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# Exploring Company Performance Measurement for Truck Manufacturers

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This paper aims to develop a quantitative model of company performance from an inventory perspective for truck manufacturers. With the inventory performance as a new dimension, fourteen indicators are identified to form a conceptual framework for truck manufacturers to measure their company performance. Accordingly, techniques of the fuzzy logic and the analytic network process (ANP) are used to generate the quantitative model, considering the interdependency between the indicators and the uncertainty arising from human qualitative judgments. A case study is conducted in nine truck manufacturers, with time series data from the fiscal year 2004 to 2015. The ranking result out of the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used as a validation, which proves the higher accuracy of the model developed.

**Keywords:** Company performance, Multi-criteria decision making, Inventory performance, Truck manufacturers.

## Introduction

Originating from Toyota production system, lean production (LP) has evolved as a best-practice strategy over time and has been widely applied beyond the automotive industry. LP focuses on creating value and eliminating waste. The notion of ‘value’ has been increasingly emphasized under the global competitive environment. Companies regard their value creation as a main objective, thus it is necessary for companies to quantify their value-added activities’ performance. The worldwide truck market can be considerably impacted by changes in politics and economy, such as the large dip during the financial crisis around the year 2009. Under the complex global competition, it is vital that truck manufacturers can adopt an effective company performance measurement, which is suitable for the specific operation and management background of the truck industry, to gauge how well they perform at adding value for their shareholders. The cost-related financial performance measurements are still being primarily relied on for company performance despite the false image of a company’s situation it may present. This is due to the lack of acceptance of some novel performance measurements which are reasonable both theoretically and practically (Fatur, 2009). Besides creating value, LP also focuses on eliminating waste. Waste is defined as any human activity which absorbs resources but creates no value (Womack and Jones, 1996). Ohno has identified seven types of waste, and excess inventory is one of them. Inventory performance is commonly operationalized as inventory turnover and inventory to sale ratio (Cannon, 2008). Inventory performance is argued to be a robust indicator in company’s financial performance.

This paper is structured as follows: next, a literature review is conducted on inventory performance and on company performance, both at the company level in manufacturing industry,

following a conceptual framework M of company performance measurement for truck manufacturers. And then the corresponding quantitative model V is developed, with the application of the fuzzy logic and ANP to get the weights of the measures within M. And then a case study is conducted in nine truck manufacturers, with time series data from the fiscal year 2004 to 2015. The validation of the model V is conducted by comparing its ranking result with the result from TOPSIS. Finally, the conclusions as well as the directions for future research are presented.

## Literature Review

### *Inventory Performance*

#### *Inventory*

In accounting, inventory is an important assets for a company, because the turnover of inventory represents one of the primary sources of revenue generation and the subsequent earnings for the company's shareholders (Virender, 2010). Inventory consists of three sub accounts: raw materials inventory (RMI), work-in-progress inventory (WIP) and finished goods inventory (FGI) (Michaloudis et al., 2008). RMI represents goods which is used in the production as a source material, WIP includes goods which is in the process of being transformed during manufacturing and is about to be converted into finished goods, and FGI represents products that have gone through the production and are ready for sale. LP has evolved as a powerful management strategy over time, and it has been applied in sectors like aerospace, steel mills, food, electronics, service, health care etc. Excess inventory is one type of waste within a company, which should be eliminated.

#### *Inventory performance*

Some research highlights the central role that inventory plays in companies' financial performance and employ publicly available inventory data to state that inventory has been decreasing in many manufacturing sectors with a better financial performance. It is concluded that companies with abnormally high inventories have abnormally poor long-term stock returns, and companies with slightly lower than average inventories have good stock returns, but companies with the lowest inventories have only ordinary returns. A case study was conducted in U.S. manufacturing companies (standard industrial classification codes from 2000 to 3999) during 1981 to 2000, and a linear mixed function was developed with "inventory to assets ratio" and "inventory days" as inventory measures, and "Tobin's Q", "market to book ratio" and "stock returns" as financial impact of inventories (Chen et al., 2005). Afterwards, the authors state that abnormally high and low inventory levels seem to negatively affect long-term stock price performance, adding "inventory to sales ratio" as the third inventory measure, with a portfolio method longitudinal analyses and a sample of retailers, wholesalers and manufacturers during 1981 to 2004 (Chen et al., 2007). As the first to systematically analyze the relationship between inventory performance and financial performance for a large sample of firms across all manufacturing industries, this research finds a significant positive correlation between inventory performance (total inventory, RMI, WIP and FGI) and financial performance (expressed by EBIT and gross profit). A case study was conducted in US-based manufacturing firms over the 26-year period from 1980 to 2005 by regression analysis (Capkun et al., 2009).

The relationship between the use of inventory management practices (expressed by inventory turnover) and the implementation of other manufacturing practices is studied, with 1160 manufacturing companies, by locally weighted smoothing approach and regression analysis. The results show that inventory turnover is weakly related to overall company performance (constructed from 15 descriptive measures from questionnaires) (Vastag and Whybark, 2005). It is concluded that inventory turnover does not lead to the improved company performance, with “ROA”, “ROI”, “market value added” and “Tobin’s Q” as measures. A case study is conducted in 244 companies from the year 1991 to 2000, and the results indicate no link between improvements in inventory performance and improvements in overall firm performance, even when fundamental changes to firms’ production approaches are taken into account (Cannon, 2008). It is revealed that the higher the level of inventories (expressed by inventory turnover and inventory days) preserved by a company, the lower its rate of returns (expressed by gross margin and net operating margin). A case study was conducted in Greek manufacturing companies in textile, food, and chemical industries from 2000 to 2002, and the results verified by means of pseudo-likelihood ratio test confirm the existence of a robust linear relationship but only in the chemicals sector (Koumanakos, 2008).

### *Company Performance Measurement*

Topics about company performance and its measurement have a long history in management and accounting literature (Neely et al., 2005). For a company, it is important to have a performance measurement as you cannot manage what you do not measure (Garvin, 2009). Traditional performance measurements are regarded as “lagged” because they are “the result of management action and organizational performance, not the cause of it” (Eccles and Pyburn, 1992). In addition, the exclusive use of a limited number of financial indicators may encourage a focus on short-term results, which is not suitable in today’s complex global competition environment (Fatur, 2009). Accordingly, performance measurement has been encouraged to evolve into integrated sets of both financial indicators and nonfinancial ones, such as the third generation of performance measurement system (Neely et al., 2003).

#### *Company performance measurement techniques*

Multi-criteria decision-making (MCDM) is one of the most widely used methodologies in fields like business and economy (Mardani et al., 2015). Over the last decades, several MCDM techniques have been proposed, such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Grey Relational Analysis (GRA), VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) and best-worst method (Rezaei, 2016), etc. Some researches utilize the fuzzy logic technique to evaluate and prioritize based on their financial performance for manufacturing industry (Fahami et al., 2015). Some researchers have focused on merging two or more techniques into one to overcome the shortcomings of each technique, which can increase the credibility of the assessment results. To evaluate business performance for high-tech manufacturing companies, a new set of 5 dimensions and 18 indicators is identified. An evaluation approach, consisting of the data envelopment analysis (DEA), AHP, fuzzy logic and TOPSIS, is developed and demonstrated with a case study in liquid-crystal display panel companies in Taiwan (Tseng et al., 2009). A lean dynamic model is developed based on parameters of conception, configuration and conception to measure the lean performance of

companies and can serve as a benchmarking tool (Beelaerts van Blokland et al., 2008). A framework is developed with 5 dimensions and 5 indicators for automobile sector. By the techniques of bivariate correlation analysis and multiple regression analysis, a performance index  $I_p$  is constructed and calculated to quantify companies' capabilities in creating value in 33 carmakers and 5 truck builders (Beelaerts van Blokland et al., 2010).

### Research Question

Literature on company performance measurement at the company level for manufacturing sectors is listed in appendix A. The literature highlights the limited research on the effect of inventory performance on overall company performance besides financial perspective. As is shown in figure 1, LP focuses on value creation and waste reducing. Traditionally, more value created means better financial performance and better company performance, and more excess inventory (a type of waste) eliminated means better inventory performance. As to the effects of inventory performance on company performance, most of the studies just replace company performance with financial performance and suggest inventory performance acts as a trigger for financial performance, while some others consider that no relation exists between the two performances in some industries.

This paper proposes the main research question as follows: *How to quantitatively measure company performance with an inventory perspective for truck manufacturers?* Based on this main research question, two sub questions are proposed, both of which are for truck manufacturers with an inventory perspective:

*RQ<sub>1</sub>: What indicators can be used to quantitatively measure company performance?*

*RQ<sub>2</sub>: Can these indicators form a quantitative company performance measurement model?*

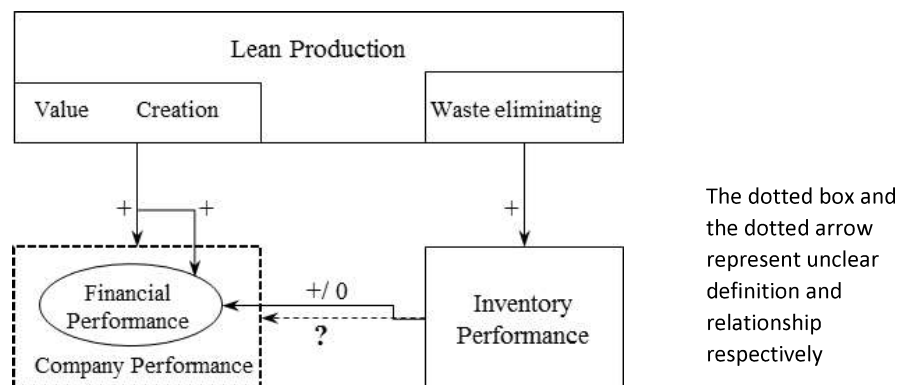


Figure 1: Framework of LP, company performance and inventory performance.

### A Conceptual Framework

During the whole process of the company performance measurement framework for truck companies, some basic requirements are always considered:

- from both a long- term and short-term perspective;
- the performance measurement should be undertaken in ways that are easily understood by the truck companies whose performance is being evaluated;

- the performance measurement should be accomplished by a limited number of performance measures that consists of both financial and non-financial measures (Tangen, 2003).

#### *Five Dimensions from Prior Research*

From the literature, four dimensions are highlighted:

1. Competition performance.
2. Financial performance.
3. Manufacturing capability.
4. Supply chain relationships.

Besides the four dimensions, innovation capability is added for a business performance evaluation dimension in high-tech manufacturing industry (Tseng et al., 2009). Besides, referring to the researches (Beelaerts van Blokland, 2010, Beelaerts van Blokland et al., 2012), this paper proposes a new conceptual company performance measurement framework M for truck manufactures. Instead of the dimension “innovation capability” for high-tech industry, this paper takes “technology performance” considering truck a manufacturing sector does get more sensitive to the technologies.

#### *Inventory Performance as an Original Dimension*

*Inventory turnover.* It reflects the overall efficiency of the supply chain, from suppliers to customers (Rabinovich et al., 2006). Inventory turnover (INT) can be calculated as sales divided by average inventory, and it is also can be calculated as the cost of goods sold (COGS) divided by average inventory. Both calculations can be available for the total inventory as well as its three sub accounts. Because sales include a mark-up over cost, the former calculation inflates inventory turnover. Thus, for higher accuracy, in this paper, inventory turnover is calculated as in equation (1), where  $I$  for inventory size,  $t$  and  $t-1$  for the fiscal year  $t$  and the fiscal year  $t-1$  respectively.

$$INT_t = COGS_t / [0.5 * (I_t + I_{t-1})] \quad (1)$$

*Inventory efficiency.* This paper adopts inventory to sales ratio (ITSR) for inventory efficiency, which measures the percentage of inventories the company currently has on hand to support the current amount of net sales. Traditionally, an increasing ITSR is a negative sign, showing the company may be in trouble keeping inventory down. Viewing this ratio over several time periods reveals the important aspect of the company’s ability to manage inventories while attempting to increase sales. It is important to compare their ratios to industry averages. In this paper, ITSR is calculated as in equation (2), where  $GS$  for Gross Sales.

$$ITSR_t = [0.5 * (I_t + I_{t-1})] / NS_t \quad (2)$$

#### *A conceptual framework M*

To answer  $RQ_1$ , a conceptual framework M is developed for truck manufacturers to measure their company performance. As is shown in table 1, M consists of six dimensions, fourteen indicators and their measures.

Table 1: The conceptual framework M of company performance for truck companies.

Dimension	Indicator	Measure	Reference(s)
Competition performance (CP)	C <sub>1</sub> Sales	Sales turnover ( $T$ ) [\$]	Doyle and Hooley, 1992, Simatupang and Sridharan, 2005
	C <sub>2</sub> Market share	Market share( $MS$ ) [%]	Kozmetsky and Yue, 1998, Govindarajan and Gupta, 1985
Financial performance (FP)	C <sub>3</sub> Profitability	Net profit margin ( $NM$ ) [%]	Doyle, 1994, Sinkey and Nash, 1993, Hsu, 2015
	C <sub>4</sub> Market capitalization	Market capitalization ( $MC$ ) [\$]	Low, 2000, Shiu, 2006, Tseng et al., 2009
	C <sub>5</sub> Financial leverage	Financial leverage ratio ( $FLR$ ) [%]	Ertuğrul and Karakaşoğlu, 2009, Murphy et al., 1996
Manufacturing capability (MC)	C <sub>6</sub> Cash flow margin	Operating cash flow margin ratio( $OCFR$ ) [%]	Volpe, 2017, Chandler and Hanks, 1993, Tan, 2002
	C <sub>7</sub> Productivity	Trucks produced per employee ( $T_p/E$ ) [#]	Brignall et al., 1991, Laitinen, 2002
	C <sub>8</sub> Continuity	Profit per employee ( $P/E$ ) [\$]	Beelaerts van Blokland, 2010, Bryan, 2007
	C <sub>9</sub> Conception	R&D expenditure per employee ( $R\&D/E$ ) [\$]	Keeble and Walker, 1994
Technology performance (TP)	C <sub>10</sub> R&D efficiency	R&D expenditure per profit ( $R\&D/P$ ) [%]	Beelaerts van Blokland et al., 2010
	C <sub>11</sub> Profit leverage	Profit leverage ratio ( $T/P$ ) [%]	Beelaerts van Blokland et al., 2010
Supply chain relationship (SCR)	C <sub>12</sub> Configuration	Turnover per employee ( $T/E$ ) [\$]	Beelaerts van Blokland et al., 2012, Clark et al., 1995
	C <sub>13</sub> Inventory turnover	Inventory turnover ( $INT$ )	Vastag and Whybark 2005
Inventory performance (IP)	C <sub>14</sub> Inventory efficiency	Inventory to sales ratio ( $ITSR$ )	Chen et al., 2007, Capkun et al., 2009

## Methodology

To answer  $RQ_2$ , an approach is developed for obtaining the quantitative function, including techniques of fuzzy logic, ANP. This paper refers to matrix manipulation approach (Saaty and Takizawa, 1986) to demonstrate its easy-to-understand in calculating the weights by ANP. A case study is conducted in nine leading truck manufacturers from the fiscal year 2004 to 2015.

### Fuzzy logic

To handle the inherent subjectivity and incompletely defined data, this paper adopts the fuzzy set theory, also referred as fuzzy logic (Werro, 2016). As a mathematical theory first introduced by Zadeh in 1965, its key idea is that an element has a degree of membership in a fuzzy set which is defined by a membership function (Taha and Rostam, 2011). The fuzzy set can be  $\tilde{a} = \{(x, \mu_{\tilde{a}}(x)), x \in R, \mu_{\tilde{a}}(x) \in [0, 1]\}$ , where  $x$  is a point in the universe,  $\mu_{\tilde{a}}$  for the membership function of  $\tilde{a}$ , and  $\mu_{\tilde{a}}(x)$  for the degree of  $x$  attributed to  $\tilde{a}$ . The membership function can be the trapezoidal function, the triangular membership function etc. Each fuzzy set corresponds to a linguistic variable, such as those associated with the nine-point scale by Saaty. This paper adopts the triangular membership function in equation (3) due to its computational simplicity for decision makers (Moon and Kang, 2001), where  $a^l$ ,  $a^m$  and  $a^u$  denote the smallest possible value, the most promising value, and the largest possible value respectively, and  $a^l \leq a^m \leq a^u$ .

$$\mu_{\tilde{a}}(x) = \begin{cases} (x - a^l) / (a^m - a^l), & a^l \leq x < a^m \\ 1, & x = a^m \\ (a^u - x) / (a^u - a^m), & a^m < x \leq a^u \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

ANP technique

It is stated that *AHP* ranked as the most frequently used *MCDA* technique in 2013 (Mardani et al., 2015). As its extension in solving *MCDA* problems, *ANP* allows dependency between factor and is more suitable to the realistic problems when being compared with *AHP* (Saaty, 2004). As is demonstrated in figure 2, there exists inner dependence within the six dimensions and fourteen indicators in this research. Thus, this paper adopts *ANP* to calculate the weights of the indicators.

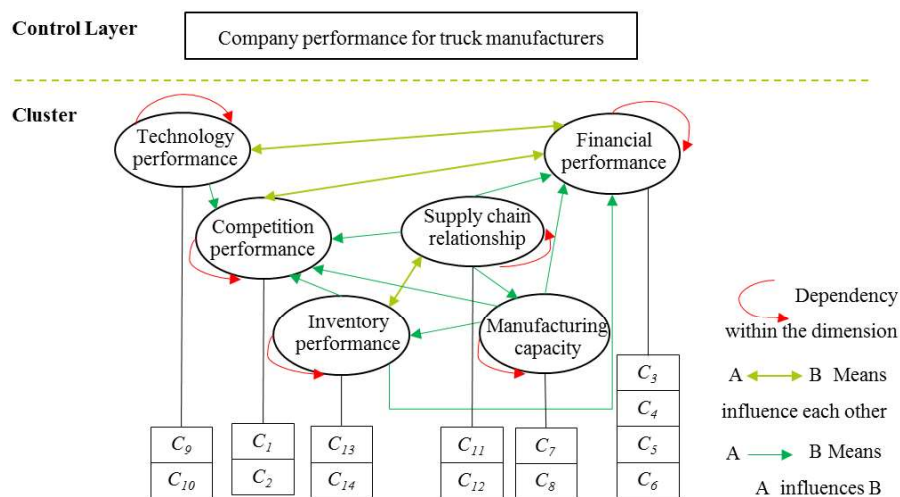


Figure 2: The structure of company performance for truck manufacturers.

According to *ANP*, the supermatrix with its sub-matrix notation for the conceptual framework *M* can be constructed in equation (4), where  $w_1$  is a vector that represents the impact of the control criterion on the cluster, namely, the impact of “company performance” on the six dimensions;  $W_2$  is a matrix with inner dependence between the six dimensions;  $W_3$  is a matrix that denotes the impact of the dimensions on the indicators; and  $W_4$  is a matrix with the impact of the indicators on each alternative, and *I* is the identity matrix. This research aims to calculate the weights of indicators on company performance.

$$W = \begin{bmatrix} 0 & 0 & 0 & 0 \\ w_1 & W_2 & 0 & 0 \\ 0 & W_3 & 0 & 0 \\ 0 & 0 & W_4 & I \end{bmatrix} \quad (4)$$



Fuzzy ANP

The steps for using fuzzy ANP to quantify company performance is as follows:

*Step 1.* Construct the ANP structure hierarchically with control layer, dimensions, and indicators.

*Step 2.* Construct the pairwise comparison matrices  $A$ , via experts' judgements and their linguistic variables (Ayağ and Samanlıoğlu, 2016, Saaty, 1989) and their corresponding importance levels from 1<sup>st</sup> and 2<sup>nd</sup> columns in table 2.

Table 2: The linguistic variables and their corresponding fuzzy numbers.

Linguistic variable	Importance levels	Fuzzy number	Membership function	$[\tilde{a}'_\alpha, \tilde{a}^u_\alpha]$
Equal importance	1	$\tilde{1}$	(1,1,2)	$[1,3-2\alpha]$
Moderate importance	3	$\tilde{3}$	(2,3,4)	$[1+2\alpha,5-2\alpha]$
Essential importance	5	$\tilde{5}$	(4,5,6)	$[3+2\alpha,7-2\alpha]$
Very strong importance	7	$\tilde{7}$	(6,7,8)	$[5+2\alpha,9-2\alpha]$
Extreme importance	9	$\tilde{9}$	(8,9,10)	$[7+2\alpha,11-2\alpha]$
Intermediate importance	2,4,6,8			

*Step 3.* Construct the fuzzy pairwise comparison matrices  $\tilde{A}$  and get it reconstructed with crisp values, as in equation (5) and (8) respectively. 1) Replace the crisp importance levels in  $A$  with the corresponding triangular fuzzy numbers from 3<sup>rd</sup> column in table 3, where reciprocal values are automatically assigned to the reverse comparison; 2) denote  $\alpha$  as the confidence level,  $\forall \alpha \in [0,1]$ ,  $a_\alpha = \{x \mid \mu_{\tilde{a}}(x) \geq \alpha\}$  as  $\alpha$  - cut set, and calculate  $\alpha$  - cut fuzzy comparison matrix with equation (6) (Taha and Rostam, 2011); 3) set the index of optimism  $\mu$ , which expresses the degree of satisfaction for the judgement matrix  $\tilde{A}$ ,  $\forall \mu \in [0, 1]$ , and calculate the elements  $\tilde{a}_{jp,\alpha}$  with the equation (7). In this paper,  $j$  and  $p$  ( $j, p = 1, 2, \dots, n$ , and  $j \neq p$ ) represent for the individual indicators for company performance measurement.

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{12}^{-1} & 1 & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{1n}^{-1} & \tilde{a}_{2n}^{-1} & \dots & 1 \end{bmatrix} \quad (5)$$

$$\tilde{a}_\alpha = [a', a^u] = [\alpha(a^m - a') + a', -\alpha(a^u - a^m) + a^u] \quad (6)$$

$$\tilde{a}_{jp,\alpha} = \mu \tilde{a}_{jp,\alpha}^u + (1 - \mu) \tilde{a}_{jp,\alpha}^l \quad (7)$$

$$A_\alpha = \begin{bmatrix} 1 & \tilde{a}_{12,\alpha} & \dots & \tilde{a}_{1n,\alpha} \\ \tilde{a}_{21,\alpha} & 1 & \dots & \tilde{a}_{2n,\alpha} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1,\alpha} & \tilde{a}_{n2,\alpha} & \dots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{a}_{12,\alpha} & \dots & \tilde{a}_{1n,\alpha} \\ \tilde{a}_{12,\alpha}^{-1} & 1 & \dots & \tilde{a}_{2n,\alpha} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{1n,\alpha}^{-1} & \tilde{a}_{2n,\alpha}^{-1} & \dots & 1 \end{bmatrix} \quad (8)$$

*Step 4.* Verify (and revise) the consistency of the comparison matrices and calculate the weights of the submatrix in equation (4). 1) For each comparison matrix, verify the consistency ratio (CR) as  $CI/RI$ , where  $CI$  is the consistency index in equation (9),  $\lambda_{max}$  is the maximum eigen value of the matrix, and  $RI$  is the

random index whose values had been assigned by *Satty* in 2001. All the *CR* values must be less than 0.10, which means the judgments are consistent enough to be acceptable, otherwise the comparison matrix should be revised; 2) calculate the vector  $w_1$  and the matrix  $W_3$ , with assumption that there is no dependence between the six dimensions or between the fourteen indicators; 3) similarly, the step 2 and step 3 for the indicators and calculate the sub-matrix  $W_2$ .

$$CI = (\lambda_{max} - n) / n - 1 \quad (9)$$

*Step 5.* Calculate the interdependent priorities of the dimensions as  $w_d = w_1 \times W_2$ , and finally calculate and normalize the weights of the indicators on company performance as the vector  $w = W_2 \times w_1 \times W_3$ ,  $w \in (0,1)$ .

*Step 6.* Construct a decision matrix  $B_{m \times n}$  and normalize the elements with the procedure in equation (10), where  $i (i=1,2,\dots,m)$  represents for the alternative truck manufacturers,  $x_{ij}^t$  for the value of indicator  $j$  on alternative  $i$  at fiscal year  $t (t=0,1,\dots,T)$ ,  $x_{ij}^{*t}$  for the normalized value of  $x_{ij}^t$ , and  $x_{ij}^{*t} \in (0,1]$ .

$$x_{ij}^{*t} = \begin{cases} \frac{x_{ij}^t}{\max_i x_{ij}^t} & \text{if } x_{ij}^t \text{ satisfies "the larger the better" category} \\ \frac{\min_i x_{ij}^t}{x_{ij}^t} & \text{if } x_{ij}^t \text{ satisfies "the smaller, the better" category} \end{cases} \quad (10)$$

*Step 7.* Aggregate and calculate the values for the nine companies as equation (11), where  $P_i^t$  is the index of company performance for truck manufacturers  $i$  at fiscal year  $t$ , and  $I_i^t \in (0,1)$ .

$$P_i^t = \sum x_{ij}^{*t} * w_j \quad (11)$$

### Analysis

To demonstrate the applicability of the approach proposed, a case study is conducted in nine influential truck manufacturers. As is listed in table 3, they are from Europe, America and Asia, and account for more than 51.7% percent of the total global vehicle production volume in 2015 (source: *IHS Automotive, KPMG International*). Yearly data is mainly collected from public available annual reports, and the currency is adjusted in US dollars for comparability. The period is from the fiscal year 2004 to 2015, which is the largest time span, since all the 9 sample companies had been listed with complete data for the research since 2004, and reports in 2016 are not available at the time of this paper.

*Table 3:* List of the nine sample truck manufacturers.

Name	Identifier	Country	Name	Identifier	Name	Identifier	Country
Daimler	DAI	Germany	Volvo	VOL	CNHTC	CNH	China
MAN	MAN	Germany	Navistar	NAV	Dongfeng	DFG	China
Scania	SCA	Sweden	Paccar	PAC	Ashok Leyland	ASH	India

#### *The company performance measurement function V*

According to the steps mentioned above, the steps for using fuzzy ANP to develop the quantitative company performance measurement function  $V$  is as follows:

Step 1. Construct the schematic structure as is demonstrated in figure 2.

Step 2. Construct the pairwise comparison matrices for the six dimensions and the fourteen indicators, assuming no dependency, and for the six dimensions assuming dependency, with respect to company performance, respectively. All the comparison matrices are filled up based on a questionnaire of pairwise comparison (appendix B) and the average scores of judgements by five industry professionals. Take the pairwise comparison for the six dimensions assuming no dependence for example, the result is shown in table 4.

Table 4: The pairwise comparison  $A_1$  of dimensions assuming no dependency among them.

Dimension	CP	FP	MC	TP	SCR	IP
CP	1	1	5	1	1	3
FP	1	1	3	1	7	3
MC	1/5	1/3	1	3	1	3
TP	1	1	1/3	1	1	5
SCR	1	1/7	1	1	1	3
IP	1/3	1/3	1/3	1/5	1/3	1

Step 3. Construct the fuzzy pairwise comparison matrices and get it reconstructed with crisp values. in table 6. 1) Replace the crisp importance levels in  $A$  with the corresponding triangular fuzzy numbers in table 5; and 2) calculate the elements  $\tilde{a}_{ij,\alpha}$  for  $\alpha=0.5$  and  $\mu=0.5$ .

Table 5: The fuzzy numbers and  $\tilde{a}_{ij,\alpha}$  values for  $A_1$ .

Dimension	CP	FC	MC	TP	SCR	IP	Eigenvector	w <sub>1</sub>
CP	1	$\tilde{1}, 1.5$	$\tilde{5}, 5$	$\tilde{1}, 1.5$	$\tilde{3}, 3$	$\tilde{3}, 3$	-0.615	0.284
FC	$\tilde{1}^{-1}, 0.75$	1	$\tilde{3}, 3$	$\tilde{1}, 1.5$	$\tilde{7}, 7$	$\tilde{3}, 3$	-0.616	0.284
MC	$\tilde{5}^{-1}, 0.208$	$\tilde{3}^{-1}, 0.375$	1	$\tilde{3}, 3$	$\tilde{1}, 1.5$	$\tilde{3}, 3$	-0.321	0.148
TP	$\tilde{1}^{-1}, 0.75$	$\tilde{1}^{-1}, 0.75$	$\tilde{3}^{-1}, 0.375$	1	$\tilde{1}, 1.5$	$\tilde{5}, 5$	-0.290	0.134
SCR	$\tilde{1}^{-1}, 0.75$	$\tilde{7}^{-1}, 0.146$	$\tilde{1}^{-1}, 0.75$	$\tilde{1}^{-1}, 0.75$	1	$\tilde{3}, 3$	-0.202	0.093
IP	$\tilde{3}^{-1}, 0.375$	$\tilde{3}^{-1}, 0.375$	$\tilde{3}^{-1}, 0.375$	$\tilde{5}^{-1}, 0.208$	$\tilde{3}^{-1}, 0.375$	1	-0.122	0.056

$$RI=1.24; \lambda_{\max}= 6.9046; CR=0.0809$$

Step 4. Verify the consistency of the comparison matrices and calculate the weights of the sub-matrix. As is shown in table 6, the weights of the six dimensions with respect to company performance assuming no dependency among them is shown in calculated as  $w_1$ , with  $CI$  value is less than 0.10. Similarly, do the step 2 to step 4 for the six dimensions assuming dependency among them to get  $W_2$ , and for the fourteen indicators to get  $W_3$ , with respect to company performance.

$$W_2 = \begin{bmatrix} 1.000 & 0.311 & 0.255 & 0.655 & 0.269 & 0.127 \\ 0.212 & 1.000 & 0.441 & 0.345 & 0.352 & 0.322 \\ 0.295 & 0.096 & 1.000 & 0.000 & 0.211 & 0.341 \\ 0.174 & 0.214 & 0.000 & 1.000 & 0.000 & 0.000 \\ 0.132 & 0.359 & 0.121 & 0.000 & 1.000 & 0.210 \\ 0.187 & 0.021 & 0.183 & 0.000 & 0.168 & 1.000 \end{bmatrix},$$

$$W_3 = (0.465, 0.534, 0.211, 0.325, 0.319, 0.145, 0.601, 0.389, 0.549, 0.450, 0.299, 0.701, 0.698, 0.302)^T$$

Step 5. Calculate the interdependent priorities of the dimensions  $w_d$ , calculate and normalize the weights of the indicators on company performance  $w$ .

$$w_d = W_2 \times w_1 = \begin{bmatrix} 1.000 & 0.311 & 0.255 & 0.655 & 0.269 & 0.127 \\ 0.212 & 1.000 & 0.441 & 0.345 & 0.352 & 0.322 \\ 0.295 & 0.096 & 1.000 & 0.000 & 0.211 & 0.341 \\ 0.174 & 0.214 & 0.000 & 1.000 & 0.000 & 0.000 \\ 0.132 & 0.359 & 0.121 & 0.000 & 1.000 & 0.210 \\ 0.187 & 0.021 & 0.183 & 0.000 & 0.168 & 1.000 \end{bmatrix} \times \begin{bmatrix} 0.284 \\ 0.284 \\ 0.148 \\ 0.134 \\ 0.093 \\ 0.056 \end{bmatrix} = \begin{bmatrix} 0.530205 \\ 0.507141 \\ 0.298183 \\ 0.244152 \\ 0.262558 \\ 0.158045 \end{bmatrix}$$

$$w = (0.123, 0.142, 0.054, 0.083, 0.081, 0.037, 0.090, 0.058, 0.067, 0.055, 0.039, 0.092, 0.055, 0.024)^T$$

Step 6. Construct a matrix  $B_{m \times n}$  with the normalized values of the indicators for each of the nine sample truck manufacturers during the fiscal year 2004 to 2015.

Step 7. Generate the quantitative function of company performance  $P_i$  for each truck manufacturer.

$$V = f[x_j^{*t}, w_j] = \sum x_j^{*t} * w_j = 0.123T + 0.142MS + 0.054NM + 0.083MC + 0.081FLR + 0.037OCFR + 0.090T_p / E + 0.058P / E + 0.067R \& D / E + 0.055R \& D / P + 0.039T / P + 0.092T / E + 0.055INT + 0.024ITSR$$

### Validation of the function

To highlight the influence of inventory factor on the company's performance, this research also generated function 12 indicators, namely excluding inventory turnover and inventory to sales ratio indicators. Similar questionnaire survey is carried on excluding the *two inventory indicators*, and fuzzy ANP is used again for generating its function as follows:

$$V' = f[x_j^{*t}, w_j] = \sum_{j=1}^{12} x_j^{*t} * w_j = 0.061T + 0.126MS + 0.095NM + 0.047MC + 0.039FLR + 0.031OCFR + 0.2T_p / E + 0.113P / E + 0.055R \& D / E + 0.074R \& D / P + 0.096T / P + 0.063T / E$$

### Comparison with the result from TOPSIS

After determining the model for company performance  $V$ , we need to prove its validity in the ranking by comparing its ranking result with the result of TOPSIS technique. The underlying logic of TOPSIS is to define both the ideal solution and the negative ideal sets. The ideal set is the collection that maximizes the benefit indicators and minimizes cost indicators, while the negative ideal set maximizes cost and minimizes benefit (Marler and Arora, 2004). The manufacturer with the best performance is closest to the ideal solution and farthest from the negative ideal solution. TOPSIS is a frequently used ranking method.

In this paper, the required data of all the nine sample truck companies in 2015 is taken as an example to show the detailed calculation for the coefficient of similarity to the ideal set in TOPSIS. The steps are as follows:

Step 1. Assemble the evaluation matrix  $X = [x_{ij}]_{14 \times 9}$  with the 14 indicators and 9 truck manufacturers

and normalize the matrix  $R = [r_{ij}]_{14 \times 9}$ , where  $r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^9 x_{ij}^2}$ .

$$R = \begin{bmatrix} 0.0095 & 0.9540 & \dots & 0.1145 & 0.8959 \\ 0.0196 & 0.9788 & \dots & 0.1175 & 0.0881 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0.3100 & 0.1585 & \ddots & 0.5305 & 0.1171 \\ 0.2312 & 0.3817 & \dots & 0.1021 & 0.5376 \end{bmatrix}$$

Step 2. Calculate the ideal set  $A^+ = \{t_i^+ | \max_j t_{ij} (\text{benefit}) \& \min_j t_{ij} (\text{cost})\}$  and the negative ideal set

$$A^- = \{t_i^- | \min_j t_{ij} (\text{benefit}) \& \max_j t_{ij} (\text{cost})\}.$$

$$A^+ = (0.458, 0.949, 0.728, 0.315, 0.172, 0.197, 1.321, 0.685, 0.264, 0.605, 0.641, 0.301, 0.008, 0.204) \times 10^{-1}$$

$$A^- = (0.053, 0.006, -0.152, 0.001, -0.524, -0.163, 0.836, -0.960, 0.054, -1.510, -3.331, 0.541, 7.996, 0.882) \times 10^{-2}$$

Step 3. Calculate the distance for each company to the ideal set  $S^+ = \sqrt{\sum_{i=1}^{14} (t_{ij} - t_i^+)^2}$  and negative

$$\text{ideal set } S^- = \sqrt{\sum_{i=1}^{14} (t_{ij} - t_i^-)^2}.$$

$$S^+ = (0.1809, 0.1647, 0.2207, 0.1935, 0.1660, 0.1750, 0.1856, 0.1814, 0.1872)$$

$$S^- = (0.0872, 0.1490, 0.0644, 0.0970, 0.1357, 0.1356, 0.0971, 0.1032, 0.1469)$$

Step 4. Calculate the similarity for each company to the ideal set.

$$C = (0.325, 0.475, 0.226, 0.334, 0.450, 0.437, 0.343, 0.363, 0.440).$$

With calculated results of the coefficient of similarity to ideal set in TOPSIS,  $V^*$  and  $V$  the ranking is shown in table 6:

- TOPSIS: 1.Daimler, 2.CNHTC, 3.MAN, 4.DFG, 5.PACCAR, 6.Volvo, 7.Scania, 8.Ashok Leyland, 9.Navstar.
- $V^*$ : 1.Daimler, 2. DFG, 3.CNHTC, 4.PACCAR, 5.MAN, 6.Volvo, 7.Ashok Leyland, 8.Scania, 9.Navstar.
- $V$ : 1.Daimler, 2.CNHTC, 3.MAN, 4. Volvo, 5.PACCAR, 6. DFG, 7.Scania, 8.Ashok Leyland, 9.Navstar.

It is obvious that the ranking result from company performance model  $V$  (taking the inventory performance dimension into account) and the TOPSIS approach are very similar compared with the result from the function excluding inventory indicators. The result indicates the rationality of adding inventory performance into company performance measurement.

Table 6: Company performance measurement of the nine sample truck companies in 2015.

	w	ASH	DAI	NAV	SCA	CNH	DFG	VOL	PAC	MAN
CP		0.008	0.265	0.014	0.018	0.022	0.029	0.044	0.029	0.025
Priority		9	1	8	7	6	3	2	4	5
C1	0.123	0.013	1.000	0.062	0.069	0.018	0.120	0.228	0.118	0.092
C2	0.142	0.046	1.000	0.047	0.069	0.142	0.103	0.112	0.101	0.097
FP		0.046	0.143	-0.018	0.125	0.155	0.044	0.127	0.082	0.149
Priority		6	3	9	8	1	7	4	5	2
C3	0.054	0.050	0.090	-0.020	0.410	1.000	0.200	0.420	0.120	0.020
C4	0.083	0.010	0.780	0.080	0.000	0.030	0.010	0.090	0.520	1.000
C5	0.081	0.560	0.910	-0.300	0.850	0.760	0.400	1.000	0.290	0.740
C6	0.037	-0.080	0.000	0.010	0.910	1.000	0.010	0.430	0.230	0.140
MC		0.095	0.054	0.034	0.034	0.071	0.175	0.044	0.107	0.012
Priority		3	5	7	7	4	1	6	2	9
C7	0.090	1.000	0.140	0.470	0.140	0.720	1.760	0.200	0.540	0.110
C8	0.058	0.090	0.720	-0.140	0.370	0.110	0.290	0.450	1.000	0.030
TP		0.002	0.070	0.035	0.043	0.018	0.010	0.059	0.029	0.097
Priority		9	2	5	4	7	9	3	6	1
C9	0.067	0.020	1.000	0.730	0.590	0.210	0.140	0.820	0.420	0.620
C10	0.055	0.010	0.060	-0.250	0.070	0.080	0.020	0.080	0.020	1.000
SCR		0.029	0.067	0.058	0.030	0.053	0.019	0.050	0.095	0.069
Priority		8	3	4	7	5	9	6	1	2
C11	0.039	0.230	0.080	-0.520	0.070	0.330	0.050	0.090	0.080	1.000
C12	0.092	0.220	0.690	0.850	0.300	0.440	0.180	0.500	1.000	0.330
IP		0.035	0.030	0.032	0.031	0.012	0.062	0.030	0.047	0.033
Priority		6	7	5	6	9	1	8	2	4
C13	0.055	0.450	0.230	0.360	0.180	0.010	1.000	0.260	0.770	0.170
C14	0.024	0.430	0.710	0.500	0.860	0.490	0.310	0.640	0.190	1.000
V'		0.279	0.488	0.104	0.246	0.409	0.466	0.306	0.390	0.350
Ranking		7	1	9	8	3	2	6	4	5
V		0.215	0.629	0.155	0.281	0.333	0.340	0.354	0.388	0.385
Ranking		8	1	9	7	2	6	4	5	3
C from TOPSIS		0.325	0.475	0.226	0.334	0.450	0.437	0.343	0.363	0.440
Ranking		8	1	9	7	2	4	6	5	3

### Discussion

With the company performance measurement framework M and V this paper proposes, each of the 9 sample truck companies' company performance during the years 2004 - 2015 can be calculated and compared. In this section, V over time for each of the 9 sample companies is shown. To give a direct and better insight in the competitiveness, this paper makes each of the nine companies' company performance plotted over time in figure 5. All the nine sample truck companies' data is normalised at the beginning year 2004.

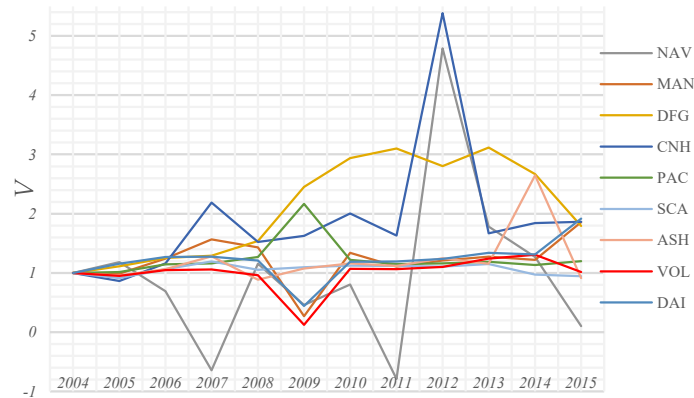


Figure 4: Values of V over time for each truck company.

In this graph, it is visible that for most of the companies, there was a peak in 2007 and after that they suffered, with a downward trend of their performance, which can be explained by the economic crisis between 2008 and 2009. In 2010, some truck companies revived, and the performance indicator increased due to the rapid economic recovery. Nevertheless, most of the truck companies' company performances remained below those of their pre-crisis, and the performance appears to have stabilized around 2013.

The highest performer over time obviously is Dongfeng, with CNHTC the second. Given the fact that Dongfeng and CNHTC are Chinese truck companies, they operate in one of the emerging BRIC countries with an increasing demand for transport of goods for new infrastructure projects, which easily leads to higher demand for trucks production. As two of the four most influential truck companies in China, Dongfeng and CNHTC are famous for their effort on independent research and development activities. The self-developed trucks like Tianlong and co-developed trucks like Jialong and HOWO, are environmental-friendly and cost-effective, and are becoming popular beyond China, contribute a lot to their better company performance. With trucks' extensive scrappage subsidy policy from the year 2009, the two companies have been pushed with the renewal of their older truck fleet. Around the year 2011, the V value of the two companies shrunk because of the negative domestic economic recession in China.

The two worst performers, Navistar and Shock Leyland, had almost all V values under 1.5 every year. For Shock Leyland, a higher company performance is expected, due to its influential position in the truck industry, however, according to its performance, it is underperforming. As reflected on the data set and the variables for the function V, the main reason for the poor performance may be that it has a larger number of employees, which makes variables like R&D expenditure per employee less, or maybe employees are not able to work very effectively by some policies, leading to the comparative low V value. As to the poor performance of Navistar, from the model and its relevant data, it was mainly caused by the unstable profitability, probably caused by the reduction of military sales and the shrinkage of demand of engines in South America. The other five companies, Paccar, Volvo, MAN, Daimler, and Scania are with average performance, normally with their V value > 1 respectively.

## Conclusion & Further Research

This paper gives insight into the following research question for truck manufacturers: the quantitative measurement of company performance with an inventory perspective. First, with literature review on company performance and inventory performance, this paper proposes a new conceptual framework of performance measurement, with inventory performance as a new dimension, for truck manufacturers, which leads to the answer to  $RQ_1$ . Second, this paper adopts the fuzzy ANP technique, for generating mathematic functions. Third, the TOPSIS technique is adopted to rank the 9 truck manufacturers. The comparisons of its result and the functions' results, indicate the rationality of adding inventory performance into company performance measurement. This gives the answer to  $RQ_2$ .

This research gave an insight on quantifying company performance measurement with an inventory perspective for truck manufacturers. To get a better understanding, more research within and beyond the truck industry should be done. This paper is limited to data available in public databases and includes only publicly listed truck manufacturers over the 2004-2015 sample period. The data set can be extended by considering more truck manufacturers and by covering more years. This the research can also be extended to a broader level by researching other unexploited fields and to see how their inventory performance affects company performance.

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## Appendix A

*Literature of company performance measurement on company level in manufacturing industry.*

<i>Author(s)</i>	<i>KPI</i>	<i>Content</i>
Power sector Vincent and Hu, 2010	<i>Productivity</i> : average monthly ratio; <i>production amount</i> : production amount; production cost: raw materials cost, direct labor cost and factory overhead; <i>inventory amount</i> : raw material amount, <i>WIP</i> amount and finished good amount; <i>quality cost</i> : internal failure cost, external failure cost and prevention cost.	For manufacturing capability; in a switch power manufacturer; with voting method, with fuzzy logic and <i>TOPSIS</i> .
Li and Zhao, 2016	<i>Economy development</i> : production value, job creation, technology investment; <i>energy utilization</i> : coal efficiency, water efficiency, electric energy efficiency; <i>refuse recycle</i> : waste water recycle, solid waste recycle; <i>pollutant emissions</i> : <i>SO</i> <sub>2</sub> emissions, <i>NO</i> <sub>x</sub> emissions, soot emissions.	For performance evaluation; in eco-industrial thermal power plants in China; with fuzzy logic, Shannon theory, <i>GRA</i> and <i>VIKOR</i> .
Process sector Deng et al., 2000	Profitability, productivity, market position and debt ratio.	For company performance; in 7 companies of Chinese textile industry; with <i>TOPSIS</i> .
Akyuz and Kuruuzum, 2010	Acceptable product rate, paint defect rate and chemical defect rate.	For measuring and improving manufacturing performance; in mirror manufacturing companies; with coefficient analysis and multiple regression analysis.
Nyaoga et al., 2016	Situations experienced, physical constraints situations, policy constraint situations, paradigm constraints situations, market constraints situations, factors motivating management of operational constraints, value chain strategies, benefit of value added tea production management and responsiveness.	For evaluating value chain performance; in the tea processing companies in Kenya; with <i>GRA</i> and <i>TOPSIS</i> .
Chmelíková, 2014	<i>Financial perspective</i> ; <i>internal process</i> : quality and cost; <i>customer perspective</i> : customer loyalty; <i>learning and growth</i> : skilled employees and employee productivity.	For company performance; in Chile breweries; with <i>BSC</i> , correlation analysis.
Rezaie et al., 2014	<i>Liquidity ratios</i> : current ratio; quick ratio; cash ratio; <i>financial leverage ratios</i> : debt ratio, shareholder's equity to total assets ratio, fixed assets to shareholder's equity and fixed assets to long term debt; <i>profitability ratios</i> : net profit margin and return on equity; <i>growth ratios</i> : sales growth, operating profit growth, shareholders' equity growth and assets growth.	For evaluating company performance by financial ratios; in 27 listed Iranian cement companies; with fuzzy logic, <i>AHP</i> and <i>VIKOR</i> .
Abbasi and Kaviani, 2016	<i>Input</i> : quality, cost, dependability, flexibility and speed; <i>output</i> : <i>ROA</i> , <i>ROI</i> and market share.	For evaluating operating effectiveness; in cement manufacturers of Iran; with fuzzy logic, <i>DEA</i> and <i>GRA</i> .
Ertuğrul and Karakışoğlu, 2009	<i>Liquidity ratios</i> : current ratio; quick ratio; cash ratio; <i>financial leverage ratios</i> : debt ratio, shareholder's equity to total assets ratio, fixed assets to shareholder's equity and fixed assets to long term debt ratio; <i>activity ratios</i> : account receivable turnover, inventory turnover ratio, current assets turnover ratio, total asset turnover ratio, accounts payable turnover ratio; <i>profitability ratios</i> : net profit margin ratio, return on equity ratio; <i>growth ratios</i> : sales growth, operating profit growth, shareholders' equity growth, assets growth.	For evaluating financial performance; in 15 listed Turkish cement manufacturers; with fuzzy logic, <i>AHP</i> and <i>TOPSIS</i> .
Moghimi and Anvari, 2014	<i>Liquidity ratios</i> : current ratio; quick ratio; <i>financial leverage ratios</i> : debt ratio, shareholder's equity to total assets ratio, fixed assets to shareholder's equity ratio and fixed assets to long term debt ratio; <i>activity ratios</i> : account receivable turnover, inventory	For evaluating financial performance; in 8 Iranian cement companies; with fuzzy logic, <i>AHP</i> and <i>TOPSIS</i> .

Parthiban and Goh, 2011	<p>turnover ratio, current asset turnover ratio, total asset turnover ratio; <i>profitability ratios</i>: net profit margin ratio, return on equity ratio. <i>growth ratios</i>: sales growth, operating profit growth, shareholders' equity growth, assets growth.</p> <p><i>Process efficiency</i>: operating cost per employee, cost of goods sold, product development time, rejection ratio, actual production against planned production, age of plant and equipment and capacity utilization; <i>product and process innovation</i>: R&amp;D expenditure, number of new products in the last 3 years and percent of products protected by patents; <i>product quality and customer satisfaction</i>: customer surveys and warranty claims, customer complaints, service responsiveness and percent of returned orders.</p>	<p>For manufacturing performance; in 2 Indian valve manufacturing companies; with <i>AHP</i> and quality function deployment.</p>
Tavana et al., 2015	<p><i>Financial</i>: EPS, P/E ratio, sales growth, debt ratio, rank of liquidity, cost of goods sold; <i>customer</i>: market share, volume of exports, customer satisfaction, customer loyalty and increasing of customer; <i>learning and growth</i>: number of registered drugs, advertising and marketing, employee satisfaction, employee training, increasing of employee and number of updating formula; <i>internal process</i>: number of products, management performance, new technologies, percent of waste and number of acquired certificates.</p>	<p>For evaluating company performance; in 21 listed pharmaceutical companies; with <i>BSC</i>, <i>DEMATEL</i>, fuzzy logic, <i>ANP</i>, <i>DEA</i> and Shannon theory.</p>
Electronics Chiu et al., 2014	<p><i>Input</i>: fixed assets, number of employees and R&amp;D stock. <i>Output</i>: revenue and patent number of stock.</p>	<p>For production efficiency; in cross-strait solar photovoltaic manufacturers; with <i>DEA</i>, Spearman's correlation analysis.</p>
Hsu, 2015	<p><i>DEA-Input</i>: number of employees, fixed assets, total asset; total debt, operating expenses, selling expenses, administrative expenses, <i>R&amp;D</i> expenses and inventory. <i>DEA-Output</i>: total revenue, net sales, net profit ratio, gross profit margin and operating income. <i>Profitability</i>: returns on assets, returns on equity, operating profit margin, net profit margin after tax and earnings per share; <i>solvency</i>: current ratio, quick ratio, debt ratio, long-term capital ratio, cash flow ratio and cash reinvestment ratio; <i>operating ability</i>: total assets turnover, accounts receivable turnover, inventory turnover, average daily sales, fixed assets turnover and shareholder equity turnover.</p>	<p>For ranking efficiency of operating performance; in Taiwan's listed semiconductor companies; with <i>VIKOR</i>, Shannon theory, <i>DEA</i>, improved <i>GRA</i> and Spearman's correlation analysis.</p>
Kozmetsky and Yue, 1998	<p>Market share and economic growth, employment and labour productivity, cost efficiency, profit margin, <i>R&amp;D</i> expenditure ratio and market value.</p>	<p>For evaluating company performance; in 56 global semiconductor companies; with <i>DEA</i> (<i>CCR</i>).</p>
Tseng et al., 2009	<p><i>Competition performance</i>: sales growth rate and market share; <i>financial performance</i>: earnings profitability, capital structure, market value and cash turnover ratio; <i>manufacturing capability</i>: cost efficiency, product yield rate, manufacturing flexibility, productivity and product quality level; <i>innovation capability</i>: number of patents, R&amp;D expenditure ratio, ability to obtain critical technology, capability to improve manufacturing processes; <i>supply chain relationships</i>: upstream materials and supplies, downstream tactical alliances.</p>	<p>For evaluating company performance; in Taiwan's large-sized thin-film transistor liquid-crystal display panel companies; with fuzzy logic, <i>AHP</i> and <i>TOPSIS</i>.</p>
Automotive Senvar et al., 2014	<p>Decreasing of inventory waiting time, increasing profit/cost of sale product, increasing of customer continuity, increasing of capacity, increasing of <i>R&amp;D</i> investment per employee, increasing of total performance of suppliers.</p>	<p>For evaluating company performance; in Turkish automobile companies; with fuzzy logic, <i>AHP</i> and <i>BSC</i>.</p>

Bulgurcu, 2013	Current ratio, acid test ratio, total debt ratio, debt equity ratio, current assets turnover, fixed assets turnover, net profit margin, return on equity, working capital turnover and return on assets.	For measuring financial performance; in the Turkish automotive companies; with <i>TOPSIS</i> and Shannon theory.
Talebnia, 2012	<i>Financial perspective, customer satisfaction perspective, internal processes perspective and organization's innovation perspective.</i>	For assessing company performance; in Iranian auto industries. with fuzzy logic, <i>AHP</i> and <i>BSC</i> .
Amrina and Yusof, 2011	<i>Environmental performance:</i> emissions, resource utilization and waste; <i>economic performance:</i> quality, cost, delivery and flexibility; <i>social performance:</i> employee and supplier.	For evaluating sustainable manufacturing performance; will in Malaysian automotive companies; with pilot study.
Fuzi et al., 2012	Environmental performance and social performance; employee involvement, customer focus, environment, corporate governance, community and society and human right.	For corporate social responsibility performance; in Malaysian automotive industry; with <i>SEM</i> and <i>FA</i> .
Amrina and Yusof, 2010	Quality, delivery, cost, time and labor.	For evaluating manufacturing performance; in Malaysian automotive small and medium companies; with <i>AHP</i> .
Automotive & Aerospace Beelaerts van Blokland et al., 2010	<i>Competition performance:</i> turnover; <i>financial performance:</i> share price; <i>manufacturing capability:</i> cars/trucks per capita; <i>supply chain relationships:</i> turnover per capita; <i>innovation capability:</i> R&D expenditures per employee.	For quantifying companies' capabilities in creating value; in 33 automotive <i>OEMs</i> and 5 aerospace <i>OEMs</i> ; with bivariate correlation analysis and multiple regression analysis.
Maaskant, 2011	<i>Competition performance:</i> operating revenue growth, operating revenue; <i>financial performance:</i> operating income, operating margin, market capitalization; <i>manufacturing capability:</i> manufacturing assets utilization, operating income per employee; <i>innovation capability:</i> R&D efficiency and R&D effort; <i>supply chain relationships:</i> operating revenue per employee, inventory turnover and operating revenue per backlog.	For operations performance based on their value creating abilities; in aerospace <i>OEMs</i> ; with <i>DEA</i> and bivariate correlation analysis.
Elferink, 2010	<i>Competition performance:</i> sales growth rate, turnover and market share; <i>financial performance:</i> share price; <i>manufacturing capability:</i> profit per employee, inventory turnover and vehicles per employee; <i>innovation capability:</i> R&D efficiency and own R&D efforts; <i>supply chain relationships:</i> turnover per employee and profit leverage.	For company performance; in 33 automotive <i>OEMs</i> and 5 aerospace <i>OEMs</i> ; with bivariate correlation analysis.
Aerospace Beelaerts van Blokland et al., 2012	Turnover per employee, R&D per employee, profit per employee.	For measuring companies' value-leverage capability; with 41 companies in aerospace industry; with correlation analysis.
Others Hourneaux Jr et al., 2017	<i>Monitoring:</i> progresses toward goals, monitors results, compares results with expectations and reviews principal measures; <i>focus of attention:</i> 6 measures; <i>strategic decision-making:</i> 7 measures; <i>legitimization:</i> 8 measures.	For evaluating company performance; in São Paulo manufacturers; with descriptive statistics analysis and <i>FA</i> .
Yalcin et al., 2012	<i>Traditional accounting-based financial performance:</i> return on assets, return on equity, earning per share and price/earnings ratio; <i>modern value-based financial performance:</i> economic value added, market value added, cash flow return on investment and cash value added.	For evaluating financial performance; in 7 Turkish manufacturing sectors; with fuzzy logic, <i>AHP</i> , <i>TOPSIS</i> and <i>VIKOR</i> .
Coskun and Bayyurt, 2008	<i>Financial:</i> financial operations and profitability; <i>process:</i> operational activities, innovation and resource utilization; <i>customer:</i> customer relations, marketing costs, market share and	For company performance; in 500 Turkish manufacturing companies; with <i>FA</i> , Canonical

	sales volume; <i>learning and growth</i> : work environment, employee relations and employee capabilities.	Correlation Analysis and <i>BSC</i> .
Behrouzi and Wong, 2011	<i>Waste elimination</i> : quality, cost and time; <i>JIT</i> : delivery.	For evaluating lean performance; in a manufacturing company; with fuzzy logic.
Digalwar et al., 2015	Top management commitment, knowledge management, employee training, innovation and technology, employee empowerment, environmental health and safety, supplier management, production planning and control, quality, flexibility, speed, cost, customer involvement, customer satisfaction, customer services and company growth.	For performance measures of world class manufacturing companies; with experts opinion and SEM.
Gomes et al., 2011	Financial, product quality and customer satisfaction, human resource management, process efficiency, social responsibility, competitive environment, quality/independence of management, product and process innovation.	For company performance; in Portuguese manufacturing organizations, with CA and regression analysis.
Susilawati, 2016	Financial perspectives, supplier issues customer issues, process, people and future.	For evaluating lean manufacturers' performance; with fuzzy logic and <i>AHP</i> .
Bititci et al., 2013	Growth in profitability, growth in value-added productivity, growth in cash flow, growth in revenue, employee satisfaction and growth in market share.	For company performance; in 37 small and medium manufacturing companies; with <i>CA</i> and <i>FA</i> .

Note: *BSC* – the balanced scorecard, *DEMATEL* - decision making trial and evaluation laboratory, *SEM* - structural equation modelling, *OEM* - original equipment manufacturer, *CA* - cluster analysis, *FA* – factor analysis

## Appendix B

*Questionnaire of company performance measures.*

Here the question is: what is the importance of the different indicators in measuring company performance? Your answer will contribute for weighting the indicators, with techniques of fuzzy logic and analytic network process.

Give the importance level of different parameters from 1 to 9 as Table 1.

**Table 1: The importance levels of the different performance indicators**

Importance levels	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

*Example: To evaluate the importance levels of Competition performance, Financial performance and Manufacturing capability with respect to company performance.* For the blue box, it represents: competition performance/ financial performance. In my opinion, I suppose CP is two times important than FP to present the company performance. So I put 2 in it.

	CP	FC	MC
Competition performance (CP)	1	2	1
Financial performance (FP)	1/2	1	1/4
Manufacturing capability (MC)	1	4	1

Noted: 1. All the data in the diagonal is fixed as 1; each blank is the importance **ratio of the horizontal parameter to the longitudinal** parameter.

Are you clear with the method? If you are ready, then **please fill out the boxes in the upper right half** (Tables 1-1) according to your own judgment and cognition.

1. Table 1-1: Comparisons of Competition Performance, Financial Performance, Manufacturing Capability, Technology Performance, Supply Chain Relationship and Inventory Performance.

<b>Company performance</b>	CP	FP	MC	TP	SCR	IP
Competition Performance (CP)	1					
Financial Performance (FP)		1				
Manufacturing Capability (MC)			1			
Technology Performance (TP)				1		
Supply Chain Relationship (SCR)					1	
Inventory Performance (IP)						1

Those dimensions probably cannot be independent with each other completely.

**Please fill out the boxes in the lower right half** (Tables 2-1 to 2-6) according to your own judgment and cognition.

2. Table 2-1: The inner-dependence comparisons with respect to “Competition Performance”

<b>Competition Performance</b>	FP	MC	TC	SCR	IP
Financial Performance	1				
Manufacturing Capability		1			
Technology Performance			1		
Supply Chain Relationship				1	
Inventory Performance					1

3. Table 2-2: The inner-dependence comparisons with respect to “Financial Performance”

<b>Financial Performance</b>	CP	MC	TP	SCR	IP
Competition Performance	1				
Manufacturing Capability		1			
Technology Performance			1		
Supply Chain Relationship				1	
Inventory Performance					1

4. Table 2-3: The inner-dependence comparisons with respect to “Manufacturing Capability”

<b>Manufacturing Capability</b>	CP	FP	TP	SCR	IP
Competition Performance	1				
Financial Performance		1			
Innovation Performance			1		
Supply Chain Relationship				1	
Inventory Performance					1

5. Table 2-4: The inner-dependence comparisons with respect to “Innovation Performance”

<b>Technology Performance</b>	CP	FP	MC	SCR	IP
Competition Performance	1				
Financial Performance		1			
Manufacturing Capability			1		
Supply Chain Relationship				1	
Inventory Performance					1

6. Table 2-5: The inner-dependence comparisons with respect to “Supply Chain Relationship”

<b>Supply Chain Relationship</b>	CP	FP	MC	TP	IP
Competition Performance	1				
Financial Performance		1			
Manufacturing Capability			1		
Technology Performance				1	
Inventory Performance					1

7. Table 2-6: The inner-dependence comparisons with respect to “Environmental Performance”

<b>Inventory Performance</b>	CP	FP	MC	TP	SCR
Competition Performance	1				
Financial Performance		1			
Manufacturing Capability			1		
Technology Performance				1	
Supply Chain Relationship					1

Please fill out the boxes in the lower right half (Tables 3-1 to 3-5) according to your own judgment and cognition.

8. Table 3-1: Comparisons of sub-measures within “Competition Performance”

<b>Competition Performance</b>	Sales Turnover	Market Share
Sales Turnover	1	
Market Share		1

9. Table 3-2: Comparisons of sub-measures within “Financial Performance”

<b>Financial Performance</b>	Profitability	Market Capitalization	Financial Leverage	Cash flow margin
Profitability	1			
Market Capitalization		1		
Financial leverage			1	
Cash flow margin				1

10. Table 3-3: Comparisons of sub-measures within “Manufacturing Capability”

<b>Manufacturing Capability</b>	Productively	Continuity
Productively	1	
Continuity		1

11. Table 3-4: Comparisons of sub-measures within “Technology Performance”

<b>Technology Performance</b>	Conception	R&D Efficiency
Conception	1	
R&D Efficiency		1

12. Table 3-5: Comparisons of sub-measures within “Supply Chain Relationship”

<b>Supply Chain Relationship</b>	Profit Leverage	Inventory Turnover
Profit Leverage	1	
Configuration		1

13. Table 3-5: Comparisons of sub-measures within “Inventory Performance”

<b>Inventory Performance</b>	Inventory Turnover	Inventory Efficiency
Inventory turnover	1	
Inventory efficiency		1

Which of the following best describes your occupation?

- Marketing and Sales occupations  Business and Financial Operations occupations
- Computer and Mathematical occupations  Management occupations
- Office and Administrative Support occupations  Production occupations
- Transportation and Material Moving occupations  Life, Environment and Social Science occupations

Other (Please Specify):

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