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Determinants of innovation management and supply chain management on Thai automotive enterprise effectiveness: A structural equation model

Suwaj Dansomboon*, Supapat Pingta

Department of Industrial and Logistics Management, Mahanakorn University of Technology, Bangkok 10530, Thailand

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Abstract

In 2015, Thailand was the 15th largest exporter of automotive products in the world, and in the first nine months of 2016 had USD 13.706 billion in sales. Achieving 80 percent localization, with over 2,000 parts suppliers, Thailand has also become the automotive industry leader in South-East Asia. To maintain this leadership status however, Thailand must examine how innovation management and supply chain management affect automotive enterprise effectiveness. As such, the researchers first performed a second-order confirmatory factor analysis to confirm the dimensions of the constructs which included supply chain management, innovation management, and effectiveness. A Structural Equation Model using analysis of moment structures was then applied to test the fit of the model and validate the research hypotheses. The sample consisted of 200 managers from automotive enterprises involved as manufacturers and distributors, both domestic and foreign, to determine whether the direction of the business was in line with market opportunities. The analysis determined that there was harmony between the models and the empirical data.
The results also indicated that there were strong and positive relationships between supply chain management and innovation management and an automotive enterprise's effectiveness with car companies now becoming data companies. Innovation, along with an increasing need for information technology skills, will play a crucial role. As the ASEAN Mutual Recognition Arrangement on Type Approval for Automotive Products and the ASEAN Trade in Goods Agreement come into effect, supply chain management combined with the essential skill of firm-to-firm communications, including English skills, will be paramount to an enterprise's success and competitiveness.

Introduction

Contributing 12 percent to Thailand's GDP, auto manufacturing is one of Thailand's most important sectors (Thailand Investment Review, 2015). With the peak years thus far being 2012 and 2013, vehicle production totaled 2.45 million units in 2012, driven by the first-time car buyer program and large demand after devastating floods hit several automotive producing areas and industrial estates in 2011 (Tribune, 2015). The following year in 2013, The Economist declared Thailand the "Detroit of the East" and stated it was Japanese carmakers that used the country as a manufacturing hub (Annonymous, 2015). In the same year, 2.5 million cars and trucks were produced moving Thailand's automotive sector into the Top 10 of global automotive manufacturing countries ("Eco-car Projects to Spur Demand," 2015).

However, in 2014, Thailand's production plunged due to internal political turmoil and external economic challenges (Sullivan, 2015), while in 2015, domestic sales managed to increase to 799,594 units, a 9.3 percent increase from the previous year.

* Corresponding author.
E-mail address: suwajd@hotmail.com (S. Dansomboon).
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Then, in the first three quarters of 2016, Thailand showed some recovery from the automotive production and sales doldrums experienced in 2014 and 2015, with production rising 3.14 percent (year-on-year) to 1.47 million units. During the same period, exports were up 11.33 percent in value and totaled USD 13.706 billion (Chaichalearmmongkol, 2016).

Partial recovery of the sector in 2016 has been attributed in some part to the easing of trade restrictions at the beginning of the year due to Thailand's membership in the ten-nation economic block of the Association of Southeast Asian Nations (ASEAN) and the reduction of tariffs on member nations. Additionally, Thailand with more than 2,000 auto part manufacturers has become the hub for auto and part exports within ASEAN.

At the end of 2016, the ASEAN Mutual Recognition Arrangement (MRA) on Type Approval for Automotive Products was due to be implemented (Shen, 2016). Under it, once a regulated automotive product is tested by a listed testing lab and/or inspected by the listed inspection body in an ASEAN country, the product can be imported and sold inside another ASEAN country without being subjected to further testing or inspection (Chindavijak, 2014).

Seeing the potential opportunity of an ASEAN base and the MRA arrangement, Germany's Bosch announced plans in 2016 for the first fuel-injector 'smart factory' in Thailand. Servicing vehicle original end-manufactures (OEM) with a production capacity of a million units per year, Bosch is expected to add globally to their existing 85 percent control of the European automotive fuel-injector market (Toomgum, 2016).

Another example of how innovation management and supply chain management will be crucial to Thailand's automotive industry effectiveness can be seen from the expansion of one of China's top five tire producers into Thailand to establish a tire-testing center and rubber-compound manufacturing facility used exclusively for export, which is already employing 2,000 workers (Ongdee, 2016).

NISSAN Motor Asia-Pacific (NMAP) has also hired 330-staff members in a testing center near Bangkok in 2016 that serves as the carmaker's main research and development hub for ASEAN as well as 90 other countries around the globe (Changsorn, 2016). Innovation is paramount here as it is the first research and development (R&D) facility to have an anechoic (echo-free) chamber, an acoustic chamber, and a vibration simulator with an environment chamber.

With regards to supply chain management, Thailand became Vietnam's leading automobile importer in quarter one of 2016, rising 64.5 percent over the same period in 2015. This is primarily due to preferential import tax policies under Vietnam's commitments to the 2016 ASEAN Trade in Goods Agreement (ATIGA). Under the agreement, the import tax on automobiles from ASEAN members will fall to zero per cent by 2018, from the present 50 percent in 2016. Thailand's automotive enterprises must therefore understand and be prepared to operate within this youthful, consumer market of 95 million, as well as the rest of the ASEAN and global automotive market places.

Research objectives

The study aimed to develop a theoretical model and validate its corresponding hypotheses to identify and explain the relationship and effects from supply chain management (SCM) and innovation management (INNO) on Thai automotive industry effectiveness (EFFECTIVE). The proposed model consisted of 10 observed variables and three hypothesized relationships, which were developed through a review of the theory and literature.

Literature Review

Effectiveness

The definition of an automotive enterprise's organizational effectiveness differs widely and depends on whether you are a stakeholder, management, or a factory floor worker (Campbell, 2014). For this study's review of theory, effectiveness was determined to be comprised of quality (QUA), flexibility (FLEX), staff satisfaction (SS), and delivery (DEL). For enterprises however, effectiveness can be defined as the efficiency with which an enterprise is able to meet its objectives without creating waste while being financially profitable.

The conceptualization of efficiency and effectiveness however has its roots in system theory with efficiency being a cost-related advantage while effectiveness is an advantage of customer-responsiveness within supply chain management research (Borgström, 2005). It can also be achieved by lowering the efficiency (for example, using preventive maintenance) which will bring about a strong increase in effectiveness, which on the bottom line creates a higher net productivity (Koch, 2016).

Quality is a measure of the rate of defects and now the rate for most automotive components is targeted at 25 parts per million or 0.0025 percent (McClintic, 2011). Effectiveness is accessed when deliveries are in line with what is agreed upon in contractual or verbal agreements (Borgström, 2005). Grigore (2007) stated flexibility is the ability to adapt and companies must realize the real competition is not firm-to-firm, but supply chain-to-supply chain. Manzoor (2012) indicated employee motivation is obtained through empowerment and recognition, with a positive relationship existing between employee motivation and organizational effectiveness, while Warren (1993) indicated that to develop and maintain a viable service delivery program, cost effectiveness and cost efficiency must be monitored.

Supply Chain Management

For purposes of the research and after a literature review, Supply Chain Management (SCM) was determined to have three manifest variables—trust (TRUST), communications (COMU), and collaboration (COLLA). Trust is at the heart of a collaborative innovation capability and without a foundation of trust, collaborative alliances can neither be built nor sustained (Fawcett, 2012). Khanjari (2012) confirmed this, and indicated that trust is also an important precondition in supply chain management, with internal communications having a significant and positive role on employee satisfaction (Jacob, 2016).

The critical nature of automotive supply chain management in the Thai automotive industry is represented in Figure 1, which shows the top-level assemblers of cars/trucks (18) and motorcycles (7) which employ 100,000 workers. Tier 1, Tier 2, and Tier 2 suppliers (2,348 enterprises) are mostly small-medium enterprises (SMEs) and together employ almost 600,000 workers.

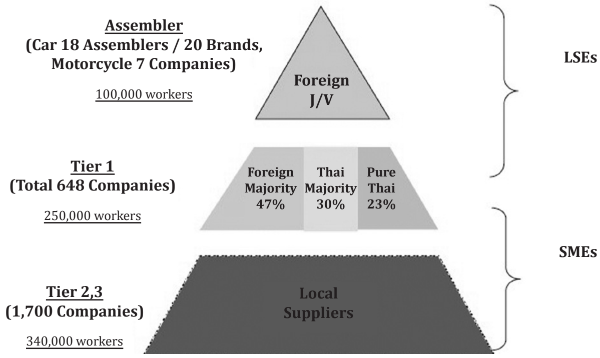

Figure 1 Thailand's automotive and motorcycle industry supply chain management tiers
Note. LSEs are large scale enterprises. SMEs are small and medium enterprises.
Source: Thailand Automotive Institute (2014).

Innovation Management

About 50 percent of the innovations in the automotive industry within the past decade have been developed by automotive suppliers, and in 2014 alone, the 100 largest suppliers invested more than EUR 40 billion into R&D (Hammerschmidt, 2015). For the study, innovation consisted of organization innovation (Organ IN), product innovation (Prod IN), and process innovation (Proc IN). Organizations which focus on innovation need to develop their resources and the ability to profit from those innovations (Lawson, Samson, & Roden, 2012). Product innovation is the creation and introduction of new components (steel, aluminum and polymers) or services (autonomous driving) that are either new, or an improved version of previous versions (Hammerschmidt, 2015). Process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software (self-driving cars). An example of this is a new Ford automobile which can be expected to have over 150 million lines of code (Baas, 2016), which is expected to increase to 300 million in coming years.

The following hypotheses were therefore formulated as follows from the theory and the current literature (Figure 2):

Hypothesis 1: Innovation management has a direct positive influence on supply chain management.

Hypothesis 2: Innovation management has a direct positive influence on effectiveness.

Hypothesis 3: Supply chain management has a direct positive influence on effectiveness.

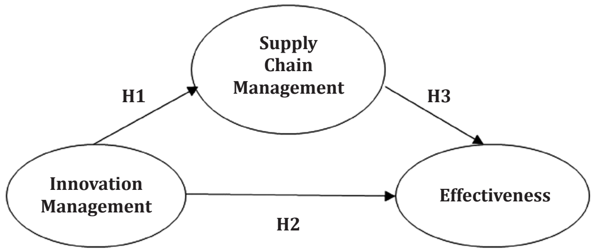

Figure 2 Hypothesized framework

Methods

Data Collection

From the analysis of the literature and theory, the researchers first developed a trial questionnaire consisting of a 7-point Likert scale (Likert, 1932) which was evaluated by use of in-depth, semi-structured, guided interviews with five automotive executives covering the following three topics:

1. Measurement of effectiveness.
2. Measurement of supply chain management.
3. Measurement of innovation.

From a pre-test of 30 respondents, the questionnaire was refined by use of Cronbach's alpha (Cronbach, 1951) to evaluate the initial samples. An acceptable value of alpha (α) ranges from 0 to 1 and may be used to describe the reliability of factors extracted from multi-point formatted questionnaires or scales, with a reliability score of 0.70 or higher being considered a reliable score by many researchers (Hair, Black, Babin, & Anderson, 2010). The correlation coefficients ranged between 0.704 and 0.827, which was deemed as reliable.

After the trial, simple random sampling was used to contact managers, supervisors, and executives by e-mail and post from the Thailand Automotive Industry Directory (2015) with 18 car/truck assemblers, 8 motorcycle assemblers, 709 Tier 1 companies, and another 1,700 Tier 2 and Tier 3 local suppliers being contacted. Follow-up phone calls were placed 30–45 days later which led to the eventual collection of 224 questionnaires. After completion of an audit, 200 were deemed accurate enough for inclusion in the study which represented a response rate of 7.9 percent.

Data Analysis

Analysis of moment structures (AMOS), an add-on module to the statistical package for the social sciences (SPSS) software, was selected by the researchers as it is specifically used for the analysis of the relationships in a structural equation model (SEM). From the research, 10 observed variables and the three latent variables were determined for the study, which Bacon (2001) stated required 200–400 cases to fit SEM models which have from 10 to 15 observed variables. Furthermore, Schumacker and Lomax (2010) have indicated that a ratio of 20 cases for each observed variable is sufficient for SEM modelling, whereas Stevens (2009) indicated that a good general rule for the sample size is 15 cases per predictor.

The researchers first performed an exploratory factor analysis (EFA) to help determine the number of latent constructs. Next, a confirmatory factor analysis (CFA) was applied to confirm the dimensions of various constructs, which were supply chain management, innovation management, and effectiveness. Finally, an SEM was used to test the fit of the model and validate the research hypotheses. As a result, the structural model achieved acceptable fit statistics and all three hypothesized relationships were significant and in the predicted direction.

Furthermore, Table 1 shows the degree of association which is measured by the correlation coefficient, denoted by *r*. It is also referred to as the Pearson correlation coefficient after its originator and is a measure of linear association (Gau, 2016) with *r* used to calculate the direction and strength between the constructs. The correlation coefficient is measured on a scale that varies from +1 to -1. When one variable increases as the other increases, the correlation is positive; when one decreases as the other increases, it is negative. Complete absence of correlation is represented by 0. The results from the study shown in Table 1 indicate positive relationships. Additionally, the variables were most correlated at the statistically significant level of $p < .01$

Results

Before conducting a factor analysis, it is essential that the sampling adequacy and sphericity is checked to see if it is worth proceeding with the analysis (Hinton, 2004). Table 2 shows the EFA outcome from the Bartlett's sphericity test and the Kaiser-Meyer-Olkin (KMO) index used for factor analysis. The KMO measures the sampling adequacy which should be greater than 0.5 (Table 3) for a satisfactory factor analysis to continue (Hinton, 2004). Analysis of the data showed that the relationships between the observed variables had a correlation between each pair of 0.397–0.735 with a statistical significance level of .01. As the relationship between the variables is less than 0.8, it can be concluded that there is a relationship between the variables, allowing the factor analysis to continue.

Bartlett's Test of Sphericity determines if there is a relationship between the variables and in so doing, determines if the factor analysis should proceed with a p value < .05 indicating that is makes sense to continue with the factor analysis. Bartlett's Test of Sphericity data was equal to 1654.239 with the degrees of freedom (df) equal to 45 ($p = .000$) which showed that the matrix correlation was in accordance with the results of the Kaiser-Meyer-Olkin index which should be near 1 (0.931) as shown in Table 3, indicating that the observed variables correlate very well and are suitable to be applied to check the consistency of the research model.

Magistris and Gracia (2008) indicated that to access the measurement models, CFA is used followed by SEM to examine the general fit of the proposed model with data and also to identify the overall relationships among these constructs. Standard modelling accepts the proposed model if the p value is higher than 0.05 and if the $\chi^2/df < 2$ as shown in Table 3 (Byrne, Shavelson, & Muthén, 1989). From the CFA in Figure 3, $\chi^2 = 39.969$, df = 28, and $p = 0.067$. This is consistent with the guidelines discussed by Kline (1998) and Ullman (2001) which indicated that the relative $\chi^2 < 2$. The Amos 22 User's Guide suggests that a value of the RMSEA of about 0.05 or less would indicate a close fit of the model in relation to the degrees of freedom (Arbuckle, 2013). From the data, RMSEA = 0.039, GFI = 0.974, and AGFI = 0.948. RMSEA values range from zero to one, with a smaller RMSEA value indicating a better model fit. Other data results are shown in Figure 3.

Table 1 Pearson Product Moment Correlation Coefficient

	Prod IN	Proc IN	Organ IN	COLLA	TRUST	COMU	QUA	FLEX	SS	DEL
Prod IN	1.000									
Proc IN	.522**	1.000								
Organ IN	.654**	.571**	1.000							
COLLA	.592**	.561**	.644**	1.000						
TRUST	.444**	.481**	.525**	.597**	1.000					
COMU	.534**	.531**	.566**	.735**	.601**	1.000				
QUA	.511**	.533**	.645**	.608**	.620**	.692**	1.000			
FLEX	.527**	.413**	.554**	.578**	.513**	.607**	.627**	1.000		
SS	.397**	.446**	.520**	.464**	.538**	.453**	.505**	.423**	1.000	
DEL	.467**	.432**	.554**	.609**	.475**	.615**	.611**	.597**	.516**	1.000
Mean	5.74	5.52	5.55	5.67	5.57	5.65	5.52	5.33	5.56	5.59
SD	1.013	.897	1.053	.952	.840	.903	.893	.993	.989	.949

** Correlation is significant at the .01 level

Table 2 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of sampling adequacy		0.931
	Approx. X^2	1654.239
Bartlett's Test of Sphericity	Df	45
	Sig.	0.000

Table 3 Validation criteria for theory consistency with the empirical data

Component	Indicator	Criterion	References
Chi-square	χ^2	Ns. ($p > .05$)	(Hair et al., 2010; Bollen & Long, 1993)
Relative chi-square	χ^2/df	χ^2/df < 2.00	(Kline, 1998; Ullman, 2001)
Goodness of Fit Index	GFI	> 0.90	(Hair et al., 2010; Jöreskog & Sörbom, 1979; Tanaka & Huba, 1985)
Comparative Fit Index	CFI	> 0.95	(Hair et al., 2010)
Normal Fit Index	NFI	> 0.90	(Bentler & Bonet, 1980)
Adjusted Goodness of Fit Index	AGFI	> 0.90	(Schumaker & Lomax, 2004)
Root Mean Square Error of Approximation	RMSEA	≤ 0.05	(Arbuckle, 2013; Hair Jr. et al., 2010; Browne & Cudeck, 1993; Hu & Bentler, 1999)
Kaiser-Meyer-Olkin (KMO) index	KMO	> 0.50 0.8 to 1	(Hinton, 2004) (1 is perfect) (Statistics How To, 2016)

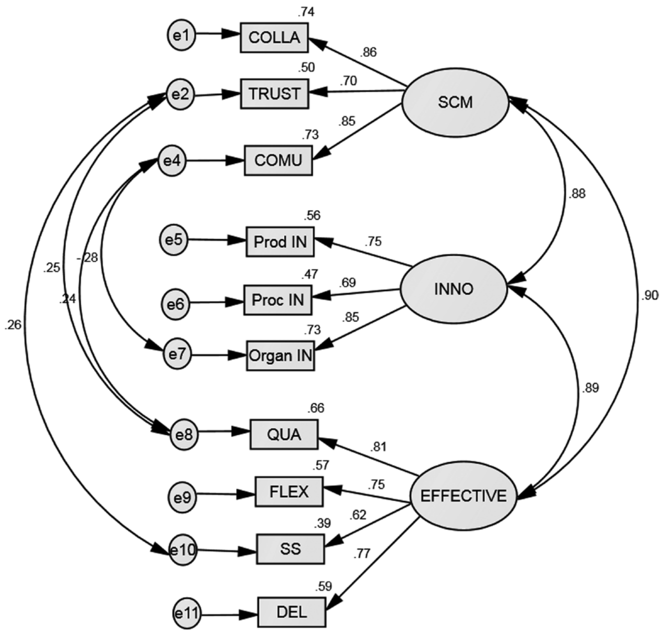

Figure 3 Confirmatory Factor Analysis path diagram with standardized results shown.
Quantities close to the variables are their squared multiple correlations. Quantities near paths are standardized loadings or correlations. χ^2 = 39.969, df = 28, p = 0.067, CMIN/DF (χ^2/df) = 1.427, GFI = 0.974, CFI = 0.993, AGFI = 0.948, NFI = 0.976 and RMSEA = 0.039

Discussion

Structural Equation Modelling is a technique for analyzing multiple variables which can combine factor analysis and multiple regression analysis. Since factor analysis is an explorative analysis, it does not distinguish between independent and dependent variables. Such techniques are used by researchers to examine the relationships between different variables at once.

Innovation management using AMOS of the SEM determined that the standard regression weight was between 0.69 to 0.84, and the R^2 or squared multiple correlation was between 0.48–0.71. The R^2 or Squared Multiple Correlation (SMC) is the communality estimate for an indicator variable. The communality measures the percentage of the variance in a given indicator variable explained by its latent variable (factor) and may be interpreted as the reliability of the indicator (Bian, 2011).

Supply Chain Management variables had a standard regression weight between 0.71 and 87, and the R^2 or SMC was between 0.51 and 0.75. Effectiveness variables had a standard regression weight between 0.58 and 0.85, and the R^2 or SMC was between 0.34 and 0.73 (Table 4).

The analysis determined that there was harmony between the models and the empirical data and that the structural equation model was a good fit with the empirical data (Figure 4) from the following test: χ^2 = 34.094, df = 27, p = .163, CMIN/DF (χ^2/df) = 1.263, GFI = 0.977, CFI = 0.996, AGFI = 0.953, NFI = 0.980 and RMSEA = 0.031.

Model Parameter Estimation

Regression weights were used for hypotheses testing when it was necessary to examine the extent of effects of exogenous latent variables on endogenous latent variables. An absolute fit measure was used to determine the degree to which the structural and measurement models were a good fit with the sample data. It was determined subsequently that all three hypotheses were supported (Table 5).

Table 4 Relative influence of items (standardized regression weights) used to access effectiveness results after adjusting the model

(n=200)

	Standard regression weights	S.E.	Squared multiple correlations	*p* value	Significance
Innovation management (INNO) affects Supply Chain Management (SCM)	0.864	0.057	0.746	13.096	***
Innovation management (INNO) affects Effectiveness (EFFECTIVE)	0.319	0.105	-	2.611	0.009
Supply Chain Management (SCM) affects Effectiveness (EFFECTIVE)	0.697	0.126	-	5.542	***
Supply Chain Management (SCM) affects Communications (COMU)	0.841	-	0.708	-	
Supply Chain Management (SCM) affects Trust (TRUST)	0.714	0.058	0.509	13.636	***
Supply Chain Management (SCM) affects Collaboration (COLLA)	0.868	0.062	0.754	17.531	***
Effectiveness (EFFECTIVE) is affected by Quality (QUA)	0.853	-	0.728	-	
Effectiveness (EFFECTIVE) is affected by Flexibility (FLEX)	0.719	0.068	0.516	13.744	***
Effectiveness (EFFECTIVE) is affected by Staff Satisfaction (SS)	0.581	0.072	0.337	10.426	***
Effectiveness (EFFECTIVE) is affected by Delivery (DEL)	0.714	0.065	0.509	13.605	***
Innovation management (INNO) is affected by Product Innovation (Prod IN)	0.765	0.063	0.585	13.928	***
Innovation management (INNO) is affected by Product Innovation (Prod IN)	0.765	0.063	0.585	13.928	***
Innovation management (INNO) is affected by Organizational Innovation (Organ IN)	0.841	-	0.707	-	

S.E. is standard error. *** level of statistical significance at $p < .01$.

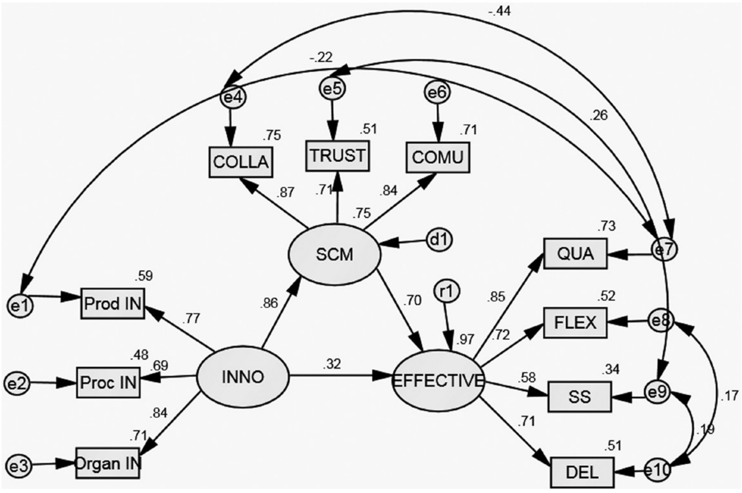

Figure 4 Final model

Table 5 Results from the hypotheses testing on effectiveness

Hypotheses	Coefficient	t-test	Total Effects	Direct Effects	Indirect Effects	Results
H1: Innovation management has a direct positive influence on supply chain management.	0.864**	13.096	0.864	0.864	-	Supported
H2: Innovation management has direct positive influence on effectiveness.	0.319*	2.611	0.920	0.319	0.602	Supported
H3: Supply chain management has a direct positive influence on effectiveness.	0.697**	5.542	0.697	0.697	-	Supported

*significant $p < .05$, ** significant at $p < .01$, Coefficient refers to the Beta (β),

Figure 4 and Table 5 show the standardized regression weights. From this, the frequencies of the customer loyalty score along with values one standard deviation above and below the mean are indicated with a significant statistical relationship between the variables indicated at .01 (** $p < .01$). Critical ratios (t-value) of more than 1.96 are significant at the .05 level.

The results in Table 5 show that:

Hypothesis 1 (H1): Innovation management has a direct positive influence on supply chain management as indicated by the standardized regression coefficient (coef.) = 0.864, a fact recognized by the assumption of statistical significance at $p < .01$.

Hypothesis 2 (H2): Innovation management has a direct positive influence on effectiveness as indicated by the standardized regression coefficient (coef.) = 0.319, a fact recognized by the assumption of statistical significance at $p < .05$.

Hypothesis 3 (H3): Supply Chain Management has a direct positive influence on effectiveness as indicated by the standardized regression coefficient (coef.) = 0.697, a fact recognized by the assumption of statistical significance at $p < .01$.

Conclusion

Car companies are now data companies, with entertainment services and self-driving capability becoming realities and not just dreams. It can clearly be seen from the continuing introduction into Thailand of world-class automotive manufacturing and auto parts industry organizations that innovation will play a crucial role in their success and sustainability and keeping the dreams alive. As the ASEAN Mutual Recognition Arrangement on Type Approval for Automotive Products and the ASEAN Trade in Goods Agreement come into effect, supply chain management combined with the essential skill of firm-to-firm communications will be paramount to an enterprise's success and competitiveness. Although not specifically discussed in the research, related research indicates English and IT/software skills will most probably play crucial roles as well, necessitating the need for a highly trained and skilled work force.

Conflict of Interest

There is no conflict of interest.

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