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Model Development of Causation Chemical Reactivity Hazards on Downstream Chemical Industry in Indonesia

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Abstract: Downstream chemical industry on Indonesia generally is in middle low scale and has conventional technology and limited human resources. In the other hand, high amount of chemical material usage and products being produced are vary that make the risk of accident of chemical reactivity hazards rate become considerably high. The objective of this study was to develop the causation model of chemical reactivity hazards on downstream chemical industry in Indonesia. By knowing the variables which cause the chemical reactivity hazards then we can take the preventives actions. The research was performed on three downstream chemical companies by distributing questionnaires to 586 workers. Modeling process was done by *structural equation modeling* method to count correlation within variables. From causation model of chemical reactivity hazards we can get relation within variables as follows: Safety Commitment has strong correlation with training process and risk assessment. Training has strong correlation with worker competency and worker competency gives strong impact to decreasing worker errors. Hazards and risk assessment have strong correlation with Standard Operation Procedure (SOP) and workplace environment. Standard Operation Procedure affects on worker errors and workplace environment. The worker error factor gives impact directly on the triggering factors of chemical reactivity hazards which are errors on mixing and process parameter, error on mixing affects contamination and imperfect mixing. Workplace environment factor affects directly on error on storing and this affects on the contamination, the last two factors become the triggering factor of chemical reactivity hazards.

Key words: Structural Equation Modelling · Latent Variable · Correlation · Structural Coeffecient · Goodness of Fit

INTRODUCTION

Accident can be categorized into two groups, individual and organization [1]. Individual accident can be classified as minor accident and organization accident as major accident or can be renowned as *catastrophic accident*. Major accident rarely occurred; there must be vast disadvantage in property, worker and environment if it happened. Major accident generally occurred in industry using modern technology such as nuclear energy industry, petrochemical industry, chemical industry, etc.

Dr. Michael Zabetakis, director of MSHA's academy (Mine Safety and Health Administration) developed Domino theory with new concept in direct accident causation model. Direct causation concept is releasing energy or hazardous material that unplanned. Dr. Zabetakis explained that most of accidents are caused by energy releasing (electricity, chemical, mechanic, heat, radiation) or hazardous chemical material (such as CO, CO2, H2S, CH4) that was unplanned or unexpected. Most of this releasing energy was caused by unsafe act and unsafe condition. In the beginning, most of accident prevention focused on identifying and correcting unsafe act and condition. Meanwhile, identifying and correcting basic accident causation should be done for further improvement. Basic accident causation can be divided into three relating groups [2]:

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- Management policy and decision
- Personal factor (worker)
- Environmental Factor

The first group are management policy and decision, such as production target and safety; working procedure; recording; responsibility delegation and authority and trust; employee selection, training, placement, supervision and direction; communication procedure, inspection procedure; tools, supply and facility design, purchasing and maintenance; standard operation procedure and emergency; cleanliness and tidiness.

Bird and Loftus [3] in 1970s developed domino theory by Heinrich using more modern thinking. This theory was not too different with Heinrich's which involved 2 accident factors, unsafe act and unsafe condition. But in this theory, Bird and Loftus not anymore focused on error occurred on human/worker, but how the management played the role to control in preventing the accident.

Reason [1] developed organization accident investigation model. This model related various elements contributing to organization accident. Based on this theory, organization accident started from failure in organization factor in making strategic decision, organization process such as forecasting, budgeting, human resource allocation, communication, audit, planning etc. This organization failure will color organization culture, worker attitude and worker ways in doing business process. The consequence of organization factor failure would spread to the whole work area and triggered unsafe act in operational procedure. This included insufficient working tools and inadequate training, lack of supervision, insufficient machine maintenance, bad communication etc. Those things trigger and increase the potential of organization accident.

Chemical reactivity hazard caused fatal accident in few industries [4-7], some of them are :

- In 1976, uncontrolled chemical reaction in Saveso, Italy, caused dioxin contamination up to a few miles from the site.
- In 1984, Isocyanate leaking in Bhopal, India, 2000 dead.
- In 2001, ammonium nitrate explosion near Toulouse, France, 30 dead, 2500 injured and destructed one third part of the Toulouse city.
- On October 13th 2002, explosion in chemical material distillation tower owned by First chemical Corporation Plant in Pascagoula, Mississippi, 3 injured and destructed most of the factory and triggered fire.
- On March 23rd 2005, huge explosion in BP Texas City Refinery, 15 dead and 180 injured.

In batch process system, worker role in operating production process is very dominant, especially in chemical industry using conventional technology. From taking the raw material in the warehouse, continue with weighing, then delivering to production department to put it in to reactor or vessel for production processed are done manually by worker or field operator. These also apply for process parameter controlling such as temperature, pressure, mixture speed, mixture time, pH quality controlling, viscosity, water addition etc. are done manually by worker or operator on the field. So, operator is integrated part of controlling system for batch process system. Even operator or field operator must make critical decision in production process. Since worker role in batch process system is huge, so the attention to the worker capacity and quality become very important factor to prevent error that can cause chemical reactivity hazards accident.

Rasmussen [8] found four main trigger in chemical reactivity hazards accident based on study in 190 chemical reactivity accidents, they are (1) polluter, (2) mixing error, (3) process condition error and (4) imperfect mixture. According to Johnson [4], reactivity hazards can also be caused by storage process error. In the research was done modeling process caused by these five chemical reactivity hazard main triggers on downstream chemical industry in Indonesia.

Theoritical Model: The hypothesis model causation of chemical reactivity hazard on downstream chemical industry was developed on this research (Fig. 1). This hypothesis model was developed based on discussion with the workers and management from 3 companies of downstream chemical industry and supported by various theories. There are 6 variables of accident causation which will be put into modeling, they are: Safety Commitment, Training and Competency, Worker Error Factor, Standard and Operation Procedure, workplace environment and Hazard & Risk Assessment. All those variables are hypothetically give impact on major trigger of chemical reactivity hazard i.e. mixing error, process parameter error, contamination, imperfect mixing and storing error.

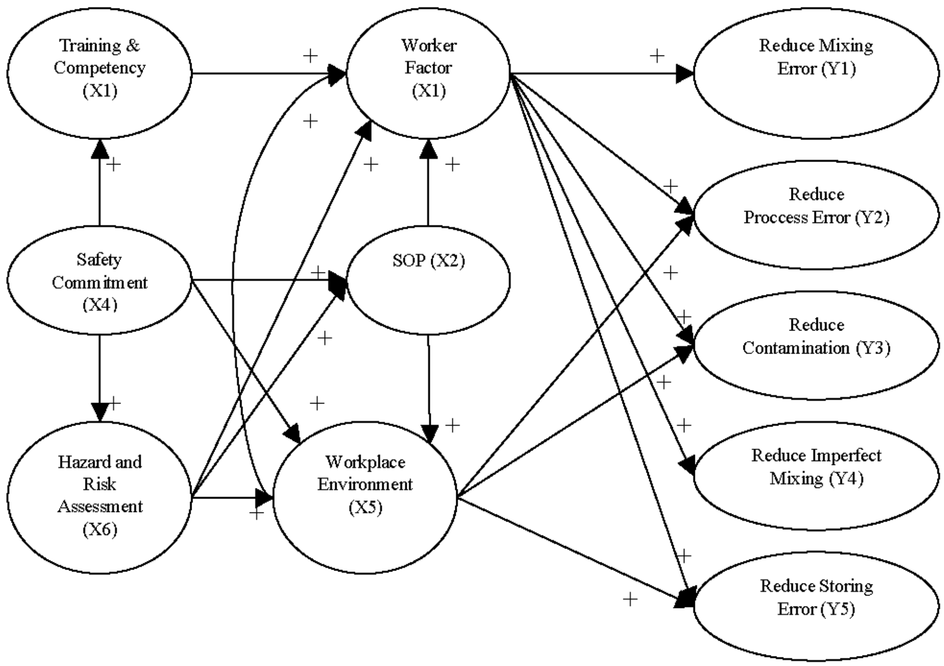

Fig. 1: Hypothesis Model of Causation Chemical Reactivity Hazard

Below is zero hypotheses which is developed based on structural model from qualitative study.

H_{01} : Safety commitment has positive influence significantly to competency or providing training for worker

H_{02} : Safety commitment has positive influence significantly to risk assessment on workplace

H_{03} : Safety commitment has positive influence significantly to Standard Operation Procedure

H_{04} : Safety commitment has positive influence significantly to workplace environment

H_{05} : Competency has positive influence significantly to reduce worker error

H_{06} : Risk Assessment has positive influence significantly to reduce worker error

H_{07} : Risk Assessment has positive influence significantly to Standard Operation Procedure

H_{08} : Risk Assessment has positive influence significantly to workplace environment

H_{09} : Standard Operation Procedure has positive influence significantly to reduce worker error.

H_{010} : tandard Operation Procedure has positive influence significantly to improve workplace environment.

H_{011} : Worker factor has positive influence significantly to reduce mixing error.

H_{012} : Worker factor has positive influence significantly to reduce process parameter error

H_{013} : Worker factor has positive influence significantly to reduce contamination.

H_{014} : Worker factor has positive influence significantly to reduce imperfect mixing.

H_{015} : Worker factor has positive influence significantly to reduce storing error

H_{016} : Workplace environment has positive influence significantly to reduce process parameter error

H_{017} : Workplace environment has positive influence significantly to reduce contamination

H_{018} : Workplace environment has positive influence significantly to reduce storing error.

Safety Commitment: Each company must have commitment to protect safety and health for all workers which may exposed to safety and health impact from their working activities [9]. In operation manual guide book OHSAS 18001 produced by British Standard Institution year 2004, OSH commitment was shown in management policy which prioritize OSH principal, willing to allocate sufficient fund and resources to OSH program, involvement of top management and management lines in each OSH program and to communicate OSH policy and program to all employees. From OSH commitment definition formed by BSI 2004 it can be understood that OSH commitment is the foundation from all OSH program in a company..

Training and Competency: A worker who got sufficient training and carefully perform his job will avoid working accident even when he carried out dangerous task, on the contrary worker who did not get training and did not carefully perform his job will get accident even when he carried out safely task [2].

Training for worker must be conducted before they perform their task. Each new employee must get sufficient training for each task that they will do. Assignment on worker which had not had training yet to perform what his incapable with will have high possibility to get an accident himself. A worker must understand well each stage the task which performed, they must not understand just on the technical process, but more to safety aspect of their job. An effective training will improve competency or ability and worker skill in perform his job. The given training must suitable to his responsibility and authority of the given assignment. [10].

Worker Error Factor: Workers are one part of the system that include all of the part of the organization or work environment - equipment, technology, environment, organization, training, policies and procedures. Human error is an inbalance between what the situations requires, what the person intends and what he/she does and rooted in failure of the system or the organization [11] .

Research result from Rasmussen [8] showed that from 190 chemical reactivity hazard accidents was found that major factors contribute to that accident are lack of worker knowledge (34%), design error (32%), procedure error (24%) and operator error (16%). Among various studies which performed showed that worker error is influenced by worker competency, workplace environment and working procedure [12].

Standard Operation and Procedure: International management system like ISO 9001 requires establishing standard operation on elements which already determined. One of the objectives of establishing procedure is to preserve each activity process performed consistently to maintain quality of product being produced. The OSH management system (OHSAS 18001) also requires establishing procedure for certain elements, for example OHSAS 18001 requires establishing procedure to identify OSH hazard and procedure to indentify all law, regulation or standard related to the risk in the company.

One of the objectives of establishing OSH procedure is to avoid working accident or control the risk and hazard on working place. As example *Chemical Reactivity Management System* produced by CCPS requires identification of chemical reactivity hazard to avoid chemical reactivity hazard in working place.

Standard operation and Procedure control stages which must be taken in each task process. In the procedure and standard operation can also be written specification or parameter in a process, product quality standard, cleanliness standard, chemical exposure treshold limit, process flow, process responsibility, personal protective equipment needed, etc. Procedure and standard operation will become guidance for all workers in performing their job so it will give influence to how they work and on to workplace environment such as cleanliness working place, tools maintenance, completeness of personal protective equipment needed, workplace environment like ventilation, lighting and noise.

Workplace Environment: According to theory of working accident by Zabetakis, that the most fundamental cause of accident is management policy, worker factor and workplace environment factor. The workplace environment factor is also called as unsafe condition, as example is using broken tools, explosion and fire hazards, dirty working area, bad ventilation, unsufficient light, inadequate working tools, no available warning system and many other [2].

Workplace environment will influence directly on worker factor. The worker cannot work well and safely if the workplace environment is not safe and comfort. For example if light is not sufficient then it will be very dangerous for worker to work, this also the same with inadequate ventilation which will be stuffy and lack of air that will disturb concentration of worker in acomplishing their job.

Hazard and Risk Assessment: Risk assessment is the most basic element in succesfull implementation of occupational safety and health. The principle for risk assessment implementation must be proactive. Hazard indentification and risk control must be performed before accident happened. Hazard identification process, risk study, implementation and risk control review must be based on OSH system throughly [9].

Research Methodology: Research methodology used in this research consisted in 3 stages: questionnaire developing, data taking through questionnaire and developed chemical reactivity hazards causation model.

Chemical Reactivity Hazard Developing Questionnaire: Question form that developed in the questionnaire was closed ended question. This closed ended question form was chosen because it was easy to guide respondence answer and to be processed [13]. Respondence chose the available answer for each question or given statement.

Answer alternative was given in the form of scale from 1 to 5 following Linkert Scale. Number 1 was really disagree and number 5 was really agree.There was also available for the answer don't know (0) for giving alternative to the respondence if there was no relation to their work or they really didn't know the answer. Linkert scale form was used in many safety behavior researches, culture and work safety environment as done by Seo D.C. *et al.* [14]. Sixty four questions were developed from variables of hypothesis model in this research.

Questionare Trial: Developed questionare was trialed to 40 workers to test reability of the questionare. The questionare was distributed to 2 chemical companies where the research was done. Questionnaire was delivered to OSH department in each company. Every page of questionnaire was completed by preamble letter and explanation about the obje#tive and system to fill in the questionnaire.

Questionnaire Data Sampling: After the trial, questionnaire was given to more than 500 workers from 3 chemical industry companies where the research was done. Questionnaire distribution process is similar with trial distribution process. Questionnaire was distributed to all worker involve with production process in 3 companies through OSH department. The distributed questionnaire numbers for each company are as follow:

PT XYZ	:	396 questionnaires, handed over on April 1st and April 20th 2010.
PT CDF	:	40 questionnaires, handed over on April 5th 2010
PT PQR	:	150 questionnaires, handed over on April 6th 2010
Total	:	586 questionnaires

Total questionnaires returned by respondence through OSH department are as follow:

PT XYZ	:	365 questionnaires, received on April 9th and April 30th 2010.
PT CDF	:	40 questionnaires, received on April 9th 2010
PT PQR	:	149 questionnaires, received on April 20th 2010
Total	:	554 questionnaires

Returning questionnaire rate from these 3 companies was quite high (94.5%). This showed that worker participationt rate in assisting to enhance OSH management system in general and especially for chemical reactivity hazard was really good. The cooperation and support from the company management in this research was really good, too.

Model Development of Chemical Reactivity Hazards Causation: The information from the questionnaires was processed using statistic program SPSS 16 and LISREL 8.50. SPSS data processing was for questionnaire reability test, normality and data multicolinearity. LISREL was used to process Structural Equation Modelling (SEM) of CRH causation

There are assumptions that must be fulfilled before doing SEM modeling process, [15]:

- Normality; data must fulfilled normality assumption, if it was fulfilled SEM modeling process can be done.
- Linearity; relation between variables must fulfill assumption of linear relation.
- Multicolinearity; there was no colinearity or perfect relation between variables.
- Outlier; there was no outlier in the data.

There were six stages in making SEM that must be done [15], they are:

- Making definition about individual construction, this stage was done during developing questionnaire.
- Developing measurement model.
- Designing a study to get empiric result.
- Appraising validity of measurement model.
- Specifying structure model.
- Appraising validity of structure model.

RESULTS

Questionnaire Reliability Test: Questionnaires were tested onto 40 respondents from two companies where the study being performed to see the reliability of developed questionnaire. The tested respondents were selected by company management. But respondents must represent department related with production process i.e.: production, laboratory, warehouse, engineering and OSH department.

Questionnaire were distributed via OSH department to be hand over to respondents which selected by management. Questionnaire were submitted in opened envelop and returned in closed one through OSH department to be hand over to researcher. Respondents were given 2 working days to return the answered questionnaire.

Table 1: Calculation Result Cronbach Alpha (Reability)

No	Latent Variable	Cronbach Alpha
1	Training and Competency (X1)	0.80
2	Procedure and standard operation (X2)	0.78
3	Worker Factor (X3)	0.76
4	Safety Commitment (X4)	0.83
5	Workplace Environmental Safety (X5)	0.77
6	Hazard or Risk Assessment (X6)	0.77
7	Mixing Error (Y1)	0.75
8	Contamination / Impurity (Y2)	0.82
9	Error in production process parameter (Y3)	0.86
10	Imperfect Mixing (Y4)	0.82
11	Storing error for raw material /product (Y5)	0.75

The result data questionnaires from 40 respondents (100% respond rate) calculated with SPSS statistic program version 16 to see the questionnaire reliability (*cronbach alpha*). The *cronbach alpha* statistic calculation result is as shown on Table 1.

From questionnaire trial result to see reliability questionnaire, all variables in the questionnaire has had cronbach alpha > 0.70, it means the composed questionnaire has sufficient reliability level and acceptable.

Structural Equation Modelling of CRH Causation: The *Confirmatory Factor Analysis* (CFA) method from program LISREL 8.50 was used to develop measurement model. Regression equation measurement model for each indicator variable (Q=Question) can be seen on Table 2.

From table 2 above we can see that t-score value (calculation) has score > 1.96 at p value <0.05, it means that all indicator variables have significance with p< 0.05. So it can be concluded that all indicator variables can be put into development of structural model.

After we got measurement model for all latent variables, then next step is to develop structural model which was built from measurement model. The construction of structural model was taken from hypothesis model (Figure 1).

In order to answer zero hypothesis of hypothesis model, the modeling were developed with LISREL program 8.50 to calculate significance value relationship for each variable based on hypothesis model. Figure 2 is a structural model based on hypothesis model with loading factor value which showed relationship within variables.

Calculation result of Goodness Of Fit (GOF) which show fit degree between hypothesis model with data is written on Table 2. From Table 2 it can be seen that 4 GOF indexes show good value of data-model Goodness of Fit and only one GOF index which show not-satisfactory value of data-model Goodness of Fit, then it can be concluded that in general Goodness of Fit is good.

Table 2: Regression Equation of CRH Causation Measurement Model

Equation	t-score	Error Variance	R^2
Q1 = 0,38*COMPETENCY	4.61	3.25	0.04
Q2 = 0,20* COMPETENCY	3.06	2.09	0.02
Q3 = 0,20* COMPETENCY	3.26	1.85	0.02
Q4 = 0,15* COMPETENCY	2.07	2.62	0.01
Q5 = 0,95* COMPETENCY	20.61	0.55	0.62
Q6 = 0,93* COMPETENCY	19.96	0.57	0.60
Q7 = 0,78* COMPETENCY	14.65	1.00	0.38
Q8 = 0,72* COMPETENCY	16.82	0.58	0.47
Q43 =0,62* COMPETENCY	15.04	0.60	0.39
Q44 = 0,17* COMPETENCY	3.51	1.17	0.03
Q45 = 0,35* COMPETENCY	6.44	1.31	0.08
Q46 = 0,24* COMPETENCY	4.89	1.08	0.05
Q47 = 0,37* COMPETENCY	6.58	1.44	0.09
Q14 = 0,37*WORKER	6.80	1.32	0.09
Q15 = 0,33* WORKER	6.61	1.15	0.09
Q16 = 0,59* WORKER	7.97	2.41	0.13
Q17 = 1,05* WORKER	15.16	1.60	0.41
Q18 = 0,94* WORKER	15.81	1.12	0.44
Q19 = 0,81* WORKER	13.90	1.19	0.35
Q20 = 0,58* WORKER	9.10	1.66	0.17
Q21 = 0,60*COMMITMENT	11.77	1.03	0.26
Q22 = 0,94* COMMITMENT	16.04	0.97	0.48
Q23 = 1,03* COMMITMENT	16.35	0.99	0.52
Q24 = 0,82* COMMITMENT	15.08	0.99	0.40
Q25 = 0,96* COMMITMENT	17.51	0.98	0.48
Q26 = 0,79* COMMITMENT	14.43	0.95	0.39
Q27 = 0,66* COMMITMENT	12.05	0.96	0.31
Q28 = 0,67* COMMITMENT	13.02	0.92	0.33
Q29 = 0,13* COMMITMENT	2.12	1.95	0.01
Q9 = 0,71*SOP	11.63	1.47	0.25
Q10 = 0,91*SOP	14.26	1.37	0.37
Q11 = 0,76*SOP	14.20	1.07	0.35
Q12 = 0,90*SOP	16.75	0.92	0.47
Q13 = 0,80*SOP	16.27	0.79	0.45
Q30 = 1,03*ENVIRONMENT	16.28	1.33	0.44
Q31 = 0,94* ENVIRONMENT	15.30	1.33	0.40
Q32 = 0,85* ENVIRONMENT	15.58	0.99	0.42
Q33 = 0,73* ENVIRONMENT	14.22	0.95	0.36
Q34 = 0,55* ENVIRONMENT	11.90	0.83	0.26
Q35 = 1,05* ENVIRONMENT	16.67	1.30	0.46
Q36 = 0,93* ENVIRONMENT	13.26	1.87	0.32
Q37 = 0,61* ENVIRONMENT	11.55	1.10	0.25
Q38 = 0,65*RISKASSESSMENT	10.77	1.53	0.22
Q39 = 1,11* RISKASSESSMENT	15.08	1.88	0.40
Q40 = 1,04* RISKASSESSMENT	16.50	1.26	0.46
Q41 = 0,86* RISKASSESSMENT	15.74	1.04	0.42
Q42 = 1,13* RISKASSESSMENT	15.48	1.84	0.41
Q48 = 1,46*MIXING	19.52	1.01	0.68
Q49 = 1,39* MIXING	21.45	1.09	0.64
Q50 = 1,66* MIXING	22.73	1.19	0.70
Q55 = 1,44*PARAMETER	22.19	1.17	0.64
Q56 = 1,61*PARAMETER	25.17	0.87	0.75
Q57 = 1,67*PARAMETER	24.37	1.12	0.71
Q51 = 1,15*CONTAMINANT	20.11	0.99	0.57
Q52 = 1,49* CONTAMINANT	23.66	0.88	0.72
Q53 = 1,51* CONTAMINANT	22.90	1.16	0.66
Q54 = 1,93* CONTAMINANT	32.64	0.10	0.97
Q58 = 1,45*IMPERFECT	20.55	1.40	0.60
Q59 = 1,61* IMPERFECT	22.76	1.23	0.68
Q60 = 1,43* IMPERFECT	18.27	2.12	0.49
Q61 = 1,47*STORING	21.76	1.00	0.68
Q62 = 1,60* STORING	23.01	1.02	0.71
Q63 = 1,52* STORING	22.14	1.19	0.66
Q64 = 1,47* STORING	18.92	1.91	0.53

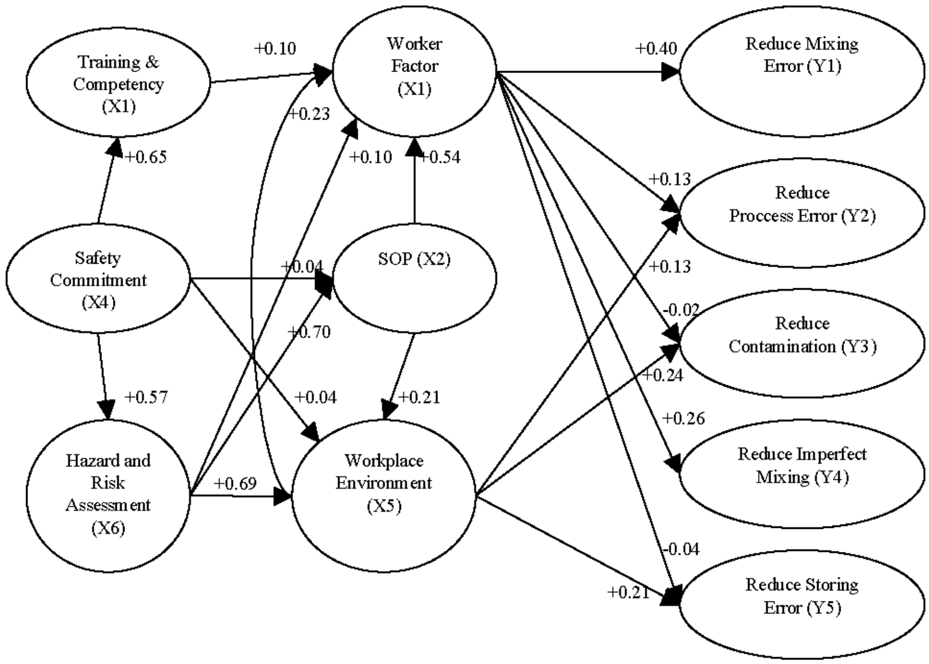

Fig. 2: CRH Causation Structural Model Based on Hypothesis Model

Table 2: Data-Model Goodness of Fit from Causation Hypothesis Structural Model

Index GOF	Proper Value Limit	Calculation Result	Remark
RMSEA	<0.07 with CFI> 0.90	0.032	Good
CFI	>/= 0.90	0.940	Good
SRMR	</=0.08 with CFI >0.92	0.080	Good
IFI	>/=0.90	0.940	Good
GFI	>/=0.90	0.870	Not satisfactory

Table 3: Regression Equation of CRH Causation Hypothesis Structural Model

No	Equation	Error Variance
1	COMPETENCY = 0.65*COMMITMENT	Errorvar.= 0.58 , R^2 = 0.42
2	WORKER FACTOR = 0.10*COMPETENCY + 0.54*SOP + 0.23*ENVIRONMENT	
	+ 0.10* RISK ASSESSMENT	Errorvar.= 0.24 , R^2 = 0.76
3	SOP = 0.70* RISK ASSESSMENT+ 0.038*COMMITMENT	Errorvar.= 0.48, R^2 = 0.52
4	ENVIRONMENT = 0.21*SOP + 0.69* RISK ASSESSMENT + 0.044*COMMITMENT	Errorvar.= 0.23 , R^2 = 0.77
5	RISK ASSESSMENT = 0.57*COMMITMENT	Errorvar.= 0.68 , R^2 = 0.32
6	MIXING = 0.40*WORKER	Errorvar.= 0.75 , R^2 = 0.25
7	PARAMETER = 0.13*WORKER + 0.13*ENVIRONMENT	Errorvar.= 0.74, R^2 = 0.26
8	CONTAMINATION = - 0.024*WORKER + 0.24*ENVIRONMENT	Errorvar.= 0.75 , R^2 = 0.25
9	IMPERFECT= 0.26*WORKER	Errorvar.= 0.73 , R^2 = 0.27
10	STORING= - 0.037*WORKER+ 0.21*ENVIRONMENT	Errorvar.= 0.87 , R^2 = 0.13

From model equation of hypothesis structural above, the regression equation were made from 10 endogen variables and 1 exogen variable. From hypothesis structural model above, we got 10 equations, Table 6 describes structural model regression equation from hypothesis model.

From hypothesis structural model equation above, the regression equation were made from 10 variables endogen and 1 variable exogen. From hypothesis structural model above, we can get 10 equations; Table 3 describes structural model regression equation from hypothesis model.

Table 4: Value of Structural Coefficient and Significance of CRH Causation Hypothesis Model

Path	SC Value	* t-calculation Value		H_0
Commitment _ Competency	0.65	4.5	Significant	H_{01}: Accepted
Commitment _ Risk Assessment	0.57	8.3	Significant	H_{02}: Accepted
Commitment _ SOP	0.04	0.64	Not Significant	H_{03}: Rejected
Commitment _ Environment	0.04	0.87	Not Significant	H_{04}: Rejected
Competency _ Worker	0.10	1.59	Not Significant	H_{05}: Rejected
Risk Assessment _ Worker	0.10	0.81	Not Significant	H_{06}: Rejected
Risk Assessment _ SOP	0.70	6.59	Significant	H_{07}: Accepted
Risk Assessment _ Environment	0.69	6.04	Significant	H_{08}: Accepted
SOP _ Worker	0.54	4.56	Significant	H_{09}: Accepted
SOP _ Environment	0.21	2.69	Significant	H_{010}: Accepted
Worker _ Mixing	0.40	4.62	Significant	H_{011}: Accepted
Worker _ Process	0.13	1.21	Not Significant	H_{012}: Rejected
Worker _ Contamination	-.0.024	-0.22	Not Significant	H_{013}: Rejected
Worker _ Imperfect	0.26	4.06	Significant	H_{014}: Accepted
Worker _ Storing	-.0.037	-0.28	Not Significant	H_{015}: Rejected
Environment _ Process	0.13	1.19	Not Significant	H_{016}: Rejected
Environment _Contamination	0.24	2.17	Significant	H_{017}: Accepted
Environment _ Storing	0.21	1.74	Not Significant	H_{018}: Rejected

*t-calculation < 1.96 not significant, Ho rejected.

Table 5: Goodness of Fit Data-Model from Hypothesis Structural Model [15]

Index GOF	Proper Value Limit	Calculation Result	Remark
RMSEA	<0.07 with CFI> 0.90	0.032	Good
CFI	>/= 0.90	0.940	Good
SRMR	</=0.08 with CFI >0.92	0.080	Good
IFI	>/=0.90	0.940	Good
GFI	>/=0.90	0.870	Not Satisfactory

Table 6: Regression Equation of Hypothesis Structural Model

No	Equation	Error Variance
1	COMPETENCY = 0.65*COMMITMENT	Errorvar.= 0.58 , R^2 = 0.42
2	WORKER FACTOR = 0.10*COMPETENCY + 0.54*SOP + 0.23*ENVIRONMENT + 0.10* RISK ASSESSMENT	Errorvar.= 0.24 , R^2 = 0.76
3	SOP = 0.70* RISK ASSESSMENT+ 0.038*COMMITMENT	Errorvar.= 0.48, R^2 = 0.52
4	ENVIRONMENT = 0.21*SOP + 0.69* RISK ASSESSMENT + 0.044*COMMITMENT	Errorvar.= 0.23 , R^2 = 0.77
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10	STORING= - 0.037*WORKER+ 0.21*ENVIRONMENT	Errorvar.= 0.87 , R^2 = 0.13

Table 7: Value of Structural Coefficient and Significance of Hypothesis Model

Path	SC Value	* t-calculation Value		H_0
Commitment _ Competency	0.65	4.5	Significant	H_{01}: Accepted
Commitment _ Risk Assessment	0.57	8.3	Significant	H_{02}: Accepted
Commitment _ SOP	0.04	0.64	Not Significant	H_{03}: Rejected
Commitment _ Environment	0.04	0.87	Not Significant	H_{04}: Rejected
Competency _ Worker	0.10	1.59	Not Significant	H_{05}: Rejected
Risk Assessment _ Worker	0.10	0.81	Not Significant	H_{06}: Rejected
Risk Assessment _ SOP	0.70	6.59	Significant	H_{07}: Accepted
Risk Assessment _ Environment	0.69	6.04	Significant	H_{08}: Accepted
SOP _ Worker	0.54	4.56	Significant	H_{09}: Accepted
SOP _ Environment	0.21	2.69	Significant	H_{010}: Accepted
Worker _ Mixing	0.40	4.62	Significant	H_{011}: Accepted
Worker _ Process	0.13	1.21	Not Significant	H_{012}: Rejected
Worker _ Contamination	-0.024	-0.22	Not Significant	H_{013}: Rejected
Worker _ Imperfect	0.26	4.06	Significant	H_{014}: Accepted
Worker _ Storing	-0.037	-0.28	Not Significant	H_{015}: Rejected
Environment _ Process	0.13	1.19	Not Significant	H_{016}: Rejected
Environment _Contamination	0.24	2.17	Significant	H_{017}: Accepted
Environment _ Storing	0.21	1.74	Not Significant	H_{018}: Rejected

*t-calculation < 1.96 not significant, Ho rejected.

From regression equation of hypothesis structural model above on table 3, it showed that structural coefficient for each path is corresponding with zero hypotheses which were made. Structural Coeffecient (SC) value and hypothesis tested (t-calculation) for each path can be seen on Table 4.

The calculation result of Goodness of Fit which shows fit degree between hypothesis models with data is put on Table 5. From that table it can be seen that 4 GOF indexes show Goodness of Fit is good value and only one GOF index show not satisfactory value, then it can be concluded that generally Goodness of Fit data-model is good.

From regression equation of hypothesis structural model on Table 6, it is shown that structural coefficient for each path is corresponding with zero hypotheses which were made. SC value and hypothesis tested (t-calculation) for each path can be seen on Table 7.

In order to get more suitable model or fit with empiric data, early model can be modified and retested with the same data. Researcher can modify early model into some models with the purpose to find one model which more suitable to the data well, but it must have the character that each parameter can be interpreted well.

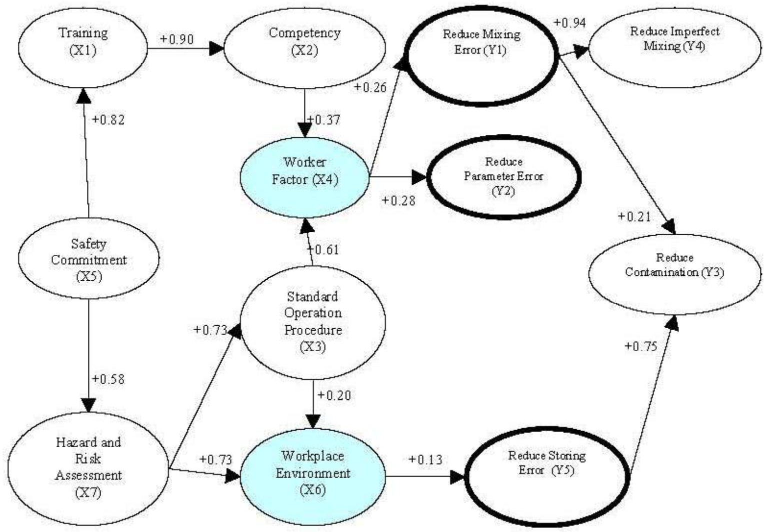

Fig. 3: Modified CRH Causation Structural Model.

Table 8: Value of Goodness of Fit Data-Model from Modified CRH Structural Model

Index GOF	Proper Value Limit	Calculation Result	Remark
RMSEA	<0.07 with CFI> 0.90	0.023	Good
CFI	>/= 0.90	0.960	Good
SRMR	</=0.08 with CFI >0.92	0.055	Good
IFI	>/=0.90	0.960	Good
GFI	>/=0.90	0.890	Not Satisfactory

Table 9: Regression Equation of Modified CRH Structural Model

No	Equation	Error Variance
1	TRAINING = 0.82*COMMITMENT	Errorvar.= 0.33 , R^2 = 0.67
2	KNOWLEDGE = 0.90*TRAINING	Errorvar.= 0.22 , R^2 = 0.78
3	WORKER FACTOR = 0.37*KNOWLEDGE + 0.61*SOP	Errorvar.= 0.10 , R^2 = 0.90
4	SOP = 0.73*RISK ASSESSMENT	Errorvar.= 0.46 , R^2 = 0.54
5	ENVIRONMENT = 0.20*SOP + 0.73*RISK ASSESSMENT	Errorvar.= 0.21 , R^2 = 0.79
6	RISK ASSESSMENT = 0.58*COMMITMENT	Errorvar.= 0.66 , R^2 = 0.34
7	MIXING = 0.26*WORKER	Errorvar.= 0.76 , R^2 = 0.24
8	PARAMETER = 0.28*WORKER	Errorvar.= 0.77 , R^2 = 0.23
9	CONTAMINANT = 0.21*MIXING + 0.75*STORING	Errorvar.= 0.29 , R^2 = 0.71
10	IMPERFECT = 0.94*MIXING	Errorvar.= 0.40 , R^2 = 0.60
11	STORING = 0.13*ENVIRONMENT	Errorvar.= 0.88 , R^2 = 0.12

Table 10: Value of Structural Coefficient and Significance of Modified CRH Structural Model

Path	SC Value	* t-calculation Value		H_0
Commitment _ Training	0.82	5.30	Significant	H_{01}: Accepted
Commitment _ Risk Assessment	0.58	8.90	Significant	H_{02}: Accepted
Risk Assessment _ SOP	0.73	7.76	Significant	H_{07}: Accepted
Risk Assessment _ Environment	0.73	7.31	Significant	H_{08}: Accepted
SOP _ Worker	0.75	4.04	Significant	H_{09}: Accepted
SOP _ Environment	0.20	2.74	Significant	H_{010}: Accepted
Worker _ Mixing	0.28	4.23	Significant	H_{011}: Accepted
Worker _ Process Parameter	0.21	3.59	Significant	H_{012}: Accepted
Mixing _ Contamination	0.20	4.63	Significant	H_{021}: Accepted
Storing _ Contamination	0.75	13.87	Significant	H_{022}: Accepted
Mixing _ Imperfect	0.94	5.53	Significant	H_{023}: Accepted
Environment _ Storing	0.13	2.96	Significant	H_{018}: Accepted
Training _ Knowledge/ Competency	0.90	4.92	Significant	H_{019}: Accepted
Knowledge _ Worker	0.37	3.75	Significant	H_{020}: Accepted

*t-calculation <1.96 not significant, Ho rejected

After performed re-specification model to get better structural model and has latent variable relation which has higher structural coefficient, researcher tried to modify by adding some paths which supported by theories or field fact. The modified CRH structural model can be seen on figure 3.

The calculation result of Goodness of Fit which shows fit degree between modified CRH structural models with the data can be seen on table 8.

From table 8 it can be seen that 4 GOF indexes show Goodness of Fit of data-model is good and only one GOF index show Goodness of Fit of data-model is not satisfactory, so it can be concluded that in general Goodness of Fit data-model is good. table 9 describes regression equation of modified CRH structural model.

From regression equation of modified CRH structural model on table 9, it showed that structural coefficient for each path is corresponding with zero hypotheses which were made. Structural Coeffecient (SC) value and hypothesis test (t-calculation) for each path can be seen on table 10.

DISCUSSION

Hypothesis that was developed in making relation between latent variable is based on qualitative study with KJ analysis method and supported by strong theory. Early hypothesis was developed based on qualitative model CRH causation, then model re-specification is performed with adding some new hypotheses to get better CRH causation model. The following explanation of relation among CRH causation model latent variables is based on qualitative model hypothesis and re-specification CRH causation model. Based on this study, the modified CRH causation structural model is acknowledge as the most suitable model for downstream chemical industry.

OSH commitment which was hypothetically can improve completeness, accessibility and effectiveness of Standard Operation Procedure and enhance safety and comfort of workplace environment is not proofed, it turn out that OSH commitment is not directly influence to both latent variables.

Findings result on this study shown that OSH commitment can improve worker competency through training program implementation, the relation between OSH commitments with training program implementation to improve worker competency is very strong (standardized coefficient path = 0.82) and relation between training program with worker competency improvement is also proofed very strong (standardized coefficient path = 0.89). OSH commitment is also proofed has strong correlation with planning and implementation of risk assessment in workplace (standardized coefficient path = 0.58). Company policy must show commitment to risk and hazard management, OSH communication and training, continuous OSH corrective and improvement effort and periodically reviewed [16].

Risk assessment in workplace was hypothetically can improve safety and comfort of workplace environment, improve completeness, accessibility and effectiveness of Standard Operation Procedure and reduce worker error level. Study result showed that risk assessment in workplace can only improve safety and comfort in workplace environment and improve completeness, accessible and effectiveness of Standard Operation Procedure. Risk assessment in workplace was not proofed in decreasing worker error level directly.

Risk assessment give strong effect to improving safety and comfort in workplace environment, the correlation between these two latent variables is very strong where its standardized coefficient path is 0.73. By performing risk assessment in workplace it will be identified potential hazard and risk that existed in workplace, then it can performed risk reducing program or risk management in workplace which finally will reduce working risk and improve workplace environment.

This study is also proofed that the risk assessment is needed to improve completeness, effectiveness and accessibility on understanding the standard operation procedure. The correlation between these variables is very strong, where its standardized coefficient path is 0.73. This showed that formation of standard operation procedure and safety will be very effective if it is based on result of risk assessment which performed. The organization shall establish and maintain procedures for the ongoing identification of hazards, the assessment of risks and the implementation of necessary control measure [17].

Safety Training on hazardous chemical was hypothetically reduce worker error, it turned out that this correlation is not significant. After model re-specification is carried out by adding hypothesis path where training is hypothetically improves worker knowledge and worker knowledge can decrease error which is impacted by worker factor, it turned out that this hypothesis can be accepted. Training of safety on hazardous chemical has very strong correlation with workers knowledge level of hazardous chemical (standardized coefficient path = 0.89). Workers knowledge of hazardous chemical is proofed in decreasing workers working error, the correlation between these latent variables is very strong (standardized coefficient path = 0.73). OSH training must focus on worker ability development on safety, hence increase awareness of hazard on workplace and improve ability to handle its hazards and understand the reasons why OSH program is performed [10].

Standard operation Procedure (SOP) was hypothetically can reduce mixing error, process parameter error, contamination, imperfect mixing and storing error, but those are not proofed. The assumption by improving or adding SOP can reduce directly all causation trigger factors of reactivity hazard actually has insignificant relation. Improving and adding SOP is proven only influent latent variable of worker error and safety/ comfort environment workplace. SOP has strong relation with worker error variable (standardized coefficient path = 0.61), it means worker error can be reduced by improving or adding standard operation procedure (SOP). All standard management system requires establishing written standard operation procedure (SOP) as guidance for worker in accomplishing their job and also maintaining working process consistency, performance and quality. SOP has also quite strong correlation with variable of workplace environment (standardized coefficient path = 0.20), even though this correlation is not so strong but it is significant enough. Recommendation from risk assessment result is better to be translated in standard operation procedure form so it can be implemented continuously to maintain safety and comfort on workplace environment. The maintenance, cleanliness of tools and workplace, production process lines, storing and placing of raw material and products and so on are better to be written on standard operation procedure to maintain work process consistency and workplace comfort [2].

Workplace environment was hypothetically can reduce product contamination, imperfect mixing and storing error. The proven significant correlation in this study is only between workplace environment with storing error and this correlation is not quite strong too (standardized coefficient path = 0.13). Raw material process line, availability and sufficient storing place, clear division of storing area and proper standard condition of storing room will influent raw material or product storing process [18].

Worker error factor is proven only influence to variables of mixing error and process parameter. Study result proofed that reducing worker error will be able to decrease mixing error and process parameter, correlation within these variables were quite strong where standardized coefficient path for mixing error is 0.26 and parameter process error is 0.21. It is understandable on downstream chemical industry where study taken place, both process were performed manually by worker.

On re-specification of CRH causation model was hypothetically that mixing error has strong correlation with imperfect mixing and contamination on raw material and products. Study result proofed that by reducing mixing error will reduce imperfect mixing and contamination. Correlation between mixing error variable with imperfect mixing is very strong where its standardized coefficient path is 0.91, meanwhile relation between mixing error variable with contamination is not so strong (standardized coefficient pa4h = 0.20).

On re-specification of CRH causation model was also been hypothesis that storing error has strong relation with contamination of product or raw material. Result of study proofed that decreasing of storing error can reduce contamination of product or raw material, the correlation both these variables is very strong (standardized coefficient path = 0.75). Storing raw material without label, expired raw material, leakage or opened packaging can increase potency of contamination on raw material or product.

In conclusion, from developed CRH causation model, there were 8 latent variables that influenced both directly and indirectly to CRH in down stream chemical industry, they are: Safety commitment, training, risk assessment, worker competency, worker factor, standard operational procedure dan workplace environment. The result from the research proved that there were two variables which influenced directly to trigger the reactivity chemical hazard, those variables are worker error factor that influenced to the mixing error and process parameter; the other variable is the workplace environment that influenced storing error.Safety commitment had a very strong correlation with training implementation (SCP=0.82) and risk assessment (SCP=0.58). Training had a very strong relation with worker competency (SCP=0.89) and worker competency gave quite strong influence to decreasing worker error (SCP=0.37). Risk assessment had a strong relation with standard operational procedure (SOP) and workplace environment (SCP=0.73). Standard operational procedure influenced worker error (SCP=0.61) and work environment (SCP=0.20). Worker error factor influenced directly to mixing error (SCP=0.26) and process parameter (SCP=0.20) and imperfect mixing (SCP=0.91). Workplace environment influenced directly to storing error (SCP=0.13) and storing error influenced to contamination (SCP=0.75).

REFERENCES

1. Reason, J., 1997. Managing the Risk of Organization Accidents. Ashgate Publishing Limted. England,
2. Heinrich, H.W., D. Petersen and N. Ross, 1980. Industrial Accident Prevention-A Safety Management Approach. Fifth Edition. McGraw-Hill Book Company.
3. Cooper, D., 2001. Improving Safety Culture, A Pratical Guide. Applied Behavioral Science. UK.,
4. Johnson, R.W., S.W. Rudy. and S.D. Unwin, 2003. Essential Practice Managing Chemical Reactivity Hazards, Center for Chemical Safety of the Institute of Chemical Engineers, 3 Park Avenue, New York, N.Y., pp: 10016-5991.
5. Chemical Safety, U.S. and Hazard Investigation Board, 2004. Reactive Explosion at First Chemical Corp. Investigation Digest, Published.
6. Chemical Safety, U.S. and Hazard Investigation Board, 2007. Refinary Explosion and Fire, Investigation Report NO. 2005-04-I-TX, Maret,
7. CCPS, 2001. Reactive Material Hazards. CCPS Safety Alert ● October 1, 2001
8. Rasmussen, B., 1989. Chemical Process Hazard Identification. Reliability Engineering and System Safety, 24: 11-20.
9. B.S., 8800:2004, Occupational Health and Safety Management System - Guide, British Standard.
10. Dingsdag, D.P., H.C. Biggs. and V.L. Sheahan, 2008. Understanding and defining OH & S competency for construction site positions: Worker perceptions. Safety Sci., 46: 619-633.
11. OHSAH, 2004. Sharing Knowledge, October 2004 Edition.
12. Zhou, Q.D. Fang. and X. Wang, 2007. A method to identify strategies for the improvement of human safety behavior by considering safety climate and personal experience. Safety Sci., xxx: xxx-xxx.
13. Jatiputra, S. and Yovsyah, 1991. Metodologi Penelitian Kesehatan. Fakultas Kesehatan Masyarakat, Universitas Indonesia.
14. Seo, D.C., M.R. Torabi, E.H. Blair. and N.C. Ellis, 2004. A cross-validation of safety climate scale using confirmatory factor analytic approach. Journal of Safety Res., 35: 427-445.
15. Hair, J.F., W.C. Black, B.J. Babin, R.E. Anderson. and R.L. Tatham, 2006. Multivariate Data Analysis. Six Edition. Pearson Prentice Hall, Pearson Education International.
16. Manpower Ministry of Republic Indonesia, Regulation no.: PER.05/MEN/1996, Occupational Health and Safety Management System.
17. OHSAS 18001:1999. Occupational Health and Safety Management System-Specification.
18. DeReamer, 1981. Modern Safety and Health Technology. Willey interscience, New York.