Performance Measurement: The ENAPS Approach

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Abstract

Performance measurement is a prerequisite to performance improvement. For enterprises to improve their performance in today's industrial environment, they must be able to measure how they are performing at present, and be able to measure how they are performing after any changes. Riggs and Felix [1983] claim that "if an improvement can't be proved, it wasn't". In particular, if an organisation wishes to improve one of its processes, then the performance of the process needs to be measured. Performance measures are also important for comparing performance between enterprises. 'Best practice' within an industry is determined by the enterprise with the most desirable levels of the performance measures used. Therefore, it would be advantageous if all similar enterprises were to use a similar set of performance measures. The ENAPS performance measurement system seeks to achieve this goal by producing a generic set of performance measures that enterprises can use to measure and compare their manufacturing practices.

Keywords: *Performance Measurement, Performance Benchmarking.*

1. Introduction

The motivation behind this paper originates from the European Commission funded ESPRIT project, ENAPS (**E**uropean **N**etwork for **A**dvanced **P**erformance **S**tudies). The objectives of this project are to establish and test a permanent European network for advanced business process performance studies in European industry and to develop a generic set of performance measures to be used in this network. The network will allow

enterprises to view performance measurement data from other enterprises all over Europe and to see their relative position on a league table of performance results.

In recent years, many changes have occurred in the way manufacturing enterprises operate. Through the use of advanced manufacturing technology, enterprises have moved from being functionally oriented to being process oriented. Although manufacturing systems have changed, the way in which they are measured has not. Therefore, there is a need for new performance measurement systems that take account of these changes in the manufacturing industry.

This paper reviews traditional performance measurement systems and why they are now invalid in today's manufacturing environment. Following on from this, modern performance measurement systems for World Class Manufacturing (WCM) are discussed and a brief review of two of these performance measurement systems (TOPP and AMBITE) is given. Some important issues and guidelines for developing a performance measurement system are also articulated. Finally, based on these guidelines, a new performance measurement system, ENAPS, is presented.

Some definitions which may be helpful to the reader are as follows:

> A **'Performance Measure'** is a description of something that can be directly measured (e.g. number of reworks per day).
>
> A **'Performance Indicator'** is a description of something that is calculated from performance measures (e.g. percentage reworks per day per direct employee).

'Performance Measurement Data' are values or results for performance measures and indicators (e.g. the number of reworks per day = 36 or the percentage reworks per day per direct employee = 2.4%).

A **'Performance Measurement System'** is a complete set of performance measures and indicators derived in a consistent manner according to a set of rules or guidelines defined in the performance measurement system.

2. Traditional Performance Measurement Systems

Traditional performance measurement systems are frequently based on cost and management accounting. These techniques were developed in the late nineteenth and early twentieth centuries to meet the needs of expanding manufacturing industries. The concepts were fully formalised in the 1930s and since then have been the basis of manufacturing performance measurement systems. In recent years, enormous changes have taken place in technology and production techniques that have made traditional performance measurement systems (management accounting based) no longer useful. These out-of-date techniques are at best irrelevant and at worst positively harmful. There are five main problems with traditional management accounting techniques for performance measurement [Maskell, 1991], namely:

(i) **Lack of relevance:** Management accounting reports are not directly related to the manufacturing strategy, are not meaningful for the control of production and distribution operations and are irrelevant and misleading to pricing decisions.

(ii) **Cost distortion:** Traditional cost accounting is concerned with cost elements. The pattern of cost elements has changed in recent years, and this detailed analysis is less important. Also, the distinction between direct and indirect costs (and variable and fixed costs) is not as rigid as it used to be and, as a result, traditional methods of apportioning overheads can significantly distort product costs.

(iii) **Inflexibility:** Traditional management accounting reports do not vary from plant to plant within an organisation and they do not change over time as business needs change. Therefore, cost accounting reports are usually received too late to be of value and, as a result, are usually viewed with disdain by operations managers because they do not help them with their job and can be used to blame the operations manager when variances are negative.

(iv) **Hindrance to progress in World Class Manufacturing:** Traditional methods of assessing the pay-back on capital projects can impede the introduction of WCM, and can cause managers to do wasteful and unnecessary tasks to make the figures look good. Also, concentrating on machine and labour efficiency rates encourages the production of large batch quantities and cost accounting requires a lot of detailed data that can be costly to obtain.

(v) **Subjection to the needs of financial accounting:** Too often cost accounts are regarded as a subsidiary ledger of financial accounts. To be of value, management accounting systems must be based on different methods and assumptions than on the financial accounts. These methods apply to such issues as inventory valuation, overhead absorption, and accounting periods.

According to Umble & Srikanth [1990] the assumptions that management accounting techniques are based on are invalid, as they are local in scope. These assumptions are listed below together with the reasons why they are considered invalid.

(a) *"The total cost of the system equals the sum of the cost of each operation."* This assumption is invalid for the allocation of overheads.

(b) *The total cost of each operation is proportional to the direct labour for that operation*. Some operations are automated and therefore have no direct labour.

(c) *"The total cost for the system, excluding material cost, is proportional to the sum of the direct labour costs."* Direct labour costs make up only a small proportion of the total cost for many systems.

(d) *"The standard cost procedure, which utilises the calculated overhead/labour ratio, can be reversed to estimate the impact of any action on the total cost of the system."* If the calculated overhead/labour ratio is invalid, then the converse must also be invalid.

(e) *"In manufacturing operations, the effect of optimising local decisions, as measured by their impact on the cost of the operation, is to optimise the total system."* Optimising some local decisions may have a non-optimum effect in other departments.

(f) *"The key to reaching the global optimum is achieving local optima."* Some local optima may be in conflict with other local optima.

Due to these problems of management accounting techniques, performance measurement systems based on these techniques are considered to be invalid for manufacturing industries today.

3. Modern Performance Measurement Systems

Apart from the problems with traditional performance measurement systems, there are other reasons why there is a need for new performance measurement systems in manufacturing industries. These include: customers are requiring higher standards of quality, performance and flexibility and management techniques used in production plants are changing significantly. As enterprises introduce world class manufacturing techniques, they need new methods of performance measurement to control their production plants. Traditional performance measurement systems are invalid for the measurement of world class manufacturing practices as they do not supply the business with the required information to compete in their industry.

As traditional performance measurement systems are based on management accounting they are primarily concerned with cost. But in today's manufacturing environment, cost based measures are no longer the only basis for decision making in enterprises. Enterprises now require performance measures that are based along other competitive dimensions, such as time and quality to aid in decision making. The new performance measurement systems required by world class manufacturing enterprises should have the following characteristics [Maskell, 1991]:

- They are directly related to the manufacturing strategy.
- They primarily use non-financial measures.
- They vary between locations[1].
- They change over time as needs change.
- They are simple and easy to use.

[1] Performance measurement systems need be similar at different locations for comparison purposes.

- They provide fast feedback to operators and managers.
- They are intended to foster improvement rather than simply monitor performance.

Modern performance measures are not newly developed, what is new is the importance placed on them. They have been around for some time, but only recently have world class manufacturers begun to replace their cost based performance measurement systems with ones that truly drive the production process. Since performance measures can also dictate behaviour, it is very important that they are suitable for the processes they are measuring.

When adopting these modern performance measurement systems, the existing systems must be abandoned. If new measures are introduced in addition to existing ones, then they will not have their intended usefulness and impact. They will either be ignored, because people are more familiar with the old measures, or both sets of measures will be used and the enterprise will not gain the coherence and focus that the new measures are intended to offer. The introduction of new performance measurement systems should go hand in hand with the introduction of new manufacturing techniques. For example, before business processes can be re-engineered there must a clear strategy (manufacturing strategy) for the enterprise and suitable performance measures must be in place to measure the impact of the re-engineering process. Strategy and new performance measures are prerequisites to Business Process Re-engineering. A brief description of two modern performance measurement systems (the TOPP system and the AMBITE system) will now follow.

3.1 The TOPP System

One example of a new performance measurement system is the TOPP system which was developed by SINTEF [1992] in Norway in partnership with the Norwegian Institute of

Technology (NTH), the Norwegian Federation of Engineering Industries (TBL) and 56 participating enterprises. TOPP is a questionnaire that is used to determine how an enterprise is performing in all the areas of manufacturing. It is divided into three parts. The first part is used to obtain an overview of the enterprise and is answered by one person. The second part is used to understand how the enterprise operates and might be answered by twenty different individuals. Finally, the third part is concerned with focusing on twenty specific areas within the enterprise that may need improvement, such as marketing, design, technological planning, product development, production planning and control, manufacturing/assembly, financial management, personnel management, information technology and improvement processes.

The TOPP system views performance measurement along three dimensions. These are (i) *Effectiveness* - satisfaction of customer needs, (ii) *Efficiency* - economic and optimal use of enterprise resources and (iii) *Ability to Change* - strategic awareness to handle changes. Answers to each question are qualitative (i.e. on scale from 1 to 7, where 1 is poor and 7 is excellent). Enterprises are requested to answer each question for their status today, and for their expected status in two years from now. They are also requested to rate how important each question is to the enterprise's competitiveness on a three letter scale, where: N = No importance, M = Medium importance and G = Great importance.

The TOPP system is very large and very time consuming to fill out. It is over sixty pages long and there is about fifteen to twenty questions on each page. Each question also requires three ratings (status today, future status and relative importance). Therefore, in total about 3,000 assessments need to be made to fill out one complete questionnaire. The TOPP system is a generic questionnaire and, therefore, the performance measures in the TOPP questionnaire are not directly related to the strategy or customer requirements of

enterprises. Also, the hierarchical relationships between the performance measures are not identified. The TOPP questionnaire is qualitative, based on the views of individuals not on actual measurements and, therefore, answers can be biased. The TOPP questionnaire is very thorough and makes enterprises think about areas of manufacturing they may not have though important before. Anything that the enterprise measures, it will want to improve, especially performance areas that are marked with 'G' (i.e. great importance). Requesting enterprises to assess their current status and their future status is a strong point of the TOPP questionnaire. If enterprises wish to estimate their likely future status to be better than their current status in a particular area, then they must realise that they must introduce an improvement project for that area. Since all enterprises use the same questionnaire, TOPP is suitable for making comparisons between enterprises.

3.2 The AMBITE System

A second example of a modern performance measurement system is the AMBITE (**A**dvanced **M**anufacturing **B**usiness **I**mplementation **T**ool for **E**urope) performance measurement framework [Bradley, 1996]. The objective of this framework is to develop a technique that senior management can use to assess the impact of the strategic decisions made by their enterprise. The framework provides a means of translating the business plan of the enterprise (i.e. critical success factors) into a set of performance measures. The performance measures will be directly related to the strategy of the enterprise and will also be process oriented. The AMBITE framework uses the business model, shown in figure 1, to describe a manufacturing enterprise.

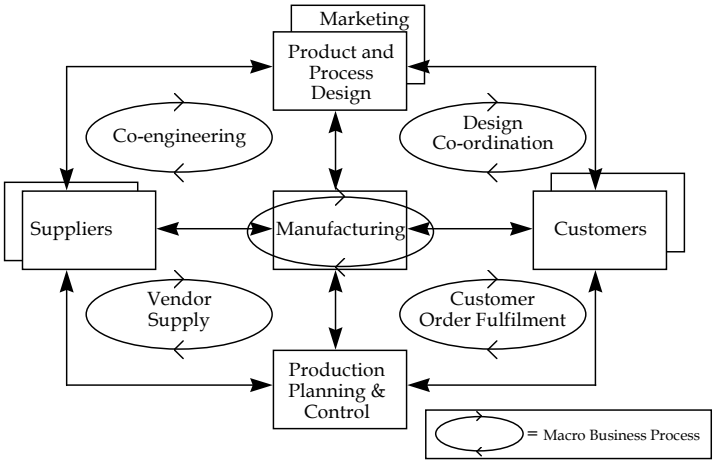

Figure 1: The AMBITE Business Model for Manufacturing Enterprises (Bradley, 1996).

Each of the five macro business processes (customer order fulfilment, vendor supply, design co-ordination, co-engineering and manufacturing) in figure 1 are mapped onto five macro measures of performance (time, cost, quality, flexibility, and the environment). This is done for the Make To Stock (MTS), Assemble To Order (ATO), Make To Order (MTO) and Engineer To Order (ETO) manufacturing environments, a typology described by McMahon and Browne [1993]. This mapping produces the AMBITE performance measurement framework as shown in figure 2.

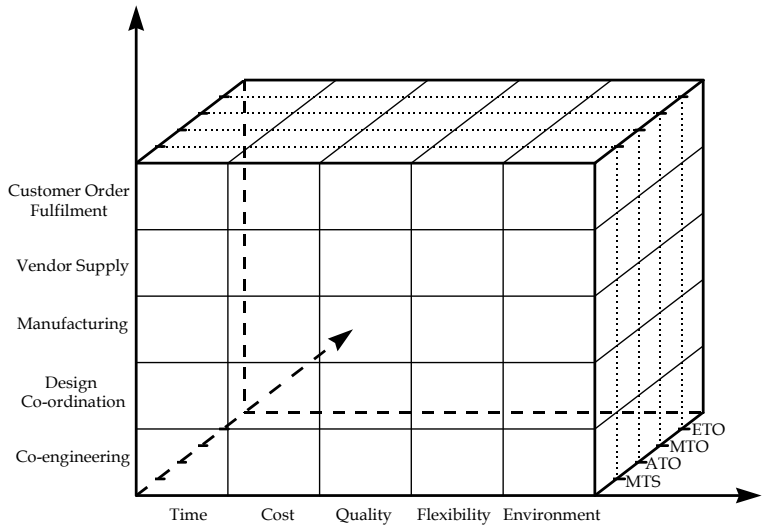

Figure 2: The AMBITE Performance Measurement Framework (Bradley, 1996).

Mapping the five macro business processes to the five macro measures of performance, produces a set of twenty-five strategic performance indicators (SPIs) for each manufacturing typology. The AMBITE method takes a critical success factor (CSF) of an enterprise and maps it on to the AMBITE framework. This produces the strategic performance indicators relevant to the enterprise. These performance indicators can then be broken down into many lower level performance indicators. The precise break down of each performance indicator will be different for every enterprise, thus producing a unique set of customised performance indicators for every enterprise.

The AMBITE performance measurement framework is complete in that, once an enterprise knows its critical success factors (based on its business strategy) it should not be too difficult to develop a consistent set of performance indicators for that enterprise that are directly related to the CSFs. The AMBITE framework produces low level specific performance indicators through the decomposition of high level performance indicators. The hierarchical relationships between the performance indicators are defined by this decomposition. It is a process oriented, generic framework and, therefore, it can be applied to almost any enterprise of any size. The framework produces a customised set of performance indicators for each enterprise that uses the framework. This makes it difficult to make comparisons between enterprises, especially with lower level performance indicators. The high level performance indicators for many enterprises will appear very similar, but they will be made up of very different lower level performance indicators . Therefore, comparisons at the highest level (i.e. 25 SPIs) are valid, but caution should be taken if comparing performance indicators at lower levels.

Apart from the two performance measurement systems (TOPP and AMBITE) described above, there are other performance measurement systems available for use by

manufacturing industries today. Some of these other performance measurement systems are: the EFQM model [EFQM, 1996], the ECOGRAI system [Doumeingts et Al., 1994], the Balanced Scorecard approach [Kaplan & Norton, 1992] and the PMQ [Dixon et al., 1990].

4. Guidelines for Performance Measurement Systems

As well as the guidelines laid out by Maskell [1991] previously, many other authors have views on how performance measurement systems should be developed. Russell [1992] states that the fact that the enterprise is committing time and resources to the development of a new performance measurement system provides motivation and credibility to the exercise. This ensures that: "cherry picking" is avoided; business processes which are important are properly measured; the linkages and conflicts are made visible and managed, not hidden under the table and the performance measures are relatively stable allowing a managed evolution as business needs change.

Dixon et al. [1990] argue that irrespective of the competitive priorities enterprises pursue, successful measurement systems will share five characteristics. These are: (i) mutually supportive and consistent with the business operating goals, objectives, critical success factors and programs, (ii) convey information through as few and as simple a set of measures as possible, (iii) focus on measures that customers can see, (iv) allows all members of the organisation to understand how their decisions and activities affect the entire business and (v) support organisational learning and continuous improvement.

Bradley [1996] claims that while modern performance measurement systems should have the characteristics defined by Dixon et al., some other aspects need to be present in a new

performance measurement system. He argues that a performance measurement system should also meet the following four requirements: (i) a framework, that allows a top down decomposition to successive levels of greater detail, that allows the strategy and/or customer requirements to be translated into a set of critical performance measures and that identifies all the business processes; (ii) a business process focus; (iii) performance measures, that are process oriented, that are quantitative in nature, that are related to a set of high level macro measures and that are related to either the strategy of the enterprise or its customers requirements and (iv) an enterprise strategy and/or customer requirement perspective. Roth et al. [1990] state that performance measures should provide feedback on the gaps between 'best-in-class' and the manufacturing unit's own performance over time and that they should accelerate organisational learning and continuous improvement. Another method of filtering a large set of performance measures is by using the 'Analytic Hierarchy Process' [Saaty, 1980] to identify critical performance measures. Critical performance measures are performance measures that are strongly related to one or more CSFs or customer requirements. This is achieved by using a 'Performance Measurement Table' and a set of 'Quality Function Deployment' symbols to identify the relationships.

All of these authors provide very useful guidelines for developing performance measurement systems, but most of them seem to have neglected one issue which is also important. In today's manufacturing environment, enterprises are working together more and more, so called extended enterprises are forming and dissolving, partnerships and strategic alliances are commonplace. Therefore, a standard set of performance measures and indicators, that could be applied to many different enterprises, would be advantageous. This standard set of performance measures and indicators would also be useful for comparison between enterprises. This type of comparison is know as 'Performance

Benchmarking'. Of course, having a standard set of performance measures and indicators is contradictory to having performance measures and indicators that are customised to the strategy or customer requirements of a particular enterprise. Therefore, both kinds of performance measures and indicators should be accommodated. High level performance measures and indicators should be suitable for both comparison purposes and to support the strategy or customer requirements, while lower level performance measures and indicators would not be suitable for comparison purposes, but would still support the strategy or customer requirements.

4.1 The Different views of Performance Measures

Certain people prefer information about performance measurement presented to them in certain ways. For example, some financial people prefer performance measurement data in terms of monetary units (i.e. costs), such as 'the amount of overhead cost', while other financial people would prefer performance measurement data in terms of ratios and percentages, such as 'overhead cost as a percentage of operating expense, and personnel people may prefer performance measurement data in terms of people (i.e. per employee), such as 'overhead cost per direct employee'. Many different people might have many different views on what to measure and how to express these measures, but it is obvious that we cannot measure everything in every possible way. What these people are looking for are customised performance indicators which are local in scope and may be in conflict with each other. A performance measurement system should measure only a core set of performance measures and a few key performance indicators.

The relationships between the performance measures and indicators in a performance measurement system should be examined and documented. Some performance measures

and indicators may have a direct effect on others. For example, decreasing the time for a particular process could be achieved by spending a lot of money and, therefore, increasing the cost of the process. Very often trade-offs need to be made to maintain performance indicators at acceptable levels according to the strategy or customer requirements of the enterprise. Therefore, when a change is made, all performance measures and indicators should be measured to assess the impact of this change. The change may have improved one performance indicator and decreased performance in another performance indicator. Therefore, what is important to the enterprise as a whole must prevail.

4.2 Necessary Information about Performance Measures

There is certain information that needs to be stored about performance measures which should make them more useful. These items of information are detailed in table 1.

Table 1: Information that should be stored about Performance Measures.

Information	Description	Example
Name	A brief description of what is to measured or calculated.	Distribution lead time
Description	A detailed description of what exactly the performance measure or indicator is supposed to measure, so that it is not left up to the interpretation of the person performing the measurement.	Distribution lead time = average time for distribution of an order from arrival of the order at outgoing stock until delivery to the customer.
Unit	The dimension along which the performance measure or indicator is measured.	Days, months, IR£s, ECUs, percent, km, etc.
Acronym	A code, 2-5 letters long.	DLT = distribution lead time.
Equation	Formula to calculate the performance indicator.	DLT = packaging time + storage

		time + transport time.
Target	A desired performance level, a goal to aspire to.	The DLT target is 5 days.
Position	At what level in the hierarchy of the performance measurement system does the performance measure or indicator belong.	DLT is a process level performance indicator belonging to the 'Order Fulfilment' process.
Where	In which area of the enterprise is the information necessary to produce a result for the performance measure or indicator?	DLT can be obtained from the shipping department.
Responsibility	The position of the person who should perform the measurement.	DLT is to be measured by the shipping manager.

There is also certain information that should be stored with the performance measurement data (the results of performance measures or indicators). This information is listed in table 2.

Table 2: Information that should be stored about Performance Measurement Data.

Information	**Description**	**Example**
Result	For quantitative performance measures or indicators this is a number and for qualitative performance measures or indicator this is a rating, such as good, poor, etc.	The DLT is 14 days.
Reason/Notes	If any unusual events occurred that would affect the result of the performance measure or indicator, they should be documented and kept with the result of the performance measure or indicator.	A truck broke down, which added a day to the average DLT
Time Stamp	The period of time that the performance measure or indicator is for. This can be a duration or a start date and end date.	The average DLT is for one year from 1/1/97 to 31/12/97.

All of the above information would make up a complete result for a performance measure or indicator. A performance measurement system which encourages the recording of all of this information, about performance measures, indicators and their results, is the ENAPS performance measurement system.

5. The ENAPS Performance Measurement System

Based on the other performance measurement systems and the guidelines laid out in this paper a new performance measurement system has been developed. This new performance measurement system is the ENAPS (**E**uropean **N**etwork for **A**dvanced **P**erformance **S**tudies) performance measurement system. Currently involved in the ENAPS project are five research partners (SINTEF, CIMRU, BIBA, GRAI and TUE) and five industrial partners (TBL, AMT, Volkswagen, and AUGRAI and ITC) in Norway, Ireland, Germany, France and The Netherlands respectively. ENAPS is currently under development, but a lot of work has already been carried out in the area of performance measurement. The ENAPS business model is shown in figure 3 and reflects a future view of a manufacturing enterprise as it incorporates the end of life use of products.

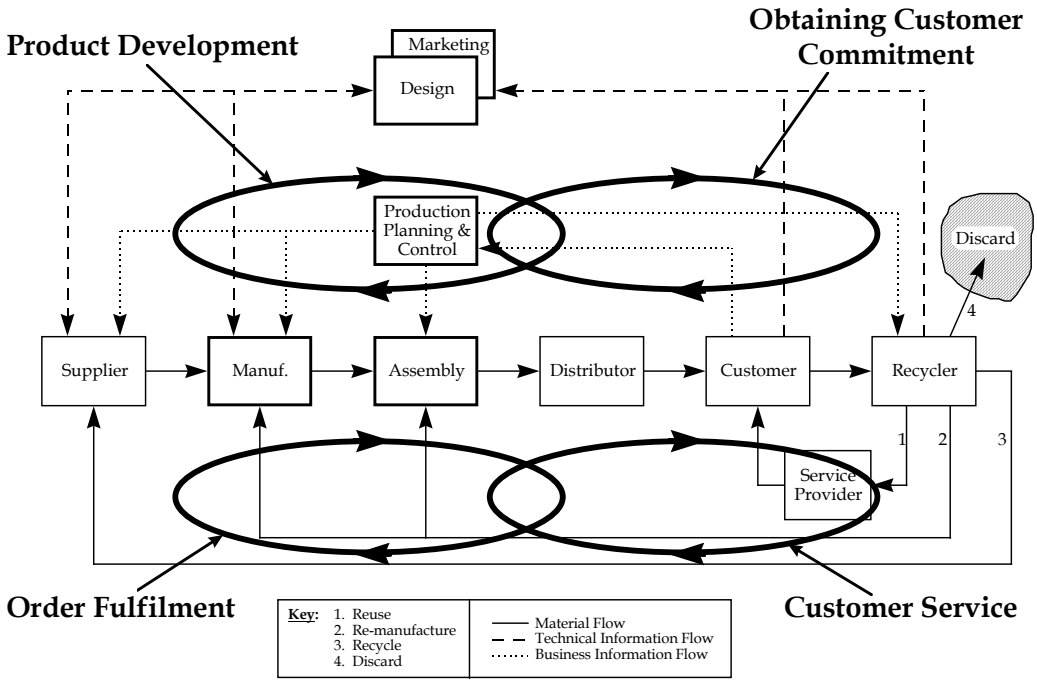

Figure 3: The extended ENAPS Business Model

From this business model, ENAPS has suggested three levels of hierarchy for defining performance indicators. These are: 'Enterprise Level', 'Process Level' and 'Function Level'. The performance measures used in calculating these performance indicators are measured from all over the enterprise under the following eight headings: 'Accounts' (13 measures), 'Product Development' (20 measures), 'Marketing and Sales' (22 measures), 'Planning and Production' (20 measures), 'Customer Service' (8 measures), 'Purchasing' (11 measures), 'Personnel' (16 measures) and 'Other' (7 measures).

Currently, there are 117 performance measures (shown in Appendix A) used in calculating the performance indicators in the ENAPS performance measurement system. All of the 'Enterprise Level' performance indicators should be suitable for every manufacturing enterprise. Nearly all of the 'Process Level' performance indicators should be suitable for nearly all manufacturing enterprises. Finally, most of the 'Function Level' performance indicators should be suitable for most manufacturing enterprises.

The ‘Enterprise Level’ performance indicators are very general indicators. They give an overview of the size and financial position of an enterprise. ENAPS has defined 16 ‘Enterprise Level’ performance indicators. Some examples of ‘Enterprise Level’ performance indicators are: Return on capital employed, Margin, Profit, Operating expense, Sales per employee and Inventory turnover.

The ‘Process Level’ performance indicators are used to determine the performance of the processes that are defined in the ENAPS framework. The ENAPS performance measurement system has identified two types of processes. These two processes are ‘Business Processes’ and ‘Secondary Processes’, and are described below.

‘Business Processes’ are the value adding processes involved in the creation and production of a product and its sale and transfer to a buyer. ENAPS has identified four business processes and these are described below.

(i) **Customer Service:** All activities involved in providing after-sales service, including product take-back.

(ii) **Obtaining Customer Commitment:** All activities involved from market analysis to sales.

(iii) **Order Fulfilment:** From receipt of an order until the customer has received and paid for the product.

(iv) **Product Development:** All activities involved in researching, designing, engineering and releasing products to manufacturing.

‘Secondary Processes’ are the non-value adding processes of an enterprise. ENAPS has identified two groups of secondary processes and these are described below.

(i) **Support Processes:** are processes that support the business and evolution processes and each other, while providing the resources and infrastructure necessary to perform these processes, such as Financial Management and Human Resource Management.

(ii) **Evolution Processes:** provide means for the enterprise to achieve its long-term strategic objectives through managing and planning the evolution of the enterprise and its environment, such as Human Resource Development and Strategic Planning.

Each of the six processes has a certain number of performance indicators assigned to them according to the following list: Customer Service (6 indicators), Obtaining Customer Commitment (13 indicators), Order Fulfilment (26 indicators), Product Development (16 indicators), Support (10 indicators) and Evolution (8 indicators).

Together with the 16 'Enterprise Level' indicators, there are currently 95 performance indicators (shown in Appendix B) in the ENAPS measurement framework. Examples of 'Process Level' performance indicators are: Product development efficiency (Product Development), Product development cost (Product Development), Outgoing delivery quality (Order Fulfilment), Average complaint resolution time (Customer Service), Customer base growth (Obtaining Customer Commitment), Preventative maintenance cost (Support) and Improvement effort (Evolution).

These 'Process Level' performance indicators where developed from 'Function Level' performance indicators that are used to determine the performance of the functions (or sub-processes) that ENAPS has defined. Each of the six processes has a set of functions associated with them. The ENAPS functions, and the processes they belong to, are listed in figure 4, and this breakdown is known as the 'ENAPS Generic Framework'.

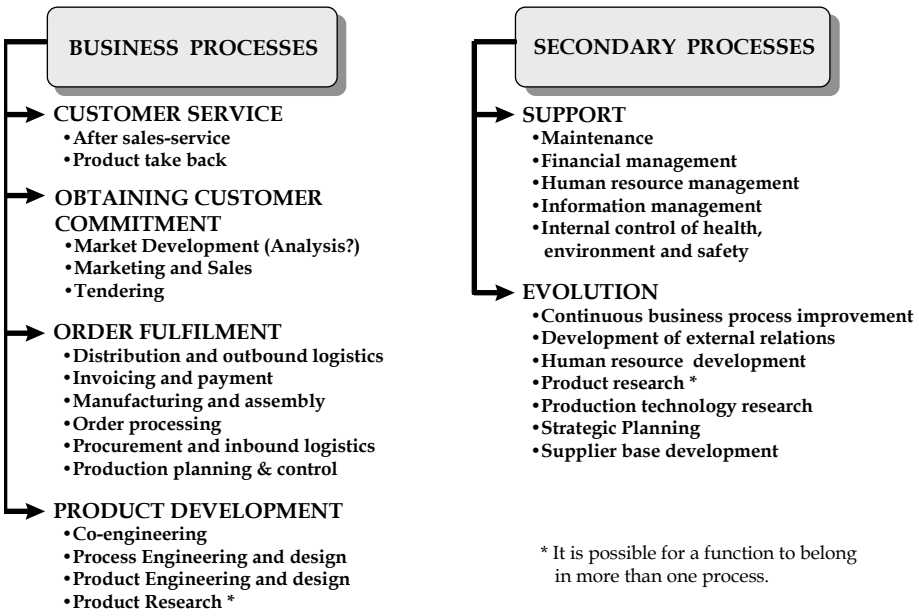

Figure 4: The ENAPS Generic Framework

No 'Function Level' performance indicators are given in the ENAPS performance measurement system, as the generic 'Function Level' indicators were grouped under their process headings and the other 'Function Level' indicators were deemed to be too specific for comparison purposes. The generic performance measures and indicators for each process and function were developed with the following six dimensions of measurement in mind: time, cost, quality, volume, flexibility and environment, but not all of these dimensions are relevant for every process or function. It was also decided that all of the performance measures and indicators would be quantitative (based on objective real data, not subjective ratings) and that the performance indicators would be calculated using only the performance measures defined. The performance indicators need to be quantitative for comparison purposes. When comparing performance indicators, it is wise to compare within the same manufacturing environment and the same industrial sector. Enterprises can also compare performance indicators by the size of their enterprise (e.g. turnover or number of employees) or by their geographical location (e.g. in one country or in a group of countries).

The ENAPS performance measurement system attempts to combine the best ideas from previous performance measurement systems. It has a generic set of performance measures and indicators (like the TOPP system) and uses a process oriented, top-down approach to developing the performance measures and indicators based on a sound business model (like the AMBITE approach). There are a large number of performance measures and indicators in the ENAPS approach, but this is necessary to make it relevant to most enterprises. Enterprises are not expected to use all the performance measures and indicators , but are encouraged to use as many as possible.

The remainder of this paper reviews the ENAPS system against the 'guidelines for performance measurement systems' previously mentioned.

The ENAPS measures and indicators meet the guidelines laid out by Russell [1992] in the previous section, because 'cherry picking' of performance measures is not encouraged and important business processes are measured in the ENAPS system. The ENAPS measures and indicators do not directly state the relationships between them, but all of the performance measures are used in the formulae to calculate the performance indicators. Therefore, each performance measure has at least one performance indicator relating to it and management is discouraged from creating their own measures or indicators to avoid sub-optimisation. The ENAPS measures and indicators are stable over time, but should be reviewed every six months. As Dixon et al. [1990] recommend, the ENAPS indicators convey information through as few and as simple a set of measures as possible. The ENAPS measures and indicators do not directly support the critical success factors of enterprises, but do support organisational learning and continuous improvement. The ENAPS system provides a complete set of measures and indicators, so that members of the enterprise can understand how their decisions and activities affect the entire business.

The ENAPS performance measurement system is based on a sound framework allowing for top down decomposition of measures and indicators, which follows the recommendations of Bradley [1996]. The ENAPS approach is process oriented and the measures and indicators are quantitative and related to high level macro measures of performance of time, cost, quality, etc. The ENAPS measures and indicators are not related to specific enterprise strategies or customer requirements for comparison purposes. Consistent with Roth et al. [1990], the ENAPS indicators promote continuous improvement, as a high score on a particular performance indicators implies an improvement in performance in that area. By using a standard set of indicators, feedback on the gaps between 'best-in-class' and the manufacturing unit's own performance over time can be determined. Using the Analytic Hierarchy Process [Kelly ,1995], an enterprise could check the suitability of the ENAPS measures and indicators to measure critical success factors.

6. Conclusions

In this paper we have argued that traditional performance measurement systems, based on management accounting techniques, fail to meet the needs of world class manufacturing enterprises. There are five main problems with management accounting techniques that render them invalid for use in a performance measurement system. These are: lack of relevance, cost distortion, inflexibility, hindrance to progress in World Class Manufacturing and subjection to the needs of financial accounting. As a result of this, there is a need for new performance measurement systems that can provide enterprises with the information they require to make business decisions in today's manufacturing environment. These new performance measurement systems should have the following characteristics: they are directly related to the manufacturing strategy, they primarily use non-financial measures, they change over time as needs change, they provide fast feedback to operators

and managers and they are intended to foster improvement rather than simply monitor performance. The TOPP performance measurement system is a comprehensive, but lengthy questionnaire, that measures the performance of twenty areas of the enterprise. The AMBITE performance measurement system is a top-down approach to developing performance indicators that are directly related to the strategy or customer requirements of an enterprise. Therefore, this approach is not the most suitable for comparison purposes.

Many authors have provided useful guidelines for developing performance measurement systems which should be taken into account. Different people want different information from performance measures and indicators to serve their own local goals. This practice should be discouraged, as what is important to the enterprise as a whole must prevail. Based on other performance measurement systems and the guidelines laid out in this paper, a new performance measurement system has been developed: the ENAPS performance measurement system. The ENAPS approach has a generic set of performance measures and indicators that were developed using a top-down approach from enterprise level to process level to function level. The ENAPS performance measurement system performs well when assessed against the guidelines previously laid out by a number of authors. The main motivation behind the ENAPS project was to develop performance indicators suitable for comparison between enterprises.

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Appendix A: A List of the ENAPS Performance Measures

Table A: The ENAPS Performance Measures.

	Measure	Value	Unit	Definition
	Accounts:			
1	Sales (Turnover)		ECU	The total amount of money received from customers during the last period.
2	Fixed assets		ECU	The present value of investment goods buildings; book value (or balance-sheet value) machines, cars, etc.; purchasing value.
3	Current assets		ECU	The present value of inventories (material value, added value NOT included), cash and other current assets.
4	Purchased material cost		ECU	The total amount of money paid to suppliers during the last period.
5	Other costs		ECU	Labour/personnel costs, rent, interest, etc. paid during the last period.
6	Equity		ECU	Shareholders Capital (Total Assets - External Capital).
7	Receivables		ECU	The present value of bills to be paid by customers.
8	Current liabilities		ECU	The present value of bills to be paid to suppliers.
9	Opening stock		ECU	Value of stock at the beginning of last period in terms of material costs only.
10	Closing stock		ECU	Value of stock at the end of last period in terms of material costs only.
11	External capital		ECU	Loans, mortgages, etc. Long term and short term.
12	Total liabilities		ECU	Current Liabilities + External Capital.
13	Profit from joint ventures		ECU	The profit made during the last period which can be attributed to joint ventures with other enterprises.
	Product Development:			
1	Number of active products		Number	Total number of active products where an active product is one which is listed in the product sales catalogue or any product which can currently be delivered to a customer. This should not include product variants.
2	Average new product development lead time		Months	The average time from product concept specification document until production ramp up, where "ramp up" means to reach full expected volume production, for new products launched during the last period.
3	Average planned product development lead time		Months	The average planned product development lead time (as defined above) for all new products launched last year.
4	Product engineering and design cost		ECU	The cost of product engineering and design. Includes labour and equipment but not overheads.
5	Product-related process engineering and design cost		ECU	The cost of developing a production process aimed specifically at producing a product. Includes labour and equipment costs but not overheads.
6	Product research cost		ECU	The cost associated with product research including labour and equipment. This includes both basic and applied research cost.
7	Number of new products		Number	Total number of new products that were launched during the last period where a new product is one which involves a major development effort and includes new technology or a new combination of technologies… … A product is considered "new" if it has been developed within the last three years and if it is published in the product catalogue as a new product and not simply a variant of an existing product.
8	Number of new product variants		Number	Total number of product variants or modified product models that were launched during the last period.
9	Number of unsuccessful new products		Number	The number of launched new products which had to be withdrawn earlier than planned. (Number of premature product deaths) that occurred during the last period.
10	Total number of customer complaint-related design changes		Number	The number of design changes for new products in the last period which were directly related to one or several customer complaints.
11	Engineering drawings change cost		ECU	The total cost of labour for all engineering drawing changes made during the last period.

12	Warranty costs for new products		ECU	Total cost of recalling and repairing new products covered by warranty during the last period. This includes labour, materials, transportation and administrative costs.
13	Number of products launched late in the last three years		Number	The number of products which failed to meet the initial scheduled launch date.
14	Number of patents granted in the last period		Number	The number of patents granted for technology or products developed by your enterprise in the last period.
15	Number of patents held		Number	The total number of patents being held by your enterprise at present.
16	Number of co-engineered products		Number	The number of active products which were partially designed by suppliers. This does not include consultants.
17	Number of components recycled		Number	The total number of product components that were recycled in the last period where recycled means re-used in new or second-hand products or recycled for reclamation of base materials.
18	Total number of components produced		Number	The total number of components produced in the last period across all products. This will be used to calculate the ratio of recycled components to components produced.
19	Number of part types with multiple usage		Number	Total number of part types which appear in more than one bill of materials.
20	Total number of part types		Number	The sum of all the part numbers minus the number of products. That is all part types that have potential for multiple usage.

Marketing and Sales:

1	Number of new customers		Number	The number of customers who ordered within the last period but had not ordered within the last three years.
2	Total number of customers		Number	The total number of active customers on the customer list, where an active customer is one that has placed an order within the last three years.
3	The percentage of customers accounting for 80% of sales volume in the last period		%	Sort all customers according to sales and then sum the sales per customer while counting the number of customers. When you reach 80% of total sales note the number of customers accounting for that amount and divide it by the total number of customers.
4	Market share for main product		%	The approximate market share that your main product (the product which results in most sales for your enterprise) held last period, where this market refers to the enterprise's target market which can be domestic, European or global.
5	Marketing cost		ECU	The total cost of all marketing including labour costs, advertising costs external service costs and equipment but not overheads.
6	Sales of products receiving an ecological certificate		ECU	The total value of sales of products which have received your country's "green" label or another ecological certificate. When a European standard becomes available this should be used.
7	Sales to new customers		ECU	The sum of the value of sales to new customers during the last period.
8	Sales resulting from tenders		ECU	The sum of the value of all sales resulting from tenders during the last period.
9	Tender preparation lead time		Weeks	The average tender preparation lead time.
10	Tender value		ECU	The sum of the value of each tender made during the last period.
11	Cost of preparing tenders		ECU	The sum of all costs of preparing tenders during the last period. This includes labour and equipment costs but not overheads.
12	Successful tenders		Number	The number of tenders during the last period which resulted in a customer order.
13	Number of tenders		Number	The number of tenders prepared and submitted during the last period.
14	Lost customers		Number	The number of customers who were expected to order but did not order during the last period.
15	Customer visits		Number	Total number of times that marketing personnel from your enterprise visited a customer site or that customers visited your site during the last period.
16	Number of invoices sent to customers		Number	The total number of invoices sent to customers during the last period where each invoice may contain several line items but is still just one single invoice.
17	Number of on-time customer payments		Number	The total number of customer payments received on or before the promised payment date in the last period where all items on the invoice are fully paid for.
18	Value of cancelled orders		ECU	The summed value of all cancelled orders in the last period where a

				cancelled order is one which appeared in your enterprises order processing system but subsequently had to be deleted before delivery due to customer request.
19	Products sold		Number	Total number of product units sold in the last period where sold implies that payment has been received.
20	Number of customer suggestions		Number	Total number of customer suggestions for product or process improvement.
21	Number of implemented customer suggestions		Number	Total number of implemented customer suggestions for product or process improvement.
22	Sales of new products		ECU	The total value of sales during the last period from new products, i.e. products which have been introduced in the last three years and include new technology or new combination of technologies.

Planning and Production

1	Number of customer orders		Number	The total number of customer orders during the last period where each customer order may contain several line items (requests for individual quantities of different products).
2	Number of on-time outgoing deliveries		Number	The total number of deliveries from your enterprise to a customer during the last period which were delivered on or not more than two days before the date specified by the customer for delivery.
3	Number of incomplete outgoing deliveries		Number	The total number of incomplete deliveries from your enterprise to a customer during the last period which contained too few items or the wrong product. A delivery may be made in two or more batches but still constitutes a single delivery.
4	Number of outgoing deliveries containing defective products		Number	The total number of deliveries from your enterprise to a customer during the last period which contained defective products. A delivery may be made in two or more batches but still constitutes a single delivery.
5	Average order fulfilment lead time		Days	The average time across all products from receipt of an order to delivery of that order to the customer and to installation where appropriate.
6	Average commercial lead time		Days	Average time taken for order processing and production planning. This begins at receipt of an order and ends when the order is released to the shop floor for production.
7	Average production and assembly lead time		Days	Average time for production of an order starting at release of an order to the shop floor until that order has been fully produced and transferred to outgoing stock. This includes waiting times + production time + internal transport.
8	Average distribution lead time		Days	Average time for distribution of an order from arrival of the order at outgoing stock until the delivery (and installation where appropriate) to the customer site. This includes packaging + storage + transport to customer.
9	Commercial costs for order fulfilment		ECU	The cost of order processing and production planning. The costs incurred by all the activities from receipt of an order to release of the order to the shop floor for production.
10	Total production cost		ECU	The cost of production in terms of direct labour costs, equipment and maintenance but not overheads.
11	Inventory costs		ECU	The total of all costs related to the storage of inventory including materials and finished products.
12	Distribution costs		ECU	The cost of distributing finished products including labour and transport costs.
13	Average cost of work in progress		ECU	The value of work in progress (in terms of materials and semi-finished product) at the beginning of the period + the value of work in progress at the end of the period divided by 2.
14	Total production hours		Number	The total number of person-hours during the last period spent on production. This includes production effort and time spent on internal transport.
15	Cost of scrap material		ECU	The total value of the material and components scrapped in the last period where the value is measured in terms of the purchase value of the materials or components.
16	Re-work hours		Number	The total number of person-hours spent re-working products or components in the last period.
17	CO_2 production		$Metre^3$	The volume of CO_2 produced by your enterprise in the last period.
18	Mass environmentally unfriendly material produced		Kilograms	Environmentally-unfriendly material can be classified according to the current country standards (Standard not available yet: When standard

				becomes available this measure may be used).
19	Mass of product produced		Kilograms	The total mass of material in the products and packaging produced by your enterprise.
20	Cost of energy		ECU	The total cost of energy used by production in the last period. This includes the cost of gas, electricity or oil.

Customer Service:

1	Number of products received back due to faults		Number	The total number of product units received back during the last period by your enterprise due to faults in the product. These products may be recalled by your enterprise or returned by a customer.
2	Number of product units taken back for recycling or re-manufacture		Number	The total number of complete product units taken back during the last period by your enterprise for recycling.
3	Cost of product takeback		ECU	Total cost of product takeback during the last period where products are taken back for recycling or re-manufacturing. The costs include labour (including disassembly), equipment and transportation.
4	Product takeback revenue		ECU	Total revenue generated from product takeback during the last period.
5	Income from after-sales service		ECU	The total income generated by after-sales services in the last period. After-sales service is defined as service activities following receipt of payment for the initial sale.
6	Average complaint response time		Days	The average time taken from when a customer complaint is received to when the complaint is acknowledged by your enterprise. To respond within the same day means a value of 1, to respond the next day means a value of 2 etc. The maximum performance is 1.
7	Average complaint resolution time		Days	The average time taken from when a customer makes a complaint to when the problem that the customer is complaining about is fully resolved and the customer is satisfied.
8	Number of customer complaints		Number	Total number of customer complaints during the last period.

Purchasing

1	Number of active suppliers		Number	The total number of suppliers which are currently supplying your enterprise or having supplied your enterprise within the last three years.
2	Certified suppliers		Number	Total number of active suppliers with quality system certification. Acceptable are: ISO-9000, BS 5750.
3	Number of purchase orders		Number	The total number of purchase orders issued during the last period where each purchase order may include several line items but still represents one single purchase order.
4	Number of incoming deliveries		Number	The total number of deliveries to your enterprise by suppliers in the last period.
5	Number of complete incoming deliveries		Number	The number of deliveries that have the exact amount of material as requested on the Purchase Order.
6	Number of incoming deliveries received on time		Number	The number of deliveries that are received on or before the day specified on the Purchase Order.
7	Number of incoming deliveries containing defective parts		Number	The total number of deliveries from suppliers which contained defective material or parts.
8	Average material procurement lead time		Days	This starts from the determination of material requirements until the material is on the shop floor in the location required to be ready for production. Includes material planning and procurement + transportation + receipt check and store + picking.
9	Purchase value of parts rejected at incoming inspection		ECU	The sum of the value of all parts (material or components) rejected at incoming inspection.
10	Number of suppliers visited		Number	The number of suppliers to whom employees of your enterprise visited during last period.
11	Number of on-time payments to suppliers		Number	The total number of payments to suppliers which were received by the supplier on or before the promised date.

Personnel

1	Average number of employees		Number	Average number of full-time equivalent employees, regardless of the contract over the last period.
2	Total wages		ECU	The total cost of wages, salaries and benefits (pensions, insurance etc.) for all employees in the last period.
3	Number of person-days lost due to absenteeism		Number	The total number of person-days lost during the last period due to absenteeism.
4	Maximum person-days available		Number	The maximum possible number of person-days available during the last period (excluding overtime). Total average number of employees multiplied by the number of person-days per employee.
5	Number of departed employees		Number	The total number of employees who left the enterprise for any reason other than retirement during the last period.
6	Number of new employees		Number	The total number of new employees who joined the enterprise during the last period.
7	Overtime cost		ECU	The total labour cost of overtime for the enterprise during the last period.
8	Average number of employees involved in product research and development		Number	The average number of employees directly involved in product development projects within your enterprise during the last period.
9	Average number employees involved in marketing		Number	The average number of employees directly involved in marketing and obtaining customer commitment within your enterprise over the last period.
10	Average number of employees involved in project teams		Number	The average number of employees who at some time during last period were involved in an improvement project.
11	Training and educational cost		ECU	The total number of ECU's spent on training during the last period. Includes internal and external training and education.
12	Average total working days for an employee		Days	The average total working days for an employee during the last period.
13	Average time spent on training for each employee		Days	The average number of days during the period for which an employee undergoes training.
14	Cost of incentive schemes		ECU	The total cost of all incentive schemes during the last period.
15	Person-hours spent at management team meetings		Hours	The total number of person-hours spent at management team meetings during the last period.
16	Management team person-hours spent on strategy		Hours	The total number of person-hours spent on the development of enterprise strategy during the last period.

Others

1	System downtime		Hours	The total percentage of time for which the main computer system in the enterprise (network server or management information system server etc.) was unavailable in the last period.
2	Number of injuries		Number	The total number of work-related injuries in the last period.
3	Cost of preventative maintenance		ECU	The total cost of preventative maintenance of machines, computers, etc. in the last period.
4	Number of employee suggestions		Number	The total number of written employee suggestions received during last period. These suggestions may relate to process improvements, product improvements or any other improvements within the enterprise and may come from any personnel.
5	Machine downtime		Hours	The sum of all hours of downtime on critical machines during the last period where a critical machine is one which is essential to maintain full production.
6	Maximum available machine hours		Hours	The sum of the maximum possible available production machine hours during the last period. This should be calculated as the total number of hours during which the entire production facility is "open".
7	Cost of improvement projects		ECU	The total cost of investment in improvement projects and associated activities during the last period. This includes labour, services (consultancy, training etc.), equipment and software for projects aimed at improving the performance of any process.

Appendix B: A List of the ENAPS Performance Indicators

Table B: The ENAPS Performance Indicators.

Enterprise Level

	Performance Indicator	Value	Units	Formula
1	Return on capital employed		%	Capital Turnover*Margin
2	Return on equity		%	Profit/Equity
3	Capital turnover		%	Sales/Total assets
4	Margin		%	Profit/Sales
5	Profit		ECU	Sales - Operating expense
6	Operating expense		ECU	Purchased materials cost + Other costs
7	Quick ratio		%	(Current assets + Receivables)/Current liabilities
8	Cash ratio		%	Current assets/Current liabilities
9	Payment capacity		ECU	Current assets - Current liabilities
10	Sales outstanding		%	(Receivables * 360)/Sales
11	Sales per employee		%	Sales/Number of employees
12	Value-added per employee		%	(Sales-Purchased material cost)/Number of employees
13	Inventory turnover		Days	Average value of stock*360/Purchased material cost
14	Debt ratio		%	External Capital/Total liabilities
15	Customer satisfaction		Ratio	Number of customer complaints/Total number of orders
16	Value of joint ventures		%	Profit made from joint ventures/Sales

Product Development

1	Average product development lead time		Weeks	The average time from product concept specification document until production ramp up, where "ramp up" means to reach full expected volume production, for new products launched during the last period.
2	Product launch target adherence		%	Number of products launched late in the last three years/Total number of new products launched in the last three years
3	Product development efficiency		Ratio	Average planned product development lead time/Average product development lead time
4	Product development cost		%	(Total product engineering and design cost + total product research cost + total product-related process engineering cost)/Sales
5	Engineering change costs		%	Cost of engineering drawing changes/Sales
6	Warranty costs of new products		%	Warranty costs of new products/Sales of new products
7	Product development reliability		%	Total number of customer complaint-related design changes/Total number of active products
8	Contribution of new products		%	Sales of New Products/Sales
9	New product introduction performance		%	Number of unsuccessful new products/Total number of new products
10	Proportion of new products		%	Number of new products developed last period/Total number of active products
11	Extent of co-engineering		%	Number of co-engineered products/Total number of new products developed
12	Patenting performance		%	Number of patents awarded last period/Total number of patents held
13	Modularity of products		%	Number of components with multiple usage/Total number of components
14	Proportion of people in product development		%	Number of people involved in product development/Total workforce
15	Product variance		%	Number of product variants/Number of active products
16	Components recycled		%	Number of produced components recycled last period/Total number of components produced last period

Obtaining Customer Commitment

1	Tender preparation lead time		Weeks	as is
2	New customer return		%	Sales to new customers/Sales
3	Tender return		%	Total cost of preparing tenders/Total sales resulting from tenders
4	Marketing cost ratio		%	The marketing cost/Sales
5	Customer base growth		%	Number of new customers/total number of customers
6	Lost customers		Ratio	Number of lost customers/Total customers
7	Market share for main product		%	as is
8	Tender efficiency		%	Total tenders value/Sales
9	Tendering hit ratio		%	Number of successful tenders/Total number of tenders
10	Customer visits		%	Number of customer visits/Number of customers
11	Value added per marketing employee		%	(Sales - Purchased material)/Number of marketing employees
12	Customer dependency		%	The percentage of customers accounting for 80% of sales volume last period.
13	Green product sales ratio		%	Sales of products receiving country's green label/sales

Customer Service:

1	Average complaint response time		Days	as is
2	Product takeback profit		%	Product takeback revenue - Product takeback cost/Sales
3	After-sales service profit		%	Income from after-sales service/Sales
4	Average complaint resolution time		Days	as is
5	Returned products ratio		%	Number of products returned because of faults/Total number of product units sold
6	Product takeback ratio		%	Number of Product units taken back/Number of product units sold

Order Fulfilment:

1	Commercial lead time ratio		%	Commercial lead lime/Order fulfilment lead time
2	Material procurement lead time ratio		%	Average material procurement lead time/Order fulfilment lead time
3	Production and assembly lead time ratio		%	Production and assembly lead time/Order fulfilment lead time
4	Distribution lead time ratio		%	Distribution lead time/Order fulfilment lead time
5	Commercial cost ratio		%	Commercial costs/Sales
6	Inventory cost ratio		%	Inventory costs/Sales
7	Distribution cost ratio		%	Distribution cost/Sales
8	Materials cost ratio		%	Purchased material costs/Sales
9	Production cost ratio		%	Production cost/Sales
10	Average order value		ECU	Sales/ Total number of customer orders
11	Work in progress		%	Cost of work in progress/(Purchased material cost + Total Production cost)
12	Value of cancelled orders		%	Value of cancelled orders/Sales
13	Outgoing delivery quality		%	Number of customer deliveries containing defective parts/Total number of customer orders
14	Outgoing delivery completeness		%	Number of complete customer orders/Total number of customer orders delivered
15	Outgoing delivery timeliness		%	Number of customer orders delivered on time/Total number of customer orders
16	Incoming delivery quality		%	Number of incoming deliveries containing defective parts/ total number of incoming deliveries
17	Incoming delivery completeness		%	Number of complete incoming deliveries/Total number of incoming deliveries
18	Incoming delivery timeliness		%	Number of incoming deliveries received on time/Total number of incoming deliveries

19	Supplier payment timelines		%	Number of on-time payments to suppliers/Total number of purchase orders
20	Customer payment timeliness		%	Number of on-time customer payments/Total number of invoices
21	Incoming rejection cost		%	Components rejected at incoming inspection/Purchased material costs
22	Percentage re-work		%	Re-work hours/Total production hours
23	Percentage scrap		%	Cost of scrap material/Purchased material cost
24	Energy cost		%	Cost of energy/Sales
25	Production process environmental-friendliness		%	Mass of environmentally-unfriendly material produced/total mass of product produced
26	CO_2 volume		M^3/ECU	Number of cubic metres of oil * CO2 ratio/Sales

Support Processes

1	Overtime cost		%	Cost of overtime/ Total wages
2	Preventative maintenance cost		%	Cost of preventative maintenance/Sales
3	System downtime		%	Number of hours the main computer system was unavailable/Total available hours
4	Employee absenteeism		%	Number of man days lost due to absenteeism/Maximum man days available
5	Employee turnover		%	Number of employees that left the enterprise/Average number of employees
6	Machine downtime		%	Sum of all machine hours of downtime/Maximum number of machine hours
7	Training investment		%	Training and educational cost/Sales
8	Time spent on training		%	Average time spent on training for each employee/Average total working time
9	Employee participation		%	Number of employee suggestions/Average number of employees
10	Health and safety		%	Number of injuries/Average number of employees

Evolution

1	Improvement effort		%	Cost of all improvement projects/Sales
2	Incentive scheme investment		%	Cost of incentive schemes/Sales
3	Employee improvement efforts		%	Number employees involved in an improvement project team/Average number of employees
4	Total person-hours spent at management team meetings		Hours	as is
5	Total management team person-hours spent on strategy		Hours	as is
6	Customer participation in developments		%	Number of implemented customer suggestions/Number of customer suggestions
7	Certified suppliers		%	Number of ISO9000-certified suppliers/Number of suppliers
8	Suppliers contact		%	Number of suppliers visited/Number of suppliers