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Research Article

Collaborative Assessment of the Automotive Sales Service Based on Co-Entropy

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Abstract: Co-entropy function was constructed based on dissipative structure, collaboration and entropy theory, while co-entropy of each management level in automotive sales service and the mathematical quantified assessment model of collaborative efficiency were built. In combination with the collaborative management activity of automotive sales service in an automotive sales company in Shanghai, the model and viewpoints presented here were applied and verified through empirical research.

Keywords: Automotive sales service, co-entropy, collaborative assessment, collaborative efficiency

INTRODUCTION

With the development of automotive industry and the enhancement of national income, China has been a major country of automotive consumption. According to the data released by the China Association of Automotive Industry, the production and sales volume of domestic automotive in 2011 reached 18.42 million and 18.51 million respectively, ranking the first among all countries in succession. According to the statistics by European and American countries, in a completely mature and internationalized automotive market, the sales margin occupies 20% of the total profit of automotive industry, parts and fittings 20% and the rest 60% comes from the after-sale service of automotive. Apparently, sales and after-sale service are the core part in terms of profit, whereas the collaborative assessment of automotive after-sale service is the guarantee for enhancement of the service quality.

Automotive sales service refers to a wide range of activities focusing on promoting automotive sales and helping consumers to use automotives. Since the proposal of launching automotive sale service (Guo-pan, 1983), the academic circles and business circles have already performed a series of researches on automotive sales service. The blueprint of automotive sales service is established and the service requirements and skills are investigated in major contact points between the customers and sales personnel in automotive sales services (Liao-Yan and Shu-wei, 2009). The sales service quality is performed effective internal assessment using comentropy weighting method based on studying the errors generated by authoritative assessment index system (Ji-Chao *et al.*, 2010). An exploratory research on the assessment model of automotive sales service quality is carried out, which was further applied to a practical case for assessment of the sales service quality (Yan-Kui, 2011). An integrated after-sales service model for automotive sales service chain has been put forward (Xu-Yang and Li-Ming, 2011).

Enterprise Management System is a cross-over composite structure system with multiple levels and functions, in which the management features close work division and collaboration for the enterprise management goal. Smooth information communication on the management activities in enterprise management system and enhancement of the collaborative efficiency of each management task are actually very complicated issues. Many domestic and foreign scholars have been focusing on relevant studies of enterprise management system by using collaborative methods, e.g., several key technologies are once put forward for actualization of inter-organization information system collaboration and investigated the methods for determining collaborative effect and collaborative design as well as establishment of interactive model (Bao-Xiang *et al.*, 2008). To solve the problems of enterprise group collaborative modeling and the existence, the formal definition of enterprise group optimal collaborative solution is given and its existence is proved by using equal incentive value theory (Lin-Lin and Yue-Ting, 2009). Based on cross-entropy, a series of mathematical models are built to solve Multiattribute Decision Making (MADM) problems under interval-valued Intuitionistic Fuzzy Sets (IVIFSs) environment (Hui-Min and Li-Ying, 2012). The extended conditional entropy is proposed for the uncertainty measurement problem in interval-valued decision systems (Jian-Hua *et al.*, 2012). ACE framework is constructed in the virtual collaborative

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environment and actualized optimal resource allocation of each organization through multiple cluster servers (Bijlani *et al.*, 2010).

Taking a general overview of the current studies, researcher on the enterprise collaboration are mostly macro and qualitative modeling and descriptions. Moreover, some quantitative modeling is less piratical and there are few researches on the collaborative assessment of enterprise management. This study attempts to combine entropy theory with collaboration to construct a mathematic assessment model for collaborative assessment of the multi-level automotive sales service.

CO-ENTROPY FUNCTION

In ordinary systems ordered and disordered conflicts always exits, given specific conditions, ordered and disordered condition can be changed and formed into system order (sequence), known as degree of order. In the different areas of science, different parameters (physical quantity) can describe different systems' degree of order. Dissipativity structure theory employs entropy to measure the internal chaotic degree of system and larger entropy stands for greater chaos and higher chaotic degree inside the system and vise versa. In collaboration theory, Hawking used order parameter to describe the order degree of a specific system, wherein the value change of order parameter is employed for qualitative description of the shift between order and disorder inside the system (Wang, 2008). When the system is in a complete irregular chaotic state, the connection between sub-systems is weak, while the order parameter is zero given the sub-system being relatively independent. When an open and complicated enterprise away from equilibrium is involved in constant exchange of energy, materials and information with the environment, with the interaction between the internal management businesses, the entropy will then decrease, resulting in a lager increasing range in the organization's degree of order than the degree of disorder, forming new orderly structure and new collaboration process.

The pioneer of information theory Claude E. Shannon defines the information entropy of each discrete event $S = (E_1, E_2, \ldots, E_n)$ with the random probability $P\{P_1, P_2, \ldots, P_n\}$ in system $H(S)$ as:

$$H(S) = -\sum P_i \log P_i \qquad (i = 1, 2, \cdots, n) \tag{1}$$

Assuming f_i the ith organization management activity or the chain number of the function collaborative relationship, totally there are n organization management activities or functions. Then the chain number of the organization management collaboration relationship is $f = \Sigma f_i$ (i = 1, 2, …, n).

Definition 1: If $P(f_i) = f_i/f$, then in accordance with the relationship among probability and Shannon entropy function, the co-entropy of the organization management activity or function (e.g., collaborative information entropy) is:

$$H = -\sum \frac{f_i}{f} \log \frac{f_i}{f} \tag{2}$$

We believe that co-entropy refers to that in the mutual cooperation process of any relatively closed organizational system departments, an irreversible process of gradual decrease of cooperation performance and increase of chaotic degree and it shows the progressive reduction of the collaborative efficiency among the internal management activities in an organization. Hence co-entropy is used to describe the collaborative degree of organizational management.

COLLABORATIVE ASSESSMENT MODEL FOR AUTOMOTIVE SALES SERVICE

Automotive sales service is a full range service which should keep meeting the consumer's various needs. It involves car selling, parts supply, second-hand car service and a series of after-sale service. It is a structure consisting of multiple management layers and its relationship can be represented by a limited discrete mathematical structures. Though the specific management function division of auto sales varies somehow in each automotive industry, the operation mechanism indeed features certain laws and hierarchic logical structure. Common hierarchic management collaborative structure consists of management function T, management activity T_i and management business unit T_{ij} (Fig. 1) and its collaborative structure relationship $\xi = (B_1, B_2, B_3, B)$, B_1 denotes the overall collaboration of grassroot management business unit T_{ij} of the automotive sales service, B_2 denotes the internal overall collaboration of the middle-layer management activity T_i of the automotive sales service, B_3 is the overall collaboration of the overall collaboration of the middle-layer management activity T_i and B is the overall collaboration of the automotive sales service function T.

Definition 2: Due to the collaborative relationship and collaboration formed between automotive sales service management business and the management business, then the collaborative and interactive influence will be reflected definitely, wherein such kind of influence can be simultaneously applied to the collaborative process and result of management business. Then the collaborative impact matrix among automotive sales service management activities will be $\varepsilon = [T_i, T_j]_{n\times n} = (\mu_{ij})_{n\times n}$:

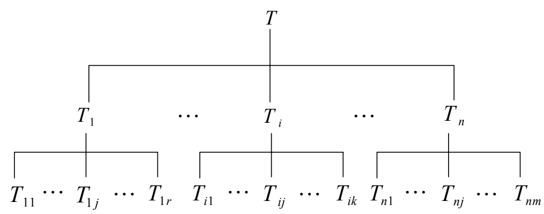

Fig. 1: Automotive sales service function collaboration structure

$$\varepsilon = \begin{bmatrix} \mu_{11} & \mu_{12} & \cdots & \mu_{1j} & \cdots & \mu_{1n} \\ \mu_{21} & \mu_{22} & \cdots & \mu_{2j} & \cdots & \mu_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \mu_{i1} & \mu_{i2} & \cdots & \mu_{ii} & \cdots & \mu_{in} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \mu_{n1} & \mu_{n2} & \cdots & \mu_{nj} & \cdots & \mu_{nn} \end{bmatrix} \tag{3}$$

$$\mu_{ij} \begin{cases} 1 & \text{Business } i \text{ and business } j \text{ share information and in a collaborative state} \\ 0 & \text{or other wise} \end{cases} \tag{4}$$

μ_{ij} or μ_{ji} represents the collaborative influential power among the ith automotive sales service management activity and the j management activity, thereby $\mu_{ij} = \mu_{ji}$, hence the collaborative impact matrix ε among automotive sales service manage-ment activities is a symmetric matrix. When $i = j$, then diagonal of a matrix μ_{ii} and it is the internal business collaborative impact formed in the ith management activity. The internal business collaborative impact of the bottom-layer automotive sales service management business unit is 1 and the internal business collaborative impact of other layer management activity is the internal collaborative information entropy calculated for the next layer. Therefore the collaborative impact among management business is 0, that is:

$$\mu_{ij} \begin{cases} 1 & \text{Bottom} - \text{layer mangement business unit} \\ 0 & \text{Mangement activity of other layer} \\ & (i = j) \end{cases} \tag{5}$$

Definition 3: If the management business of automotive sales service operates collaboratively with the management business of the same management layer, $h(i, j)$ is a node of T_i with all related management business T_j on the collaborative track, the total number of the management node is k, then the node set on the collaborative track of T_i management business is h $h = [(T_i, T_1), (T_i, T_2), \cdots, (T_i, T_j), \cdots, (T_i, T_k)], (k \le n)$. If T_i and all the other management business T_j involves in the collaboration and the element μ_{ij} in row i or column j of the management business collaborative matrix is 1, then the automotive sales service management business is known as full-collaborative state, or otherwise the management business is in a non-full-collaborative state (Hua-Ling *et al.*, 2009).

Assuming the automotive sales service management activity T_i consists of k management business unit, Y_{iq} is the number of management business in full-collaborative state at management business unit j of management activity T_i, if Y_{if} is the number of management service unit in the non-full collaborative state at management business unit j of management activity T_i and Y_j is the number of all the management business unit in T_i of management activity Y_j, $Y_j = Y_{jq} + Y_{jf}$; then the node on the collaborative track of the automotive sales service management layer or the co-entropy of the management business unit is:

$$H_{iq}(T_{ij}) = -\frac{Y_{jq}}{Y_j} \log \frac{Y_{jq}}{Y_j} \tag{6}$$

$$H_{if}(T_{ij}) = -\frac{Y_{jf}}{Y_j} \log \frac{Y_{jf}}{Y_j} \tag{7}$$

Then the internal co-entropy value of automotive sales service management activity T_i is:

$$H_{iq}'(T_i) = \sum_{j=1}^{k} H(T_{ij}) = -\sum_{j=1}^{k} \frac{Y_{jq}}{Y_j} \log \frac{Y_{jq}}{Y_j} \tag{8}$$

Definition 4: Assuming that $H_{iq}''(T_i)$ is the co-entropy between the automotive sales service management activity T_i and the management activity of the same level, since the collaborative relationship of management activity T_i can be divided into internal collaboration and external collaboration, hence the co-entropy of T_i is sum of the total co-entropy between each management business unit inside T_i and the co-entropy between T_i and other management activity T_j, then:

$$\begin{aligned} H_{iq}(T_i) &= H_{iq}'(T_i) + H_{iq}''(T_i) \\ &= -\sum_{j=1}^{k} \frac{Y_{jq}}{Y_j} \log \frac{Y_{jq}}{Y_j} + H_{iq}''(T_i) \end{aligned} \tag{9}$$

Similarly the co-entropy of the management function T can also be inferred:

$$\begin{aligned} H &= \sum H_{iq}(T_i) = \sum (H_{iq}'(T_i) + H_{iq}''(T_i)) \\ & - \sum \sum_{j=1}^{k} \frac{Y_{jq}}{Y_j} \log \frac{Y_{jq}}{Y_j} + \sum H_{iq}''(T_i) \end{aligned} \tag{10}$$

Definition 5: It can be inferred from the equations above, H_{iq} is the entropy value of management business in a collaborative state, H_{if} is the entropy value of management business in non-collaborative state, H_{iq}, H_{if} denotes the chaotic degree of the automotive sales service management business, that is, the deviation degree of collaboration between automotive sales service management business, thus collaborative efficiency of R can be defined as:

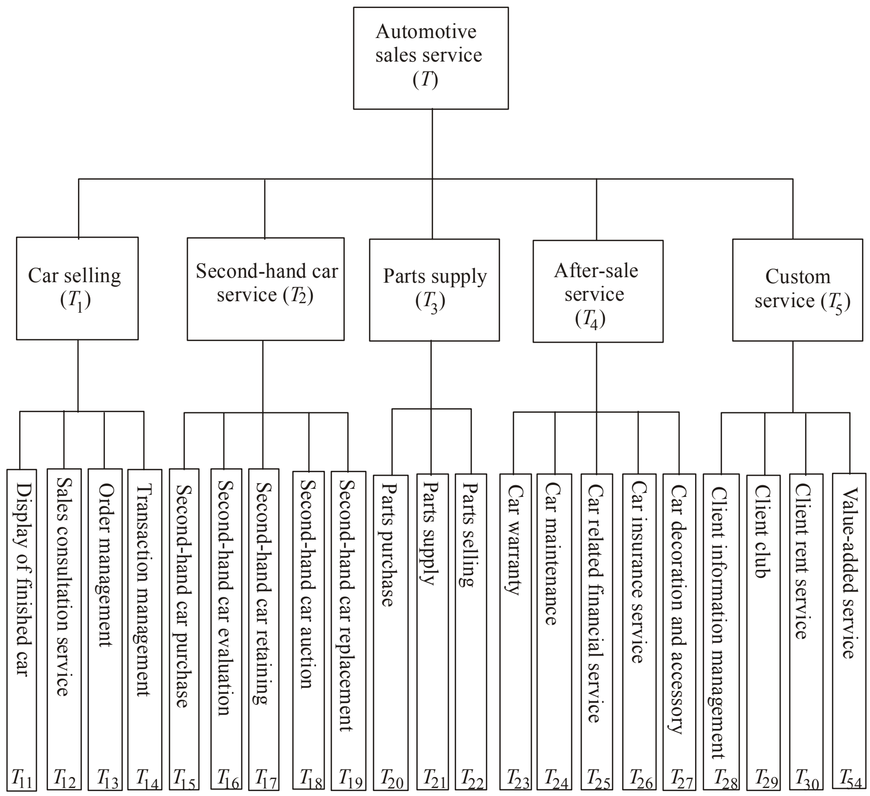

Fig. 2: Automotive sales service function structure of ASSCS

$$R=1-\frac{H_{iq}}{H_{iq}+H_{if}}=1-\frac{Y_{jq}}{Y_j}\log\frac{Y_{jq}}{Y_j}\Big/\left(\frac{Y_{jq}}{Y_j}\log\frac{Y_{jq}}{Y_j}+\frac{Y_{jf}}{Y_j}\log\frac{Y_{jf}}{Y_j}\right) \quad (11)$$

According to function log and the feature of probability, a larger number Y_{jq} of the management activity in a full-collaborative state means a smaller number of management activity Y_{if} in non-collaborative state, which will conduce to overcoming the chaos and deviation of the target management activity and result in a higher collaborative efficiency R which indicates a better collaborative degree between automotive sales service management business.

When $Y_{jq} = Y_j$, that is, the management business in the corresponding management layer is all in full-collaboration and then its collaborative efficiency R is 1.

CASE ANALYSIS

Business profile of automotive sales service: An Automotive Sales Service Company in Shanghai (ASSCS), subordinating to an automotive industry Group, is the most powerful and competent comprehensive automotive sales service enterprise. The company, oriented by the Chinese consumers' needs of cars, built the car service brand "Anji" with main business of car selling, parts supply, second-hand car service and a series of after-sale service, as shown in Fig. 2.

Collaborative assessment: According to Fig. 2 and the collaborative relationship between management activities, the collaborative impact matrix is $\varepsilon = [T_i , T_j]_{5\times5} = (\mu_{ij})5\times5$ among the management activities T_1, T_2, …., T_5, $\varepsilon_1 = [T_{2i} , T_{2j}]_{\times4} = (\mu_{ij})_{4\times4}$ among T_{11}, T_{12}, T_{13}, T_{14}, $\varepsilon_2 = [T_{2i} , T_{2j}]_{5\times5} = (\mu_{ij})_{5\times5}$ among T_{21} , T_{22}, …., T_{25}, $\varepsilon_3 = [T_{3i} , T_3]_{5\times5} = (\mu_{ij})_{3\times3}$ among T_{31}, T_{32}, T_{33}, $\varepsilon_4 = [T_{4i}, T_{5j}]_{5\times5} = (\mu_{ij})_{5\times5}$ among T_{41}, T_{42}, ….., T_{45},and $\varepsilon_5 = [T_{5i} , T_{j5j}]_{4\times4} = (\mu_{ij})_{4\times4}$ among T_{51}, T_{52}, T_{53}, T_{54}. Based on large quantity of investigations on each of the business of this automotive industrial group service, the collaborative impact matrix of each management activities and the management business unit are shown as follows:

$$\varepsilon_1=\begin{bmatrix}1&1&0&0\\1&1&1&1\\0&1&1&1\\0&1&1&1\end{bmatrix},\varepsilon_2=\begin{bmatrix}1&1&0&0&0\\1&1&1&1&1\\0&1&1&1&0\\0&1&1&1&0\\0&1&0&0&1\end{bmatrix},\varepsilon_3=\begin{bmatrix}1&1&1\\1&1&0\\1&0&1\end{bmatrix},\varepsilon_4=\begin{bmatrix}1&1&0&1&1\\1&0&0&1&1\\0&0&1&0&0\\1&1&0&1&0\\1&1&0&0&1\end{bmatrix}$$

$$\varepsilon_5=\begin{bmatrix}1&1&1&1\\1&1&0&0\\1&0&1&0\\1&0&0&1\end{bmatrix},\varepsilon=\begin{bmatrix}0&1&0&1&1\\1&0&0&0&1\\0&0&0&0&1\\1&0&0&0&0\\1&1&1&0&0\end{bmatrix}$$

The calculation results based on the afore-stated mathematical model are given in Table 1-5.

Bottom-layer management business unit:

Table 1: Collaborative assessment table of the bottom-layer management business unit (T_{ij})

T_{ij}	T_{11}	T_{12}	T_{13}	T_{14}	T_{21}	T_{22}	T_{23}	T_{24}	T_{25}	T_{31}	T_{32}
H_{iq}	0.1505	0	0.0937	0.0937	0.1592	0	0.1331	0.1331	0.1592	0	0.1174
T_{if}	0.1505	0	0.1505	0.1505	0.1331	0	0.1592	0.1592	0.1331	0	0.159
R	0.5	1	0.6163	0.6163	0.4554	1	0.5446	0.5446	0.4554	1	0.5753
T_{ij}	T_{33}	T_{41}	T_{42}	T_{43}	T_{44}	T_{45}	T_{51}	T_{52}	T_{53}	T_{54}	B_1
H_{iq}	0.1174	0.0775	0.0775	0.1398	0.1331	0.1331	0	0.1505	0.1505	0.1505	2.1698
H_{if}	0.159	0.1398	0.1398	0.0775	0.1592	0.1592	0	0.1505	0.1505	0.1505	2.4811
R	0.5753	0.6434	0.6434	0.3566	0.5446	0.5446	1	0.5	0.5	0.5	0.5335

The co-entropy of T_{13} is $H_{iq}(T_{11})$ =-(2/4)log(2/4) = 0.1505 , $H_{if}(T_{11})$ =-(2/4)log(2/4) = 0.1505 and the collaborative efficiency $R(T_{11})$ =1- $H_{iq}(T_{11})$/ ($H_{iq}(T_{11})+H_{if}(T_{11})$) = 1-0.1505/(0.1505+0.1505) = 0.5

Table 2: Internal collaborative assessment of management activity (T_i)

	T_1	T_2	T_3	T_4	T_5	B_2
H_{iq}'	0.3379	0.5846	0.2348	0.5610	0.4515	2.1698
H_{if}'	0.4515	0.5846	0.3180	0.6755	0.4515	2.4811
R	0.5720	0.5000	0.5753	0.5463	0.5000	0.5335

The co-entropy of $T_1$is

Table 3: Collaborative assessment of management activities (T_i)

	T_1	T_2	T_3	T_4	T_5	B_3
T_{iq}''	0.1331	0.1592	0.1398	0.1398	0.1331	0.7050
H_{if}''	0.1592	0.1331	0.0775	0.0775	0.0775	0.5248
R	0.5446	0.4554	0.3566	0.3566	0.3680	0.4267

The co-entropy of T_1 is

Table 4: Overall collaborative assessment of management activity (T_i)

	T_1	T_2	T_3	T_4	T_5	B
H_{iq}	0.471	0.7438	0.3746	0.7008	0.5846	2.8748
H_{if}	0.6107	0.7177	0.3955	0.753	0.5290	3.0059
R	0.5646	0.4911	0.5136	0.5180	0.4750	0.5111

$H_{iq}(T_1)$ = 0.3379+0.1331=0.471

Table 5: Unified collaboration of automotive sales activity

	B_1	B_2	B_2	B
H_{iq}	2.1698	2.1698	0.7050	2.8748
H_{if}	2.4811	2.4811	0.5248	3.0059
R	0.5335	0.5335	0.4267	0.5111

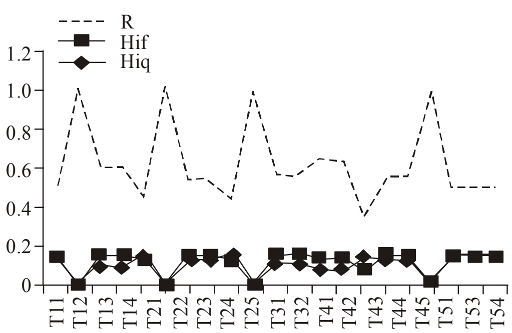

Fig. 3: Collaboration evolution chart of the management business unitT_{ij}

$$H_{iq}(B_1) = \sum H_{iq}(T_{ij}) = 2.1698$$

$$R(B_1) = 1 - H_{iq}(B_1)/(H_{iq}(B_1) + H_{if}(B_1)) = 0.5335$$

$$H_{iq}'(T_1) = \sum_{i=1}^{4} H_{iq}(T_{1i}) = 0.3379$$

Collaborative efficiency:

$$R(T_1) = 1 - H_{iq}(T_1)/(H_{iq}(T_1) + H_{if}(T_1)) = 0.572$$

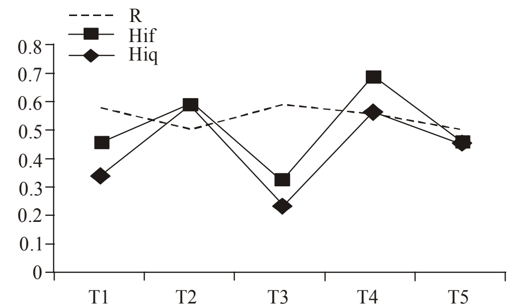

Fig. 4: Internal collaboration evolution chart of the management activity T_i

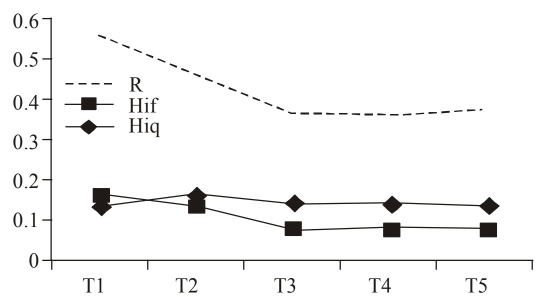

Fig. 5: Collaboration evolution chart of the management activity T_i

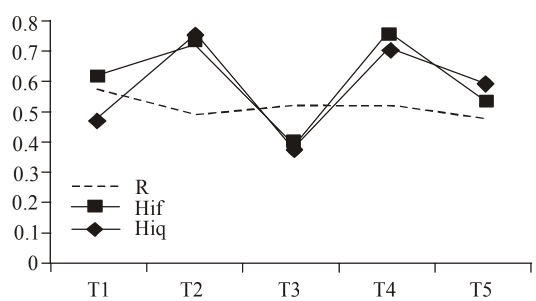

Fig. 6: Overall collaboration evolution chart of management activity T_i

$$H_{iq}''(T_1) = -(3/5)\log(3/5) = 0.1331$$

Analysis of collaboration: The features and evolving laws of collaboration of the automotive sales service management business are analyzed and the evolving features of the collaboration at each management layer can be observed from Fig. 3 to 7. Figure 3 show that the

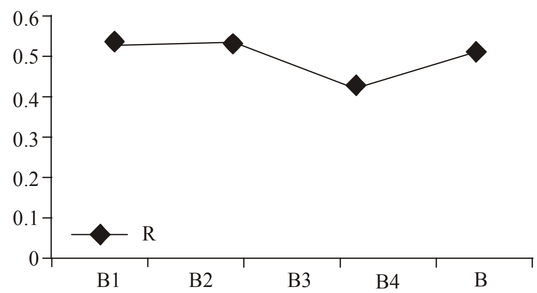

Fig. 7: Collaborative efficiency

four business units including sales consultation service, second-hand assessment etc. are all in a full-collaborative state. Figure 3 and 5 apparently indicate that the management business unit or the co-entropy among management activity is in a relatively low level and the entropy efficiency shows great fluctuation, yet the management activities shown in Fig. 4 and 6 reveals an increasing trend in the internal or overall co-entropy, despite the evident difference, the collaborative efficiency is tending to be stable. Figure 7 displays that the co-entropy of management level among management activities are the lowest.

CONCLUSION

To actualize the goal of automotive sales enterprise goal, for automotive sales service, the order degree of the automotive sales enterprises should be enhancing constantly, while the entropy and complexity should be reduced. Enterprise management collaboration, as a methodology in management science, can be applied to enhancement of the degree order and efficiency of management system. As a matter of fact, the internal EPR system, OA system and a variety of collaboration software management is to optimize the various management flows and to share management information, reduce the probability of non-optimal and low-efficiency operation state, as well as decrease complexity and entropy and finally enhance the overall collaborative efficiency.

Co-entropy functions for different management levels and the collaborative efficiency mathematical models were constructed. In the process of application and empirical demonstration of automotive sales service collaborative management activities, the following conclusions are drawn:

- Application of co-entropy has effectively reflected the degree of collaboration among the management activities and a larger co-entropy means a lower collaborative degree.
- Collaborative efficiency effectively displays the collaborative efficiency of the management activities; a larger collaborative efficiency stands for better collaborative effect of the management activities.
- The higher the management levels, the lather the co-entropy and eventually the lower collaboration, this is because higher management levels stand for more management activities and complicated collaborative relationship. This study attempts to establish a quantitative and practical management collaboration assessment method with application of co-entropy and efficiency.

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