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Exploring the Safety Risk Factors on High-Rise Building Projects through Partial Least Square Structural Equation Modelling

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Abstract

Malaysia construction industry have played a great role in the growth of the country's economy over the years. However, there have been incidents of increasing injuries as a result of being exposed to accidents within the industry. Some studies in the construction field have shown that safety performance has been decreasing. Most of the construction activities carried out by the construction companies has been in dangerous situations thereby exposing the workers to minor and major injuries which may sometimes lead to death. As a result, the organizations may sometimes change the goals of the projects because of the accident, thus affecting the organization's level of advancement in the industry. To address the aforementioned issue, this paper aims to identified the significant relationship between risk factors and types of accident occurred during construction high-rise building project. Around 114 respondence from construction companies that registered under the CIDB Malaysia among Penang state, Malaysia construction companies were surveyed. PLS-SEM technique was used in this research to assess both the measurement and structural models. The results showed that management, personal and job safety risk factors categories played a significant positive relationship with types of accident.

Keywords: Safety Risk Factors, High-Rise Building, Partial Least Square, Structural Equation Modelling, Accident.

Introduction

In Malaysia, construction industry has an important role towards the development of the economy. Although the construction industry is not the main sector that contributes to Malaysia economy growth, it actually acts like a catalyst to other sector of economy such as education, finance, manufacturing and others. This actually means that the construction industry can be represented as one type of economic engine in Malaysia. Besides, the construction industries in Malaysia have an important role in order to produce wealth and improvise the quality of living in this country. In addition, from the establishment of this industry, there are many jobs can be offered to the citizen and this can help the growth of other industries in Malaysia. In response to economic development, construction industry at present took a new turn towards high rise building construction i.e., hotels, commercial buildings, office complexes and high-rise dwellings. However, the statistics on occupational accidents revealed that high-rise building construction is as one of the riskiest workplaces in Malaysia (Hsu, et al., 2008). Construction workers who work within the construction industry face a greater risk of fatality than workers in other industries.

To prevent accidents, we need to know the causes and types of accidents in the working environment such as inherently hazardous construction projects, personal and project factors, and mechanisms or equipment that lead to accidents. So, this research aims to identified the significant relationship between risk factors and types of accident occurred during construction high-rise building project.

Literature Review

a. High-Rise Building Construction Project

According to the Council of Tall Buildings and Urban Habitat High rise are buildings whose height creates different conditions in the design, construction, and use than those that exist in common buildings of a certain region and period.” There is no precise definition of high-rise building that is universally accepted. Nevertheless, various bodies have tried to define what 'high-rise' means: The National Fire Protection Association (NFPA 2000) defined a high-rise building as a building taller than 75 feet (23 meters) in height measured from the lowest level of fire department vehicle access to the floor of the highest occupiable story. Whilst, in another opinion says a high-rise structure is one that extends higher than the maximum reach of available fire-fighting equipment and it is between 75 feet and 100 feet. A particular building is deemed a high-rise specified by the fire and building codes in the area in which the building is located (Craig, 2009). Building is defined by the US Uniform Building Codes as a high- rise building when it has floors for human occupancy which are more than 75 feet above the lowest level of fire department access. Second definition as stated in under the Malaysia Uniform Building by law (UBBL), high rise is the building that meet the definition, to be equipped with an automatic fire sprinkler system designed in accordance with requirements in Uniform Building Codes Building codes vary in their definition of high-rise buildings, but the intent is to define buildings in which fires cannot be fought successfully by ground-based equipment and personnel. Furthermore, High-rise buildings are not inherently dangerous structures, but they do require additional systems and features that other buildings do not’(Craig, 2009). It is common that when a building exceeds a certain size (high-rise), the inspection must be made by the construction licensing and supervisory authorities after corresponding plans have been submitted to them. This inspection procedure not only encompasses aspects under the building code such as building compliance with specified distance and the specified height and size of a building or its type of use, but also the safety of the people (Mansor et al., 2012).

b. Types and Causes of Accidents

An accident can be defined as an unplanned, undesirable, unexpected, and uncontrolled event. An accident does not necessarily result in an injury. It can be in term of damage to equipment and materials and especially those that result in injuries receive the greatest attention (Hinze et al., 1997). In high-rise building construction project, accidents mostly occur at temporary structures that the failure prone than the permanent structure because it is easily getting damaged due to frequent dismantle and reuse (Sofwan et al., 2016). It is extremely difficult to talk about construction safety management in the absence of an understanding of the causes of accidents. Before one can embark on effectively and efficiently improving safety on the project site, one must first understand the theory of accident causation and prevention. Theories of accident causation are used to predict and prevent accidents in construction project. The famous accidents causation models started from domino theory produced by Heinrich in 1930 and multiple causation theory developed by Petersen in 1971.

Methodology
The research instrument is a questionnaire. This method is chosen as it is one of the most widely used and accepted instruments for research purposes (Sekaran, 2006). The items from the existing literature and former researches were adopted and adjusted to construct the questionnaire items in order to make sure that all the important points are covered during measurement. The total number of 50 copies of questionnaire was distributes personally and others via google form. The sample size for this research was 255 companies in Penang. Quantitative method was used in this research as it is more structured than the qualitative method of data collection. Hence, the data was collected by using the questionnaire. As stated above, the method used in this research for data collection process was the questionnaire as it is found to be easier for the collection of data from the respondents. The answers to the questions were recorded by taking input from the respondents and without the need for an interview. In analyzing the data, SPSS software version 26.0 was used for respondents' demographics such as nature of company, types of company, age of company, gender, position in the company, working experience and qualification. The data analysis adopted for both independent and dependent variables was Smart PLS version 3.3.7. Five- point Likert scale was adopted to measure the independent and dependent variables which range from (1) strongly disagree, (2) disagree, (3) moderately, (4) agree, to (5) strongly agree.

Result and Discussion
A. Demographic Respondents
As shown in Table 1, respondents with work experience of 1-3 years, 3-5 years, 5-10 years, and more than 10 years were approximately 39.6%, 31.9%, 16.0%, and 12.5%, respectively. The highest respondents' groups (39.6%) had 1-3 years of experience and more than 60% of respondents had more than 3 years' experience. These results collectively indicate the high qualifications and experience level of the respondents. As such, some level of confidence in their input can be exercised. Most respondents were civil engineers (29.3%) followed by site supervisor (23.4%), project managers (14.6%), safety site supervisor (SSS) (9.0%), safety officer (4.2%) and others (19.5%). The highest participants were the contractors (58.3%), followed by the consultants (23.6%) and client/developer (14.6%). The respondents' academic credentials were 20.83%, 49.31%, 9.72, and 2.08% for DIP, BS, MS, and Ph.D. degrees, respectively.

Table 1
Demographic Respondents

Type	Items	Percentage (%)
Gender	Female	13.2
	Male	86.8
Age	20 29 Years	32.6
	30- 39 Years	33.3
	40-49 Years	18.1
	>50 Years	16.0
Qualification	Unknown	11.11
	Secondary School	6.94
	Diploma	20.83
	Bachelor	49.31
	Master	9.72
	PhD	2.08
Position	Engineer	29.3
	Project Manager	14.6
	Safety officer	4.2
	SSS	9.0
	Site Supervisor	23.4
	Others	19.5
Working Experience (Years)	1 - 3 Years	39.6
	3 - 5 years	31.9
	5 - 10 Years	16.0
	> 10 Years	12.5
Working Experience in high-rise building project	1 - 3 Years	50.7
	3 - 5 years	25.0
	5 - 10 Years	8.3
	> 10 Years	16.0
Nature of Company	Client	14.6
	Consultant	23.6
	Contractor	58.3
	Specialist	3.5

B. Partial Least Square-Square Equation Modelling Result

The data analysis and results present in detail the results from the analysis of the data. PLS-SEM analysis that includes the assessment of Measurement and Structural Model. The measurement model establishes the reliability and validity of the construct. The structural model ascertains the significance of hypothesized relationships. Different hypotheses were proposed to evaluate the relationship of predictors on the outcome.

H1: There is significant impact of CRF on TOA.
H2: There is significant impact of MRF on TOA.
H3: There is significant impact of PRF on TOA.
H4: There is significant impact of JRF on TOA.
H5: There is significant impact of CRF on TOA.

Where,
CRF- Combined Risk Factors
MRF- Management risk Factors
PRF- Personal Risk Factors
ERF- Environment Risk Factors
JRF- Job Risk Factors
TOA- Types of Accident

Measurement Model (Lower Order)

Quality of the constructs in the study is assessed based on the evaluation of measurement model. The assessment of the quality criteria starts with evaluation of the factor loadings which is followed by establishing the construct reliability and construct validity.

(i) Factor Loading

Factor loading refers to the “the extent to which each of the items in the correlation matrix correlates with the given principal component. Factor loadings can range from -1.0 to +1.0, with higher absolute values indicating a higher correlation of the item with the underlying factor” (Pett et al., 2003, p. 299). None of the items in the study had factor loading less than the recommended value of 0.50 (Hair et al., 2016). Hence, no items were further removed. Factor loadings are presented in Table 2.

Table 2
Factors Loading

	ERF	JRF	MRF	PRF	TOA
ERF1	0.895				
ERF10	0.576				
ERF2	0.762				
ERF7	0.688				
ERF8	0.705				
JRF1		0.799			
JRF2		0.705			
JRF3		0.73			
JRF5		0.754			
MRF1			0.687		
MRF10			0.796		
MRF11			0.769		
MRF12			0.759		
MRF13			0.64		
MRF14			0.702		
MRF2			0.727		
MRF4			0.674		
MRF5			0.731		
MRF6			0.677		
MRF9			0.662		
PRF1				0.759	
PRF10				0.573	
PRF11				0.742	

PRF2	0.862	
PRF3	0.778	
PRF4	0.831	
PRF5	0.845	
PRF7	0.803	
PRF8	0.579	
TOA1		0.645
TOA10		0.558
TOA11		0.616
TOA3		0.549
TOA4		0.767
TOA6		0.776
TOA7		0.779
TOA8		0.82
TOA9		0.811

(ii) Reliability Analysis

According to Mark (1996) “Reliability is defined as the extent to which a measuring instrument is stable and consistent. The essence of reliability is repeatability. If an instrument is administered over and over again, will it yield the same results” (p. 285). The two most used methods for establishing reliability include Cronbach Alpha and Composite Reliability (CR). The results for both Cronbach alpha and composite reliability results are presented in Table 3. The Cronbach Alpha ranged from 0.746 to 0.907 whereas Composite Reliability statistics ranged from 0.835 to 0.923. Both indicators of reliability have reliability statistics over the required threshold of 0.07 (Hair et al., 2019). Hence, construct reliability is established.

Table 3
Construct Reliability Analysis) Cronbach Alpha and Composite Reliability)

	Cronbach's Alpha	Composite Reliability
ERF	0.821	0.850
JRF	0.746	0.835
MRF	0.903	0.919
PRF	0.907	0.923
TOA	0.872	0.900

(iii) Construct Validity

Statistically using PLS-SEM, construct validity is established when there is convergent validity and discriminant validity. “Convergent validity is the degree to which multiple attempts to measure the same concept are in agreement. The idea is that two or more measure of the same thing should covary highly if they are valid measures of the concept” (Bagozzi et al., 1991, p. 425). When the AVE value is greater than or equal to the recommended value of .50, items converge to measure the underlying construct and hence convergent validity is established (Fornell & Larcker, 1981). Convergent validity results based on the AVE statistics in the current study show that all the constructs have an AVE value greater than .50. Hence, convergent validity is established. Table 4 show the AVE value for each of the constructs.

Table 4
Construct Convergent Validity (AVE)

	Average Variance Extracted (AVE)
ERF	0.537
JRF	0.559
MRF	0.508
PRF	0.576
TOA	0.504

(iv) Discriminant Validity

"Discriminant validity is the degree to which measures of different concepts are distinct. The notion is that if two or more concepts are unique, then valid measures of each should not correlate too highly" (Bagozzi et al., 1991, p. 425).

Heterotrait-Monotrait HTMT

Henseler et al (2015) proposed the heterotrait-monotrait (HTMT) ratio of the correlations (Voorhees et al, 2016). The HTMT is defined as the mean value of the item correlations across constructs relative to the (geometric) mean of the average correlations for the items measuring the same construct. Discriminant validity problems are present when HTMT values are high. Henseler et al. (2015) propose a threshold value of 0.90 for structural models with constructs that are conceptually very similar, for instance cognitive satisfaction, affective satisfaction, and loyalty. In such a setting, an HTMT value above 0.90 would suggest that discriminant validity is not present. But when constructs are conceptually more distinct, a lower, more conservative, threshold value is suggested, such as 0.85 (Henseler et al., 2015). In addition to these guidelines, bootstrapping can be applied to test whether the HTMT value is significantly different from 1.00 (Henseler et al., 2015) or a lower threshold value such as 0.85 or 0.90, which should be defined based on the study context (Franke and Sarstedt, 2019). More specifically, the researcher can examine if the upper bound of the 95 per cent confidence interval of HTMT is lower than 0.90 or 0.85 (Hair et al., 2019). In this study, square HTMT values for constructs were found less than the required threshold of 0.90 (Table 5). Hence, providing strong support for establishment of discriminant validity.

Table 5
Heterotrait-Monotrait HTMT values

	ERF	JRF	MRF	PRF	TOA
ERF					
JRF	0.414				
MRF	0.306	0.845			
PRF	0.384	0.866	0.859		
TOA	0.272	0.493	0.626	0.430	

Cross Loadings

Cross loadings help assess if an item belonging to a particular construct loads onto its own parent construct instead of other constructs in this study. The results on Table 6 shows that factor loading of all the items is stronger on the underlying construct to which they belong instead of the other construct in the study (Ningshuang ZENG et al., 2021). Hence, based on the evaluation of cross-loadings, discriminant validity is attained.

Table 6
Discriminant validity-Cross Loadings

	ERF	JRF	MRF	PRF	TOA
ERF1	**0.895**	0.369	0.403	0.477	0.287
ERF10	**0.576**	0.215	0.085	0.142	0.042
ERF2	**0.762**	0.263	0.288	0.295	0.221
ERF7	**0.688**	0.193	0.071	0.183	0.039
ERF8	**0.705**	0.148	0.070	0.129	0.219
JRF1	0.402	**0.799**	0.592	0.521	0.364
JRF2	0.150	**0.705**	0.424	0.406	0.215
JRF3	0.251	**0.730**	0.471	0.578	0.239
JRF5	0.174	**0.754**	0.592	0.620	0.374
MRF1	0.103	0.409	**0.687**	0.508	0.402
MRF10	0.165	0.651	**0.796**	0.605	0.448
MRF11	0.349	0.644	**0.769**	0.550	0.398
MRF12	0.217	0.638	**0.759**	0.644	0.357
MRF13	0.267	0.402	**0.640**	0.586	0.349
MRF14	0.180	0.491	**0.702**	0.624	0.423
MRF2	0.311	0.509	**0.727**	0.608	0.513
MRF4	0.219	0.473	**0.674**	0.535	0.371
MRF5	0.271	0.474	**0.731**	0.533	0.420
MRF6	0.133	0.388	**0.677**	0.462	0.439
MRF9	0.316	0.523	**0.662**	0.565	0.275
PRF1	0.230	0.611	0.599	**0.759**	0.433
PRF10	0.312	0.541	0.505	**0.573**	0.168
PRF11	0.388	0.596	0.517	**0.742**	0.248
PRF2	0.226	0.582	0.603	**0.862**	0.248
PRF3	0.211	0.552	0.593	**0.778**	0.171
PRF4	0.250	0.632	0.789	**0.831**	0.420
PRF5	0.326	0.489	0.714	**0.845**	0.364
PRF7	0.398	0.504	0.571	**0.803**	0.363
PRF8	0.362	0.428	0.384	**0.579**	0.195
TOA1	0.085	0.358	0.503	0.321	**0.645**
TOA10	0.212	0.333	0.307	0.229	**0.558**
TOA11	0.079	0.303	0.416	0.253	**0.616**
TOA3	0.254	0.146	0.385	0.297	**0.549**
TOA4	0.211	0.219	0.366	0.312	**0.767**
TOA6	0.203	0.254	0.366	0.230	**0.776**
TOA7	0.206	0.337	0.436	0.334	**0.779**
TOA8	0.310	0.263	0.313	0.305	**0.820**
TOA9	0.280	0.389	0.488	0.354	**0.811**

Multicollinearity Test
Variance Inflation Factors (VIF) statistic is utilized to assess multicollinearity in the indicators (Fornell & Bookstein, 1982). According's to Hair et al (2019) multicollinearity is not a serious issue if the value for VIF is below 5. Table 7 presents the VIF values for the indicators in the study and reveals that VIF for each of the indicators is below the recommended threshold.

Table 7
Multicollinearity Statistics (VIF) for indicators

	VIF
ERF1	2.193
ERF10	2.377
ERF2	1.762
ERF7	3.116
ERF8	1.903
JRF1	1.469
JRF2	1.546
JRF3	1.537
JRF5	1.275
MRF1	1.868
MRF10	2.893
MRF11	2.750
MRF12	2.577
MRF13	1.797
MRF14	2.289
MRF2	2.239
MRF4	2.000
MRF5	2.241
MRF6	2.323
MRF9	2.187
PRF1	2.413
PRF10	1.605
PRF11	2.185
PRF2	3.785
PRF3	2.633
PRF4	3.306
PRF5	3.482
PRF7	2.804
PRF8	1.775
TOA1	1.535
TOA10	1.771
TOA11	1.692
TOA3	1.392
TOA4	2.676
TOA6	2.151
TOA7	2.345
TOA8	2.874
TOA9	2.496

Normality Test (Mardhias Test)

Test of data normality is an important check when using multivariate approaches to data analysis, including regression analysis and SEM. By the way, alternatives should be utilized when a normality assumption is violated. In this study, the normality of data was measured as an elementary assumption, and the normality test results for all variables in the model are

shown in Table 8. Byrne (2010), stated that if the skewness value is between -2 to +2, and the kurtosis value is between -7 to +7, the data are considered normal. As shown in the following table, the skewness ranged from -
-0.176 to -0.662, and the kurtosis ranged from -0.655 to 1.177 revealed that all variables are normally distributed.

Table 8
Result of Normality Test

Variable	**Skewness**	**Std. Error**	**Kurtosis**	**Std. Error**
ERF	-0.485	0.202	-0.469	-1.169
JRF	-0.176	0.202	0.31	0.772
MRF	-0.662	0.202	0.398	0.992
PRF	-0.315	0.202	-0.655	-1.631
TOA	-0.6	0.202	1.177	2.932

Table 9
Hypotheses Testing (Lower Order)

Construct	β	Standard Deviation (STDEV)	T Statistics	P Values
H1: ERF -> TOA	0.132	0.068	1.932	*0.053*
H2: JRF -> TOA	0.035	0.086	0.401	*0.689*
H3: MRF -> TOA	0.637	0.128	5.010	0.000
H4: PRF -> TOA	-0.160	0.111	1.437	*0.151*

Where,
H1: There is a significant impact of ERF on Types of Accident
H1 evaluates whether ERF has a significant impact on the types of accident. The results revealed that ERF has a insignificant effect on TOA (β =0.132, T = 1.932, P > 0.005). Hence H1 was not supported.
H2: There is a significant impact of JRF on Types of Accident
H2 evaluates whether JRF has a significant impact on the types of accident. The results revealed that JRF has a in significant effect on TOA (β = 0.035, T = 0.401, P = 0.689). Hence H2 was not supported.
H3: There is a significant impact of MRF on Types of Accident
H3 evaluates whether MRF has a significant impact on the types of accident. The results revealed that MRF has a significant effect on TOA (β = 0.637, T = 5.010, P < 0.001). Hence H3 was supported.

H4: There is a significant impact of PRF on Types of Accident
H4 evaluates whether PRF has a significant impact on the types of accident. The results revealed that PRF has a insignificant effect on TOA (β = -0.160, T = 1.437, P = 0.151). Hence H4 was not supported.

Structural Model (Higher Order)
Composite Risk Factors was the higher order construct in this study based on four lower order constructs Personal, Job, Management and Environment &Heredity. To establish the higher order construct validity Outer Weights, Outer Loadings, and VIF. The outer weights were

found significant (Hair et al., 2016). Furthermore, outer loadings were found greater than 0.50 for each of the lower constructs (Sarstedt et al., 2019) except for ERF (0.481) and this construct will be deleted. Finally, VIF values were assessed to check collinearity, all VIF values are less than recommended value of 5 (Hair et al., 2016). Since, all criterions are met, the Higher order construct validity was established.

Table 10
Higher Order Construct Validity

Constructs	Outer Weight	T Statistics	P Values	Outer Loadings	VIF
H1: ERF -> CRF	0.119	*1.569*	*0.117*	*0.482*	1.187
H2: JRF -> CRF	0.050	*0.354*	*0.724*	0.704	2.377
H3: MRF -> CRF	1.072	6.076	0.000	0.977	3.017
H4: PRF -> CRF	-0.251	*1.401*	*0.161*	0.707	3.134

Because outer loading for ERF to CRF less than 0.7 (0.482), so the indicator ERF needs to remove from model.
The next step in structural equation modelling is assessment of the hypothesized relationship to substantiate the proposal hypotheses.

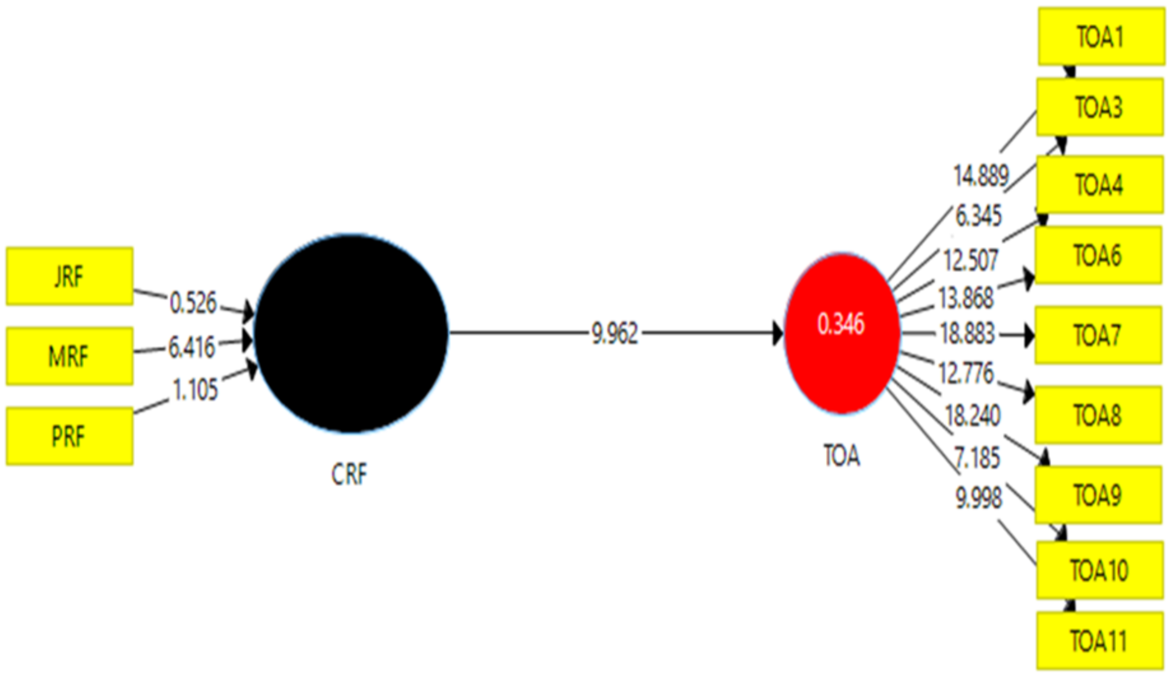

Figure 1. Structural Model (Path Analysis)

Hypotheses Testing
Higher Order
H5: There is a significant impact of CRF on Types of Accident.
H5 evaluates whether CRF has a insignificant impact on the types of accident. The results revealed that CRF has a significant effect on TOA (β = 0.606, T = 10.186, P < 0.001). Hence H5 was supported.

Table 11
Hypotheses Testing (Higher Order)

Construct	β	Standard Deviation (STDEV)	T value	P value
H5: CRF -> TOA	0.606	0.062	10.186	0.000

Conclusion

This study focuses on investigating the significant relationship between safety risk factors and types of accidents during high-rise building projects. The results show that there is a significant effect of the combination of risk factors (MRF, PRF & JRF) on the type of accident. Also, information on possible causes of accidents during the construction of high-rise buildings in Penang has been revealed. This model will be able to help construction management in planning to avoid fatal accidents during high-rise building projects.

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