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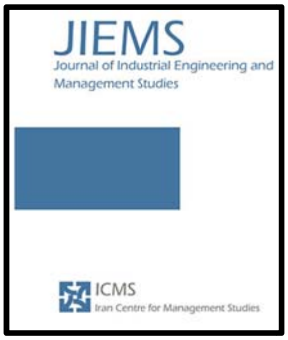

Calculation of the fuzzy reliability in Neishabour train disaster; a case study

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Abstract

Fuzzy reliability is often used in analyzing the reliability in the large industrial systems. In this paper, a relatively new method is presented to analyze Neishabour (also called Nishapur, a city in Iran) train disaster. In this regards, by using the certain and uncertain propositions, unreliability circuit of the system is depicted .Due to the inability to provide exact values for the unreliability of each subsystem, regarding the opinion of experts, fuzzy logic is applied and triangular and Gaussian membership functions are attributed depending to the type of each subsystem and the fuzzy unreliability value of the system is calculated. Finally, by defuzzification and comparing the obtained value with the classification table of linguistic variables, unreliability of the system is identified.

Keywords: Fuzzy Reliability; Triangular Membership Function; Gaussian Membership Function; Neishabour train disaster; α-cut.

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1. Introduction

Reliability History goes back to World War II. In 1954, the first meeting in America was held in the field of reliability and in 1962, the first graduate school of system reliability engineering was presented at the air institute in Ohio (Dhillon. 2006). Today reliability plays a significant role in the field of engineering and technology. In matters relating to the products and man-made systems, the role of design engineer in removal and reduction of defeat and destruction on a large scale (eg, transportation equipment accidents, which threatens lives and explosions resulting from industrial processes in plants (Alipour Dashbolagh et al. 1389, 1389)) is vital. Information about the long-term characteristics of materials and equipment will be effective in designing products with higher reliability.

System reliability analysis is done in a state of uncertainty. This uncertainty may be caused by ambiguous or inaccurate information or lack of sufficient information. In such a situation that

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uncertainty is not only due to an accident use of probability theory to deal with uncertainty is not enough and fuzzy logic theory should be used. Because unlike the classical reliability theory, a system does not comprise only two conditions, the failure mode and the operation mode, rather, the system performance is on a scale ranging from complete failure to full health and thus fuzzy logic theory is more appropriate to express the state of a system. In real world the information about system parameters always cannot be determined precisely and even with the most accurate experiments cannot be said decisively that how long is the lifetime of a system.

In 1974, for the first time, Mamdani et al studied in fuzzy control and fuzzy logic controllers and employed this theory in the field of control (control of the steam engine). During the years 1986 and 1987, for the first time fuzzy logic was used to automatic control of subway in Japan and shortly after hundreds fuzzy controller was designed and applied in Japan (Faghih et al. 1383).

The use of fuzzy set theory in reliability has stated since Kaufman`s research (1975),he used possibility theory Instead of using probability theory to calculate the reliability.But at that time he could not justify the effectiveness of his theory in terms of the engineering and math. In fact, the major part of the application of fuzzy methodology in reliability has been after 1980. Most of these models have focused on determining the reliability of system components and simple systems (Cai. 2000).Here some of the most relevant articles in the field of fuzzy reliability are shown in Table 1.

Table 1: Classification of studies in the field of fuzzy reliability

year	Subjects
2014	Human reliability assessment for medical devices (Lin et al. 2014)
	solving multi-objective reliability optimization problems by fuzzy optimization technique (Garg et al. 2014)
	Using fuzzy logic for allocating reliability in design process and initial development of engineering systems (Khanmohammadi et al. 2013)
2013	A non-linear fuzzy regression for estimating reliability in a degradation process (Gonzalez et al. 2013)
	Interval optimization based line sampling method for fuzzy and random reliability analysis (Luyi et al. 2013)
2012	A novel approach for analyzing fuzzy system reliability using different types of intuitionist fuzzy failure rates of components (Kumar et al. 2012)
	A new fuzzy parameters reliability analysis model (Chen et al. 2012)
	Fuzzy structural analysis based on fundamental reliability concepts (Hurtado et al. 2012)
2011	Interpretations of alternative uncertainty representations in a reliability and risk analysis context (Aven et al. 2011)
	Simulation PATROL-F system in form of fuzzy to achieve reliability levels (Tajeddine et al. 2011)
	Reliability optimization by using an ant colony approach (Ahmadizar et al. 2011)
	Bayesian system reliability assessment under the vague environment (Taheri et al.2011)
2010	Fuzzy Bayesian reliability and availability analysis of production systems (Görkemli et al. 2010)
	Hybrid probabilistic fuzzy and non-probabilistic model of structural reliability (Ni et al. 2010)
	Reliability analysis on competitive failure processes under fuzzy degradation data (Wang et al. 2011)
	Fuzzy logic-based direct load control(DLC) of air conditioning loads(ACL) considering nodal reliability characteristics (Goel et al. 2010)
2009	Reliability estimation based on fuzzy lifetime data (Viertl. 2009)
	A production inventory model with fuzzy random demand and with flexibility and reliability considerations (Bag et al. 2009)
	Calculation fuzzy shortest path with the highest reliability (Keshavarz et al. 2009)
	Using fuzzy quality control to improve reliability (Unver et al. 2009)

2008	Fuzzy universal generating functions for multi-state system(MSS) reliability assessment (Ding et al. 2008)
	Moment Method Based on Fuzzy Reliability Sensitivity Analysis for a Degradable Structural System (Jun et al. 2008)
2007	Assessment of human reliability factors by fuzzy approach (Bertolini. 2007)
2006	Bayesian reliability analysis for fuzzy lifetime data (Huang et al. 2006)
	Fuzzy Bayesian system reliability assessment based on exponential distribution 9Wu et al. 2006)
	Fuzzy multi-objective mathematical programming on reliability optimization model (Mahapatra et al. 2006)
	Fuzzy reliability-based optimum design of laminated composites (Junhong et al. 2006)
	Impact of interconnection photovoltaic/wind system with utility on their reliability using a fuzzy scheme (El-Tamaly et al. 2006)
	Time-dependent reliability under consideration of fuzzy randomness (Moller et al. 2006)
2005	Reliability assessment method for pressure piping based on fuzzy probability (Zhou. 2005)
	Composite system reliability assessment using fuzzy linear programming(FLP) (Verma et al. 2005)
2004	Evaluation of a power plant fuzzy reliability (Mohanta et al. 2004)
	Fuzzy reliability analysis of concrete structures (Biondini et al. 2004)
	Fuzzy-based approaches to substation reliability evaluation (Bai et al. 2004)
2003	A numerical algorithm of fuzzy reliability (Jiang et al. 2003)
	A fuzzy logic based approach to reliability improvement estimation during product development (Yadav et al. 2003)
2002	Analysis of structure reliability through fuzzy numerical software approach (Moller et al., Savoia. 2002)
	Incorporating fuzzy operators in the decision network to improve classification reliability (Chiang et al. 2002)
2000	A practical engineering method for fuzzy reliability analysis of mechanical structures 9Bing et al. 2000)
	A fuzzy-based approach for generation system reliability evaluation (Narasimhan et al. 2000)
	Reliability analysis of slopes using fuzzy sets theory (Dodagoudar et al. 2000)
Before 2000	Before 2000, articles are emphasized on basic concepts and researches such as Fuzzy theory in reliability analysis, modeling concepts of fuzzy reliability analysis, analysis of reliability and fault tree On fuzzy sets, evaluation of fuzzy human errors in the Chernobyl accident and etc are done.

In this paper, Neishabour train disaster has been studied in terms of man- machine reliability and with describing the accident based on the relevant documents and evidences, accident system modeling provided.

2. Background of the Neishabour event

The incident began in near the city of Neishabour on 18 February 2004, where 51 railway wagons carrying sulfur, fertilizer, petrol and cotton broke loose from their siding at Abu Muslim Station and after taking a few kilometers some of them are upside down and catch on fire. In this accident over 300 people were killed and several villages were destroyed (IRNA news agency. 29 Bahman 1382, Mehr news agency. 29 Bahman 1382, Fars news. 3 Aban 1384, Mehr news agency. 30 Bahman 1382). This incident Damage is listed in Table 2.

Table 2: Neishabour accident damage [Mehr news agency. 29 Bahman 1382, Mehr news agency. 30 Bahman 1382, IRNA news agency. 7 Esfand 1382, Mehr news agency. 16 Esfand 1382]

Section	Damage

Deaths	state workers 150, ordinary people 139
Injured	460 people
Financial losses	250-300 billion rials
Destruction radius	10 km
100% damaged buildings	90
60% damaged buildings	80
30% damaged buildings	955
Crater caused by the explosion	Depth of 25 to 30 meters, width between 80 and 150 m and 150 m
The number of wagons	51
No. of villages affected	20

In order to further investigate two categories of propositions are collected in Table 3:Certain propositions and uncertain propositions of accident, using these propositions unreliability circuit of event (Figures 1 and 2) can be drawn.

Table 3: Classification of certain propositions and uncertain propositions of Neishabour accident

Certain propositions		1. Scene of disaster (Abu Muslim Station, near Neishabour) 2. Time of the accident (18 February 2004) 3. wagons Freight: sulfur, fertilizer, petrol and cotton 4. Sloping road 5. Overturning of 48 wagons
uncertain propositions	1.Wagon release	1. Breaking brake shoe due to Load pressure 2. Technical defect in the braking system of wagons 3. Probability of Staff carelessness in dragging the Parking brake 4. Probability of Staff carelessness in placing the brake shoes 5. Earthquake 6. Due to human error
	2.Fire	1. Probability that another wagon has caught on fire previously then have bop with overturned wagons. 2. Probability of ammonium nitrate explosion due to clash or fire caused by clash.
	3.Explosion	1. Unlike the regulations, transportation of fuel, fertilizer, sulfur and cotton together. 2. Wrong analysis by firefighters for selecting extinguishing method. 3. Spread of petrol fire and sulfur due to the use of water 4. Using the wrong extinguisher 5. The absence of an expert before starting to fighting fire 6. Explosion of the remaining wagons containing ammonium nitrate 7. Explosion of Petrol wagons due to heat transfer 8. Explosion of sulfur exposed to air or oxidizing materials

3. The unreliability of Neishabour accident

Since this incident has occurred, so we calculate the unreliability of the incident that indicates system failure and probability of event occurrence. For this purpose, Neishabour train accident is modeled as a serial trilateral system, in which, these three members are: wagons escape subsystem, fire subsystem and explosion subsystem (Figure 1).These three subsystems are not independent because creating unreliability in fire subsystem is depends on unreliability in wagons escape subsystem and in the same way creating unreliability in explosion subsystem is depends on unreliability in fire subsystem, In other words, with absence of one of them, the incident will not occur (Zanjani et al. 1389, Madani et al. 1390).

Figure 1: Unreliability circuit of Neishabour accident (Zanjani et al. 1389, Madani et al. 1390)

According to the mentioned certain and uncertain propositions, unreliability circuit of Neishabour accident is drawn in Figure 2.

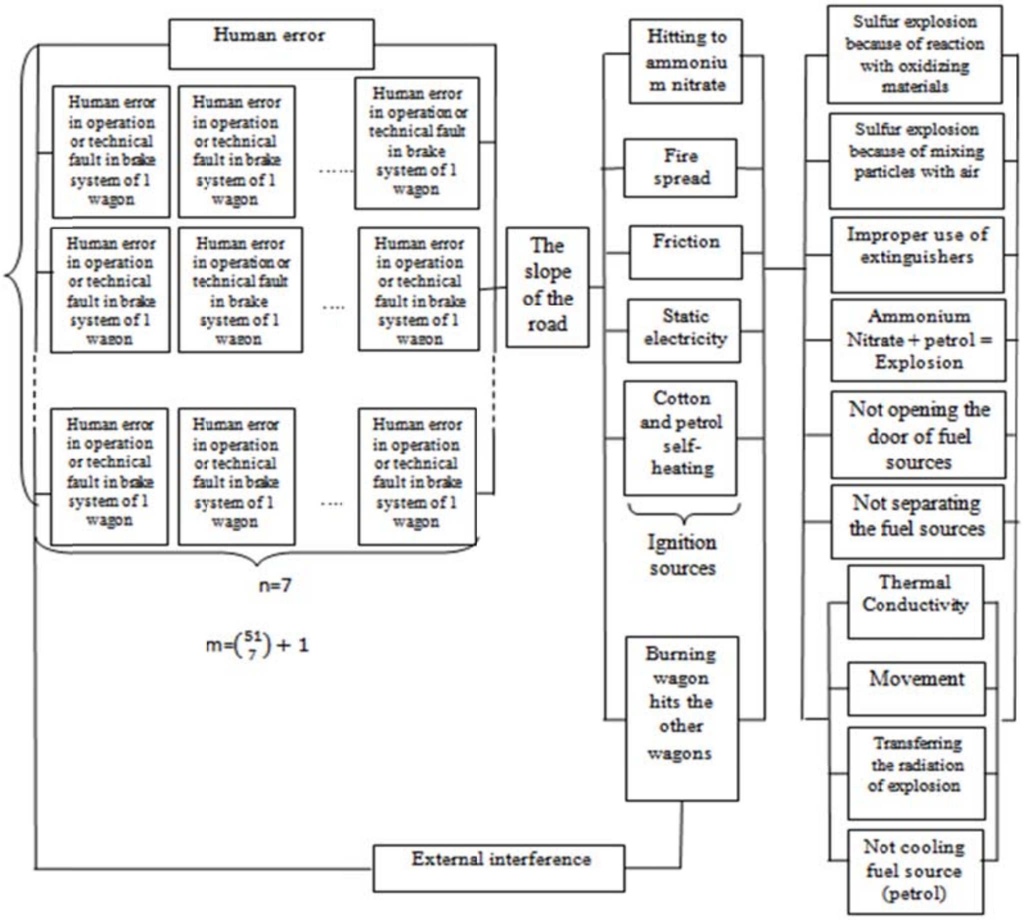

Figure 2: Schematic unreliability circuit of Neishabour accident (Zanjani et al. 1389, Madani et al. 1390)

4. Calculation of fuzzy unreliability

To calculate the unreliability of this incident and given the unreliability circuit shown in Figure 2 and according to expert's opinions, for each subsystem estimated and inaccurate values can be considered and therefore the fuzzy logic can be used.

Before that and to calculate the exact value of unreliability for wagons escape sub system, it is obviously that wagons escape often occurs when the train is without locomotive and parking brake and brake shoes are not used for its harness and control, so the train began to move in the direction of the slope (Akbari et al. 1388). So train stopping system is composed of two types of brake: internal brake for each wagon and line brake shoes (external brake) (Wiley. 2006, Craig, 2002). Each of these brakes can stop the wagon singly. Thus, these two types of brakes work simultaneously and create active redundancy and given that a brake failure rate does not influence on the other brakes failure rates, as a result, the train brake system has system redundancy with hot standby.

In a parallel system consists of two non-repairable elements in which for each element the time interval until the occurrence of failure follows an exponential distribution and failure rate is equal to 1(f / yr), reliability is calculated by the following formula:

$$R(t)=1-\left(1-e^{-\lambda t}\right)^2 \qquad (1)$$

So if the time of evaluation is considered 1 hour leading to accident, then a wagon brakes system reliability will be 0.600 and as a result, system unreliability is 0.400.

Although reliability describes the ability of a system to function under stated conditions for a specified period of time, but for systems with a continuous operation another concept called availability is used. In Neishabour train disaster, since employees have not noticed the braking system downtime and therefore wagons escape is happened thus this system can be considered as a non-repairable system. Now for calculating the wagon unreliability, when internal brake works correctly (X1) and brake shoe work well (X2),train stopping system failure rate can be drawn in Figure 3:

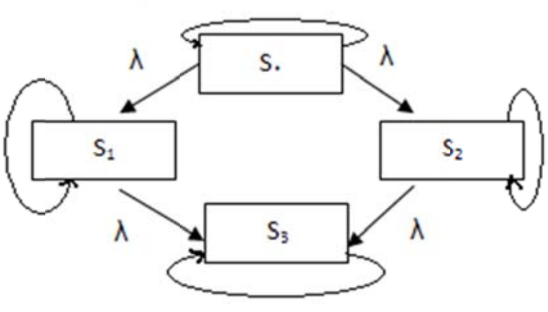

Figure 3: Diagram of state changing system of two train wagons brakes

And according to calculations, availability and non-availability of two train wagon brake system is:

$S0=X1X2$ 0 Failure (2)
$S1=\overline{X}1\ X2$ 1 Failure
$S2=X1\overline{X}$
$S3=\overline{X}1\overline{X}$ 2 Failures

So the availability of this system is equal to:

$$A=P_0(t)+P_1(t)+P_2(t)=e^{-2\lambda+1}+\ 2e^{1-\lambda}-e^{1-2\lambda} \qquad (3)$$

And the non-availability of this system is:

$$U=1-e^{-2\lambda+1}+2e^{1-\lambda}-e^{1-2\lambda} \qquad (4)$$

In other hand and according to railway experts, if 7 wagons of the 51 wagons were completely inhibited (whether by brake shoes or internal brake), wagon escape would not have happened and in this case, the system reliability is calculated according to following formula:

$$R(k,n,p)=\sum_{r=k}^{n} p^r\,(1-p)^{n-r} \qquad (5)$$

The above calculations indicate that the exact unreliability for wagon failure is 0.4.Also, according to railway experts computational error for wagon escape reliability can be considered as a triangle fuzzy number (a_1 ، a_2 ، a_3), thus reliability in form of a triangular fuzzy number is defined according to the following equation:

$$\mu_{\tilde{R}}(x)=\begin{cases}\frac{x-a_1}{a_2-a_1} & , \quad a_1\le x\le a_2\\ \frac{a_3-x}{a_3-a_2} & , \quad a_2\le x\le a_3 \quad , x\in[0,1]\\ 0 & , \quad \text{otherwise}\end{cases} \qquad (6)$$

And the α-cut interval, based on the concept of triangular membership function, can be written as follows [Dutta et al. 2012]:

$$A_\alpha = [(a_2 - a_1)\alpha + a_1, -(a_3 - a_2)\alpha + a_3] \quad (7)$$

So the unreliability of train wagon brake is expressed as (0.2, 0.4, 0.6).Because the brake Systems on all wagons are similar, therefore only one α-cut is defined for subsystems:

$$A_\alpha = [(0.4 - 0.2)\alpha + 0.2, -(0.6 - 0.4)\alpha + 0.6] = [(0.2)\alpha + 0.2, -(0.2)\alpha + 0.6] \quad (8)$$

The intended overall system is a partial parallel system, because if the brakes of just 7 wagons (from 51 wagons) worked the accident had not happened.α-cut in partial parallel systems can be calculated using the following formula:

$$R_\alpha^s=[\sum_{i=k}^{n}\binom{n}{i}(m_1)^i(1-m_1)^{n-i}, \sum_{i=k}^{n}\binom{n}{i}(m_2)^i(1-m_2)^{n-i}] \quad (9)$$

In whichm_1 and m_2 are the α-cut lower and upper bound in the analysis for a wagon. Thus in this formula, the α-cut is as follows:

$$R_\alpha^s=[\sum_{i=7}^{51}\binom{51}{7}((0.2)\alpha+0.2)^i(1-(0.2)\alpha-0.2)^{51-i}, \sum_{i=7}^{51}\binom{51}{7}(-(0.2)\alpha+0.6)^i(1+(0.2)\alpha-0.6)^{51-i}] \quad (10)$$

And by continuing the calculations Table 4 have been obtained. According to this table the reliability of the system is located in the interval (4.8053E -06, 0.013496807).

Table 4: Fuzzy unreliability of wagon escapes partial parallel system

α	One wagon		Wagon escape subsystem	
	L	U	L	U
0	0.2	0.6	0.0016844	0.107578
0.1	0.22	0.58	0.0003612	0.0718858
0.2	0.24	0.56	7.77E-05	0.0442285
0.3	0.26	0.54	1.76E-05	0.0252706
0.4	0.28	0.52	4.81E-06	0.0134968
0.5	0.3	0.5	2.31E-06	0.0067735
0.6	0.32	0.48	2.74E-06	0.0032082
0.7	0.34	0.46	5.72E-06	0.0014398
0.8	0.36	0.44	1.44E-05	0.0006147
0.9	0.38	0.42	3.77E-05	0.0002509
1.0	0.4	0.4	9.86E-05	9.86E-05

Human functioning error probability is divided into four categories: strategic, tactical, opportunistic and scrambled. According to earlier research, they can be considered as Figure 4. (Konstandinidou et al. 2006)

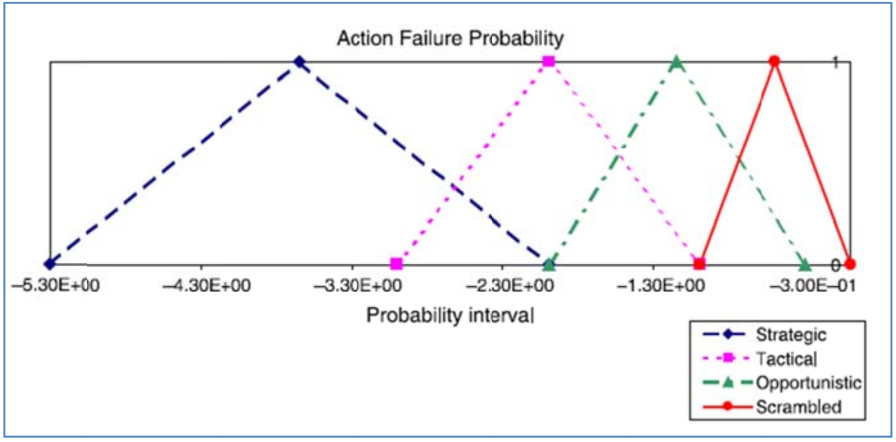

Figure 4: Fuzzy sets representation of the 'action failure probability' output variable. (Konstandinidou et al. 2006)

According to Figure 4, the probability of functioning error is as Table 5:

Table 5: Extent of human functioning error (Konstandinidou et al. 2006)

functioning error probability	
strategic	$10^{-2}\times1<p<10^{-5}\times0.5$
tactical	$10^{-1}\times1<p<10^{-3}\times1$
opportunistic	$10^{0}\times0.5<p<10^{-2}\times1$
scrambled	$10^{0}\times1<p<10^{-1}\times1$

It is enough that in occurrence time of the event, only one of the four aforementioned errors might have occurred, so human error subsystem is considered as a set of four parallel subsystems, including the four errors (Figure 6).It should be noted that external interference error, according to the concept of this error, is considered only in form of the opportunistic error.

Table 6: Unreliability of human error subsystem

	human error subsystem		scrambled		opportunistic		tactical		strategic	
α	U	L	U	L	U	L	U	L	U	L
0	1	0.1099	1	0.1	0.5	0.01	0.1	0.001	0.01	0.000005
0.1	0.97884	0.17982	0.955	0.145	0.4755	0.0345	0.09505	0.00595	0.0095	0.000505
0.2	0.95545	0.24686	0.91	0.19	0.451	0.059	0.0901	0.0109	0.009	0.001005
0.3	0.92977	0.31103	0.865	0.235	0.4265	0.0835	0.08515	0.01585	0.008501	0.001504
0.4	0.90178	0.37238	0.82	0.28	0.402	0.108	0.0802	0.0208	0.008001	0.002004
0.5	0.87145	0.43094	0.775	0.325	0.3775	0.1325	0.07525	0.02575	0.007501	0.002504
0.6	0.83873	0.48676	0.73	0.37	0.353	0.157	0.0703	0.0307	0.007001	0.003004
0.7	0.80359	0.53987	0.685	0.415	0.3285	0.1815	0.06535	0.03565	0.006501	0.003504
0.8	0.76599	0.59029	0.64	0.46	0.304	0.206	0.0604	0.0406	0.006002	0.004003
0.9	0.72589	0.63808	0.595	0.505	0.2795	0.2305	0.05545	0.04555	0.005502	0.004503
1	0.68327	0.68327	0.55	0.55	0.255	0.255	0.0505	0.0505	0.005002	0.005003

Unreliability of the slope of the road subsystem can be considered as a non-fuzzy variable. The slope of the road had definite effect on incident occurrence, so the unreliability of this subsystem is considered 1.

On the other hand, to make ammonium nitrate more sensitive and convert it to an explosive mixture, add the petrol or kerosene (liquid fuels) to it (known as ANFO: Ammonium Nitrite Fuel Oil). Ammonium nitrate at a temperature of 325° C, within 3 seconds absolutely explodes, and soit can be concluded that the possibility of forming an explosive mixture of petrol and ammonium nitrate existed. (Taulbee et al, 2009)

The unreliability of the hitting to ammonium nitrate can be expressed as follows:

$$Q=1-e^{-\lambda t} \qquad (11)$$

With failure rate 1 Fail/yr, the failure function (in 1 hour leading to accident) with Substituting in above formula is equal to 0.63. Due to the exponential format of this formula, fuzzy variable of this subsystem can be considered with Gaussian membership function (Figure 5), with the center of 0.63.

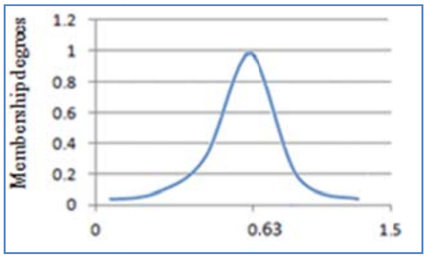

Figure 5: Fuzzy unreliability of hitting to ammonium nitrate subsystem with Gaussian membership function

And α-cut interval based on Gaussian membership function definition in the interval [μ-3σ, μ +3 σ], can be written as follows:

$$\alpha_A = [\mu - \sigma\sqrt{-2\mathrm{Ln}\alpha}, \mu + \sigma\sqrt{-2\mathrm{Ln}\alpha}] \tag{12}$$

According to figure 5 and in Gaussian mode, membership function estimation can be considered with an average of 0.63 and standard deviation 1.

Other subsystems, with little probability have triggered wagons ignition, but because probability of each of them is not clear certainly so fuzzy concept has been used to quantifying the unreliability of this complex system. In each of subsystems mentioned in the unreliability circuit (except what was already mentioned), a triangular fuzzy variable can be considered, Point 0 meaning that this subsystem has not created the ignition and point 1 meaning that this subsystem is the main reason to start fire. Recalling that the considered probabilities are not quantitative probabilities based on the frequency, rather these are qualitative probabilities based on expert opinions or subjective judgments. For each subsystem different vertices centers are considered. The membership functions are shown in Figure 6.

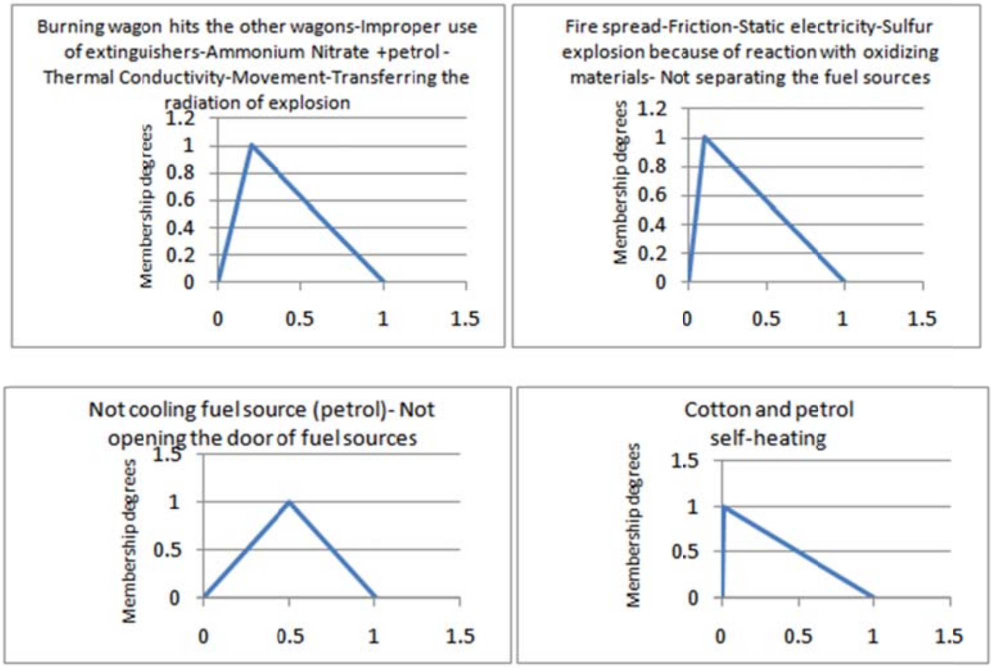

Figure 6: Fuzzy unreliability of subsystems with triangular membership function

Given the unreliability circuit, membership functions and α-cut formula, unreliability α-cut of fire subsystem (which includes several parallel subsystems), with 3 modes of hitting to ammonium nitrate, can be displayed in Table 7.

Table 7: Unreliability of fire subsystem

1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0	α	
1	0.9879	0.9866	0.9897	0.9936	0.9968	0.9987	0.9997	0.9999	1	1	U	**Fire with triangle ammonium nitrate**
0.8104	0.761	0.7057	0.6441	0.5758	0.5003	0.4173	0.3262	0.2266	0.1181	0	L	
0.63	0.667	0.704	0.741	0.778	0.815	0.852	0.889	0.926	0.963	1	U	
0.63	0.567	0.504	0.441	0.378	0.315	0.252	0.189	0.126	0.063	0	L	
1	1.003	1.014	1.019	1.018	1.014	1.008	1.004	1.001	1		U	**Fire with Gaussian ammonium nitrate**
0.81	0.542	0.384	0.227	0.058	-0.129	-0.343	-0.597	-0.915	-1.368		L	
0.63	1.09	1.3	1.47	1.64	1.81	1.98	2.18	2.42	2.78		U	
0.63	0.171	-0.038	-0.215	-0.381	-0.547	-0.724	-0.922	-1.164	-1.516		L	
1	0.964	0.955	0.96	0.971	0.983	0.991	0.997	0.999	1	1	U	**Fire subsystem**
0.49	0.45	0.41	0.36	0.32	0.27	0.22	0.17	0.12	0.06	0	L	
0.08	0.17	0.26	0.35	0.45	0.54	0.63	0.72	0.82	0.91	1	U	**Cotton self-heating**
0.075	0.068	0.06	0.053	0.045	0.038	0.03	0.023	0.015	0.008	0	L	
0.075	0.168	0.26	0.353	0.445	0.538	0.63	0.723	0.815	0.908	1	U	**Static electricity**
0.075	0.068	0.06	0.053	0.045	0.038	0.03	0.023	0.015	0.008	0	L	
0.08	0.17	0.26	0.35	0.45	0.54	0.63	0.72	0.82	0.91	1	U	**Friction**
0.075	0.068	0.06	0.053	0.045	0.038	0.03	0.023	0.015	0.008	0	L	
0.08	0.17	0.26	0.35	0.45	0.54	0.63	0.72	0.82	0.91	1	U	**Fire spread**
0.075	0.068	0.06	0.053	0.045	0.038	0.03	0.023	0.015	0.008	0	L	
0.3	0.4	0.4	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1	U	**Burning wagon hits the other**
0.3	0.27	0.24	0.21	0.18	0.15	0.12	0.09	0.06	0.03	0	L	

Similarly, α-cut of explosion subsystem (which includes several parallel subsystems), can be displayed in Table 8.

Table 8: Unreliability of explosion subsystem

1	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0	α	
0.99555	0.99726	0.99892	0.999694	0.99994	0.999	1	1	1	1	1	U	**explosion subsystem**
0.839	0.797	0.748	0.688	0.616	0.53	0.429	0.308	0.166	0	0	L	
0.2	0.28	0.36	0.44	0.52	0.6	0.68	0.76	0.84	0.92	1	U	**Not cooling fuel source (petrol)**
0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.02	0	L	
0.2	0.28	0.36	0.44	0.52	0.6	0.68	0.76	0.84	0.92	1	U	**Transferring the radiation of explosion**
0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.02	0	L	
0.2	0.28	0.36	0.44	0.52	0.6	0.68	0.76	0.84	0.92	1	U	**Movement**
0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.02	0	L	
0.2	0.28	0.36	0.44	0.52	0.6	0.68	0.76	0.84	0.92	1	U	**Thermal Conductivity**
0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.02	0	L	
0.1	0.19	0.28	0.37	0.46	0.55	0.64	0.73	0.84	0.91	1	U	**Not separating the fuel sources**
0.1	0.09	0.08	0.07	0.06	0.05	0.04	0.03	0.02	0.01	0	L	
0.4	0.46	0.52	0.58	0.64	0.7	0.76	0.82	0.88	0.94	1	U	**Not opening the door of fuel sources**
0.4	0.36	0.32	0.28	0.24	0.2	0.16	0.12	0.08	0.04	0	L	
0.2	0.28	0.36	0.44	0.52	0.6	0.68	0.76	0.84	0.92	1	U	**Ammonium Nitrate + petrol = Explosion**
0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.02	0	L	
0.2	0.28	0.36	0.44	0.52	0.6	0.68	0.76	0.84	0.92	1	U	**Improper use of extinguishers**
0.2	0.18	0.16	0.14	0.12	0.1	0.08	0.06	0.04	0.02	0	L	
0.05	0.145	0.24	0.335	0.43	0.525	0.62	0.715	0.81	0.905	1	U	**Sulfur explosion because of mixing particles with air**
0.05	0.045	0.04	0.035	0.03	0.025	0.02	0.015	0.01	0.005	0	L	
0.05	0.145	0.24	0.335	0.43	0.525	0.62	0.715	0.81	0.905	1	U	**Sulfur explosion because of reaction with oxidizing materials**
0.05	0.045	0.04	0.035	0.03	0.025	0.02	0.015	0.01	0.005	0	L	

Considering the relationships between subsystems in unreliability circuit, finally the unreliability of event is defined as Table 9.

Table 9: Unreliability of Neishabour train accident system

	Gaussian ammonium nitrate subsystem		**triangle ammonium nitrate subsystem**		**Regardless of ammonium nitrate subsystem**	
α	U	L	U	L	U	L
0			1	0.01	1	0
0.1	1.000044276	0.0447103 -	0.988904642	0.061720364	0.988879918	0.007999962
0.2	0.98942408	-0.05439544	0.975516423	0.118750241	0.975172048	0.02754953
0.3	0.977490684	-0.04213694	0.959537397	0.181692074	0.958048468	0.057622738
0.4	0.964179833	-0.01045603	0.940578028	0.249750792	0.936668086	0.097093697
0.5	0.948743747	0.039571851	0.918183003	0.321183903	0.910529071	0.144481878
0.6	0.929673676	0.10624393	0.891922972	0.393931574	0.879801499	0.198029319
0.7	0.904955424	0.1871702	0.8616	0.465951	0.845661	0.255895
0.8	0.87300902	0.2802393	0.827692	0.535418	0.810705	0.316324
0.9	0.835120167	0.38599	0.792634	0.601512	0.78001	0.377766
1	0.802511193	0.5481696	0.764059	0.667535	0.764059	0.438899

According to the Table 9, membership function diagram of the system fuzzy unreliability (respectively from right to left: regardless of ammonium nitrate subsystem, triangle ammonium nitrate subsystem, Gaussian ammonium nitrate subsystem) is shown in Figure 7.

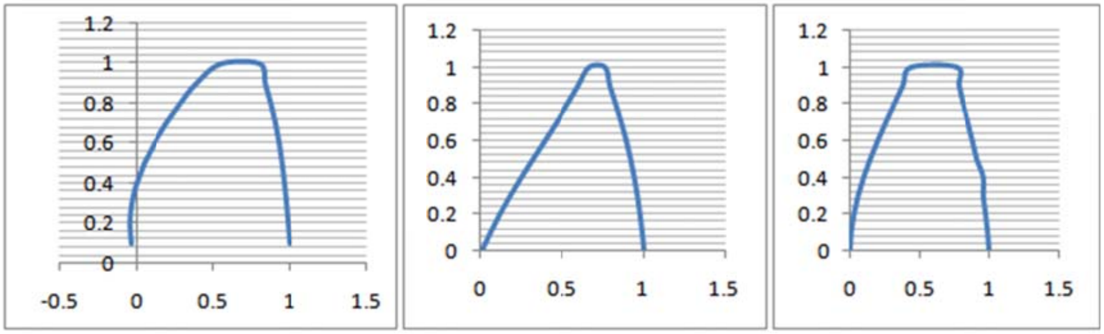

Figure 7: The membership function diagram of the Neishabour train disaster fuzzy unreliability

And to convert the fuzzy value to crisp value, following formula is used (Shavandi, 1385):

$$x^* = \frac{a+b}{2} \tag{13}$$

Thus, the unreliability in the case of ignoring the ammonium nitrate subsystem is 0.601, in the case of triangle ammonium nitrate subsystem is 0.675 and when Gaussian ammonium nitrate subsystem is considered is equivalent to 0.716. According to "the linguistic classification of reliability based on the element fuzzy reliability", the numerical values 0.65-0.75 are relatively high, therefore the unreliability of the overall system, which led to the accident, was relatively high.

5. Conclusions

In accident analysis usually methods like risk analysis, crisis management and etc, are used. For more emphasis on the various components of the system, modeling and reliability analyzing can be used. In this method the relationship between the subsystems and their position in comparison with the total system will become more visible. So in this paper, the fuzzy reliability method is used to analyze the incident and the incident is considered with the systemic and humanitarian dimensions. In the first and to analyzing the incident, using certain and uncertain propositions, unreliability circuit of the event was plotted and then the whole incident was simplified to a serial trilateral system, because of the inability to provide exact values for the unreliability of each subsystem, regarding the opinion of experts, fuzzy logic was applied and depending on type of each subsystem, triangular and Gaussian membership functions were attributed to it. Then by using α-cut method, fuzzy unreliability value of system (In three cases: regardless of ammonium nitrate subsystem, triangle ammonium nitrate subsystem, Gaussian ammonium nitrate subsystem) was calculated. Finally by doing defuzzification for each of three mentioned cases separately and comparing the obtained result with the classification table of linguistic variables, unreliability of the system was identified.

Based on the results, by enhancing precision and discipline (in wagon escape subsystem), planning appropriate instruction for material arrangement inside the wagon also in putting wagons together (in fire subsystem) and finally by separating and cooling resources (in explosion subsystem), with high probability similar events do not occur.

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