Research Article

Warehouse Performance Measurement: Structural Equation Modeling Technique and PEST Analysis

Anucha Hirunwat, Premporn Khemavuk* and Vichai Rungreunganun
Department of Industrial Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand

* Corresponding author. E-mail: premporn.k@eng.kmutnb.ac.th DOI: 10.14416/j.ijast.2017.12.004
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Abstract
This research aims to propose a new model for warehouse performance measurement by overcoming the limitations of the traditional technique called productivity ratio. The proposed model is built up from 215 warehouses with Structural Equation Modeling (SEM) technique. This research focuses on exploring the relationships among four warehouse performance indicators. The indicators are classified and grouped according to the dimensions of time, cost, productivity and quality. In order to maintain consistency among metrics from different warehouse areas, a standard warehouse is defined according to layout, activities and indicators measurement units. Finally, the proposed model can help manufacturing firms to know the firm warehouse performance. This research also analyzes the effects of external factors on warehouse performance. Political, economic, social, and technological factors, called PEST, are used as an analytical framework. After that the PEST analysis is applied with the proposed model the results found that the technological factor has the highest impact on warehouse performance. The economic factors are the next level of impact assessment. The last two factors are social and political issue, could be the least significant.

Keywords: Warehouse performance, Structural Equation Modeling, External factors, PEST analysis

1 Introduction

Performance measurement is one of important keys to smoothly manage supply chain as a whole. In various products and services, performance is often tested in each step from supplier's views down to distributor's views in order to satisfy customer requirements as same as take responsibility to society as well. For examples, Choi *et al*. [1] studied performance and exhaust emission of a large LNG-Diesel engine; Poompipatpong *et al*. [2] also tested the effects of Diesel-waste plastic oil blends on engine performance. Later Kardono [3] studied environmental performance of hazardous waste incinerator. Nowadays, warehouse management is the implementation of advanced techniques and technologies to optimize all functions throughout the warehouse. There are very large number and varieties of products with complicated tasks throughout warehouse operations. However, gaining control of the warehouse can reduce costs, improve customer service and turn the warehouse into a profit center instead of an ongoing problem. Typically, a company has one or more than warehouse and every single warehouse is different in term of operational efficiency. One of key success factor is to apply efficient technologies to serve required services. For example, warehouse management system has been improved by using software and automatic data collection especially barcodes or RFID technology. F. Saleheen *et al*. [4] represent a case study which investigates the current major challenges the

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supermarket industry face. The warehouse management goal is to ensure operational efficiency while focusing on cost reduction. Warehouse performance measurement benchmark comprise of quality, speed, flexibility, dependability, reliability and time linked with few internal as well as external factors. Anas *et al.* [5] comment that the warehouse system has become more reliable and efficient by implementing automated warehouse management system. The main purpose of automated warehouse management system is to control the movement and storage of the products, together with the benefit of enhanced security and quicker handling.

In this context, the objective is to propose a new model for warehouse performance measurement by overcoming the limitations of the traditional technique. Such limitations have been overcome by Khemavuk and Hasan [6] where a model for measuring warehouse performance was developed with structural equation modeling technique and analogy-based approach. F. H. Staudt *et al.* [7] presented the set of warehouse performance measurements is classified according to the dimensions of time, cost, productivity and quality. Moreover this research was conducted to study of external factors effect on warehouse performance. The PEST analysis is used as a framework to explore the significant factors impacted warehouse performance.

The paper is organized as follows: section 2 describes the literature review considering warehouse management, warehouse performance indicators, external factors affecting warehouse performances, section 3 offers a sequence of steps that was elaborated in building up a proposed model for measuring warehouse performance. Finally, the findings will be analyzed and concludes with suggestions for the prospect research.

2 Literature Review

The recent literature regarding warehouse management research presents the traditional tools for measure warehouse performance. The tools are single metrics and single productivity ratio. Gunasekaran *et al.* [8] developed a conceptual framework for improving the effectiveness of warehousing operations under JIT and TQM perspectives. Ezziane [9] develops a mathematical model to evaluate a customer service performance in warehousing environments. Keifer and Novack [10] did an empirical study on how firms measure the performance of their warehouse operations regarding the supply chain implementation. De Koster and Warffemius [11] studied on performance by comparing whether rented warehouse is better than own warehouse and whether Asian performs better than American among European distribution centers in Netherlands. Huq *et al.* [12] compare a one-warehouse, N-retailer replenishment system to a two-warehouse, N-retailer replenishment system with cost per unit of distribution and delivery lead-times as the performance measures.

Warehouse performance evaluation has been explored in different ways by researchers. Some of them focus on one specific area while others try to cover all warehouse activities. The performance measurement is commonly assessed by the use of indicators and the majority of existing works. However, in several literatures, it does not exist a common understanding on the definition of performance indicators and on how to measure them. Many studies are developed using indicators that are classified and measured differently in each work.

However, the warehouse performance has been traditionally measured by single metrics and single productivity ratio. This traditional warehouse performance measurement is very easy to measure. Based on their traditional methods of warehouse performance measurement, several companies cannot benchmark their performance over time [13].

2.1 *Warehouse management*

In this paper, the considered standard warehouse layout is shown in Figure 1. It is divided in three parts: unit of measure, warehouse layout, warehouse activities. Typically, main warehouse activities with their respective boundaries are determined according to the definitions as follows:

- *Receiving*: operations that involve the assignment of the carrier's vehicle to docks and the scheduling of unloading and checking activities [3]
- *Put-away/Storage*: material movement from unloaded area to its decided place in inventory [14], [15].
- *Replenishment*: product transfer from reserve storage area to forward pick area [16].

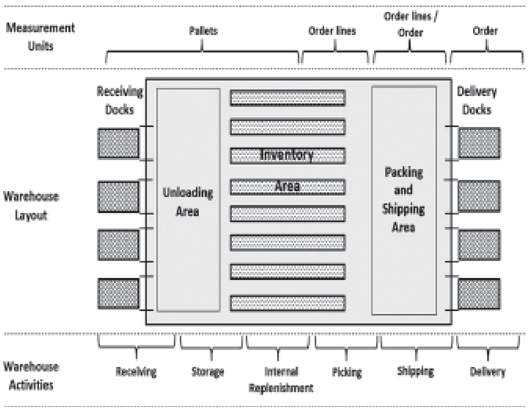

Figure 1: Standard warehouse layout and its activities [7].

● *Order picking*: process of obtaining a right amount of the right products for a set of customer orders [17]. This is the main and the most labor intensive activity of warehouses [18].

● *Shipping*: execution of packing and truck's loading after order picking, involving also the assignment of trucks to docks [13].

● *Delivery*: transit from the warehouse to the customer.

2.2 *Warehouse performance indicators*

A literature research is carried out in order to identify the indicators utilized by many researchers to measure warehouse performance. Once the set of indicators are extracted from papers, they are classified according to the dimensions of *Time* [15], [19], *Cost* [20], [21], *Productivity* [21], and *Quality* [19].

● *Time indicators* such as: labor hour, receiving time, put-away time, dock to stock time, replenishment time, order picking time, delivery lead time, order lead time.

● *Cost indicators* such as: inventory cost, transportation cost, infrastructure cost, labor cost, maintenance cost, information processing cost.

● *Productivity indicators such* as: receiving productivity, storage productivity, replenishment productivity, picking productivity, shipping productivity, delivery productivity, inventory utilization, transport utilization, warehouse utilization, equipment utilization, labor utilization.

● *Quality indicators* such as: receiving accuracy, storage accuracy, replenishment accuracy, physical inventory accuracy, picking accuracy, order shipped accuracy, delivery accuracy, on time delivery, orders shipped on time, customer satisfaction, stock out rate, perfect order.

2.3 *External factors affecting warehouse performances*

Most of businesses could be challenged by issues occur outside boundaries of their organization which they cannot control. These are external factors. Mostly, they relate to inflation rate, government policies, political stability, environmental awareness, demographics, innovation and technology enhancement. It could both positive and negative impact businesses. In logistics services sector, Tongzon [22] indicated market potential, purchasing power, government policy and regulations incentives for investors, infrastructure development and technology base are significant factors in term of competitiveness. To determine impact of external factors on business performances, there are several tools to provide analytical framework. PESTLE is an acronym of Political, Economic, Social, Technological, Environmental and Legal factors. It is a framework for investigating and analyzing the external environment for a business organization. The key areas commonly considered are: PEST, STEEPLE or PESTEL depend on business characteristics. Hirunwat and Khemavuk [23] found the technological factor is the most significant on warehouse performance, comparatively. Meanwhile, the social and economic factors are at the same level of impact assessment. They should be concerned as socio-economic aspect which has an impact in term of supply and demand side of warehouse operations. The last factor, political issue, could be the least significant.

In this paper, a PEST technique is used as an analytical tool. It is a general framework for comprehensive strategic analyzing external factors influence logistics operations. They can also be classified as opportunities and threats in an SWOT analysis.

● *Political factors* could imply to the public policies and regulations that created by government. They able to impact an organization both positively and negatively. The stability of political situation also has serious implication for business operations. The factors could be defined to government leadership, corruption levels, trade restricts and reform, tax regulations and employment and operation laws.

- *Economic factors* can be commonly considered such as wage rate, economic change and energy cost, inflation, ease to do business, financial issues and exchange rate. Folinas and Aidonis [24] found that the economic crisis in Greece had influenced significantly all the main function of logistics management included warehousing, inventory management, transportation and distribution.
- *Social factors* could refer to labour relations changes, consumer behaviors and lifestyle, demographics, social mobility, historical issues. These factors should be concerned for formulating business strategy and operational improvement plan. Social factors also play a critical role in international and global markets. These changes could often be subtle, and hard to predict or identify pending a major impact is raising.
- *Technological* factors could cover technology and innovation development and information and communication system. Information technology enhancements can also instigate extensive business impacts, it often across industries or a range of organizations. It can be developed an advance operation in an industry or market in particularly.

3 Methodology

It will appear that internal factors impact warehouse performances [18]. External factors become an issue to be concerned on warehousing strategy. In order to examine an interaction of warehouse performance measurements and affected external factors on the performance, this paper was conducted to study the effects of external factors affecting warehouse performance. Initially, the state of problem is how significant of each external factor on warehouse performances as shown in Figure 2.

The hypotheses of this study are described below:

H1: There are relationships among time, cost, productivity and quality indicators.

H2: Time indicator is significant to warehouse performance.

H3: Cost indicator is significant to warehouse performance.

H4: Productivity indicator is significant to warehouse performance.

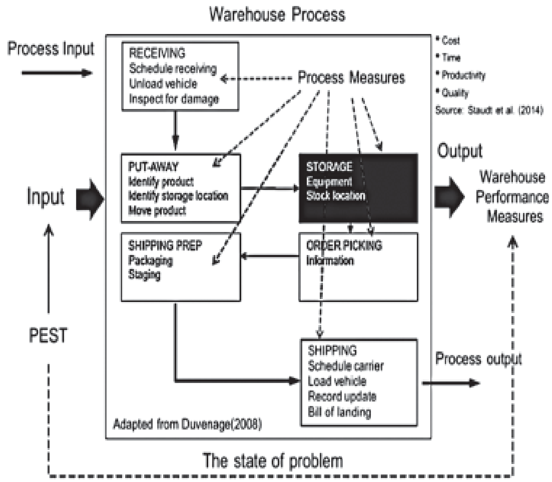

Figure 2: The state of problem.

H5: Quality indicator is significant to warehouse performance.

3.1 *Questionnaire design*

The questionnaire was designed to examine the relationship among four warehouse performance indicators and the effects of external factors on each warehouse performance indicators.

From Figure 3, all warehouse performance indicators consist of 15 variables as follows.

1. Time indicators. (3 variables)
   The scale used in T1–T3 are 1 to 7 scales.
   1.1 Labor hour for each month. (T1)
   1.2 Average delivery cycle time. (T2)
   1.3 Average warehouse order cycle time. (T3)
2. Cost Indicators. (6 variables)
   The scale used in C1–C6 are 1 to 7 scales.
   2.1 Ratio of labor cost per sale for the 12 month period. (C1)
   2.2 Ratio of holding cost per sale for the 12 month period. (C2)
   2.3 Ratio of transportation cost per sale for the 12 month period. (C3)
   2.4 Ratio of maintenance cost per sale for the 12 month period. (C4)
   2.5 Ratio of infrastructure cost per sale for the 12 month period. (C5)

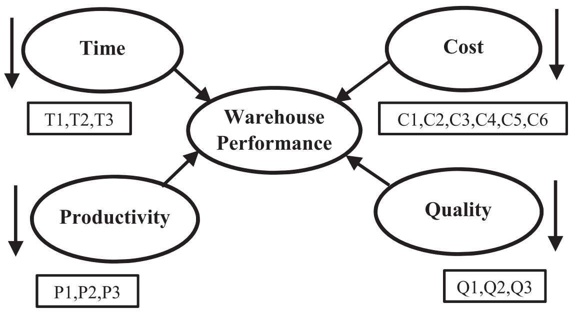

Figure 3: Major warehouse performance indicators.

2.6 Ratio of information processing cost per sale for the 12 month period. (C6)

3. Productivity indicators. (3 variables)

The scale used in P1–P3 are 1 to 7 scales.

3.1 Warehouse utilization for the 12 month period. (P1)

3.2 Equipment utilization for the 12 month period. (P2)

3.3 Transport utilization for the 12 month period. (P3)

4. Quality indicators. (3 variables)

The scale used in Q1–Q3 are 1 to 7 scales.

4.1 Inventory accuracy for the 12 month priod. (Q1)

4.2 Customer satisfaction for the 12 month period. (Q2)

4.3 Perfect order for the 12 month period. (Q3)

3.2 *Build up the proposed model*

3.2.1 Data collection and analysis

After the pre-test, the questionnaires were sent out to 260 companies in three different industries in Thailand, namely rubber and plastic, electronic and electrical equipment, motor vehicles and trailers.

The questionnaires were received from 240 companies with 265 warehouses. After that the 265 warehouses were divided into two groups. Firstly, a dataset of 215 warehouses was used to build up a proposed model. The second dataset of 50 warehouses was used to test the proposed model.

In this paper SPSS software and statistical techniques including outlier, standardization, collinearity statistics and reliability test were used to analyze the questionnaire data as described below.

- Outlier technique: First the data should be filtered, and any outliers removed from the data. The result shows that there was no unusual data of any indicators.
- Standardization: The data should be normalized or standardized to bring all of the variables into proportion with one another. A z-score is a standard score obtained by subtracting the mean from a score and dividing by the standard deviation. For example, indicator T1 will be standardized to ZT1.
- Collinearity statistics: Multicollinearity or collinearity refers to a situation in which two or mor explanatory variables in a multiple regression model are highly linearly related. The result shows that the value of the Variance Inflation Factor (VIF) for ZQ2 is 0.183. Multicollinearity occurs with ZQ2 and the data were neglected from analysis, then 14 independentindicators are used to build up a proposed model.
- Reliability test: This step is to test the reliability of the questionnaire whether it is suitable for using as a tool for data collection. The result shows that the value of Cronbach's Alpha is 0.624 meaning that the questionnaire is reliable for collecting the data.

3.2.2 Structural Equation Modeling (SEM) technique

The details in this session show how to build up the proposed model by applying the Structural Equation Modeling (SEM) technique with AMOS software. After testing the correlation between the 14 independent indicators, All warehouse indicators were group into factors before doing SEM technique. First, the KMO value would generally be used to test whether all data were appropriated for applying factor analysis technique or not.

$$KMO_j = \frac{\sum_{i\neq j} r_{ij}^2}{\sum_{i\neq j} r_{ij}^2 + \sum_{i\neq j} ru_{ij}^2}$$

After testing KMO value, the result shows that the KMO is 0.765 indicating that this dataset is appropriate for factor analysis technique.

Therefore, varimax rotation method was chosen to group those 14 independent indicators into factors as shown in Table 1.

Table 1: Rotated component matrixa

	Component			
	1	2	3	4
ZT1	.431	.744	.073	–.113
ZT2	.768	.032	–.030	.147
ZT3	–.025	–.028	.804	.207
ZC1	.134	.002	.766	.052
ZC2	.129	.088	.140	.877
ZC3	.780	–.019	.082	–.273
ZC4	.825	–.184	–.025	.029
ZC5	.719	–.269	.037	.349
ZC6	.677	–.312	.095	.397
ZP1	–.291	.593	–.111	–.083
ZP2	–.207	.820	–.037	–.015
ZP3	–.448	.648	–.014	.028
ZQ1	–.069	.691	–.241	.287
ZQ3	.086	.323	–.492	.153

Extraction method: Principal component analysis.

Rotation method: Varimax with kaiser normalization.

[a]Rotation converged in 6 iterations.

The hypothesis model in Figure 4 assumes that time, cost, productivity and quality measures are being significant to warehouse performance.

Next, the factor coefficient of all indicators was used in order to group into factors (see Table 2). Thus, all indicator variables can be grouped into 4 factors as follows.

Factor 1 (F1): ZT2 ZC3 ZC4 ZC5 ZC6
Factor 2 (F2): ZT1 ZP1 ZP2 ZP3 ZQ1
Factor 3 (F3): ZT3 ZC1 ZQ3
Factor 4 (F4): ZC2

However, Factor 4 (F4) consists of only one indicator variable that is ZC2. In order to run the hypothesis model with AMOS software, ZC2 was needed to group into another factor. From Table 1, the factor loading value of ZC2 for factor 3 is 0.140, thus ZC2 can be grouped into factor 3 (F3). Then three factors are used with AMOS software program to build up a proposed model.

During each analytical step, data were tested several time by using AMOS software until the proposed model is accepted. According to the goodness-of-fit measure in Table 2, a proposed model is acceptable based on those 5 measures there are chi-square, Goodness-of-Fit Index (GFI), Normed Fit Index (NFI), Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA).

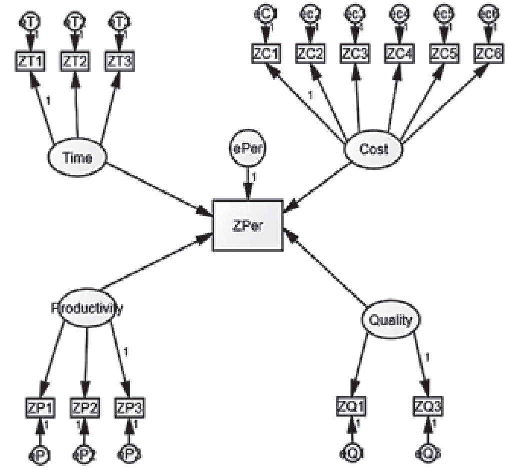

Figure 4: Hypothesis model with AMOS software.

After several analytical steps with AMOS software program, the proposed model of warehouse performance measurement is presented in Figure 5 and acceptable based on those 5 measures as shown in Table 2.

Table 2: Model fit summary

Goodness-of-fit measures	Recommended values*	A proposed model
Chi-square (χ^2)	P ≥ 0.05	P = 0.876
Goodness of Fit Index (GFI)	GFI ≥ 0.9	GFI = 0.979
Normed Fit Index (NFI)	NFI ≥ 0.9	NFI = 0.975
Comparative Fit Index (CFI)	CFI ≥ 0.9	CFI = 1.000
Root Mean Square Error of Approximation (RMSEA)	RMSEA ≤ 0.06	RMSEA = 0.00

* Hu and Benler, 1999 Chau, 1977

From a proposed SEM model of warehouse performance measurement in Figure 5.

$$Performance = [(0.08*F2)+(0.81*F3)–(0.1*F1)] \quad (1)$$

$$F1 = [(0.61*ZT2)+(0.5*ZC3)+(0.8*ZC4)+(0.83*ZC5)+ (0.78*ZC6)]$$

$$F2 = [(0.59*ZP1)–(0.07*ZT1)+(0.76*ZP2)+(0.76*ZP3)+(0.56*ZQ1)]$$

$$F3 = [(0.16*ZQ3)–(1.01*ZT3)–(0.45*ZC1)–(0.23*ZC2)]$$

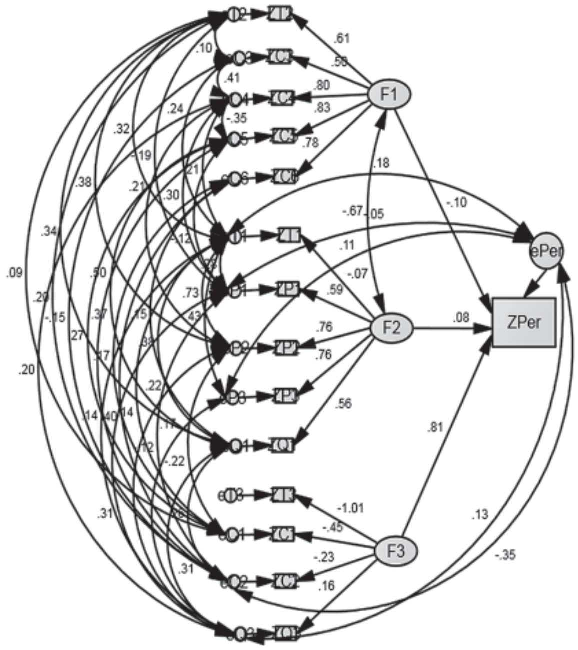

Figure 5: A proposed SEM model of warehouse performance measurement.

Then:

$$Performance = [(0.0472*ZP1)-(0.0056*ZT1)+(0.0608*ZP2)+(0.0608*ZP3)+(0.0448*ZQ1)]+[(0.1296*ZQ3)-(0.8181*ZT3)-(0.3645*ZC1)-(0.1863*ZC2)]-[(0.061*ZT2)+(0.05*ZC3)+(0.08*ZC4)+(0.083*ZC5)+(0.078*ZC6)] \quad (2)$$

Equation (1) shows a proposed model of warehouse performance measurement, it indicates that 14 variables are significant to warehouse performance with level of significant at 0.05. These indicators are labor hour for each month (ZT1), average delivery cycle time (ZT2), average warehouse order cycle time (ZT3), ratio of labor cost per sale (ZC1), ratio of holding cost per sale (ZC2), ratio of transportation cost per sale (ZC3), ratio of maintenance cost per sale (ZC4), ratio of infrastructure cost per sale (ZC5), ratio of information processing cost per sale (ZC6), warehouse utilization (ZP1), equipment utilization (ZP2), transport utilization (ZP3), inventory accuracy (ZQ1) and perfect order (ZQ3).

Equation (2) shows the first three significant factors that impacted warehouse performance measurement are average warehouse order cycle time (ZT3), ratio of labor cost per sale (ZC1), and ratio of holding cost per sale (ZC2).

3.3 *PEST analysis*

From Equation (2), these three warehouse performance indicators; ZT3, ZC1, and ZC2 have the first three highest negative coefficient values of –0.8181, –0.3645, and –0.1863 respectively. These negative values demonstrate that the decrease in order cycle time, labor cost, and holding cost are associated with the increase in warehouse performance. Therefore, the external factors were considered in order to find the level of their impact on those three internal factors as shown in Table 3.

Table 3: Effect of PEST on warehouse performance indicators

	Political	Economic	Social	Technological
Average warehouse order cycle time (ZT3)	0.938%	6.042%	6.466%	13.460%
Ratio of labor cost per sale (ZC1)	4.833%	20.083%	4.104%	3.667%
Ratio of holding cost per sale (ZC2)	2.667%	19.425%	2.646%	6.038%

The data was collected from warehouse managers. It shows that the impact level of technological factor was assessed the most influence on order cycle time as technology can speed up the warehouse operations. Similarly, economic factor was also ranked the most and second most impact on labor cost and holding cost consecutively with very close scores. On the other hand, political and social factors were considered less influence on those internal factors. Implicitly, the data indicates that the performance of warehouse should be higher by investing more on technology. However, the economic situation must be monitored as it drives the numbers of sale in which labor cost and holding cost should be seriously managed.

4 Conclusions

The proposed model for measuring warehouse performance with Structural Equation Modeling (SEM) technique in this study can overcome limitation of traditional models and it shown the first three significant warehouse performance indicator that effect on warehouse performance measurement were average warehouse order cycle time (T3), ratio of labor cost per sale (C1),and ratio of holding cost per sale (C2). The proposed model can help manufacturing firms to know the firm warehouse performance and support to observe the resources of other warehouse in order to improve their own performance.

After that the PEST analysis is applied with the proposed model the results found that technological factor is the most significant on warehouse performance. That mean the warehouse performance can increase more if they use the new technology or automated system on warehouse management. Meanwhile, the economic factors are the secondary level of impact assessment. They should be concerned as economic aspect which has an impact in term of supply and demand side of warehouse operations. The last two factors are social and political issue, could be the least significant. It could hardly even an affect the performance pending might not to be concerned.

In the real situation of warehouse operations, it could be difficulty determined a relationship between external factors and warehouse performance. But several literatures and business cases have been some clues that external factors are likely to affect business performances.

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