3강. 재해조사 모델

사고 발생 모델

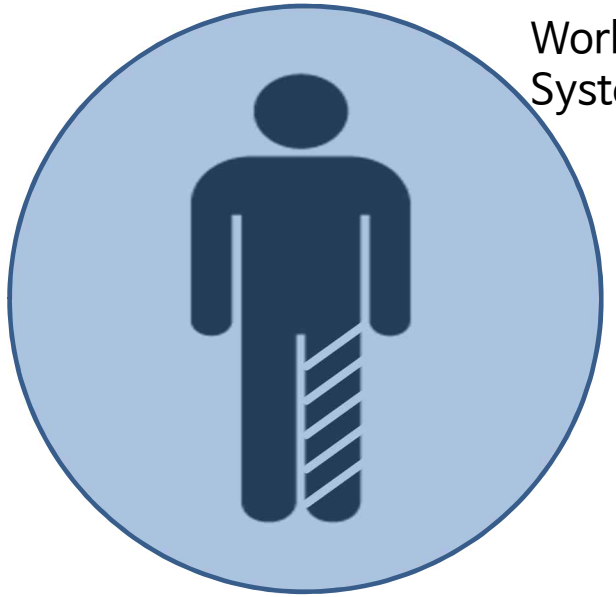
- Why do accidents happen? This question has concerned safety and health decision-makers for decades, because in order to prevent accidents we must know why they happened.

  왜 사고가 나는가? 사고를 막기 위해서는 왜 사고가 발생하는 지를 알아야 하기에, 이 질문은 지난 수 십 년 간, 안전보건 분야의 의사결정자들의 관심을 끌어 왔다.

- 사고 발생의 구조를 설명하고 효과적 예방대책을 수립하기 위해서는 사고발생 모델이 필요

개인이냐? 시스템이냐?

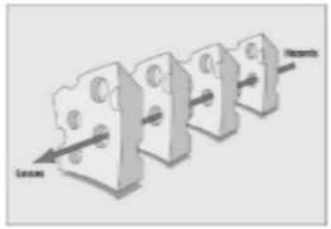
Accident Prone
(사고빈발자이론)



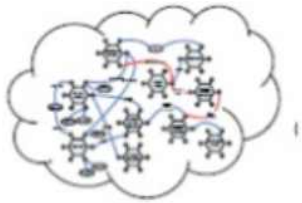
Look! System
(시스템이론)

시스템모델의 분류

Domino Theory (Heinrich, 1931)



Chees model (Reason, 1997)



FRAM (Hollnagel, 2000)

Sequential model (simple linear)

- Decomposable in parts (probability of parts-fault tree)
- Chain of events (domino effect)
- Humans are another chain
- Route cause

Epidemiological model (complex linear)

- Decomposable in parts
- Latent failures (management and/or design)
- Pathogens activated by other factors/errors
- Degradation of barriers/defenses

Systemic model

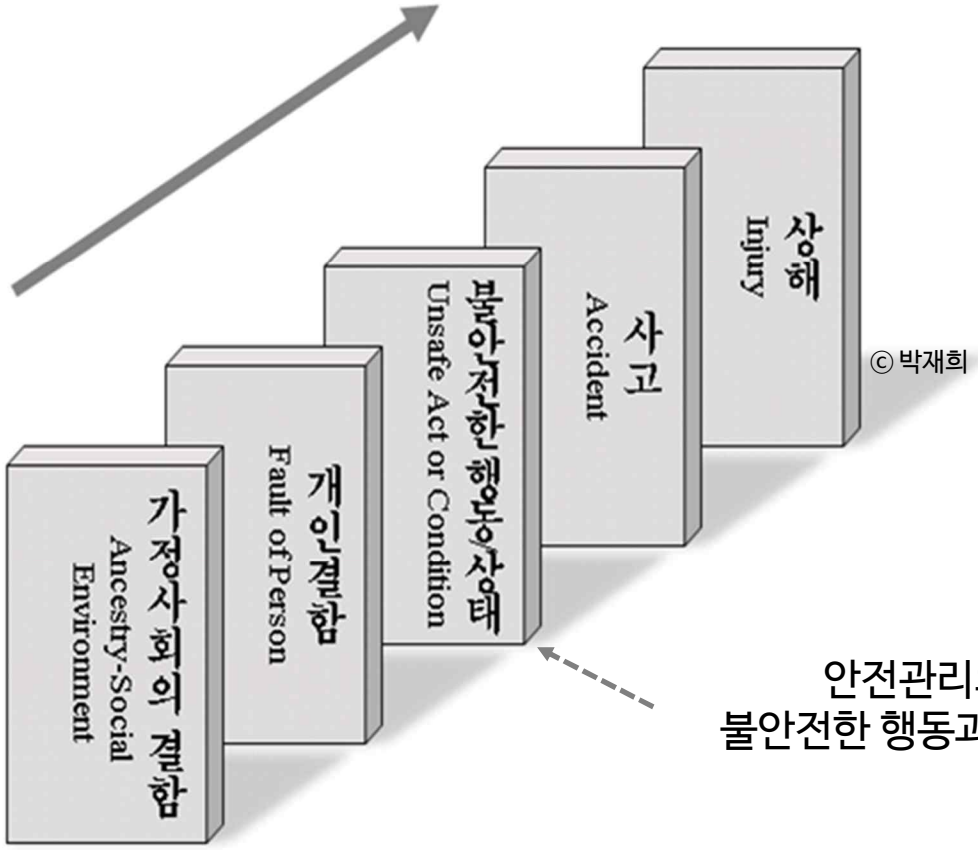
- Decomposition does not work for socio-technical systems → emergent properties
- Socio-technical systems are non-linear
- Accidents result from unexpected combinations (resonance) of normal performance variability
- Safety requires constant ability to anticipate to future events avoiding resonance

사고발생 모델

재해발생모델의 종류

1. Heinrich 도미노 모델
2. Bird 도미노 모델
3. Adams 도미노 모델
4. Reason 스위스 치즈 모델
5. 정보처리 모델
6. Surry 도미노 + 정보처리 모델
7. 인간공학 PSF 모델
8. SHELL 모델
9. NTSB의 4M 모델
10. Harvey의 3E 모델
11. 산업재해조사보고서 모델
12. Accimap 모델
13. STAMP 모델
14. FRAM 모델

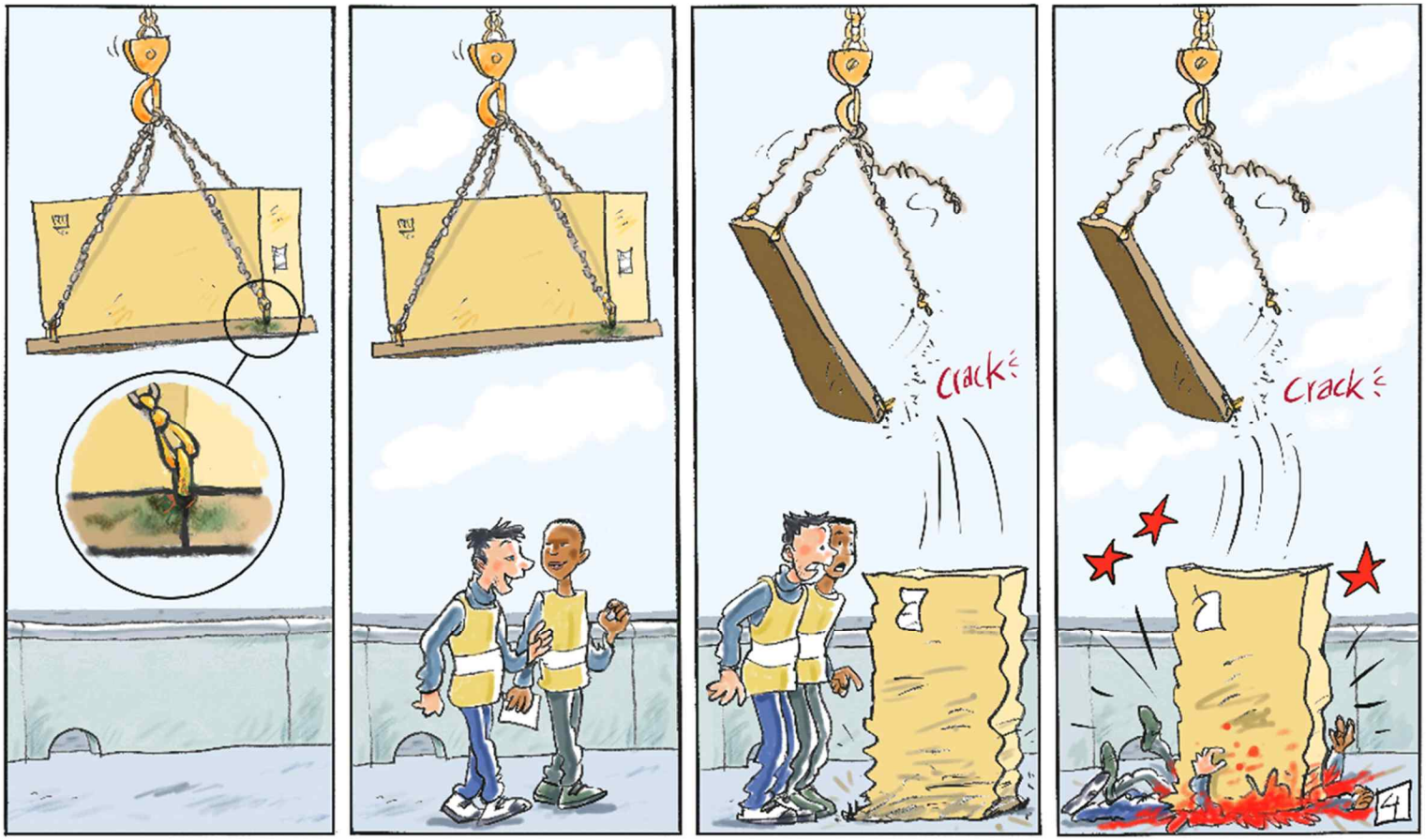
1. Heinrich 도미노 모델



ⓒ 박재희

안전관리의 대상
불안전한 행동과 상태의 제거

블안전한 상태와 행동



불안전한 상태 불안전한 행동 아차 사고 재해

불안전한 상태와 불안전한 행동 예

Unsafe workplace conditions: (Check all that apply)

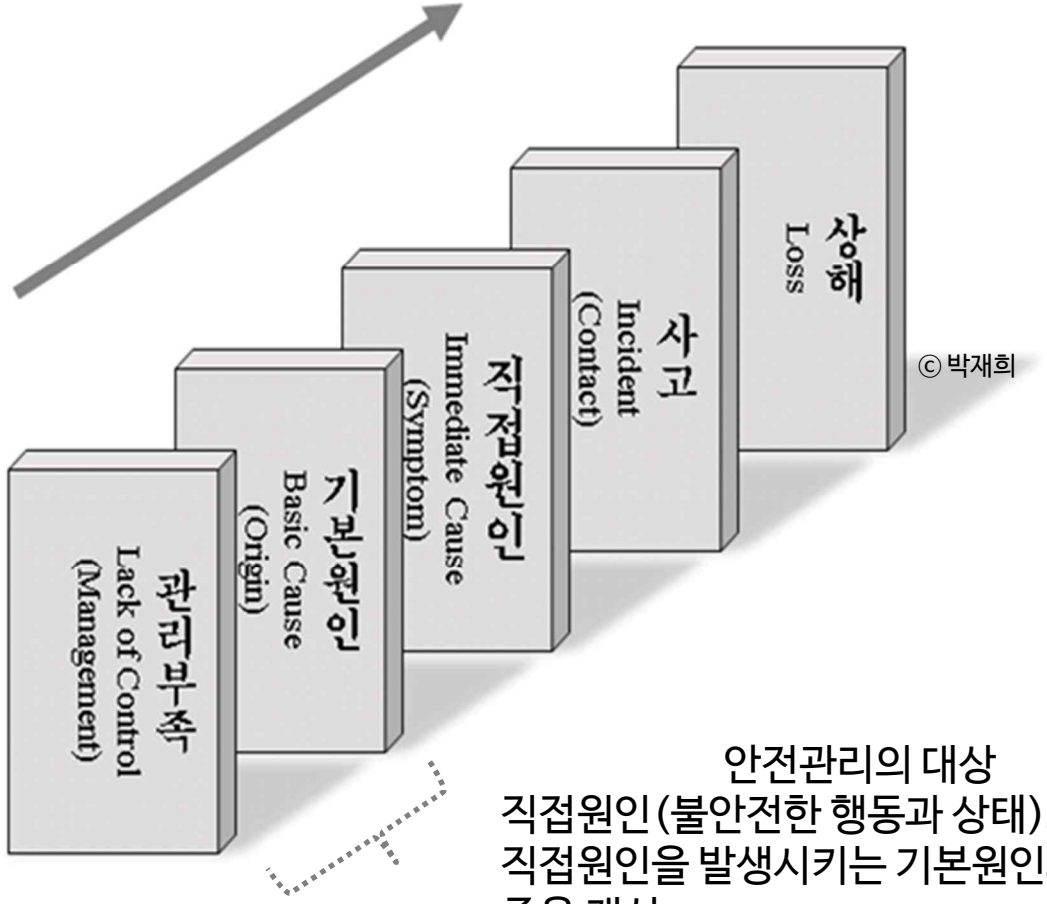
- ❑ Inadequate guard
- ❑ Unguarded hazard
- ❑ Safety device is defective
- ❑ Tool or equipment defective
- ❑ Workstation layout is hazardous
- ❑ Unsafe lighting
- ❑ Unsafe ventilation
- ❑ Lack of needed personal protective equipment
- ❑ Lack of appropriate equipment / tools
- ❑ Unsafe clothing
- ❑ No training or insufficient training
- ❑ Other: _____

Unsafe acts by people: (Check all that apply)

- ❑ Operating without permission
- ❑ Operating at unsafe speed
- ❑ Servicing equipment that has power to it.
- ❑ Making a safety device inoperative
- ❑ Using defective equipment
- ❑ Using equipment in an unapproved way
- ❑ Unsafe lifting by hand
- ❑ Taking an unsafe position or posture
- ❑ Distraction, teasing, horseplay
- ❑ Failure to wear personal protective equipment
- ❑ Failure to use the available equipment / tools
- ❑ Other: _____

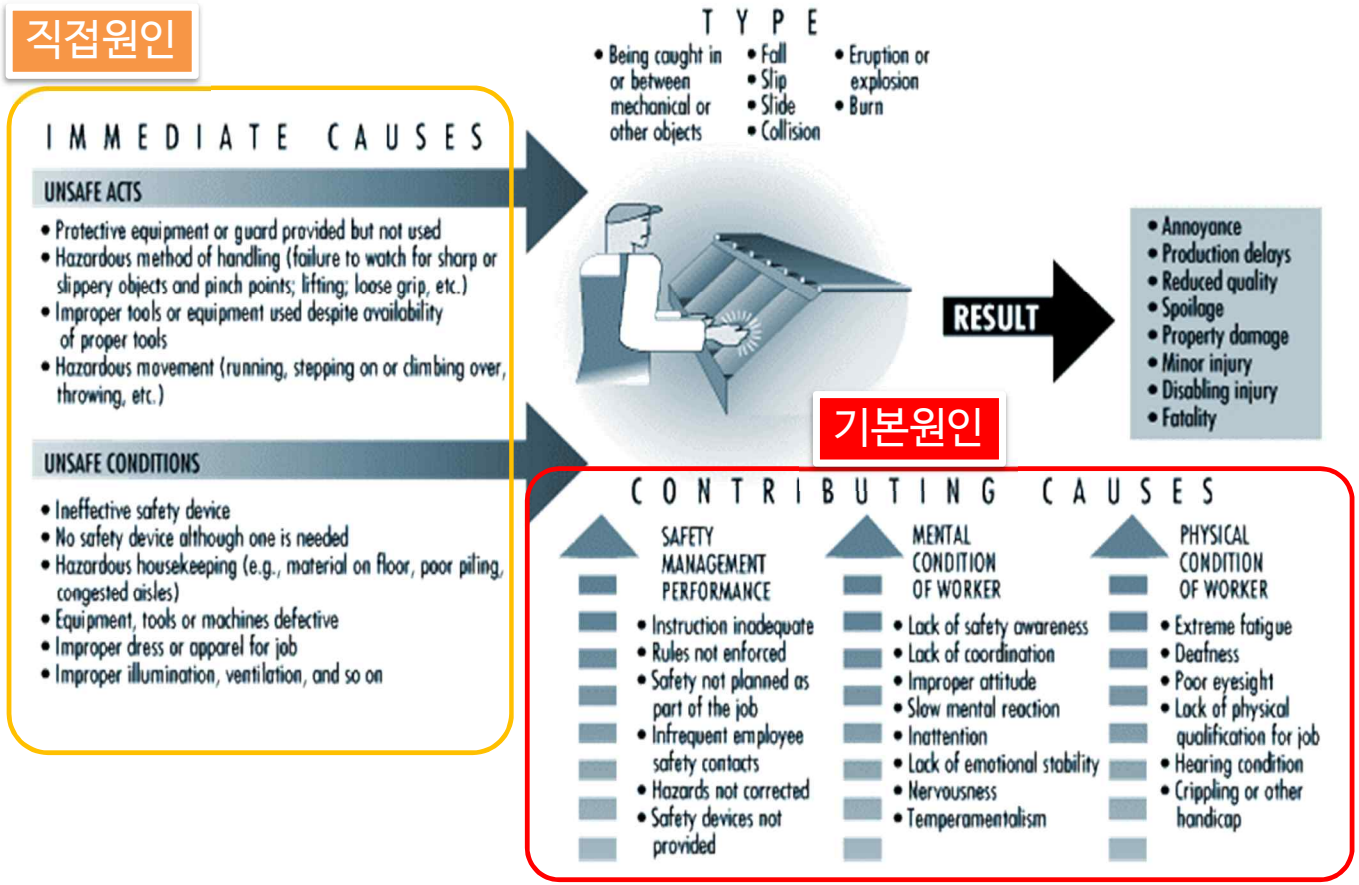
|출처| USA department of labor and industries

2. Bird 도미노 모델



안전관리의 대상
직접원인(불안전한 행동과 상태)보다
직접원인을 발생시키는 기본원인과 관리부족을 개선

기본원인



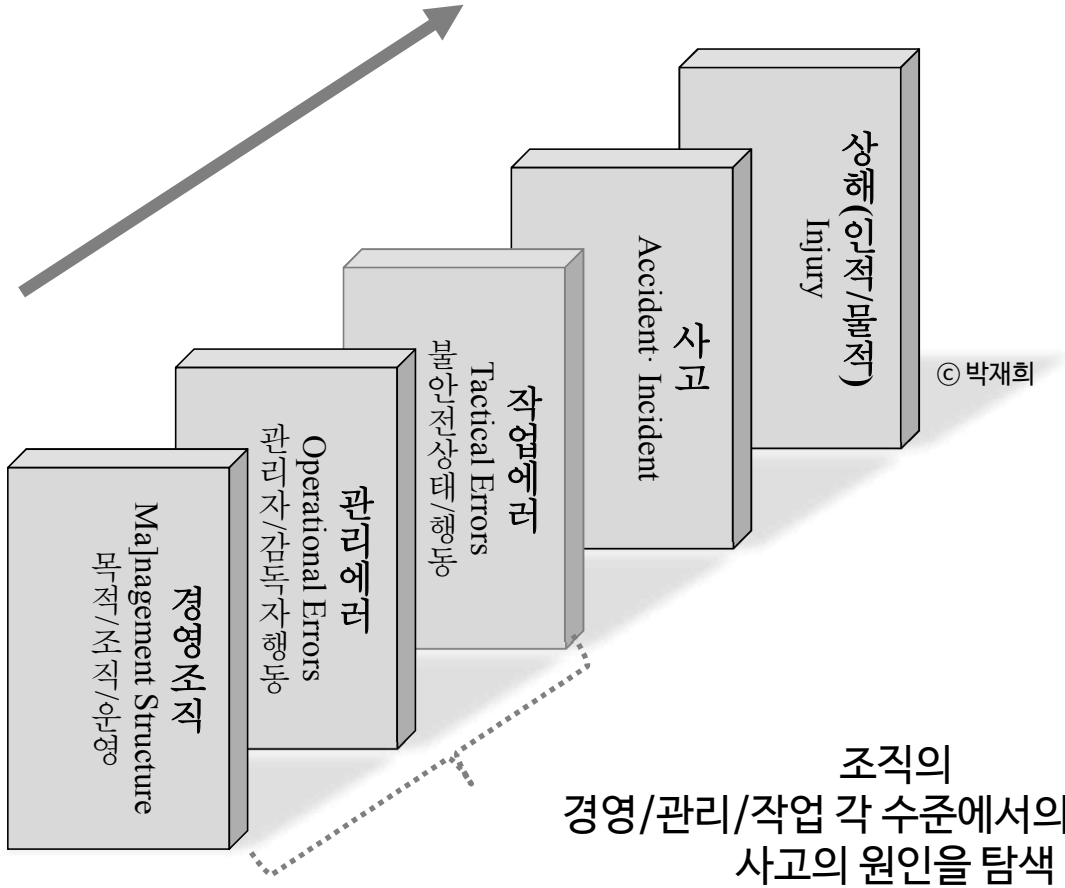
|출처| USA department of labor and industries

기본원인 목록

Immediate Causes	
Unsafe Acts:	*Unsafe Conditions:*
Operating without authority	Inadequate guards and devices
Failure to make secure	Inadequate warning systems
Failure to observe / Use warning devices	Work environment
Nullifying safety devices	Excessive noise
Using defective equipment	Hazardous placement or storage
Using equipment unsafely	Inadequate physical contact
Taking unsafe position, Improper physical effort /act	Untidy site
Influence of alcohol / drugs, Horseplay	Weather
Failure to use PPE	Inadequate PPE
Failure to follow procedure; Inattention	Inadequate isolation
Underlying Causes	
Lack of competence	Improper motivation
Inadequate supervision	Inadequate maintenance / inspection
Inadequate job instruction	Inadequate engineering design
Inadequate physical/mental capacity	Inadequate work / safety procedure
Inadequate planning/organisation	Inadequate procedure

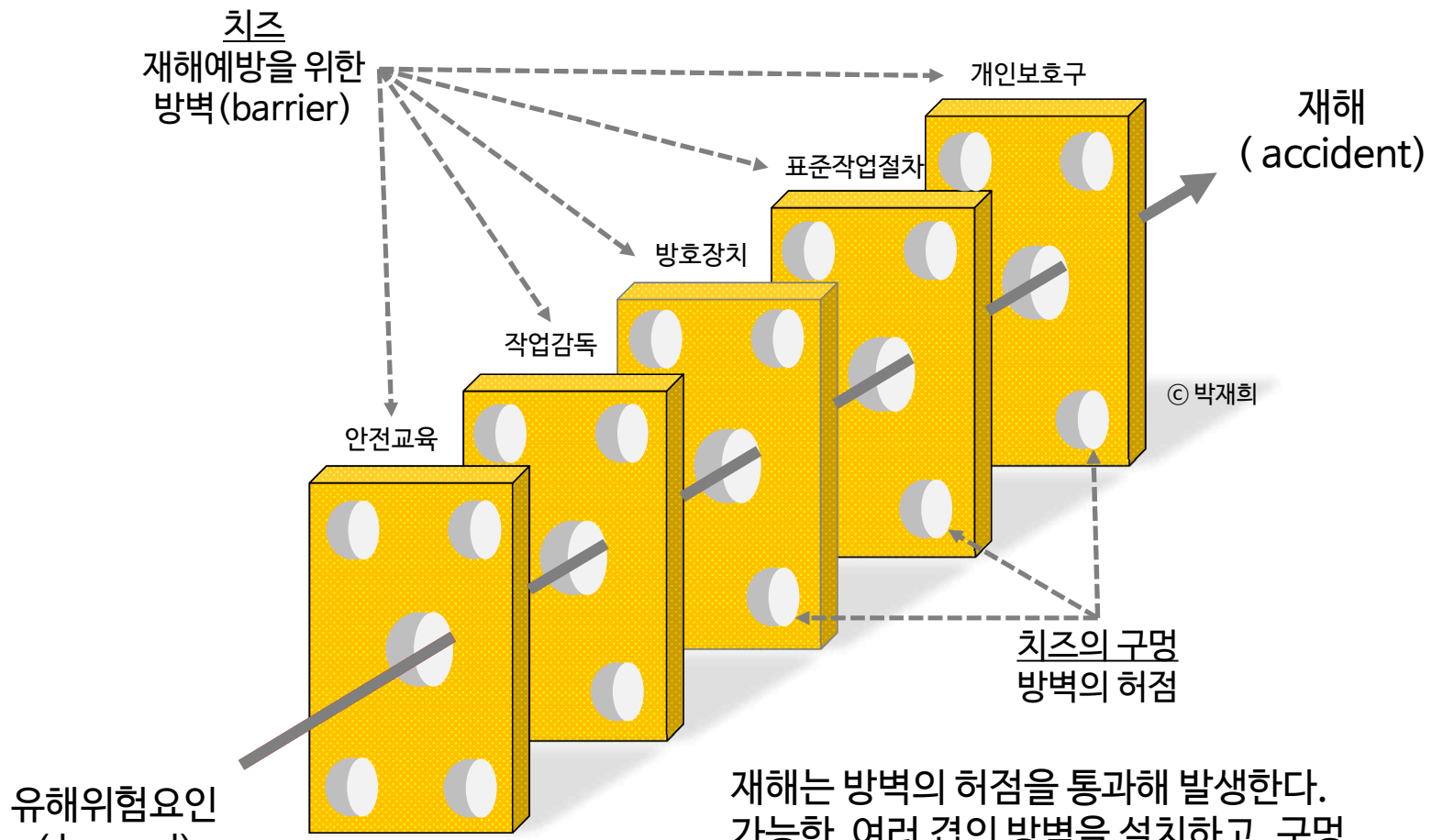
|출처| USA department of labor and industries

3. Adams 도미노 모델



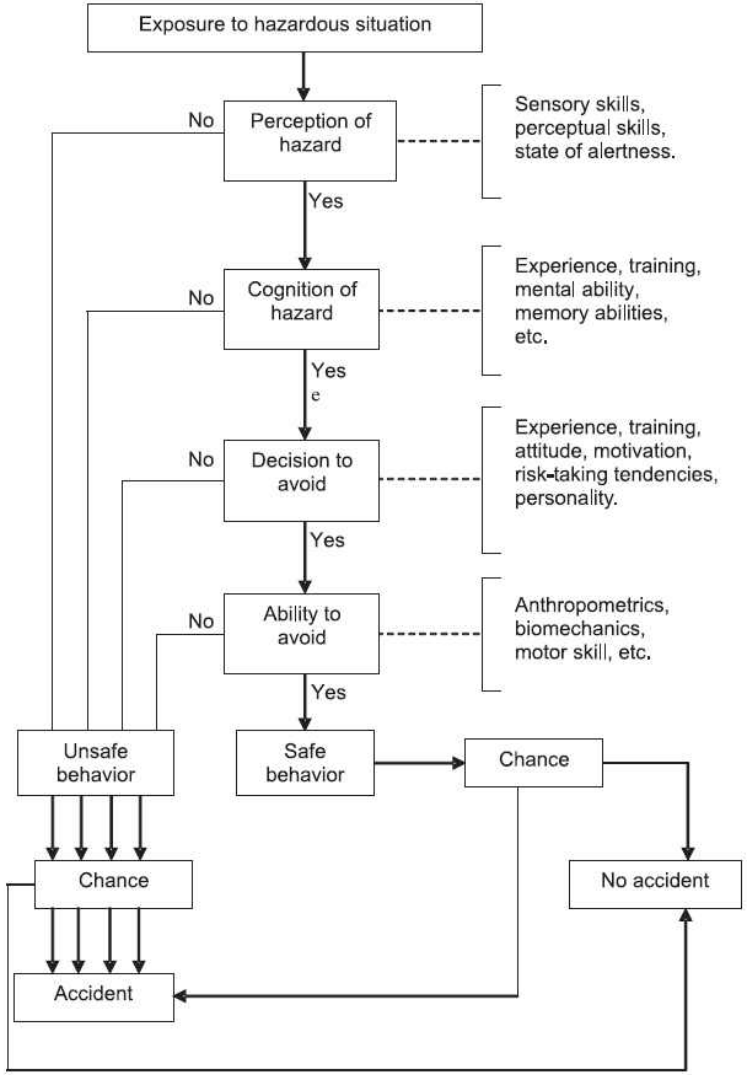
조직의
경영/관리/작업 각 수준에서의 에러에서
사고의 원인을 탐색

4. 스위스 치즈 모델(Reason)



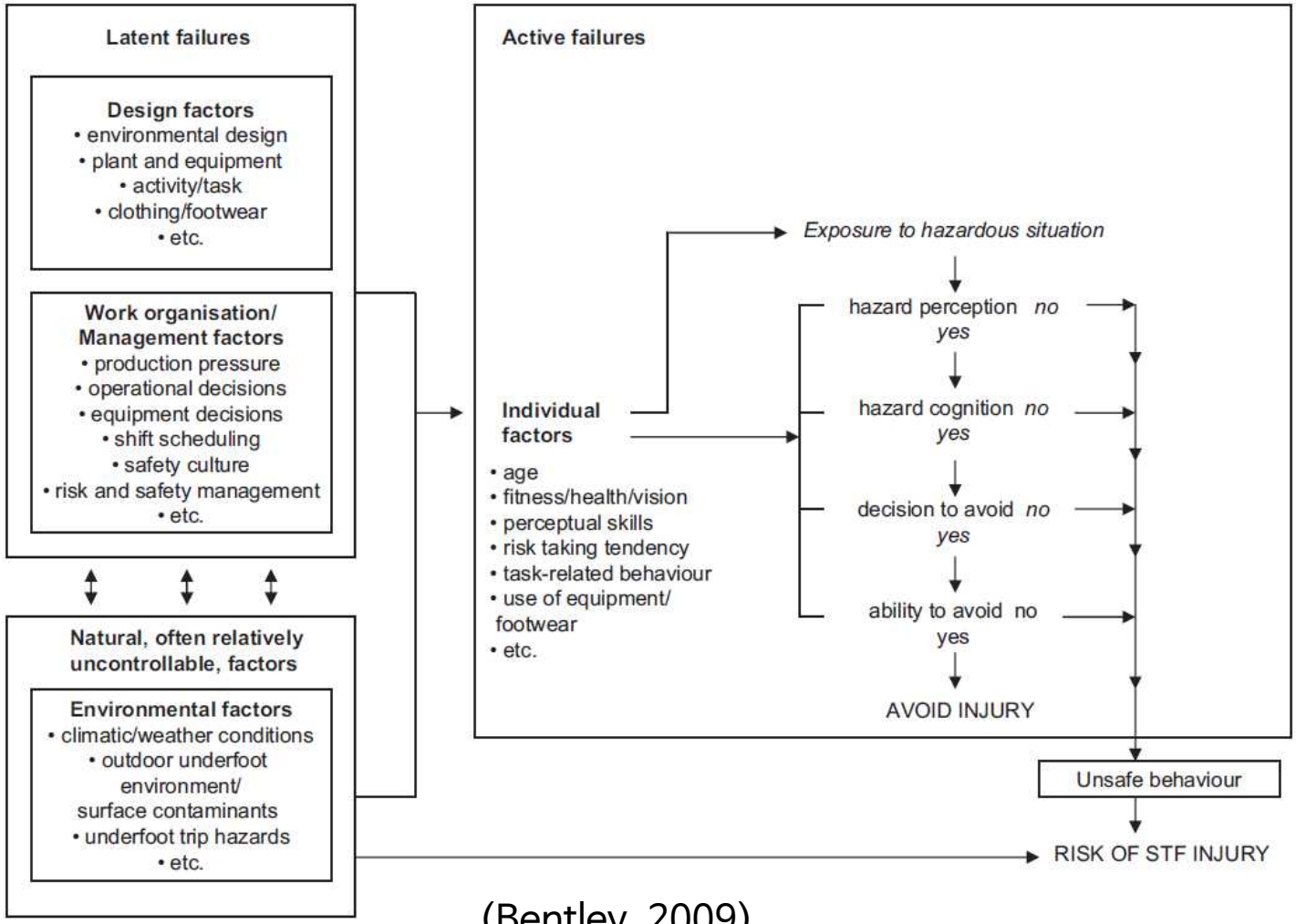
재해는 방벽의 허점을 통과해 발생한다. 가능한 여러 겹의 방벽을 설치하고, 구멍이 적어야 재해발생을 예방할 수 있다 (Reason, 1990).

5. 정보처리모델(Ramsey)



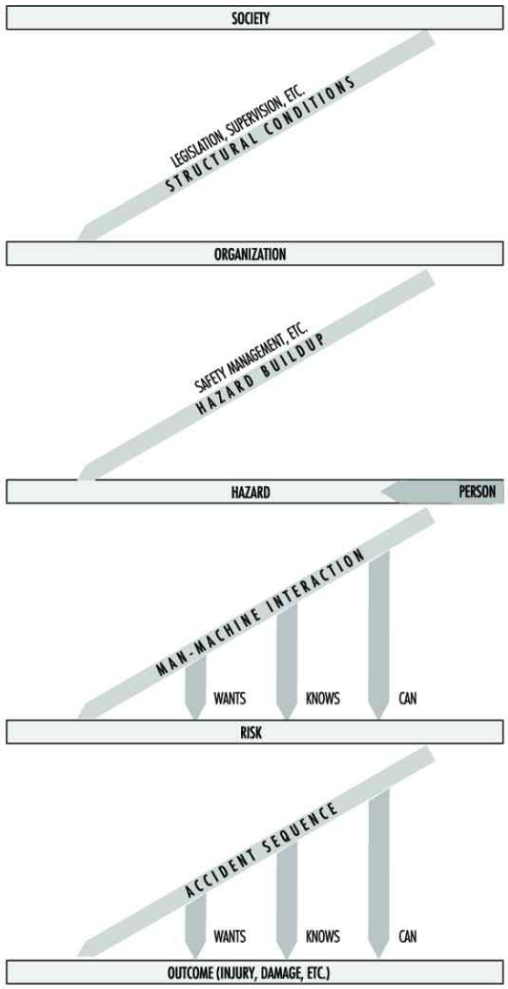
(Ramsey, 1985)

5. 정보처리모델(Bently)



(Bentley, 2009)

6. 도미노+정보처리모델(Surry)



Source: Based on Surry 1969.

사회

조직(기업)

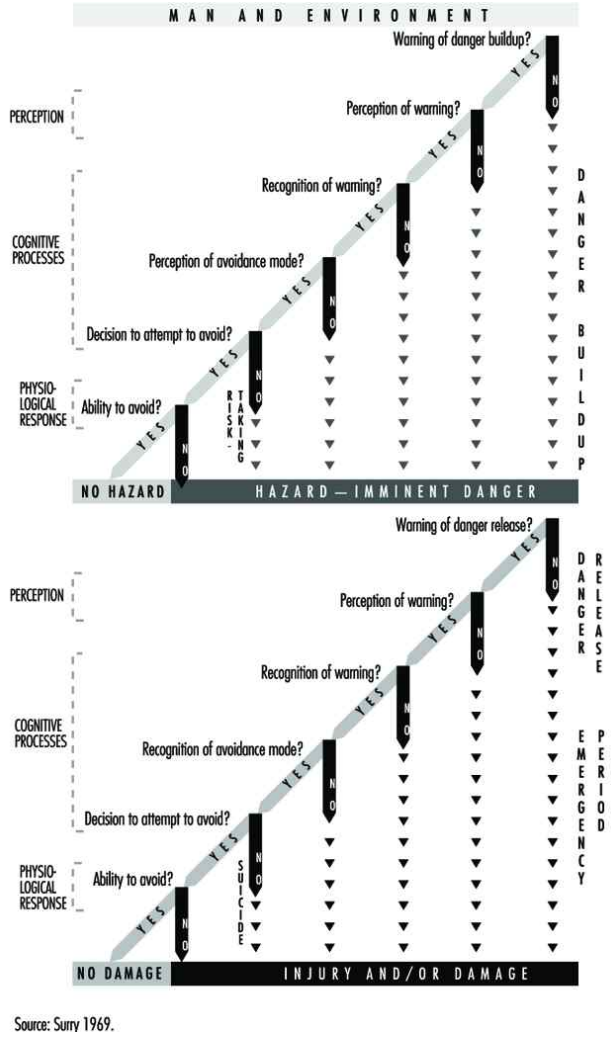
유해요인

위험

재해

(Surry, 1969)

Surry의 모델



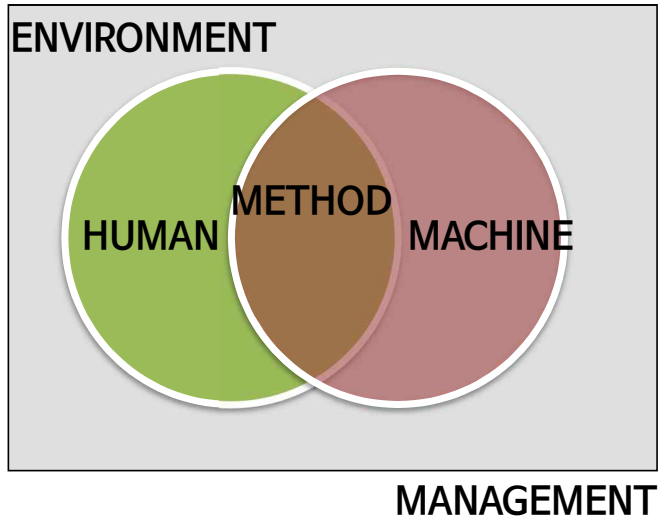
Source: Surry 1969.

(Surry, 1969)

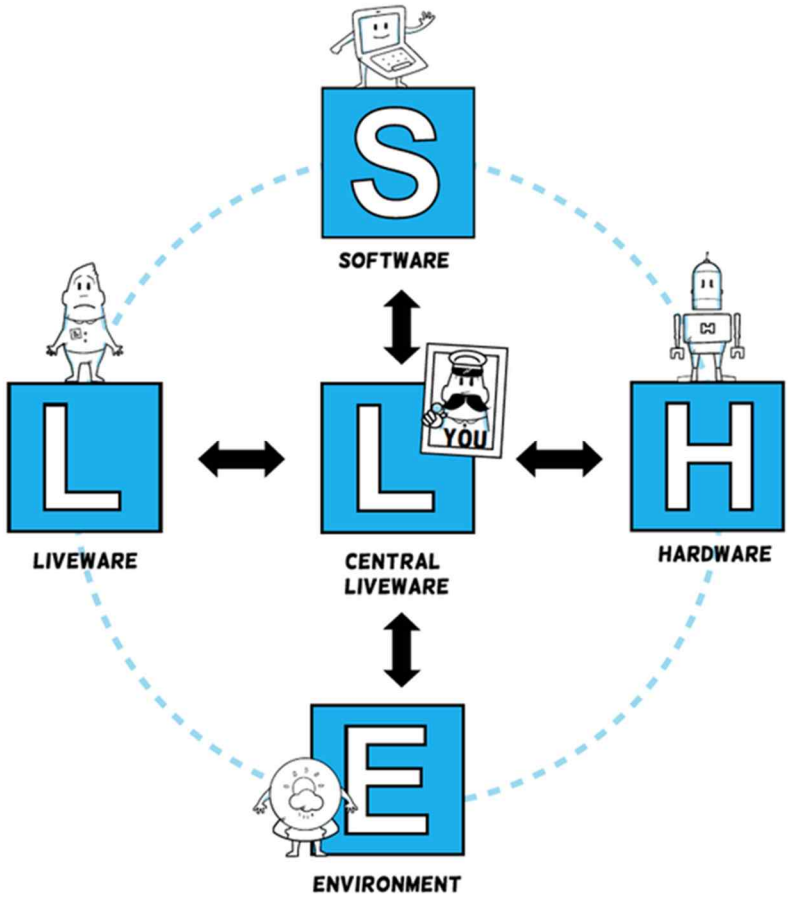
7. 인간공학 PSF 모델

사고의 원인을 5 개의 수행도 형성요인(PSF; Performance Shaping Factors)으로 구분 파악

- Human
- Machine
- Method(Work)
- Environment
- Management



8. SHELL 모델


S
SOFTWARE
L
LIVEWARE
L
YOU
CENTRAL
LIVEWARE
H
HARDWARE
E
ENVIRONMENT

9. NTSB의 4M 모델

Man
신체능력
인지능력
성별연령

Machine
기계설비
방호장치
인터페이스

Media
작업방법
작업절차
작업환경

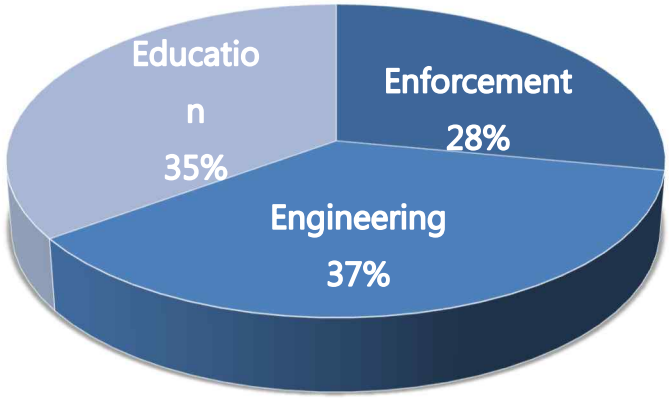
Management
법규준수
교육훈련
관리감독

교통사고 원인분석에 사용되나 산업재해에도 적용
NTSB(National Transporation Safety Board) 미국 연방 교통안전위원회

10. Harvey 3E 모델

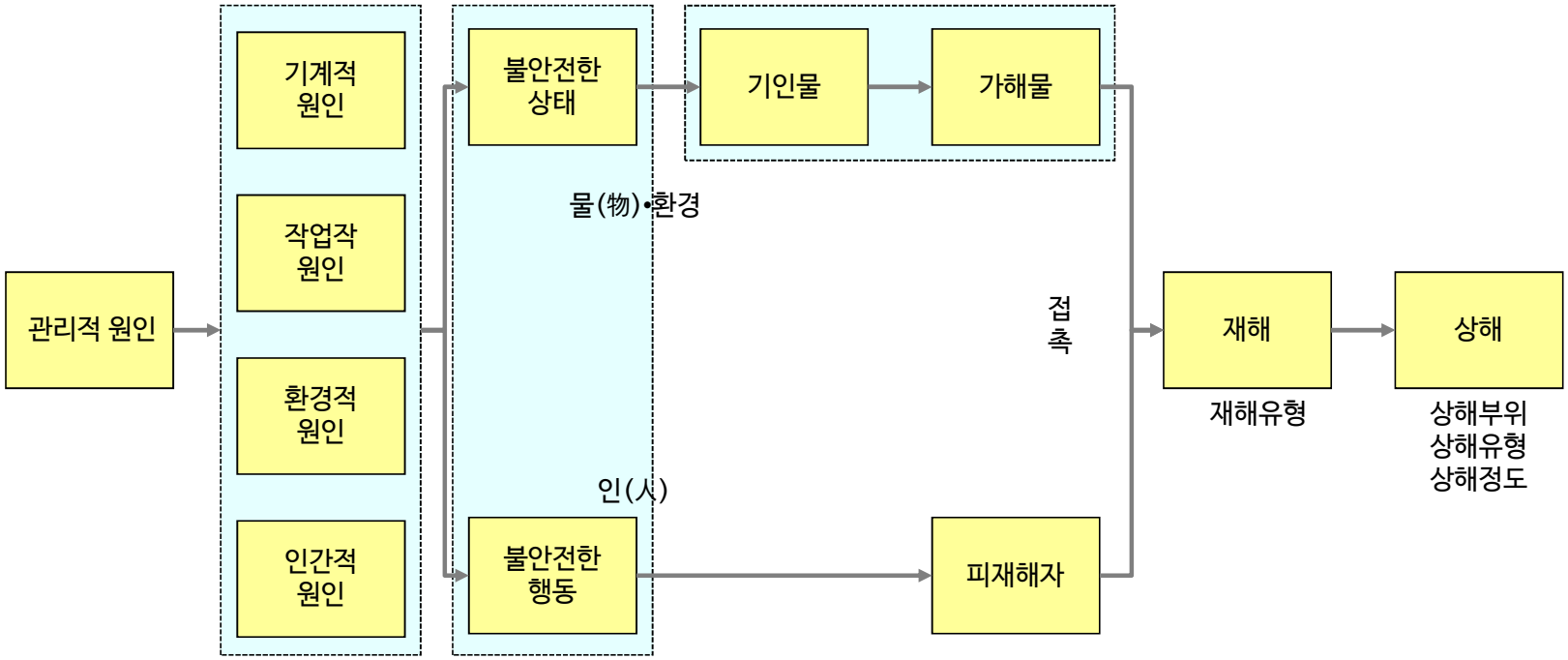
- 사고의 원인과 대책을 3E 차원에서 고려

- 기술 Engineering
  - 기계설비, 공정의설계 상 문제
- 교육 Education
  - 안전교육. 관리감독 상 문제
- 규제 Enforcement
  - 법규, 표준, 회사 내 규정 등 문제



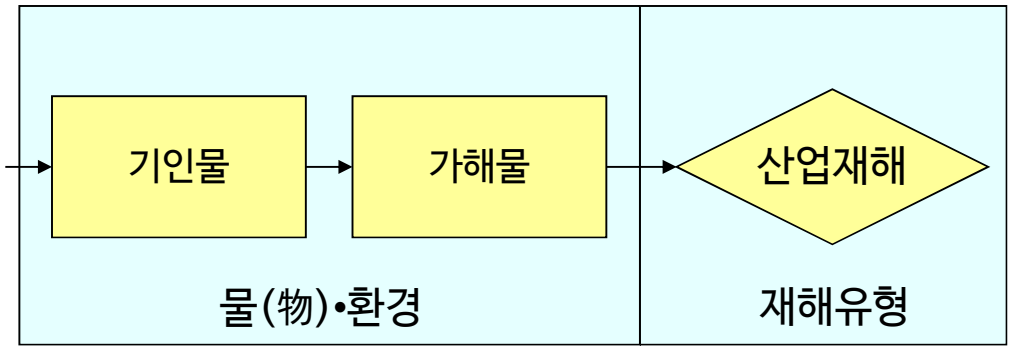
재해원인분석(고용노동부, 2003)

11. 산업재해 모델



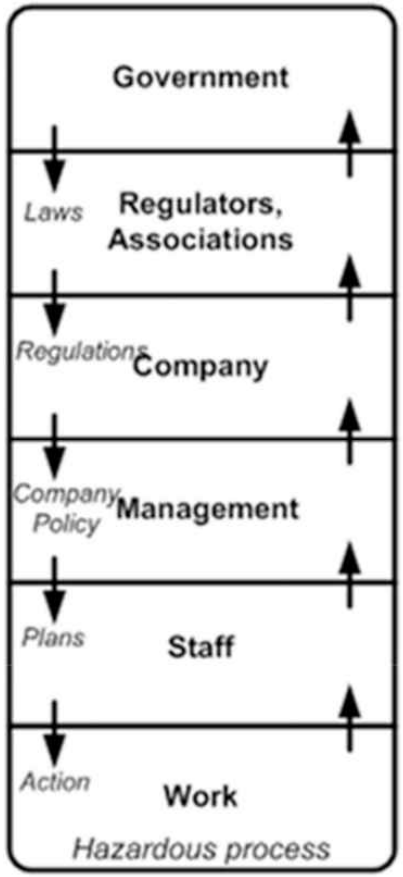
Bird의 모델과 인간공학 PSF 모델 결합한 모델

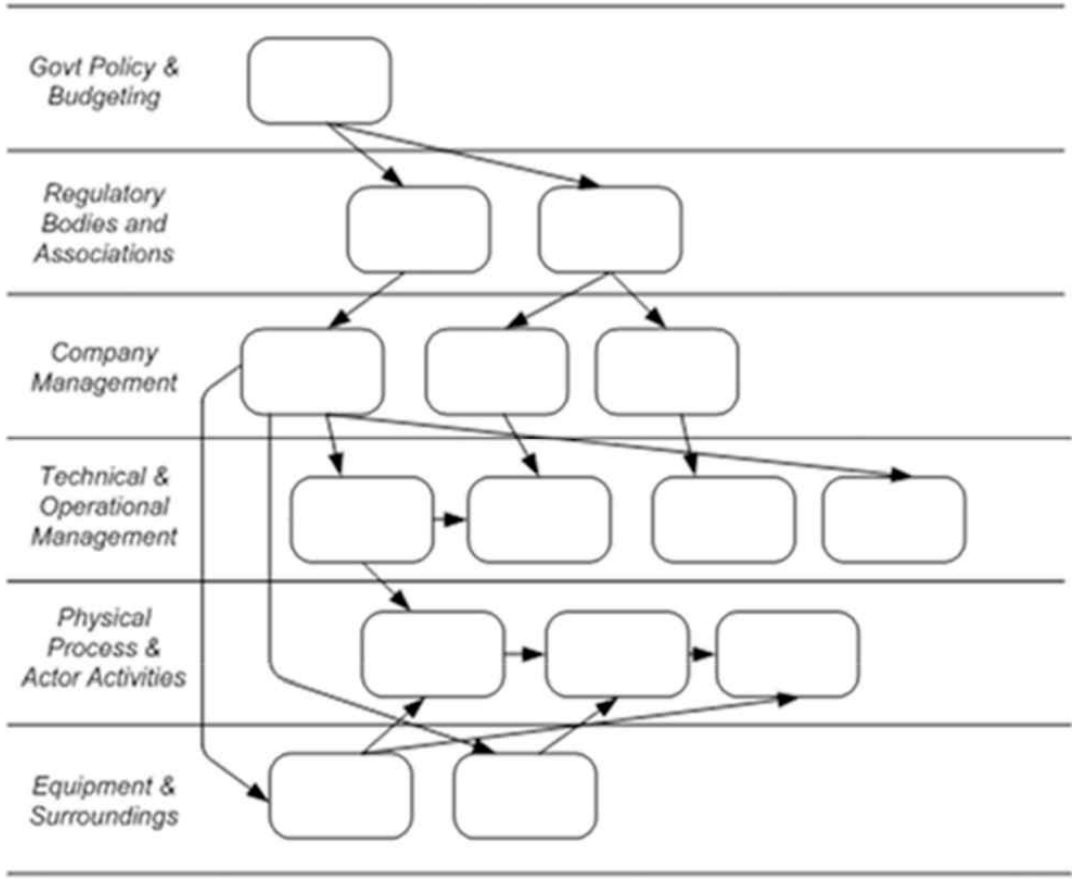
기인물-가해물-재해유형



동력기계	기인물동일	추락 전도
일반기계	기인물파편	낙하 비래
운반기	유해물질	붕괴 도괴
압력용기	비래낙하물	감김 협착
용접장치	설비모서리	절단 감전
재료	바닥	촉발 화재
화학설비		충돌 중독
환경		질식 익사

12. Accimap





Rasmussen(1997)

Accimap 분석 예

세월호 사고에 대한 분석

Lee et al. (2017)

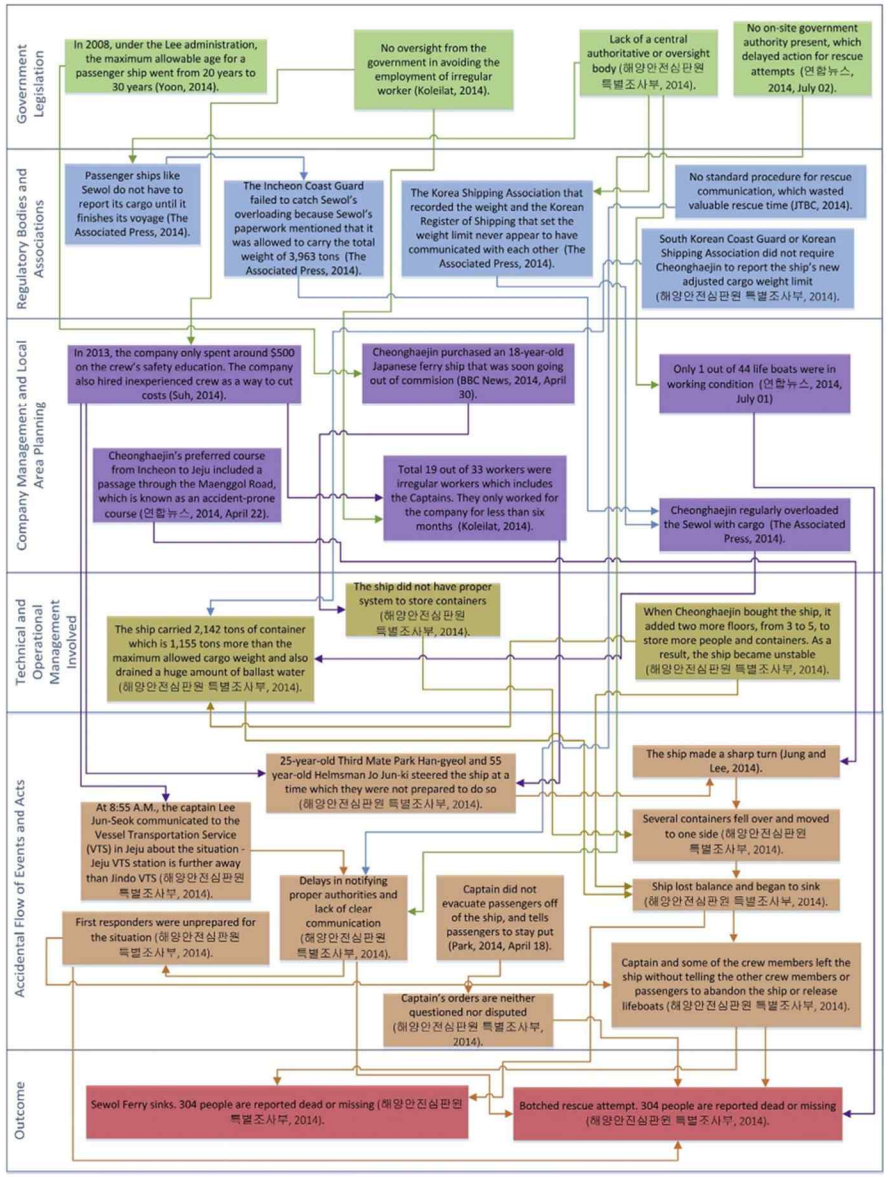
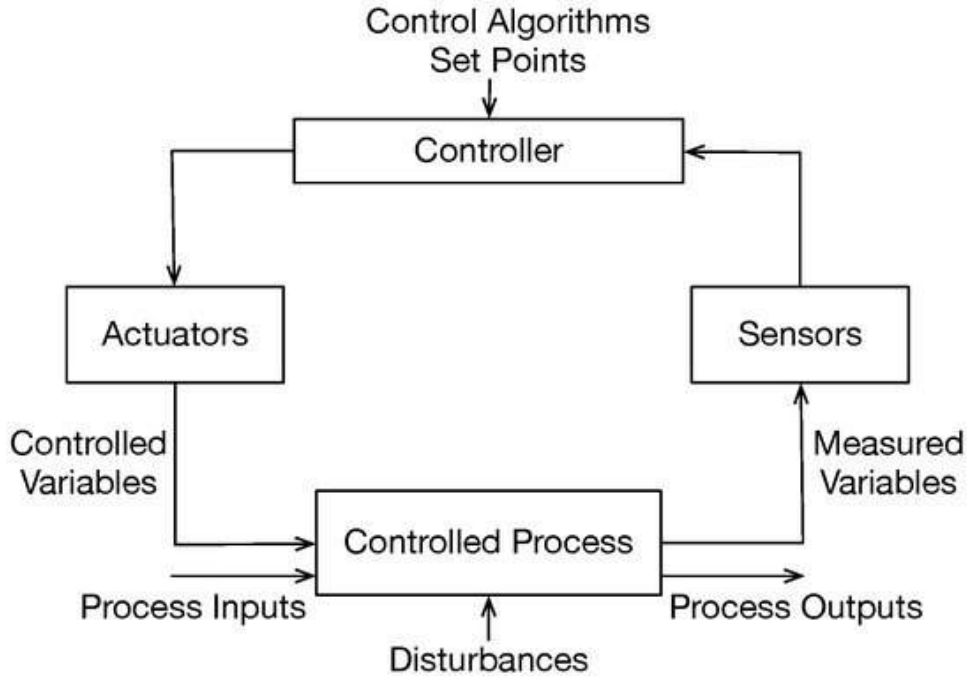


Fig. 2. The developed AcciMap framework for the analysis of the Sewol Ferry accident.

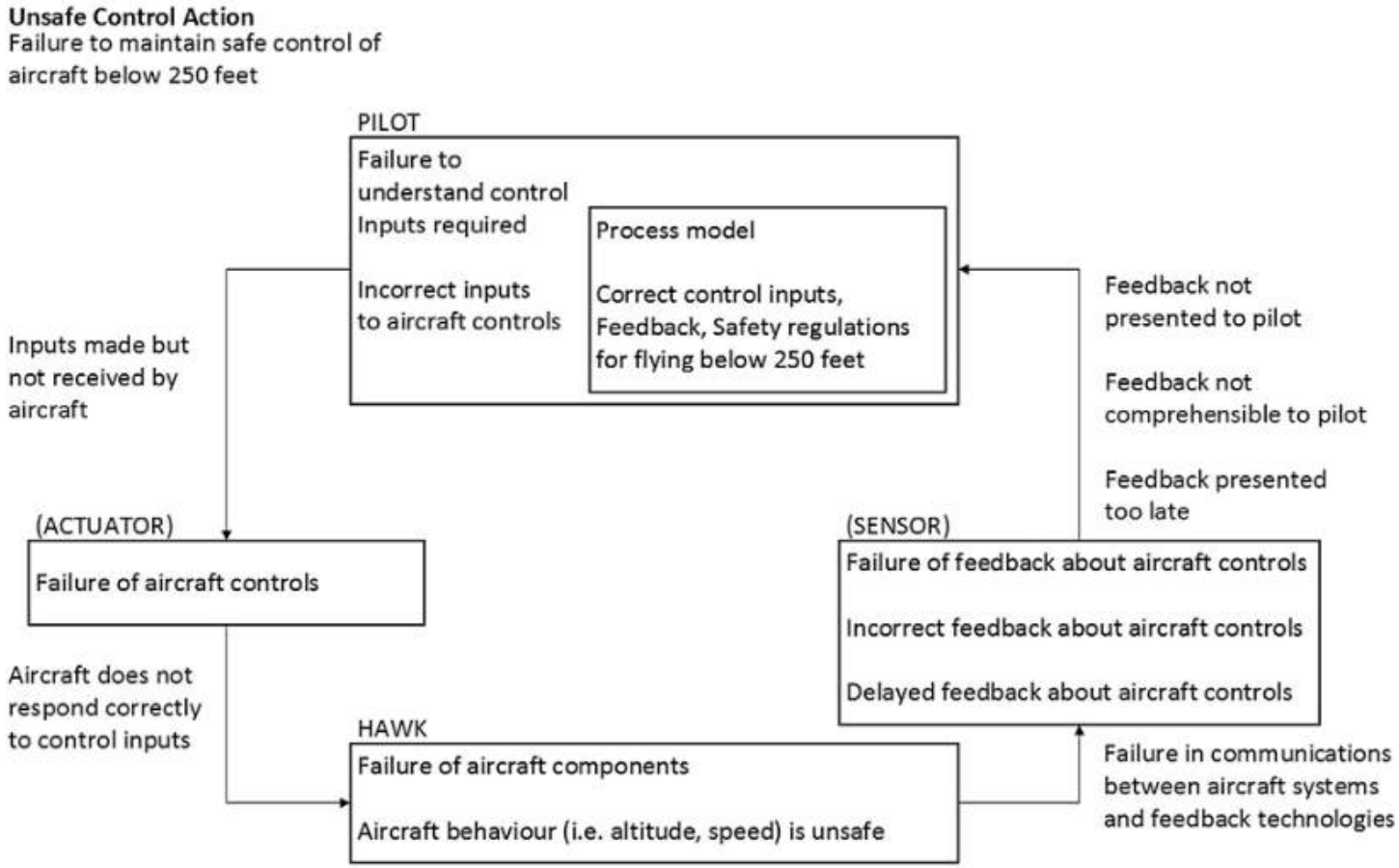
13. STAMP

- STAMP(Systems Theoretic Accident Model and Processes)
- 동적 상황에서 통제와 피드백의 실패로 사고 발생



Leveson(2004)

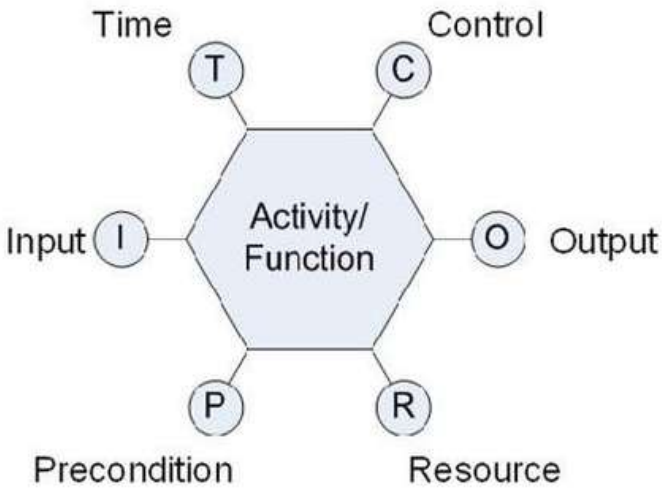
STAMP 분석 예



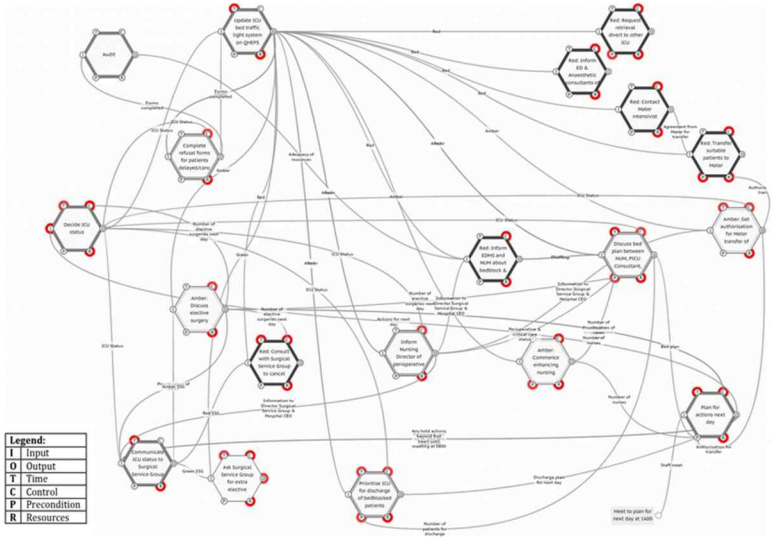
Stanton (2019)

14. FRAM

- FRAM (Functional Resonance Accident Model)

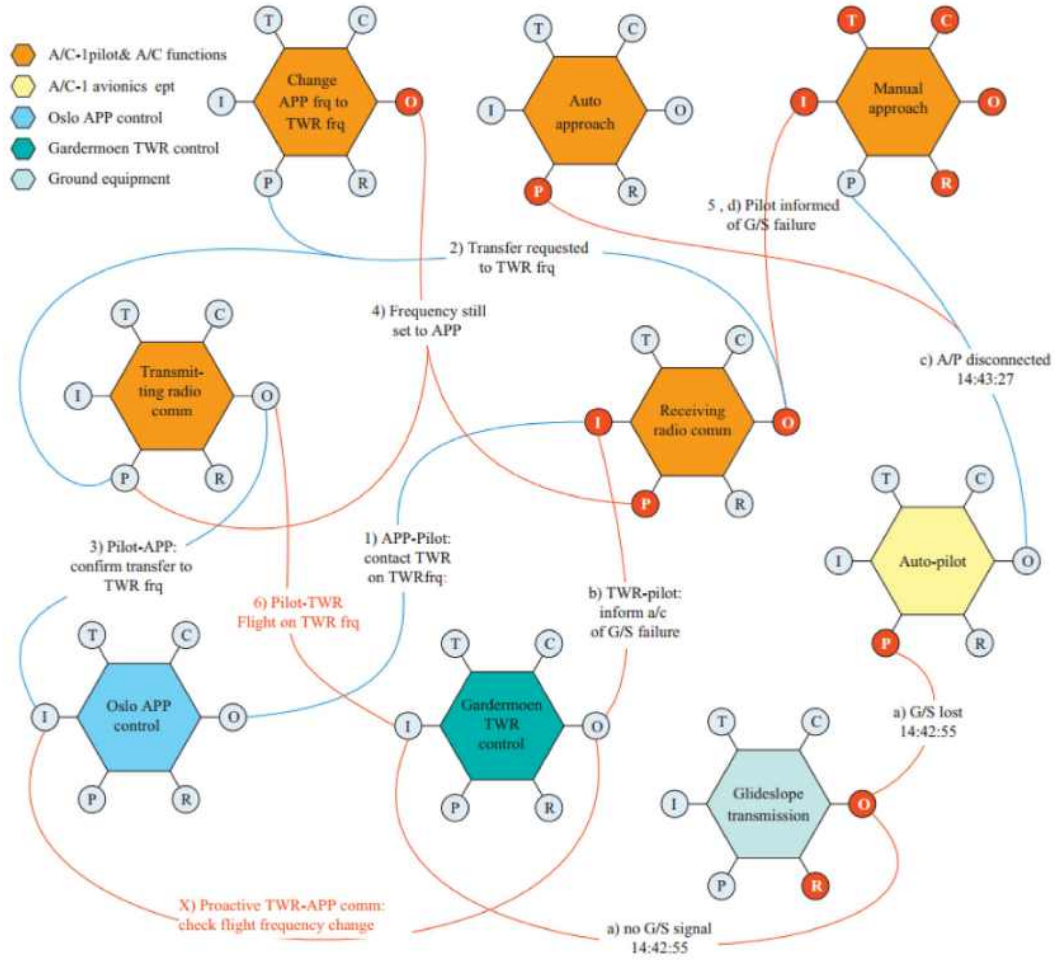


기본 단위



FRAM 분석

FRAM 분석 예


A/C-1pilot& A/C functions
A/C-1 avionics ept
Oslo APP control
Gardermoen TWR control
Ground equipment
Change APP frq to TWR frq
Auto approach
Manual approach
5 , d) Pilot informed of G/S failure
2) Transfer requested to TWR frq
4) Frequency still set to APP
Transmit-ting radio comm
Receiving radio comm
c) A/P disconnected 14:43:27
3) Pilot-APP: confirm transfer to TWR frq
1) APP-Pilot: contact TWR on TWRfrq:
6) Pilot-TWR Flight on TWR frq
b) TWR-pilot: inform a/c of G/S failure
Auto-pilot
Oslo APP control
Gardermoen TWR control
Glideslope transmission
a) G/S lost 14:42:55
X) Proactive TWR-APP comm: "check flight frequency change
a) no G/S signal 14:42:55

사고발생 모델 비교

Accident causation model	Proposed year	Factors definition	Object factors	Human factors	Organisational factors	Modularity	Simple chain	Complex chain	Systematic mesh
APT	1919	×	×	○	×	×	○	×	×
Domino theory	1931	×	○	○	×	○	○	×	×
Accident liability	1949	×	○	○	×	×	○	×	×
Accident epidemiology	1949	×	○	○	×	×	○	×	×
Bird's model	1966	×	○	○	○	○	○	×	×
ETT/ EARM	1968	×	○	○	○	○	×	○	×
Surry's model	1969	×	×	○	×	○	○	×	×
Hale's model	1970	×	×	○	×	×	○	×	×
Wigglesworth's model	1972	×	×	○	×	×	○	×	×
Lawrence's model	1974	×	×	○	×	×	○	×	×
Kitagawa's model	——	×	○	○	○	○	○	×	×
OIT	1980s	×	○	○	○	○	○	×	×
Tripod Beta model	1980s	×	○	×	×	×	×	○	×
Swiss cheese model	1990	×	○	○	○	○	○	×	×
3 M/5 M model	——	×	○	○	○	×	×	○	×
Bow-Tie model	1990s	×	○	×	×	×	×	○	×
AcciMap	1997	×	○	○	○	○	×	×	○
CREAM	1998	×	○	○	○	×	×	×	○
Stewart's model	2001	×	○	○	○	○	×	○	×
HFACS	2001	○	○	○	○	○	×	○	×
STAMP	2004	×	○	○	○	○	×	×	○
OAC	2006	×	○	○	○	○	×	×	○
OOGM	2010	×	○	○	○	○	×	×	○
SHIPP	2011	×	○	○	○	○	×	×	○
IPICA	2011	×	○	○	○	○	×	×	○
FRAM	2012	×	○	○	○	×	×	×	○
TeCSMART framework	2016	×	○	○	○	○	×	×	○
24Model (*V*4.0)	2016	○	○	○	○	○	×	×	○

APT: Accident Prone Tendency; OIT: Orbit Intersecting Theory; ETT: Energy Transfer Theory; EARM: Energy Accidental Release Model; OAC: Occupational Accident Model; OOGM: Offshore Oil and Gas Model.