System Dynamic Modeling Approach on Safety Culture Assessment in Korean Nuclear Power Plant

(for IAEA Safety Culture Conference)

Hanyang University
Seoul, Korea

Namsung Ahn, Ph. D. (nsahn1955@naver.com)

Motivations for this work

- History of long safe and highest record operations encourages growing complacency. However, the transition to a new administration forced the organizational change including manpower resource reduction.

- The success of nuclear power plant export to UAE in 2009 and the green growth national vision caused the rapid growth in Korean Nuclear industry

- Concealment of SBO at Kori 1 was revealed by media and led to the entire investigation of the whole nuclear power plants. It was just after Fukushima accident.

- Many cases to skip the process of checking the component certification were found through the investigation for last 2 years and raised the safety culture issue by the media.

- Public is strongly affected by the media. The critics from the media accelerated to change the perception of public about the nuclear power plant safety.

Safety Culture

A culture is commonly defined by sociologists as **the shared set of norms and values that govern appropriate individual behavior**.

Although the psychological research on occupational safety emphasizes either human error or technical failure as the source of accidents, organizational factors such as safety culture are now widely recognized as having a high importance .

Safety culture is the subset of organizational culture that reflects the general attitude and approaches to safety and risk management. Therefore, the study on safety culture has to be started from the understanding the organizational complexity.

Organizational Culture Research In Academics

Research on social psychology identifies a range of organizational variables (management Commitment to safety, leadership style, and Work Pressure or the conflict between production & safety, quality of communication…) that can impact safety behavior (Zohar).

However, it can not answer the dynamic questions of how safety in an organization can be improved or deteriorated or why in some cases, safety culture erodes over time. In response to this, organizational learning research focus more on learning process to answer the above questions with viewing safety as a dynamic problem in which organization must learn from mistakes.

In the research on organizational learning, it is known that the production pressure have a significant influence on the ability of an organization to learn, regardless of the strength of communication norms and that the role of decision makers with regard to production pressure is crucial to fostering a culture of learning (John Lyneis, Stuart Madnick)

Why System Dynamics Modeling Approach?

Many evidences show that organizational complexity, resulted from the interaction among components of the socio-technical system, causes the safety culture issue of the high hazard organization.

Accidents in system dynamics approach are viewed as the result of flawed processes involving interactions among people, societal and organizational structures, engineering activities, and physical system components.

System dynamics, originated by Forrester in MIT, has been used successfully on numerous occasions to model the experience of particular organizations with regard to safety and accidents (Leveson et al, 2005; Cooke, 2003; Minami & Madnick, 2007), and to generate more general theory concerning both the causes of disaster (Rudolph & Repenning, 2002), and accident prevention (Cooke & Rohleder, 2006).

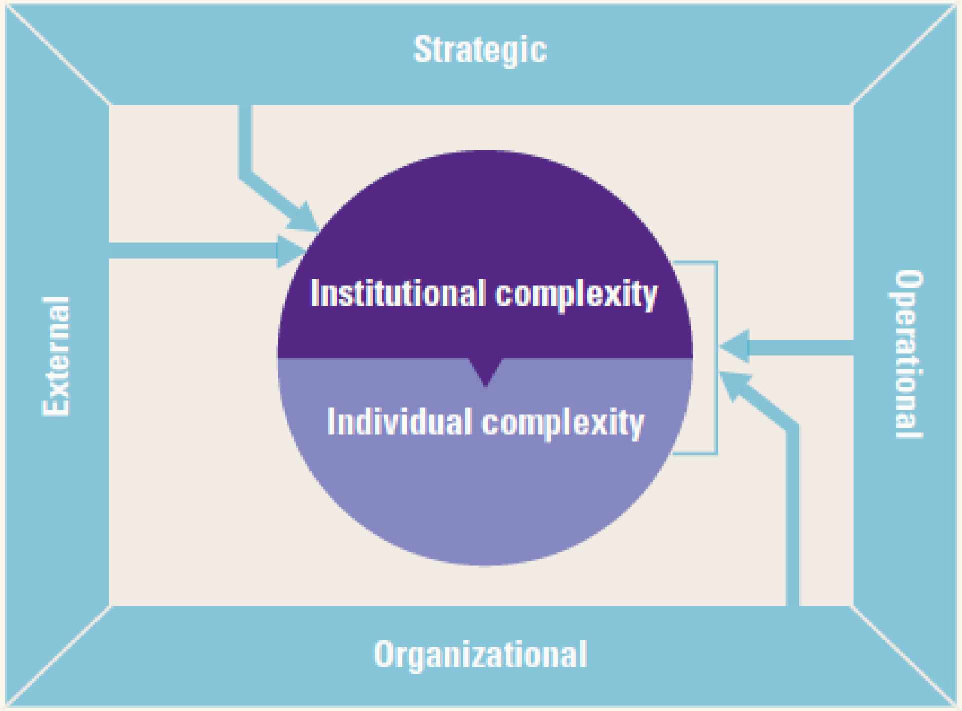
Organizational Complexity

***Institutional* complexity**
The number of countries the company operates in, the number of brands or people they manage.

***Individual* complexity**
The way employees and managers experience and deal with complexity.
(poor processes, confusing role definitions, or unclear accountabilities, poor safety culture…)

Mapping Complexity

Interrelated levels of complexity



Strategic choices
- Number of products and services
- Number of countries
- Sources of competitive differentiation

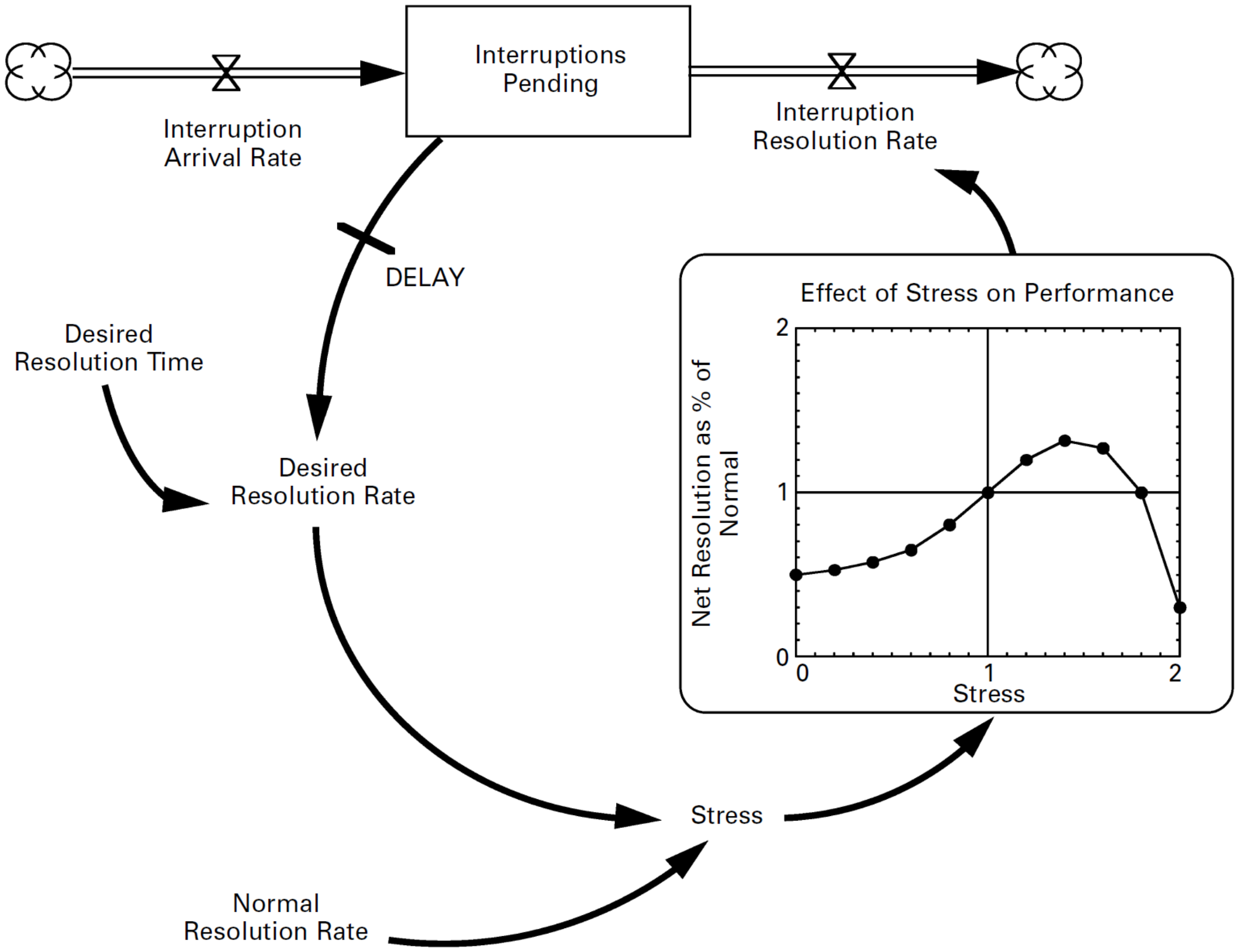
External context
- Regulatory changes
- Intensity of competition
- Speed of competitive evolution

Organizational choices
- Structural design
- Role definition
- Process refinement
- Development of capabilities
- Culture

Operational choices
- Manufacturing (eg, lean), R&D, value chain
- Use of technology

Source: Cracking the Complexity Code (Mckinsey, 2015)

Dynamic Interruption Theory of Stress Model Structure

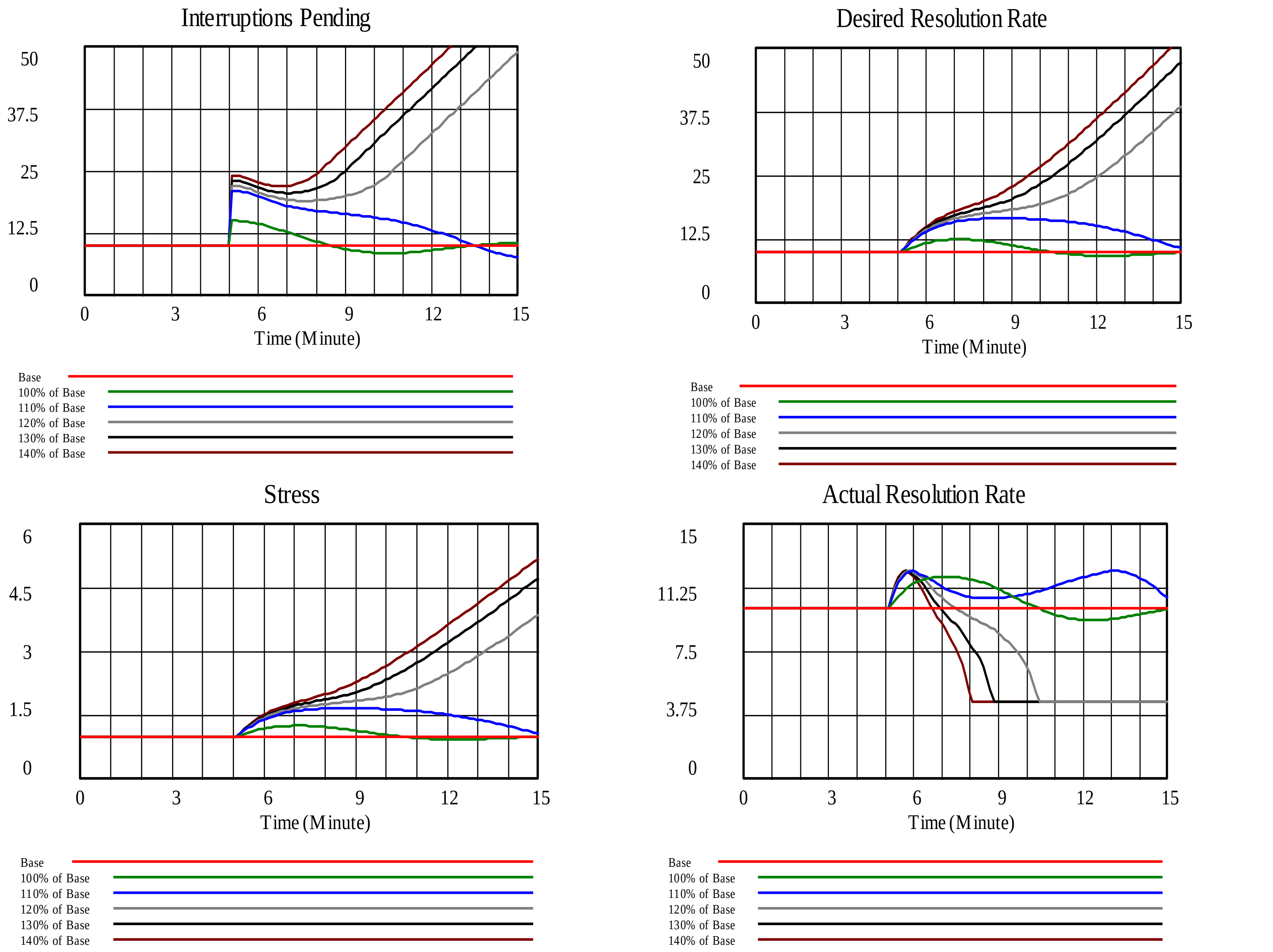


Interruption

Any unanticipated or ill structured event, external or internal to the individual, that prevents completion of some action, thought sequence, plan, or processing structure (Mandler, 1982)

Yerkes-Dodson Law

This law is widely interpreted as an inverted U shaped relationship between stress/arousal and performance on difficult tasks. As stress climbs, performance rises-up to a certain level- and then decline as stress continues to rise



Interruptions Pending
50
37.5
25
12.5
0
0
3
6
9
12
15
Time (Minute)
Base
100% of Base
110% of Base
120% of Base
130% of Base
140% of Base
Desired Resolution Rate
50
37.5
25
12.5
0
0
3
6
9
12
15
Time (Minute)
Base
100% of Base
110% of Base
120% of Base
130% of Base
140% of Base
Stress
6
4.5
3
1.5
0
0
3
6
9
12
15
Time (Minute)
Base
100% of Base
110% of Base
120% of Base
130% of Base
140% of Base
Actual Resolution Rate
15
11.25
7.5
3.75
0
0
3
6
9
12
15
Time (Minute)
Base
100% of Base
110% of Base
120% of Base
130% of Base
140% of Base

The History of Nuclear Accident

TMI → **Chernobyl** → **Fukushima**

TMI	Chernobyl	Fukushima
Human Error	Human Error+ Design Deficit	Natural Disaster
INPO	WANO	Organizational Culture
	Safety Culture	

If 4th accident? Management Failure to Accident
(Safety Culture, Supply Chain Management, Management Policies…)

(Psam2012, Tokyo, Japan)

Characteristics of Nuclear Power Plant

High Risk Complex Industry

Organizational Complexity, Managerial Policies including the technical, social and cultural issues

Machine model rather than ecological model. Limit the creativity, innovation of operator (Proceduralization rather than Professionalism)

Machine Organizational Culture

Conflict between Production and Safety

Safety first policy. However, economics is also important

Social, Cultural Factor

Engineering based safety analysis model (PSA). Operational procedure designed by engineers only.

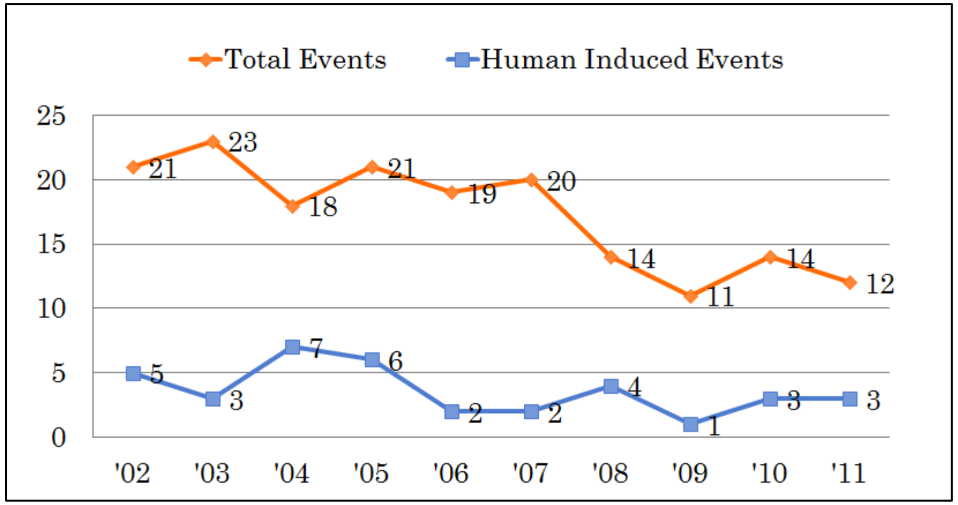
Limitation to analyze organizational factors. Communication and learning issues

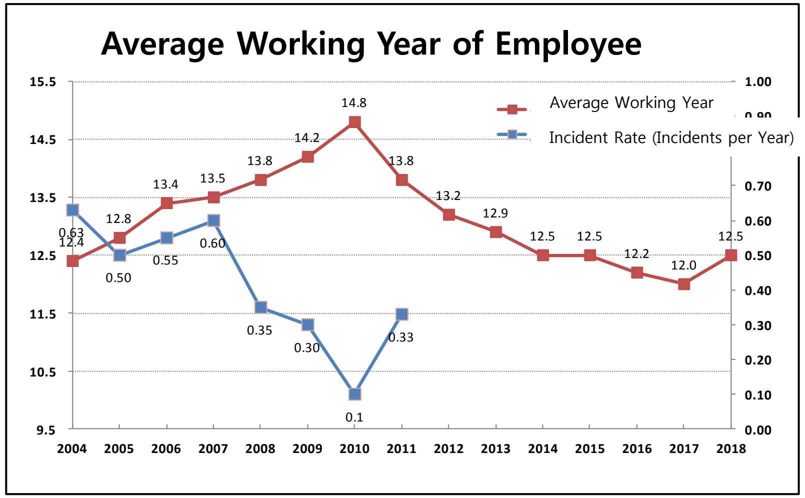
Big Change in Korean Nuclear Industry after New Administration in 2009 (Green Growth national Vision)

	Before 2009	After 2009
Organizational Complexity	**Number of Model × Number of Component × Number of Plants**	**Number of Model × Number of Component × Number of Plants** **× Number of Overseas Site × Number of Overseas Plants × Number of Overseas Model** **× Number of New Power Plant Construction (Domestic)**
Management Priority (Cost Reduction)	**Safety > Quality > Production (Growth)**	**Production (Growth) > Safety > Quality**

Factor by Export of NPP

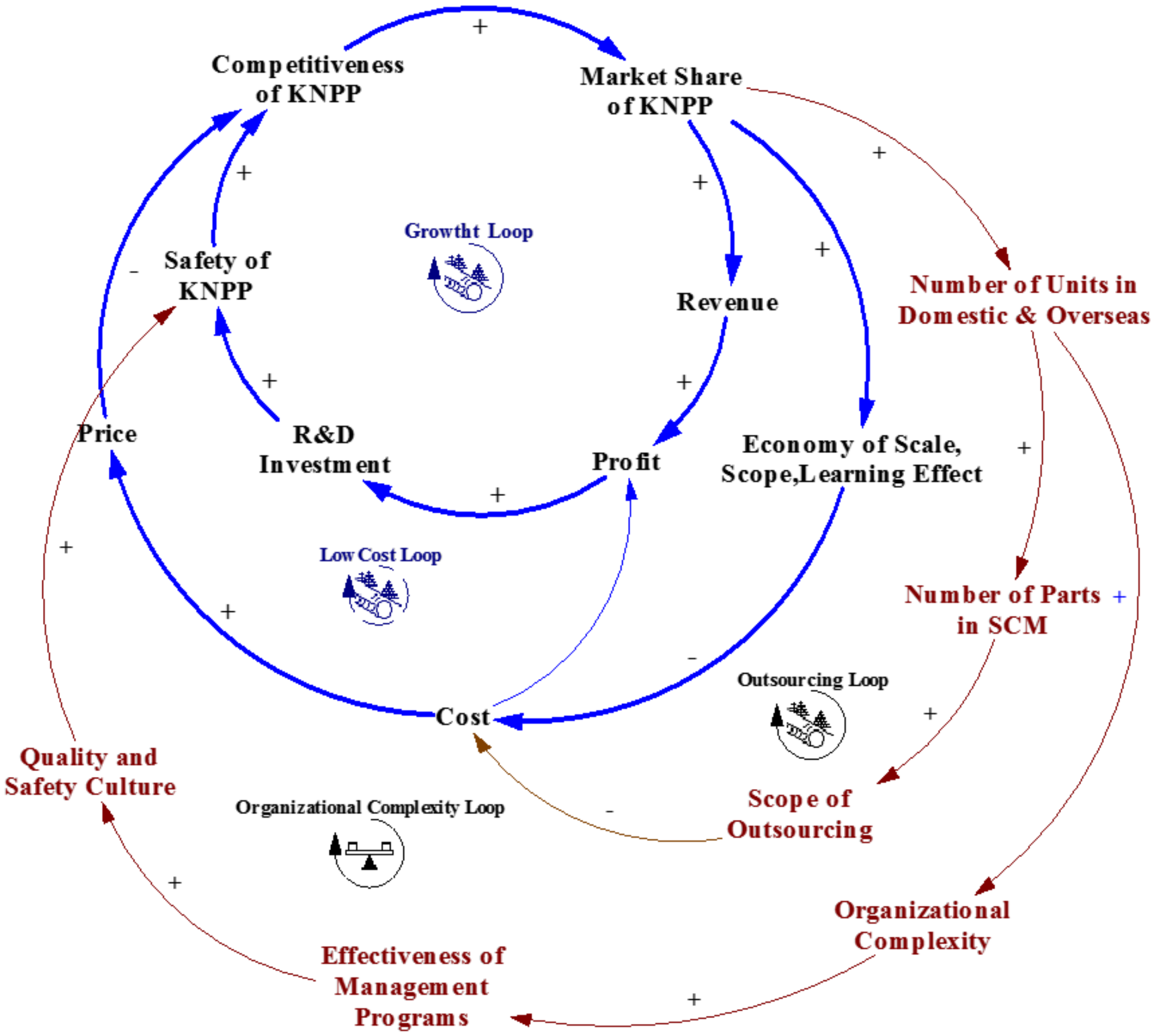
Factor by Domestic New Construction





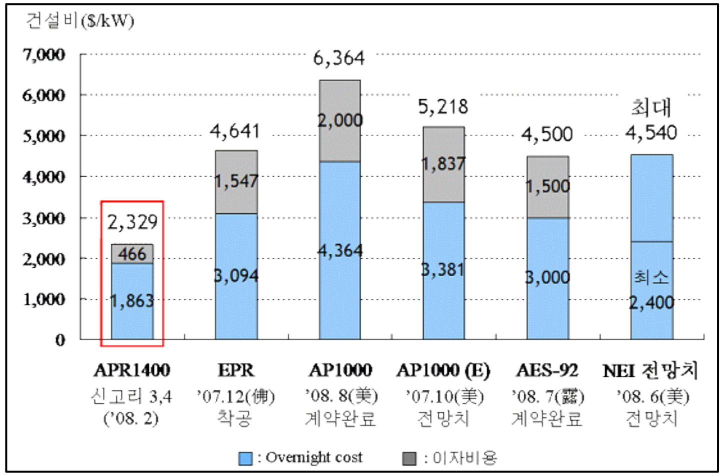
O&M Investment over Time											
											(단위 : 억원)
Items	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Number of Operating Units(A)	18	18	18	19	20	20	20	20	20	20	21
O&M Cost(B)	2,841	3,454	3,867	4,716	4,717	5,405	6,544	6,626	7,359	6,792	7,698
Additional Investment (C)	919	926	1,373	1,253	1,889	2,391	5,373	5,244	8,991	6,711	7,147
Total Investment(D=B+C)	3,760	4,380	5,240	5,969	6,606	7,796	11,917	11,870	16,350	13,503	14,845
Investment per Unit (D/A)	209	243	291	314	330	390	596	594	818	675	707

Overview of Organizational Complexity in Korean Nuclear Industry

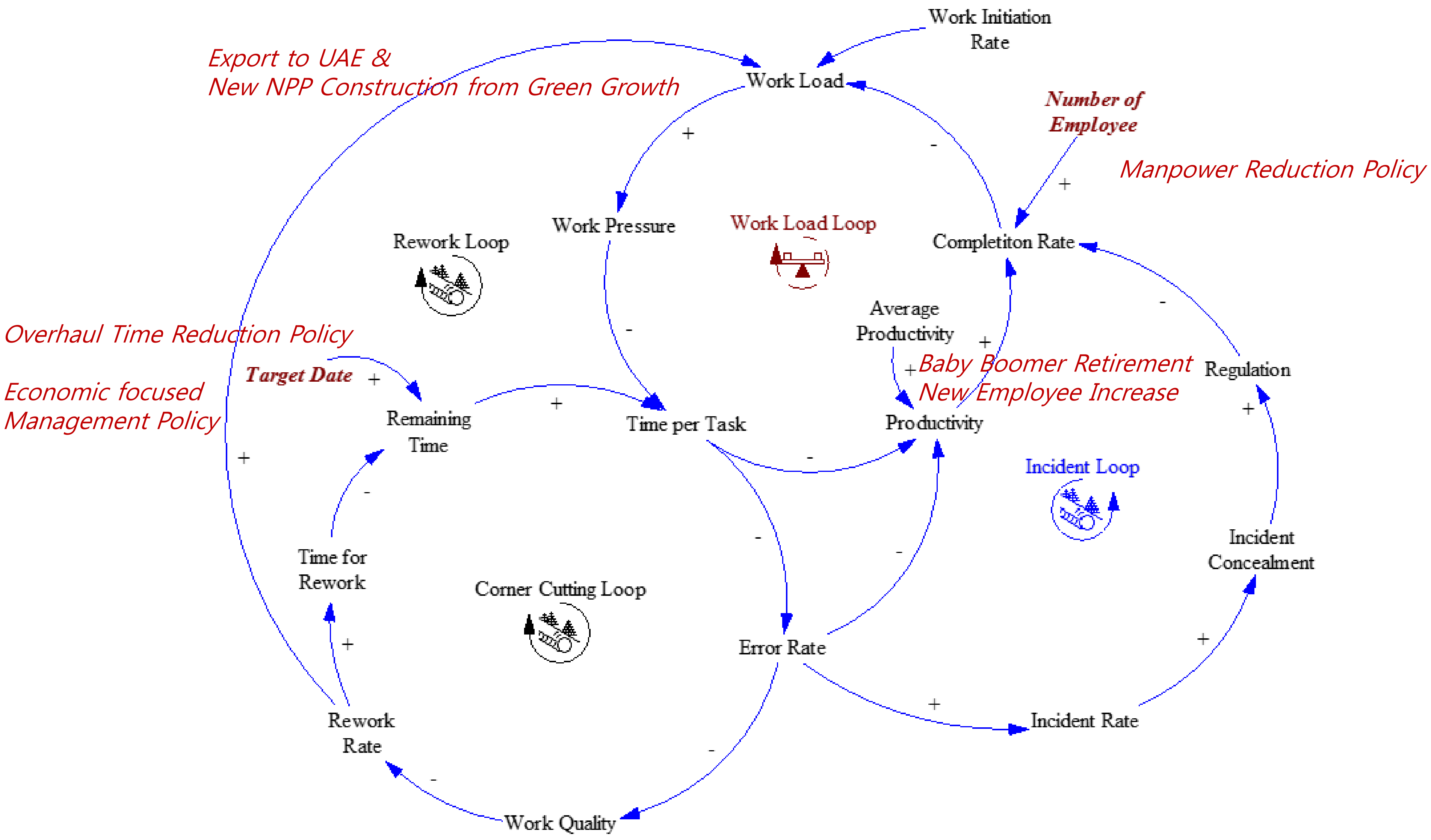


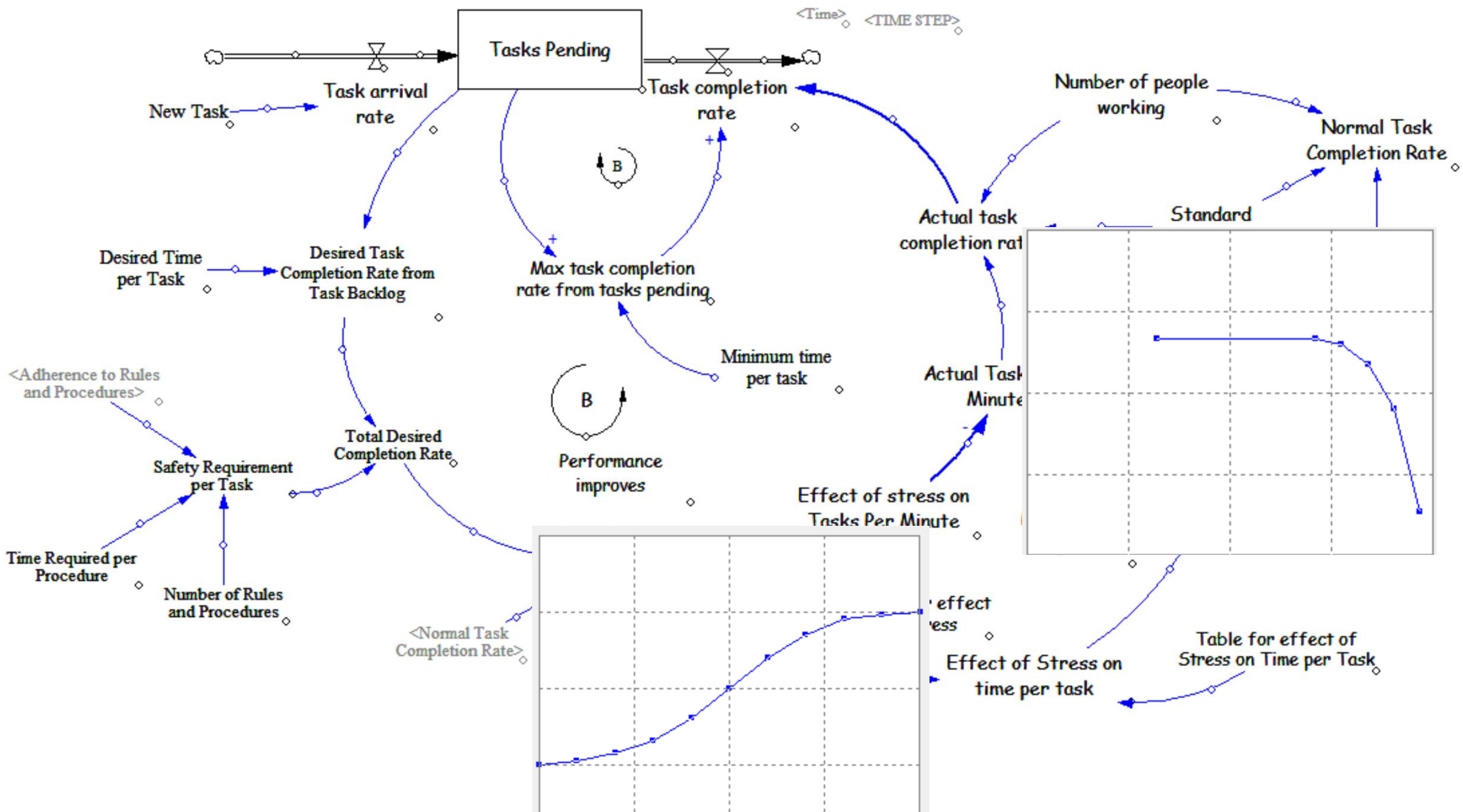
Content	'01	'02	'03	'04	'05	'06	'07	'08.8
Capacity Factor	93.2	92.7	94.2	91.4	95.5	92.3	90.3	94.78 ('08.6)
Shutdown	8	8	11	12	10	11	12	4
Shutdown rate / unit-year	0.5	0.4	0.6	0.6	0.5	0.55	0.6	0.3
World Avg. Capacity Factor	78.9	78.9	76.5	78.8	79.3	79.5	77.8	-

Source: Korean Nuclear Industry and Competitiveness, 2008, KEPCO



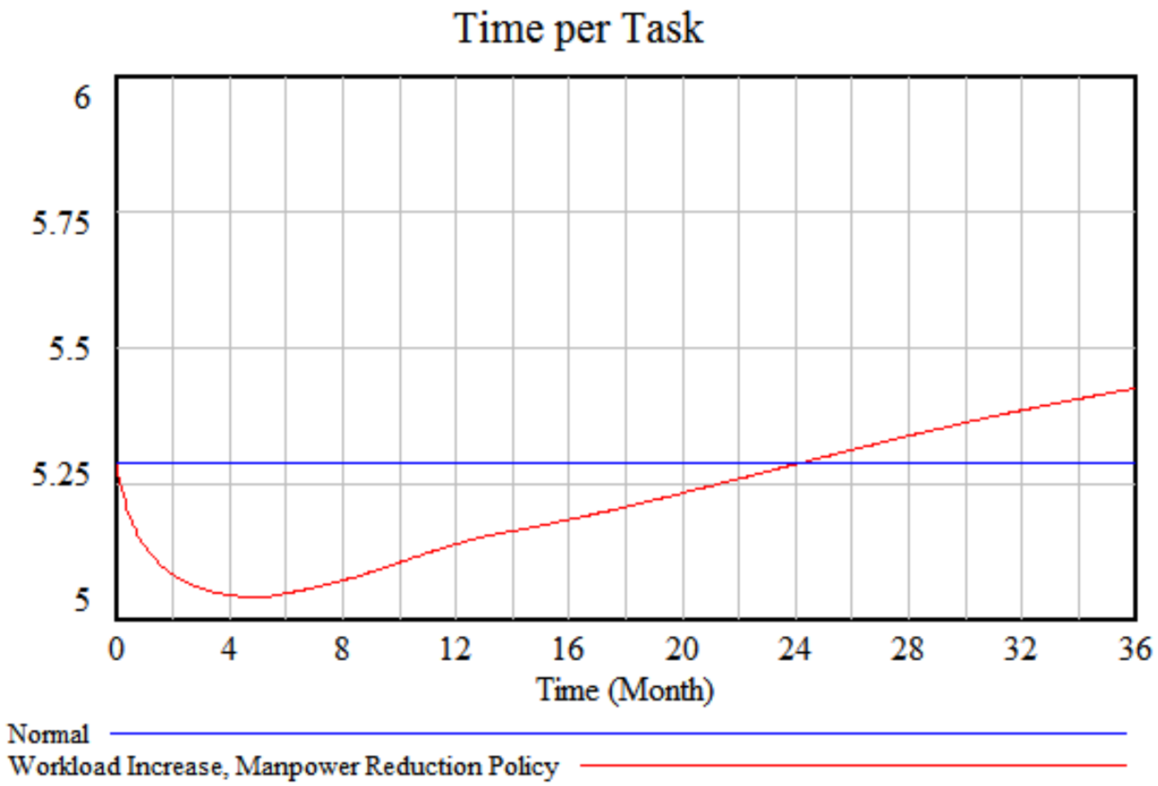
Important Management Policies in KHNP





Tasks Pending
<Time>
<TIME STEP>
Task arrival rate
New Task
Task completion rate
Number of people working
Normal Task Completion Rate
Standard
Actual task completion rat
Desired Time per Task
Desired Task Completion Rate from Task Backlog
Max task completion rate from tasks pending
B
Minimum time per task
Actual Task Minute
<Adherence to Rules and Procedures>
B
Total Desired Completion Rate
Safety Requirement per Task
Performance improves
Effect of stress on Tasks Per Minute
Time Required per Procedure
Number of Rules and Procedures
effect
ess
<Normal Task Completion Rate>
Table for effect of Stress on Time per Task
Effect of Stress on time per task

Simulation Results for KHNP Case(Workload 5% Increase, Manpower 10% Decrease, 10% Increase)



Lessons learned from KHNP case

The effects of organizational factors on safety like management policies does not appear immediately because of business dynamics (cause and effect are not obviously related in time and in space). The effect is accumulated and appear as an counterintuitive and unexpected behavior of organization when we have a incorrect mental model.

Looking at the dynamics of system can improve understanding of accidents and investigation recommendations. This KHNP example can be another cases to other countries because it was originated from the inherent structural problems of nuclear power plant.

System dynamics approach is very powerful to see the structural problems and describe the dynamic changes of the safety culture system, which has been known as the limitation of engineering model (PSA) and the social psychology model.

Developing Safety Culture Archetypes in Nuclear Power Plant

System dynamics approach is very effective to see the structure of the safety culture system. However, It is difficult to build system dynamics model. It does not come naturally to the non-experts.

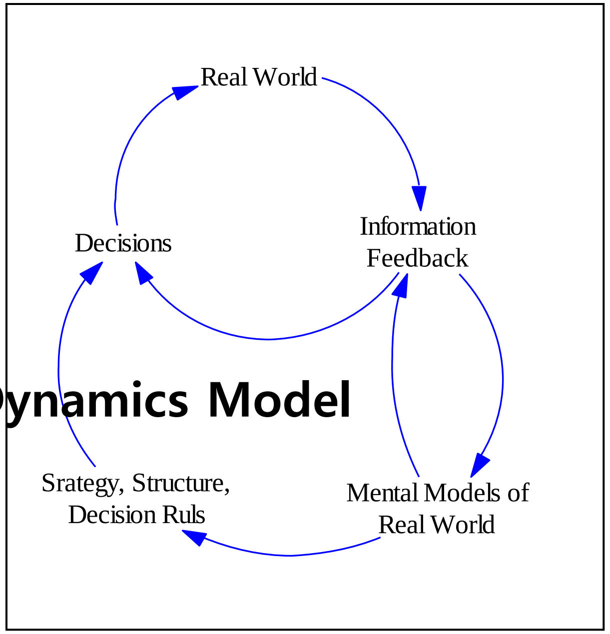
System dynamics model can be used to correct the mental model. Behavior is determined by the perception influenced by the mental model of the individual. However, it is very hard to change the mental model through training or education…. We need a help from the tools to change the mental model.

Many systems exhibit common behavior and flaws in the safety culture that leads to accident archetypes. Develop and use the safety culture archetypes to understand more effectively the structure of safety culture.

Safety Archetype in Nuclear Power Plant

Organisational Behaviour

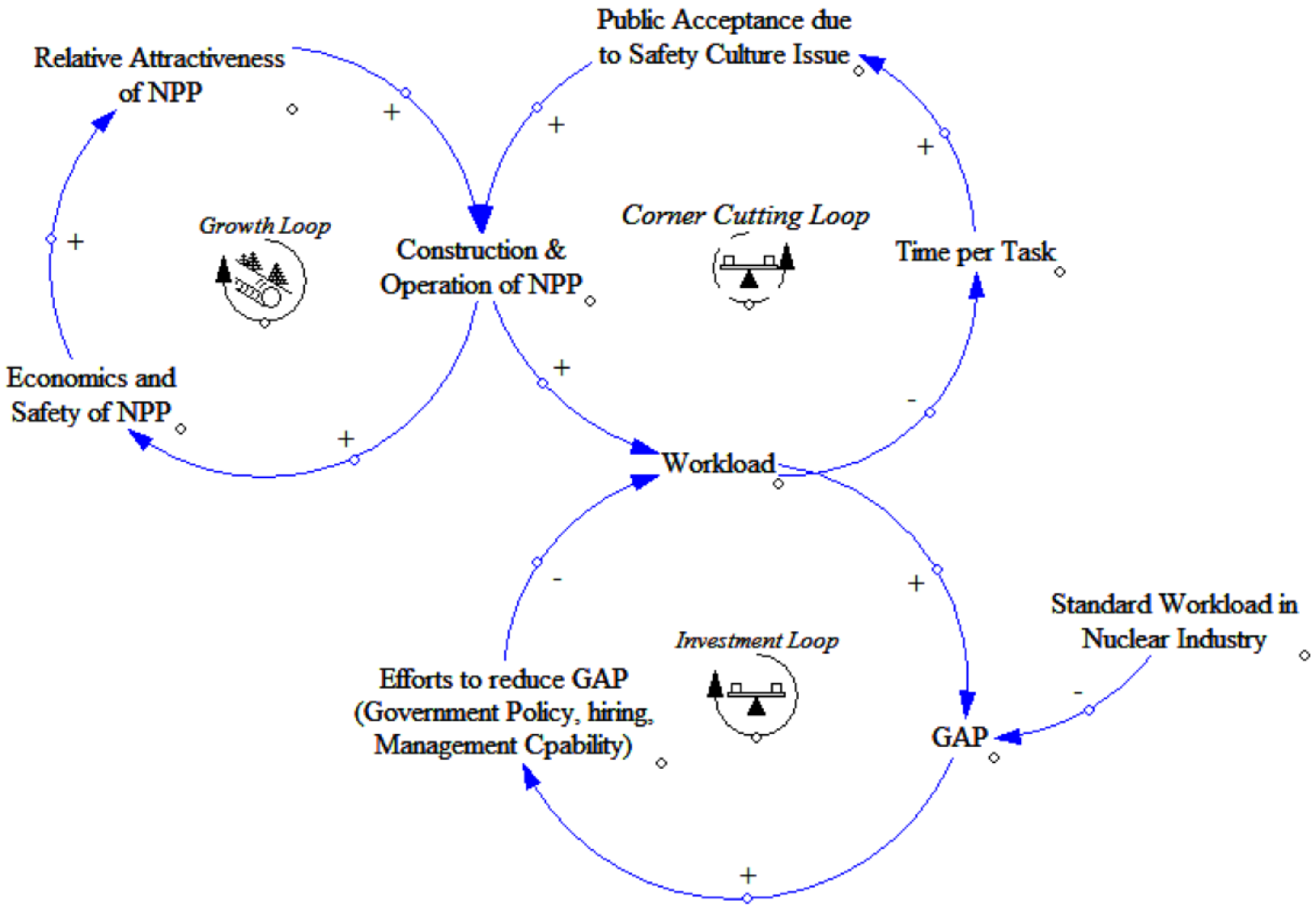
Safety Engineering



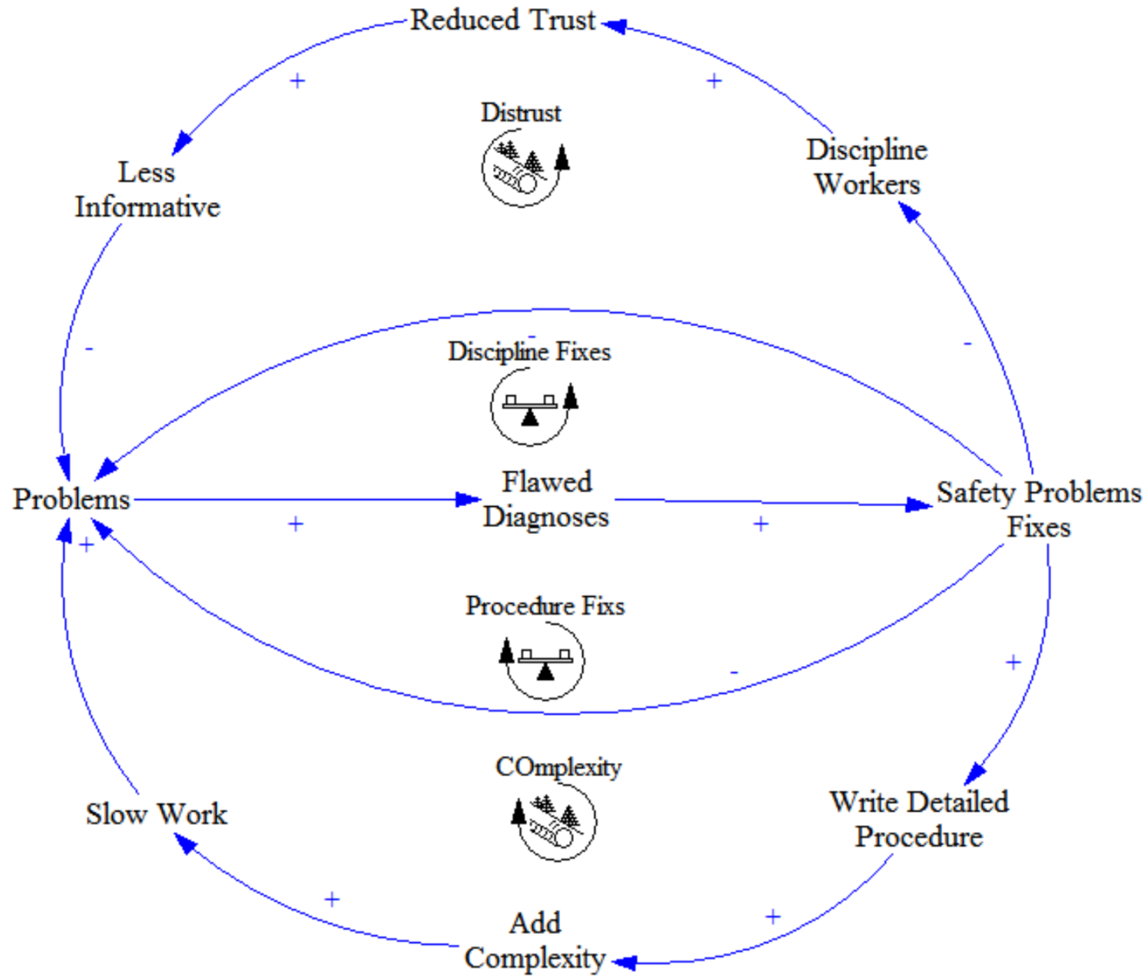
System Dynamics Model

Safety Culture Archetypes specific to Nuclear Power Plant

Growth and Underinvestment Archetype in Korean Nuclear Industry



Example 2: Unintended Side Effects of Safety Fixes



Archetypes for Organizational Safety, Karen Marais & Nancy G. Leveson

Disciplining workers and writing more detailed procedures may not increase safety

Typical fix for maintenancerelated problems

- Detailed procedures and closer supervision seen as mistrust and regimentation
- Discourages problem solving
- Blaming individuals encourages all workers to hide problems
- When incidents are concealed, underlying problems stay hidden, often worsen, and may lead to more problems

If some safety culture archetypes in the nuclear power plant are developed and added to the IAEA Screen9ng methodology, it will be very effective to understand the structure of safety culture system in nuclear power plant