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ALAMAT REDAKSI
MAGISTER BISNIS DAN ADMINISTRASI TEKNOLOGI
INSTITUT TEKNOLOGI BANDUNG
Gedung Barrac
Jl. Gelap Nyawang. No.1, Bandung 40132
Telp. (022)-2504308, 2501645 Fax. (022)-2504897
e-Mail : jurnal@mba.itb.ac.id, http ://www.mba.itb.ac.id

A HYBRID KB-AHP-GAP ANALYSIS FOR THE PERFORMANCE MEASUREMENT SYSTEM (PMS) IN A MANUFACTURING ENVIRONMENT

Part 1: The PMS framework

D. Wibisono
Master of Business Administration
Institut Teknologi Bandung

:: Abstract ::

Designing and implementing PMS is an integral part of management control systems. To be effective, performance measures need to reflect the changes in competitiveness. However, traditional PMS is criticised for being obsolete, irrelevant to managerial decision making, unrelated to strategic objectives and detrimental to organisational improvements. Given the shortcomings of traditional PMS, there is need for a new framework that can lead to the design of a PMS that balances short-term and long-term measures, internal and external measures, and financial and operational measures. This paper presents on designing and managing performance of a manufacturing unit from the corporate level to the shop floor level. It seeks to fill some of the gaps in the research by addressing three areas: steps in designing a PMS, frame work of PMS specific to a manufacturing environment, and implementation of Knowledge Based (KB) systems, Gauging Absences of Pre-requisite (GAP) analysis and Analytic Hierarchy Process (AHP) approach in an integrated PMS.

Key words : Performance Measurement System (PMS), Knowledge Based (KB), Analytic Hierarchy Process (AHP), GAP analysis, Manufacturing

1. INTRODUCTION

Manufacturers, more than ever before, are realising that the need for accurate and comprehensive information about their activities is of crucial importance. This is because, as Medori and Steeple (2000) stated, that to be classified as World Class Manufacturers (WCM), manufacturing organisations need to have a number of critical ingredients; one such ingredient is that of an appropriate Performance Measurement System (PMS). Throughout the 1990s, various novel frameworks have been derived, to aid manufacturing organisations to select and implement measures, such as *Prism* (Neely *et al*, 2002), the *Balanced Scorecard* (Kaplan & Norton, 1996), *Vital Signs* (Hronec, 1993) and *Questionnaire Methods* (Dixon *et al*, 1990). However, as Zairi and Letza (1994) have observed, research in the area of performance measurement has not produced solid findings and this remains a challenge. Neely and Bourne (2000) support this argument through their research findings which show that some 90% of managers fail to implement and deliver their organisation's strategies by the performance measurement applied. They argue that this failure is mostly because the business performance is itself a multi-faceted concept that need a different type of PMS. Furthermore, as noted by Sellenheim (1991) and by Ljungberg (1994), methods for developing and implementing detailed measures, adapted to the environment of a specific company, are seldom described in detail.

The methodology supported by Knowledge Based (KB) systems approach in the PMS has not been carried out in the past. The KB approach is chosen based on the reasons that first, a large number of performance variables are usually involved in successful implementation of PMS and the relationship between them are quite complex. Second the priorities of improvement performance variables needs supporting tools to keep the validity and consistency of decision making. Third, the benchmarking process in figuring a company's competitiveness also has to be facilitated by appropriate tools. These situations make the selection of the proper methodology and its implementation quite a difficult task for

practitioners in industry. The KB systems are applied to make the performance measurement systems provided valid, consistent, and practical for implementation. Application of KB systems provides the opportunity to interact with users in an appropriate manner and to assist in the decision-making process. The tedious and cumbersome calculations involved in performance variables' formulas and benchmarking process can be easily and accurately incorporated within the rule-based structure. Furthermore, by incorporating explanatory features, the KB system can be used as a learning device for all members of an organisation. These features of KB systems, coupled with the analysis of qualitative features of PMS through an embedded Gauging Absence of Pre-requisite (GAP) analysis and Analytic Hierarchy Process (AHP) approach, will make the hybrid PMS Model of KB-AHP-GAP analysis a real, practical and effective decision-making for practitioners.

2. THE FOUNDATION FOR THE DEVELOPMENT OF A PMS

There are three main important stages that have been considered in the development of the Hybrid KB-AHP-GAP analysis of proposed PMS Model: *Basic Information, Core of Performance Measurement, and Mechanism of Performance Measurement. Within these three features of the Model, the KB is used as the main foundation, as depicted in the Figure 1.*

2.1 Figure 1 - Stage 1

From the Figure 1, it can be seen that in *The Basic Information stage there are three important sets of information that need to be considered: Company Environment Information, Financial and Market Information and Product Information.*

The function for the *Company Environment Information is for positioning the area in which the company currently competes. The data required includes type of industry, number of employees, age of company, age of industry, competitors and business life cycle.*

The reasons for considering company *Financial and Market Information is that financial performance indicates how the company is presently being run in terms of efficiency and effectiveness (Kaplan & Norton, 1996). While Market reflects how competitive the company's products and services are, and also provides an indication of customer satisfaction in comparison to that of competitors (Neely et al, 2002).*

Since the *Product Information is a backbone of manufacturing competitiveness, the information about the products that the company is manufacturing and selling is absolutely crucial.*

2.2 Figure 1 - Stage 2

In the *Core of Performance Measurement aspect there are several important pieces of information that should be considered such as: company statements, performance variables, linkage among performance variables, weight of each variables relative to the company performance and performance standards of each variables.*

Since company statements such as company strategy, vision, mission, and objectives determines the future direction, it is therefore important to explore whether the company not only has these statements but also communicates them to all employees at all levels. All company statements should become a 'compass' for guidance in determining performance variables. This is based on the argument that all performance variables used in the PMS have to be aligned with the company strategies, vision, mission, and objectives (Kaplan & Norton, 1996).

From the Figure 1 it can also be seen that there are four different groups of manufacturing company performance variables related to the management responsibility: *Customer Perspective, Manufacturing Competitive Priority, Internal Process and Resource & Method Availability. Each of these four groups consists of several performance variables. The most critical thing in this stage is in determining which performance variables are most appropriate to the company. Choosing just a single variable will misrepresent the overall factory performance, while using all the possible variables may represent the real performance but would be very complex and in many cases, performance against some variables may be adequately represented by the measurement of others (Hayes & Pissano, 1996).*

Referring again to the Figure 1, the *AHP* is embedded in the system for determining quantitative and qualitative linkage patterns among performance variables in the *Customer Perspective, Manufacturing Competitive Priorities, Internal Process* and *Resource & Method Availability*. These linkages are important to determine the cause and effect between performance variables in the different levels and to know the improvement priority that should be taken among performance variables in the same level.

The essence of *Benchmarking* is to encourage continuous learning and to lift organisations to higher competitive levels. Benchmarking is not a means of winning at any cost. It is a legitimate, systematic, overt and ethical process of bringing about effective competitiveness (Zairi, 1998).

2.3 Figure 1 - Stage 3

Referring to the Figure 1, the Mechanism of Performance Measurement aspect consists of four main steps : *Measurement, Evaluation, Diagnosis* and *Action.*

Performance Measurement has been implemented in the factory level for most manufacturing companies. However, *Performance Measurement* often seems to have become a routine activity, without any determined strategy for the required follow up action. The results of the performance measurement tends to give an insight where the actual performance is worse than expected; it does not give an insight into why the actual performance differs from the one nor does it inform how one can improve the actual performance. It is clear that performance measurement does not automatically give an answer to the question how good the actual performance is, neither does it give suggestions for where performance improvements are possible (Stoop, 1996). Performance measurement thus, is a starting point for further analysis.

The *Performance Evaluation* is the assessment of a possible situation in comparison with plans and or standards previously set as a target. There are two ways in which to set a performance target: internal and external standards. The internal benchmark could be conducted based on comparisons to the best previous performance, the technical standard, the other departments in the company, the average in a certain period or the last period of performance. The external target is based on the benchmarking of best practice in a similar industry, industry benchmarking or current competitors.

The *Performance Diagnosis is defined as the process of finding causes of performance deviations and explaining the achieved performance. Diagnosing the performance is important because to some extent, management often claim to know the causes for performance deviations (Wibisono, 1998). According to Stoop (1996), the danger of qualitative explanations regarding the deviation of performance is that it is possible that the assumed causes are not all the causes that explain the observed performance gap.*

one can use this information to reinforce the intuition. Thirdly, due to all kinds of changes on the shop floor itself or its environment, there is the danger that problems are solved only by using the past experience to find possible causes, whereas there may have arisen new factors.

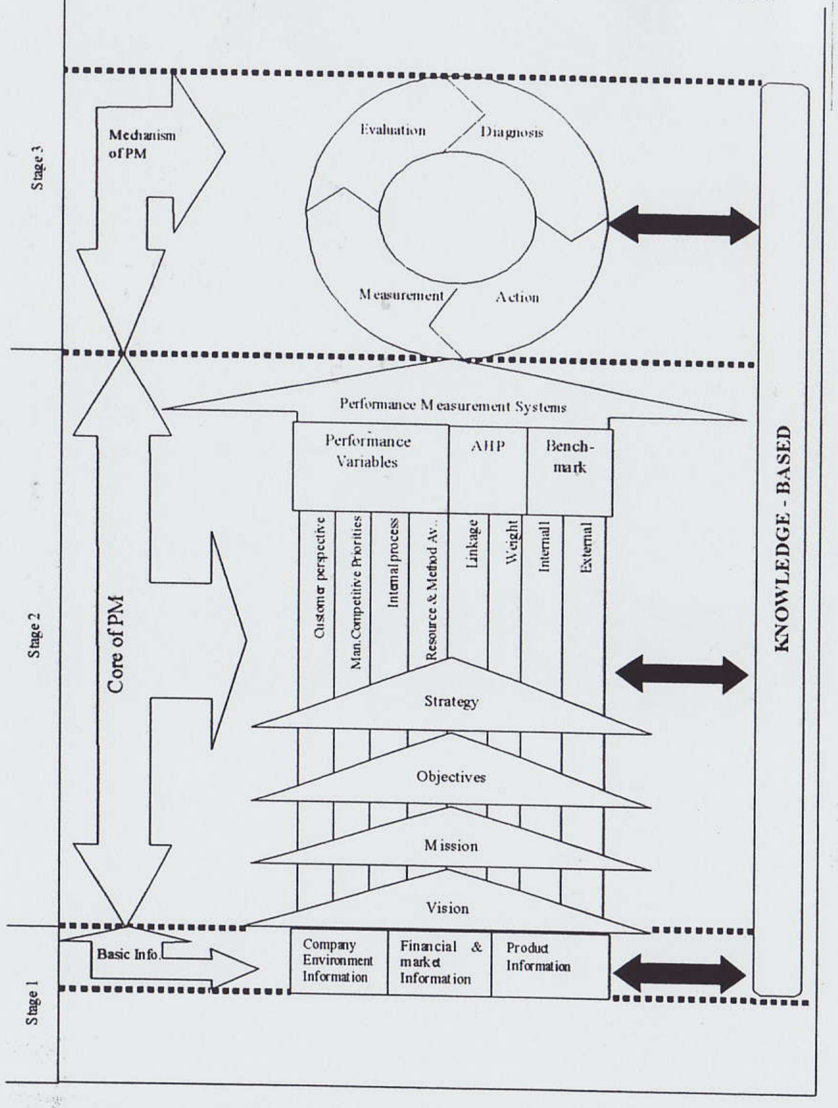

Figure 1 Stages that have been considered in designing Hybrid PMS Model

The *Action plan* is concerned with identifying action that needs to take place if performance improves either satisfactory or unsatisfactory. There are two different aspects to improvement actions: strategic and technical (Skinner, 1996). The strategic aspect is more concerned with decision making in the higher level of management and in the long-term policy. In the technical aspects, the effort of improvement is mainly concerned with the sort-term activities.

3. THE HYBRID PMS MODEL

The Hybrid PMS Model introduced in Section 2 can also be visualised from a strategic and operational structure, as depicted in Figure 2. This Figure 2 is a clearer interpretation of how the Hybrid PMS
Model has been actually developed within the AM software.

From the Figure 2 it can be seen that there are one prerequisite (Level 0) and five perspectives (Level 1 to Level 5) of a company performance proposed in the Hybrid PMS Model. The *Business Perspective* and *Customer Perspective* are grouped as strategic performance measurement since these perspective are concerned with the strategic decision making at business level while the remaining three levels are grouped as operational performance measurement because these parts are more concerned with day to day operational matters.

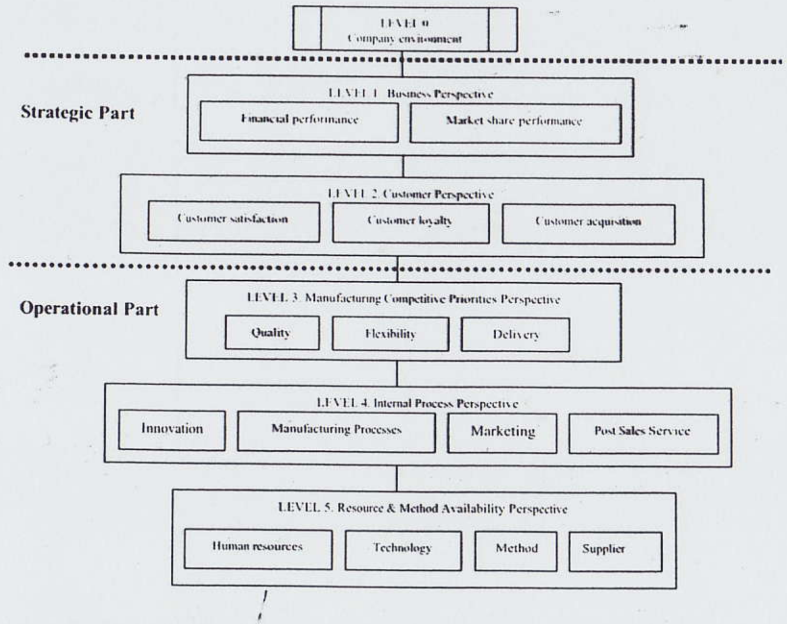

Figure 2. A Hybrid PMS Model

The *Business Perspective* assesses a company's financial performance and market share through specific performance criteria. The financial performance is based on the *Income Statements* and *Balance Sheet* of the company. Four financial performance criteria of the company that will be analysed include *Leverage, Liquidity, Profitability* and *Return on Investment* (ROI). The market share performance is measured based on the domestic and global market share that is achieved by a company relative to its competitors.

If business units are to achieve long-run superior financial performance, they must create and deliver products and services that are valued by customers (Kaplan & Norton, 1996). The three most important performance measures in the company 's perspectives are *customer satisfaction, customer loyalty* and *customer acquisition* (Kaplan & Norton, 1996). Referring to Kaplan and Norton's argument, the *Customer Perspective* in the hybrid PMS Model will diagnose customer satisfaction, customer loyalty and customer acquisition, as a key measure of external performance measurement.

Internal process has been a focus of a company's improvement in competitiveness for a long time (Kaplan & Norton, 1996). Since an internal process represents the effectiveness and efficiency of internal manufacturing performance, it is therefore important to manage the performance rigorously (Wibisono & Khan, 2002b). Four of the most important performance parameters in the *Internal Process Perspective* that will be assessed are *Innovation, Manufacturing Process, Marketing* and *Post Sales Service*, each aspect consisting of several performance sub-variables.

Organisations must also invest in their infrastructure: people, systems and procedures if they are to achieve ambitious long-term financial growth objectives (Kaplan & Norton, 1996). In the proposed Hybrid PMS Model this infrastructure is named as *Resource & Method Availability Perspective*. There are four main categories of resources and method in manufacturing that will be assessed: *Human Resource, Technology, Method* and *Suppliers*, within which there are a number of sub categories.

The assessment of company performance in the Hybrid PMS Model is conducted through sequential questions that measure both qualitative and quantitative information on the company performance in each level based on the Gauging Absences Pre-requisites (GAP) analysis. GAP analysis is used to determine the disparity between the essential or desirable prerequisites and what actually exists in an organisation. This analysis is to identify likely problem areas, which must be addressed by the management if an effective implementation is to be achieved. The mechanism of GAP analysis is conducted through the responses of the user to the questions provided in the Hybrid PMS model. The problems highlighted for each negative reply is categorised under the following headings in descending order of importance (Kochhar *et al*, 1991).

Category 1: This indicates a serious problem, which should and can be resolved in the short-term, and the resolution of the problem is quite likely to provide real short-term benefits

Category 2: This indicates a serious problem which is likely to have pre-requisites, and is thus better dealt with as part of an appropriate and logical improvement and implementation plan

Category 3: This is not a serious problem, but can be dealt with now. If resolved, it is likely to yield short-term benefits

Category 4: This is not a serious problem. Although it could be dealt with now, it is unlikely to yield short-term benefits. Therefore, it should only be dealt with if it is a pre-requisite for other things

Category 5: *This is not really a Good or Bad point it self; the questions associated with this category are primarily asked to identify certain situations in the environment which, upon subsequent probing by succeeding questions, may well reveal problems.*

Based on the results of the GAP analysis, the Hybrid PMS Model then processes the results using the AHP approach (Saaty, 1980) to determine which aspect should be in priority of improvement and how the weight of priority between sub-modules in one perspective. It needs to be reiterated that the GAP analysis provides the priorities actions needed internal to each sub-module (in terms of *Problem Category)* where the AHP output provides the prioritised actions between sub-modules. The procedure embedded in the KBPMS model in transferring the results of the GAP analysis into the AHP approach can be illustrated in Figure 3 (*Customer Perspective* module is taken as an example for this illustration with three sub-modules: *Customer Satisfaction (CS), Customer Loyalty (CL)* and *Customer Acquisition(CA)*).

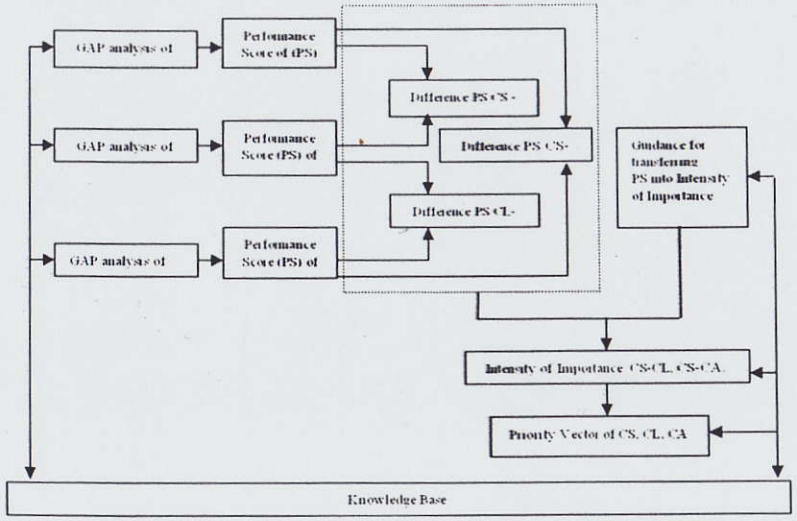

Figure 3. Mechanism of Translating GAP Analysis into AHP Approach

It has been explained that in the GAP analysis there are five *Problem Categories* for each performance condition assessed, while the AHP approach (Saaty, 1980) provides nine *Intensity of Importance* to be implemented for the each sub-module level. Thus the five scales GAP methodology needs to be scaled (transferred) to the nine-scale AHP methodology. To carry out this scaling exercise, several assumptions are made.

The weighting scale applied for *Problem Category* (PC) is stated in Table 1. From this table, it can be seen that the elimination of PC 1 is assumed as two times the weighting (and hence importance) for improvement compared to the PC 2, three times to PC 3, four times to the PC 4 and five times to the PC 5. Of course, the study has assumed (and hence defined) the weightings of each *Problem Category* based on the authors interpretation of the *Problem Category* (and others may differ in their weighting). Nevertheless, this methodology applied in terms of priorities the *Problem Category* is consistent in its approach.

	PC 1	PC 2	PC 3	PC 4	PC 5
PC 1	1	2	3	4	5
PC 2	½	1	3/2	4/2	5/2
PC 3	1/3	2/3	1	4/3	5/3
PC 4	¼	2/4	¾	1	5/4
PC 5	1/5	2/5	3/5	4/5	1

Table 1 Comparison of Weighting Among Problem Category

From the relative weighing scale amongst the PC categories in the Table 1 above, then it can be calculated that the PC category 1 is weighted as 5, PC 2 is 2.5, PC 3 is 1.67 and PC 4 is 1.25, PC 5 as 1. Hence the baseline is the PC5, which in essence is a neutral position in that it is not really a good or a bad point.

The weighting scale of PC then needs to be translated into the *intensity of importance* (1-9) based on the Saaty (1980) approach.
The mechanism of transferring PC weighting scale to the *intensity of importance* can be explained using the example below.

For example, the process of GAP analysis implemented in the Hybrid PMS Model gives a result, as depicted in the Table 2 below.

BP	Resulting answer for Customer Satisfaction (%)	Resulting answer for Customer Loyalty (%)
1	80	60
2	10	20
3	5	15
4	5	5
5	0	0
Total	100	100

Table 2 Example of GAP Analysis Result

The Table 2 states that there are 80% of PC1, 10% of PC2, 5% of PC 3 and 5% of PC 4 respectively for the company performance on *Customer Satisfaction* (CS) aspect. On the other hand, the company achievement on *Customer Loyalty* (CL) aspect are 60% of PC1, 20% of PC2, 15% of PC3 and 5% of PC4. How important is *Customer Satisfaction (CS)* relative to the *Customer Loyalty (CL)*? Based on the previous assumption (Table 1 & Figure 3), the responses shown in the Table 2 can then be converted into the Table 3.

PC (1)	Weight of PC (2)	Customer Satisfaction (A (%) (3)	Performance Score Of (4)=(2)x(3)	Customer Loyalty (B) (%) (5)	Performance Score Of B (6)=(2)x(5)
1	5	80	400	60	300
2	2.5	10	25	20	50
3	1.67	5	8.35	15	25.05
4	1.25	5	6.25	5	6.25
5	1.0	0	0	0	0
	Total	100	439.6	100	381.3

Table 3 The Conversion of PC scale

From the Table 3 it can be seen that the performance score of CS is 439.6 and for CL is 381.3. This indicates that the CS has to be a greater improvement priority relative to the CL. The transferring of *performance score* into *intensity of importance* of the Saaty (1980) approach is based on the difference of this *performance score*. From this example, we get the difference of *performance score* between CS and CL as 58.3 (439.6 381.3). Then the score of 58.3 is transferred into the *intensity of importance* based on the guidance stated in the Table 4.

Intensity of importance	Definition	Explanation	Performance Score
1	A) is equal importance with (B) in improvement priority	Two activities contribute equally to the objective	0 - 44
2	(A) is very weak importance with (B) in improvement priority	Experience and judgement very slightly favour one activity over	45 -89
3	(A) is weak importance of (B) in improvement priority	Experience and judgement slightly favour one activity over	90 -134
4	(A) is importance of (B) in improvement priority	Experience and judgement favour one activity over another	135 - 179
5	(A) is essential or strong importance than (B) in improvement priority	Experience and judgement strongly favour one activity over another	180-224
6	(A) is quite strong or demonstrated importance than (B) in improvement priority	An activity is favoured quite strongly over another	225-269
7	(A) is very strong or demonstrated importance than (B) in improvement priority	An activity is favoured very strongly over another; its dominance demonstrated in	270-314
8	(A) is almost absolute importance than (B) in improvement priority	The evidence favouring one activity over another is almost of the highest possible order of affirmation	315-359
9	(A) is absolute importance than (B) in improvement priority	The evidence favouring one activity over another is of the highest possible order of affirmation	360-400

Table 4. Guidance of Transferring Performance Score into The Intensity of Importance

Since the maximum difference of performance score that can be achieved is 400, to be translated into the nine scale *intensity of importance introduced by Saaty (1980), the maximum difference is divided by 9 and the result of this division (400/9 = 44) is used to make the linear range of that performance score as shown in Table 4.*

4. CONCLUSION

The new aspects of the proposed hybrid PMS model as compared to the previous framework are; first, the proposed model is supported by Knowledge Based approach. Second, the benchmarking process and performance standards are provided explicitly for each performance variable based on the GAP analysis. Third, the model is pro-active by providing a list of recommendation for improvement. Fourth, the software provided in the model makes the mechanism of implementation much easier, more accurate, more consistent and provides a recommended list of actions to improve the performance. The details of this hybrid PMS model are covered in the related Paper2.

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