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Nuclear Procurement System: Fraudulent Items of Nuclear Power Plant in Republic of Korea

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Abstract

Nuclear Procurement System: Fraudulent Items of Nuclear Power Plant in Republic of Korea

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In May 2013, it turned out that a few items were supplied to NPPs with fraudulent certificate. The documents were the reports of verification - Quality Verification Document (QVD), Equipment qualification (EQ), and Commercial Grade Items Dedication (CGID) - which are required to submit when suppliers deliver the items to the operator. The fraudulent documents were the result of collusion between suppliers and certificate authorities. As the unqualified items were detected, operators had to halt the operation and delay the construction of NPPs for the replacement of fraudulent items and inspection on overall facilities. As the result, power reserve level dropped significantly and rolling blackouts were conducted, which led to economic loss of industry. In addition, the disclosure of fraudulent items acted as the catalyst for the public negativity which has been grown since Fukushima Daiichi nuclear accident.

These unqualified items are dealt with the concept of Counterfeit, Fraudulent, and Sub-standard Items (CFSIs). CFSIs are detected in various components of NPPs, and these could be direct factors of accidents, such as reactor shutdown, unanticipated release of radioactive materials, and damage of fuel. CFSIs also have the potential to degrade the performance of safety functions and safety-related system. Since 1980s, regulations on CFSIs were first developed in USA, and currently adopted globally. However, in Korea, the CFSIs had not been considered as a significant issue, and meanwhile, CFSIs occurred. The purpose of research is to define the root cause of CFSIs and suggest policy recommendations as solutions.

For the comprehensive research of nuclear procurement system, three different methodologies were applied; the analysis on Korean laws and regulations, interviews on the subjects of nuclear procurement, and statistical analysis on contracts between suppliers and operators. According to Nuclear Safety Law, regulatory authority has a duty to inspect on operators, suppliers, and certificate authorities, regarding to quality assurance. The laws and regulations were well-organized to prevent the CFSIs. Therefore, interviews were conducted to figure out the inherent issues, and following problems were pointed out; shortage of manpower for verification and independence of certificate authorities.

In addition, statistical analysis on bidding and contract procedures were conducted to understand the issues. First of all, it was recognized that bidding processes were delayed up to 5 weeks, without extending the deadlines for supply, as the compensation of delay. Moreover, in a few bidding processes, procedures were ignored at all.

Based on the analysis on the laws and regulations, interviews, and statistical analysis, nuclear procurement system was modeled. System dynamics was taken as the methodology to find out the interrelation between various factors.

In the early of NPPs operation, the investment had been concentrated on safety issues, and as the result, the operating hours were increased consistently. However, when the operation of NPPs became stable with barely no safety issues, the operator has decreased planned maintenance period for stable power generation. The reduced period was a burden to suppliers, because the deadlines for supply are cut down. Accordingly, it caused the CFSIs in NPPs.

Another aspect shown in the nuclear procurement system is the concern on quality control. If there are a number of safety issues, quality control is conducted intensively, which lead to reduction of CFSIs. However, because the safety-related issues barely occurred since 1990s, the control on CFSIs couldn’t be conducted properly.

The requirement of registration for suppliers is another factor of CFSIs. During the bidding, open tendering with the lowest price is performed for the profit of operators. Thus the fewer suppliers apply, the more income they get. To keep other competitors from applying, suppliers pushed operator to maintain the high requirement and the small number of suppliers was preserved. But it induced the delay on bidding process. It caused suppliers not to have enough time for verification and became the reason for the CFSIs. In addition, the confined pool of suppliers made operators to involve vendors and foreign countries into the supply chain. The extension of supply chain disturbed quality control, which led to CFSIs.

Finally, the number of certificate authorities could be the reason of CFSIs. In the case of QVD, since the private authorities could be qualified to conduct verification, the number of authorities have increased up to 2500.

The competition among them became fierce, so that suppliers could exert power over certificate authorities. It undermined the independence of certificate authorities and led to the corruption during the verification procedure. On the other hand, in the case of CGID, there is only one domestic certificate authority. It made the time for verification to be extended, which also induced the CFSIs.

As the solutions to the four mentioned problems, policy recommendations were suggested in the aspect of operator, supplier, regulatory authority, and certificate authorities. First of all, operators need to adopt a storage inventory management. Foreign operators have developed various researches for inventory management. However, Korean operator doesn’t have such program because of insufficient budget. If the inventory management could be conducted properly, operators could guarantee the deadlines for supply, and quality assurance also could be conducted in comprehensive way. Operator should alleviate the standard for suppliers, and allow more suppliers to register. It reduce the period of bidding procedure. In addition, government should support the control of CFSIs by supplementing manpower for certificate authorities, reinforcing specialty, and establishing institution for verification. Certificate authorities for QVD should secure their independence and perform verification procedure properly by reducing the number of authorities through the reinforcement of standard for themselves. In case of CGID, the establishment of domestic certificate authorities should be promoted. It will decrease the time for verification and CFSIs also will be reduced.

Keywords : Nuclear procurement, CFSIs, Fraudulent items,
Quality control, Quality assurance,
Nuclear supply chain
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Chapter 1 Introduction

In May 2013, Nuclear Safety and Security Commission (NSSC) in the Republic of Korea revealed that fraudulent items were supplied in nuclear power plants (NPPs). It was astonishing that not only suppliers but also operator and certificate authorities were involved in this scandal. Control cables were sent to foreign certificate authorities for quality verification through a domestic certificate authorities, but the result of test was failed. Nevertheless, the domestic certificate forged the failed document as succeeded by conspiring with the supplier and operator.

Since then, the operator suspended operation and construction of NPPs in which counterfeit items were used. For this reason, Korea's power reserve level dropped significantly which led to power shortages. A number of companies had to shut their factories down due to the rolling blackouts. In order to maintain the power reserve level, an electric power company produced additional electricity from liquefied natural gas and diesel fuel, whose unit cost is much expensive than that of nuclear power. All of these caused enormous financial loss of Korean government.

Over the grown anxiety after Fukushima daiichi nuclear accident, these forged documents acted as a catalyst for public suspicion in nuclear safety.

Furthermore, this fraud event had bad influence on reliability for Korean NPPs after winning the first deal to build in the United Arab Emirates.

1.1 Background

When a NPP operator need components during construction or maintenance, they give a public notice of a bid to suppliers. After selecting a supplier, they contract a supply of components and the supplier proceed to manufacture items. The supplier requests to a certificate authority to test components and get quality certified documents. Finally, the supplier deliver components to operator with certified documents.

There were three kind of forged documents; Quality Verification Document (QVD), Equipment Qualification (EQ), and Commercial Grade Item Dedication (CGID). QVD is a document verifies the design feature. (e.g. report of non-destructive test, test report of materials. And report of chemical analysis). EQ is a document verifies performance and safety of components in accident condition such as high-temperature, pressure, and radioactivity during seismic tremor, conflagration, etc.

Commercial grade dedication (CGD) is a process used to enhance quality and therefore provide reasonable assurance that commercial items designed and manufactured outside of a nuclear quality program meet technical and quality requirements for safety related end uses in an NPP.

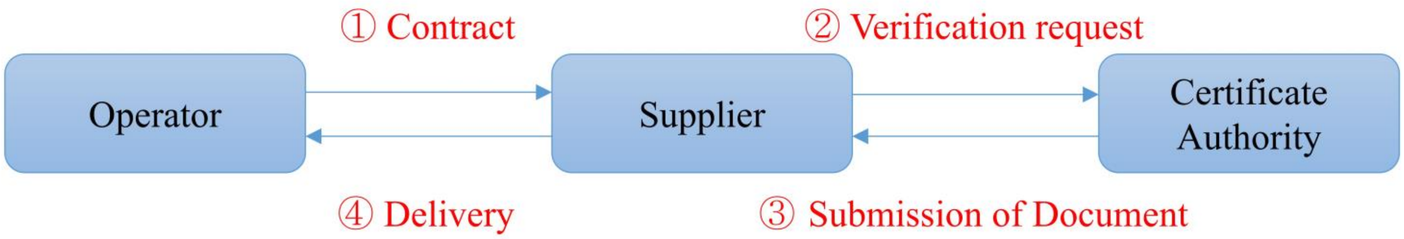

Figure 1.1.1 Process of procurement for NPP components

The process has been necessitated in many jurisdictions due to reduction in NPP construction, which has caused many suppliers to not maintain their nuclear management systems or quality programs. Parts may no longer be available, or even if available not with required nuclear quality program documentation. Because of this, there is no supplier assurance that component design is controlled, and it is also possible that sub-standard items may be manufactured due to lack of quality control in manufacturing. The CGD process is designed to allow the purchase of such commercially produced items and perform additional quality checks on them to ensure they are acceptable in safety related applications.

Supply chain and procurement processes have a role in detecting and preventing the entry of counterfeit, fraudulent, and substandard items (CFSIs) into nuclear facilities. Items can be classified according to the categories shown in Figure 1.1.2. **Counterfeit** items are intentionally manufactured or altered to imitate original products in order to pass themselves off as genuine. **Fraudulent** items are misrepresented with intent to deceive, including items with incorrect identification of false certifications. They may also include items sold by entities that have acquired the legal right to manufacture a specified quantity of an item but produce a larger quantity than authorized and sell the excess as legitimate inventory. **Sub-standard** or **non-conforming** items are simply those that do not meet intended requirements or function, and may be provided by legitimate suppliers without intent to deceive. Non-conformances can emerge at any stage of the supply chain, including design, manufacturing, storage, and transportation **Suspect** items are those about which there is an indication by visual inspection, testing, or other preliminary information that they may not conform to the accepted standards, specifications and/or technical requirements and there is a suspicion that the item may be counterfeit, fraudulent, or non-conforming. Additional information or investigation is needed to determine whether the suspect item is acceptable, nonconforming, counterfeit or fraudulent.

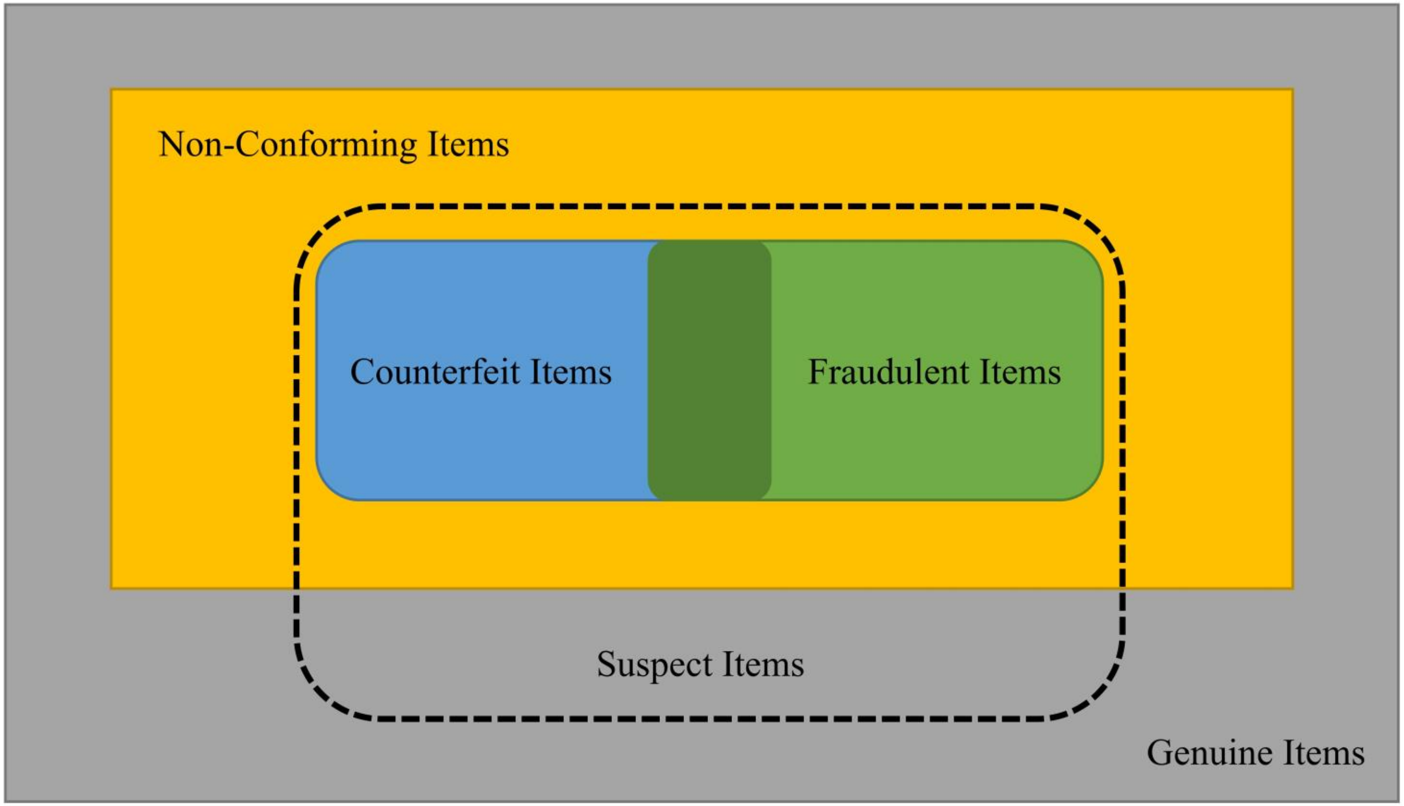

Figure 1.1.2 CFSI classification

1.2 Objective

As NPPs age obsolescence of original equipment is increasingly a concern. This increases demands on plant engineering and procurement organizations for equivalent replacement parts. This is in contrast to the desire to maintain NPPs in the exact same configuration as originally designed, thereby eliminating any chance of inadvertently altering the design basis or invalidating assumptions regarding safety system equipment performance or failure modes. Where originally equipment manufacturers are unavailable, such replacement or parts substitutions can require complex engineering assessments, reverse engineering or associated design changes in order to ensure needed requirements are met.

Procurement itself is becoming increasingly complex. There is a changing marketplace in many NPP operating countries. Many former nuclear suppliers may have gone out of business or have withdrawn from the nuclear business, either via a decision not to supply material or to simply to let their nuclear quality assurance program or management system lapse. This in turn has made it more difficult for nuclear operators to identify and procure replacement components and parts that meet original design and quality requirements. Original vendors themselves have tended to increase their numbers of sub-suppliers, making tracking and auditing of parts production more difficult.

Chapter 2 Review of the State of the Art

In this chapter, the research is introduced regarding to the fraudulent items of NPPs. In 2.1 Example of CFSIs, the research of Korean case and foreign cases are displayed. 2.2 CFSIs impact on safety explained the influence that fraudulent items could exert on the safety of NPPs. In 2.3 Integrated management system requirement, domestic and foreign cases of nuclear procurement system are introduced. 2.4 Procurement scenarios shows the four scenarios related to nuclear procurement system and quality assurance. 2.5 Establishment quotation displays the methods of contract for supply of components.

2.1 Example of CFSIs

Most recently discovered case of CFSIs is in the Republic of Korea. After the fraudulent items were found at the end of 2012, as mentioned in introduction, NSSC performed the inspection on all the items that have been purchased for last 10 years. The inspection team found out that about 8000 CGI were supplied with forgery qualify certified documents. Most of items among them were fuses, switches, and cooling fans. These items turned up not affecting nuclear safety, but the operator decided to shut down tow NPP units, and replaced all the forgery items. In addition, safety-related control cables with forgery test reports were found in two more units, on May 28, 2013. The power outage for four reactors was performed to replace all the installed control cables. The inspection team found that certificate authority forged the result of test for control cables, and supplied faulty items as they are not. Figure 3 and 4 show falsified EQ reports and Table 1 and 2 show the result of inspection for operating and constructing NPPs. Most of fraudulent documents is by re-using of old version and forging the test result as shown in Figure 5 and 6.

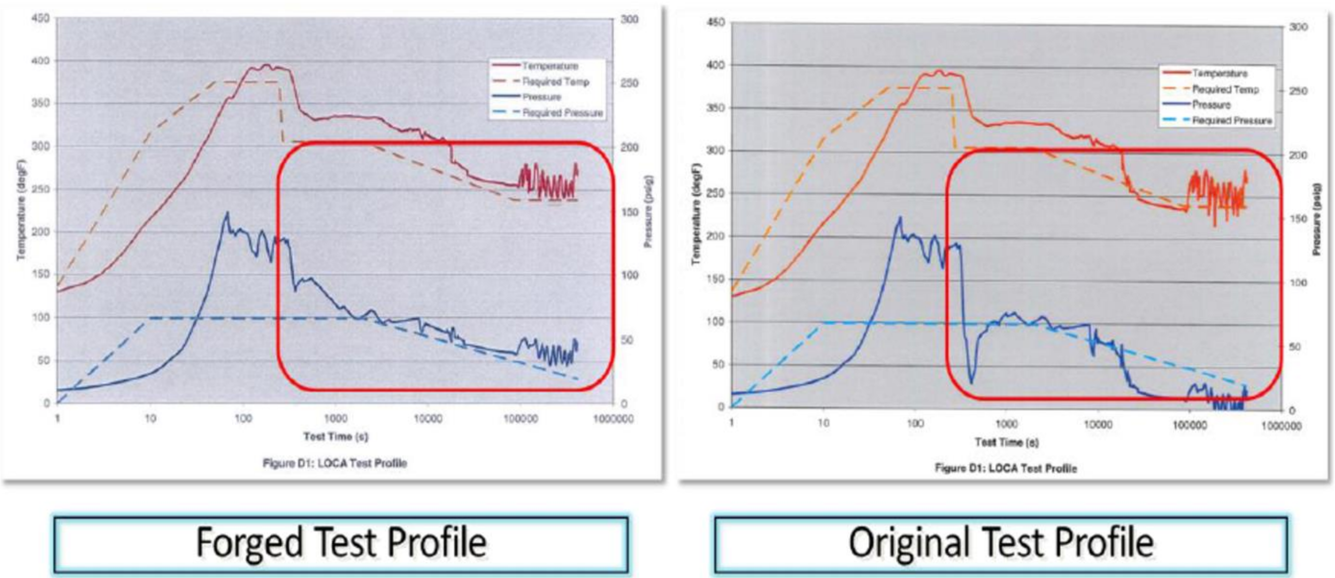

Figure 2.1.1 Korean examples of falsified EQ report (1) (Song, 2014)

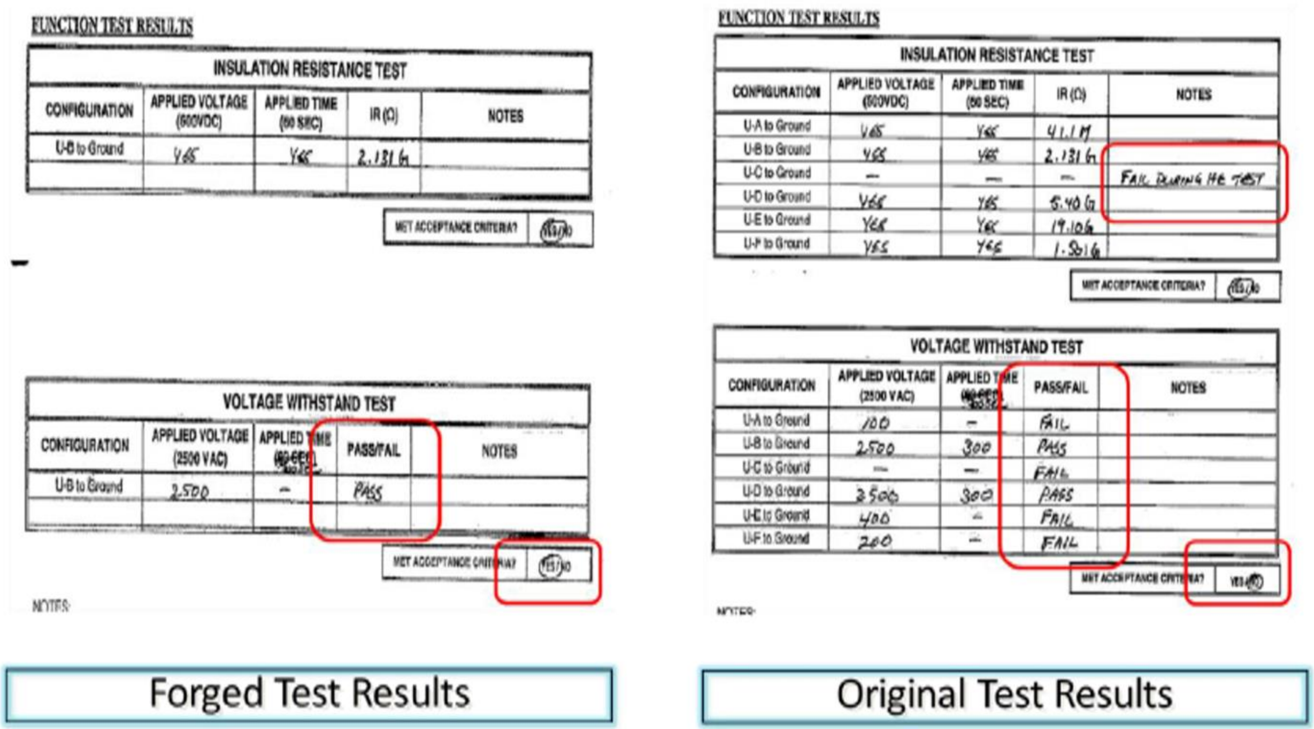

Figure 2.1.2 Korean examples of falsified EQ report (2) (Song, 2014)

Table 2.1.1 Investigation results of QVDs (Song, 2014)

Type of Inspection	Reviewed QVDs	Result	
		Forged	Unidentified
Replaced Materials for 20 Operating NPPs	21,681	247	408
Construction Materials of Newly Built Shin-Kori 1&2, Shin-Wolsong 1	109,558	1,178	14,746
5 NPPs under construction (Shin-Kori 3&4, Shin-Wolsong 2, Shin-Hanul 1&2	163,696	800	45,678
Total	294,935	2,225	60,832

Table 1.1.2 Investigation results of EQ reports (Song, 2014)

Equipment Qualification	Environmental Qualification		Seismic Qualification		Total	
	Reviewed	**Forged**	**Reviewed**	**Forged**	**Reviewed**	**Forged**
20 operating NPPs	342	20	689	10	1,031	30
3 recently constructed and 5 constructing NPPs	159	13	1,509	19	1,668	32
Total	501	33	2,198	29	2,699	62

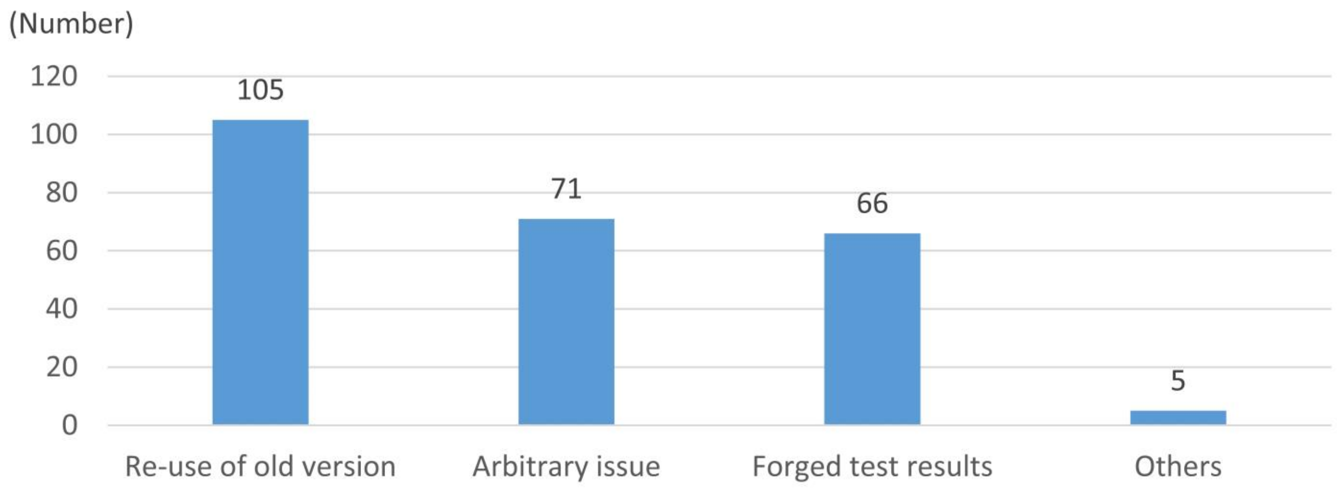

Figure 2.1.3 Types of 247 forged QVDs (Song, 2014)

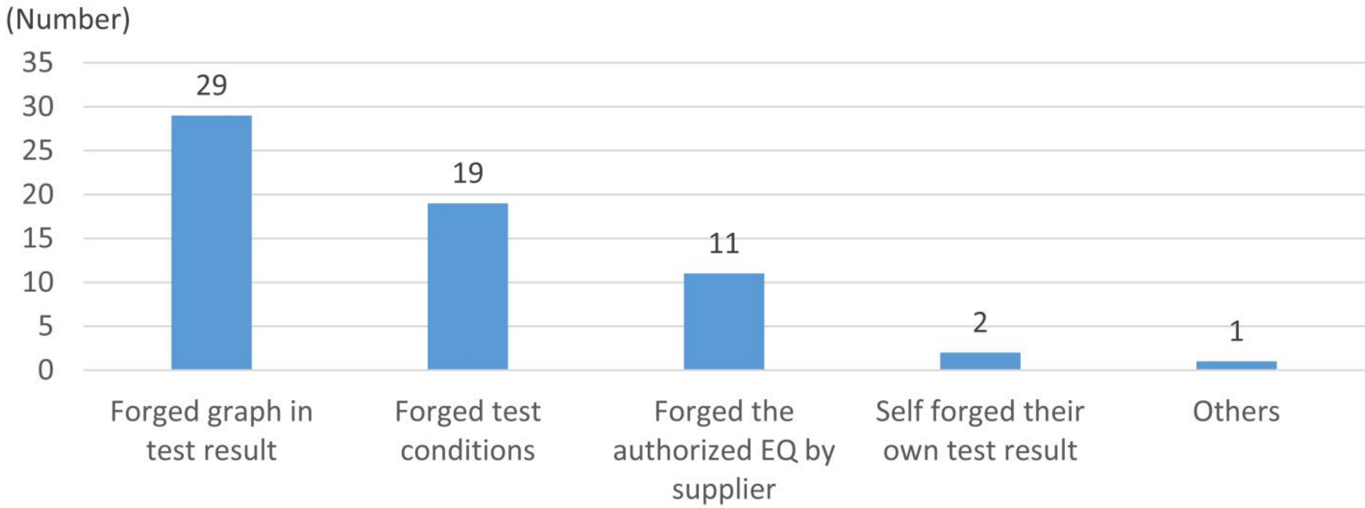

Figure 2.1.4 Types of 62 forged EQs (Song, 2014)

CFSIs of concern to NPPs are those that look nearly identical to original items but contain sub-standard, poorly assembled, or aged components or material. They can be difficult to detect by standard industrial quality assurance inspections but can cause catastrophic failures or loss of safety related functional capability when needed. Generally counterfeiters go after recognized, high-demand items to maximize their profit, which in some way has insulated older nuclear fleets from major issues. In the construction industry steel items (plate, pipe, fasteners and valves) are the most counterfeited, followed by electrical devices such as circuit breakers, and then rotating equipment (CII, 2010). Some photos of documented counterfeited articles are shown in Figures 7 and 8.

Figure 2.1.5 Counterfeit (left) and legitimate breaker (right) supplied to hospital in Montreal (courtesy CSA Group Inc.) (Geralde, 2010)

Figure 2.1.6 Flanges received as "new" at Savannah River - note clamp marks, different rivet sizes clamp marks, different rivet sizes (DOE, 2007)

The US Department of Commerce reports that there was a 140% increase in counterfeit incidents amongst suppliers of industrial parts to the US Department of Defense, from 2006 through 2009 (OECD-NEA, 2011b). The value of counterfeit goods seized in Canada increased by 500% in less than a decade, according to 2012 intellectual property crime statistics (RCMP, 2013). Governments in many jurisdictions have been active in the area, with one example being an anti-counterfeiting trade agreement negotiated between Australia, Canada, EU, Japan, Korea, Mexico, Morocco, New Zealand, Singapore, Switzerland and USA. Electric Power Research Institute (EPRI) has documented cases of recent counterfeiting in the nuclear and other industries (EPRI, 2009). General industry and nuclear power share many of the same types of components, and significant increases are viewed with concern and suspicion. Certain utilities have created awareness and training programs for supply chain and other personnel (on early detection and what to look for) on the subject of counterfeit items.

The OECD-NEA has issued a report on NPP operating experience related to CFSIs (OECD-NEA, 2011b). Table 2.1.3 below documents a number of these and other issues that have become public in the nuclear industry.

Table 2.1.3 Experiences or regulations with CFSIs in the nuclear industry

Country/ Institution	Document	Issue
Canada	REGDOC-3.1.1 Reporting Requirements for Nuclear Power Plants (CNSC, 2014)	Licensee shall report on the discovery of CFSIs during the conduct of licensed activities.
IAEA	IAEA-TECDOC-1169 (IAEA, 2000)	Provides examples of known CFSIs for specific types of components and lessons learned following their identification as of the year 2000.
OECD-NEA	CNRA regulatory guidance Booklet on the Regulator's Role in Assessing the Licensee's Oversight of Vendor and Other Contracted Services (NEA/CNRA/R(2011)4) (OECD-NEA, 2011a)	Booklet aimed at all types of contracted services; however, prevention of CFSI and other sub-standard items is part of this overarching topic.
OECD-NEA	Regulatory oversight of Non-conforming, Counterfeit, Fraudulent and Suspect Items (NCFSI) (OECD-NEA, 2013)	Provides insights that should be useful to regulators and Others in the nuclear safety community for addressing the issue of CFSI within the nuclear industry's supply Chain.

Table 2.1.3 Experiences or regulations with CFSIs in the nuclear industry

Country/ Institution	Document	Issue
United Kingdom	Nuclear Safety Technical Assessment Guide NS-TAST-GD-077 Revision 2 (ONR, 2013a)	Requires purchasers to have processes in place and support of suppliers to investigate examples found of non-conforming suspected fraudulent items.
United States of America (CII)	Product Integrity Concerns in Low-Cost Sourcing Countries: Counterfeiting in the Construction Industry (CII, 2010)	Consensus of 187 industry and government leaders from eight countries interviewed, was that magnitude of counterfeiting problem has grown from “big” to “very big”.
United States of America (EPRI)	Plant Support Engineering: Counterfeit, Fraudulent, and Substandard Items (EPRI, 2009)	Discovery of counterfeit integrated circuits and electrolytic capacitors at Millstone NPP. Capacitors discovered through dimensional checks and subsequent investigation. NPP instrument manufacturer questioned validity of several phototransistor optocouplers used in timers for several NPP customers.
United States of America (NUMARC)	NUMARC 90-03 Nuclear Procurement Program Improvements (NUMARC, 1990)	Recommended putting more emphasis on technical verification product quality than on relying on supplier documentation.

Table 2.1.3 Experiences or regulations with CFSIs in the nuclear industry

Country/ Institution	Document	Issue
United States of America (USNRC)	IN 89-03 (USNRC, 1989a)	Possible electrical equipment problems. Inspection findings showed counterfeit, substandard, or questionable electrical equipment or components had been used in NPPs. Several electrical suppliers identified as refurbishing and selling defective equipment components to nuclear and non-nuclear industries.
United States of America (USNRC)	IN 89-39 (USNRC, 1989b)	Information provided on a database of parties (manufacturers, vendors and contractors) excluded from receiving federal contracts due a variety or practices including poorly manufactured or fraudulent/counterfeit parts being used in the nuclear industry.
United States of America (USNRC)	IN 89-70 (USNRC, 1989c)	Possible Indicators of Misrepresented Vendor Products. Increased number of instances of misrepresented vendor products being supplied to the nuclear industry. At receipt inspection labels in wrong location or appearing different, or if tags attached with screws rather than rivets is a potential indicator of a CFSIs. Measurement and testing during receipt inspection is also important.

Table 2.1.3 Experiences or regulations with CFSIs in the nuclear industry

Country/ Institution	Document	Issue
United States of America (USNRC)	IN 2007-19 (USNRC, 2007)	Fire protection equipment recalls and counterfeit notices. Documents fire protection equipment recalls and counterfeit notices issued by various manufacturers.
United States of America (USNRC)	IN 2008-04 (USNRC, 2008)	Counterfeit parts supplied to NPPs. Documents cases of supplying counterfeits part to NPPs installed in a non-safety related system during maintenance activities on a similar valve in vicinity of installed counterfeit.

2.2 CFSIs impact on safety

Accident consequences at an NPP can be severe if the plant does not operate as designed under accident scenarios. An important aspect of safe operation is ensuring that safety related components operate as intended; thereby ensuring safety related systems perform their intended safety function. To facilitate this operators must ensure that items procured for maintenance of safety related systems meet original design requirements.

Items of a NPP perform various functions, interacting with each other. To let it perform those functions fluently, a number of standards and codes are set. Safety-related items especially guarantee either of normal operation and reliability in an accident. Once safety-related items are negatively affected by CFSIs, the safety cannot be secured.

According to the report on the influence of CFSIs of NPPs, CFSIs have a significant effect on the safety. About the half of all the cases resulted in severe accidents, such as unplanned reactor shutdown, unanticipated release of radioactive materials, or damage of fuel. The other half of them appeared not to have direct connection to NPPs (Ziedelis, 2012). However, most of these CFSIs have the potential to lower the performance of safety functions and safety related system.

The procurement function for NPPs plays a key role in nuclear safety. Beyond ensuring that required parts are available when needed for operations and maintenance activities, the procurement function helps ensures that correct equipment and components are installed in the correct locations in the plant, helping to maintain proper configuration management and safety functions.

IAEA Safety Standard SSR-2/2 on Commissioning and Operation of NPPs (IAEA, 2011b) requires that operating organizations establish suitable arrangements to procure, receive, control, store and issue materials (including supplies), spare parts and components, and to use these arrangements to ensure that their characteristics are consistent with applicable safety standards and with the plant design.

IAEA Safety Report Series No. 65 on application of configuration management (IAEA, 2010) emphasizes the need to maintain plant configuration to support design basis maintenance, stating that:

"The fundamental concept of configuration management is to provide assurance to the owner, operator and regulator that a plant is designed, operated and maintained in accordance with the actual licensing and design basis, complying with the commitments for the safety of the public and protection of the environment."

Most design and licensing basis requirements of and NPP are enacted through specifications for equipment to be installed in the plant. Failure to ensure that suppliers fulfil these requirements, or that facility warehousing, operations, and maintenance staff do not take action contrary to such requirements, can lead to equipment to fail or not function as required during design basis accidents.

Lack of confidence by a regulator in a plant's control of purchasing and configuration related processes can lead to costly plant shutdowns. Lack of confidence in a single component such as particular relay module or type of cable can lead to its need to be replaced in a large number of equipment locations and systems.

2.3 Integrated management system requirements

Materials are essential to NPP operation and maintenance, and their proper procurement contributes to safety and reliability. It is fundamental to NPP safety and for prevention of accidents that defense in depth is provided by an effective management system. Such a system should include a strong management commitment to safety. This includes ensuring plant materials are of high quality and reliability (IAEA, 2010).

A Key safety fundamental of all NPPs is the fact that "the person or organization responsible for any facility or activity that gives rise to the radiation risks…has the prime responsibility for safety" (IAEA, 2010). This means that an NPP owner, when purchasing items or services that can affect nuclear safety, still retains responsibility for that safety and needs to have processes in place to maintain safety under all conditions. This prime responsibility cannot be transferred or delegated to suppliers.

Management systems are a set of interrelated or interacting elements for establishing policies and objectives and enabling objectives to be achieved in an efficient and effective way. They have evolved over time from pure quality control systems, to quality assurance and quality management systems, to more recently integrated management system approaches like that described in IAEA Safety Requirements GS-R3 (IAEA, 2006b) and Safety Guides GS-G-3.1 (IAEA, 2006a) and GS-G-3.5 (IAEA, 2009). The key difference with the integrated management system approach is that safety is incorporated into the management system. This is included in every aspect of the organization and particularly for procurement specifications, and evaluations of suppliers and supplier requirements.

Table 2.3.1 that follows lists examples of standards and requirements from various countries and international organizations applicable to areas.

Table 2.3.1 National and international standards related to NPP procurement activities

Country/ Institution	National code or standard related to procurement	Comment
France	RCC-E Design and Conception Rules for Electrical Equipments of Nuclear Islands (AFCEN, 2012)	Section A3300 has requirements surrounding procurement related documents. A3710 has requirements surrounding monitoring files covering manufacturing processes. Other sections provide guidance (e.g. selection of suppliers, sampling methods, inspections etc.) for specific components.
Russia	OPB-88/97 (PNAE G- 01 011-97) General Regulations on Ensuring Safety of Nuclear Power Plants (ROSATOMNADZOR, 1997)	Requires safety classes of NPP elements be designated by design (4 classes defined), and quality assurance requirements assigned to safety Classes 1, 2, and 3 be specified in regulatory documents
Russia	NP-082-07 Nuclear Safety Rules for Reactor Installations of Nuclear Power Plants (ROSTECHNADZOR, 2007)	Requires quality assurance programs be developed for all stages of NPP life, safety important components be subjected to inspections and test during manufacturing to verify design characteristics, and that designs contain list of systems and components whose performance and characteristics are to be verified.

Table 2.3.1 National and international standards related to NPP procurement activities

Country/ Institution	National code or standard related to procurement	Comment
Russia	NP-061-05 Safety Rules for Storage and Transportation of Nuclear Fuel at Nuclear Facilities (ROSTECHNADZOR, 2005)	Establishes technical and organizational requirements for nuclear fuel storage and transportation systems at NPPs, including separate storage on NPP sites, off-site facilities, nuclear research installations, and on-shore and floating nuclear fuel storage facilities.
United Kingdom	NG-TAST-GD-077 Rev 2 : Procurement of Nuclear Safety Related Items or Services (ONR, 2013a)	Informs regulatory assessment of supply chain arrangements which are particularly important to supply of items or services significant to nuclear safety designated for use in the UK Covers requirements on purchasers, supplier selection, procurement documents, quality plans, contract variations, competence, deviations and technical query, records, inspection and surveillance activities, non-conforming counterfeit and suspect items, and management system certification.

Table 2.3.1 National and international standards related to NPP procurement activities

Country/ Institution	National code or standard related to procurement	Comment
United Kingdom	NS-TAST-GD-049 Rev. 4 Licensee Core and Intelligent Customer Capabilities (ONR, 2013b)	Helps regulatory inspectors assess suitability of approaches a licensee may take to maintenance of in-house expertise to maintain control and oversight of nuclear safety at all times, and use and oversight of contractors whose work has potential to impact nuclear safety.
United Kingdom	BS OHSAS 18001:2007 Occupational health and safety management systems Requirements (BSI, 2007)	Defines requirements for an occupational health and safety management system. It is going through process of becoming ISO 45001.
United State of America	10 CFR Part 50 Appendix B Quality Assurance Criteria for Nuclear Power Plants (OFR, 2005)	Regulations requiring control of procurement of safety related items. Includes specific requirements surrounding procurement document control, control of purchased items and services, inspection and test control, control of MTE, handling storage and shipping non-conformances and corrective action, and others.

Table 2.3.1 National and international standards related to NPP procurement activities

Country/ Institution	National code or standard related to procurement	Comment
United State of America	10 CFR Part 21 Reporting of defects and noncompliance (OFR, 2012)	Section 21.31 procurement documents specifically indicates that Part 21 reporting of defect requirements apply to procurement participants. This includes such things as maintaining records, providing access to the NRC, reporting defects to the NRC, etc.
United State of America	ASME NQA-1:2012: Quality Assurance Requirements for Nuclear Facility Applications (ASME, 2012)	QA system utilized for US NPPs and referenced in some other jurisdictions. See IAEA Safety Reports Series No. 70 (IAEA, 2012b) for comparison of NQA-1-2008 and IAEA GS-R-3.
United State of America	ANSI N45.2.13 Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants (ANSI, 2012)	Original QA standard used for NPP procurement. Now replaced / incorporated into ASME NQA-1. Remains referenced in many NPP licenses.

Table 2.3.1 National and international standards related to NPP procurement activities

Country/ Institution	National code or standard related to procurement	Comment
United State of America	EPRI: Analysis and Comparison of ANSI/ISO/ASQ Q9001:2000 with 10CFR50, Appendix B (report 1007937) (EPRI, 2003b)	Analyzes quality requirements in ANSI/ISO/ASQ Q9001:2000 with those of 10CFR50 Appendix B, as they apply to suppliers/ manufacturers/service providers to the nuclear industry. Findings were that there was one gap related to independent inspection, and that ASME has more explicit requirements regarding independence of design verification than defined in ISO.
United State of America	EPRI: An Overview of Other Industry Experience with the ISO 9000 Quality Management System (report 1008258) (EPRI, 2003a)	Presents results of EPRI studies in support of determining how the US nuclear industry can more broadly employ suppliers certified to ISO 9000. Identified OPEX from automotive, aerospace, telecommunications, and other industries promoting ISO, and regulated industries without a sector specific ISO programme. Also reviews Canadian experience and IAEA comparisons of standards. Concluded that quantified experience contributed by licensees thus far has not led to conclusive evidence that would suggest product quality is solely dependent on a supplier’s particular QA programme, but rather the implementation of a quality programme.

Table 2.3.1 National and international standards related to NPP procurement activities

Country/ Institution	National code or standard related to procurement	Comment
United State of America	NEI 06-14A Revision 7 Quality Assurance Program Description (NEI, 2010)	Provides template for applicants to implement applicable requirements of a QA programme meeting 10 CFR 50, Appendix B, and 10 CFR Part 52
International Standards Organization (ISO)	ISO 9001:2008: Quality Management System – Requirements (ISO, 2008)	See IAEA Safety Reports Series No. 69 (IAEA, 2012a) for comparison to IAEA GS-R-3.
International Standards Organization (ISO)	ISO 9004:2009: Managing for the Sustained Success of an Organisation – a Quality Management Approach (ISO, 2009)	Provides guidance to organizations supporting achievement of sustained success by a quality management approach. Provides wider focus on quality management than ISO 9001, addressing needs and expectations of all relevant interested parties.
International Standards Organization (ISO)	ISO 14001:2004 Environmental Management system – Requirements with guidance for use (ISO, 2004)	Specifies requirements for an environmental management system for organizations. Often adopted by utilities and for a requirement for suppliers within the nuclear supply chain.

Table 2.3.1 National and international standards related to NPP procurement activities

Country/ Institution	National code or standard related to procurement	Comment
Nuclear Quality Standards Association (NQSA)	NSQ-100 Nuclear Safety and Quality Management System Requirements (NQSA, 2011)	Industry led initiative open to major nuclear utilities, nuclear engineers and manufacturers designed to produce a common quality standard based on IAEA GS-R-3:2006, ISO 9001:2008 and ASME NQA-1-2008. Document layout is similar to various QA standards are also published.

2.4 Procurement scenarios

Supplier identification involves determining what suppliers on the market can meet the procurement requirements defined in the previous step. An important consideration in this phase is the quality program that will be applicable to the purchase, and whether the operating organization's or the supplier's programme will be used.

These considerations depend on the procurement scenario planned for the item, which is derived from the item's safety function and availability of suppliers in the marketplace for that item with acceptable quality programs. Four basic procurement scenarios exist for safety related and augmented quality items:

Scenario A: Item procured under supplier's management system.

- Supplier responsible for assuring quality of item under a management system which includes processes for reporting of defects and non-compliances;
- Operating organization is responsible for approving the supplier's management system;
- Suppliers do not always consider all parts or items to be safety related, in such a case the operating organization should either

use a different procurement scenario or procure from a supplier with an approved management system applied to all parts and not from one only with only a partial program (covering for example only pressure retaining parts).

- In order to assure no misunderstanding of supplier responsibilities, utilities should consider adding a statement in their procurement documents stating that the operating organization considers all parts of an item procured to be safety related unless otherwise stated.

Scenario B: Item procured as a Commercial Grade Items (CGI) for dedication under the operating organization's management system.

- If an item is procured as a CGI intended for use in a safety related application it is the operating organization's responsibility for dedicating the item and assuring quality under the operating organization's management system. Guidance is contained in IAEA GS-G-3.5 (IAEA, 2009) and EPRI NP-5652 (EPRI, 1988).

Scenario C: Item procured under operating organization's management system.

- When an item intended for use in a safety related application does not meet the definition of a CGI and a qualified supplier cannot be identified or is not capable of meeting commercial or schedule requirements, an operating organization may procure the item under its management system which may be extended to monitor item production.

Scenario D: Item procured as an augmented quality item. The operating organization is responsible for assuring that item quality meets requirements.

- Augmented quality item are non-safety related and unless the operating organization has made specific commitments to the contrary, are not required to be procured under a qualified nuclear management system. The operating organization should produce a document or other guidance detailing what components it considers augmented quality and any requirements specific to such items.

A review by EPRI in the 1990's indicated that a typical operating NPP in the USA or Canada orders approximately 10% of its material as safety related (scenario A or C), 7% as CGI (scenario B), 3% as augmented quality (scenario D), and 80% as non-safety related (EPRI, 1997).

2.5 Establish quotations or bid

Once approved suppliers have been identified, a process is required for obtaining final quotations or bids for the items to be purchased and supplier selected. Various terms can be applied to this request process (each with slightly different meaning by different organization) including an invitation to tender, request for proposal, request for quotation, invitation to bid, or expression of interest.

A bid invitation specification or other enquiry document is assembled. It typically includes an invitation transmittal letter, contract information, project, facility, and coordination detail, and the specific job requirements. The size and scope of the documents involved will depend on such things as type of contract, size and scope of project/item purchased, work complexity, project controls, financing requirements, type of contractor, and resources available to prepare the documents. For project or services work, information from potential bidders should be requested as to how they would mobilize, organize, staff and control the project, procedures to be used, industrial safety program employed, corrective action program, and any measures as required to meet a compressed schedule. Information on jobs of a similar nature should also be sought, as should be detailed information on cost rates of personnel by function, additional cost (travel, training, administrative costs etc.), and mark-ups on direct costs for profits or fees.

There are two basic methods of obtaining bids: open tendering and selective tendering. In open tendering any interested party can submit bids, with the client advertising locally, nationally or internationally. To ensure serious bids potential suppliers may be asked to purchase the tender documents or deposit money in the form of a bank guarantee or bid bond. The tender process may be two-stage (bidders submit technical bids first exclusive of price, then technically acceptable proposals submit full bids with pricing later), use the two-envelope method (separate sealed technical and economic bids are submitted at the same time and evaluated separately), or use a "three-envelope" process in which following initial bid evaluation (using the standard two-envelope process) a request to bidders is made for final pricing to take into consideration differences between the received bids. That is an attempt is made to levelize differences in approach so that a consistent basis for price comparison can be made.

Open tendering provides transparency to the procurement process, ensures good competition and minimizes potential for collusion. It does tend however to drive decision makers to a lowest (apparent of submitted) cost solution if care is not taken to careful evaluate all factors (reliability of bidders, quality, lifetime or life cycle cost etc.). Some jurisdictions require all public sector procurement to follow an open process (e.g. the European Union Directive covering procurement).

Selective or **restrictive tendering** is a process whereby only specific bidders are invited to submit tenders. Such a process is more favoured by the private sector, and has the advantages of having reduced costs and duration of tendering, ensures only capable contractors bid (assuming there is a track record of successful work between the customer and client), and helps maintains the contractors economically viable through a regular steam of work. It does however have contractors are routinely successful (prices may rise, less attention given to the work, etc.), misses the potential for new (more eager or otherwise better) suppliers, and increases risks of collusion among routinely successful contractors are a sub-set of this process. Such a selective or single-source process is becoming more common for nuclear projects in the form of inter-governmental agreements, but does carry these increased risks.

Negotiated tendering is another variation on selective tendering. In this process a contractor with proven experience with a client is chosen early in the design stage and performs preliminary work on the project (depending on scope definition it may be on a fixed price or time and materials basis). Once detailed design information is available, the contract is renegotiated on typically a fixed price bases. Such models are good at obtaining constructability input early in a project’s life, can shorten lead times, and can minimize financial commitments until full scope definition is obtained. Some organizations utilize two organizations at the preliminary stage and select a single company to proceed with for the detailed design.

Where competitive bidding is used, questions or requests for clarifications or exceptions by suppliers should be formally controlled. This ensures all requests are recorded and reviewed by suitable personnel for their effects on procurement requirements. Any response to one prospective supplier should be provided to all bidders to aid in bid comparison and to ensure fair treatment.

Procurement organizations should establish controls related to the security and opening of sealed bids. These are typically categorized by bid value, with low value bids having minimal controls and higher value bids having stringent controls. For example low value bids might be opened by person in procurement group who would record details such as date received, prices, durations, alternatives offered etc., medium bids might have the opening being witnessed by another staff person, and higher value bids might be witnessed by an independent senior staff member recording all suppliers who tendered, submitted prices, whether the tender was received on time or late, any suppliers who did not tender (and reasons, if possible, for addition to the supplier database), and comments on omissions or non-conformance with the procurement requirements.

Bid evaluation can be said to need to adequately weigh the relative importance of functional (technical) requirements, cost and schedule requirements, and operating costs (both economic requirements). It also can be said that for equipment the manufacturer is most concerned with the first, the engineering contractor with the second, and the end user the third (Ward, 2008). It is important that the evaluation process be done as objectively as possible and that all participants appreciate the issues involved in each area.

Evaluation generically can take number of forms, from just "choosing whom you want", negotiating with a preferred tenderer, choosing the lowest price from well recognized brands, throwing out the lowest and highest prices, methods that attempt to evaluate "value for money" or life cycle cost, or others that use a combination of formal technical and economic evaluation (often within a defined points system). A most economically advantageous tender or lowest evaluated tender methodology is one of the latter methods. It seeks to evaluate all aspects of a submission (e.g. schedule, management commitment, personnel, capability, etc.) after evaluating its technical acceptability.

Even if the potentially successful bidder is practically chosen in advance (e.g. via a single source selection or inter-governmental agreement), there should be an evaluation done to confirm the proposal meets minimum technical, quality, and commercial requirements, and is superior that a “do-nothing” option or other alternative.

A typical bid evaluation process using separate technical and economic evaluation steps is described in conjunction with a framework adapted from NG-T-3.9 (IAEA, 2011a). The process includes both technical and economic bid evaluation. These evaluations are done separately and then combined as a decision to proceed with contract negotiation is made.

Chapter 3 Research Design

Following chapter introduces research design including the subjects, scope, and methodology. 3.1 Research question suggests four questions regarding to the cause of CFSIs. The approach and methodology for these question are explained in 3.2 Methodology. The selection of cases for the research and the logic behind the selection is described in 3.3 Case selection.

3.1 Research questions

Four questions can be raised for the reasons of CFSIs occurred in Korea.

"Are there appropriate laws and decrees, and are they being implemented properly?"

The existence of suitable laws and decrees is the key factor to carry out the regulation and inspection regarding to CFSIs. In other words, the institution for the regulation and the inspection according to laws and decrees should exist, and their duties also need to be defined. Furthermore, setting the laws and decrees is essential since this can locate the responsibility and specify whom to be punished. Besides, as mentioned in chapter 2.3 Integrated management system requirements, crucial issues are the system to fulfill the quality assurance and rigid regulation. Therefore applicable laws, decrees, and regulations are the fundamental elements to avoid CFSIs.

"Is the deadline for supply fair enough?"

The deadline for suppliers is closely interrelated to CFSIs. The standards for NPP items are much higher than those of general industrial items, and the products can be provided only after coming up to those standards. This means that for NPPs items to pass the test, it takes additional time to product and to get the result of the test compared to general industrial items. Accordingly, the contract should note sufficient deadline for these procedures. Otherwise, the larger possibility of corruption during the procedure of production and test is inevitable.

"Are the suppliers for NPPs being managed faithfully?"

One important factor for this question is whether the supplier is properly qualified. Even though the laws, decrees, system and the deadline for the delivery are fair enough, if the supplier’s qualification is doubtful, CFSIs still appeared. Since the operators are responsible to care all the factors that can affect the nuclear safety, all the supplier is being filtered by operators with a registration program for the suppliers. However, if the standard for the filtering is too low or there is lobbying between the supplier and the operator, the supply from unqualified suppliers will occur. Another important factor is to secure sufficient supply chains. Without adequate supply chains, the procurement system cannot operate well. This can cause the delay of operator’s work process, and in case of domestic procurement system, it can let the operators to look for supply chains from foreign suppliers, which can result in the higher occurrence of CFSIs.

“Is the independence of certificate authorities is fully guaranteed? Is the proper procedure established?”

Once the certificate authority is exposed to any external corruption such as lobbying, the possibility of CFSIs increases. Thus, it is important for the government to set a standard of qualification requirements for certificate authorities and to continuously monitor if tasks regarding to certification are being performed according to the standard. For the second question, the issue related to the dead line, the inadequate number of certificate authorities can induce the overloading and increasing uses of foreign authorities. From the supplier's point of view, this means the delay on the manufacturing, which can result in the increase of overall process.

3.2 Methodology

In "Setting the Concept of System" step, the subject, boundary, and the scope for the research are set, and they are displayed in a diagram. First CFSIs-related laws and decrees should be reviewed. Since Korean law system has five different stages; law, the Presidential decree, regulations, notifications, guidelines and standards. The review need to be done on each stage. Then observation is taken on the quality assurance related to procurement regulation. That is, the research is performed on the systems which consist of the regulatory authority, operator, and supplier; specifically, the regulatory authority is the performer of regulation and the operator and supplier are the objects of regulation. With these processes, the subject, boundary, and the scope for the research can be decided.

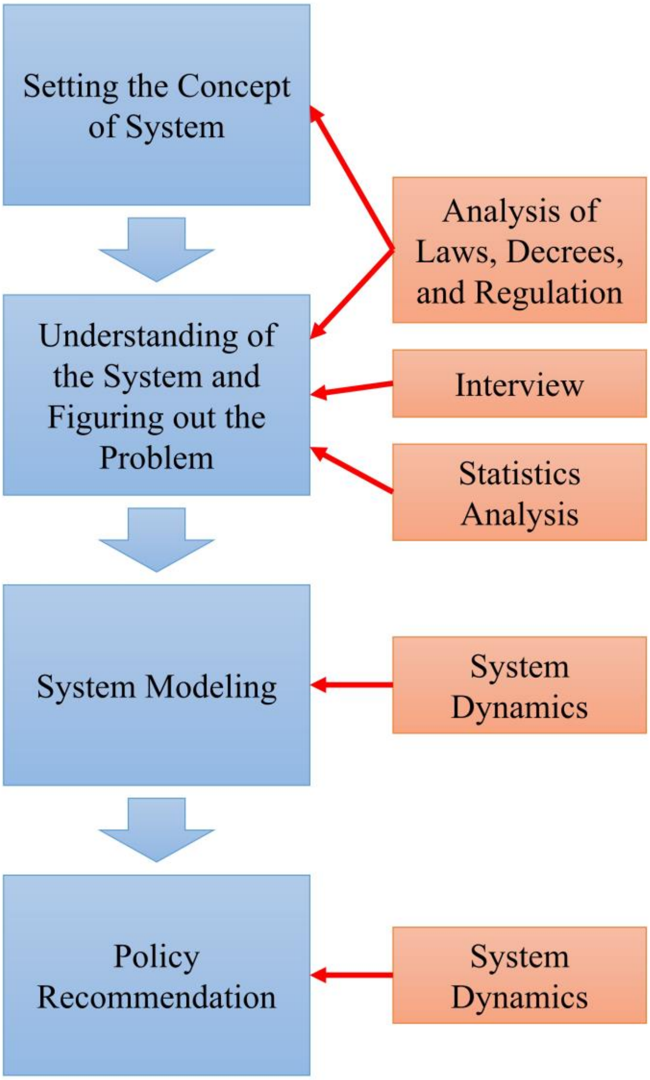

Figure 3.2.1 Methodology

In “Understanding of the System and Figuring out the Problem” step, two issues need to be analyzed – The principle of system in set boundary, and the cause of internal problems, which can be studied with 3.1 Research questions. There are three different ways to access to this topic; review on laws and decrees, interview on the research objects, and the statistics analysis on actual data regarding to the procurement process between the operator and the supplier. The interview needs to be general and independent so that internal problems, which are difficult to be noticed by the outside, can be found out. The statistics analysis on procurement data can let the implementation issues, which are deeply related to the procurement processes, come to the front. The KHNP Procurement System[1] provide the date required to the research. The system contains various types of information such as details of the contract about the regulation for supply, public notice of bidding on individual items, suppliers who contracted. The obtained information are classified into following topics; the public notices of bidding by the operator, contract details, types of items, types of contract, safety-related grades, the announcement dates, participating companies, contract dates, and delivery dates. The statistics analysis can be used to understand the actual implementation of procurement.

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[1] http://ebiz.khnp.co.kr

Table 2.2.1 Schedule of interview

Date	Subject
2013.06.28	Regulatory body, Operator
2013.07.17 – 2013.07.18	Operator
2013.08.07 – 2013.08.08	Regulatory body, Operator
2013.08.30	Supplier, Certificate authority

In “System modeling” step, the modeling on the system that includes all the mentioned issues is performed. For the modeling process, system thinking is adopted to understand procurement system. Also, casual loop diagram, one of methodologies for system dynamics, is applied. The system dynamics is a tool to assist in the understanding of the complex structure. Professor Jay Forrester from Massachusetts Institute of Technology proposed this tool for the integrated understanding of the industrial system (Sterman, 2000). Currently, it is used in a wide range of researches such as population, economics, environmental studies, and engineering. The system dynamics is proposed for this project, because the subjects of procurement system and related factors interact with each other in extremely complicated way. Especially, the factors that affect nuclear safety are inter-dependent to each other and widely distributed, so the evaluation on influence by each factor is meaningless. Therefore, system dynamics is more suitable for this research than analysis of indicators by factors.

A causal loop diagram is a feedback loop that illustrates the cause and effect relations between each factor. How the relations are developed in the system can be outlined through the diagram. This diagram is useful to understand the structure by illustrating the relationships among diverse factors. The factors used for the diagram include items, events, conditions, and decisions, and each of factor are connected by + or – arrow.

As shown in the figure 3.2.2, each arrow indicates if A have a positive or negative effect on B. Positive arrow denotes that B increases as A increases and B decreases as A decreases, and negative arrow denotes that B decreases as A increases and B increases as A decreases. The closed loop s which consist of these arrows are called feedback loops, because a change of a certain factor affects back to itself after going through all other cause and effect relations. There are two types for such loops; a positive or reinforcing loop, and negative or balancing loop. Positive loop forms a feedback to enhance the change of the factor which tends keep increasing or decreasing. On the other hand, negative loop forms a feedback to restrain the change of the factor, and shows the tendency to converge into equilibrium plateau.

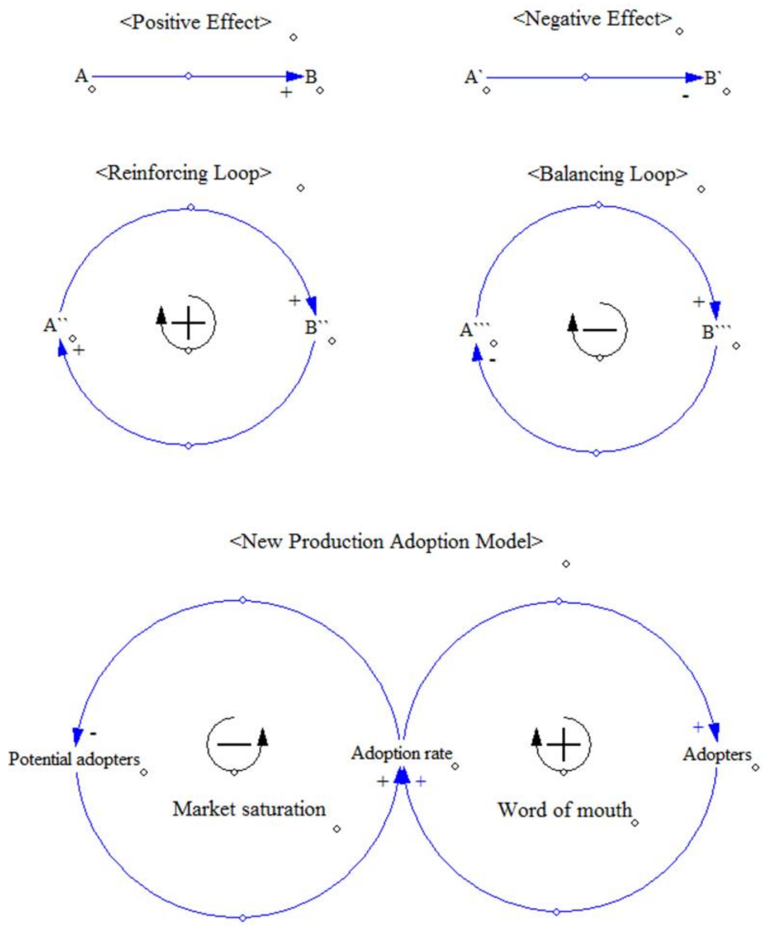

Figure 3.2.2 Correlation, feedback loop, and the New Production Model in System dynamics

The loops presented in the figure below are New Product Adoption Model (Kirkwood, 1998). Looking at the Word of mouth feedback on the right side, the increase of Adoption rate leads to the increase of Adopters, and the increased number of Adopters grows again through the word of mouth. Accordingly, this represents the continuous increase of Adopters and Adoption rate. In contrast, when Adoption rate is reduced, Adopters get also reduced. Thus this situation shows that Adopters and Adoption rate continue to decline. Looking at the Market saturation feedback on the left side, as Adoption rate increases the rest of Potential adopters decrease and this let Adoption rate reduce. On the other hand, the reduced Adoption rate leads to the increase of Potential adopters, which becomes the cause of the increase of Adoption rate. In the New Product Adoption Model, there are Adoption rate, Potential adopters, and Adopters as factors, and they mutually influence each other. The factors of Adoption rate appear not to be simply explained by Adopters and Potential adopters.

Therefore, casual loop diagram are the applicable tools to clarify the phenomenon for the system with such complex relationships. Consequently, we can understand the system of Korean procurement and find out the involved problems and solutions by setting various factors and constructing the relations among the factors with the mentioned tools.

3.3 Case selection

If demand for items occurs, the bidding is noticed with purchase specification prepared based on the quantity, and delivery-related information. When a winner is selected among the suppliers who participated in the bidding, the operator contracts with the supplier. Then supplier products the items. The items could be delivered after it passes the verification by a certificate authority. Among these processes, during the production, an operator and a regulatory authority perform on-site inspection and receipt inspection. Thus the research scope was set as a series of steps to supply items to NPPs, and four bodies within the scope - operator, supplier, certificate authority, and regulatory authority - were decided to be the subjects.

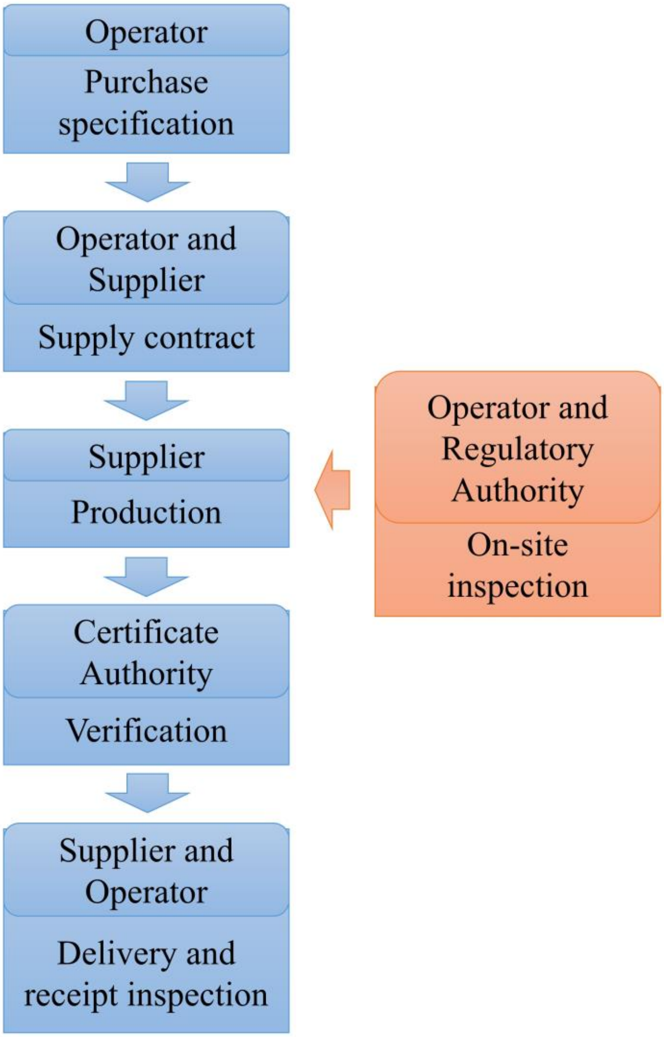

Figure 3.3.1 Scope of research

For the next step, the range of data was determined. Table 3.3.1 is distinguishing the safety-related grades of items which are supplied to Korean NPPs. According to methods of bids, mentioned in 2.5 Establish quotations, selective tendering and negotiated tendering are performed for Q1-graded and Q2-graded items, and selective tendering and open tendering are performed for Q3-graded and A-graded items. In 2013, NSSC carried out the inspection on all of the Q-graded and A-graded items, which were delivered to NPPs. The data analysis was performed on Q3-graded items, which take high proportion of safety-related issues.

The period of date to be collected was fixed from May 1st to October 31st, 2012. This is because the data regarding to selective tendering were open to the public since May 2012, and the outbreak of CFSIs was disclosed in November 2012. To minimize the influence from external factors, the data after November 2012 were excluded.

During the given period, the number of Q3-graded items whose bidding and contract was completed is 660. The analysis on the procurement system was performed with the regarding contract details.

Table 3.3.1 Classification of safety-related items in NPPs

KHNP	Korea / US	Core Function [Relevant Case]	Safety Influence [Safety Design]	Dedication [Applicability]
Q (Safety)	First Grade	Fluxion, protection and isolation of high temperature, pressure, and radioactive cooling fluid (Ex. Reactor)	Supervising for the radioactive material (Enough safety load margin)	No
	Second Grade	Assist device of high-temperature, pressure, and radioactive cooling fluid (Ex. Shaft seal device)	Supervising for the radioactive material (Safety margin + multiplexing)	No
	Third Grade	Support function of first and second grade equipment (Ex. Filter, fuse)	Component failure and safety shutdown (Multiplexing and multiplication of equipment and system, fail to safety)	Depletion of organized equipment and replacement component
A (Safety Impact) S (General Industry)	Non-safe Grade	Safety control of radioactive material and maintenance of operating environment for the first, second, and third grade equipment	Component failure and safety shutdown (Safety margin, multiplexing, multiplication)	Depletion of organized equipment and replacement component

Chapter 4 Analysis of Nuclear Procurement System in Republic of Korea

Following chapter shows the analysis which are introduced in 3.2 Methodology. 4.1 Laws and regulations on nuclear procurement displays the analysis on Korean laws and regulations related to CFSIs. 4.2 Interview on subjects of nuclear procurement explains the issues which could be found out from the interview with operator, supplier, regulatory authority, and certificate authority. 4.3 Statistical analysis on nuclear procurement system shows the status of contract implementation between operator and suppliers regarding to the bidding procedure.

4.1 Laws and regulations on nuclear procurement

There are Nuclear Safety Laws to prevent radioactive accidents and aim at public safety by regulating nuclear-related research, development, production, use, and relevant safety management. The Nuclear Safety Law states that operator, supplier, and certificate authority have to be monitored by NSSC regarding to the construction and operation of nuclear reactors for electricity generation or related facilities. It also states that correction and supplementation could be requested when the result is below the standards and any violation is uncovered.[2]

In addition, according to the enforcement ordinance of Nuclear Safety Law, which is a Presidential decree under Nuclear Safety Law, quality assurance includes the examination on compliance with quality assurance plan submitted by the supplier. It also states that NSSC could perform the inspection on supplier and certification authority, regarding to the planning, manufacturing, and quality assurance, of safety-related facilities.[3]

The quality assurance is specified by enforcement regulation on Nuclear Safety Law, regulation on technical standards for reactor facilities, regulation and notification of nuclear safety committee regarding to technical standards for radioactive safety management, guidelines for safety regulations, and standards for industrial technology, as well.

Mentioned laws, regulations, and notifications state that all the procurement related bodies - operators, suppliers, certificate authorities, and regulatory authority - are responsible for the management of NSSC's supply

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[2] Article 3 The construction and operation of nuclear reactors and related facilities, Section 1 The construction on nuclear reactors and related facilities for electricity generation, Subsection 16 Inspection.

[3] Article 3 The construction and operation of nuclear reactors and related facilities, Section 1 The construction on nuclear reactors and related facilities for electricity generation, Subsection 31 Quality assurance

to NPP. This shows that laws and systems for NPP procurement system are established properly.

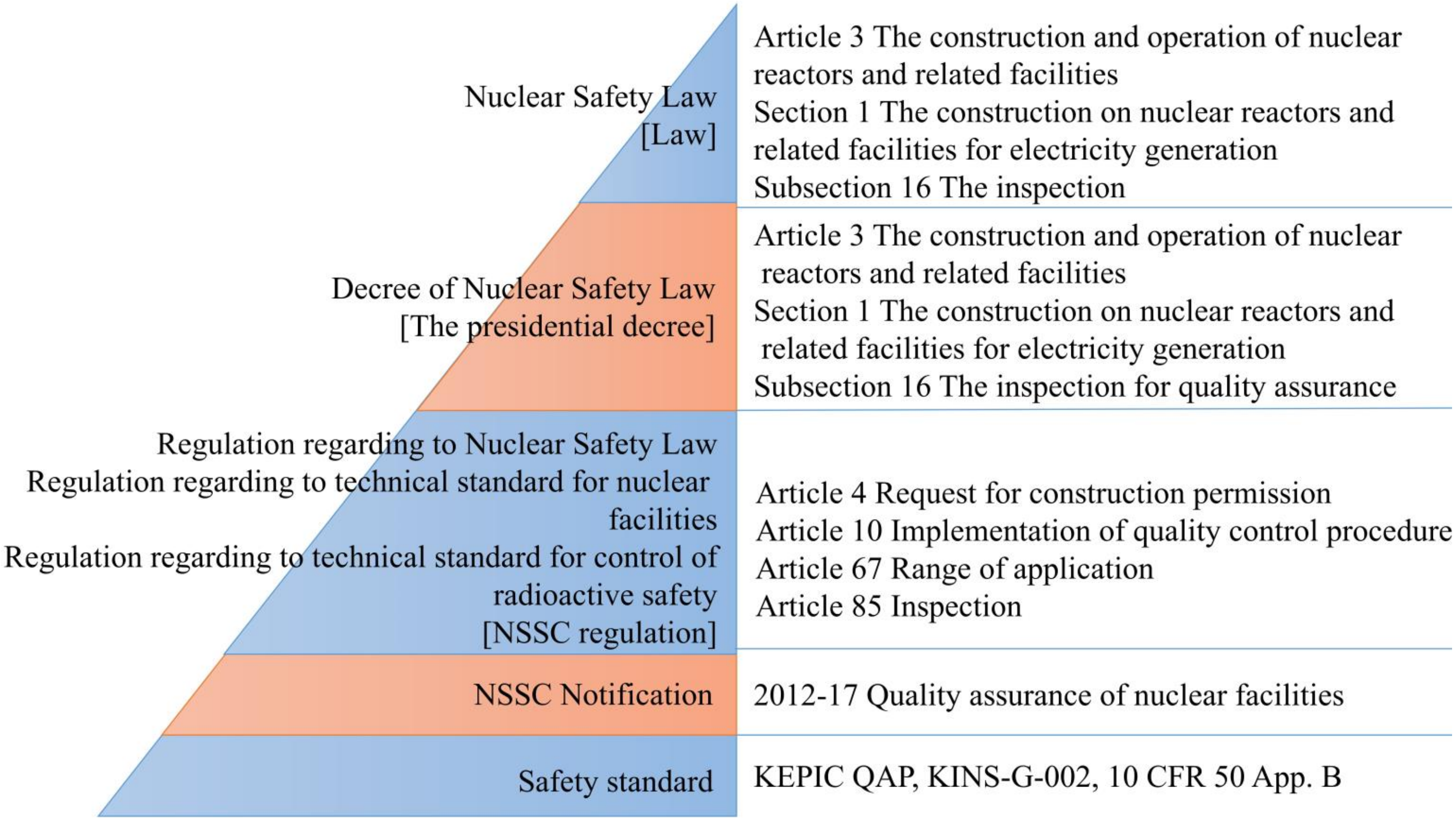

Figure 4.1.1 Laws and regulations regarding to CFSIs in the Republic of Korea

4.2 Interview on subjects of nuclear procurement

Even with suitable laws and systems, CFSIs still occurred. This implies that there are problems in the implementation unrevealed in laws and systems. To find out the problems, interviews were performed on four bodies of procurement system.

First of all, the operator considered a lack of workforce, and not enough deadlines for delivery, as the obstacles of quality assurance. The area of quality assurance is suffering from a shortage of manpower. A top priority for operators is electricity generation, and this let them to concentrate on generation and operation rather than maintenance. Construction of new NPPs in UAE is also another reason to make the problem even severe. In addition, operators are running job rotation with a period of five year to eradicate the corruption. However, this disturbs the workers to have specialty, which negatively affects tasks for maintenance. For these conditions, quality assurance teams check if the required documents are submitted, instead of investigation on the distortions of documents. Thus, it is not easy to filter out CFSIs during the inspection. To solve the problems, people who have worked in operators said it would be better for government to establish an institution for quality control.

Another comment was that the deadlines for supply are decided without enough consideration on the time needed for verification. When the supplier delivers items, it goes through production and verification processes. The operator makes the deadline to be enough so that both of the processes can be covered. However, in many cases this consideration turns out not to be enough. For example, if domestic quality certificate authorities are overloaded and foreign authorities are in charge of verification, delay could be caused. Although, in these cases, operators are blaming suppliers for the overdue.

According to the interview on suppliers, workers do not properly understand the need and procedure of quality assurance. Although, training courses for quality assurance doesn’t exist, and it induces the delay and additional cost, disturbing thorough quality management.

Certificate authorities said that independence of quality assurance procedure is not sufficiently guaranteed, because the influence of suppliers is getting significant. Since private certificate authorities could be qualified for verification of NPP items in early 2000s, the whole number of certificate authorities has increased sharply. It made private authorities to depend on the profitability. Naturally, suppliers could exercise their power on certificate authorities. They also mentioned that the solution could be the enforcement of standards for certificate authorities and governmental support for verification costs.

Regulatory authorities commented that the suppliers are not managed practically by the government. Even though the duty of the control is stated on the laws, the control is not practiced properly. It is because the ways to supply the items to operator are various; from domestic suppliers, foreign suppliers, and vendors.

4.3 Statistical analysis on nuclear procurement system

Figure 4.3.1 is the flow chart which visualized procurement system according to the details of contract codes. When operators need components during the construction and maintenance, the department of purchase decides the details such as design standard, the constituent, characters, and the presumed price. Technical section provides the information about the design standard, constituent, and characters. The presumed price could be determined from production cost, profit, and tax. With the details, the department of purchase notices the specification through the procurement system. Then the suppliers decide whether to bid or not with the noticed specification. If a supplier decides to participate, it submits the bidding price.

Here, only the suppliers who are qualified with registration procedure are allowed to participate, because nuclear items are more sensitive in safety.

During the process of bid, suppliers who suggested higher price than the presumed price are not considered to be chosen. Therefore, the following procedure depends on the number of appliers with lower price than the presumed price. If there is no initial applicant, the re-announcement should be repeated until at least one supplier applies. If the applicants are more than two, the one who suggested the lowest price wins the bid. This procedure is called open tendering with the lowest price. In the case with one initial applicant, the bidding is announced again, and if there are additional applicants after the re-announcement, the winner is the one with the lowest price among initial and the latest applicants. It is open tendering with the lowest price, as well. However, if there still no more applicant, the supplier who applied alone is chosen. This procedure is called selective tendering. Summing up, either of open tendering with the lowest price or selective tendering is practiced in the bidding procedure, and the procedure of the bidding shows that if there is less than two applicants, the delay could be caused.

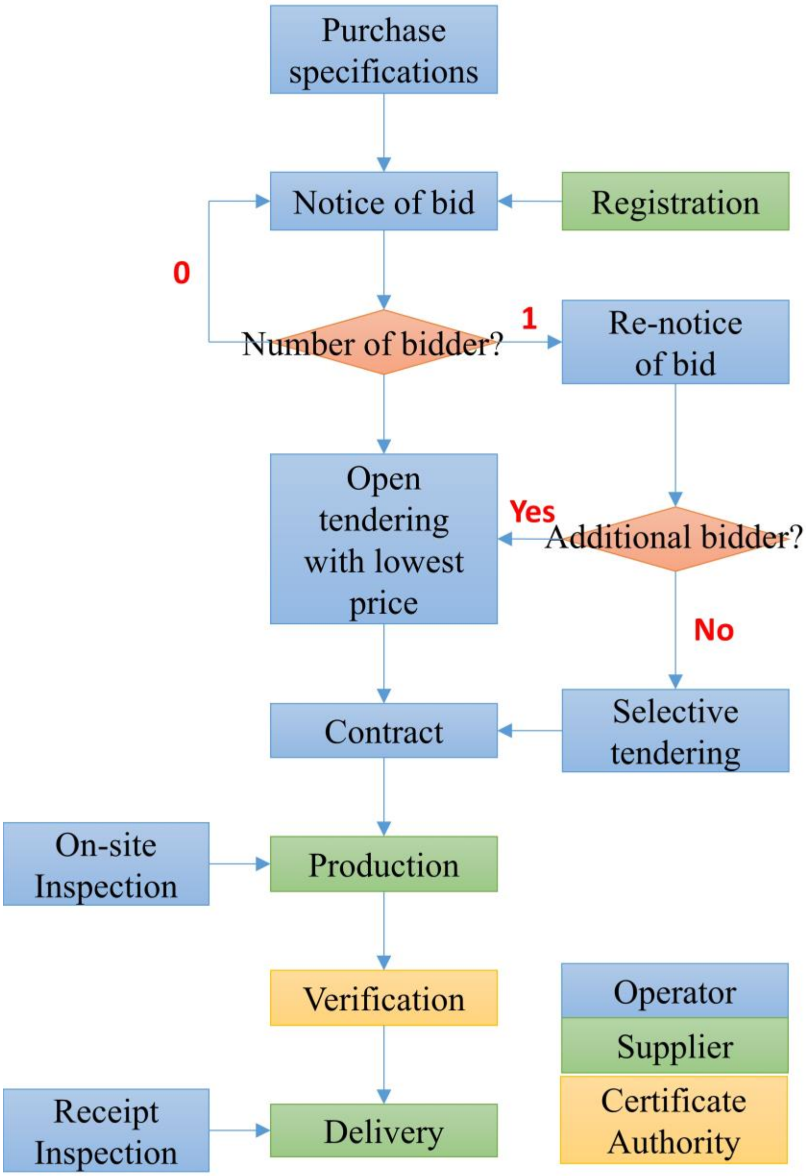

Figure 4.3.1 Procedure of nuclear procurement

The next step is the production of items for NPPs. In this step, to perform on-site inspection is the duty of regulatory authorities and operator. But as explained in 4.2 Interview, it is not being done properly because of a lack of manpower. When the production is finished, the items are sent to certificate authorities for the verification. The verification that cannot be performed in domestic authorities is requested to foreign authorities. Then the certificate authority sends the result to the supplier, and the supplier submits the items and result of verification to the operator. The operator performs the receipt inspection on the items and documents regarding to the number, design, and result of verification. In principle, the operator has to investigate on the distortion of documents, but again, because of the shortage of workforce, only the number of required documents is being checked. In conclusion, the delay of bidding and incompleteness of inspection processes are the main issues of procurement system.

To study more about the delay of bidding, the database of contracts was analyzed. Appendix A shows the raw data of Q-graded items. Among the given data, the deadlines stated in the notice and the contracted deadlines were compared to analyze the influence to suppliers. The deadlines on the notice and contract were compared to see if the delay of bidding procedure was reflected on the contract.

Table 4.3.1 Statistic analysis on bidding procedure

	Open tendering			Selective tendering		Total
	Compliance	Shortening	Irregularity	Compliance	Shortening	
First notice	351	67	3	-	-	421
Second notice	3	60	7	31	46	147
Third notice	-	51	-	17	5	73
Fourth notice	-	-	-	4	-	4
Fifth notice	-	-	-	-	-	0
Sixth notice	-	15	-	-	-	15
Total	354	193	10	52	51	660

Table 4.3.1 shows the statistic data of the difference between the delayed period and contracted deadline. Among 660 items, 421 items were successful without any re-notice, 147 items were contracted on second notice, 73 items were contracted on third, 4 items were contracted on fourth, and 15 items were contracted on sixth. Considering that it takes about a week for each announcement, it could be implied that the biddings were delayed up to five weeks.

Out of 66- items, 557 items were contracted through open tendering with the lowest price, and 103 items went through selective tendering. Among 557 items, which were contracted by open tendering with the lowest price, for 354 items, operator guaranteed the deadline as they noticed. For 193 items, the contracted deadlines were shortened as much as the bidding was delayed.

Also, the table shows the correlation between the delays of bidding procedure and the reduction of deadlines. According to the bidding procedure, the delay could occur when there is re-notice. As shown on the table, among the 239 items which were contracted after second notice, 177 items were contracted with reduced deadlines. This is about 75%, which is significant percentage, compared to the items contracted on the first announcement. The data implies that the delay caused the shortened on the first announcement. The data implies that the delay caused the shortened deadlines, which could be pressure to suppliers.

For the other 10 items, delivered date was even earlier than the date of contract. It means that these 10 items were delivered in advanced without the contract, and then contracted later. In these cases, contract codes and all the bidding procedure were ignored.

On the other hand, among the 103 items, which went through selective tendering, about half of them were contracted with shortened deadlines. It shows that the ratio of items with shortened deadline was higher in case of selective tendering than open tendering with the lowest price.

Figure 4.3.2 displays the ratio of the shortened period to the deadline for 244 items. The analysis is based on the ratio rather than the shortened period itself, because the deadline varies from one month to six months. According to the figure, the deadlines for half of items were shortened more than 30%, and the deadlines on about 10 contracts were shortened more than 50%. It could be shown as the delays of bidding become the high pressure to suppliers, and obviously the production and verification cannot be practiced properly with deadlines shortened by more than 30%. However, the analysis shows that operators shortened the deadlines without counting the delay of bidding.

(Contract for component)

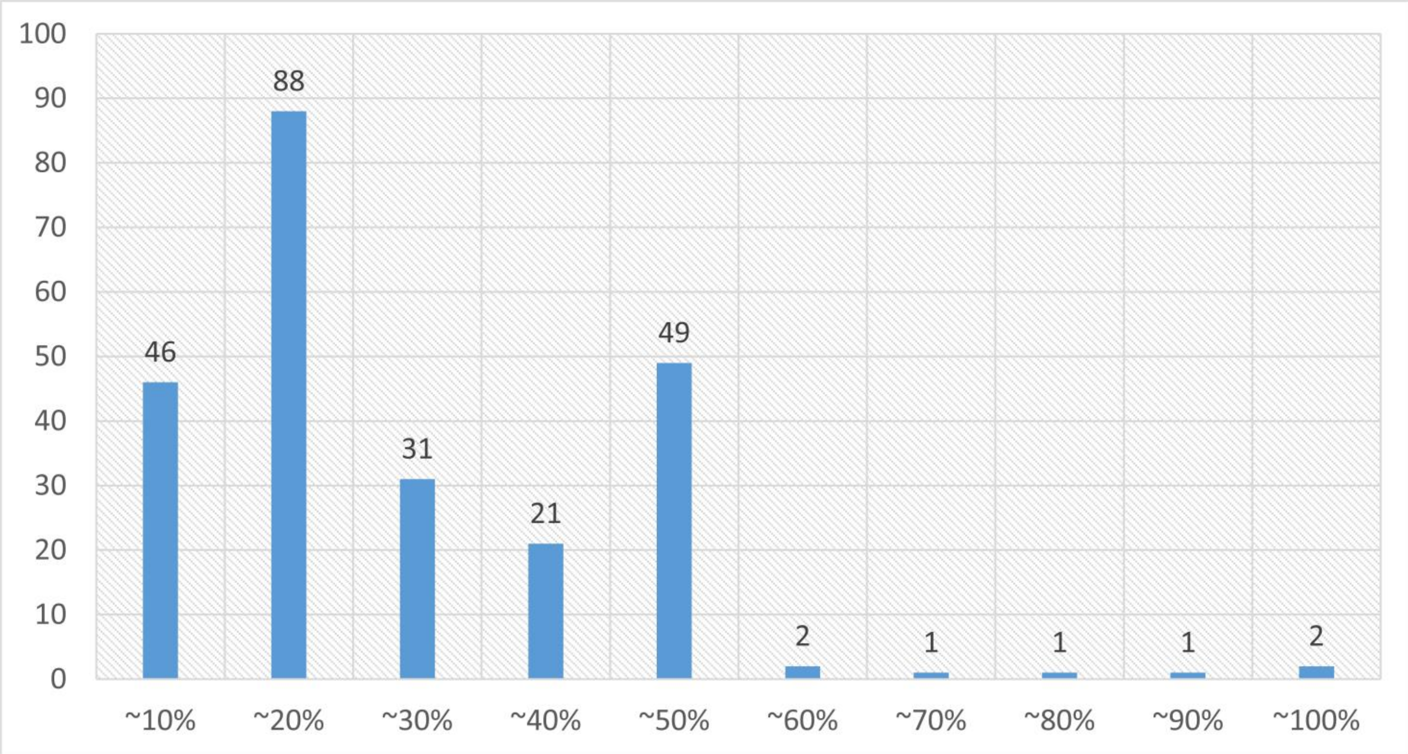

Figure 4.3.2　The ratio of the shortened period to the deadline for 244 items

Suppliers had to accept the shortened deadlines because of the pressure from suppliers and the competition with other suppliers. According to the analysis of data, it is a burden for suppliers to contract without the consideration on the overall process, and this could lead to corruption during the process of production and verification.

Chapter 5 Nuclear Procurement Model

Based on the drawbacks from laws, regulations, interviews, and statistical analysis in Chapter 4, nuclear procurement system is modeled by System dynamics. Through the six models, nuclear procurement system could be visualized and analyzed. Accordingly, the models show cause of the occurrence of CFSIs.

5.1 Safety improving feedback

Figure 5.1.1 is the data from the Power Reactor Information System (PRIS) of the International Atomic Energy Agency (IAEA). It shows the operating factor of Korean NPPs. Operating Factor (OF) is the ratio of operating hour. Unplanned Unavailability Factor (UUF) is ratio of time that NPPs are stopped because of unplanned accidents. Before 1990, UUF had been kept decreasing, and OF had been kept increasing. It is because, at the very beginning of NPPs operation, there were a lot of technical problems which caused unexpected suspensions. But as technology advances, such suspensions occurred much less, and operating factors got increased.

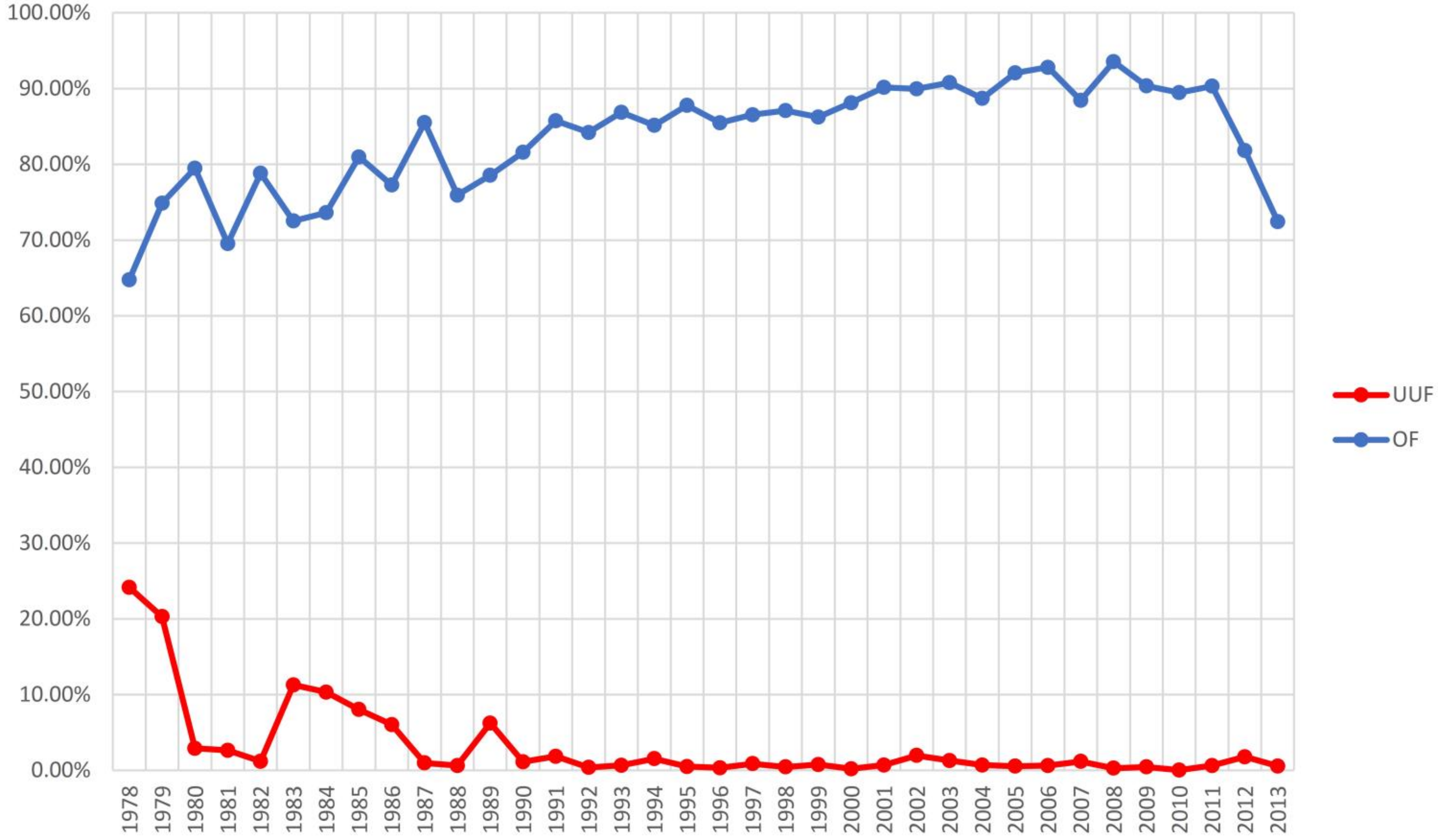

Figure 5.1.1 OF and UUF in the Republic of Korea

Based on the related data, casual loop diagram could be illustrated as Figure 5.1.2. The investment for human resource and technology decreases the occurrence of safety issue, and this increases the operating hour. The increased operating hour help NPPs to generate more electricity, which results in to the higher profit of operators. Then the operators invest more on the technology, and it means that this is reinforcing loop where the investment on technology increases through the feedback.

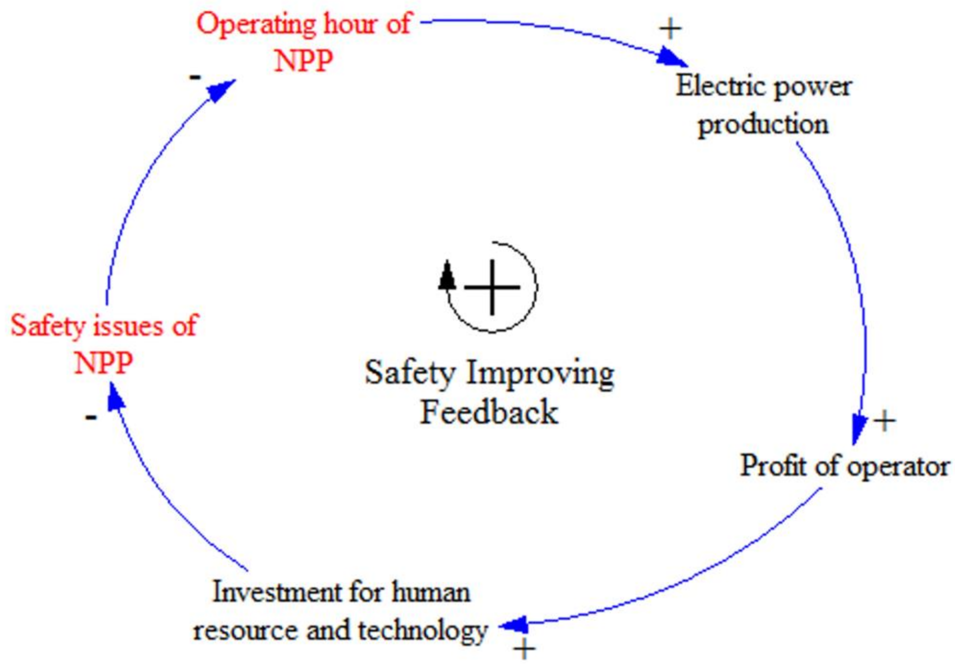

Figure 5.1.2 Safety Improving Feedback

5.2 Planned maintenance feedback

In figure 5.2.1, Planned Unavailability Factor (PUF) is added. PUF is the ratio of planned halt of NPPs such as the replacement of nuclear fuel and overhaul. According to the data since 1990, UUF is consistently near to zero. It implies that the technology is developed enough to prevent unplanned suspensions almost completely. However, even though UUF is near to zero, OF keeps increasing from 1990 to 2008. The increase could be explained by PUF. Looking at the data from 1990 to 2008, PUF is consistently decreasing. PUF depends on planned halt which could be manipulated by operator. That means operator has decreased PUF, and it caused the increase of OF.

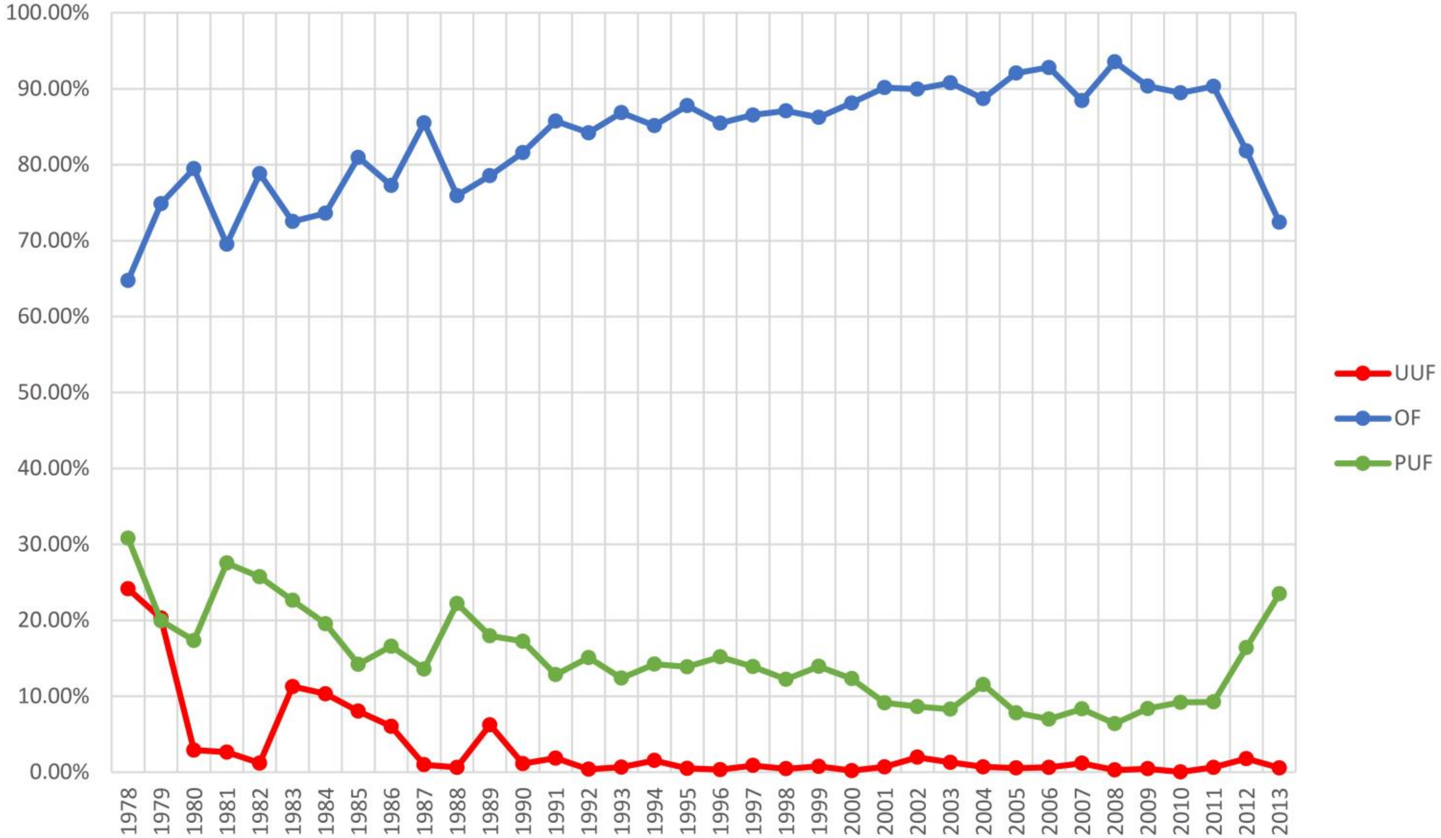

Figure 5.2.1 OF, PUF, and UUF in the Republic of Korea

Figure 5.2.2 is the causal loop diagram that illustrates the situation. For the few years after installation of NPPs, large portion of budget was investigated to decrease the safety issues. However, since 1990, when safety issues occurred much less than before, the investigation was taken for the purpose of decreasing planned maintenance period. Therefore, planned maintenance period was reduced and operating hour was increased. As in the safety improving feedback, increased operation hour let the NPPs to generate more electricity, which made more profit. Then the operator could concentrate more on technology for maintenance, and this reduced the planned maintenance period. In overall it formed a reinforce feedback.

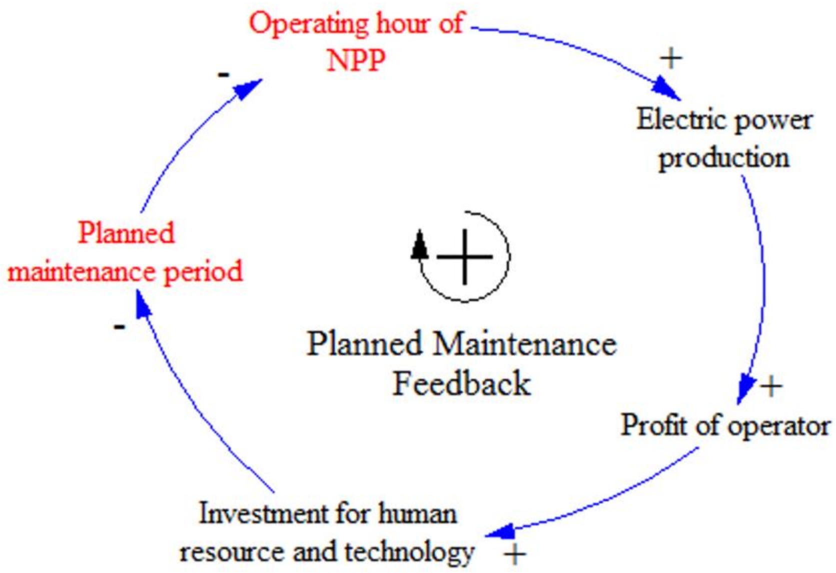

Figure 5.2.2 Planned Maintenance Feedback

5.3 CFSIs manufacturing feedback

In Figure 5.2.1, looking at the PUF and OF after 2011, PUF have been increased sharply, and together OF have been decreased sharply. This is because CFSIs were detected in 2011, so that CFSIs had to be replaced during the overhaul period. It decreased the operating hours of NPPs, and this is shown as a casual loop diagram in Figure 5.3.1.

In CFSIs manufacturing feedback, if planned maintenance period decreases, overall duration of supply for NPPs items reduces, and then remaining time for supply also decreases. Here, if remaining time for supply is shorter than whole period of process, it is impossible to supply by standard process. It could lead to fraud during the production and verification procedure, which could make more CFSIs to be produced. As CFSIs increases, safety issues of NPPs also increases, and it decreases the operating hour.

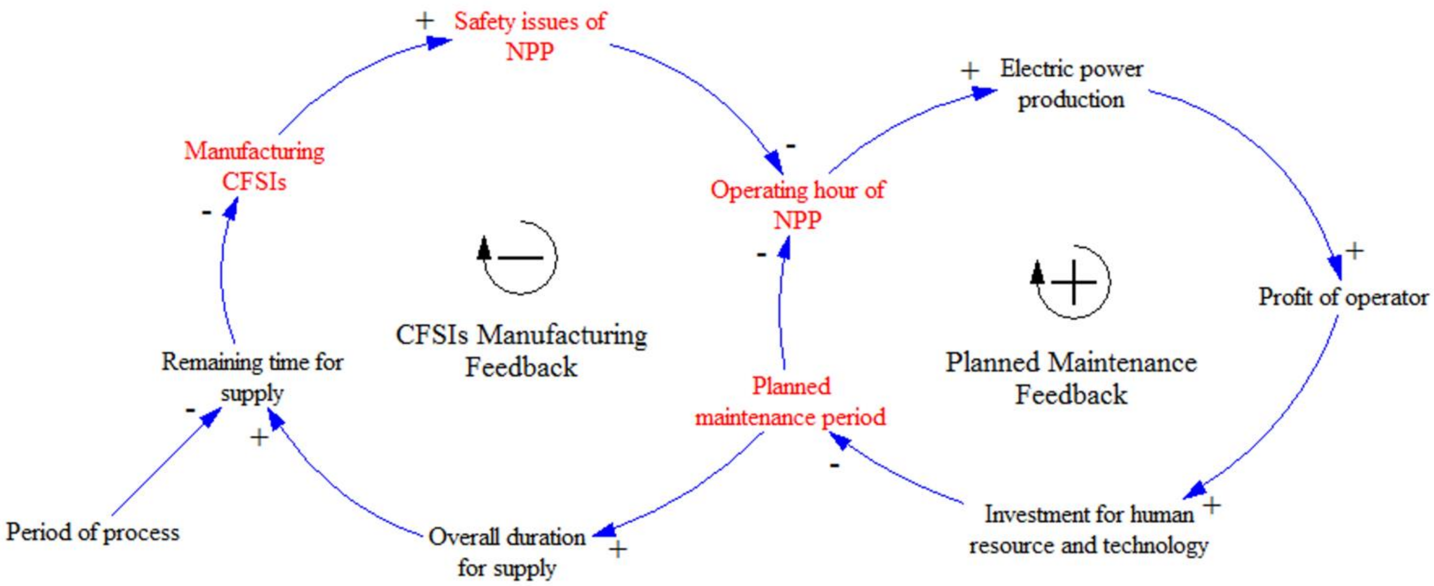

Figure 5.3.1 CFSIs Manufacturing Feedback

5.4 Quality control feedback

In quality control feedback, when the frequency of safety issue increases, quality control on NPP items is enforced and the enforced quality control could decrease CFSIs. However, Figure 5.1.1 is showing that UUF have been almost zero since 1990. That is, before CFSIs were detected in 2011, NPPs barely have not been stopped because of safety issues, so that quality control has been considered to be less important. This means that quality control feedback couldn’t work in appropriate way.

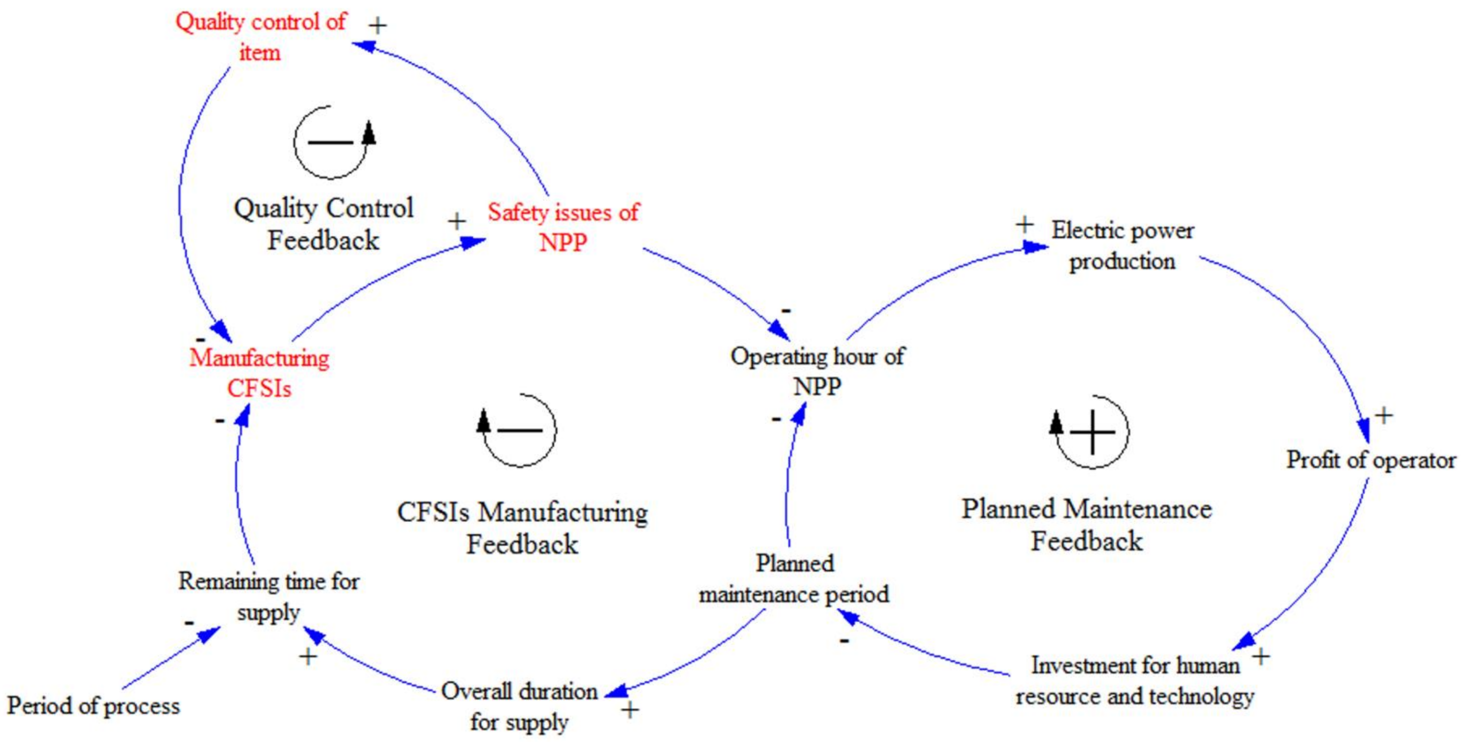

Figure 5.4.1 Quality Control Feedback

5.5 Lowest bidding feedback

As mentioned in 4.3 Statistics analysis, operator conducts open tendering with the lowest price for Q3-graded items. The open tendering with the lowest price is closely related to the number of suppliers who applied. If there are many applicants, the competition is overheated, which makes the bidding price lower. For the suppliers, the reduced price means the less profit. For these reasons, suppliers who participate in the bidding decrease. Through these processes, open tendering with the lowest price form a balancing feedback that makes the bidding price to converge.

Operators conduct open tendering with the lowest price to maximize the profit by lowering the price of items. On the other hand, for suppliers, the fewer suppliers apply, the more income they get. Regarding to the procurement procedure, operators let the suppliers to register only when they meet the standard. Here, to keep other competitors from applying, suppliers are making an effort to maintain the high standard. Operators, as well, were coy about lowering the standard, because they thought high standard could help to enforce the safety of NPPs.

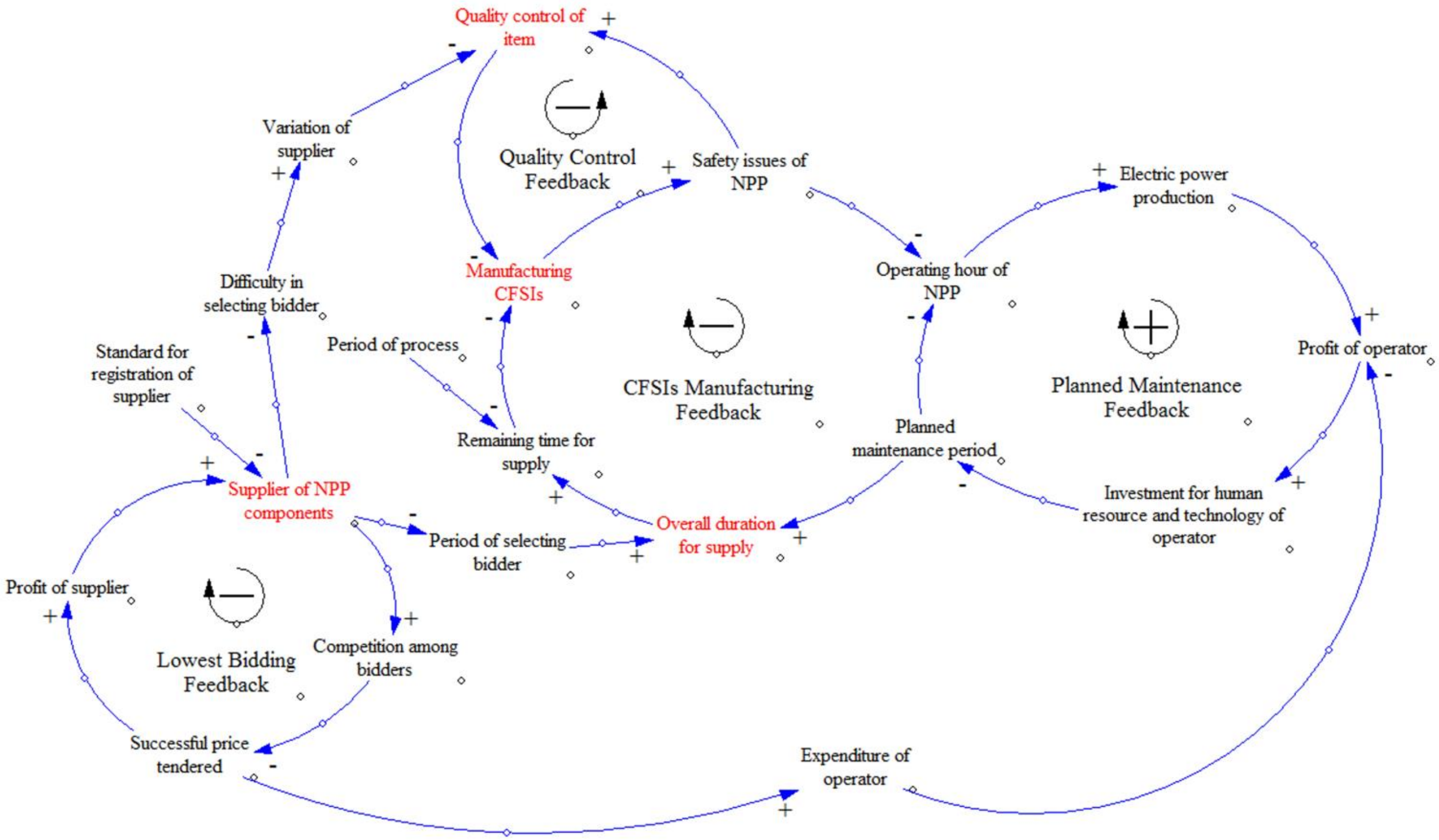

Figure 5.5.1 Lowest Bidding Feedback

However, this situation influenced the nuclear procurement system in unexpected way. First of all, it increased the CFSIs by shortening the deadlines for supply. It is because, as explained in 4.3 Statistic analysis, the few applicants could make the bidding process to be delayed, and operators cannot extend the deadline, because they need to finish the replacement during the overhaul period.

Another influence that few applicants could make is the diversification which could make quality control of regulatory authority difficult. If there are not enough applicants, operators cannot select the supplier in regular method, which makes the diversification occur. That is, operators have to find out other ways, such as supplies by vendors and foreign suppliers. It could make the quality control procedure complicated, and induce the increase of CFSIs.

5.6 Certificate authority feedback

There are about 2600 certificate authorities used by domestic supplier; 2500 domestic authorities for QVD, 42 domestic authorities and 45 foreign authorities for EQ, and 1 domestic authority and 12 foreign authorities for CGID (민병주, 2013). As shown in the data, the number of authorities for three documents varies widely, so that the influences by certificate authorities depend on the type of document.

First of all, as mentioned in 4.2 Interview, the extended qualification of certificate authorities allowed the private certificate authorities to conduct verification of QVD. It made the number of certificate authorities for QVD to increase sharply in short term. As the result, the competition between the certificate authorities became serious and the profitability also decreased. Naturally, for certificate authorities, it became very competitive to contract with suppliers and collusive tender occurred. This situation led to the CFSIs, as quality control by regulatory authority became demanding.

On the other hand, in the case of CGID, a number of suppliers request the verification to the only one domestic authority, or they request it to the foreign authority. This also led to the increase of CFSIs, because the time for the verification was extended.

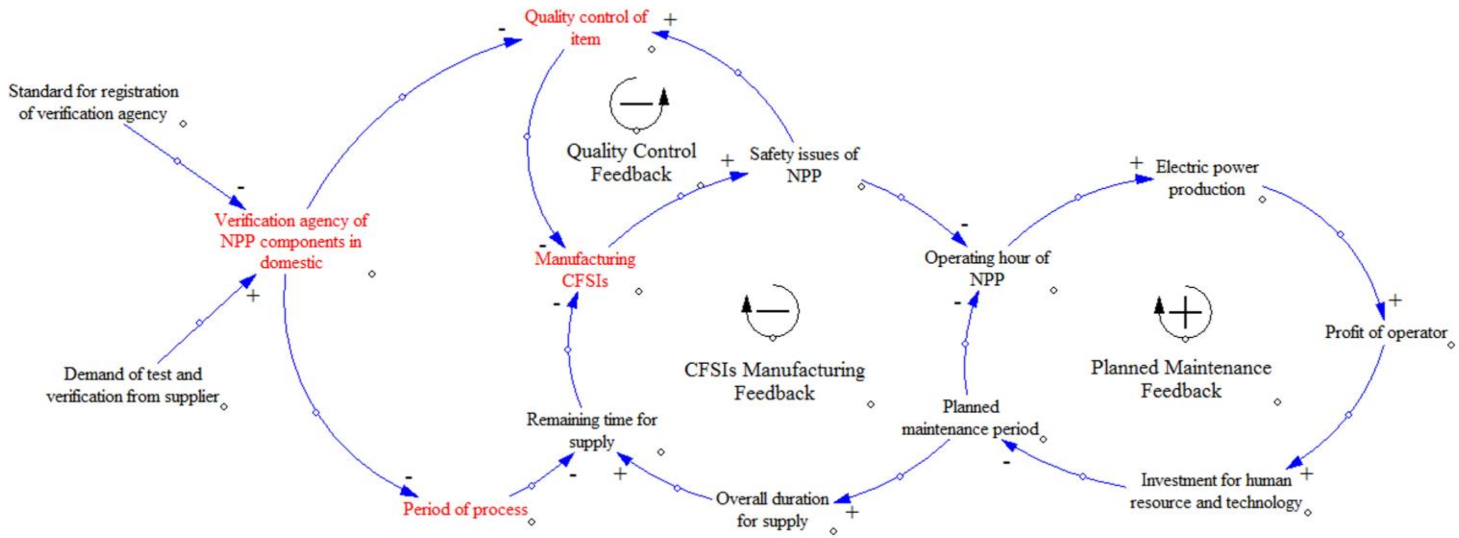

Figure 5.6.1 Certificate Authority Feedback

Chapter 6 Policy Recommendation on Nuclear Procurement System in Republic of Korea

In this chapter, policy recommendations are suggested with the six feedback loops modeled in chapter 5. These recommendations are specified in four subjects mentioned in 3.3 Case selection; operator, supplier, regulatory authority, and certificate authority. The recommendations are studied by adding a new factor or reformation of the given model.

6.1 Operator

The cause of CFSIs in the aspect of operator is that operating hour was increased by the decrease of planned maintenance period. This is because unexpected suspension barely occurred since 1990 with advanced technology, and the operating hour had to be continuously raised for the stable power supply and the profitability. However, during this planned maintenance period, overall NPP facilities need to be organized, and not only obsolescence items, but also items whose problem is newly found have to be replaced. As the result, continuous shortening of the deadlines became the pressure to suppliers. The effective solution that could be suggested to this situation is stores inventory management.

Inventory carrying cost is an important consideration as associated activities do not produce any revenue for operating organizations. Inventory carrying cost includes the costs of warehousing (direct costs for space rental, utility cost, staff cost, etc., plus the opportunity cost of invested funds; taxes, insurance, shrinkage, and obsolescence-risk costs etc.).

A sound stocking strategy allows for prudent financial management consistent with reliable plant operation. Optimized inventory strategies place greater emphasis on engineered spare parts availability, reducing consumable item process costs while maintaining adequate stock for plant use and elimination of excess obsolete inventories. NEI indicates (NEI, 2003) that an inventory optimization strategy can include the following optimization methods:

- Standardizing parts;
- Reducing duplications;
- Identifying exchangeable pars;
- Integrating supply chain with work control practices;
- Supporting work control scheduling processes;
- Maintaining data integrity of stock item information;
- Stratifying inventory (consumable, chemical, repairable, critical,

etc.);

- Measuring performance;
- Partnering with suppliers;
- Partnering with alliances, inter-utility, intra-utility;
- Identifying obsolescence;
- Ensuring compliance and consistent supply chain processes through the use of procedures and guidelines;
- Utilizing industry standards and operational experience;
- Developing a stocking plan that supports the business plan;
- Analyzing usage patterns;
- Applying total cost of ownership philosophy;
- Utilizing inventory analysis tools;
- Participating in the design change process early in the process/schedule;
- Encouraging use of existing inventory.

Robust IT systems are a necessity for proper control of the large amount of data associated with NPP inventory. Such systems should incorporate such features as a single source of data entry, requisition entry, demand planning, material tracking (including need dates), interfaces with engineering design systems, interfaces with expediting personnel, control of materials at multiple receipt and storage locations, recording of material status (e.g. damaged, awaiting inspection, quarantined, issuable etc.), allocation of material to installation work orders, tracking of individual components to storage locations and end locations (for recall purpose), inventory management, material recipient, material substitutions, and payment function. Various in-house and commercial solutions are available in industry, including enterprise resource planning systems and materials management software. Examples include SAP, Ventyx Asset Suite (PassPort), Areva VPRM, Intergraph SmartPlant Materials, Maximo, and many others.

In foreign operators, stores inventory management is being practiced in mandatory, and the research on the effectiveness of the management system is consistently conducted. However, in Korean NPPs, which haven't invested enough budgets on inventory management, 1247 Q-graded items without any inventory were detected. This is because operators concentrated on the installation and operation of new NPPs rather than inventory management. If the operators consider the inventory management as a significant issue and assign more budgets, CFSIs manufacturing feedback in Figure 6.1.1 would disappear and the occurrence of CFSIs will decrease.

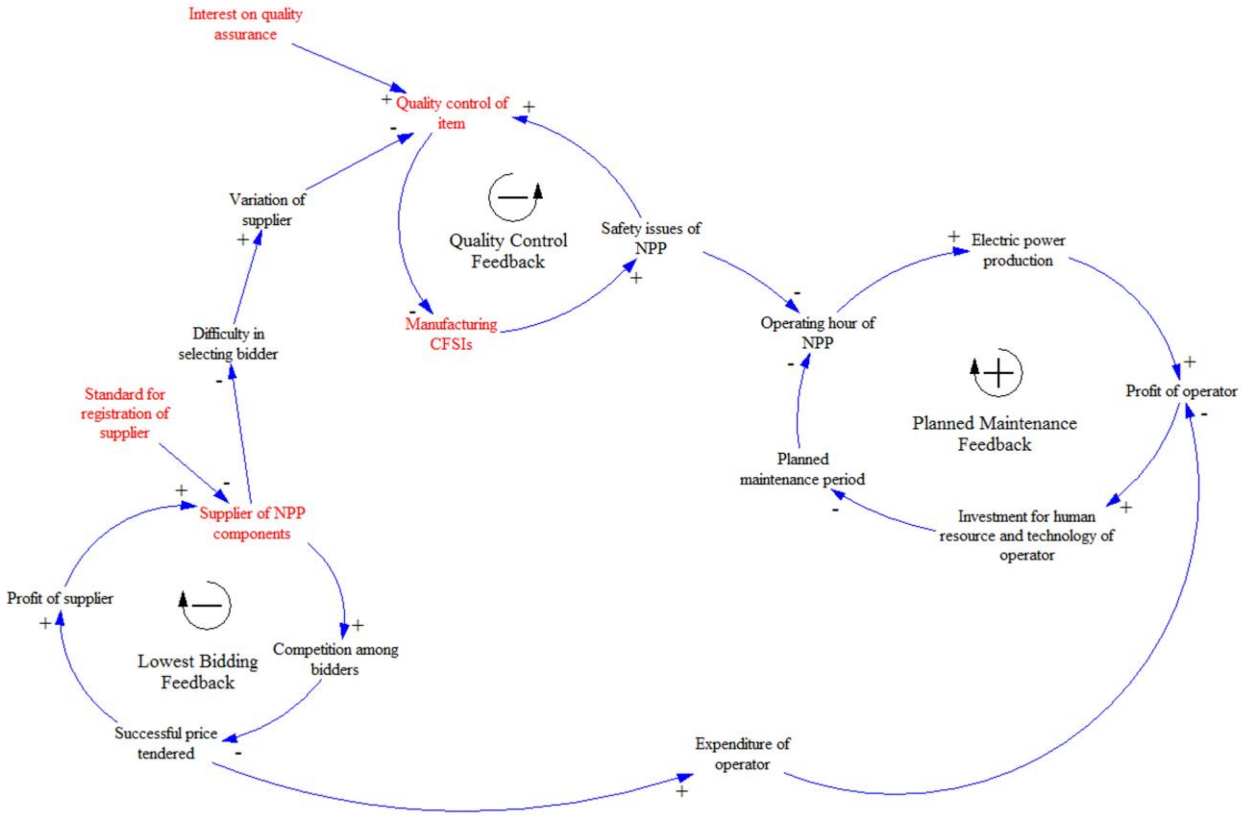

Figure 6.1.1 Policy recommendation in the respect of the operator, supplier, and regulatory authority

6.2 Supplier

Another cause of CFSIs is the high standard of registration program for suppliers. Suppliers have been kept the standard high to maintain their profit. Therefore it was not easy for the other suppliers to register as a new NPPs items supplier, and as it was explained in 4.3 Statistic analysis, this induced the delay of the bidding process.

Therefore, if the standard could be lower, the new suppliers also will be able to register on the program and it will reduce the delay. In addition this could also prevent the supplier chain from being connected to foreign suppliers and vendors, so that quality control could be conducted effectively.

6.3 Regulatory authority

The recommendation that could be suggested to regulatory authorities is the enforcement of quality control. According to quality control feedback, if safety-related issues increase, quality control could be improved. But UUF is nearly zero, as shown in Figure 5.1.1, so quality control should be enforced by external and continuous effort. The consistent concentration on quality control is visualized with casual loop diagram in Figure 6.1.1. The on-site and receipt inspection on suppliers is not practiced properly because of the overload and the shortage of manpower. To solve this problem, a new institution has to be established to manage the tasks for inspection.

6.4 Verification agency

For certificate authorities, the recommendations differs depending on the type of the certificate documents, because the issues regarding to QVD and CGID were different from each other as mentioned in 5.6 Certification Authority Feedback.

To begin with, the number of certificate authorities for QVD is overwhelming, so that quality control by regulatory authority is getting difficult to keep it under control. To deal with this issue, regulatory authority could allow only those who meet the higher standard to register, as operators are practicing a registration program to suppliers. Ii will lead to the reduce in the number of certificate authorities, and by keeping the proper number, tight competition could be stopped and the effectiveness of quality control could be enhanced.

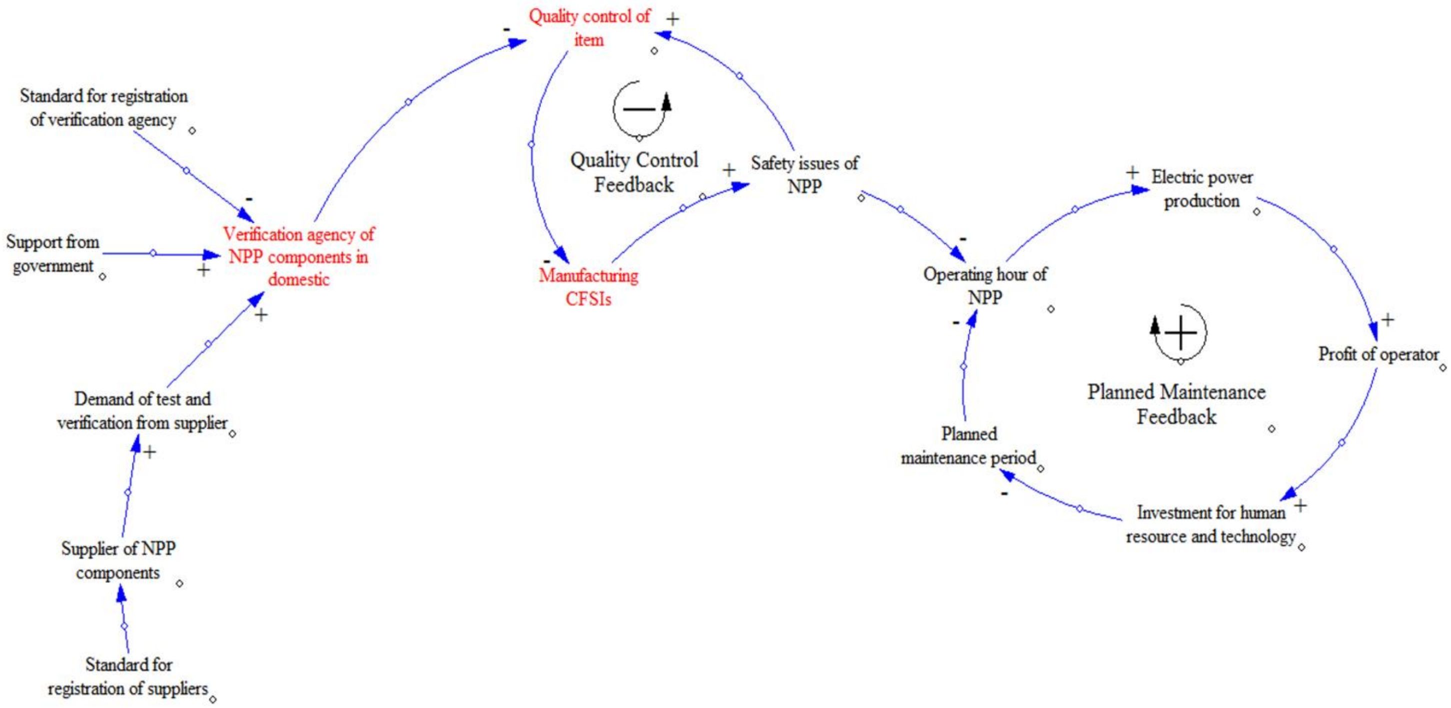

Figure 6.4.1 Policy recommendation in the respect of the certificate authority

On the other hand, there is only one domestic certificate authority for CGID, so all the verification for CGID should be requested to this authority or other foreign authorities. This made the verification procedure take a lot of time. Furthermore, if the standard for suppliers is lowered, there would be more suppliers for NPPs, and the demand of CGID would also increase sharply. Therefore, the government has to support on the establishment of domestic certificate authorities for CGID. The preparation to have more domestic authorities for CGID is in a necessity when more suppliers are encouraged to supply.

Chapter 7 Conclusion

In 3.1 Research questions, four research questions were suggested. In 7.1. Summary and findings, the research details, problems, and the solution for the questions will be introduced. Also the supplementation for the research and the parts that need further study will be offered in 7.2 Future work.

7.1 Summary and findings

“Are there appropriate decrees and systems, and are they being implemented properly?”

As mentioned in 4.1 Laws and regulations, NSSC is responsible for the inspections on operator, supplier, and certificate authority as stated on Nuclear Safety Law and its implementation regulation. However, even with the suitable laws, on-site and receipt inspection is not conducted virtually because of the obstacles like overload of work and the shortage of manpower. Accordingly, one solution could be the installation of a new institution for the tasks regarding on inspections and supplement of workforce.

“Is the deadline for supply fair enough?”

For the few years after the installation of NPPs, operator extended the operating hours by the investment on reducing the safety-related issues. Then, when the operation of NPPs became stable, operators have been decreased planned maintenance period to increase the operating hours. Reduced planned maintenance period makes the period for the replacement of items decrease as well. In addition, the operators don’t have an organized inventory management, so the deadlines for the supply have to be shortened. As the deadlines are not enough for the production and verification, it became a stressful burden to suppliers and as a results, CFSIs occurred. Therefore the solution for this issue is to adopt stores inventory management and guarantee the enough deadlines by the new management system. The budgets, which are currently concentrated on the construction and operation, need to be distributed to the development of inventory management.

“Are the suppliers for NPPs being managed faithfully?”

Operators have been filtering the suppliers by establishing a standard for suppliers, and the standard helped to keep the number of suppliers. Also, operators conduct open tendering with the lowest price to purchase the items in lower price. However, if the competition between the suppliers grows, it becomes less profitable for suppliers. To prevent this, suppliers have been tried to keep the number of suppliers from increasing by not loosening the standard for suppliers. But the small suppliers made the bidding procedure to be extended, and it became a burden to the suppliers as the shortened deadlines. If the standard could be lowered, more suppliers could apply. Then quality control could be conducted thoroughly and procurement system could be guaranteed.

“Is the independence of certificate authorities is fully guaranteed? Is the proper procedure established?”

In the case of QVD, the qualification of certification was extended to private authorities, which lead to the increased number of certificate authorities. However, the competition between certificate authorities for QVD has grown, and it gave suppliers the power over certificate authority. The solution for QVD is to reduce the number of certificate authorities by enforcing the qualification, so that the competition could be alleviated and the independence of certificate authorities also could be guaranteed. On the other hand, there is only one domestic certificate authority for CGID. Therefore, the domestic authority was overloaded, and some of the verification processes were requested to the foreign authorities. These made the verification to take more time, and it led to the occurrence of CFSIs. This could be solved by the development of domestic authorities with governmental support.

7.2 Future work of dissertation

The research is based on the modeling by investigating on literature review, interview, and statistical analysis. The model included the systems with the problem, and policy recommendation was suggested through the modification of model. In other words, the feedbacks with the problem were detected and the ways to delete and correct the feedbacks were suggested. However, the research on the implementation is still needed. The change of procurement system by the recommendations should be analyzed with a simulation for short- and long-term. Because the alternative recommendation could induce a new phenomenon by interacting with other factors. Therefore, the simulation over time should be conducted with the modeling by Stock and flow diagram in System dynamics.

In addition, comprehensive research is required on stores inventory management, one of the policy recommendations. It could contains the reason why inventory management was not conducted properly in Korean operator. Comparative analysis between various inventory management used in Korea and other foreign countries also could be conducted.

Appendix　Data for bidding process

Title of notice	No. of notice	Status	Date of notice	Closing date	No. of items	Deadline in notice	Deadline in contract	Date of contract
금속제 씰링 84EA (Q등급/제작)	W120668010	Failure	2012.10.31	2012.11.08	1	After 60		
	W120668011	Success	2012.11.16	2012.11.22	1	After 60	2012.12.10	
울진 6호기 O/H MANWAY GASKET 정비 자재 구매	U120871010	Failure	2012.10.10	2012.10.18	3	2012.11.02		
	U120871011	Success	2012.10.31	2012.11.06	3	2012.11.26	2012.10.18	
기계용 플러그(규격참조) 3EA 등 6종	K120625010	Failure	2012.10.22	2012.10.30	6	2013.01.26		
	K120625011	Success	2012.11.14	2012.11.20	6	2013.01.26	2013.02.12	
금속제 파이프(규격참조) 1BON 등 14종	K120630010	Success	2012.10.22	2012.10.29	14	2012.12.21	2012.12.21	2012.11.02
지지대(규격참조) 1EA 등 13종	K120635010	Failure	2012.10.22	2012.10.29	13	2012.12.21		
	K120635011	Failure	2012.10.30	2012.11.05	13	2012.12.21		
	K120635012	Failure	2012.11.08	2012.11.15	13	2013.01.10		
	K120635013	Selective			13		2013.01.10	2012.12.03
압력용 지시기(규격참조) 5EA 등 4종	K120688010	Failure	2012.10.29	2012.11.06	4	2012.12.21		
	K120688011	Failure	2012.11.07	2012.11.13	4	2012.12.21		
	K120688012	Failure	2012.11.16	2012.11.22	4	2012.12.21		
	K120688013	Failure	2012.12.07	2012.12.13	4	2013.02.26		
	K120688014	Selective			4		2013.02.26	2012.12.20

전동기(규격참조) 1EA 등 2종	K120691010	Notice	2012.10.29	2012.11.06	2	2012.12.20		
	K120691011	Success	2012.11.07	2012.11.13	2	2012.12.20	2012.12.20	2012.11.14
제어카드 9종	B120031010	Notice	2012.10.26	2012.11.05	9	2012.12.10		
	B120031011	Success	2012.11.07	2012.11.13	9	2012.12.10	2012.12.10	2012.11.19
고리 1,2호기 방수문 제작 구매	K120600010	Notice	2012.10.08	2012.10.22	37	2013.08.31		
	K120600011	Success	2012.10.24	2012.11.05	37	2013.08.31	2013.08.31	
전력용 케이블(규격참조) 1ROL 등 12종	K120627010	Failure	2012.10.17	2012.10.23	12	2012.12.14		
	K120627011	Failure	2012.10.24	2012.10.30	12	2012.12.26		
	K120627015	Selective			12		2013.01.10	2012.12.10
가스켓(규격참조) 6EA 등 5종	K120632010	Failure	2012.10.17	2012.10.23	5	2012.12.21		
	K120632011	Failure	2012.10.24	2012.10.30	5	2012.12.21		
	K120632012	Failure	2012.11.05	2012.11.12	5	2012.12.21		
	K120632013	Selective			5		2012.12.21	2012.11.19
작동기용 플런저(규격참조) 3EA 등 13종	K120654010	Success	2012.10.24	2012.11.01	13	After 30	2012.11.30	
베어링 하우징(규격참조) 1EA 등 2종	K120655010	Success	2012.10.22	2012.10.30	2	After 30	2012.11.30	
유체용 필터 64EA (Q등급)	W120616010	Failure	2012.10.04	2012.10.12	1	After 30		
	W120616011	Success	2012.10.22	2012.10.25	1	After 30	2012.12.08	
컬럼어셈블리(규격참조) 외 3종(품질: Q등급)	Y120784010	Success	2012.10.22	2012.10.30	4	2013.01.28	2013.01.28	
전동기(규격참조) 외 1종(품질: Q등급)	Y120780010	Failure	2012.10.19	2012.10.29	2	2012.12.21		
	Y120780011	Success	2012.11.07	2012.11.14	2	2012.12.21	2012.12.21	

가동원전 필수 고압전동기(4KV) 예비품 24대	C120020010	Success	2012.10.18	2012.11.14	22	2013.11.29	2013.11.29	2013.01.03
기계용 부품키트 5SET 외 1품목 (Q등급/제작)	W120645010	Success	2012.10.18	2012.10.26	2	After 60	2012.12.24	
베어링(규격참조) 외 16종(품질: Q등급)	Y120770010	Success	2012.10.18	2012.10.26	17	2013.01.14	2013.01.14	
롤러(규격참조) 외 1종 (품질: Q등급)	Y120772010	Success	2012.10.18	2012.10.26	2	2013.01.03	2013.01.03	
파이프용 엘보우(규격참조) 16EA 등 49종	K120631010	Success	2012.10.17	2012.10.23	49	2012.12.21	2012.12.21	2012.11.01
비금속제 호스 56EA 외 14품목 (Q등급/제작)	W120626010	Failure	2012.10.10	2012.10.18	15	After 80		
	W120626011	Failure	2012.11.01	2012.11.07	15	After 80		
	W120626012	Failure	2012.11.13	2012.11.19	15	After 80		
	W120626013	Failure	2012.11.21	2012.11.27	15	After 80		
	W120626014	Failure	2012.12.10	2012.12.17	15	After 80		
	W120626015	Success	2012.12.20	2012.12.26	15	After 80	2013.02.10	
밸브용 시트 4EA 외 1품목 (Q등급/제작)	W120596010	Failure	2012.09.19	2012.09.27	2	After 45		
	W120596011	Success	2012.10.09	2012.10.15	2	After 45	2012.11.16	
송풍기, 순환식(규격참조) 1종	Y120746010	Failure	2012.10.02	2012.10.08	1	2012.11.09		
	Y120746011	Failure	2012.10.09	2012.10.15	1	2012.11.09		
	Y120746012	Selective			1		2012.11.09	2012.11.01
송풍기, FOR VENTILATION(규격참조) 1종	Y120747010	Failure	2012.10.02	2012.10.18	1	2012.11.09		
	Y120747011	Failure	2012.10.09	2012.10.15	1	2012.11.09		
	Y120747012	Selective			1		2012.11.09	2012.11.01

케이블, 전력용(규격참조) 외 3종	Y120751010	Success	2012.10.04	2012.10.12	4	2012.11.09	2012.11.09	
전자 모듈, 표준화형(규격참조) 1종	Y120671010	Failure	2012.09.19	2012.09.27	1	2012.11.12		
	Y120671011	Failure	2012.09.28	2012.10.04	1	2012.11.12		
	Y120671012	Selective			1		2012.12.05	2012.11.14
씰링 1종(품질: Q등급)	Y120711010	Failure	2012.09.21	2012.09.28	1	2012.10.27		
	Y120711011	Success	2012.09.28	2012.10.15	1		2012.10.27	
안전방출 밸브(규격참조) 1EA 등 2종	K120578010	Failure	2012.09.27	2012.10.05	2	2012.12.14		
	K120578011	Failure	2012.10.09	2012.10.15	2	2013.03.08		
	K120578012	Selective			2		2013.03.08	2012.11.09
게이트형 밸브(규격참조) 2EA 등 16종	K120582010	Success	2012.09.27	2012.10.05	16	2012.12.14	2012.12.14	2012.10.10
라이너 4EA (Q등급/제작)	W120609010	Success	2012.09.26	2012.10.04	1	After 40	2012.10.15	
퓨즈, 통형(규격참조) 외 10종	Y120665010	Failure	2012.09.17	2012.09.25	11	2012.10.19		
	Y120665011	Failure	2012.09.25	2012.10.02	11	2012.11.09		
	Y120665012	Selective			11		2012.12.14	2012.11.01
가스켓 외 7종(품질: Q등급)	Y120717010	Success	2012.09.24	2012.10.04	8	2012.10.27	2012.10.27	
활성탄(첨착활성탄,5%) 1종(품질:Q등급)	Y120684010	Success	2012.09.19	2012.09.27	1	2012.10.31	2012.10.31	
전력용 케이블(규격참조) 1,000FT	K120575010	Success	2012.09.18	2012.09.26	1	2012.12.14	2012.12.14	
통풍조절장치, 판넬 냉각설비 어셈블리(규격참조) 외 1종	Y120662010	Success	2012.09.17	2012.09.25	2	2012.11.05	2012.10.25	
5호기 소내방사선감시설비	U120769010	Failure	2012.09.05	2012.09.13	2	2012.12.31		

전원공급기 등 정비자재 구매	U120769011	Success	2012.09.13	2012.09.19	2	2012.12.31	2012.12.31	
울진 3호기 O/H 공기조화설비 고효율 입자 공기필터 정비자재 구매	U120790010	Success	2012.09.12	2012.09.20	1	2012.10.22	2012.09.24	
	W120585010	Success	2012.09.12	2012.09.20	5	After 60	2012.11.19	
금속제 파이프(규격참조) 2BON 등 2종	K120528010	Failure	2012.08.30	2012.09.07	2	2012.12.10		
	K120528011	Failure	2012.09.11	2012.09.17	2	2012.12.10		
	K120528012	Selective			2		2012.12.10	2012.09.21
유량용 지시기(규격참조) 2EA 등 2종	K120529010	Failure	2012.08.30	2012.09.07	2	2012.11.15		
	K120529011	Failure	2012.09.11	2012.09.17	2	2012.11.15		
	K120529012	Selective			2		2012.11.15	2012.09.21
슬리브형 베어링(규격참조) 1EA 등 10종	K120560010	Success	2012.09.11	2012.09.19	10	After 30	2012.11.30	
제어카드 13종	B120024010	Failure	2012.08.28	2012.09.03	13	2012.12.10		
제어카드 16종	B120024011	Failure	2012.09.05	2012.09.11	16	2012.12.10		
	B120024012	Selective			16		2012.12.10	2012.10.09
피토관(규격참조) 1종	Y120592010	Failure	2012.08.23	2012.08.31	1	2012.10.22		
	Y120592011	Success	2012.08.31	2012.09.06	1	2012.10.22	2012.10.22	2012.09.14
게이트형 밸브(규격참조) 4EA	K120527010	Success	2012.08.30	2012.09.07	1	2012.12.10	2012.12.10	2012.09.11
볼트 12EA 외 1품목 (Q 등급)	W120541010	Failure	2012.08.20	2012.08.28	2	After 40		
	W120541011	Failure	2012.08.30	2012.09.07	2	After 40		
	W120541012	Selective			2		2012.10.23	2012.09.14
파이프(금속제, SMLS, 6M, SCH 40, ASTM A312) 외 11종(품질: Q등급)	Y120576010	Failure	2012.08.17	2012.08.27	12	2012.11.28		
	Y120576011	Success	2012.08.30	2012.09.06	12	2012.11.28	2012.11.28	

6호기 O/H 계측분야 피팅류 정비자재 구매	U120743010	Success	2012.08.29	2012.09.06	33	2012.10.21	2012.10.21	
필터 엘리맨트(유체용,CART,6.65*21.225IN) 외 1종(품질: Q등급)	Y120618010	Success	2012.08.29	2012.09.06	2	2012.09.28	2012.09.28	
피토관, FLOW ELEMENT(규격참조) 1종	Y120622010	Success	2012.08.29	2012.09.06	1	2012.10.19	2012.10.19	2012.09.14
6호기 원자로격납건물 주요계측기 피팅류 자재 구매	U120707010	Failure	2012.08.16	2012.08.24	3			
	U120707011	Success	2012.08.24	2012.08.30	3	2012.10.10	2012.10.10	2012.09.03
글로브형 밸브 3EA 외 1품목 (Q등급/제작)	W120533010	Failure	2012.08.13	2012.08.21	2	After 60		
	W120533011	Failure	2012.08.24	2012.08.30	2	After 60		
	W120533012	Selective			2		2012.11.12	2012.09.14
울진 6호기 PMS/PDAS간 네트워크 허브 구매	U120681010	Success	2012.08.22	2012.08.30	1	2012.10.19	2012.10.19	2012.09.03
전원공급기(규격참조) 1종	Y120560010	Failure	2012.08.13	2012.08.21	1	2012.10.22		
	Y120560011	Failure	2012.08.21	2012.08.27	1	2012.10.22		
	Y120560012	Selective			1		2012.10.22	2012.09.12
글로브형 밸브 1종 (Q 등급)	W120539010	Success	2012.08.20	2012.08.28	1	After 45	2012.10.21	2012.09.07
파이프용 엘보우 5EA 외 8품목 (Q 등급)	W120540010	Success	2012.08.20	2012.08.28	9	After 120	2012.11.10	2012.08.31
특수형 구조물 3BON 외 8품목 (Q 등급)	W120542010	Success	2012.08.20	2012.08.28	9	After 60	2012.11.10	2012.08.31
밸브디스크(TILTING DISK, SB148, CHECK V/V) 외 1종(품질: Q등급)	Y120568010	Success	2012.08.20	2012.08.28	2	2012.10.18	2012.10.18	
파이프, 금속제(규격참조) 외 7종	Y120587010	Success	2012.08.20	2012.08.28	8	2012.09.28	2012.09.28	

유체용 필터 10EA (Q등급/제작)	W120547010	Success	2012.08.17	2012.08.27	1	After 45	2012.11.19	
용접봉(INCONEL FILER METAL 52M) 외 1종(품질: Q등급)	Y120570010	Success	2012.08.17	2012.08.27	2	2012.10.15	2012.10.15	
링(웨어링,ASTM A494 GR M-35,50mm) 외 5종(품질: Q등급)	Y120574010	Success	2012.08.17	2012.08.27	6	2012.10.22	2012.10.22	
판(RCP 속도센서 브라켓, 센서 고정용) 1종(품질: Q등급)	Y120563010	Success	2012.08.16	2012.08.24	1	2012.10.26	2012.10.26	
기계구동장치용 하우징 4EA (Q등급/제작)	W120536010	Success	2012.08.14	2012.08.22	1	After 80	2012.11.12	
나비형밸브(규격참조) 6EA	K120485010	Success	2012.08.13	2012.08.21	1	2012.09.20	2012.09.20	2012.08.30
나비형 밸브 5종	B120023011	Success	2012.08.09	2012.08.16	5	After 90	2012.11.15	2012.08.24
밸브용 시트(규격참조) 3EA 등 9종	K120473010	Success	2012.08.09	2012.08.21	9	2012.10.31	2012.10.31	2012.08.29
히터(공간형,FIN,TUBE:SUS316 L) 외 8종 (품질: Q,A등급)	Y120536010	Success	2012.08.09	2012.08.17	9	2012.10.31	2012.10.31	
밸브(SWING CHECK VALVE, SA182 F316) 1종(품질: Q등급)	Y120538010	Success	2012.07.31	2012.08.08	1	2012.12.21	2012.12.21	
씰 세트(STATIONARY BELLOWS SEAL) 외 3종(품질: Q등급)	Y120501010	Failure	2012.07.12	2012.07.20	4	2012.09.25		
	Y120501011	Failure	2012.07.25	2012.07.31	4	2012.09.25		
	Y120501012	Selective			4		2012.09.25	2012.08.22
필터 엘리맨트(EC FILTER,CART,6(3/4)) 1종 (품질: Q등급)	Y120518010	Success	2012.07.23	2012.07.31	1	2012.09.14	2012.09.14	2012.08.06

튜브용 컨넥터(규격참조) 50EA 등 2종	K120420010	Success	2012.07.19	2012.07.27	2	2012.08.27	2012.08.27	
공기조절용 필터 엘리멘트 66EA (Q등급/제작)	W120488010	Failure	2012.07.10	2012.07.18	1	After 60		
	W120488011	Success	2012.07.19	2012.07.25	1	After 60	2012.07.23	
울진 1,2호기 1차측 공기조화필터 정비자재 구매	U120615010	Success	2012.07.18	2012.07.26	1	2012.08.31	2012.08.31	
메카니칼씰(규격참조) 2SET 등 7종	K120406010	Success	2012.07.10	2012.07.18	7	2012.09.11	2012.09.11	
전력용 케이블(규격참조) 300M 등 16종	K120411010	Success	2012.07.05	2012.07.13	16	2012.09.03	2012.08.20	
울진 4호기 O/H 노심냉각감시계통 히터컨트롤러 자재 구매	U120593010	Success	2012.07.04	2012.07.12	1	2012.11.30	2012.11.30	
필터 엘리멘트(공기조절용,MED EFFICIENCY)외 2종(품질: Q등급)	Y120483010	Success	2012.07.03	2012.07.11	3	2012.08.16	2012.08.16	
슬리브(규격참조) 3EA 등 3종	K120395010	Success	2012.07.02	2012.07.10	3	2012.09.01	2012.09.01	
공학적안전설비작동계통 전원회로개선자재 구매	U120520010	Failure	2012.06.11	2012.06.19	2	2012.09.30		
	U120520011	Success	2012.06.20	2012.06.26	2	2012.09.30	2012.09.30	
울진 6호기 O/H 안전등급 충전기 정비용 자재 구매	U120546010	Success	2012.06.18	2012.06.26	12	2012.10.04	2012.10.04	
메카니칼 씰 3SET(Q등급)	W120429010	Success	2012.06.18	2012.06.25	1	After 90	2012.06.11	
슬리브용 부싱 6EA 외 1품목 (Q등급/제작)	W120425010	Success	2012.06.13	2012.06.21	2	After 40	2012.06.28	
전송기(규격참조) 1EA 등 2종	K120297010	Failure	2012.05.11	2012.05.17	2	2012.06.28		

	K120297011	Failure	2012.05.21	2012.05.29	2	2012.06.28		
	K120297012	Failure	2012.06.07	2012.06.13	2	After 45		
	K120297013	Selective			2		2012.08.03	2012.06.19
전송기(규격참조) 1EA 등 2종	K120298010	Failure	2012.05.11	2012.05.17	2	2012.06.28		
	K120298011	Failure	2012.05.21	2012.05.29	2	2012.06.28		
	K120298012	Failure	2012.06.07	2012.06.13	2	After 45		
	K120298013	Selective			2		2012.08.03	2012.06.19
볼트 2SET(Q등급)	W120373010	Failure	2012.05.23	2012.05.31	1	After 25		
	W120373011	Success	2012.06.07	2012.06.13	1	After 25	2012.05.21	
밸브용 시트 외 1품목 (Q등급)	W120358010	Success	2012.06.05	2012.06.13	2	After 60	2012.06.30	
전력용 케이블 6종 (제작)	W120408010	Success	2012.06.05	2012.06.13	6	2012.07.06	2012.07.06	
축용 플렉시블 커플링(규격참조) 6EA 등 17종	K120318010	Success	2012.06.04	2012.06.12	17	2012.08.20	2012.08.20	
전기장치용 분배시스템(규격참조) 2EA 등 5종	K120335010	Success	2012.06.04	2012.06.11	5	2012.12.26	2012.12.26	
1,2호기 1차측 공기조화필터 교체용 정비 자재 구매	U120485010	Success	2012.05.22	2012.05.30	1	2012.07.06	2012.07.06	
솔레노이드 밸브(규격참조) 5EA	K120283010	Failure	2012.05.11	2012.05.21	1	2012.07.13		
	K120283011	Failure	2012.05.25	2012.05.31	1	2012.07.13		
	K120283012	Selective			1		2012.07.13	2012.06.15
공정제어계통 전원공급기	W120353010	Failure	2012.05.14	2012.05.21	1	2012.06.15		
	W120353011	Failure	2012.05.25	2012.05.31	1	2012.06.30		

	W120353012	Selective			1		2012.06.30	2012.06.12
밸브용 스템(규격참조) 1EA 등 9종	K120269010	Failure	2012.05.02	2012.05.10	9			
	K120269011	Success	2012.05.16	2012.05.22	9	2012.08.20	2012.08.27	
울진 1,2호기 1차측 공기조화필터 교체용자재 구매계획	U120476010	Success	2012.05.16	2012.05.24	1	2012.06.22	2012.06.22	
튜브 21BON(Q등급)	W120346010	Success	2012.05.11	2012.05.17	1	2012.06.20	2012.06.20	
유니온 44EA외 7종(Q등급)	W120347010	Success	2012.05.11	2012.05.17	8	2012.06.20	2012.06.20	
금속제 파이프 50BON 외 3종(Q등급)	W120349010	Success	2012.05.11	2012.05.17	4	2012.06.20	2012.06.20	
필터 엘리맨트(유체용,CART,6.65*21.225IN) 외 1종(품질: Q등급)	Y120432010	Success	2012.05.11	2012.05.21	1	2012.06.15	2012.06.15	
울진 6호기 O/H 냉각해수펌프 출구 격리 밸브 구매	U120393010	Success	2012.04.27	2012.05.08	2	2012.09.20	2012.09.20	
3호기 O/H 1차계통 계측피팅류 자재 구매	U120411010	Success	2012.04.25	2012.05.03	18	2012.06.12	2012.06.12	
전자식 계전기(규격참조) 3EA 등 51종	K120260010	Failure	2012.04.24	2012.04.30	51	2012.08.02		
	K120260011	Failure	2012.05.03	2012.05.09	51	2012.08.02		
	K120260012	Success	2012.05.10	2012.05.16	51	2012.08.16	2012.08.02	
플런저(CHARGING PUMP용, 작동기용) 외 1종(품질: Q등급)	Y120388010	Failure	2012.04.18	2012.04.25	2	2012.05.25		
	Y120388011	Success	2012.05.09	2012.05.16	2	2012.06.04	2012.05.04	
필터 엘리맨트(규격참조) 150EA	K120248010	Failure	2012.04.27	2012.05.04	1	2012.05.10		
	K120248011	Success	2012.05.07	2012.05.14	1	After 30	2012.05.10	

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초 록

2013년 5월, 검증서가 위조된 원자력 발전소의 부품이 납품되었던 것이 발견되었다. 위조된 검증서는 시험성적서(QVD), 기기검증서(EQ) 및 일반규격품 품질검증서(CGID)로서, 공급자가 검증기관으로부터 검증을 마친 후 물품과 함께 운영자에게 물품과 함께 보내게 된다. 발생한 부정은 공급자와 검증기관이 담합하여 검증서의 조작이 발생하였다. 원자력 발전소 운영자는 위조 부품을 교체하기 위해 운전중인 발전소를 정지하거나 건설중인 발전소의 공정을 지연시키며, 전수조사 및 위조 부품에 대한 교체를 수행하였다. 이로 인해 당해 여름의 예비 전력량이 크게 떨어지게 되어 순환정전을 수행하게 되었고, 가정 및 기업에서는 금전적인 피해가 발생하게 되었다. 또한 후쿠시마 원전 사고 이후 원자력 발전소의 안전성에 대한 불안감이 커지고 있는 상황에서 위조 부품의 발견은 대중들로 하여금 원자력 발전소에 대한 불신이 커지게 된 계기로 작용하였다.

이러한 위조 부품은 CFSIs (Counterfeit, Fraudulent, and Sub-standard Items)로 정의하며 원자력 발전소 운영 국에서 다양하게 발견되고 있다. CFSIs는 원자력 발전소에서 노심정지, 방사능의 누출, 핵연료의 손상 등의 사고를 유발하는 직접적인 원인으로 작용하기도 하며, 안전 관련 시스템의 성능을 저하시키는 간접적인 원인으로도 작용한다. 이를 방지하기 위하여 1980년 이후 미국을 중심으로 다양한 연구 및 규제가 수행되고 있다. 따라서 한국에서 발생한 CFSIs의 원인을 파악하고 이를 방지할 수 있는 정책을 제언하는 것이 연구의 목적이다.

납품 체계에 대한 이해를 위해 한국의 법률과 규제 제도의 분석,

관계 기관과의 인터뷰, 계약 과정에 대한 통계 분석이 수행되었다. 원자력 안전법에서는 운영자, 공급자 및 규제기관에 대한 검사와 위반 사항에 대한 교정에 대해 규정하고 있다. 또한 시스템 내부에 존재하고 있는 문제의 원인을 파악하기 위하여 관계 기관에 대한 인터뷰를 수행하였다. 이를 통해 품질 관리를 수행하는 인력의 부족, 검증 기관의 독립성 저하가 문제의 원인으로 발생하였다는 것을 알 수 있었다.

또한 낙찰자 선정 과정에 대한 문제를 파악하기 위하여 입찰 및 계약 과정에 대한 통계 분석을 수행하였다. 우선 낙찰자 선정까지의 과정에서 많게는 5주의 기간까지의 지연이 발생한 것이 확인되었다. 또한 상당수의 물품이 낙찰자 선정과정에서 지연된 시간만큼 납품기간이 단축되어 계약을 체결한 것이 확인되었다. 그리고 낙찰자 선정 절차가 무시된 경우도 발생하였다는 것을 확인하였다.

위에서 수행한 법률 및 규제 제도의 분석, 인터뷰 및 통계 분석을 바탕으로 납품 과정에 대한 모델링을 수행하였다. 모델링은 다양한 인자들에 대한 상호 연관성을 분석하기 용이한 시스템 다이나믹스 기법을 이용하였다.

원자력 도입 초기에는 발전소의 안전성을 확보하기 위해 인력 및 자본에 대한 투자가 수행되었고, 이에 따라 지속적으로 가동률이 올라가는 모습을 보였다. 하지만 기술이 확보됨에 따라 안전 문제의 발생이 줄어들게 되었고, 이 후 많은 전력을 안정적으로 공급하기 위하여 계획예방정비의 기간을 단축하게 되었다. 하지만 이는 공급자에게 납품기간에 대한 부담을 가중시켜 CFSIs가 발생하게 된 요인으로 작용하였다. 그리고 안전 문제의 발생이 늘어나게 될 경우 엄격한 품질 관리가 수행되고 따라서 이는 CFSIs의 발생을 줄여줄 수 있게 된다. 하지만 1990년 이후 안전 관련 문제 발생이 현격히 줄어들게 되었고 이에 따라 품질 관리에 대한 관심이 지속적으로

낮아지게 되었고 따라서 CFSIs에 대한 효과적인 규제가 이루어 지지 못하였다. 그리고 운영자의 수익을 증대하기 위하여 최저가 낙찰제를 실시하고 있는데 이는 공급자의 수익이 줄어드는 요인으로 작용하였다. 이에 공급자는 자신들의 수익을 보장하기 위해, 공급자 등록 자격을 높게 유지될 수 있도록 하였다. 이로 인해 적은 수의 원자력 물품 공급자가 유지 되었고 이는 통계 분석을 통해 살펴 보았듯이 낙찰자 선정 과정 상에 지연이 발생하게 되었다. 하지만 계획예방정비 기간의 단축으로 인해 운영자는 이를 반영하지 못하고, 공급자에게 단축된 납품 기간을 제시하게 되었다. 따라서 제작 및 검증에 필요한 기간이 보장되지 못한 채 납품이 수행되었고 이 또한 CFSIs가 발생할 수 있는 원인이 되었다. 그리고 적은 수의 공급 업체로 인해 공급망을 넓혀 대리점 또는 해외 공급자를 통한 납품을 수행하게 되었고 이는 품질관리의 어려움으로 연결되어 CFSIs가 발생하는 원인으로 작용하였다. 마지막으로 시험성적서 검증 기관의 경우 2000년대 이후 검증 기관에 대한 자격이 민간으로 확대되어 현재 2500여개에 달하는 많은 검증 기관이 존재하고 있다. 이로 인해 검증 기관의 수익성 악화로 공급자로부터의 독립성이 유지되지 못하여 부정이 발생할 가능성이 높아졌지만, 이에 대한 효과적인 관리가 이루어지지 못하였다. 그리고 국내에서 일반규격품 품질검증서를 발급할 수 있는 기관이 하나 밖에 존재하지 않기 때문에 검증 과정중에 소요되는 시간이 길어지게 되었고 이는 CFSIs 가 발생할 수 있는 여건으로 작용하였다.

위의 다양한 CFSIs의 발생 원인을 통해 이를 방지할 수 있는 새로운 정책을 운영자, 공급자, 규제기관, 검증기관의 측면에서 제시하였다. 우선 운영자의 경우 효과적인 재고 관리 프로그램의 운영이 필수적이다. 해외 원자력 발전소 운영자들은 다양한 재고 관리 프로그램을 개발하여 자신들의 실정에 맞는 프로그램을 사용중이다.

하지만 한국의 경우 예산상의 이유로 재고관리가 이루어지지 않고 있는 물품이 상당수 존재한다. 재고관리가 효과적으로 수행된다면 공급자들에 대해 단축된 납품기간을 제시할 필요가 없을 뿐만 아니라 효과적인 품질 관리도 수행될 수 있을 것이다. 공급자의 측면에서 살펴보면, 공급자 자격 기준을 허용 범위 한도에서 낮추어 많은 수의 공급자들이 입찰에 참여할 수 있도록 해야 한다. 이를 통해 낙찰자 선정 과정의 기간도 단축될 것이며, 운영자의 수익성도 증대될 수 있을 것이다. 또한 검증 기관의 인력 보충, 전문성 강화, 검증 수행 전문 기관의 신설 등을 통해 이러한 CFSIs에 대한 관리가 효과적으로 수행될 수 있도록 정부의 지원이 필요할 것이다. 시험 성적서 검증 기관의 경우 자격 요건을 강화하여 점진적으로 기관의 수를 줄여나감을 통해 독립성을 확보하고 효과적인 품질 관리가 수행될 수 있도록 해야 한다. 마지막으로 일반규격품 품질검증서 발급 기관의 경우 국내의 검증기관의 육성에 대한 필요성이 절실하다. 이를 통해 공급자가 검증 수행에 필요한 기간을 단축시켜 준다면 CFSIs의 발생 가능성은 자연적으로 줄어들 것이다.

주요어 : 원자력 납품, CFSIs, 부정 부품, 품질 관리, 품질 보증, 원자력 공급망

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