DESIRED FLOW OF RADIOACTIVE MATERIALS IN TURKEY

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ABSTRACT

DESIRED FLOW OF RADIOACTIVE MATERIALS IN TURKEY

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In recent years, increased use of radiation and radioactive materials have made radiation protection a concern even in our daily lives. Although we are not aware of it, the radioactive sources are constantly being transported via air, road and ocean ways for medical, industrial, research etc. purposes throughout the world. The quantity of radioactive materials transported all around the world varies from negligible quantities in shipments of consumer products to very large quantities in shipments of irradiated nuclear fuel. In this study, we aim to discover desired flow of radioactive materials from regulatory, health, safety, environment and logistics quality perspectives. In doing so, we will take Turkey as an example to demonstrate implementation of regulations in real life, problems between actors in radioactive cargo transportation, history of radioactive incidents and the quality measures to be taken for improved and safe, legal environment. We firstly start with identifying dangerous goods and then continue with narrowing our focus point to radioactives.

Key Words: Radiation protection, health, safety and environment perspective, dangerous goods, radiaoactive shipment, regulations, logistics quality.

ÖZET

Tuğçe Yavaş

TÜRKİYE'DE ARZU EDILEN RADYOAKTİF MADDE TAŞIMACILIĞI SÜRECİ

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Son yıllarda radyasyon ve radyoaktif maddelerin kullanımının artması radyasyondan korunmayı önemli bir konu haline getirmiştir. Bizler farkında olmasak da, radyoaktif kaynaklar hava, kara, deniz ve hatta demiryoluyla sağlık, endüstri, araştırma vs. amaçlar doğrultusunda sürekli olarak taşınmaktadır. Bu taşımalara konu olan radyoaktif maddelerin miktarı, küçük miktardaki nihai tüketici ürünlerinden, büyük miktarlardaki ışınlanmış nükleer yakıt taşımalarına kadar değişkenlik göstermektedir. Bu çalışmada, radyoaktif madde taşımacılığının kurallar, sağlık, güvenlik, çevre ve lojistik kalitesi açılarından nasıl yapılması gerektiğini keşfetmeyi amaçlıyoruz. Bunu yaparken, Türkiye'yi örnek olarak alarak; kuralların gerçek hayatta nasıl uygulandığını, radyoaktif kargo taşımacılığına dahil olan aktörler arasındaki sorunları, geçmişte radyoaktif kargo taşımacılığında yaşanan olayları, güvenli, yasalara uygun hareket edilen bir çevre için alınması gereken önlemleri anlatmaya çalışacağız. Ilk olarak tehlikeli maddelerin neler olduğunu açıklayıp, sonrasında açımızı daraltarak radyoaktif maddeler üzerinde yoğunlaşacağız.

Anahtar Kelimeler: Radyasyondan korunma, sağlık ve güvenlik konuları, tehlikeli maddeler, radyoaktif yükleme, yönetmelik

To my grandmother…

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ABBREVIATIONS

ALARA : As Low As Reasonably Achivable

DGSA: Dangerous Goods Safety Advisor

EPA: Environment Protection Agency

IAEA: International Atomic Energy Agency

LSQ : Logistics Service Quality

RESA: Radiation Early Warning System

RA: Radioactive

RIS : Radiation Monitoring System

SERVQUAL: Service quality

TAEA: Turkish Atomic Energy Agency

CHAPTER I

INTRODUCTION

Advances in medicine and technology have increased the use of radiation. At the same time the ratio of radiation exposure has increased dramatically. Radiation is an energy that can be found in nature or produced by machines. We can categorize radiation as ionizing and non-ionizing radiation. Ionizing radiation comes from the elements, cosmic particles from outer space and x-ray machines which generates risk to living things by damaging tissue and DNA in genes due to its high level of energy (Environment Protection Agency [EPA], 2015). Non-ionizing radiation sources do not have proven danger to health and seem more innocent than iozing sources with their low energy. Non-ionizing radiation is being spreaded from the appliances we use in our daily lives such as microwaves, cell phones, radios, remote controls etc. So, we are all exposed to low-level of radiation at all time.

Today, ionizing radiation sources have wide range of uses such as agriculture, industry, medical, security, research, education etc. In acordance with these purposes, there is always radioactive cargo movement in all around the world. So, we can say that, this thesis will be based on movement of ionizing radiation sources

Increased usage and importance of nuclear energy and radioacive materials, have forced scientists to investigate solution for radiation protection. Two big radiation accidents in the history (Fukushima and Chernobyl) caused fear and radiation opposition in public. In 2013 a Turkish inventor Faruk Durukan, obtained sodium pentaborate from purified boron and then he mixed sodium pentaborate and cement. As a result, he invented a more robust and unbreakable type of concrete. But the most important feature of this new concrete is, it is radiation-proof. He received The Best Invention Of The Year Award from Middle East Technical University in 2014 (ODTÜ'den Yılın Buluşu Ödülünü Aldı, 2014). If this invention is supported and developed, in future it can be used in building nuclear power plants, military warehouses, tunnels, bridges, dams, radioactive storage areas, x-ray rooms in the hospitals and maybe in shielding containers containing radioactive material. His invention already attracted attention in the world. Recently, Dr. Anatoly Tkachuk who was the head of research and rescue team of Chernobyl disaster, visited Faruk Durukan. Also some chemists, biologists and technicians from Germany visited him to have detailed information about his invention (Türk Bilim İnsanına İlk Ziyaret Alman Parlamenterlerden, 2015).

In 2014, Işıklar Military Air School students also worked on sodium pentaborate and invented a protective clothing which prevents radiation with ratio of %75 and they received Young Researchers of the Year Award from The Scientific and Technological Research Council of Turkey (TÜBİTAK) (Askeri Öğrencilerden Radyasyondan Koruyan Kumaş, 2015). This fabric/clothing is much more lighter than ordinary lead sheilds and can be used in hospitals, nuclear power plants, radiation experiments conducted in the laboratories and military areas against radiation exposure. The students also investigated the cosmic radiation level that pilots receives from the outer space and realized cancer is the most common reason of pilots' death. Because of that reason, they produced the glass on the top of the cockpit using sodium pentaborate and found out that, it reduces the radiation level with the ratio of %49 that pilots are exposed.

Most of the inventions have been done for medical usage to protect patients and the medical personnel from radiation exposure and inventions have also been done for nuclear power plants and shielding of the packagings to prevent radioactive leakage.

In this study, we aim to find desired flow of radioactive materials to ensure compliance with the regulations, to secure public and environment safety, and to raise awareness of radiation exposure. With the help of inventions and developments in science, and the strict application of regulations will enable us to secure safe production, transportation and storage of radioactive materials in near future.

Our approach employed in this thesis is a methodological triangulation consist of combining 3 methods in order to increase validity and reliability of our results. The first method, secondary data collection has the biggest part in our study. Global customer care system reports of world's leading freight forwarder company have been reviewed. These records showed us the problems they faced during radioactive cargo transportation and the actions they took to identify root causes and preventive actions. Regulations of international regulatory authorities and academic studies in this area have also been checked in terms of secondary data collection. Second method we used is structured interview which was done with a licensed radioactive cargo transporter in Turkey and we followed a paper based and note taking method during the interview. Third method is critical instance case study based on data gathered from IAEA and TAEA reports, newspapers and internet regarding to big radioactive accidents in the history.

With the help of these methods mentioned above, we tried to find an answer to our research questions listed below:

- Why do we need to regulate safety?
- What are the fundamentals of safe radioactive cargo transportation?
- What are the current problems among involved actors in radioactive cargo transportation?
- What are the barriers to reach desired flow?
- How does it look like with improved legal environment and reduced problems?

We first explain dangerous goods, its classes, then continiue with radioactive materials which is one of the classes of dangerous goods and will deep dive into this topic in following chapters. In doing so, we will also refer to hot topics in this area such as radiation protection, radioactive wastes, public awareness, risk assesstments.

1.1 Dangerous Goods

Dangerous goods are substances, mixtures or articles that present an immediate hazard to people, property or environment because of their physical, chemical or toxicity properties (Hazardous Substances and Dangerous Goods, 2016). Dangerous goods may be corrosive, flammable, combustible, explosive, oxidising, water-reactive or have other hazardous properties. There is always risk in logistics of dangerous goods starting from production to packaging and to delivery.

Incidents involving hazmat cargo can lead to severe consequences characterized by fatalities, injuries, evacuation, property damage, environmental degradation, and traffic disruption (Erkut, Tijandra, Verter, 2007). In order to minimize risk, the design of logistics process such as choosing storage areas, or transportation routes should be handled by trained people under the guidance of regulations.

Business producing, handling, transporting dangerous goods have to appoint a Dangerous Goods Safety Advisor (DGSA) in order to secure safely handling of dangerous goods, comply with international agreements and related legislation for human and environment security and safety. According to an official notification (Resmi Gazete, 2014) from Turkish Ministry of Transport, Maritime Affairs and Communications, it has become an obligation for all mentioned business in Turkey as of 22 MAY 2014. The Turkish armed forces and police are excluded in this notification.

Requirement of being DGSA are; not receiving a prison sentence in the past, having fire extinguisher training certificate, graduating from university, attending to DGSA training course and to become succsessful on the final exam. The certificate of DGSA should be renewed in every 5 years. UK Department of Transport states the responsibilities of DGSA as below (Moving Dangerous Goods, 2012):

-Monitoring compliance with rules governing transport of dangerous goods

-Advising its business on the transport of dangerous goods

-Preparing an annual report to management on the business' activities in the transport of dangerous goods

-Monitoring procedures and safety measures

-Investigating and compiling reports on any accidents or emergencies

-Advising on the potential security aspects of transport

The necessity of working with DGSA in dangerous goods logistics is a good example for Zheng & Zhang's (2011) study, whom added 3 new management goals to logistics management in addition to common goals such as reducing logistics cost, improving efficiency and customer satisfaction, optimization of logistics process etc. These 3 new management goals are implemented to dangerous goods logistics and can be explained as follows:

Security Management: The main goal of dangerous goods management should be the safe transportation of the goods. Otherwise the lives of the involved parties such as employees in manufacturer, handling agent, the driver of the truck, the passengers in the aircraft will be endangered. For example, the cargoes containing dangerous goods need specially designed packaging for safety and they are carefully labelled and marked indicating the type and degree of their hazard to attrack people's attention.

Sensivity Management: Dangerous goods logistics requires awareness and preparedness to incidents. Because of that reason, emergency response plan should be prepared and all employees should be trained to implement it when needed. Also, close tracking of material flow, accurate flow of information is needed all time. By this way, the cargoes can be transported under full control of transporter.

Specialization Management: All logistics activities of dangerous goods are designed to reduce and prevent hazard of their danger. The differences between logistics activities of dangerous goods and general goods can be seen easily in packaging, handling, warehousing, routing, documentation processes.

For instance, an ordinary wire can be shipped in a carton box or as reeled but a radioactive source wire should be packed, shielded, labelled and marked to draw attention to its danger as shown below:

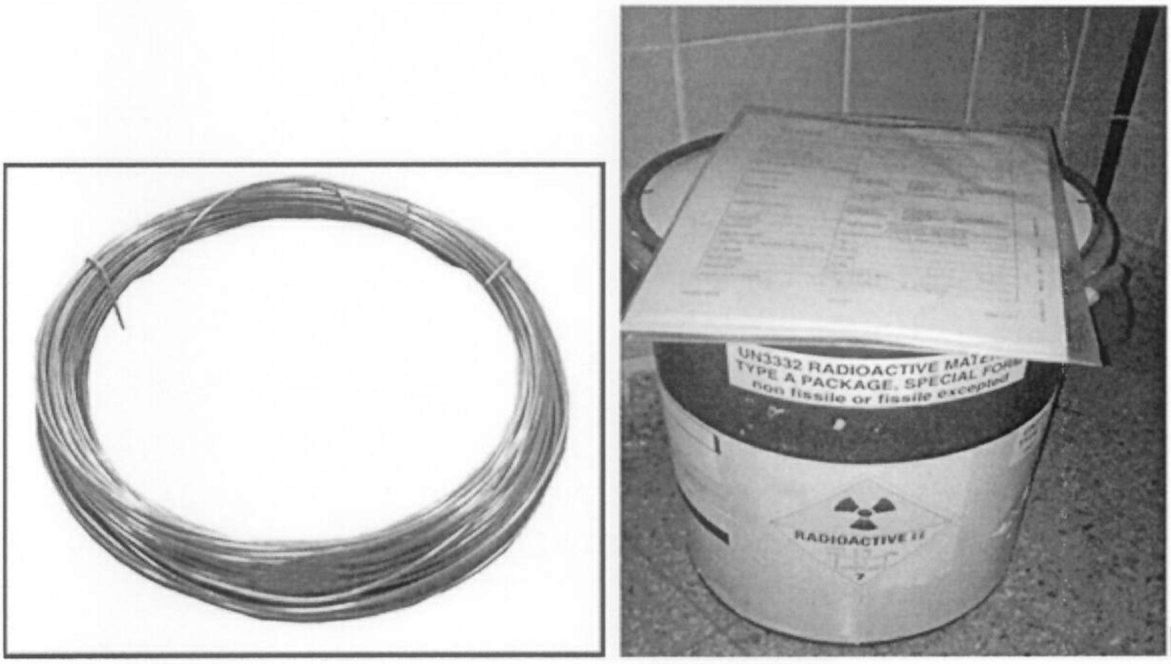

Figure 1: Difference between general cargo and radioactive cargo (photos are respectively taken from google grafics and taken by me).

1.2 Classes of Dangerous Goods

Dangerous goods are divided into 9 groups according to their danger:

Class 1: Explosive substances and articles

Class 2: Gases

Class 3: Flammable liquids

Class 4.1: Flammable solids, self reactive substances and solid desensitized explosives

Class 4.2: Substances liable to spontaneous combustion

Class 4.3: Substances which in contact with water, emit flammable gases

Class 5.1: Oxidizing substances

Class 5.2: Organic peroxides

Class 6.1: Toxic substances

Class 6.2: Infectios substances

Class 7 :Radioactive material

Class 8: Corrosive substances

Class 9: Miscellaneous dangerous substances and articles

The labelling of dangerous goods are established differently from each other according to their class in order to draw attention and guide people at first sight. Below table shows us the labels of dangerous goods and the difference between colours and symbols of each class.

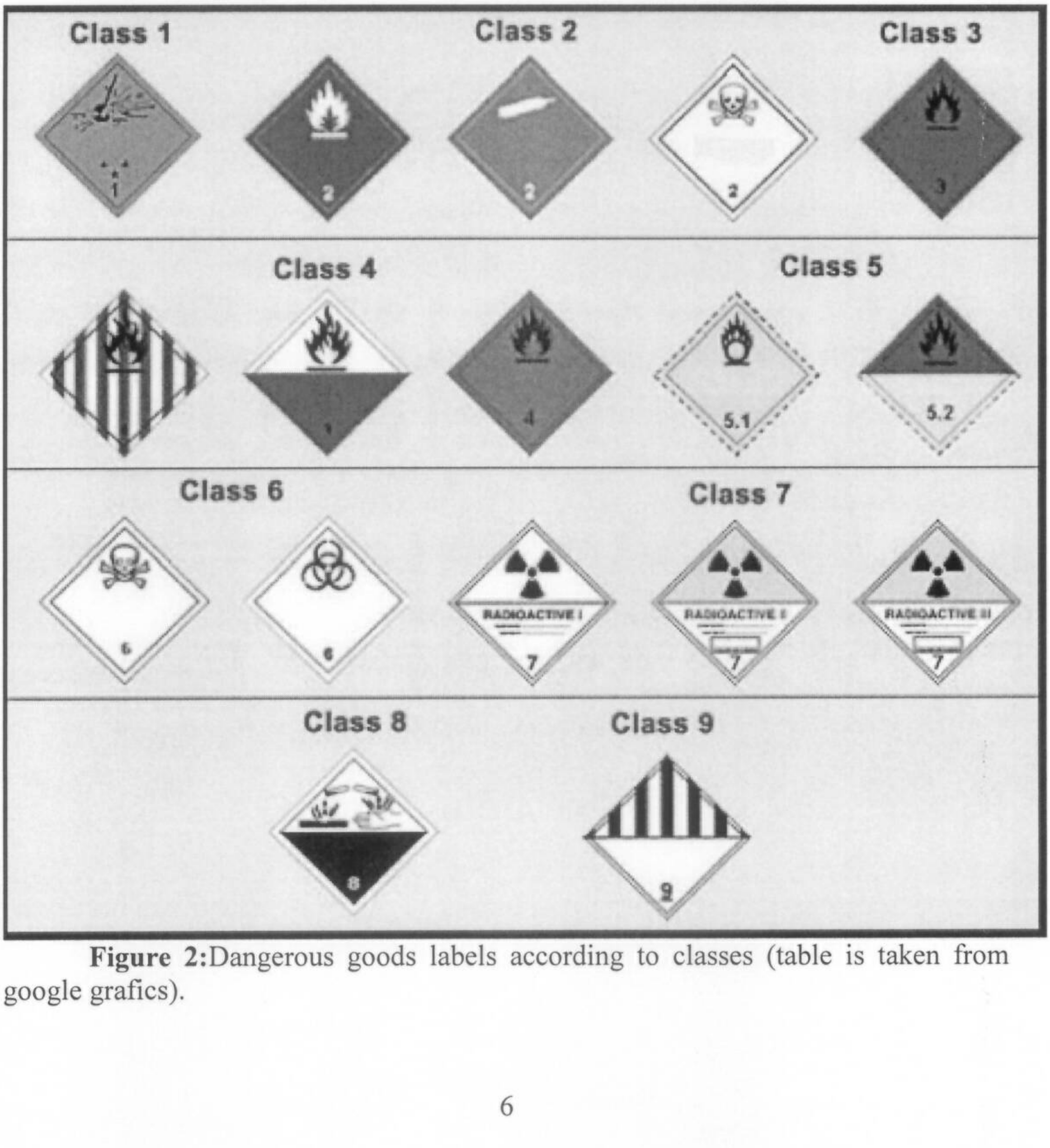

Figure 2: Dangerous goods labels according to classes (table is taken from google grafics).

Each dangerous good in different classes has been assigned to a UN number. Also, Substances other than classes 1, 2, 5.2 , 6.2, 7 and other than self reactive substances of class 4.1 are assigned to packing groups. Whilst the class defines the type of danger which a substance presents, packing group (PG) defines how dangerous it is. There are three packing groups; PG I is the most dangerous, PG II represents a moderate danger and PG III is the least dangerous (What are dangerous goods, 2016).

1.3 Radioactive Materials

Figure 3: Trefoil symbol representing radioactive substances (picture is taken from google grafics).

Radioactives include the most insidious hazard among all other classes. They spontaneously and continuously emit ionizing radiation, that can be harmful to the health and environment. The radiation cannot be detected by any of the human senses (sight, smell, hearing, touch, or taste). Because of that reason, some devices named Geiger Müler counter, radiacmeter are used to detect and measure radioactivity. Also, people who work close to radioactive materials like drivers of vehicles carrying radioactive cargo, people in production facilities, hospitals have to carry dosimetry with them at all time. The amount of radiation exposure is followed and reported to the relevant institutions in regular basis.

Figure 4 : Dosimetry (photo is taken by me).

CHAPTER II

LITERATURE REVIEW

In this chapter, we would like to present a review of the literature related to two main topics of our study that we introduced earlier: logistics and radioactive materials. Since the radioactives are part of the dangerous goods, we will review literature accordingly and reveal the studies carried out under dangerous goods topic as well.

During the research phase of this study, it is seen that, there are wide variety of studies conducted in the field of logistics from articles to books including reverse logistics, green logistics, humanitarian logistics, third party logistics, logistics service performance and network design. While some of the researchers adopted case study method, some of them designed models in order to obtain qualitative and quantitative observations.

We reviewed the literature for dangerous goods and recognized that, most of the studies are focused on risk assesment in dangerous goods logistics. Researchers evaluated the risk by comparative studies, worst-case scenarios and probabilistic approaches. In risk assesments, resident population, visitor population and ecologically sensitive areas are commonly considered. However, meteorological conditions and local demographics should be considered as well.

When we narrow down our perspective from dangerous goods to radioactive materials, we see that, many researchers from various disciplines such as environmental engineering, chemistry, physics, radiology, military, logistics worked on radioactive materials. In these studies, researchers investigated radiation protection, radioactive wastes, naturally occuring radioactive materials in environment, usage of radioactives in treatments, doses of radioactivity in a treatment etc. Radiological accidents in history has also been interesting for researhers and they investigated the root causes, impacts of the accidents on environment and society, health and safety, public awareness perspectives and also investigated the preventive actions to be taken for future. On the other hand, hazardous materials and radioactive materials have been less attactive for social science researchers, and the existing studies are mainly focused on regulations and international agreements.

Logistics of radioactive materials has been a niche area for researhers. They evaluated the risks of this special area, even developed a computer coding program named RADTRAN which is capable to predict the radiological impacts associated with specific radioactive material shipment schemes and mode specific transport variables (Madsen, Taylor, Ostmeyer, Reardon, 1986). These variables can be duration of truck stops, distance from truck, number of persons exposed to truck etc. Radiation exposure should be taken into account in route selection since many people are exposed to radiation during transit. An interesting study carried out by Friedberg, Copeland, Duke, Nicholas, Darden and O'Brien (2001) claims that, crew members on commercial aircraft are exposed to higher doses of ionizing radiation than normally received by members of the general population in most parts of the world because of galactic cosmic radiation from sun and radioactive cargoes and they are also exposed to the nonionizing radiation generated by the aircraft's electronic systems.

Waste management of radioactives is one of the big concerns of today's world and consists of safe transportation and storage of radioactive wastes. Because of that reason, many researhers worked on solution oriented studies. According to Ewing, Weber and Clinard (1995), the main sources of nuclear waste are: (i) spent nuclear fuel from nuclear reactors used for commercial and research purposes (ii) liquid waste produced during the reprocessing of commercial spent nuclear fuel; (iii) waste generated by the nuclear weapons and naval propulsion programs. We also add medical wastes containing radioactivity as they are one of the low level radioactive wastes. So, due to usage of radioactive materials in different areas, various disciplines worked on waste management as well.

We would like to start detailed view of literature with mentioning about logistics. In 1986, The Council of Logistics Management defined logistics as 'process of planning, implementing and controlling procedures for the efficient and effective transportation and storage of goods including services and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements and includes inbound, outbound, internal and external movements' (Logistics, 2016).

The main objective of logistics can be explained with so-called 'Seven R's' principle which states the objective as making available the right amount of right product at the right place at the right time in the right condition at the right price with the right information.

Stock and Lambert (1993) specified key logistics activities as follows:

- Customer service
- Demand forecasting planing
- Inventory management
- Logistics communications
- Material handling
- Order processing
- Packaging
- Parts and service support
- Plant and warehouse site selection
- Procurement
- Reverse logistics
- Traffic and transportation
- Warehousing and storage

We analyzed some of the logistics activities in Logistics Service Quality frame such as customer service, logistics communications, material handling, order processing, packaging, reverse logistics, traffic and transportation, warehousing and storage which are the main basis of this thesis.

Logistics Service Quality (LSQ) was developed by Mentzer, Flint, and Kent (1999) to deliver a quality service and generate greater satisfaction with the delivered service. Saura, Frances, Contri and Blasco (2008) analyzed the quality, satisfaction, and loyalty sequence in the logistics service delivery contex considering the role of information and communication technologies and then explored how intense the relation between these features.

In chapter IV we created a logistics flow chart based on operational processes of the freight forwarding company we are in touch with; and differently from existing studies, we implemented mentioned LSQ dimensions to our chart in order to explain how to reach desired flow of radioactive materials with the help of logistics service quality dimensions.

Early in 1900's, logistics was defined from military perspective like conduct of military action, preparations of war and maintenance during war. In today's world as stated by Klaus (2010), logistics is being addressed primarily in the 'civilian' context of improving business operations and the effectiveness of the economy.

Poist (1989), categorized logistics discipline into three eras: pre-logistics, logistics and neologistics. In pre-logistics era (1960's), companies focused on efficient logistics systems. In logistics era (1970's and early 1980's), companies designed logistics systems rather than simple transport systems considering total costs, total profit. In neologistics era (1990's), companies fitted their logistics systems into overall corporate mission and objectives starting from production to marketing and post delivery activities. He also divides neologistics era into two and calls today's logistics environment as second neologistics phase in which companies consider social implications of logistics decisions as well as corporate implications.

Today, logistics service providers in a tough competition to make difference in their logistics activities and become the most preferable in the market. In accordance with this purpose, they aim to widen their network, to provide the highest standards of service quality, to create product variety. In doing so, as a requirement of todays's world, they need to be responsive to the environment; using recyclable packaging, reducing CO2 emmision with combined transports, taking safety measures to protect health & environment in case of any dangerous goods accidents.

Morino, Ohara, Nishizawa (2011) investigated atmospheric behaviours of the radioactive materials after Fukushima disaster which caused atmospheric deposition of radioactive materials through evaporation from contaminated soil and inland water to atmosphere. According to their study, %35 of the radioactive materials in atmosphere deposited over land in Japan, the rest was deposited in the ocean or transported out of Japan. This result shows us how sprawling effect radiation has. An accident outside of our city or county can easily effect our food, environment and health. Also, a disaster outside of our borders can significantly affect trade and the global supply chain. For instance, after Fukushima disaster, some countries placed restrictions on imports from Japan due to fears of radiation contamination. Customers outside of the Japan requested certificates that states the goods are free of radiation contamination. Additionally, Canis (2011) states that, shortage of electricity, closed highways connecting to manufaturers and non-operational ports effected from disaster caused distruption in global supply chain.

In discussing the literature for logistics and radioactive materials, we implemented radioactive materials into the field of logistics activities. We would like to explain interaction of logistics and radioactive materials with simply dividing logistics activities into 3 stages as; production, transportation and delivery.

Manufacturer has key role to secure safety logistics of radioactive materials with their packaging, labelling, marking and documentation responsibilities. In MTS-type (make to stock) logistics systems, for example, supplier forecasts the demand and produces according to demand recorded in past or market information etc. (Ghiani, Laporte, Musmanno, 2013) This type of logistics systems requires storage till an unpredictable date or for a long term; because of that reason, it is not suitable for production of radioactive materials since radioactivity decays day by day. In MTO-type (make to order) logistics systems, for example, customers order from supplier or the distributer and then supplier produces the requested amount according to demand. So, we can say that, MTO system is suitable for radioactive materials since they are being stored temporarily for a short-term. All players should act according to 'make to order' rule.

The second stage, transportation, is designed in compliance with requirements of produced radioactive material. Safe handling and short transit time are the main focus areas of transportation. Additionally, security of the cargo has vital importance in today's world since terrorist actions are rapidly growing. We can see some route selection studies in literature conducted in order to generate alternative routings for terrorist attacks. Rosoff and Winterfeldt (2007) analyzed possible terrorist attacks on the bustling ports of Los Angeles and Long Beach using a radiological dispersal device ("dirty bomb") and they explained that, these terrorist attacks may aim to shut down port operations and cause substantial economic and psychological impacts as well as mass destructions.

Sometimes dangerous goods are not declared for transport although it is required by the regulations and this is a safety hazard for all involved in the transport operations (Ellis, 2010). This may be caused by the shippers who do not have knowledge of dangerous goods regulations so they are not able to identify and classify dangerous properties contained in the cargo, however as per their point of view it may be a non dangerous good. Samsolo and Vidal (2008) worked on a case study explaining the need of regulatory controls in Argentina for import and export shipments. Their study is based on an import shipment, which's total amount of radioactivity was not declared adequately by the consignor. They suggest to establish a procedure that makes it possible to verify external radioactive measurement of the activity consigned in shipments when importing and exporting. This would be helpful to perform the regulatory control of the incoming and outgoing radioactive material to and from any country. The function to identify undeclared dangerous goods should be performed by carrier's acceptance staff. X-ray machines and sniffer dogs can be used as well. Although it is not possible to detect radioactive materials by pshyical check, it is an easy method to identify it with radiation detection instruments.

The last stage of our simple logistics model is delivery. When we assume logistics process is carried out according to regulations, the most important point on last stage is, to deliver the radioactive cargo to the authorized person, on requested time, at appropriate place. Otherwise it may generate a safety concern including all hazards and risky situations we explained.

As the literature review suggests, there are not many studies looking at desired flow of radioactive material transportation including all actors of the process. This has been the main motivation of our study. Additionally, there are few studies in radioactive material movement in Turkey, and they are mainly related to waste management, applications in medical treatments, environmental effects of Chernobyl in Blacksea region.

Our aim is to look from broader perspective taking into consideration the disasters in the past, developments in regulations, current problems of involved parties, the barriers to reach desired flow. At the end of this study we designed a desired flow of radioactive materials in lights of logistics service quality, regulations and health & safety protection measures.

CHAPTER III

USAGE OF RADIOACTIVE SOURCES

Although its inherent hazard to human health and environment; commercial, industrial and medical benefits of radioactive materials are significant and resultant positive impacts on society (Sorenson, 2015).

3.1 Medical Use

Nuclear medicine and radiology are the medical techniques that involve radiation or radioactivity to diagnose, treat and prevent disease Radiography is making an image on film using a radiation source (from x-ray or gamma radiation). In nuclear medicine radioisotopes are introduced into the body internally (Nuclear Medicine Applications,2014).

Nuclides are used by a physician or healthcare professional to identify cancer metastases, detect heart damage or dysfunction, and to identify tumors. They are safe and painless and don't require anesthesia and have wide range of usage from pediatrics to cardiology to psychiatry. Nuclides are also used for cancer treatment. For instance, Iodine-131 is used to treat thyroid cancer and hyperthyroidism. Strontium-89 is used to treat bone pain in advanced cancer patients. Palladium-103 and Iodine-125 implants are used to treat prostate cancer. Removable Iridium-192 and Cesium-137 implants are used to treat other types of cancers such as breast (Uses of Radioactive Materials, 2016).

Radionuclides represent a small but definite potential risk to health through exposure to ionising radiation. Medical personnel usually wear protective aprons, thyroid lead collar, and leaded glasses to prevent radiation exposure. But there is also possibility to be exposed to scattered radiation coming from the patients. Some operators may be exposed to radiation level higher than permitted per year. So, health care providers need to be extremely careful not to expose themselves and the patients to unwanted radiation and work within ALARA principle. US Center for Nuclear Science and Information states that, employment of nuclear medicine technologists is projected to grow 20 percent from 2012 to 2022, faster than the average for all occupations (Nuclear Medicine Applications,2014).

As of end of 2014, 20188 radioactive sources were used in medical area for diagnostics, treatments, disease management and dentistry in Turkey. Below Figure 5 and Figure 6 (TAEK, 2015) give us an idea about distribution and usage of radioactive sources used for medical purposes in Turkey. Istanbul has the highest number of radiotherapy devices in Turkey. Then other big cities of Turkey; Ankara, Izmir and Adana come. We see that there is no radiotheraphy device almost in half of the country. However, Figure 6 shows that, usage of radiology devices in dentistry is so common and its application is available in all cities.

Figure 5: Distribution of Radiotheraphy Devices Acording to Provinces (TAEK, 2014)

Figure 6: Distribution of Radiology Devices in Dentistry According to Provinces (TAEK, 2014)

3.2 Industrial Use

In industry, common uses include non-destructive testing, radiation sterilization of health care products, modification of polymeric materials, on-line process control systems, elemental analysis of raw materials, mineral resource evaluation, food irradiation and oil and gas exploration (IAEA, 2016). Radiography also is used to determine the structural integrity of boilers, bridges, digesters and other industrial processing equipment to ensure worker safety and process control (Uses of Radioactive Materials, 2016).

In Turkey, as of the end of 2014, 4295 radioactive sources were used in industrial area for industrial radiography, nuclear gauges, density and moisture gauges purposes (TAEK, 2014). Also there are 4 irradiation facilities built in Turkey for irradiation of food, medical devices, feed and other goods that need sterilization before usage. In Figure 7 we see that, number of industrial radiography / radioscopy devices in Turkey is higher in the cities such as Istanbul, Manisa, Izmir, Ankara, Kocaeli where industry is developed.

Figure 7: Distribution of Industrial Radiography/Radioscopy Devices According to Provinces (TAEK, 2014)

3.3 Others

Other usage areas of radioactive materials are; agricultural applications, art and science, commercial applications, enhance productivity in energy, space, security etc.

For example, in agricultural applications it is used to kill bacteria, molds, and parasites in our food, to increase productivity, to treat animal diseases and in develop irrigation practises. In art and sciense it is used to understand our past with carbon-14 dating, to enhance natural conditions of gemstones to a desirible color, to restore and preserve artifacts by killing microorganisms in the air, with the help of x-ray fluorescence technique we can identify forgery, the origin and age of the artwork. Also it is used in genetic engineering research, heart pacemakers, smoke detectors, criminal investigation, coating non-stick frying pan, luggage and security screening to make our lives easier and more productive.

Since it is a very impressive example, we would like exemplify the runway lights in Alaska which are made with tritium gas, a waste product of nuclear power plants. These lights burn for up to 10 years without wires or an external power source, and could cost only 1/5 to 1/2 the price of using regular lights (Uses of Radioactive Materials, 2016).

In Turkey, most common usage of radioactive materials are in security applications. In airports, customs, seaports, shopping malls radiation sources are used for imaging the inside of luggage and packages. The map in Figure 8 explains the distribution of package control devices in Turkey.

Figure 8 : Distribution of Package Control Devices According to Provinces (TAEK,2014)

CHAPTER IV

FUNDAMENTALS OF RADIOACTIVE CARGO TRANSPORTATION

In Turkey, sea freight and road freight are the most used transport modes in international transportation. Below table (Table 1) shows us ratio of transport modes used in international trade in 2013 and we can see that sea freight is the leader, road freight is the second, air freight is the third, pipeline (others) is the forth and the rail freight the fifth preferred mode.

	Sea Freight	Road Freight	Air Freight	Rail Freight	Others
Export	%54.64	%35.37	%8.52	%0.63	%0.84
Import	%55.6	%15.92	%12.95	%0.7	%14.82

Table 1: Ratio of transport modes used international trade in in 2013 (billion dollars) (Türkiye'nin lojistik görünümü, 2013)

Although it is the third on above table, airfreight is the most suitable mode for carriage of radioactive materials due its advantages. The advantages of airfreight are; being the fastest mode, suitable for transportation of small and medium size quantities, extensive network of airports, high safety and security measures, organized flight schedules, the care in cargo handling and loading process. Also, connections from origin airport to destination airport prevent some bureaucracy problems such as transit permits that cause cargoes to wait for days. When dangerous goods are considered, this time takes longer than usual due to their danger. However, disadvantages of airfreight transportation are; highest transportation costs compared with other modes, being not suitable for carriage of all kinds of products and big size quantities, the need to use road freight to deliver the cargo to consignee (Hava Kargo Taşımacılığı ve Türkiye, 2003).

In inland carriage activities, road freight is the most preferred transport mode in Turkey for carriage of general goods and dangerous goods (TC Dışişleri Bakanlığı, 2004). Also, there are 55 airports in operation and international flights are carried out in 23 of them (Türkiye'deki Havalimanları Listesi, 2016).

Despite government efforts to improve rail transport in recent years, a long time is required to complete the projects, establishing connections between railways and industrial areas, seaports, airports and main railways. Usage of pipeline and inland waters is also so limited in Turkey. Because of that reason, we will keep those out of our scope and try to explain radioactive cargo transportation in Turkey with using most common transport modes which are sea freight, air freight and road freight.

In order to understand how information and material flow, the impacts of regulator, and the critical points for health & safety protection; we drew a logistics process chart shown in Table 2, and will explain steps of radioactive cargo movement accordingly. While drowing the logistics process chart, we needed a support from sector to study real life practices closely. World's one of the biggest freight forwarding company supported us with some non internal company records, those include some examples of their radioactive cargo shipments, shipping documents, pictures of radioactive cargoes they handle and information from their operational processes.

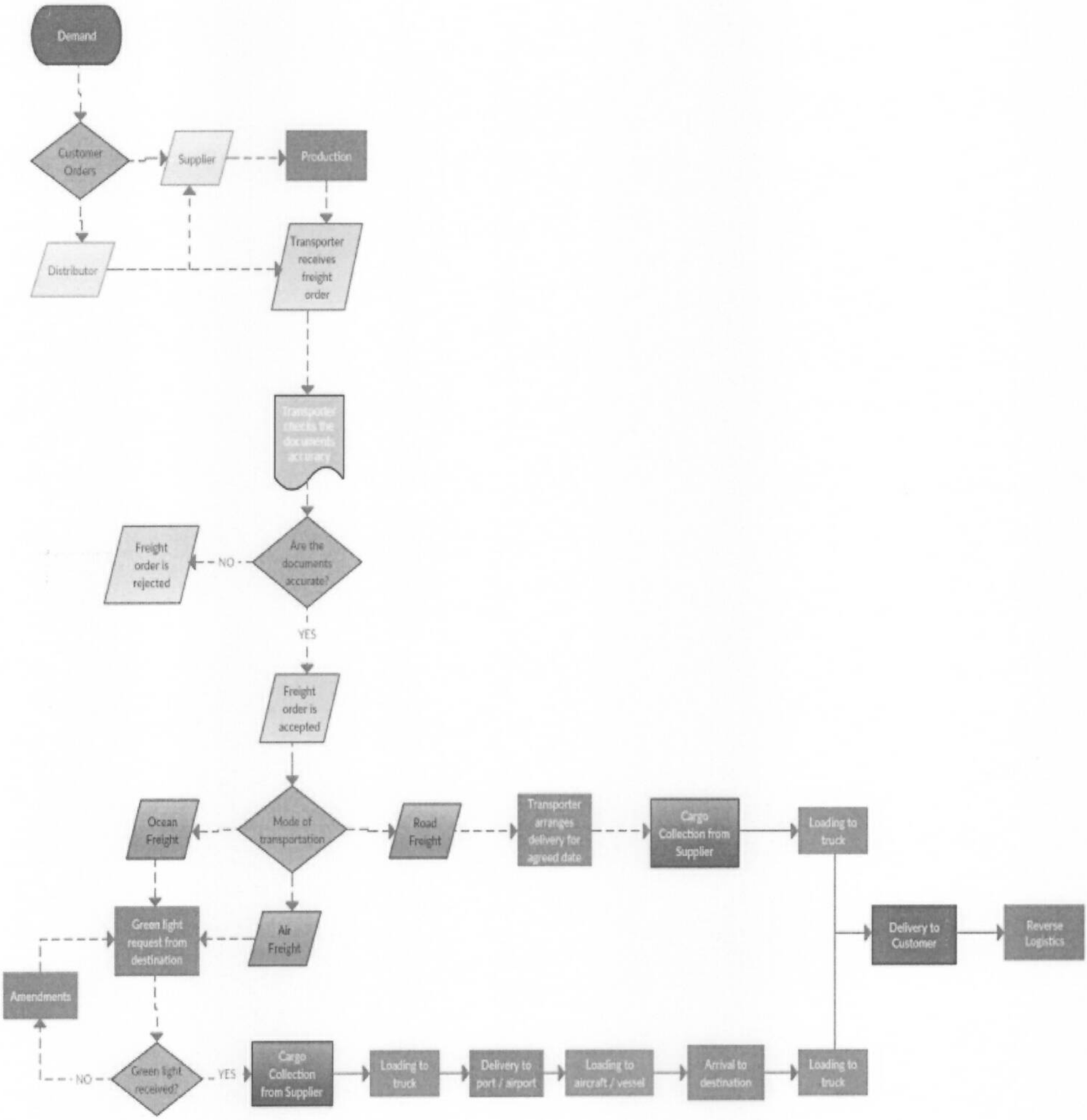

Table 2: Representation of logistics process of a radioactive cargo (the table is drawn by me)

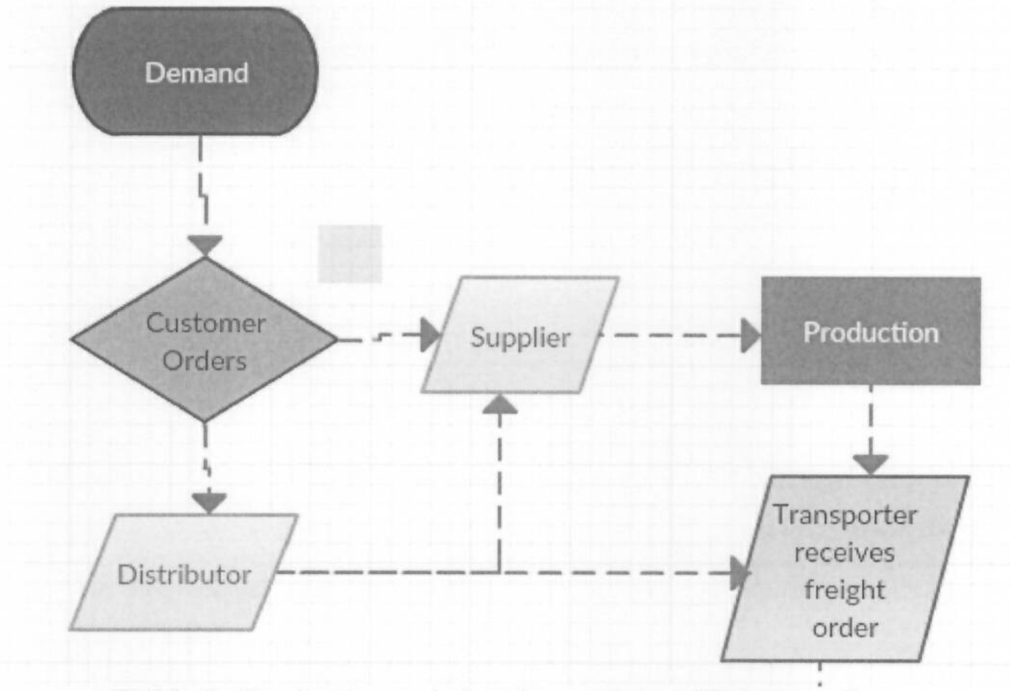

Table 3 : Production and planning process of RA cargo flow

Production and Planning : Table 3 shows the begining of logistics process which is production and planning. Manufacturer produces radioactive source upon receiving the order from final customer. The customer can directly impart the demand to supplier or impart the demand to supplier via distributer. Once the supplier is informed about the demand, they plan the production, produce the source and inform transporter for collection of the cargo.

Critical Points: The customer (consignee) should have their import license and permissions from local authorities before ordering. At the same time, supplier or the distributor should have their export licenses. Lack of permissions and licenses may cause radioactive source to wait at customs for a long time which means radiation exposure for people and radioactive decay due to waiting.

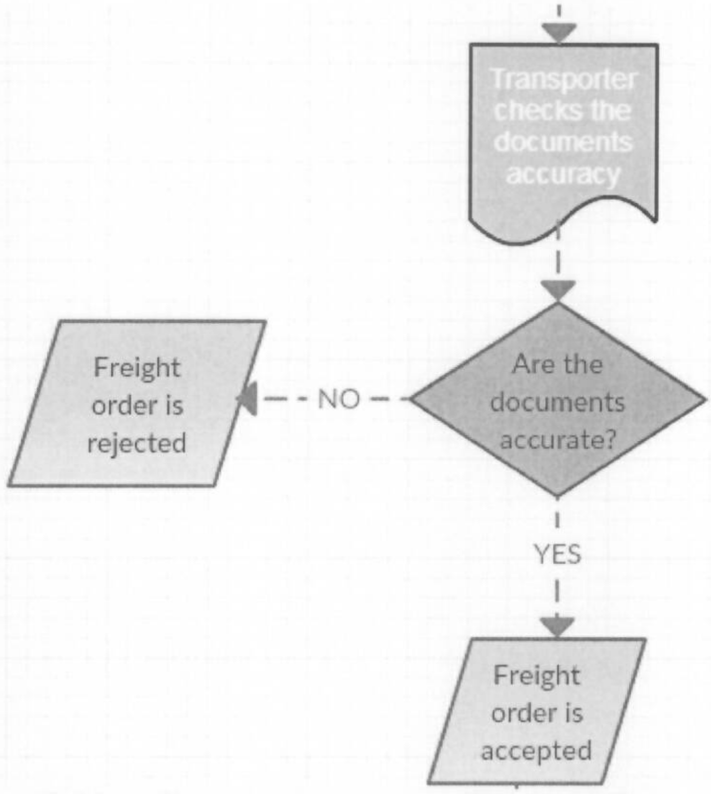

Table 4: Freight order process of RA cargo flow

Freight Order : Table 4 explains how manufacturer hands over the RA material to transporter. Transportation company receives freight order from supplier / distributor upon production. First of all they need to check the documents of the cargo and then confirm to collect the source from the agreed place (from manufacturing facility or specially designed radioactive storage area).

Critical Point : The documents accuracy has high level of importance in this stage. Any undeclared radioactive contented cargo or non accurate information on documents lead transporter into an error in transport planning. They may send a regular truck instead of specially designed van or they may book with passenger flight although the transport index is high for passanger flights and cargo is only acceptable for cargo aircraft.

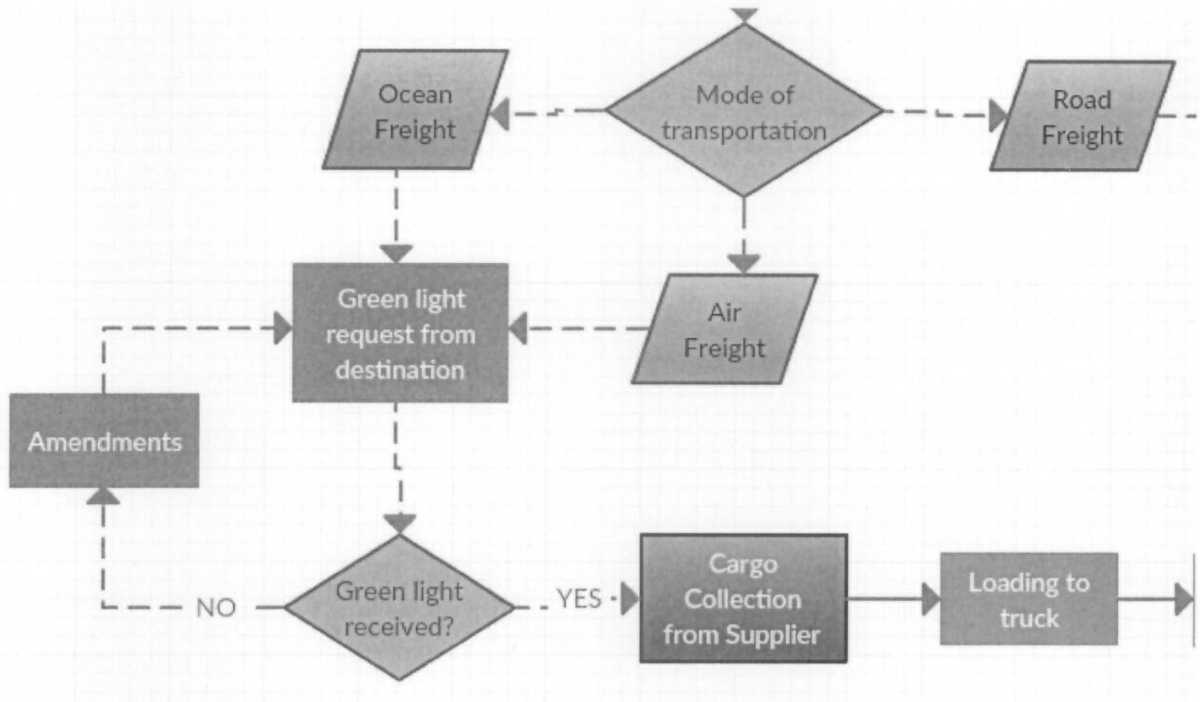

Table 5: Transport planning process of RA cargo flow

Transport Planning: If the documents are properly prepared and cargo is packed, labelled and marked according to regulations, transporter accepts the freight order and directs the trucker to collect the source. At the same time, they decide on the mode of transportation and book for the most appropriate trip in order to meet given lead time. As stated in Figure 5, there is a green light process in air and ocean ways. The airline or the oceanline reviews the shipping documents and asks for green light from their destination office. If there is no embargo to import radioactive cargo in destination country, the destination office of the carrier contacts with the final consignee and asks confirmation for acceptance of the radioactive cargo. If consignee is unreachable or rejects the shipment, or if there is embargo in destination or connection points during the routing, the carrier doesnt accept the shipment or offer an alternative routing. In this case the transportation company who received the freight order has to reroute the shipment.

Critical Point: It is important to carry out instructions of the carrier and to catch cut off time otherwise the cargo would be rejected by airline, oceanline or the road contractor. For instance, the radioactive cargo is being checked prior to loading under name of 'DGR Check' and any incorrect information, damage on documents, labels or package cause cargo to be rejected and also the supplier has to pay some fine due to negative DG check.

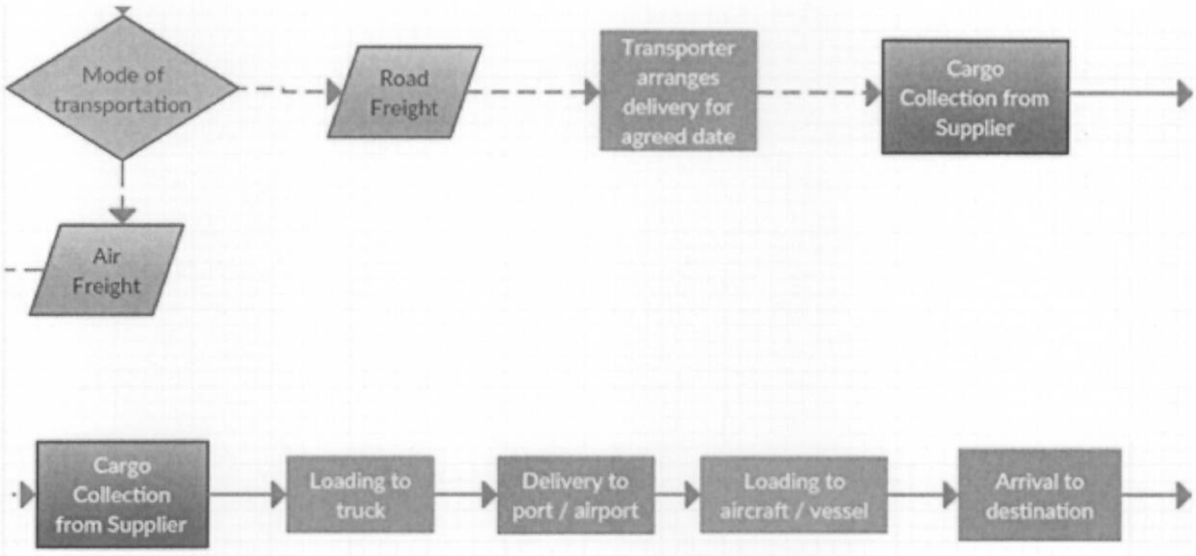

Table 6: Transportation process of RA cargo flow

Transportation : Table 6 shows us the transportation process of RA cargo. Once the mode is decided, the truck which collected the source from supplier delivers it to the airport or to the seaport according to mode of tranportation and the customs officers receives the cargo for export customs clearence. The customs process shows variety according to countries and type of commodities. But we can say that the most significant difference in customs clerance of radioactive commodity is, the required documents. The export license of exporter, the import license of importer, source certificate, packaging certificate are reviewed by customs authorities during customs clereance.

After customs clearence process, the cargo is loaded to aircraft / vessel. Upon arrival to destination, the customs broker of consignee performs import customs clearence and hand over cargo to trucker for delivery.

Critical Point: If any damage is detected during loadig/unloading, local authorities should be informed accodingly. Also, these cargoes should be handled with priority the carrier should prevent ofloadings as much as possible. If possible, customs brokers of shipper and consignee should make prearangements to enable smooth transfer and minimize waiting time at country borders.

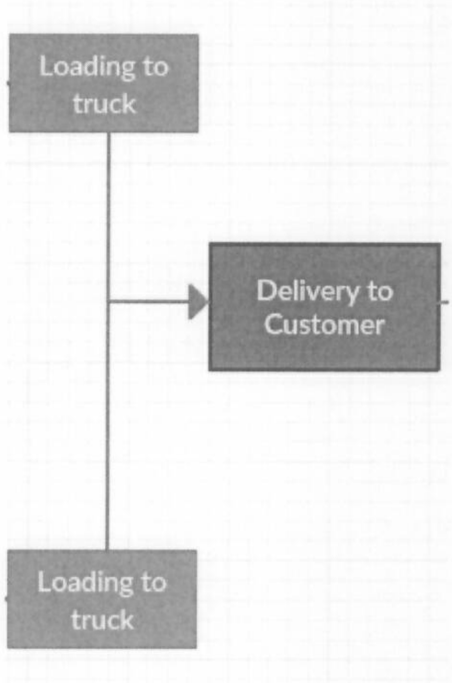

Table 7: Delivery process of RA cargo flow

Delivery : When cargo is released from customs, delivery process starts. The trucking company collects the source from carrier's warehouse / storage area and delivers to the consignee who started the radioaoctive cargo flow with its demand. So, we can see that, whatever the mode is, air or ocean, it is an obligation to use road freight in collection and delivery process of the cargo.

Critical Points: Delivery should be done to the authorized person. Any reason whatsoever, the cargo should not be delivered to reception, gatekeeper, security guard unless they are authorized to receive demanded radioactive cargo. However, during the road transportation, driver should always carry his dosimetry, driving license (SRC5 license) with him at all time.

As mentioned, radioactivity decays day by day and after a while the source wire needs to be changed in order to maintain same level of radioactive power. The depleted sources should return back to manufacturer for disposal or should be delivered to disposal facilities. All commodities that touches the radioactivity has a contamination and should be treated as radioactive waste. There are 3 types of waste : (i) Low level wastes, (i) Medium level wastes, (i) High level wastes.

Low level wastes are commodities that are contaminated due to short term contact with materials containing radioactivity. Boiler suits, injection syringe, transport containers can be example of low level wastes. Medium level wastes are more like industrial wastes which are used with nuclear metarial or wastes released reprocessing. High level of radioactive wastes contain very high radioactivity resulting in fission reactions and have long life radioactive elements. Table 8 gives us information about how much time does radioactive decay take.

Isotope	Half life (Approx)
Stronsiyum-90	29 year
Sezyum-137	30 year
Amerisyum-241	430 year
Amerisyum-243	7 400 year
Plütonyum-239	24 000 year
Teknesyum-99	213 000 year

Table 8 : Half life of some high level wastes isotopes (TAEA, 2010)

Radioactive wastes are buried in the specially designed plant. To increase insulation inside the under ground tank is covered with concrete or similar materials. The spaces between waste packages is also filled with clay or concrete (TAEA,2010).

In Turkey, Çekmece Nuclear Research and Training Center was built for research, development, application and training activities in nuclear field. It also has role in waste management of low level radioactive materials. When it was built in 1962 around Çekmece Lake, it was located in a vacant land which is far away from residental areas. But due to growing population, residental areas gradually spreaded out and now Çekmece Nuclear Resarch and Training Center is surrounded by many buildings. This situation further increases the safety concerns.

Nowadays, due to appropriate characteristics of the continent for deep geological disposal, South Australia is reccomended to be the storage and disposal area of international used nuclear fuel and intermediate-level wastes (Chang, 2015). The country is in the process of evaluating the consequences of being the nuclear dump from economic benefits and public objection perspectives.

CHAPTER V

REGULATORY APPLICATIONS OF RADIOACTIVE CARGO TRANSPORTATION

As the applications of radioisotopes to many sectors are continuously increasing, the amount of transport of radioisotopes has also increased in recent years. According to Sorenson (2015), it is a process that is being played out between the public, industry, regulator and international oversight orginizations. In this chapter, the regulatory bodies and their applications will be explained.

5.1 The Need For Safety Arrangements

We live in a radioactive world. Some radiation sources are man made but most of them can be found in nature such as in rocks or soil. So we can say that, most of the things we eat or drink have kind of radiation. (Safe handling of Radioactive Consignments, 2016) But this should not be the reason of being incoutious. Radiation is fatal and gives irreparable damages to health and environment. Because of that reason radioactive sources should always be under control.

The radiological accident in Turkey perfectly explains how severe the consequences of radiation exposure. This accidents is one of the most important radiological accidents in world.

The company based in Ankara, was licenced by TAEA to import, export and transport radioactive sources. In 1993, they declared that, they will send three used radiotheraphy sources to the manufacturer in USA into individual type B(U) packages. TAEA officials checked the containers and confirmed all preperations were done in accordance with Safe Transport of Radioactive Materials dated 1985 (TAEA, 1998). Although the company got permission from TAEA, they did not send the sources back and stored them in their facility from 1993 to 1998 (IAEA, 2000).

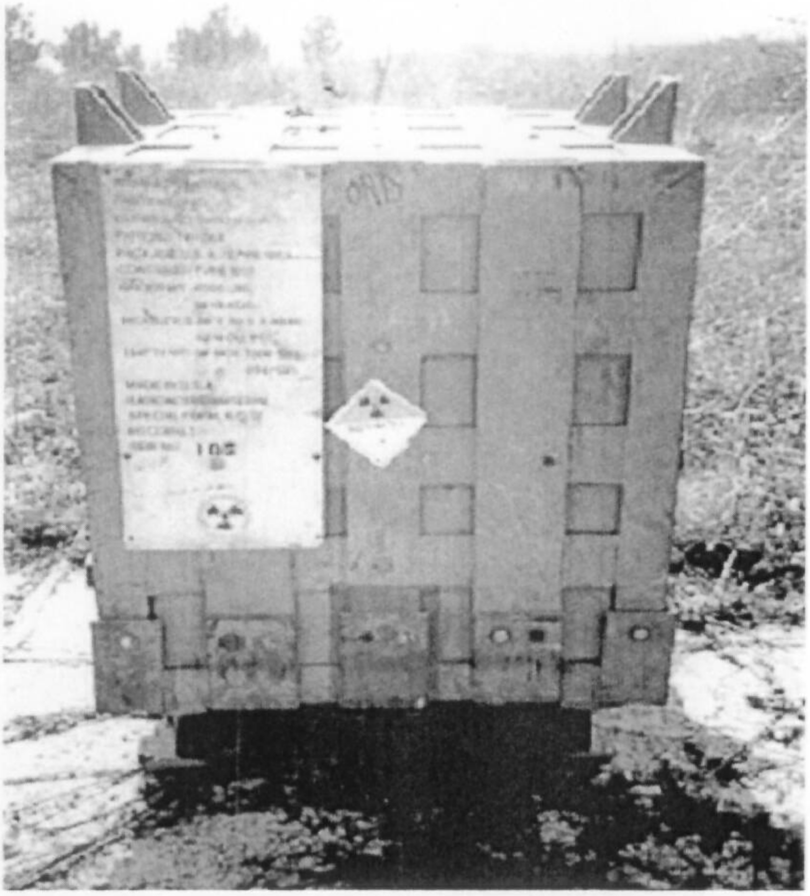

Figure 9: The source subjected to accident in Type B(U) transport package (IAEA, 2000).

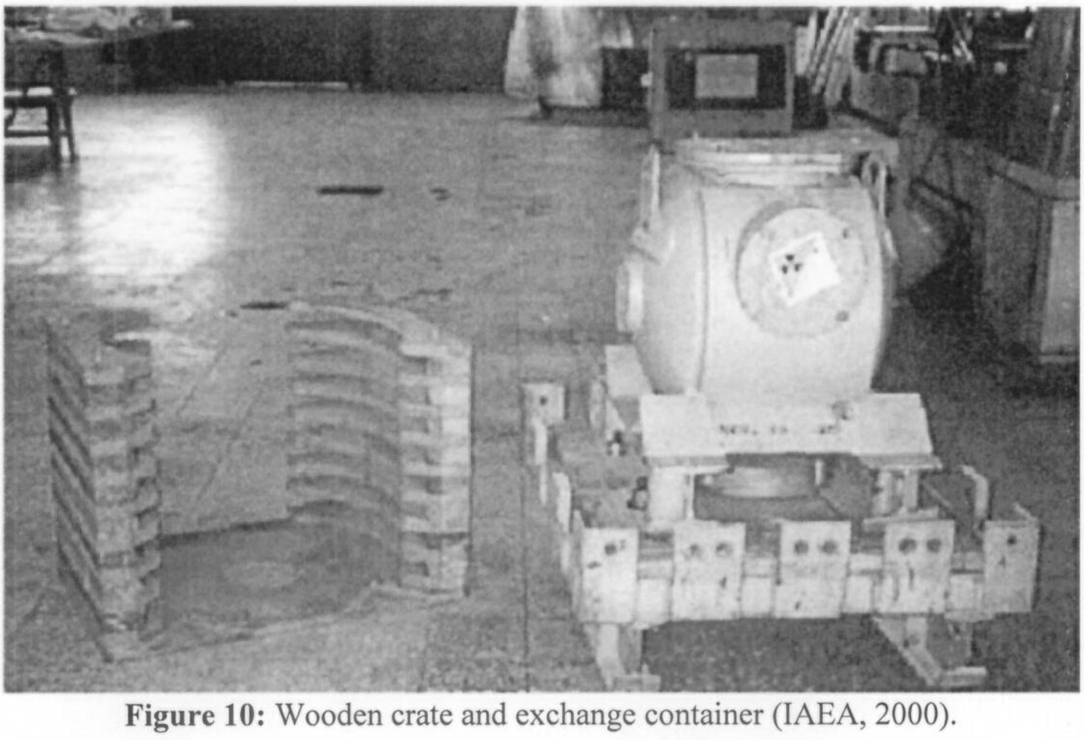

Figure 10: Wooden crate and exchange container (IAEA, 2000).

In February 1998, two of the sources were transported from Ankara to Istanbul and stored in a warehouse which was being used for general purposes. After a while the sources were re-transported from the warehouse to adjoining property due to lack of space. Approximately nine months later, this property was sold, and the new owners sold off two containers to scrap dealers on 10 December 1998 without knowledge of the content of those containers (IAEA, 2000).

The scrap dealers did not know they purchased Cobalt-60 source despite the radiation hazard labels on containers. They brought all the goods they bought to their house, including the radioactive sources, in order to break them down into pieces. During this process, the scrap dealers and the people around them were exposed to radiation. On 13 December 1998, ten people went to the hospital because of nausea and sickness. The doctors thought it was food poisining or lead poisoning and sent them back to home after some medical treatment. On 17 December 1998, some reddening appeared on the top of two fingers of one of the scrap dealers who put his hand inside the container to identify what was in it.

In following days, they continiued to break down the containers. They took inner container out, dismantled the shielding, loaded them to the truck, changed their storage area and unloaded them from the truck by hand. Because of these close contacts with radioactives, they started to loose weight, suffered from weakness, lack of appetite, bleeding gums but the reason of the ilness could not be recognized by doctors almost for four weeks. On 8 January 1999, two of the sick people sought medical asistance in a bigger private hospital in their neighbourhood. One of the doctors questioned the patients during the medical examination and learnt that the patients were working with lead containers. The doctor suspected that the lead might have been used for sheilding radioactive material. Also the son of one of the patients told the doctor that he saw a trefoil sign on the container. By this way, the doctor became sure the patients were exposed to radiation and alerted the authorities immediately (IAEA, 2000).

TAEA created ten teams for investigations. One unshielded container was found in the scrapyard and recovered safely. Since the radioactive source capsule was not damaged, there had been no radioactive leakage. Unfortunately the second source is never found. It was even impossible to find out if the second source was still in Turkey or sent back to manufacturer due to discrepancies in seller's and buyer's records. As a result of careful investigations carried out by TAEA teams, they declared that the second container was empty or if it is not empty, the radioactivity of the lost source was so low and has no danger to environment.

Considering the effects on humans, 404 people passed a medical examination. 18 of them were hospitalized and 14 of the hospitalized people were diagnosed with acute radiation. In later times, one of the scrap dealers whose fingers reddened, has been amputated due to wounds on his fingers.

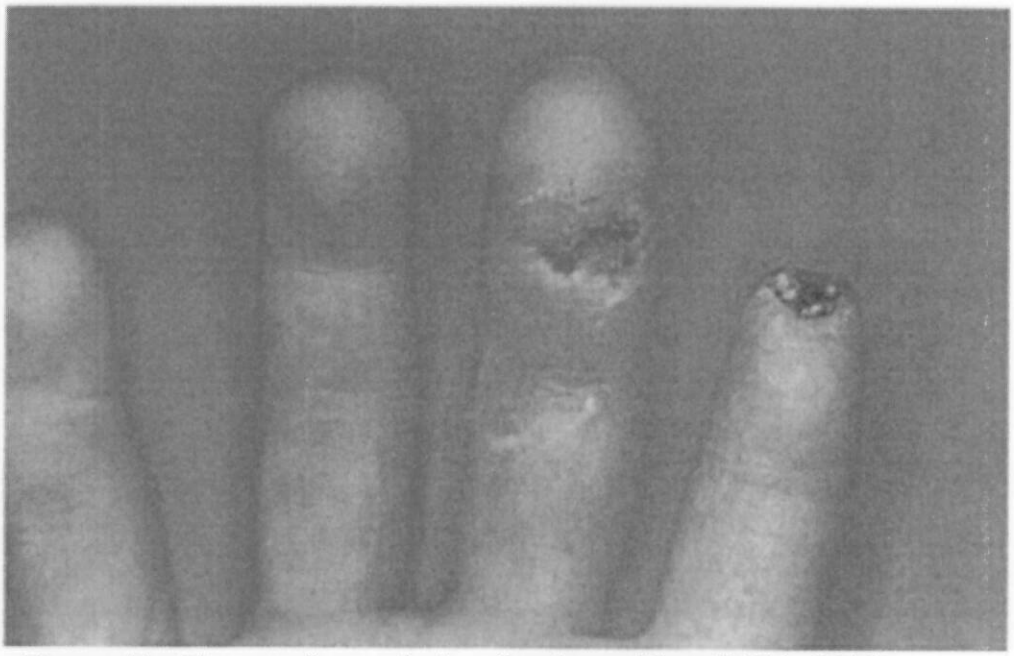

Figure 11 : Fingers of scrap dealer after the accident (IAEA, 2000).

Their father had got cancer in 2004 and passed away in 2006. The men of the family which were exposed to radiation struggled with infertility and had children through in vitro fertilization(1952-2011 Yillari Arasindaki Nukleer Kazalar, 2015).

TAEA took some actions to prevent reoccurance in future. Radiotheraphy centers were inspected. License conditions, inventory records were reviewed. Licencee's were informed about re-export procedures and they have been obligated to re-export the source within 15 days once they applied for export. It is also decided to keep used sources in TAEA approved storage facilities.

5.2 Existing Rules And Regulations Concerning Radioactive Cargo Transportation

Strict measures are required in regulations of radioactive cargo transportation to ensure adequate containment, shielding and the prevention of criticality in the event of a transport accident. As explained in chapter IV, transportation of cargoes can be classified according to the mode of transport, namely: road, rail, inland waterways, sea, air, and pipeline. Some shipments are intermodal; they are switched from one mode to another during transit (E.Erkut,V.Verter,S.A.Tijandra,2007). For instance there is always need to use road freight to transport cargoes from manufacturing facility to departure airport or sea port. These modes of transport are regulated by international 'modal' regulations. But the provisions regarding to class 7 (radioactive materials) are based on the principles of IAEA's regulations for Safe Transport of Radioactive Materials which offer guidance all regulatory bodies (Güner-Deniz, 2008). The regulatory bodies in most used modes are explained as follows:

IATA the International Air Transport Association is a non-governmental organization works with its airline members and the air transport industry as a whole to promote safe, reliable, secure and economical air transportation for passengers and cargoes. IATA explains their mission for dangerous goods regulations as being "field manual" version of International Civil Aviation Organization's technical instructions. the Dangerous Goods Regulations Written and edited by airline dangerous goods experts, present the requirements for shipping dangerous goods by air in a user friendly, easy to interpret format (What Do We Do? , 2016).

IMO the International Maritime Dangerous Goods (IMDG) code provides guidance on transporting dangerous goods by sea.

ADR the European Agreement concerning the International Carriage of Dangerous Goods by Road regulates the road freight was created on 30 September 1957, and entered into force on January 29, 1968. ADR provisions 2008/68 / EC Directive through the Council of Europe has entered the European Community law. Turkey has been a party to ADR on 22 March 2010 (Tehlikeli Mal ve Kombine Taşımacılık Düzenleme Genel Müdürlüğü, 2016).

5.3 The Authority In Turkey To Control Radioactives

Turkish Atomic Energy Agency (TAEA) explains their mission as 'to be a pioneer in ensuring that our country benefits from nuclear technology and to perform the regulatory and supervisory activities in nuclear field' (TAEK, 2011). All national decision makers should put practices in compliance with international organizations and their regulations. Figure 12 clearly shows us the interaction between organizations which aim global nuclear safety and security in common.

Figure 12: Global Nuclear Safety and Security Network (IAEA, 2014)

According the above figure, TAEA is the main regulator in Turkey who has control over radioactive materials in transportation, usage, application and researches. However, TAEA decisions or applications can never conflict with International Atomic Energy Agency which is the main regulator in the world.

IAEA can also provide asistance to Member States upon request in case of accidents or emergency planning. Their asistance may include: technical advice on emergency planing, preparednes and responce, assistance with a radiological survey, assistance with the retrieval of sources, asisstance for verification of the radiological conditions and technical advice and medical advice to overexposed people (IAEA, 2000).

Main responsibilities of TAEA are as below:

- To determine plans and programs to use atomic energy for peaceful purposes and support all kinds of atomic energy research, development, review for the benefit of country's scientific, technical and economic development.

-To determine the general principles to be followed, advise and collabrate during the usage of nuclear materials for nuclear field exploration, extraction, refining, business, manufacturing, distribution, import, export, trade, transfer and storage.

-Establishing and operating research and training centers, unit, laboratories, test centers where necessary.

-To set up a system for operation of radioisotope production, measurement, distribution and quality checks.

- Preparing rules and regulations for import & export activities and usage of radioisotopes, setting up basis of insurance liability and radiation protection.

-To conduct all licensing procedures, audits

- Taking masures for safety handling of radioactive wastes

- To cooperate with international organizations in the field of atomic energy

-To carry out studies, investigations in atomic energy applications and to enlighten the public on nuclear issues.

- In the nuclear field to work on national and international law and to propose the necessary arrangements (TAEK, 2014).

In Turkey, Disaster and Emergency Management Authority (AFAD) regulates the emergency situation to minimize loss of life and property, reduce risks against human health and environment in case of any chemical, biological, radiological, nuclear threat and danger that will come from within country or abroad and affect our country. In case of any nuclear accident or disaster, TAEA and AFAD will work in partnership to coordinate public and private enterprises, governer, universities, military forces and civil society organizations for planing, preparations, emergency action and recovery actions (AFAD,2014). Prime Ministry AFAD charged almost 400 chemical, biological, radiological and nuclear (CBRN) experts, more than 200 personnel from 11 search and rescue brigates, more than 150 personnel from AFAD provincial directorates related to CBRN risks (AFAD, 2013).

CHAPTER VI

HEALTH & SAFETY & ENVIRONMENT PROTECTION

Transportation, handling and production processes of radioactive materials are being done by people instead of machines. As stated by Cho (2016), there is no shielding to 100% protect people and environment from radiation exposure. Although this radiation dose and the resulting risks are expected to be relatively small with the help of protective measures, there is always risk to develop cancer in human body.

IAEA (1996) identifies the objectives of protection and safety measures as follows: "Protection objective: to prevent the occurrence of deterministic effects in individuals by keeping doses below the relevant threshold and to ensure that all reasonable steps are taken to reduce the occurrence of stochastic effects in the population at present and in the future. "Safety objective: to protect individuals, society and the environment from harm by establishing and maintaining effective defences against radiological hazards from sources." Radiation hazard is received in 2 ways:

(i) External radiation hazard

Human body receives the radiation from outside of the body originated from a machinery, radioactive source or an area. The essential principle of external radiation protection is covered with so-called ALARA (as low as reasonably achievable) principle (Waller,E.2014). If radiation is to be used, ALARA principle should always be taken into account in order to keep the dose in the lowest level. TAEA states there are four safety principles of reducing external radiation, protection and maintaining ALARA principle.

In general, protection from radiation is afforded by:

- minimizing the time exposed to radioactive materials;
- maximizing the distance from the source of radiation;
- shielding from external exposure and inhaling radioactive material

(Dirty Bomb, 2012)

-Distance: The radiation dose received depends on how close we are to the package, because the radiation level drops off rapidly as you get farther away from the package.
-Time: The radiation dose we receive also depends on how long we stay near a radioactive materials package.
-Shielding : Shielding is the barrier that keeps radiation as much as possibly inside the packaging and reduces external exposure.

Radiation Contamination Control should also be considered as 4. radiation protection method (Dikkat Radyasyon Tehlikesi, 2009). It is the responsibility of everyone involved in radiological activities to ensure they are not contaminated. People must follow the instructions and established proceedures to avoid radiation exposure. People who think they touched to a radioactive source or a packaging exposing radiation should wash their hands, inform their supervisor or radiation safety oficer, then apply for the nearest hospital (IAEA, 2006).

Packages of radioactive materials are safe to handle under normal conditions. The radiation exposure received from properly packed cargoes is not likely to cause any adverse health effects. However, unnecessary radiation exposure should be prevented by following above rules.

(ii) Internal radiation hazard

It is defined as the exposure received from radioactive materials taken into the body either by breathing or swallowing radioactive dusts, vapours, gases or from internal therapeutic application of substance such as radium. It is possible to absorb material through a cut, abrasion and bring about the same effect (Rao 2010).

In 2006, Alexander Litvinenko, a retired member of the Russian security services (FSB), died from radiation poisoning in London, UK and became the first known victim of lethal Polonium 210-induced acute radiation syndrome. That radioactive substance was secretly mixed to his drink 2 times and he died in 22 days after he was hospitilized (Aleksandr Litvinenko, 2016).

6.1 The Fundamentals of Safety Principles

Packaging : As previously mentioned in chapter I, there is no packing group for radioactives since only specially designed packages with shielding are used in order to enable safe transport of RA materials.

Excepted packages include small quantity of radioactive material.
Industrial packages has low hazard potential.
Type A packages is suitable for small quantities.
Type B Packages is suitable for larger quantities.
Type C Packages is used for significant quantities.

Packaging must pass practical transport related tests and meet the needs of the substance it contains and must be certified by a national competent authority (Moving Dangerous Goods, 2004).

The essential tests are the following:

-Drop test onto concrete surface from the height of 9 m and onto drift from the height of 1.20 m;

-Fire resistance test at 800° C. for 1/2 hour;

-Water resistance test, when the consignment submerged in water is subjected to a pressure corresponding to 15 m depth of water.

Marking and Labelling : Main purposes of labelling and markings are; to make dangerous goods easily recognizible from distance with the help of its shape, colour, symbol and to provide first guide for handling, stowage and segregration (United Nations, 2009). All types of radioactive cargo packages should be legibly and durably marked on the outside of the packaging with an identification of package type, UN number and consignee (ADR II, 2015). The Regulations require that consignments containing dangerous goods should be properly marked and labelled. This includes hazard labels and written material giving the United Nations identifying number and the proper shipping name of the contents. People involved in handling the consignment can identify the nature of the risk and take appropriate precautions should there be a leak or breakage. Labels, stating the content (identification of the radioactive material inside the package), activity of radioactive material and transport index should be affixed to two opposite sides of the package or four sides of the container or tank. Any label or marking which is not related should be removed or covered (ADR II, 2015).

Placarding: Placards are larger, more durable (not paper) versions of hazard labels that are usually placed on bulk packages or transport vehicles to communicate the hazards of "hazardous material" inside. Rail or highway shipments containing excepted quantities and packages with the empty, Radioactive White-I, and Radioactive Yellow-II labels do not require vehicle placarding. Placards must be printed in the square-on-point configuration measuring 250 mm on all sides and include a solid inner border that is 12.5 mm from the edge of the placard. The number "7" (UN hazard identification number for radioactive materials) should be written at the bottom of the placard.

Below photo was taken in the facility of licensed radioactive transporter in Turkey. There is no radiation placards on the vehicle since it is empty but we can clearly see the places where placards will be put into.

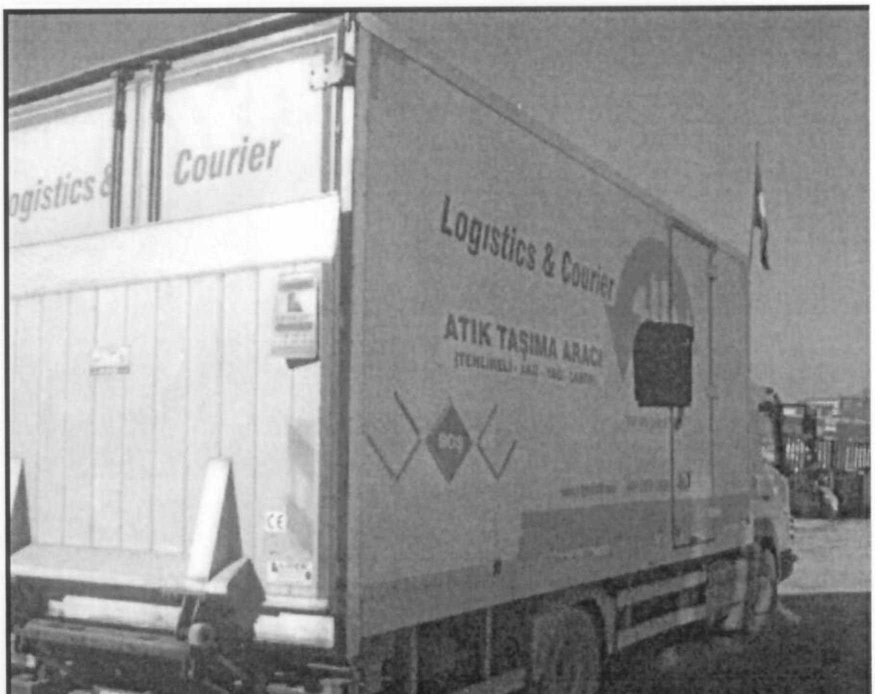

Figure 13 : Vehicle designed to carry radioactive waste (the photo is taken by me)

Trained Employees : An essential element to ensure the safe transport of radioactive materials is appropriate training. This ranges from the shipper being trained to ensure any dangerous products or radioactive materials are appropriately classed and packaged, to the carrier operator's staff being trained in the acceptance and examination of cargo, how to identify potentially undeclared dangerous goods, and to ensure that declared dangerous goods are packaged, prepared and handled in accordance with the proper instructions and that the accompanying documentation is correct (Dangerous Goods-Risk Reduction Strategy 2016).

License: All actors in logistics of radioactive material should have license to be appointed to produce, carry, import, export and use radioactive materials. All licence proceedures are taken by TAEA in Turkey. Any conflict with license requirements may cause licence cancellations.

Year	New Licence	Renewed License
2010	3327	81
2011	3309	834
2012	3591	1186
2013	3789	1251
2014	4479	1150
2015	5101	1170

Table 9 : Number of licenses in TR between 2010-2015 (TAEK,2015)

6.2 The Risks & Scenarios

Hazmat transport incidents can occur at the origin or destination (when loading and unloading) or en-route (Erkut et. al 2007). Heywood, Blenkin, Wilkonson and Murray (1997) explains incident as 'Any event, other than an accident, occurring before or during the carriage of a consignment of radioactive material which caused, or might have caused, damage to or loss of the containment or unforeseen radiation exposure of workers or members of the public'.

After Chernobyl nuclear accident, TAEA has begun to build Radiation Early Warning Systems (RESA) in 1986. The system works 24 hours and it is based on detecting an increase in gamma radiation levels in the air and alerts RESA control tower immediately in case of any radiation danger. The data taken from RESA stations are being sent to AFAD and European Radiological Data Exchange Programme (EURDEP) in every hour (TAEA, 2012). Figure 14&15 is the picture of RIS station in Sabiha Gökçen Airport which also alters TAEA in case of any radiation detection. Table 10 shows the number of RESA stations and the increase between 2010-2015. Currently there are 193 RESA stations in Turkey and 44 of them are located at country borders. In Figure 16, we can see the distribution of RESA and RIS stations in Turkey.

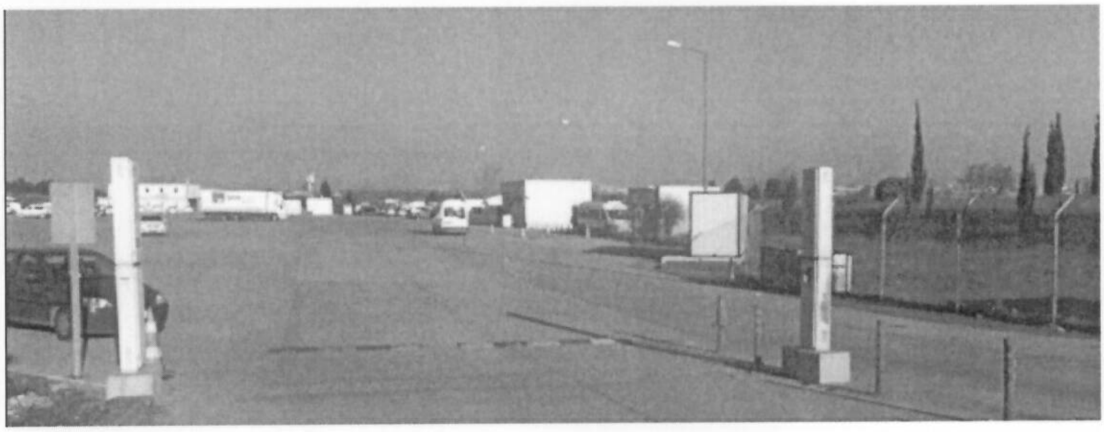

Figure 14: RIS Station in Sabiha Gökçen Airport (the photo is taken by me)

Figure 15: RIS Station in Sabiha Gökçen Airport (the photo is taken by me)

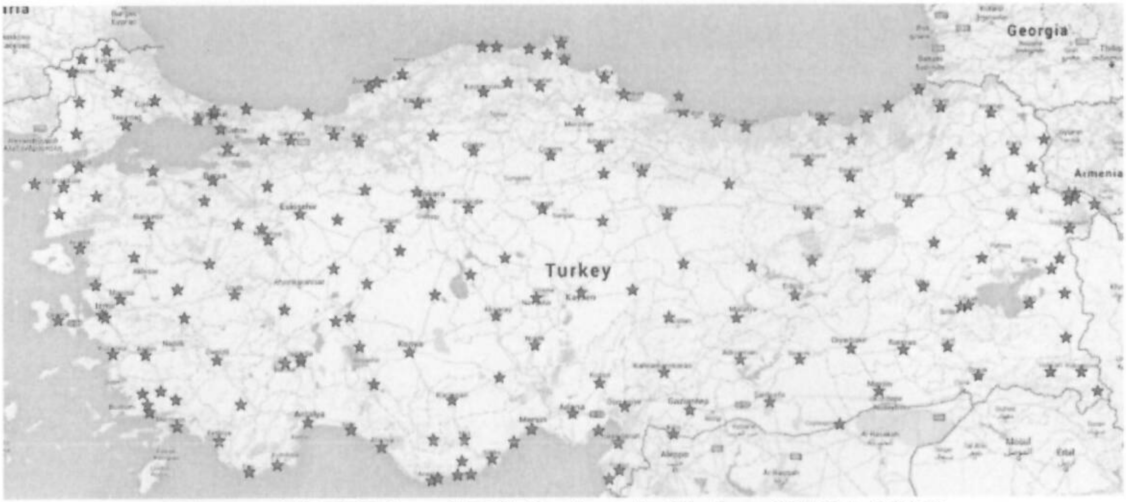

Figure 16: RESA and RIS Stations in Turkey (TAEA,2013)

Year	Total No of RESA Stations	Total No of RESA & RIS at Borders
2010	99	47
2011	124	48
2012	148	48
2013	153	45
2014	173	40
2015	193	44

Table 10: RESA Stations in Turkey (Table is drawn by me according to TAEA activity reports)

The main risks & scenarios are explained as follows:

(i) Accidents

The vital point of accident prevention and emergency rescue is to study and analyze the transportation risk involved (Zhang, Zhao 2007).

In the event of accidents or incidents, emergency provisions as established by national or international organizations should be applied to protect people, environment and property. Emergency procudures should take into account the possibility of reaction between dangerous contents of the cargo and the environment in the event of accident. (ADR) The guideline prepared by IAEA states that; 'If a transport accident occurs that results in a significant release of radioactive material, loss of shielding or loss of criticality control, the consequences should be controlled or mitigated by proper emergency response actions'.

(ii) Robbery

There is no special guideline arranged in case of loss or theft of radioactive material. However, procedures developed for the notification of transport accidents involving radioactive material by various international, state and local organizations may also be applicable to cases of loss or theft (IAEA ,2002).

(iii) Disaster

Before industrial revolution, the disasters were limited with flood, snowslide, landslide or earthquake. After the industrial evolution, the main materials of industry such as oil, radiation, chemicals caused disasters in addition to natural disasters.

As seen on below table, natural disaster may trigger technologic disasters such as industrial accidents, radiological and nuclear acidents, dangerous goods transportation accidents however, the technologic accidents may trigger natural disasters such as floods, landslide, snowslide .

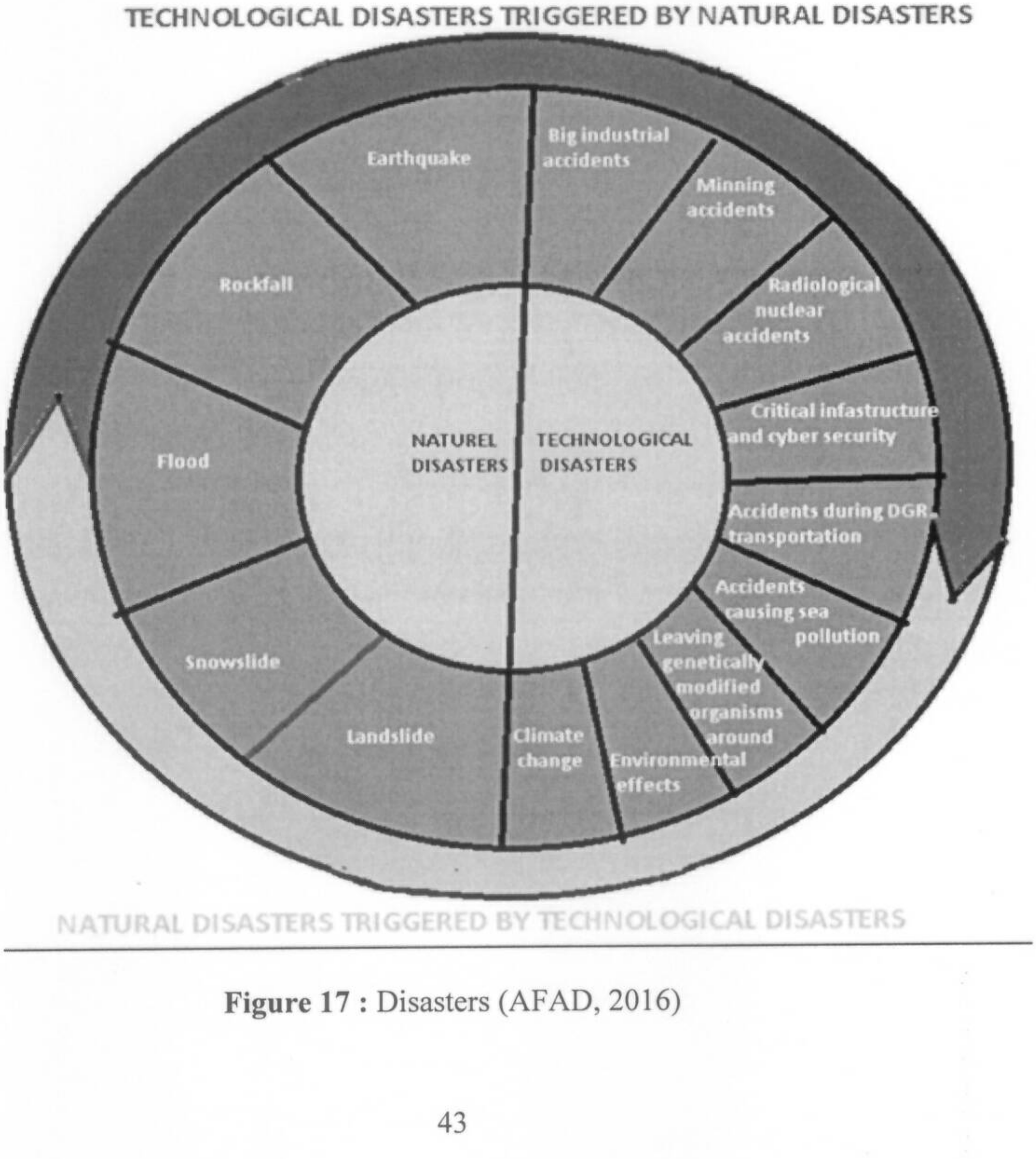

Figure 17 : Disasters (AFAD, 2016)

In 2011 the magnitude 9 earthquake and subsequent tsunami hit Japan, which is considered as a disaster since 20,000 people died and more than 500 square kilometers of land were flooded (Watts, 2015). Fukushima nuclear facility which is a place for radiation manufacturing, storage and handling was damaged due to diseaster that naturally occured. Although, the cores of three nuclear plant's reactors were damaged and a large amount of radioactive material was released into the environment, non of these deaths were caused by radiation at that time. But the impacts both from the initial releases and from the ongoing nuclear crisis have yet to be fully seen. 160.000 people were sent away from their homes, almost 45.000 workers who were exposed to radiation have been involved in a cleanup and decommissioning effort that is expected to cost billions of dollars and take about 40 years (McCurry, 2015).

Below is a pretty dramatic photograph showing us the effects of radiation release to the environment. Contaminated radioactive soil from the surface of the fields has been bagged for removal to clean deeper layers. The bags filled with contaminated soil are stacked in layers.

Figure 18 : Contaminated radioactive soil in bags, Japan. (McCurry,2015)

Day by day, the effects of radiation release will be seen. Some people may die due to radiation release they are exposed from Fukushima nuclear facility or the environment and cancer cells will be transferred from parents to the next generations.

(iv) Terrorist Attack

Terrorist activities involve assassinations, bombings, random killings, ana hijackings; which are mostly used for political purposes by the groups. Terrorism is a modern tool of rebellion, and it has strong psychological impact on public (Burchfield, 2009).

Public opposition to hazmat shipments has increased in recent years, due to fears of terrorist attacks on hazmat vehicles (Erkut et. al. 2007). In March 2016, after the terrorist attack in Belgium airport, an employee from nuclear facility was murdered. This raised a fear in country about a new terrorist attack to nuclear facility. Because of that reason, the facility was emptied for a while and government increased security measures in case of any attack.

CHAPTER VII

LOGISTICS SERVICE QUALITY PERSPECTIVE

Companies should always aim logistics excellence to drive higher performance on profitability, revenue and to gain a competitive advantage in the sector. But when it comes to logistics of dangerous goods and the radioactive goods as a part of it; the main purpose of logistics excellence must be safety. In order to achieve logistics excellence, it is needed to understand logistics service quality.

The study carried out by Mentzer, Flint and Kent (1999) expanded the service quality (SERVQUAL) domain of Parasuraman, Zeithaml and Berry into a logistics context and developed logistics service quality (LSQ) instruments to measure customer perception of logistics services. They conducted a qualitative method via survey to understand the LSQ needs of selected organization's logistical function. According to their study, LSQ has nine dimensions: Personel contact quality, order release quantities, information quality, ordering procedures, order accuracy, order condition, order quality, order discrepancy handling and timeliness.

In this chapter, as a case study, we have investigated the logistics activities of one of world's leading transportation companies who operates in more than 220 regions and has 340.000 employess in all around the world and one of their key account customers who is a leading radiation oncology treatments and software maker with 6,500 employees in 70 sales and support offices. We will give examples from the logistics activities of their IR-192 contented radioactive cargoes and will evaluate the problems they faced within logistics service quality perspective.

Personnel contact quality is the first dimension and it refers to the actors in logistics who has responsibilities for safe transport of dangerous goods. Firstly, all the parties in charge of safe transport of radioactive materials have to take necessary trainings mentioned in chapter 6.1. By this way, the people involved in the logistics process such as manufacturer, transporter, importer or the end user become more knowledgeable, sensitive, conscious and solution oriented to these substances that require special handling. After understanding the nature of radioactive goods and safety precautions, people can dominate the correct operating procedures that meet safety standarts (Zheng&Zhang 2011).

During the incident happened in March 2015, the driver of a road freight contractor was instructed to collect a depleted radioactive source from a hospital in England. Once the driver arrived hospital, it was realized that, he is not able to speak in English although English speaking driver was requested by the customer in exception for UK shipments. Additionally, he was not able to provide his ID card showing he is qualified to handle radioactive materials since at that time he did not have the ID card with him. The dispute caused by the language, discussed as a competence issue and, it was decided to explain local proceedures to the drivers detailly and always ensure they have their ID cards with them as required by the customer and regulations.

Order release quantities is the second dimension which is related with product availability and capacity. We can shortly express it as 'right amount at right time'. Customers should be the most satisfied when they are able to obtain the quantities they desire (Mentzer, Flint, Hult, 2001). But production is only one part of the logistics process so we prefer to look at from broader framework including storage, transportation, distribution and handling. For example due to terrorist attack in Belgium (22.03.2016), the government strengthened the security level from 2 to 4. One of the measures required for transportation companies was to operate with 2 drivers within the country. As a result, the transportation company had to operate with limited capacity and could not meet customer's demand and focused on urgent shipments rather than others within their contingency plan.

The third dimension **information quality** shows how well the communication flows and how the information is perceived among involved parties. Relevance, accuracy, timeliness, completeness, coherence, validity and accessibility are the key features of information quality. Below table we created is a simple example of material & information flow and shows us how vital the information quality is in order to provide smooth and accurate transfer of radioactive cargo. A mistake on information flow causes delays on producton or delivery and extra charges (fine, storage fee, amendment fee) to occur.

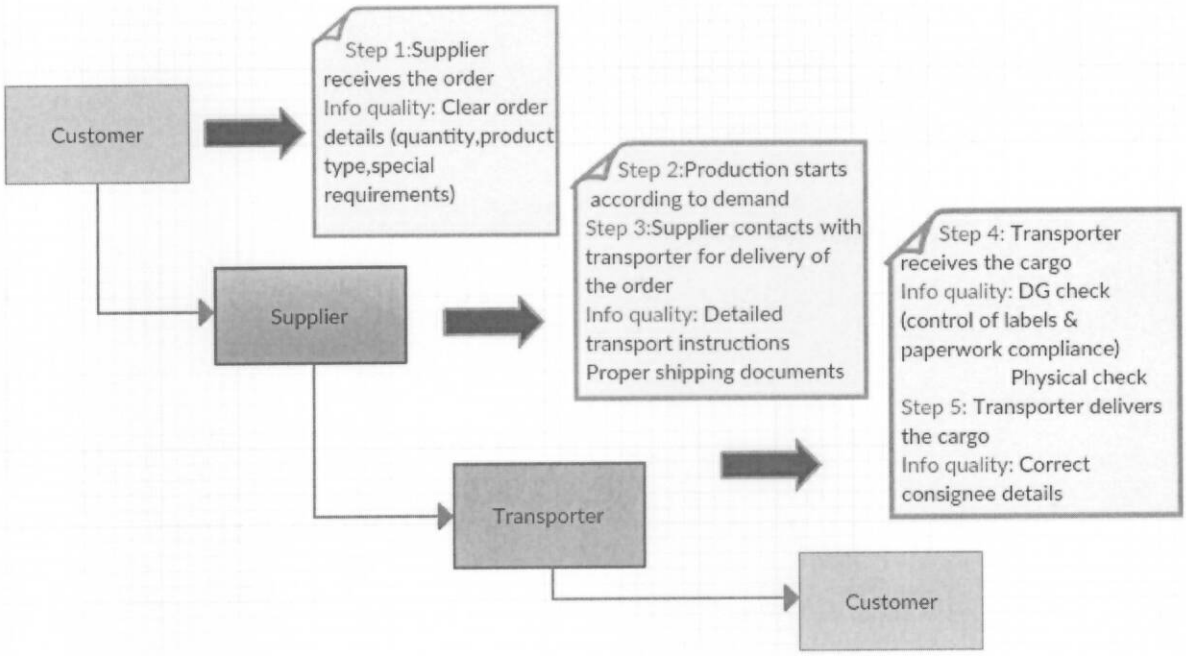

Table 11: Information flow chart is prepared by me according to my experiences in real life / logistics sector.

In October 2015, the radioactive cargo was left at Wellington airport unattended for two weeks due to poor communication between origin and destination offices of transporter. Firstly, the prealert mail which informs destination about upcoming shipment was sent to the wrong distribution list. Secondly, the destination office was thinking this is a cargo for Auckland due to wrong data entrance in internal tracking system, and did not take over the control of shipment. As a result this cargo sat at the airport for two weeks and this caused failure from service, security and quality perspectives. The transporter put a new procedure in place and amended pre alert distribution list of destination contacts as preventive action for future.

Another dimension, **ordering procedures**, refer to the efficiency and effectiveness of the procedures. The time spent during ordering, the system of ordering, its accessibility and easiness are the fields in need of improvement continuously. Ordering procedures of radioactive materials take longer time than general cargo. Once the transport request is received from the customer, all the documents such as customer's license, packaging certificate, source certificate should be checked and if all the documents are proper, the transporter accepts to carry this cargo as explained in Chapter IV. Since high control over the radioactive materials is required due to their danger; a suggestion has been received from sector which is about receiving all transport instructions over TAEA website in Turkey. For instance, shipper can load all documents to TAEA documents portal, and send transport instructions to transportation company afterwards. By this way, it would be easier for TAEA to check releveance of documents and track radioactive source flow in Turkey. We believe this way helps to shorten ordering procedures because shipper, carrier and consignee will be under pressure of acting according to regulations in every step and this will prevent amendments on documentation, cargo rejections by carrier due to incorrect labelling, packaging and all other irregularities.

Order accuracy means right items with right amount of order. In general, it creates big dissappointment for consignee to receive different cargo than ordered. This can be a result of wrong production plan or mixing of cargoes during transportation or handling. This is a loss of time, money and energy for involved parties. When it comes to dangerous goods and the radioactive cargoes, the consequences of non accurate order are more serious then general cargoes. For example in December 2015, two radioactive sources were mis-routed and sent to wrong hospitals in US since the documents were mixed up after customs clearence process. The hospital had received another hospital's source and installed it to their brachytheraphy device. When the correct source was taken to the hospital, the mistake came out and the hospital had to reject the source. Luckily, two hospitals were using same kind of radioactive source and as a corrective action, the rejected source was routed to another hospital. In this case, the first hospital had to use the source wire shipped for another hospital and the second hospital received the source wire shipped for the first hospital with a delay. The preventive action taken for this incident was adapting a new set up for warehouse team of transporter which requires them to double check labels and documents of the cargoes and in case of any discrepancy they are required to hold the shipment and report to responsible people.

Order condition is related with safe and proper transportation and handling of the cargo. Any damage on the container, seal, packaging or labels should be reported to authorities immediately. Damages on the container may cause radiation leakage which is risky for living things. Also this damage may not be the result of a small accident. The radioactive source container might be touched by evil-minded people. So, after reporting the damage, root causes should be investigated. Corrective actions should be taken to amend the damage – if possible. Lastly, preventive actions should be implemented not to face with such an incident in future.

For example, the sealed radioactive sources are sealed in an impervious container that has sufficient mechanical strength to prevent contact with and dispersion of the radioactive material under the conditions of use and wear for which it was designed (Burchfield, 2009). One of IR-192 suppliers used to face with broken seal problem oftenly since they use plastic seals. As a process improvement, they took an action and decided to use metal seals to avoid such problems in future.

Order quality is more related to production and beyond our focus since we worked on storage, handling and transportation of radioactive cargoes. But we can say that, any faulty production invalidates all these regulations and measures which needs to be applied according to content of the product.

Order discrepancy handling has key role in corrective and preventive actions exemplified previously and it contributes to customer's perception of the quality of the service (Mentzer et. al 2001). Poor quality of information, contact people or failures in ordering cause discrepancy in logistics process. Timely intervention and adressing the issue to right contacts are the keys of correcting discrepancies.

Timeliness is important to meet customer's demand. It also has major role in logistics of radioactive cargo. First of all each day the radioactivity decays. Secondly, short lead time helps to prevent radioactivity to spread around. Because of that reason air freight is the most suitable transportation mode for radioactive cargoes in long distance due to its speed. Discrepancies can cause interruption of transportation and delays on arrivals / deliveries and in such cases alternative solutions should be provided and implemented accordingly.

All dimensions have different impact on logistics process. However all are linked to each other. Based on the case study we conducted, we drew below table which explains us the interaction between dimensions, the importance of each dimension in desired flow, and their relevance with this study.

No	LSQ Dimension	Relevance	Importance	Interaction
1	Personnel Contact Quality	Strong	High	5,3,8,9
2	Order Release Quantities	Weak	Low	9
3	Information Quality	Strong	High	5, 8, 9
4	Ordering Procedures	Medium	Medium	5, 9
5	Order Accuracy	Weak	Medium	-
6	Order Condition	Medium	High	8
7	Order Quality	Weak	Low	-
8	Order Discrepancy Handling	Strong	High	3, 9
9	Timeliness	Medium	High	2, 3, 4

Table 12: Relevance, importance and interaction table of LSQ dimensions developed by me according to the explanations written below.

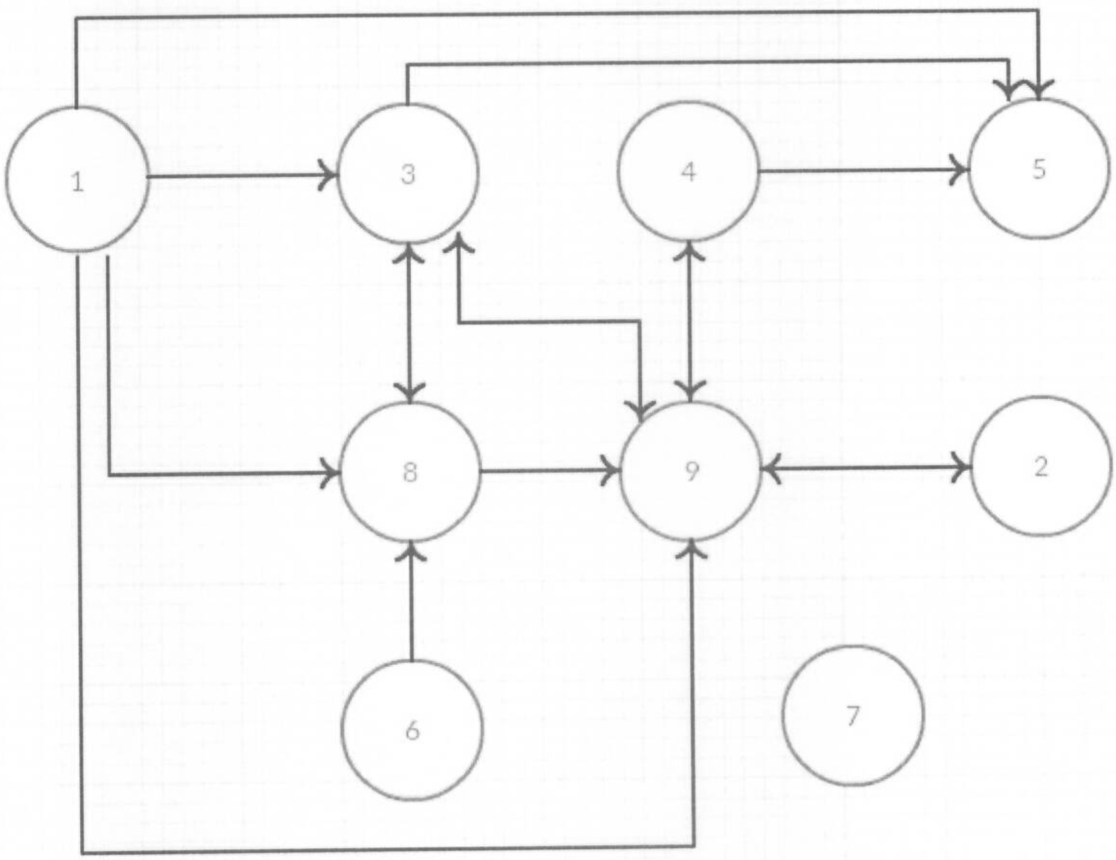

Table 13: Interaction chart of LSQ dimensions is showing the one-way or feedback relationship between dimensions.

Table 12 shows us the relevance, importance and interaction of logistics service quality dimensions and Table 13 explains us the interaction between the dimensions. According to mentioned tables, *personnel contact quality* (1) is in one way interaction with information quality (3), order accuracy (5), order discrepancy handling (8) and timeliness (9). Although these dimensions are affected by personnel contact quality, they are not able to affect it. We can say that, personnel contact quality has a great role in reaching the desired flow due to its high importance and strong relevance with our study. *Order release quantities (2)* is in two way interaction with timeliness (9). How large the time interval, the greater the amount of product that can be moved or produced. But it has low importance in reaching the desired flow and weak relevance in our study. *Information quality (3)* is in two way interaction with timeliness (9) and order discrepancy handling (8) whereas it is in one way interaction with order accuracy (5) and personnel contact quality (1). Since information quality has vital role in safe and secured transport of radioactive materials, it is strongly related with our study and has high importance in reaching the desired flow. *Ordering procedures (4)* is in two way interaction with timeliness, both directly affects each other. Long and complex ordering procedures take long time and time is valuable in radioactive cargo shipments due to radioactive decay. Short interval of time can be a barrier to completion of necessary procedures. Its impacts are considered as medium level in terms of relevance and importance. *Order accuracy (5)* is affected by personnel contact quality (1), information quality (3) and ordering procedures (4). If these three dimenstions take place properly, order accuracy would be secured by producer and transporter. It has medium level importance and weak relevance in this study. Although *Order condition (6)* is only in one way interaction with order discrepancy handling (8), it has medium level relevance and high level of importance in this study. Any damage on packaging can cause radioactive leakage which is a big threat for public and the environment. *Order quality (7)* has no interaction with other dimensions, because of that reason it is considered as an independent dimension. It has weak relevance and low importance in ur study. *Order discrepancy handling (8)* is in interaction with information quality (3), timeliness (9), order condition (6), personnel contact quality (1). Personnel contact quality (1) and order condition (6) impact order discrepancy handling (8) however, order discrepancy handling (8) impacts timeliness (9). Also it is in two way interaction with information quality (3).

We believe order discrepancy handling has one of the key roles in desired flow as well as personnel contact quality and information quality. It has strong relevance and high importance in our study. Lastly, *timeliness (9)* is in two way interaction with order release quantities (2), ordering procedures (4) and information quality (3). At the same time, the interaction with personnel contact quality (1) and order discrepancy handling(8) has one was direction and they affects timeliness (9). It has medium level of relevance and strong importance in our study.

We implemented LSQ dimensions to our logistics process chart represented in Table 2 (Chapter IV) and generated Table 14 pointing out the relevant LSQ dimensions in production and plannig, freight order, transport planning, transportation and delivery stages of logistics. According to Table 14, personnel contact quality, info quality timeliness and order discrepancy handling, order condition are the most important dimensions in radioactive cargo transportation since we see their impacts in all stages.

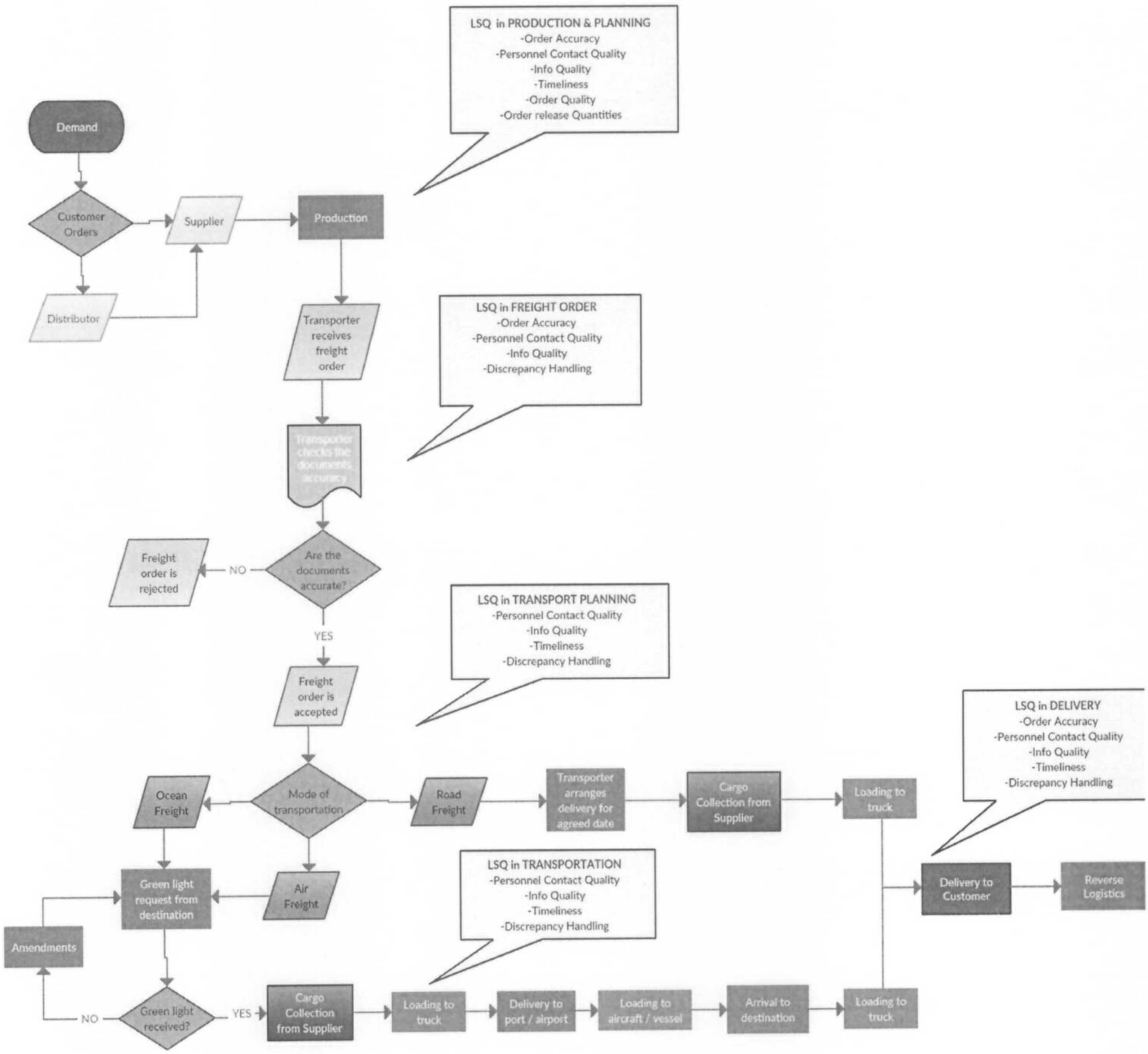

Table 14: Logistics Service Quality Dimensions in Desired Flow prepared by me according to the literature reviews and my experiences in real life.

7.1 Current Problems Among Involved Actors

We conducted a qualitative researh a by doing an interview with the only licensed road freight contructor in Turkey who is allowed to carry radioactive cargoes. The company was found in 1999 in İstanbul. They offer wide range of services such as storage, handling, courier service, LTL& FTL road freight service within city limits or outside of the city. Their expertise areas are the logistics of automative spare parts, white appliences, hazardous materials and recycling.

With the help of this interview, we see the applications of some parts of our logistics process chart in real life .We started our interview with talking about the first step of transportation which is receiving transportation request from the customer. We see the Firstly, all the documents of radioactive source is being checked by the dangerous goods safety advisor of the transportation company as stated on Table 2. These documents are: source certificate, dangerous goods declaration form, special form certificate, site license (approved by TAEA). At this stage the critial point is; these checks are mostly being done over e-mail and transporter arranges the delivery based on the information customer provided. If all documents are available and correctly issued, they send their truck to transport mentioned radioactive cargo. The driver also checks the documents and cargo when he physically receives the cargo. So, we can see how important role information quality and the personnel contact quality have here. As a process improvement, they wish to check accuracy of these documents over TAEA website by the time they receive the transport order from customer. TAEA would review and approve the shipping documents prior the shipment. By this way the transporter would never doubt about accuracy of documents.

As a company policy, they keep confidencial the transport plan between DGSA, operations manager, driver and the customer. They plan the routing, then inform the driver, seal the box of the vehicle and lastly track it by vehicle tracking system during en route. Additionally, the drivers have to call and report the status of their trip in every two hours to radiation safety officer of the transportation company. If the radioactive source has high financial degree or high activity, the radiation safety officer escorts the truck with another vehicle.

Table 15 gives us some idea about mentioned transport company's portfolio. According to below table, healthcare sector has the biggest portion with ratio of %70,53 in their radioactive cargo transportation activities. So we divided the sectors they provide service as healthcare and industry and then created Turkey maps showing the cities they most commonly transport radioactive sources (Table 16 & 17).

Sector	No of Transportation	Ratio
Healtcare	146	70,53%
Oil Industry	10	4,83%
Metal Industry	6	2,90%
Packaging Industry	3	1,45%
Wood Industry	3	1,45%
Research	2	0,97%
Textile Industry	1	0,48%
Other Industry	36	17,39%
TOTAL	**207**	**100%**

Table 15: Logistics activities of the company in 2015 is calculated by the dangerous goods safety adviser of trucking company and allowed to use in this study.

Table 16: Transportation of Radioactive Healthcare Products (the map is drawn by me according to data received from trucking company we interviewed)

Table 17: Transportation of Radioactive Industral Products (the map is drawn by me according to data received from trucking company we interviewed)

After receiving information about their transportation process, we continiued with audits of TAEA. These audits are being carried out in yearly basis by TAEA officials on agreed date. In the audits TAEA checks the training of employees, their emergency plan, materials and devices required for RA cargo transportation (dosimetry, warning signs etc). As a process improvement, we can suggest them to audit the companies without informing them upfront. A sudden audit would always show them the truth about how much the regulations are being applied in an ordinary day. Also, the Ministry of Transport, Maritime Affairs and Communication officials may also examine the trucks & drivers during en route.

In order to do that, all traffic polices and gerdarmery should be trained about hazardous material transportation and its requirements. Another criticism about audits is, the result of audits is not announced on TAEA website or no official document showing the result given to the transportation company.

According to interview results; the major criticism we received during our interview is about authorization to carry RA cargo in Turkey. To obtain an authorization to carry RA materials in Turkey, it is needed to receive licence of authorization from Ministry of Transport, Maritime Affairs and Communication, the operation certificate compliant to ADR requirements, to employ DGSA and a driver with SRC5 and Class 7 training certificate, and lastly it is needed to have dangerous goods and dangerous wastes liability insurance policy. When TAEA gives licence to the companies, it authorizes them to import, export and carry radioactive materials.

So, some of the licenced companies carry RA cargoes of other companies as well, in commercial purposes. Regardless of compliance with the requirements of being an authorized transport company, most of the licensee's of TAEA carry RA materials because of the gaps in regulations.

7.2 The Barriers To Reach Desired Flow

Transportation of dangerous goods including radioactives is a new topic for Turkey and needs to be developed in terms of regulations, audits, trainings, public awareness. In June 2015, 16.000 business got certificate to operate hazardous materials. In same year, only 2.000 people got certificate for being dangerous goods safety advisor (TMGD, 2016). The first version of ADR entered into force in 29 January 1964 whereas it is entered into force in 22 March 2010 in Turkey.

With the help of the interview we conducted, it is seen that, logistics providers stay away from entering this new special area. Main reasons can be the high costs of requirements such as designing storage areas, personnel trainings, supplying special equipments etc. This area in logistics sector can be developed with goverment's support. So that the companies who are trading radioactive materials can hand over inland transport to logistics professionals. On the other hand, creating a competitive environment in transportation of radioactive cargoes can be beneficial to the sector in terms of new ideas, development projects, new investments etc.

Also, deficiencies recognized during cargo inspection should be reported to TAEA so that preventive actions can be taken, if needed penal sanctions can be implemented to violators. These deficiencies are missing documentation (dangerous goods declaration form, certificates) or missing info on documentation, marking, labelling and placarding discrepancies, deficiencies on storage areas. Although it is easier to detect and report deficiencies in international shipments with the help of inspections by customs authorities, in inland transport it is not easy to report since many of them are covered up. So, in addition to regular audits, random controls should be done by germandary or police.

CHAPTER VIII

CONCLUSION AND FURTHER RESEARCH

In this study we aim to discover desired flow of radioactive materials. We give definitions regarding to logistics, dangerous goods and radioactives. Moreover, we mention about the regulations, risk scenarios; implement logistics service quality dimensions to logistics process chart and discuss problems among actors in radioactive material transportation.

We believe that, the effects of radiation and radioactivity are not well known among public, emergency responders, medical personnel, patients or people in logistics industry. This could lead to unwarranted panic, refusal to respond to the incident, being late to take action and other unfortunate reactions during the emergency phase of any response and to ensure protection from radiation exposure.

After Chernobyl accident, many people suffered from cancer in Blacksea region of Turkey and researchers found out contamination in fish, tea leaves, hazelnut in Blacksea. In those days, government officials tried to encourage people against radiation danger with drinking tea in front of media. Today, people know the hazards of radiation, some of them even trying to prevent non-ionizing radiation received from television, computers or microwaves due to fear of radiation. This fear against radiation should be destroyed, and a conscious approach to radiation should be displayed.

We live in a world where security is often interrupted due to terrorist attacks. A truck on its way to delivery is an open and easy target for those people. Because of this reason, extra safety measures should be taken to avoid evil minded people to take possesion of any radioactive material. A radioactive cargo monitoring system can be improved by researchers in order to trace packages. Or a specially designed packages may include tracking devices. This would enable TAEA to closely follow up radioactive cargo movement in the country for safety purposes and also for their records.

In Turkey, waste management should be improved as well. As mentioned earlier, Çekmece Nuclear Research Center which is located in Küçük Çekmece area and surrounded by many buildings, stores radioactive wastes in Turkey. The facility should be move outside of the city and any residential area around it should be forbidden for public safety. This may be an interesting topic for researchers who are interested in facility location problems.

One of the points we emphasis its importance during our study is information accuracy. In international shipments it is easier to identify and amend improper documents or improper information on documents due to strict regulations in borders. But for inland transport, we see a slack control mechanism. Compliance with rules left to the initiative of the licensed companies. The government agencies (TAEA, Ministry of Transport, Maritime Affairs and Communication, Ministry of Health, Police, gendarmerie) should intensify the audits and checks working in cooperation.

Logistics of radioactive materials is in a development process and there are many new topics for researchers in Turkey to study such as regulatory environment, information systems, accident analysis, hazard mitigation, risk assessment, routing, community preparedness, incident management, facility location problems and route selection. All disciplines related to this area should work in cooperation in order to ensure safe, secured transportation of radioactive materials for environmental protection and public health.

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APPENDIX

Appendix – A. Interview

TÜRKİYE'DE RADYOAKTİF KARGO TAŞIMACILIĞI ÜZERİNE RÖPORTAJ

City Lojistik Tehlikeli Madde Güvenlik Uzmanı ve Radyasyondan Korunma Sorumlusu Ferit YAZGAN ile Türkiye'de radyoaktif kargo taşımacılığı üzerine Şubat 2016'da , İstanbul'da soru – cevap şeklinde yapılan röportaja ait notlar aşağıdaki gibidir:

1) Radyoaktif kargo taşımacılığında hangi sektörlere hizmet vermektesiniz? Sayısal veriler elinizde mevcut mudur?

Taşınan radyoaktif kaynağın aktivitesinden ve paket adedinden bağımsız olarak bir araçla yapılan her taşımayı bir operasyon olarak değerlendirirsek, City Lojistik olarak yaptığımız taşımaların dağılımı şöyledir:

Sector	No of Transportation	Ratio
Sağlık	146	70,53%
Petrol	10	4,83%
Metal Endüstrisi	6	2,90%
Ambalajlama	3	1,45%
Ağaç Endüstrisi	3	1,45%
Araştırma	2	0,97%
Tekstil Endüstrisi	1	0,48%
Diğer Endüstri alanları	36	17,39%
TOTAL	207	100%

2) Radyoaktif kargo alım / teslimat süreçleriniz hakkında kısaca bilgi verir misiniz? Kritik noktalar nelerdir?

Radyoaktif kargo taşıma talebi firmamıza ulaştığında öncelikle taşıması yapılacak olan kaynağa ait bilgi ve belgeler müşteriden talep edilmektedir. Bu bilgi ve belgeler:

- Radyoaktif kaynak sertifikası
- Paket sertifikası
- Radyoaktif kaynağın veya radyoaktif kaynağın kullanıldığı cihazın TAEK lisansı
- Taşımacılığa esas bilgiler (UN numarası, kaynak tipi, kaynağın tehlikeli madde deklarasyon formu, aktivitesi, paket tipi, etiket özellikleri, taşıma indeksi, yüzey ölçümleri)

- Kaynağın teslim alınacağı yetkili kişinin detayı, şirket bilgileri, teslimatın yapılacağı yetkili kişi detayı, alıcı şirket bilgileri
- Fiziksel paket bilgileri (ebat, ağırlık)

Gerekli olan bu bilgi ve belgeler Radyasyondan Korunma Sorumlusu olarak tarafıma ulaştıktan sonra tehlikeli madde taşıma evrağını hazırlayarak taşıma için gerekli bütün bilgileri tek bir fromda topluyorum ve operasyon müdürü ile operasyon planlaması yaparak müşteriye fiyat teklifimizi ve operasyon detaylarını iletiyorum. City Lojistik olarak radyoaktif kaynakların depolamasını yapmamaktayız bu nedenle operasyon planı kaynağın adresten teslim alınmasını ve en kısa sürede alıcıya teslimatını kapsamaktadır. Olası bekleme durumlarında malzeme araç içerisinden çıkartılmadan, aracın güvenli bir bekleme alanına çekilerek bekletilmesi operasyon planına dahil edilmektedir.
Bu süreçte kritik olan nokta, müşterilerin gönderdiği belgelerin doğruluğunun kontrol edilmesidir. Belgeler çoğunlukla dijital ortamda e-mail ile tarafımıza gönderilmektedir. Islak imzalı belge olmadığı için müşterinin beyanlarına ve belgelerin doğruluğuna güvenmek zorunda kalmaktayız. Kaynak ve paket seri numaralarının kontrolü ancak kargo teslim alınırken yapılabilmektedir.
TAEK, radyoaktif cihaz lisanslarının kurumun web sitesi üzerinden kontrol edilebilme imkanı olsaydı bu bizim için zaman ve emek bakımından tasarruf etmemizi sağlardı.

3) Türkiye içinde hangi şehirlere hizmet sağlamaktasınız? Sayısal veriler elinizde mevcut mudur?

Türkiye'nin bütün şehirlerine radyoaktif kargo taşımacılığı yapabilmekteyiz. En çok taşımacılığı sağlık sektörüne yönelik yapmaktayız ve bu taşımaları yaptığımız başlıca illerimiz: Adana, Amasya, Antalya, Bitlis, Çorum, Diyarbakır, Erzurum, Elazığ, Giresun, Karabük, Kayseri,Konya, Malatya, Rize, Samsun, Tokat, Trabzon, Van, İstanbul, Ankara, İzmir, Balıkesir, Çanakkale, Zonguldak, Tekirdağ'dır.
Daha seyrek olarak endüstriyel amaçlı kullanılan radyoaktif kaynakların taşımasını yaptığımız başlıca illerimiz: Kocaeli, Sakarya, Adana, Hatay, Erzurum, Kayseri, İstanbul, İzmir'dir.

4) Kaza, hırsızlık veya terörist saldırı risklerini en aza indirmek için ne gibi güvenlik önlemleri almaktasınız?

Öncelikle radyoaktif kaynak taşımasına ait bilgi ve belgelerden Radyasyondan Korunma sorumlusu ve Tehlikeli Madde Güvenlik Danışmanı olarak benim ve Operasyon Müdürü dışında kimsenin bilgi sahibi olmamasına özen göstermekteyiz. Taşımayı yapacak olan şoför kurye bile bile ancak operasyon günü bilgi sahibi olmaktadır.

- Taşımayı yapacak araç bilgisi yükleyici ve alıcı şirket yetkilileri dışında kimseyle paylaşılmamaktadır.
- Yol güzergahı operasyon planında belirtilmektedir ve araçların bu güzergahın dışına çıkmamaları sağlanmaktadır.
- Tüm radyoaktif kargo taşımaları mühürlenebilir kapalı kasa araçlarla yapılmaktadır.

- Tüm araçlarımızda araç takip sistemi bulunmaktadır.
- Taşımalarda iki adet şoför kurye görevlendirilmektedir.
- Şoför kuryelerle şirketin sağladığı cep telefonları ile iletişim kurulmaktadır.
- Aktivitesi ve mali değeri yüksek radyoaktif malzeme taşıma operasyonlarında Radyasyondan Korunma Sorumlusu olarak ben de ayrı bir araçla eskortluk yapmaktayım.
- Taşıma organizasyonu hem araç takip sisteminden takip edilmekte hem de 2 saatlik aralarla şoför aranarak gerekli kontrol sağlanmaktadır.
- Radyoaktif kaynak taşımalarında şoför kuryelerin kolaylıkla görebileceği acil durum telefonları araç kabini içerine yerleştirilmektedir.

5) Denetlemeler hangi sıklıkta, kim tarafından yapılıyor? Denetim süreci nasıl ilerliyor?

Denetlemeler TAEK tarafından yapılmaktadır. City Lojistik olarak TAEK'den radyoaktif kaynak taşıma lisansımızı 2013 yılında almıştık. 2014 ve 2015 Ağustos aylarında TAEK tarafından denetime tabi tutulduk. Denetim sonucu tarafımıza yazılı olarak bildirilmemesine rağmen, denetlemeye gelen uzmanın sözlü beyanına istinaden tüm evraklarımızın ve operasyon işleyişimizin kurallara uygun olduğu bildirildi.

6) Radyoaktif kargo taşımacılığında en sık karşılaştığınız sorunlar / engeller nelerdir? Yasal ya da uygulamadaki sorunlar ve 3rd party (şoför, araç donanımı, alıcı & yükleyici tarafındaki yetkili kişiler...vs) ile yaşanan sorunlar bakımından açıklamanızı rica ederiz.

City Lojistik olarak radyoaktif malzeme taşımalarımızı kendi özmal araçlarımızla gerçekleştirmekteyiz. Yaşadığımız en büyük sorun yetkisiz firmaların radyoaktif taşıma yapmasıdır. TAEK, 'ithalat, ihracat ve taşıma' olmak üzere firmalara tek bir lisans vermektedir. Bu lisansı verirken firmaların diğer yasal koşulları yerine getirip getirmediğine bakılmamaktadır. Oysa ki yurtiçinde radyoaktif madde taşıyabilmek için şu şartları yerine getirmek gerekmektedir:

- Ulaştırma Bakanlığı'ndan karayolu taşıma yönetmeliği uyarınca yetki belgesi,
- Ulaştırma Bakanlığı'nın Tehlikeli Maddelerin Karayoluyla Taşınması Hakkında Yönetmelik ve Tehlikeli Madde Faaliyet Belgesi Hakkında Yönerge gereği 'Tehlikeli Madde Faaliyet Belgesi',
- Tehlikeli Madde Güvenlik Danışmanlığı Hakkında Tebliğ gereği 'Tehlikeli Madde Güvenlik Danışmanı' istihdamı,
- K1'e kayıtlı araç,
- SRC5 belgesi ve Sınıf 7 belgesi,
- Tehlikeli Maddeler ve Tehlikeli Atık Zorunlu Mali Mesuliyet Sigorta Poliçesi
- Bunlara ek olarak TAEK'in lisans gerekliliklerini de yerine getirmek gerekmektedir.

7) Bu sorunlar için çözüm önerileriniz nelerdir?

TAEK websitesinden lisans alan firmaların dağılımı şöyledir:

Lisans Tipi	Firma Sayısı
İthalat, ihracat, taşıma	51
taşıma	14

Tüm bu firmalar içerisinde ana faaliyet konusu 'taşımacılık' olan tek firma City Logistics & Courier Taşımacılık Hizmetleri A.Ş.'dir. Diğer lisanslı firmaların tamamı sağlık sektöründe faaliyet gösteren firmalardır. Yönetmelikte belirtilen yetki belgelerine (C1, C2, K1, K2, L1, L2, R1, R2) sahip olmak gerekmektedir. Karayoluyla radyoaktif kargo taşmacılığı hizmeti verebilmek için C1, K1, L1, R1 belgelerinden birine sahip olmak gerekmektedir. Yani eğer C2, K2, L2, R2 belgelerinden birine sahipseniz sadece kendi firmanıza ait radyoaktif kaynakları taşıyabilirsiniz. Diğer firmalara radyoaktif kargo taşımacılığı hizmeti veremezsiniz.
Başka bir firmaya ait radyoaktif malzemeyi taşımak ve bu hizmeti diğer firmalara devamlı olaak sunmak istiyorsanız öncelikle Ulaştırma Bakanlığı'nın ticari mal taşıması için şart koştuğu yetki belgesini, daha sonra da ADR yönetmeliği gereği Tehlikeli Madde Faaliyet Belgesi'ni almak ve Tehlikeli Madde Güvenlik Danışmanı istihdam etmek, SRC5 ve Sınıf 7 belgeli şoför istihdam etmek, Tehlikeli Maddeler ve Tehlikeli Atık Zorunlu Mali Mesuliyet Sigorta Poliçesi yaptırmak gerekmektedir.
Oysa ki TAEK lisans başvurusu için bu şartları talep etmediği için kurumlar arası uyumsuzluktan ötürü yetki belgesiz firmalar taşıma yapmakta ve denetime tabi olmamaktadır. Bunun önüne geçilebilmesi için önerilerim şu şekildedir:

- Lisans başvurusunda yetki belgesiyle birlikte SRC5 ve SRC7 belgeli personel istihdam edildiği,
- Taşıma yapan şoför kuryelerin kişisel doz takibinin yapıldığı,
- Ticari mal taşıması yapacak araç listesi (K1'e kayıtlı araç) ,
- Tehlikeli Maddeler ve Tehlikeli Atık Zorunlu Mali Mesuliyet Sigorta Poliçesi

ibraz edilmelidir.

Bir diğer çözüm önerisi ise, tüm radyoaktif kaynak taşımalarının TAEK tarafından aktif olarak denetlenebilir olması ve TAEK'in tüm taşımalar için taşıma evraklrını rapor olarak talep etmesi olabilir. TAEK şu anda yurtiçinde yapılan radyoaktif kaynak taşımacılığı ile ilgili hiçbir denetim yapmamaktadır ve taşımaların TAEK'e bildirilme zorunluluğu olmadığı websitelerinde belirtilmektedir.
Konuyla ilgili olarak TAEK'e yaptığımız yazılı başvuruda da aynı yaklaşım çerçevesinde bu yaklaşım çerçevesinde, karayolu denetiminin Ulaştırma Bakanlığı'nda olduğu yönünde görüş bildirilmiştir.