

Optimization of Jindo VTS Shift System

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The Sewol Ferry has sunk



The Sewol Ferry

- Built by the Japanese company in 1994
- Later bought by Chonghaejin Marine Company
- Renamed *Sewol* and refurbished.
- Round-trips every week from Incheon to Jeju.



- 9 p.m. of 15 April : Departure***
- 8 : 48 a.m. of 16 April : sunk on Jindo***

2014.06.19 total
-174 rescued
-292 dead
-12 missed

The Sewol Ferry has sunk

Why?

What to do?

No Ethics

Ethics - Training

*Bad
VTS
System*

*No
Emergence
System*

*Develop VTS
System*

Develop Emergence System

Jindo VTS System

What is VTS ?

Vessel Traffic Services=VTS

- Marine traffic monitoring system
- Use radar, CCTV, VHF radiotelephony, and automatic identification system
- **Increase Safety & Efficiency of vessel traffic**

Jindo costal VTS

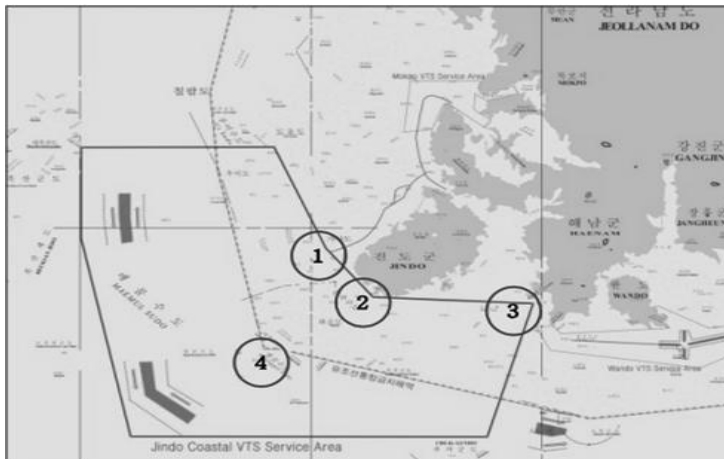
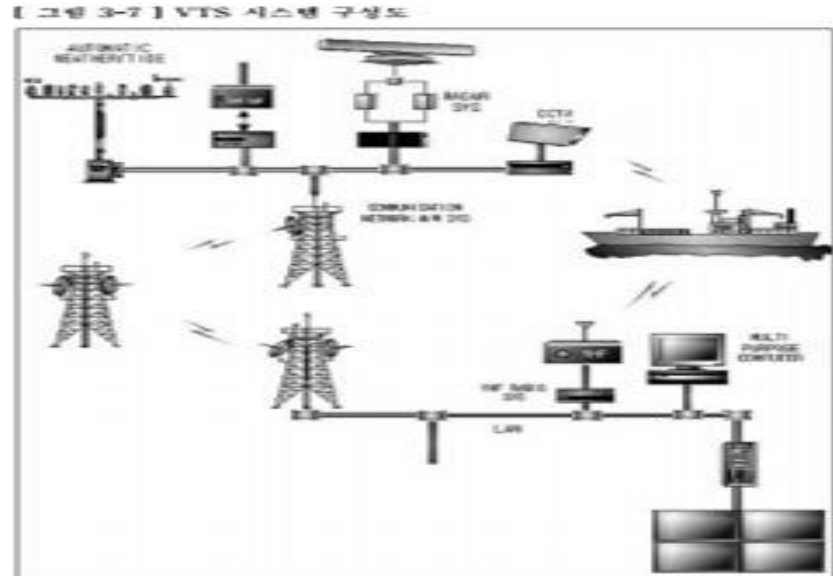


Fig. 2. Service area of Jindo coastal VTS.



출처 : 인천지방해양수산청 항만관리과(2008), "인천항 해안교통관제센터 운영원칙"



Jindo VTS Shift System

Jindo costal VTS

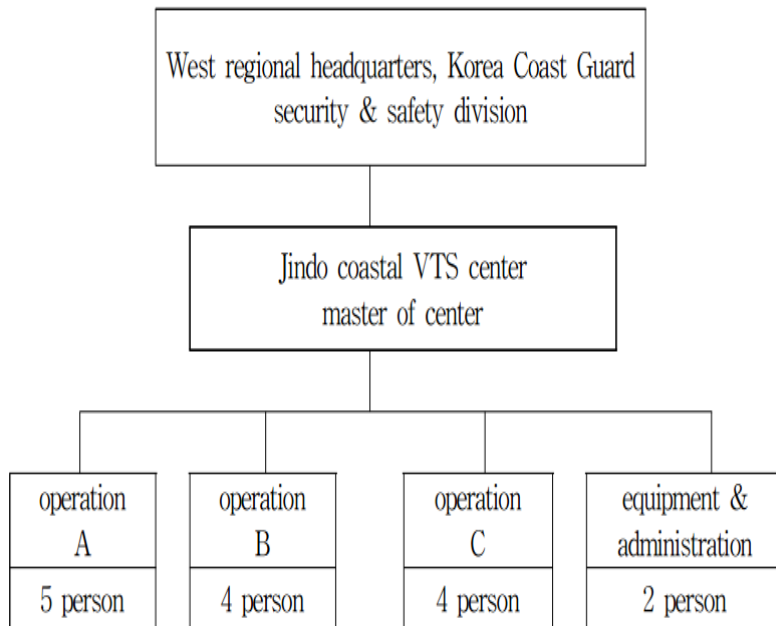


Fig. 1. Organization chart of Jindo coastal VTS.

Shift System

- 12 Controllers
- Each 4 people
- 3 rotation – 24 hours

Stress → Efficiency decrease

요일	월	화	수	목	금	토	일
1주-주	A	B	C	A	B	C	A
야	A	B	C	A	B	C	A
2주-주	B	C	A	B	C	A	B
야	B	C	A	B	C	A	B
3주-주	C	A	B	C	A	B	C
야	C	A	B	C	A	B	C

Jindo VTS Shift System - Problems

Working Environment

< 표 4-4 > 근무여건에 관한 설문



Sleepiness

< 표 4-1 > 졸음과 권태감에 관한 설문



Working Regulation

-Korea, England, Australia, Canada

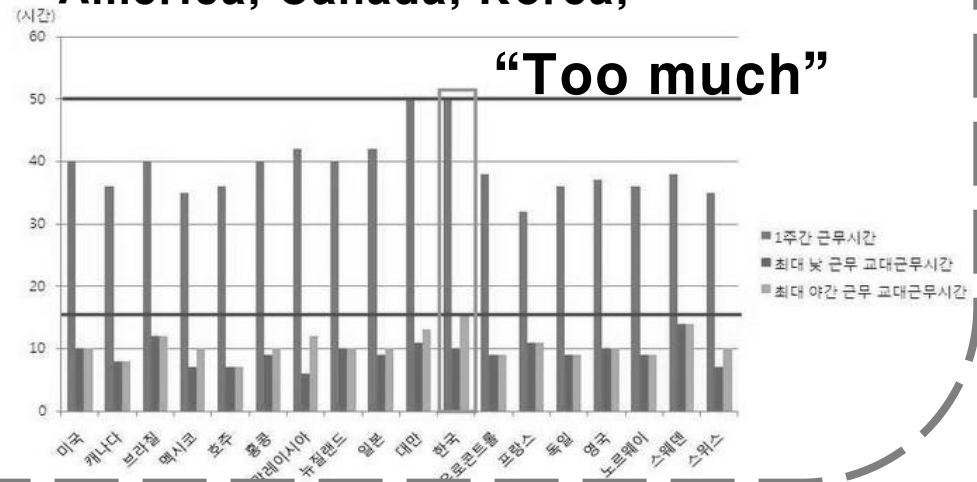
한국과 해외 항공교통관제 근로시간 규정 비교(2011년 기준)

자료: 연세대 인간행동연구소(항공종사자 인적 요인의 안전영향 및 안전관리방안 연구) 보고서

	한국	영국	호주	캐나다
근무 후 최소 휴식	8시간 이상	11~12시간	10시간 이상	8시간 이상
주당 근무시간	40시간	36시간	36시간	37.5시간
야간근무	규정 없음 (실제 15시간)	9.5시간 이내 이틀 연속 금지	최대 8시간	최대 8.5시간

Working Hours

-America, Canada, Korea,...



Jindo VTS Shift System - Solutions

1. Make new work-cycle

-Jindo VTS shift system of 2014

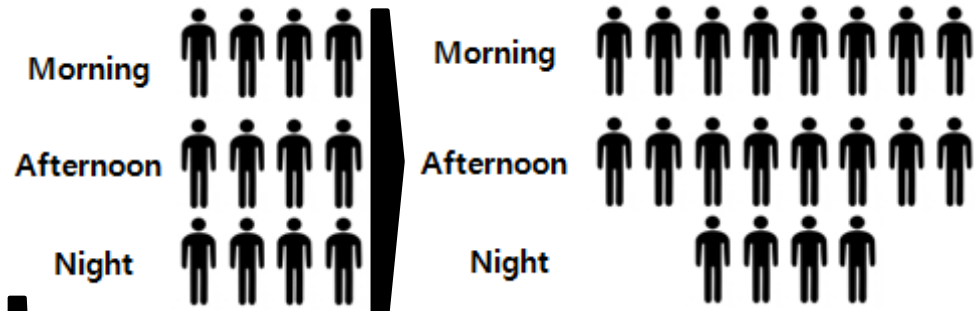
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3주-주	C	A	B	C	A	B	C
야	C	A	B	C	A	B	C

-HongKong VTSO shift system
(Good Example)

< 표 5-6 > 홍콩 VTSO 당직 체계 - 평균 33.6시간 / 주

5 Day Cycle					
1	2	3	4	5	6
오후 조	휴무	오전 조 + 야간 조	휴무	휴무	오후 조

2. Employ MORE controllers



-NEW Jindo VTS shift system

Day of the week	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Morning (7:45~13:00)	X	X	X	X	X	O	O
Afternoon (12:45~22:00)	O	X	X	O	X	X	X
Night(21:45~08:00)	X	X	X	X	O	X	X

Modeling

Sets and parameters

- I : Set of day of the week, $I = \{1,2,3,4,5,6,7\}, i, j \in I$
- T : Set of shift time (morning, afternoon, night), $T = \{1,2,3\}, l \in T$
- $h_{\min} = 33.6, h_{\max} = 40$: Weekly minimum/maximum working hours,
- $t_l = \{5.25, 9.25, 10.25\}$: working hours

Decision Variables

- x_{il} = Whether he works on i _day of l _time $i \in \{1,2,3,4,5,6,7\}, l \in \{1,2,3\}$
- y_i = Whether he works on i _day $i \in \{1,2,3,4,5,6,7\}$
- e_i = number of employees starting shift cycle on i _day $i \in \{1,2,3,4,5,6,7\}$
- u = converging variable of each employee

Output

- k_{il} = the number of employees working on i _day of j _time
 $i \in \{1,2,3,4,5,6,7\}, l \in \{1,2,3\}$
- z_{ijl} = Whether employee starting shift cycle on i _day work on i _day of l _time
 $i, j \in \{1,2,3,4,5,6,7\}, l \in \{1,2,3\}$

Objective

- Minimize $\sum_{l=1}^3 \sum_{i=1}^7 (k_{il} - u)^2$: Employee of each time on each day converges.

Constraints

- Constraints on decision variables
 - $x_{il} \in \{0,1\}, y_i \in \{0,1\}, e_i \in \{Integer\}, u \in \{Integer\}$
 - $\sum_{l=1}^3 x_{il} \leq 3y_i \leq 3 \sum_{l=1}^3 x_{il}$ for $i \in \{1,2,3,4,5,6,7\}$: y_i = Whether it works on i day
- Other constraints
 - $\sum_{l=1}^3 x_{il} \leq 2$ for $i \in \{1,2,3,4,5,6,7\}$: Work maximum two times on a day
 - $x_{i3} + x_{(i+1)3} \leq 1$ for $i \in \{1,2,3,4,5,6,7\}$: No continuous working night
 - $\sum_{i=1}^7 y_i = 5$: Work five days on a week
 - $h_{\min} \leq \sum_{l=1}^3 (t_l * \sum_{i=1}^7 x_{il}) \leq h_{\max}$: minimum <= Weekly working hours <= maximum
 - $z_{ijl} = x_{(i-j+1)l}$ ($x_{0l} = x_{7l}$) : seven days cycle
 - $\sum_{j=1}^7 (z_{ijl} * e_j) \geq 4$ for $i \in \{1,2,3,4,5,6,7\}, l \in \{1,2,3\}$: More than four employees - each time on each day

KEY #1 : The Sewol Ferry has sunk

What?

SOUTH KOREA | The Sewol Ferry has sunk.
APR. 16th, 2014 8:48 AM



More than three hundred lives
were trapped in the ferry.

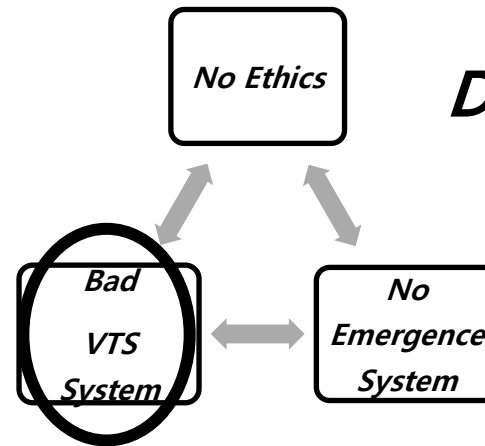
Not one was rescued.

NYT Funding Article

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Why?



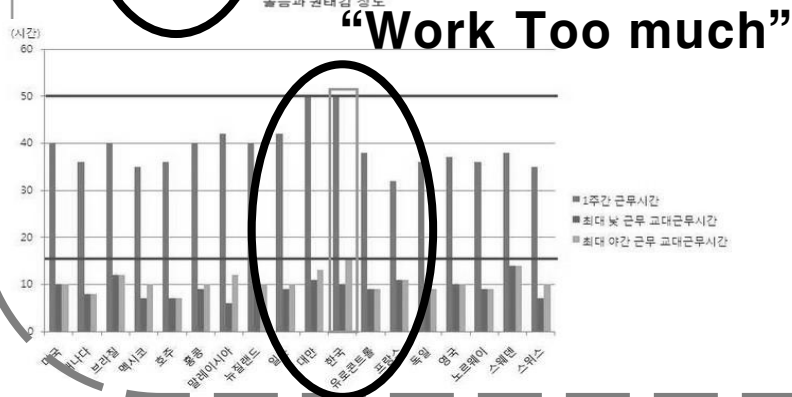
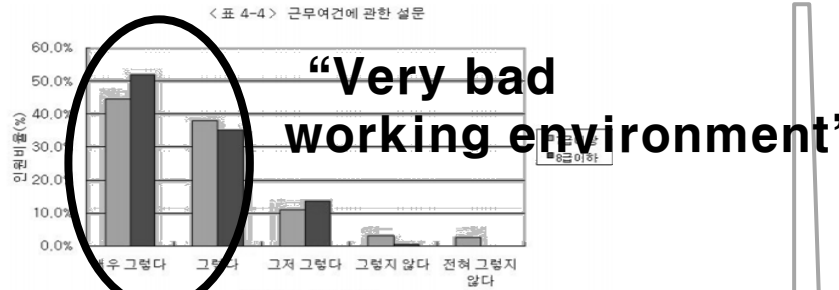
***Develop VTS
System !***

Jindo costal VTS

JindoVTS Shift System

KEY #2 : Jindo VTS Shift System

Problems



2014 VTS System

요일	월	화	수	목	금	토	일
1주-주	A	B	C	A	B	C	A
야	A	B	C	A	B	C	A
2주-주	B	C	A	B	C	A	B
야	B	C	A	B	C	A	B
3주-주	C	A	B	C	A	B	C
야	C	A	B	C	A	B	C

Morning (A, B, C)
 Afternoon (A, B, C)
 Night (A, B, C)

- three rotations
- four people

New VTS System

1. Work maximum TWO times on a day
2. No continuous working night
3. Work FIVE days on a week
4. $33.6 \leq \text{Weekly working hours} \leq 40$
5. Each day : More than FOUR employees

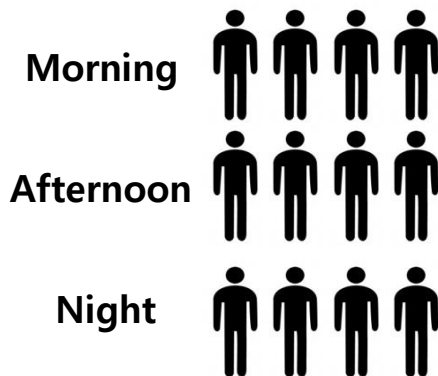
KEY #3 : Modeling Results

1. Make NEW work-cycle

-Jindo VTS shift system of 2014

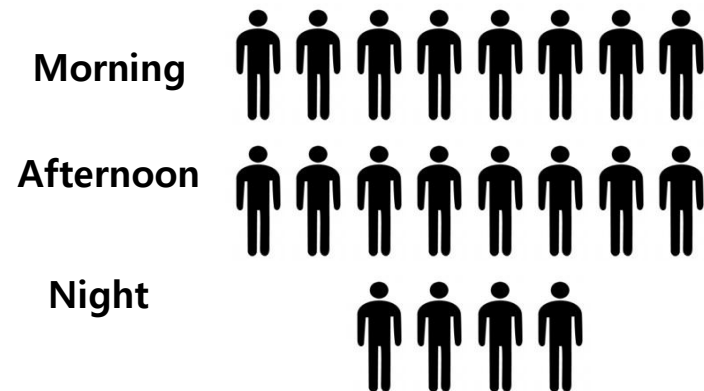
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2. Employ MORE controllers



-New Jindo VTS shift system

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Night(21:45~08:00)	X	X	X	X	O	X	X



Reference

- ✓『해상교통관제사의 스트레스 측정 모듈 개발에 관한 연구』, 김유순, 한국해양대학교 대학원, 2014.
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- ✓Bring The Truth To Light, NewYork Times, April 16th, 2014.

Appendix - Modeling Results

Whether work on time l of day i	1	2	3	4	5	6	7	Start work cycle on day j	
1	0	0	0	0	0	1	1	2	1
2	1	0	0	1	0	0	0	2	2
3	0	0	0	0	1	0	0	1	3
Whether work on day i (y_i)	1	0	0	1	1	1	1		4
	1	0	0	1	1	1	1		5
1. Max two times on a day : total ≤ 2	≤	≤	≤	≤	≤	≤	≤		6
	2	2	2	2	2	2	2		7
2. No continuous night work : x _{i,l} + x _{(i+1),l} ≤ 1	≤	≤	≤	≤	≤	≤	≤		
	1	1	1	1	1	1	1		
3. Work 5 days : y ₁ + y ₂ + ... + y ₇ = 5	5 =		5						
4. total ≤ 3 * y ≤ 3 * (total)	≤	≤	≤	≤	≤	≤	≤		
	3	0	0	3	3	3	3		
	≤	≤	≤	≤	≤	≤	≤		
	3	0	0	3	3	3	3		

Time - Employee	1	2	3	4	5	6	7	6. More than four work on each time of each day	1	2	3	4	5	6	7
1	8	8	8	8	8	8	8	≤	1	4	4	4	4	4	4
2	8	8	8	8	8	8	8	≤	2	4	4	4	4	4	4
3	4	4	4	4	4	4	4	≤	3	4	4	4	4	4	4
total	20.00	20.00	20.00	20.00	20.00	20.00	20.00								

Objective	Each number of employees converges
Minimize Variance	77
Total Employee	28