of sea areas(1st step)

It is the first step of SL model, and it is divided into 3 big types of sea areas which are sea areas that need speed limit which are stationing, entering and leaving sea area, entrance of the sea area and open sea areas. These three types of sea areas cannot be decided easily by finding related literature or some kind of law enforcement. it is necessary to base on the definition of sea area under the composition of consultation on members of a committee by the traffic related professionals, vessel professionals, VTSO, pilot and director of harbour management who are bright with harbour situations. The essay is defined as followed.

(1) Open sea : It doesn't get bothered by sea obstacles or obstacles on top of the sea like island, water bridge, drilling vessel and marine wind power plant facilities. It is also possible for the vessel to sail freely.

(2) Approaching channel sea : It is a harbour used for the vessel

to enter a certain harbour for sea areas that can be protected from the sea or sea obstacles. In the other hand, it is an open sea without sea obstacles and sea, but it was appointed by the mother country of the harbour for fluent traffic flow.

(3) Maneuvering area : sea areas where it needs to reduce it's speed by less than 10 knots for entering and leaving port.

3.2 selecting the model ship and the vessel applied with speed limit(2nd step)

3.2.1 Vessel applied with speed limit

In Korean harbour, it shows a big difference for each harbour of the vessel applied with speed limit and unapplied vessels. Most of the harbour divides the vessels with size, but some harbours divide the vessel with type and carried cargo(ex. dangerous cargo ship). The speed limit is used as the measure of management to administrate the speed of the sailing vessel. In the limited waterway, when unapplied vessel's sailing and overtaking of applied vessel is repeated, there can be lots of stress for many vessel sailors using the appointed water where it can bother safe traffic flow.

So, it is judged to be a more logical method to divide the non monitored vessel and VTS monitored vessel rather then dividing by vessel's carried cargo, size and type.

3.2.2 Model ship

The model ship is selected as the high frequent entering vessel or model vessel of the biggest vessel which is expected to enter the appointed harbour which needs the 4th step(traffic safeness evaluation). In the research, the biggest vessel was selected as the model ship.

3.3 Selecting the range of maximum and minimum speed(3rd step)

3.3.1 Max. speed each area

The possible maximum speed of the areas means that out of the vessels sailing in according sea areas, the ideal maximum speed that it can have in each area if the biggest vessel doesn't get bothered by other vessels or doesn't get effected by the wave.

(1) Open sea area : For vessels using the according open sea area, it applies the navigation full speed(NFS) that the biggest vessels can have. For the loaded state of different sizes of VLCC, the maximum speed is in the range of 14.7~16.5 knots like the shown table 1(Yoon, 2002). table 2 is showing the maximum speed and has researched on biggest vessel of different types of vessel, the container vessels with 10,000TEU has the maximum speed of 24.4 knots with loaded state, the car carrier is 19.5 knots with 8,000 cars being avaliable, LNG carrier is 19.0 knots with 130,000 tons and bulk is 15.1 knots with 180,000 tons(SHI, 2010; HSHI, 2008; DHSC, 2011; HHIC, 1995).

Table 1. Speed by VLCC sizes at full loaded condition

D.W.T (ton)	L.O.A (m)	Breath (m)	Depth (m)	Draft (m)	Max. Speed(kn)
50K	221	30.5	15.7	12.2	16.1
100K	262	40.4	20.9	14.8	16.5
150K	294	46.2	25.0	16.6	16.1
200K	317	50.0	24.3	18.2	16.5
250K	336	54.5	26.0	19.6	16.5
300K	346	53.3	32.0	24.7	15.1
450K	378	62.0	36.0	28.2	14.7

Table 2. Speed by ship's type at full loaded condition

Division	Container ship	PCC (PCTC)	LNG carrier	Bulk carrier
D.W.T(ton)	118,800	74,000	130,000	180,000
L.B.P(m)	334	222.4	257	283
NFS(kn)	24.4	19.5	19.0	15.1
Remarks	10,000TEU	8,000CEU	130K	180K

(2) Approaching channel area : In the approaching channel, the engine always has to be ready for use of the vessel because the navigational obstacles increase due to vessels often sailing. Normally, when a vessel enters the entrance of waterway, it lowers NFS to the maneuvering full speed(MFS). The MFS normally has the range of 70~75 % for the NFS speed, and statistically there is a research saying that the range is between 14~15 knots. The maximum speed of the waterway entrance uses the MFS of the biggest vessels for the expected sailing of according sea areas, or statistical MFS 14~15 knots is applied. But if the biggest vessel's MFS is lower than statistical MFS, the engine has to be lowered to the next step of MFS, the half ahead to keep the speed limit of standard vessel. And due to this, it brings about heavy traffic and reduction of sailing speed of all the harbours.

(3) Maneuvering areas(in harbour): The stoppable speed has to be maintained for vessels at anytime in the harbour maneuvering areas. Table 3 is showing the stopping distance

on each speed of container vessel with more than 10,000 TEU and due to the speed inertia, 8.216 m of 24.6 L distance is needed to stop the vessel and unless the crash stop is used, it can't be determined that it is a safe speed(SHI, 2010). Like the table 4, in the maneuvering area (within 6NM of distance from the harbour) speed was less than 9 knots according to the plan of Daesan standard pilotage(Daesan Harbour Pilot's Association, 2014). in the marine traffic examination, the sailing speed was examined as 9~10 knots for vessels sailing the according water area. So, the maximum speed is 9~10 knots.

Table 3. Stopping distances of 10,000TEU class container ship

Division	Speed (kn)	Shortest stopping distance (Crash stop)	Normally stopping distance (Inertia stop)
NFS	24.4	15.5 L	35.5 L
MFS	13.5	4.3 L	24.6 L
Half ahead	9.1	2.5 L	15.3 L
Slow ahead	6.7	1.7 L	6.0 L
Here, L is L.B.P(334 m) of 10,000TEU class container ship.			

Table 4. Standard pilotage speed per distance of VLCC

Distance from berth to ship(NM)	Speed (kn)	Remarks
9	12~13	MFS
6	9	
3	5	
1	3	
0.3	1	
The front of wharf(within 2B)	0	First stop

3.3.2 The minimum speed

For any kinds of sea areas, it is logical to see the minimum speed as the possible maneuvering speed(normally 5~7 knots). the speed limit less than the possible maneuvering speed can't control the vessel itself, so there is no meaning behind it.

3.4 Evaluation of the traffic safeness(4th step)

The evaluation of the traffic safeness is processed through 23 consideration factors obtained from the survey research. Each categories of evaluation standard and risk factors were selected through group of experts' opinion. The evaluation standard should try to use specific data with evidences, but if there is no evident for the data, standard is built through process of total derivation.

3.4.1 Risk factors and evaluation standard of speed limit consideration factors

Table 5~11 below shows the risk factors and evaluation standard of each consideration factors. The risk factors and evaluation standard need to be shown from 23 categories, but 18 categories are excluded where the information are just labeled on 5 categories which are traffic hazard, vessel maneuvering ability, shortest distance of stopping, visibility, and tidal wave.

Table 5. Evaluation criteria and risk index about visibility

Risk factors	Evaluation standard
1	7 days less than
2	7~30 days
3	30~90 days
4	90~180 days
5	more than 180 days
Here, the dates are the summation of fog, rain, snow days.	

Table 6. Evaluation criteria and risk index about transverse current

Risk factors	Evaluation standard
1	0.2 knot less than
2	0.2~0.5 knot
3	0.5~1.5 knot
4	1.5~2.0 knot
5	more than 2.0 knot

Table 7. Evaluation criteria and risk index about longitudinal current

Risk factors	Evaluation standard
1	1.5 knot less than
3	1.5~3.0 knot
5	more than 3.0 knot

Table 8. Evaluation criteria and risk index about crash stop distance

Risk factors	Evaluation standard
1	6 L less than
2	6~9 L
3	9~12 L
4	12~15 L
5	more than 15 L
Here, L is ship's L.B.P(m)	

Table 9. Valuation criteria and risk index about traffic congestion

Risk factors	Evaluation standard
1	TC is 30 % less than
2	TC is 30~40 %
3	TC is 40~50 %
4	TC is 50~60 %
5	over than TC is 60 %
Here, TC is traffic congestion	

Table 10. Evaluation criteria and risk index about ship maneuverability

Risk factors	Evaluation standard
1	Good (Sum of score is 3 point)
3	Normal (Sum of score is 4~6 point)
5	Bad (Sum of score is 7~9 point)

Score of ship's maneuverability	Evaluation standard		
	Ad	TD	$\alpha 20_1$
1 point	less than 2.5L	less than 3.0L	less than 18°
2 point	2.5~3.5L	3.0~4.0L	18~22°
3 point	3.5~4.5L	4.0~5.0L	22~25°
Here, Ad(Advance), TD(Tactical diameter), $\alpha 20_1$(First angle of 20/20 Overshoot angle test), L(Vessel length), Score of ship's maneuverability is sum of the score of Ad, score of TD and score of $\alpha 20_1$			

3.4.2. Making the table 11 of integrated result from the traffic safeness evaluation

The method of making the table of integrated result is like the table 8 as followed.

① The given danger index cost that was from the 3.4 chapter of evaluation standard is filled up on the unit from the danger index of the table of integrated result.

② The weight unit(f) that was calculated from each element using the AHP method is filled up on the unit from the weight unit of the table of integrated result.

③ The third SE_{score} of the table of integrated result is the cost multiplied from the danger index(r) and weight unit(f) and it means the score of safeness evaluation of each element.

④ SE_{total}(total score of the safeness evaluation) on the table of integrated result is the all added cost of SE_{score} found from the third harbour.

when the top process is organized as a formula, it is just like the below formula (1).

$$SE_{total} = \sum_{k=1}^{n} SE_{score} \quad (1)$$

where SE_{total} is the total point of the safeness evaluation, the summation of 1st safeness evaluation elements score to the last 23rd safeness evaluation elements score; SE_{score} is Calculated with $R \times f$ and is the evaluation safeness score on each section. R is the risk factors and f is the weight by AHP survey.

The maximum cost of the SE_{total} is 5.0 and the minimum cost is 1.0. when the SE_{total} gets closer to 5.0, it means that 'the danger level of the harbour is high'.

3.5 Suggesting the appropriate speed limit(5th step)

The appropriate speed can be defined as considered speed with safeness around the place within the range of maximum speed and minimum that a vessel can have in an ideal condition. In this research, the appropriate speed limit is decided with safeness evaluation result cost being subtracted within the range of maximum speed and the minimum speed a vessel model can have.

$$SL = SP_{\max} - a \times b \quad (2)$$

where SL is the appropriate speed limit(knot); $SP_{\max}$ is the maximum speed that has been negotiated in the process of 3rd step(knot); a is the difference of the minimum speed and the maximum speed that has been negotiated in the process of 3rd step(knot); b is the cost for converting the SE_{total} of safeness evaluation to the speed.

The 'b' is the cost of conversion from the danger index to the speed. It is a divided from 10 once again, after multiplying it with 2 for converting the measure of 10 points from the measure of 5 points of safeness evaluation SE_{total}.

$$b = \frac{2 \times SE_{total}}{10} = 0.2 \times SE_{total} \quad (3)$$

where SE_{total} is the total point of the safeness evaluation(sum of 1st~23rd SE_{score}).

Table 11. Making the table of integrated result

Division	Evaluation elements	① Risk factors (R)	② Weight (f)	③ SE_{score}
1	Visibility	3	0.085	0.255
2	Height of wave	4	0.025	0.100
3	Current	5	0.051	0.255
4	Wind	3	0.034	0.102
5	Crash stop distance	5	0.040	0.200
⋮	⋮	⋮	⋮	⋮
20	Possible to using tug	1	0.045	0.045
21	Possible to pilot	1	0.044	0.044
22	Possible to VTS assistance	1	0.033	0.033
23	Past marine accidents occurrence numbers	5	0.017	0.085
SE_{total}		-	1.0	④ 2.862

Here, R : The risk factors cost with appointed evaluation standard following the chapter 3.4

f : weight by the result of AHP survey, refer to Kim(2015)

SE_{score} : Calculated with $R \times f$ and is the evaluation safeness score on each section

SE_{total} : The total point of the safeness evaluation(sum of 1st~23rd SE_{score})

3.6 Execution and evaluation(6th step)

In the 5th step, the speed limit was decided but before enforcing it with statute or harbour management guideline it is necessary to have a period of testing operation. This period of testing evaluation is properly estimated to be 1~3 months. During this testing operation period, a procedure of readjustment on the problems found during the test is needed. Evaluation on the speed limit is done to see if it has accomplished the first goal it had, and has to be identified to see the effect it is causing on economic aspect and harbour operation of the speed limit.

4. Application of the SL model

To apply the speed limit decide model, the Busan harbour was selected as the research harbour. The Busan harbour ranked 1st place in amount of traffic and is named for frequent traffic from various vessel including large cargo ship. It is a harbour with high marine accident occurrence compared to other and has big standard deviation and average speed. Also, it's named for having consistent problems for having proper speed limit selected presently.

4.1 Division of water(1st step)

For Busan port, open water, deceleration water, and stop water hasn't been decided where it was divided like fig. 2 through group of experts' advisory.

(1) Approaching channel area(A area) : 3NM water centering from the end of Jodo breakwater.

(2) Maneuvering area(B area) : Fairway (about 2.5NM) from inner harbour breakwater to Jodo breakwater.

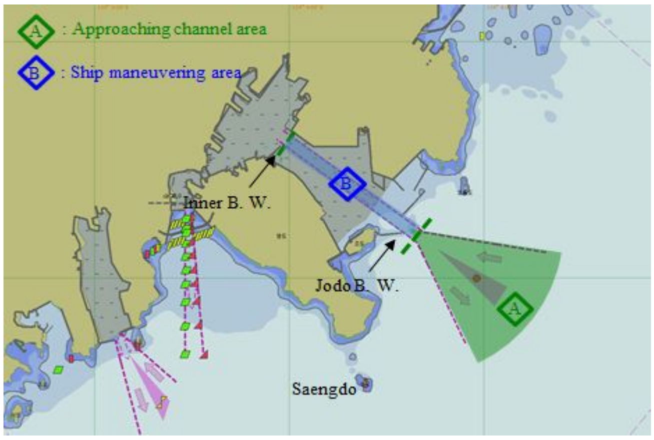

Fig. 2. Division of water in Busan port.

4.2 Selecting of the model ship(2nd step)

Busan container pier depth is estimated to be 11~16 m, and it is normally known that the biggest vessel to enter Busan harbour is 8,000TEU container.

Recently there was an incident where 9,200TEU, 9,600TEU, 14,000TEU container ships were entering the Busan harbour. But if the following vessels enter the Busan harbour in full loading condition, they get restricted on the draft. The A area and B area's average tide level is 1.2 m, and the max. and min. depth like blow table 12. So, in the research, the 10,000TEU container ship was selected as the Busan harbour's biggest vessel so it was selected as the model vessel. The table 13 and table 14 shows the speed of the model ship and main specification of the model vessel(SHI, 2010).

Table 12. Depth of the A area and B area

Division	Max. depth(m)	Min. depth(m)	Average tide level(m)
A area	31.2	30.0	1.2
B area	16.2	15.0	1.2

Table 13. Specification of the model ship

Division	Ship’s condition	
	Ballast	Full loaded
Ship’s type	10,000TEU class container ship	
L.O.A	349.6 m	
L.B.P	334.0 m	
Breadth	45.6 m	
Depth	27.2 m	
Gross tonnage	113,412 tons	
D.W.T	118,800.4 tons	
Draft(mean)	7.4 m	15.0 m
Displacement	64,827 tons	155,920 tons
Main propulsion output	MCR 93,360 BHP×102 RPM	

Table 14. Speed of the model ship

Eng. order	R.P.M	Speed each ship’s condition	
		Ballast	Full loaded
NFS	98.5	26.18	24.42
MFS	55.0	14.30	13.46
Half ahead	39.0	9.73	9.15
Slow ahead	30.0	7.15	6.73
Dead slow ahead	23.0	5.15	4.85

4.3 Selecting the range of max. and min. speed of each water(3rd step)

1) Approaching channel area(A area)

The approaching channel area in Busan port is an area from Jodo breakwater to 3NM where the traffic separation scheme is applied and has a spot for pilot aboard/discharge and is a mixture of vessels that are trying to enter/leave harbour following the fairway and vessels that are trying the leave the fairway and sail. Also, there are lots of small vessels trying to move from Oryukdo to Taejongdae. In such water, it is preferred to sail in maneuvering full speed, where you can reduce the speed at any time. The max. speed of entering waterway should apply the MFS(15 knots) for normal vessels and select the MFS(13.5 knots) of the model vessel. When the MFS of model ship is lower than MFS of normal vessel, it is preferred to see max. speed as the normal vessel MFS speed. So, the max. speed of A area selects the MFS 15.0 knots of model ship as the max. speed.

The min. speed has to be steerageway. This is because speed limit under steerageway is meaningless. The model vessel's steerageway is 4.85 knots of loaded condition as is set as the min. speed of this water.

2) Maneuvering areas(B area)

Maneuvering area(B area) has to maintain the condition where the vessel can be stopped at anytime and has a short distance between the fairway and the pier. It also has to have a quick speed where it doesn't bother other vessel within the approaching area. During the vessel sailing, when one tries to stop the vessel by putting full astern from advance engine, the RPM is normally between the Dead slow ahead to slow ahead where it is the starting point where the starting air is produced for starting up the reverse engine. During this time, the vessel speed is 7~9 knots.

Daesan harbour's standard pilotage method is that it is appropriate to maintain 9.0 knots, if the remaining distance from present position to approaching position is 3NM(Daesan Harbour Pilot’s Associationt, 2014). So, the max. speed of B area is 9.0 knots, and the min. speed is steerageway 4.85 knots.

4.4 Evaluation of the traffic safeness (4th step)

1) Evaluation on the safeness of traffic on the A area

Table 16 is the overall result table of A area. This result is the result of the risk factors and the evaluation standard of traffic safeness on chapter 3.4. The total point of evaluation on the A area was calculated to be 2.862 followed by formula (1).

2) Evaluation on the traffic safeness on the B area

The total point of the evaluation on the safeness of B area was derived to be 2.615 following the formula (1).

4.5 Suggesting the appropriate speed limit(5th step)

Table 15 is the cost of the result on deriving from the speed limit of the A area and B area using the formula (2). On the research, the B area was calculated to be 6.46 knots and the A area was 9.2 knots for the suggested by the SL model.

Currently, this water's speed limit of the A area is 10 knots, the B area is 7 knots(Busan Regional Maritime Affairs & Port Office, 2008), showing the difference of 0.8 knots and 0.54 knots compared to the appropriate speed limit of the SL model. This research is the first research on the speed limit select model, and it suggested result of method on deriving the appropriate speed limit, priorities, consideration factors when deciding on the speed limit. The suggested speed limit select model's feasibility verification is to be waited.

Table 15. Result of SL model

Division	A area	B area
$SP_{\max}$	15.0kn	9.0kn
$SP_{\min}$	4.85kn	4.85kn
a	10.15kn	4.15kn
SE_{total}	2.862	2.615
Result of SL model	9.2kn	6.46kn
Present speed limit	10kn	7kn
Present average speed	12.2kn	10.7kn

The derivation process of the speed limit of A area is as followed.

$$SL = SP_{\max} - a \times b \ = 15.0 - 10.15 \times 0.2 \times 2.862 = 9.2kn$$

The derivation process of the speed limit of B area is as followed.

$$SL = SP_{\max} - a \times b \ = 9.0 - 4.85 \times 0.2 \times 2.615 = 6.46\,kn$$

Table 16. Overall result of traffic safety assessment in the approaching channel area(A area)

Division	Evaluation elements	Risk factors (R)	Weight (f)	SE_{score}
1	Visibility	3	0.085	0.255
2	Height of wave	4	0.025	0.100
3	Current	5	0.051	0.255
4	Wind	3	0.034	0.102
5	Crash stop distance	5	0.040	0.200
6	Ship’s draft	5	0.030	0.150
7	Steerageway	3	0.055	0.165
8	Ship maneuverability	5	0.073	0.365
9	Ship’s wake	2	0.021	0.042
10	Headway or distance between ship to ship	3	0.058	0.174
11	Traffic flow	3	0.050	0.150
12	Traffic volume or traffic congestion	3	0.068	0.204
13	Passing of small boat, fishing boat, leisure boat, etc.	3	0.041	0.123
14	Distance to berthing vessel	1	0.034	0.034
15	Width of route	5	0.035	0.175
16	Depth of route	1	0.034	0.034
17	Bend of route	1	0.032	0.032
18	Obstruction on the water	1	0.026	0.026
19	Obstruction under the water	1	0.069	0.069
20	Possible to using tug	1	0.045	0.045
21	Possible to pilot	1	0.044	0.044
22	Possible to VTS assistance	1	0.033	0.033
23	Past marine accidents occurrence numbers	5	0.017	0.085
SE_{total}		-	1.0	2.862

5. Conclusion

The speed limit shouldn't be decided on considering just one factor, it should be selected with consideration on the harbour's efficiency and economical factors, the effect that can be caused around the harbour and waterway also should be counted. The speed limit can be recognized as a logical speed limit only when it provides satisfaction for every users of harbour and users of facilities around the waterway.

This research suggested a method on selecting the speed limit by using the professional group of experts to derive a logical speed limit. This research is processed through 1~6 steps of speed limit select model. The speed limit is decided on considering the maritime traffic safeness between the range of maximum speed and the minimum speed that a vessel can have on the following water.

This model was used to derive the appropriate speed limit on the harbour water and the Busan harbour's approaching channel. The result on the appropriate speed limit of the Busan harbour's approaching channel area(A area) was turned out to be 9.2 knots, the harbour water(B area) was calculated to be 6.46 knots. The present speed limit on this water's entrance waterway is 10 knots, the harbour water is 7 knots, which is similar to the result of the speed limit on this research.

This research is the first research on the speed limit model, and it suggested result of method on deriving the appropriate speed limit, priorities, consideration factors when deciding on the speed limit. But there are certain limits on finding out the perfect speed limit select model. More detailed standards on the safeness of traffic evaluation must be found and additional study is necessary on discriminating consideration of the elements. This research has its value where it provides instances of aboard cases on guidelines of selecting the speed limit and is the first research where it was tried without a realistic manual.

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