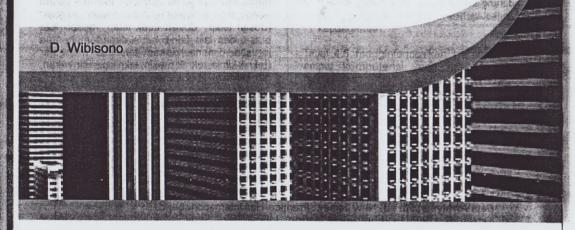
Part 2: The Detailed PMS System



#### Abstract

This paper presents on designing and managing performance of a manufacturing unit from the corporate level to the shop floor level. A Hybrid Knowledge Based (KB) Analytic Hierarchy Process (AHP) Gauging Absence of Pre-requisite (GAP) analysis of Performance Measurement System (PMS) Model is developed that considers five levels of company performance: Business Perspective, Customer Perspective, Manufacturing Competitive Priorities Perspective, Internal Process Perspective, and Resource & Method Availability Perspective. The research validation was confined to four industry sectors: aircraft component manufacturing, electronics manufacturing, computer and office equipment manufacturing and telecommunication products manufacturing. The results of the validation exercise indicate that the present Hybrid PMS Model is a suitable decision-making tool to assist the practitioners of PMS and provides consistent and detailed results.

Key words: Performance Measurement System, Knowledge Based, Analytic Hierarchy Process, GAP analysis, Manufacturing

A hybrid KB-AHP-GAP analysis...

## 1. The Hybrid PMS Model Strategic Level

In the Strategic Level, three modules that will be assessed are Company Environment, Business Perspective and Customer Perspective, shown in the Figure 1. From Figure 1, it can be seen that in Level 0 Company Environment Module, the information needed are type of industry, number of employee, age of company, age of industry, competitors and business life cycle stage. The Company Environment Module is the starting point of the KBPMS Model and is used to identify the existing condition of the company and its operating environment. The KB system processes the user's company details through the rule-base to categorise the company based on the technology implemented (high, medium, low), number of employees (big, medium, small), competition (high, medium, low) and business life cycles (growth, sustain, harvest). The information from the Company Environment Module, including the result of the KB process (e.g. classification of the company).

will then be used in the next module to positioning company in which the performancestandards have to be applied (e.g. a high-technology industry has a higher performance standard of quality compared to low-technology industry). The necessary information is then stored in the Information Base and the next module (Business Perspective Module) is loaded. The Level 1- Business Perspective Module is related to the procedures for measuring company performance in terms of financial ratios and market share. The assessing of financial performance in this module is based on the Income Statement and Balance Sheet of company for three years in which four financial ratios that are Leverage, Liquidity, Profitability and Returns on Investment are then calculated. The conclusion of financial performance is drawn, based on the benchmarking from literature. In this module, market share is measured based on the percentage of business received from customers domestically and alobally.



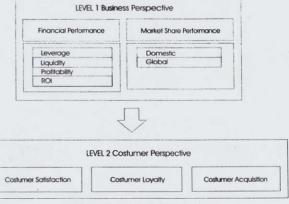


Figure 1 Hybrid PMS Model - Strategic Level

Referring again to the Figure 1, the Customer Perspective Module consists of three Sub-modules namely Customer Satisfaction (CS), Customer Loyalty (CL) and Customer Acquisition (CA). Structure of the Customer Perspective Module shows, in Figure 2. It can be seen that the KB system firstly assess the company concerns on the CS. The KB system will then assess the CL and the CA in a similar manner. Based on the assessment of CS, CL and CA, the KB system, using the AHP approach embedded in the model, then determines what improvement priority should be taken by the company. It should be noted that the CS Sub-module has been covered in great detail in this section, to show the breadth and depth of the Hybrid PMS Model and its Knowledge Base. Subsequent sub-modules (CL, CA) and modules for levels 3, 4 and 5 in the Operational Level (Section 2) will not be covered in the same level of detail, due to brevity reasons.

From Figure 2, it can also be seen that there are two types of question implemented in the Customer Perspective Module: general and specific. The general type of questions is relating to company commitment, company programmes and programmes achievement in the last three years. The specific questions such as communication— (in the Company Commitment), programmes content (in the Company Programmes) and detail of programmes achievement (in the Programmes Achievement) appear within the specific aspects of the Hybrid PMS Model.

Relating to the management commitment on the CS, not only are the top management being assessed in the CS Submodule but also Sales/ Marketing, Product Design and Production Management, as shown in Figure 3. An example of rule-base for assessing the Production Management commitment is listed below (only few rules are given)

IF Production Management is responsible for establishing performance indicators on CS (Good Point)

AND is not responsible for determining key benchmarks & competitors on CS (Problem Category 1)

AND is responsible for determining data source of Customer Satisfaction relatives to its competitors (Good Point)

AND is not responsible for developing employees' capabilities on implementation of CS programmes in production department (Problem Category 1)

AND is responsible for preparing production facilities related to CS programmes (Good Point)

AND is responsible for monitoring CS programmes on shop floor implementation (Good Point)

THEN Production Management commitment on CS achieves 4 Good Points and 2 Problem Category 1

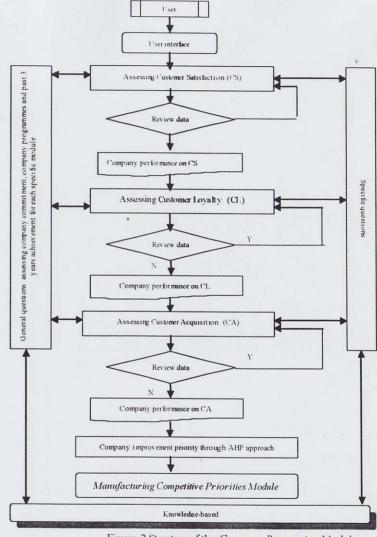


Figure 2 Structure of the Customer Perspective Module

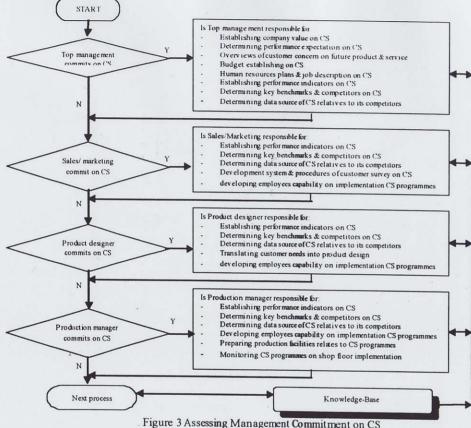


Figure 3 Assessing Management Commitment on CS

The structure of assessing CS programmes content can be seen in Figure 4. From Figure 4, it can be seen that the programmes content relates to the existence of CS programmes on quality of product, quality of service, safety and value for money which the procedures to assess this aspect is conducted through the rules-base as the previous explained.

The assessment of company programmes achievement on CS in the last three years basically refers to the achievement of program content stated in the above section.

In summary, in the CS sub-module output, the number of questions for each aspect and the Problem Category can be shown in Table 1.

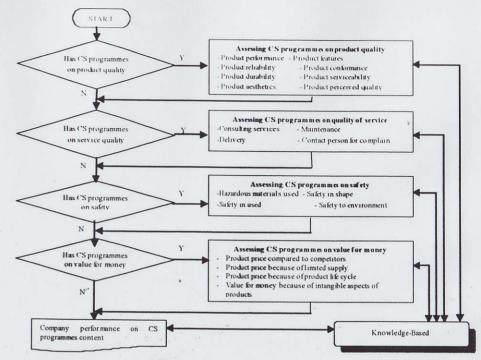


Figure 4 Structure of KB for CS Programmes Content

A HYDRIG NB-AMP-GAP analysis.

Aspect		Number of questions		ial Probl		gory	
112			1	2	3	4	5
Commit ment	Top management on CS	10	10	0	0	0	0
	Sales/ marketing on CS	5	5	0	0	0	0
	Product designers on CS	4	4	0	0	0	0
	Production management on CS	6	6	0	0	0	0
	Communication of CS to employees	6	3	5	0	0	0
Programmes	Content of CS programmes	25	10	15	0	0	0
	Employee participation on CS programmes development	18	2	4	3	0	9
	Project manager existence & reliability	23	10	1	0	0	12
	CS programmes reliability	30					
Programmes	Product quality	24	24	24	24	24	0
achiev ement	Service of quality	12	12	12	12	12	0
	Safety	9	9	9	9	9	0
	Value for money	12	12	12	12	12	0
TOTAL		184	107	82	60	57	21

Table 1 Questions and Problem Category for CS sub-module

Based on the input data from CS, CL and CA sub-modules, the KBPMS Model then determines the improvement priority that has to be undertaken by the company to improve its competitiveness for the Customer Perspective Level. The process of transferring from the Problem Category to the Intensity of Importance of Saaty (1980) for the AHP approach has been explained in the Paper Part 1.

### 2. The Hybrid PMS Model Operational Level

The three modules that are assessed in the operational level include Manufacturing Competitive Priorities Perspective, Internal Process Perspective and Resource & Method Availability Perspective, shown in Figure 5.

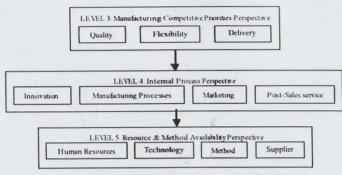


Figure 4 Hybrid PMS Model - Operational Level

Figure 4 shows the Manufacturing Competitive Priorities Module consists of three sub-modules that will be assessed: Quality, Flexibility and Delivery. The KB systems assess the company commitment on Quality - Flexibility - On-time delivery, the existence of programmes, the employee participation on the programmes development, the existence and reliability of project manager, the reliability of the programmes and the statistic of the programmes achievement in the last three years through similar procedures with those for the Customer Satisfaction Sub-module in the context of Quality-Flexibility-On-time delivery.

Referring to Figure 4, in the Internal Process Perspective Module, four submodules that will be assessed are Innovation, Manufacturing Processes, Marketing and Post-Sales Service. Figure 4 also shows the Resource & Method Availability Module that consists of four sub-modules namely Human Resources, Technology, Method and Supplier that will be assessed in the Hybrid PMS Model. Again, the structure of the KB system of those sub-modules follows the general patterns of question illustrated in the section 1.

# 3. A Case Study

The next stage after developing the Hybrid PMS Model is the testing, verification and validation of the Model. Validation of a KB system involves the validation of the knowledge (rules and conditions) incorporated into the system and the correct use of the knowledge to solve a problem (Hussain, 1998; Razmi, 1998). Real information is obtained from four Indonesian manufacturing companies. The validation process of the Model is based on interviews, questions and input/information. The input/information (answers to questions and input data) provided by each person in each company is their own data (based on their current and previous data, past experiences and judgement). The knowledge contained in the model is also tested and verified (through user feedback during the system testing). The profile of the companies for the verification and validation processes is listed in Table 2.

Description	Α	13	(,	D
Core Business	Electrical machinery	Communication equipment	Aeroplane part	Computer, office machinery
Number of employee	1,250	1,100	1,600	2,000
Turnover	£ 10,000,000	1.30,000,000	£ 50,000,000	£8,000,000
Products	Broad castings, Transmission, IT. Signalling, Defence electronics, Energy & power electronic	Telephone, Communication network & component	CNC, maintenance Machine/ tools re- calibration	IC, Semiconductor
Number of plants	1	1	1	1
Markets	Indonesia	Indonesia	Indonesia, USA, Spain, German, British, Japan	Indonesia Singapore

Table 2 Summary of Company Profile for KBPMS Model Validation

As mentioned in Section 1, the Company Environment Module is the starting point of the KBPMS Model and is used to identify the existing condition of the company and its operating environment. The Company Environment Module is tested and verified for the accuracy of the information entry and knowledge. The user tested the behaviour of the KBPMS system regarding the KNOWLEDGE (RULE-BASE) contained in the Module. The Model performs a check in detecting any possible incorrect input. The general information provided in the Company Environment Module will then be exported to the next module (Financial & Market Share Module).

Since the data input for the *Company Environment Module* is mostly raw and general information needed for the subsequent modules, hence there is no crucial issue in this module regarding the company performance itself, rather the KB mechanism implemented in the system is to process these data for the other modules.

The Business Perspective Module is the first level of the KBPMS Model that is to be used as starting point to analyse the company competitiveness. Based on the data of Income Statement and Balance Sheet, the KB system uses its internal rules to produce the output shown in Table 3, which presents examples of various financial ratios of company A in terms of leverage, liquidity, profitability and Return on Investment (ROI).



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Return on Equity

ROI

continuously

system presents the results of GAP analysis, interactive questions implemented sequentially in the system. In each sub-module, the KB The user validates the reliability of Customer Perspective Module through

that are faced by the company.

the Good Points and the Problem Categories which consists of the number of question asked,

Fluctuated

Improved continuously

After processing all three sub-modules (CS-CL-CA) sequentially, the KB system applies the AHP methodology to these three sub-modules, as highlighted in the previous section.

Table 4 shows the summary of GAP analysis provided by the Hybrid PMS Model related to CS, CL and CA.

Description	Last year		2 Years ag	0	3 Years a	go	Trend
	Ratio	Category	Ratio	Category	Ratio	Category	
Leverage ratio							
Debt ratio	0.95	Fair	0.98	Fair	0.89	Fair	Fluctuated
Times Interest Earned	10.28	N/A	9.59	N/A	3.72	N/A	Improved continuously
Liquidity ratio			•				
Net Working Capital to Total Assets	0.43	N/A	0.27	N/A	0.07	N/A	Improved continuously
Current ratio	2.88	Excess idle cash	1.97	Good	1.15	Good	Improved continuously
Quick ratio	1.03	Good	1.11	Good	0.58	Fair	Fluctuated
Cash ratio	0.37	Bad	0.46	Bad	0.31	Bad	Fluctuated
Interval measures	72.13	Fair	366.47	Good	286.53	Good	Fluctuated
Profitability ratio			***************************************				
Sales to Total Assets	1.38	Good	0.51	Bad	0.45	Bad	Fluctuated
Sales to Net Working capital	5.43	N/A	1.99	N/A	1.75	N/A	Improved continuously
Net Profit Margin	16.92	Good	28.30	Good	9.96	Good	Fluctuated
Inventory Turnover	4.12	Good	1.23	Good	1.09	Good	Improved continuously
Average Collection Period	218.92	Bad	218.92	Bad	218.92	Bad	Steady
Return on Total Assets	23.37	N/A	14.32	N/A	4.44	N/A	Improved

Table 3 Example of Financial Performance for Company A

2195.79

14.6560

Good

Good

494.53

4.6117

Good

Fair

3211.81

24.5485

Good

Good

GRANDTOTAL							(CA)	Customer							(CL)	Customer													(CS)	Customer	Simporations:
F	TOTAL	Programmes achi evement				Programmes		Commitment	TOTAL	Programmes achievement				Programmes		Commitment	TATOT			actuevement	Programmes				Programmes					Commitment	waperi
		Existing CA achievement	Reliability	Projed manager	Employees participation	Content	Budget allocation	Top management		Existing CL achi evenent	Reliability	Projed manager	Employees participation	Content	Budget allocation	Top management	,	Value for money	Safety	Service quality	Product quality	Reliability .	Projed manager	Employees participation	Content	Communications	Production management	Production designers	Sales/marketing	Top management	ouo-aspect
350	, 79	6	16	23	18	7	3	6	87	12	18	23	18	7	3	6	184	12	9 0	12	24	30	23	18	25	6	6	4	5	10	questions of
124	22	2	9	0	w	w	3	2	33	ω	10	4	9	6	0	-	69	0	0	0	0	14	Ξ	9	20	4	2	0	0	9	Points
226	57	4	7	23	15	4	0	4	ž	9	00	19	9	-	3	5	115	12	9 -	12	24	16	12	9	5	2	4	4	5	-	Total
124	21	4	ω	10	-	-	0	2	26	90	3	6	0	0	u	5	77	12	9	12	24	w	0	0	-	2	4	4	5	1	Total 1 2 3
31	12	0	3	-	w	w	0	2	0	0	4	-	0	1	0	0	13	0	0	0	0	9	0	0	4	0	0	0	0	0	2
7	w	0	-	0	2	0	0	0	1	0	-	0	0	0	0	0	w	0	0	0	0	w	0	0	0	0	0	0	0	0	w ea
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	-	0	0	0	0	0	0	0	0	4

Table 4 An Example Summary of GAP Analysis for Customer Perspectives Module for Company A

27

From 184 questions of CS, the company achieves 69 Good Point and 115 Problem Category (PC) that consists of 77 PC 1, 13 PC 2, 3 PC 3, 1 PC 4 and 21 PC5. In the submodule Commitment, Company A has a good commitment for top management but very poor for sales/ marketing, production designers and production management, indicating that the commitment from top management is not being implemented lower down. The lack of commitment from this middle management has further impact on the programmes achievement (again very poor results), for customer satisfaction. From this table it can be seen that the Customer Satisfaction for product quality, service quality, safety and value for money are all very poor with the total Problem Category 1 for these four aspects being 115 out of 184. This is a tremendously negative performance for Company A and drastic actions are needed.

For the Customer Loyalty (CL) aspect, from a total of 87 questions, the company achievement is 33 Good Points and 54 Problem Categories (PC) consisting of 26 PC 1, 6 PC 2, 1 PC 3, 0 PC 4 and 21 PC 5, again indicating very poor performance.

Finally, for the Customer Acquisition (CA) aspect, from 79 questions asked, Company A achieves 22 Good Points and 57 Problem Category consisting of 21 PC 1, 12 PC 2, 3 PC 3, 0 PC 4 and 21 PC 5.

Based on the results of the GAP analysis, the Hybrid PMS Model then processes the results using the AHP approach to determine which aspect should be in priority of improvement and how the weight of priority between CS, CL and CA should be determined. Table 5 shows an example of the *Priority Vector* for CS, CL and CA based on the result of the GAP analysis shown in Table 4.

Aspect	Customer Satisfaction	Customer Loy alty	Customer Acquisition	Priority Vector
Customer Satisfaction	1	2	2	0.500
Customer Loyalty	1/2	1	1	0.250
Customer Acquisition	1/2	1	1	0.250

Table 5 Priority Vector for Customer Perspective

The Table 5 shows that the Priority Vector for CS is 0.500, for the CL and CA are both 0.250. It means that based on the GAP analysis and AHP process embedded in the system, the company should place its improvement priority firstly on the CS as two times compared to CL and CA aspect, and improvement for CL and CA as a similar priority. The similar procedures of performance assessment are conducted for the Manufacturing Competitive Priorities Module, Internal Processes Module and Resource & Method Availability Module.

The process of verification and validation of Hybrid PMS Model through the other three manufacturing companies is conducted in a similar manner as has been explained for the Company A. Tables 6 and 7 show the summary results for the GAP analysis and the AHP analysis (in terms of *Priority Vector*). It needs to be reiterated that the GAP analysis provides the priorities actions needed internal to each sub-module (in terms of *Problem Categories*) where the AHP output

provides the prioritised actions between the submodules.

Table 6 shows the content findings by the Hybrid PMS Model for the four companies, indicating that the present performance of these companies is distant from the benchmark standards contained in the model. The results indicate for each company where it needs to focus for each of the sub-module.

Table 7 provides a summary of the AHP analysis and shows, relatively, which issues to be tackled initially. The bold figures show the priorities for each major perspective. Hence in the Customer Perspective, for Company A the priority is deemed to be CS (over CL and CA), for Company B it is all tree, for Company C it is CS and for Company D it is CL. Similar observations can be coped out for the other perspectives, to determine the key actions required at the sub-module. Thus the Hybrid PMS Model has not only provided the details of where the performance can be improved, but it has also provided an in-depth and prioritised decision-making tool for the practitioners.

Model	Sub-Module	Number			COMPANYA	ANNA					Company B	y B				Co	Company C					Con	Company D	1
		and done	00	Drow	Drobl em Category	TOTAL			GP P	roblem	Problem Category	2	-	9	GP Pro	Problem Category	Megory			d.b	Proble	ProblemCategory	ory	
		decanon	5	-	2	3	4	5	1	-	2	-	4		L	2	3	41	5		-	2	3	-1
	200	104	9	77	13	3	-	21	63 4	46	43	01	1 21		50 78	33	2	0	21	8.2	31	44	0	0
i de	38	101	33	36		-		t	t	31	13	2	0 21	1 2	2 21	20	3	0	21	15	30	16	5	0
Perspectave	75	90	200	210	- 2		0 0	t	1	22		3	-	1 22	2 26	10	0	0	21	11	24	0.1	3	-
	CA	17	77	1,0			,	1	1	t	yy	-	44	t	4 125	5 63	2	0	63	108	85	29	14	-
	TOTAL	350	124	174	31		-	1		1	3 3		1	+	+	+	-		-	85	2.4	0	1	- 3
Manuficturing	Ouality	142	43	44	23	10		21	00	28	32		7 0	1		2	-	-	:	2			1	-
Competitive	Flexibility	84	0	36	19		0	21	22   1	80	13	90	2 2	1 23	3	4	2	-	7	400	-	=	,	1
•	Delivery	S.O.	~	28	17	9	0	21	18 2	25	==	2	0 21		7 13	12			7.1	40	-	^	7	3
10	TOTAL	306	15	108	59	24	1		100	71	56	14 2	2 63		130 42	36	15	20	63	155	56	100	20	9
	20101		100	20	3,0	0.1	1.3	16	28	3	23	10	19 21	1 64	4 16	10	0	(**)	21	29	23	28	10	-1
Internal	Innovaton	1	1	200	2		-	1	t	48	+	,	0	1 37	7 32	23	17	0	21	55	25	11	10	C+
Process	Man Process	130	5	90	2		-	†	+	0		+	1	1	01 0	36	1	0	21	4.6	112	21	*1	0
Perspective	Marketing	104	41	2	73	=	0	717	t	1	1	1	1		0	100	-	c	23	20	10	13	1 2	0
	bss	88	2	34	22	0	0	1	1	2	1	1	†	t	+	200	36		6.4	140	10	83	26	0
	TOTAL	436	83	128	84	38	19	84	134	123	6	17	19 84	1	180	5	1	. -		1	1		6.2	-
Recourse &	HR	109	49	37	7	7	0	0	48	20	27	2	0	1	10	-	7	- (	1	200		-		- 0
Mathod	Technology	94	39	4	16	14	0	21	33	0	91	2	0	1 42	7 10	- 4	-	0	7		*	300	. 00	9 6
Availability	Mathod	145	44	22	50	9	0	21	36 3	32 4	41	15	0 21	1 55	5 21	33	-2	0	7	24	7	200	2	9
James of the	INICHIOG	25	-	3.4	c	0	6	16	17	1	13	7	0 2	-	19 11	18	9	0	21	30	0	0.	0	9
Leisbergae	Supplier	133	11/4	0.0	63	27	t		134	20 07	10	32 (	0 7:	72 1	173 58	78	11	1	72	182	57	62	50	-
		676	207	+	256	5	-	1	1	372	274 82	+	24 2	282 5	577 301	1 245	5 86	24	282	604	247	252	110	3.5
GRANDIULAL	-	crer	402	_	200	2	1	1	1					DOC -	100									

e 6 Summary of Hybrid PMS Model Validation Results for GAP Analysi

Module	Sub-Module	Company A	Company B	Company C	Company D
Customer	CS	0.500	0.333	0.500	0.200
Perspective .	C1.	0.250	0.333	0.250	0.400
	CA	0.250	0.333	0.250	0.400
	TOTAL	1.00	1.00	1.00	1.00
Manufacturing	Quality	0.250	0.260	0.200	0.608
Competitive	Flexibility	0.500	0.410	0.400	0 199
Prionties	Delivery	0.250	0 330	0.400	0 199
Perspective	TOTAL	1.00	1.00	1.00	1.00
Internal Process	Innovation	0 173	0124	0 144	0.289
erspective	Man Process	0.399	0 237	0.391	0 247
	Marketing	0.069	0.071	0 319	0.176
	PSS	0 359	0.567	0144	0.288
	TOTAL	1.00	1.00	1.00	1.00
Resource & Method	HR	0.244	0.234	0.250	0 304
Availability	Technology	0.099	0 198	0.250	0.277
Perspective	Method	0.219	0.284	0.250	0.304
	Supplier	0.437	0.284	0.250	0 113
	TOTAL	1.00	1.00	1.00	1.00

Table 7 Summary of Hybrid PMS Model Validation Results for AHP (Priority Vector) Analysis

#### 4. Conclusion

The design of PMS is a complicated process as it involves many performance variables and formula. Using a hybrid (Knowledge Based, GAP analysis and AHP approach) methodology, the PMS model consisting five performance levels was developed to serve the purpose. The hypothesis of this research was to show that the application of KB systems was a viable PMS methodology to improve company competitiveness based on

the financial and non-financial variables and both based on the qualitative and quantitative assessment processes. This has been shown to be a valid hypothesis, whereby the development and the subsequent application of the Hybrid PMS model in four industrial applications have identified key areas of performance improvements. In the validation processes based on the industrial information, the Hybrid PMS model can determine accurately (for every level) which performance variables should be tackled for improvement by the company.

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