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Diplomarbeit

Modelling of a systematic for the determination and categorisation of critical Performance Measures in manufacturing companies

A Hybrid Model

ausgeführt zum Zwecke der Erlangung des akademischen Grades eines

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unter der Leitung von

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Wien, im Oktober 2014

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Wien, im Oktober 2014

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Stefano Rossetti

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Abstract

As suggested by the title, the aim of this work is to establish an effective and flexible methodology for the determination of performance measures in manufacturing companies.

The focus of this work resides in particular in the determination of Performance Measures of low hierarchical levels, strictly connected with the shop floor and which have to answer to executive, operational and at maximum tactical needs.

The objective is also trying to avoid direct strategic influences: in fact our aim is to develop performance measures for the production level (or shop floor) using a brand new bottom-up systematic, which can allow us to integrate the measures design at the lower level, with a strategy-based framework.

This approach in the process of measures design is quite new and it has found few previews attempts. Therefore this work can be considered a newness in this field and it can be considered a starting point for a new focus in the performance measurements research.

However, as the following pages will show, in order to develop an effective performance measurement system, coherent with the overall objectives (mission and vision) of the company, the strategy, even in small part, has to be considered even at the lower levels.

The results of this work will show that, instead of avoiding the strategy influence at executive and operational levels, an effective systematic for performance design at these hierarchical levels should try to integrate the “instructions” coming from the management, with the “needs” coming from the shop floor.

The most difficult part is therefore trying to keep an effective equilibrium between these two dimensions with the aim of producing an efficient, flexible and reliable Performance Measurement System (PMS). A PMS that nowadays is no more just a control tool (see chapter 2.3), but it is a fundamental part of the company management.

It is therefore important to remark that this work is to be seen as the basis for the developing of a system for decision-making support.

Contents

1 Introduction

In the last twenty years of the past century, most of the manufacturing companies in the western countries have experienced a big evolution of the needs of their businesses and therefore of their management style.

In particular, in order to compete in a global market with companies able to produce cheaper and higher quality goods, they had to change radically their management approach and organization.

In this framework, a big step ahead has been made with the introduction of “holistic” performance measurement systems, in which the financial perspective (DuPont scheme) has been flanked by other ones. The customers’ opinion, the quality, the time and the continuous progress of the company have become necessary dimensions to be analysed.

The introduction of modern systems like the Balanced Scorecard[1] by Kaplan and Norton or the Key performance Indicators (KPI) system has been an incredible breakthrough and, since that moment, a constant evolution has characterized the performance measurement field, transforming these schemes from simple “controlling” into holistic management systems.

Because of this, the strategy and how to develop measures from the strategy has been the main focus of the academic research in this field, developing many “top-down” systematics in which the measures were the clear consequence of the corporate goals of the company itself.

Less attention has been put on the needs coming from the shop floor and how these can be implemented in a coherent PMS.

This work tries to fill this hole putting in first position the needs of the shop floor more than the requests of the strategy; because of this, beside the established top-down models, of which the specific literature is full, a bottom up approach will be proposed, in order to make the measures *emerge* from the shop-floor, channelling them into the strategic guidelines.

In other words, this work will propose a *hybrid* systematic for the developing of operational performance measures, which will constitute the foundation for a decision support system. As already said in the lines before, this hybrid systematic will try to develop and combine the common top-down approach for measures design, with a brand new bottom-up one.

[1] cf. Kaplan, R. and Norton, D., 1992

Before getting into details of the proposed model, a theoretical background about Performance Measure, Performance Measurement Systems and designing approach will be given.

In brief, the structure of this thesis will be the following: at first a global overview of the state of the art of the performance measurement systems will be given (chapter 2); here all the theoretical basis for the work will be explained and the different models will be compared. In the following chapter (chapter 3) a conceptual model, main object of this work, will be presented in all its parts. In the end of this chapter, before drawing the conclusions, a brief section is dedicated to the possible “useful tools” (analytical and methodological), which can be used in order to facilitate the process of measures design. They will be deeply treated in the appendix (chapter 5), just after the conclusions (chapter 4), which will draw the results of this research, its strengths but also some remarks. Moreover some suggestions for future investigation in this field will be introduced.

2 Theoretical Basis

In this first section of the work it will be given a first overview of the most important theoretical background needed for the comprehension of the conceptual model.

After the first section dedicated to the methodological approach, the following two sections (see chapters: 2.2 and 2.3) will treat the following topics:

- What the performance measures are
- What a performance measurement system is and its importance for managing a company.

Afterwards, two main performance systems will be deeper analysed, because in strict connection with the aim of this work, that is (it is important to remember): finding a reliable and effective systematic (or methodology) for operational measures design in manufacturing companies.

At last an insight about Top-Down and Bottom-Up approaches will be given.

2.1 Methodological Approach

Before getting into details of which are the theoretical foundations of this work, it is important to dedicate a brief section about how the research activity has been conducted and also how its results have been used to build the necessary ideas for the conceptual model (see chapter: 3), core of this work.

This work is mostly theoretical and it finds its basis in the theory proposed by the nowadays knowledge on the topic (performance measures). Because of this, in order to gain the knowledge needed for the proposition of the systematic (see chapter: 3) a lot of time has been spent in the activity of literature research and analysis.

The literature research activity has followed a rigorous method:

1. At first the main areas of interest have been identified. These areas are:
    - Performance Measures
    - Performance Measurement Systems
    - Designing Approaches
2. For each one of these areas, a separate literature research has been conducted, in order to gain a general overview of the main topics.
3. Recursively the research has been refined and deepened: some documents have been kept, while others have been discarded. In particular some main authors (e.g. Kaplan and Norton, Neely, etc.) have been

identified as the most influencing ones and they have become extremely important in setting the agenda of this work. In this procedure the work of Marr and Schiuma has been extremely useful. [2]

4. The research has progressed following the directions given by the papers that were found to be the most interesting and pertinent. In order to do this, for each of the chosen works, the literature have been analysed and new material has been collected. This process continued until the each literature background have been analysed and any further research resulted in already seen or read works.

5. After the research terminated in each of the three directions, another phase began: the attention moved towards the cross sections of the already quoted areas. These cross sections are:

    - Performance Measures – Performance Measurement Systems
    - Performance Measures – Designing Approaches
    - Performance Measurement Systems - Designing Approaches

6. For each one of these cross sections the process described at points 3 and 4 has been repeated. The overall research activity terminated when each one of these cross sections has been deeply investigated.

7. At last it has to be said, that after the previous point the main research activity has terminated, but on the other side a continuous process of literature study and refinement has been carried on.

After explaining how the literature has been investigated we would like to inform the reader of which have been the sources for the literature research; of course the main source of information of our time has been used: the internet. This has been the main way of accessing to the knowledge for this work; anyway it has been exploited in two different ways:

- Free research in the Internet exploiting research engines: this is the easiest approach, but also the most dangerous one. That is why the source of the materials found in this way have been analysed more deeply and the author made himself sure of the reliability of the source
- Way of access to the on-line portals of the libraries of different well-known institutions: especially the on-line resources of the Politecnico di Milano and of the Technische Universität Wien. This has been the main source and access to the information that will be treated later on.

[2] cf. Marr, B., 2003, pp. 680ff

Besides the use of the Internet, also a personal research in the “physical” library of the previously mentioned universities and of other institutions has been conducted.

At last it is important to say how this literature has been used and how it contributed to develop in the author the knowledge and the ideas contained in this work.

Each work has been read few times and analysed in details, by the most of them useful examples and ideas have been extracted, in order to develop a coherent systematic (or methodology) for the measures design.

The methods by which this has been done are the typical of the scientific (logical) reasoning:

- Deduction
- Induction (and Abduction)

Explaining briefly what they mean, we can say that:

- Through the process of Deduction, the specific knowledge has been obtained from general theoretical statements or axioms. This means that traits of general theories on this specific topic have been translated on the particular case of operational measures design.
- Through the process of Induction, instead, some general knowledge has been obtained looking and comparing some specific examples (observations). A particular type of induction is the Abduction, which instead of looking at the general knowledge behind some experience, tries to give the most plausible reason behind an effect. The problem of the Abduction (and the Induction in general) is that potentially there could be countless causes of the investigated effect: that is why sometimes it can be erratic; on the other side the bigger is the number of observation by which an induction is made, the surer we are the induction (or abduction) is right.

2.2 Performance Measures

What are performance measures and why are they important for nowadays companies?

To answer to the first part of this question, a good help comes from Andy Neely:

> "*A performance measure can be defined as a metric used to quantify the efficiency and/or effectiveness of an action.*"[3]

It is therefore clear, that speaking of performance measures is like speaking of numbers. The quantification of performances is essential for companies because, as Lord Kelvin (1824-1907) used to say:

> *"When you can measure what you are speaking about and express it in numbers, you know something about it…"*[4]

Now the answer to the previous question should be clear: the performance measures are quantifications of the actions and the results of a company; thanks to this "quantification", analyses of the current performances are possible and therefore it is possible to increase them and effectively lead the company.

This notion is something known since a long time and the first attempts of performance measuring have been made in the first decades of the past century.[5]

Since the nature of measures is strictly connected with numbers, they developed in the first place in the department of the company where the "numbers" (or performances) were already recorded: the financial department.[6]

At first these measures were enough for the companies management, but then, as it has been already anticipated, the management system has evolved and therefore also the measures.

Nowadays there are many kinds of measures with many other different aims: there can be financial as well as customer satisfaction measures, productivity measures, but also learning and improvement measures; moreover they can be divided and categorised according to many different criteria: lead and lag, individual and collective, or, moreover, according to their aims or reference departments.[7]

Many authors have attempted to define which are the characteristics of performance measures and Neely has clearly summarised them in one of his paper: he used them to develop an useful framework for the categorisation and organisation of

[3] Neely, A, 2005, pp. 1229
[4] Kelvin, W.T.,1883
[5] cf. Neely, A., 2005, pp. 1228-1243
[6] cf. Sprotte, A., 2009, pp. 39-41; cf. Neely, A., 2000, pp. 1121-1124
[7] cf. Neely, A., 2005, pp. 1228-1243

performance measures. This will be mentioned also in the following chapter (see chapter: 3.3) about the tools applicable together with the proposed systematic and deeply treated in the appendix (see chapter 5). [8]

The most important characteristics of the performance measures, which should be kept in mind for this work are[9]:

- Simple to understand
- Relate to specific but achievable goals
- Clearly defined
- Be part of a closed management loop
- Based on an explicit formula
- Precise and objective

The fact that the measures should be simple and clear is a principle that has never to be forget: measures are important and even fundamental (even though not everything worth to be measured), but the effort for the measurement should not be bigger than the advantages derived by the acquired knowledge. The measures should give straightforward information and they should not mislead or be misinterpreted.

Every measure has to be accompanied by a “specific and achievable” goal, because, without this reference value (or aim), it is impossible to make any evaluation of the performance itself. Every measure and the related goal are elements of a feedback loop: a Deming circle (or PDCA: Plan Do Check Act) is essential in any performance measurement system, because it foster the continuous improvement process.[10]

The importance of the Deming circle has been ratified by the international community through its introduction into the European and International Norms about the Quality management.[11]

Moreover every measure should be based on an explicit formula (together with its metric) in order to guarantee its objectiveness and precision.

Other important aspects connected to measures are:

- The responsible parties
- The frequency[12]

[8] cf. Neely, A., 1997, pp. 1135-1136
[9] cf. Neely, A., 1997, pp. 1135-1136
[10] cf. Neely, A., 1997, pp. 1137-1138
[11] cf. DIN EN ISO 9001, 2008, pp.7
[12] cf. Neely, A., 1997, pp. 1139-1140

Regarding the first aspect, the responsible for every measure should be identified; the responsibility towards the measures can be split into two parts: the responsible for data collecting and, likely, reports compilation and a responsible for the analysis of the previous report and the consequent actions (decision making).

Nowadays the first responsibility can be easily delegated to the information systems, while the analysis and the action phase is still in charge to humans.

The second aspect (the frequency) is strictly connected with the previously quoted trade off between costs of measurement and the benefits connected with the information collection.

Even if nowadays manufacturing companies are more and more automatized and more and more "on-line" or "connected" thanks to the usage of information systems like the Manufacturing Execution System (MES), it should be kept in mind that each piece of information has a cost, each data has a cost.[13] Because of this, if the amount of collected data is too big, the costs can overcome the benefits and make the measuring action not just useless, but even harmful.

The frequency can be intended as frequency of data collection but also as frequency of data reporting: both these two aspects do not have to be underestimated. As already said each data has a cost, the more data we want, the more cost we have from the point of view of performance requested to the information system. As already pointed out, modern technologies have brought this cost towards zero, but still it is important to keep in mind that the number of information cannot be increased towards infinity. [14]

More important is the aspect of the reporting frequency: having every piece of information second by second with its connected report do not necessarily improve the knowledge of the company performance; on the contrary it can have really bad influence on the management, that would be overwhelmed by data.

Every measure has its optimal frequency of collection, especially of reporting; in the process of measures design this aspect has to be clearly defined.[15]

The last important aspect connected with measures is their number: this is for sure something that has to be deeper developed in the section about the PMSs, but it is better to make it clear from now: the number of measures should be constrained as much as possible in order to reduce the costs of measuring, but in particular to avoid

[13] cf. VDMA 66412-1, October 2009
[14] cf. http://www.qad.com/Public/Collateral/Freedom%20MES%20White%20Paper.pdf (visited on 02/10/2104)
[15] cf. Neely, A., 1997, pp. 1135-1140

the risk of reporting too many measures that can show contradictory results and therefore mislead the actions of the management.[16]

The performance measures should be constrained to the essential ones.

2.3 Performance Measurement System (PMS)

In the previous section the main characteristics and aspects of the performance measures have been drawn, now it is important to understand how they relate to one another in order to give shape to a coherent system.

Using again a definition by Neely:

> *"A performance measurement system can be defined as a set of metrics used to quantify both the efficiency and effectiveness of actions."*[17]

This definition is clear and straightforward, but it leaves great freedom to interpretation of what should be measured in order to assess efficiency and effectiveness.

Which are the right measures to asses the efficiency and effectiveness of a company is the central point of measures design and it has changed a lot through the years of evolution of the PMSs; this will be better explained in the following section about the history of PMSs.[18]

First of all it is important to focus on the general aspects of modern PMSs.

Nowadays the PMSs are more than a simple collection of measures with the scope of reporting the performances of the companies. They are not just instrument of control, but they have become complete management systems. [19]

In fact these systems have now the purpose to implement the strategy throughout the organisation: choosing which measure has to be taken into account, setting the goals, etc. are methods to translate into numbers a strategy conceived in words. [20]

Reaching a goal is not just accomplishing a duty (for the employee) or a symptom of good health of the department (for the management), it is much more: it is realizing part of a bigger strategy designed to give competitiveness (and hopefully success) to the company.

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[16] cf. Wouters, M., 2008, pp. 65-68 and Lohman, C., 2002, pp. 279
[17] Neely, A., 2005, pp. 1229 (quoted from: Neely, 1994)
[18] cf. Sprotte, A., 2009, pp. 39-52; cf. Neely A., 2000, pp. 1121-1124
[19] cf. Sprotte, A., 2009, pp. 46-52; cf. Neely A., 2000, pp. 1121-1130
[20] cf. Kaplan, R. and Norton, D., 1993, pp. 134

Therefore the analysis of the performances has become a central point of each management meeting: this means that the system have to be conceived in order to give the essential information to the right person, at the right time, in a straightforward way.

In this field there are many aspects to face: from the visualisation methodology to the number of measures themselves, passing by goals, calculation methodology and data sources. [21]

This last aspect is fundamental in the conception of a PMS: the management has to face few essential and meaningful measures in order to not be overwhelmed by too many data (sometime contradictory). This suggest that the top management measures should be highly concise, but at the same time it should be allowed to reach as many aspects of the company as possible. [22]

A hierarchical structure through which it is possible to break down the synthetic measures into more specific parameters is, therefore, common of each PMS. The needs of some modern systems require overcoming some hierarchical steps, but the main structure remains. [23]

This structure normally shows a pyramidal shape: at the top there are few measure which express synthetically the performance of the company; going down towards the bottom, these measures are broken down into their components. [24]

Besides these, there are measures proper of each hierarchical level: every level has in fact different purposes and horizons: if at the top there are the strategic measures, at the bottom there are the operational/executive ones.

This means that at each level there will be a mixture of measures derived from the level above and some proper of that very level.

This leads to a big challenge for the PMS designers: creating a PMS, which contains all the measures needed at each level, avoiding repetition or redundancy and which guarantee effectiveness and coherence among its parts. [25]

[21] cf. Lohman, C., 2002, pp. 272-280
[22] cf. Lohman, C., 2002, pp. 272-280
[23] cf. Kaplan, R. and Norton, D., 1993; cf. Kaplan, R. and Norton, D., 1996
[24] cf. Lohman, C, 2002, pp. 279
[25] cf. Lohman, C, 2002; cf. Wouters, M., 2008; cf. Neely, A., 2000

2.3.1 Brief History Review of the PMS Evolution

The need of measuring the performance of a company is a need that was present since the beginning of the past century; what really changes in these hundred years is mostly the objective of the measuring activity.

The first example of a PMS, in fact, was a system oriented just on the financial perspective: it was the department in which collecting the data was straightforward and it was also enough to manage a company properly. In fact the global competition was low and the world was still proceeding at "low speed"; there was enough time to wait the financial results and take the correspondent actions. [26]

This system, firstly introduced ca. in the 1920s, is still used and it was the only performance measurement system for a long time. It has been developed by the DuPont Corporation (from this its name: DuPont Scheme) and for the first time it presented a hierarchical structure that shows clearly all the financial components, which contributes to build the measure of the Return on Investment (ROI).

The ROI is a financial performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments; it can be defined according to the following formula[27]:

$$ROI = \frac{\text{Net Profit [€]}}{\text{Cost of Investment [€]}}$$

Formula 1: Return on Interest (ROI)

in which the net profit is defined as:

$$\text{Net Profit} = \text{Gain of Investment [€]} - \text{Cost of Investment [€]}$$

Formula 2: Net Profit

From Figure 1 it is possible to point out the strict hierarchy of the system: the ROI has been broken down in all its components and also the mathematical operations among the different parts were underlined.

The company was lead looking at the result of the ROI, which was just a mere result of the outcomes of its different components.

Its power resides in the great possible synthesis: just looking at the ROI it was possible to manage a company. This is the big innovation brought by this model and, even nowadays, all the modern system seeks for establishing a sort of hierarchy,

[26] cf. Neely, A., 2000, pp. 1124
[27] cf. http://www.investopedia.com/terms/r/returnoninvestment.asp (read on: 23.09.2014)

which allows building synthetic measures, which can be used to control a company in a simpler way. [28]

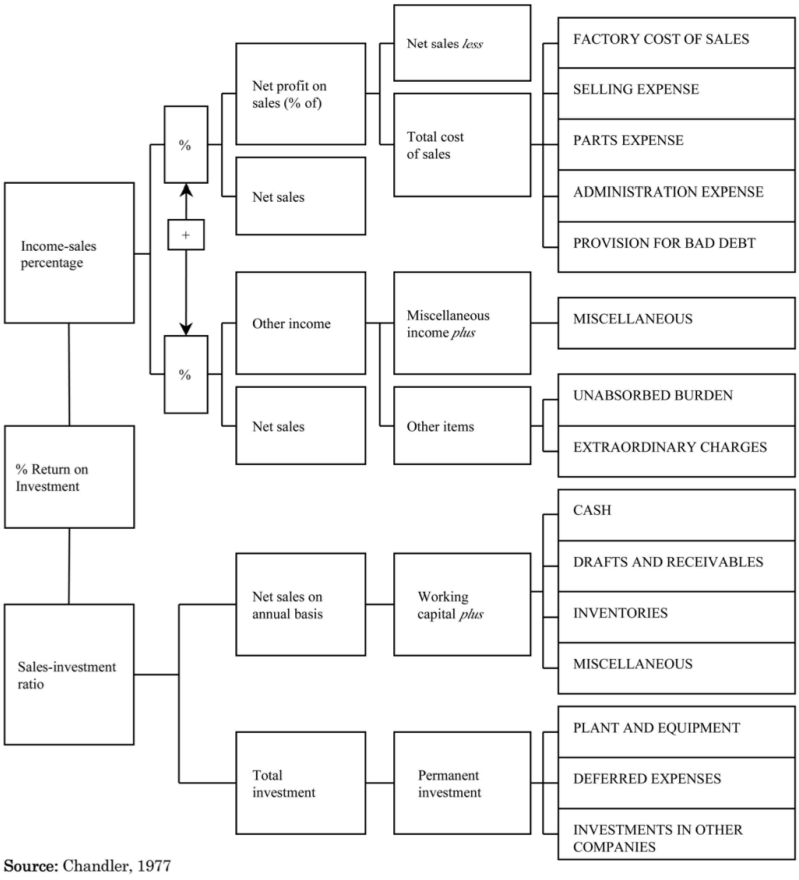

Figure 1: Example of DuPont Model[29]

On the other hand, in the past years it appeared to be clear that the only financial view could not be enough: nowadays just one number is too little to lead a company.

In order to face the difficulties and the competition that the globalisation brought to all the western manufacturing companies, they had to change their business form: under the pressure of reducing costs (the competition of China was and still is too strong) and increasing quality, the manufacturing companies had to reassess their priorities and establish new business model. [30]

At first there were the American companies, which tried to follow the example of the champions in this field: Japan. They tried to copy their philosophy and introduced the Just in Time (JIT) philosophy, which opened, in the following times, the way to other

[28] cf. Neely, A., 2000, pp. 1124 and Sprotte, A., 2009, pp. 40-41
[29] Neely, A, 2000, pp. 1224
[30] cf. Kaplan, R. and Norton, D., 1996, pp. 53-56 and Maskell, B.H., 1991, pp. 19-74

innovation like the Total quality management (TQM) or the Continual improvement process (CIP), known in Germany as Kontinuierliche Verbesserungsprozess (KVP).[31]

All these new business models required different perspective of analysis and the DuPont model became not enough. Besides the financial perspective, there was the request of measuring the customer satisfaction, the internal efficiency and productivity as well as many others.

In other words there was a need of a holistic measurement system, which was able to analyse at the same time different parameters like: quality, efficiency, effectiveness, productivity, flexibility and so on. [32]

Moreover, thanks to the IT revolution, the world started going much faster than before and transactions, orders, etc. became activities almost in “real time”. This put a lot of pressure on the manufacturing companies, which were used to evaluate the results *a posteriori* using the financial records and take the related action in consequence. It was clear that now the companies should have had found some other ways to align the company with a strategy that was in a certain way able to forecast the results (or better the goals) of the company itself in order to remain competitive.

Taking inspiration from the *Tablaeu de Bord* in use in France since the 1970s (sometimes even before), in the 1990s Kaplan and Norton introduced a new concept of PMS: the Balanced Scorecard (BSC). This will be explain more in details in the following section; here it will be underlined its importance in the measurement systems evolution. [33]

The *Tablaeu de Bord* gave for the first time the example of how important and useful could have been to group together, in a synoptic way, all the measures needed to analyse a process: in these “tables” or “spreadsheets ” the measures were grouped according to cause-effect relations and in this way they were able to give to the responsible part a complete overview of the performance of the process.

Kaplan and Norton, in their work of the 1992, went even further: they did not constrain this synoptic overview just to simple processes inside the companies, but they tried to give a complete overview of whole the company itself. [34]

Moreover they integrated in it the strategic view of the company. In fact they organised all the possible performance measures of the company according to four different perspectives, responsible of representing the key aspects of the organisation, and they coupled these measures to the vision and the strategy.

[31] cf. Maskell, B.H., 1991, pp. 19-74 and Sprotte, A., 2009, pp. 40-46
[32] cf. Maskell, B.H., 1991, pp. 19-74 and Sprotte, A., 2009, pp. 40-46
[33] cf. Sprotte, A., 2009, pp. 40-46 and Neely, A., 2005
[34] cf. Kaplan, R., 2010, pp.4-18

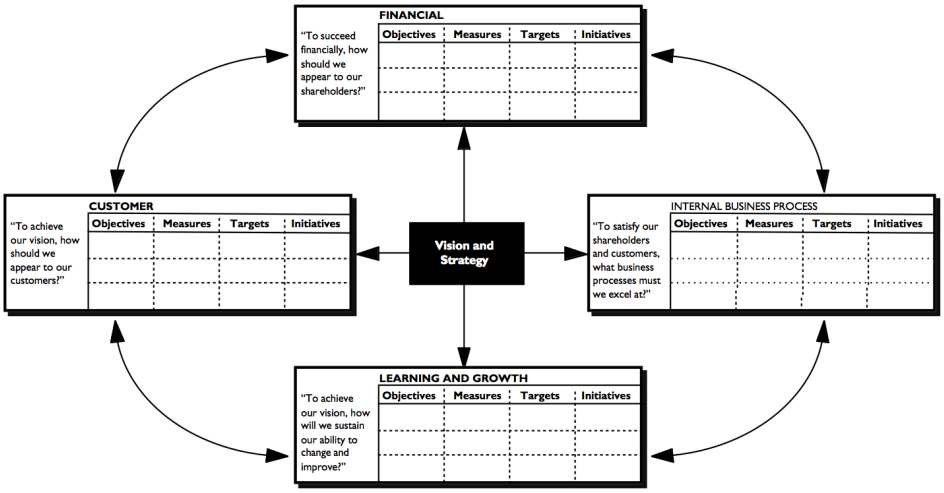

Figure 2: Example of a Balanced Scorecard[35]

In the previous example, developed by Kaplan and Norton, is possible to see how at the centre of everything there are the Vision and the Strategy: the different measures in the four basic perspectives have to be aligned to them. [36]

Now it is clear that also another big step has been made: thanks to the BSC in fact the measurement systems evolved from simple tools of controlling the company to real management systems.

Aligning all the measures, and therefore all the relative goals, to the strategy, allows managing the company through the strategy: in this way the measures are the indicators by which the level of the strategy implementation can be controlled. Moreover, through the updating the relative goals. it is possible to lead the company in a coherent way towards the objectives stated by the strategy.

These innovations were a real breakthrough for the field and the BSC spread all over the countries; it became the state of the art of the Performance Measurement Systems. Anyway it evolved a lot since its first publishing and it has been adopted and developed in many different ways.

As many researches show, the works of Kaplan and Norton have been, by far, the most influencing ones in the field of performance measurements. [37]

[35] Kaplan, R., 1996, pp.54
[36] Kaplan, R., 1996, pp.54
[37] Marr, B., 2003, pp.682

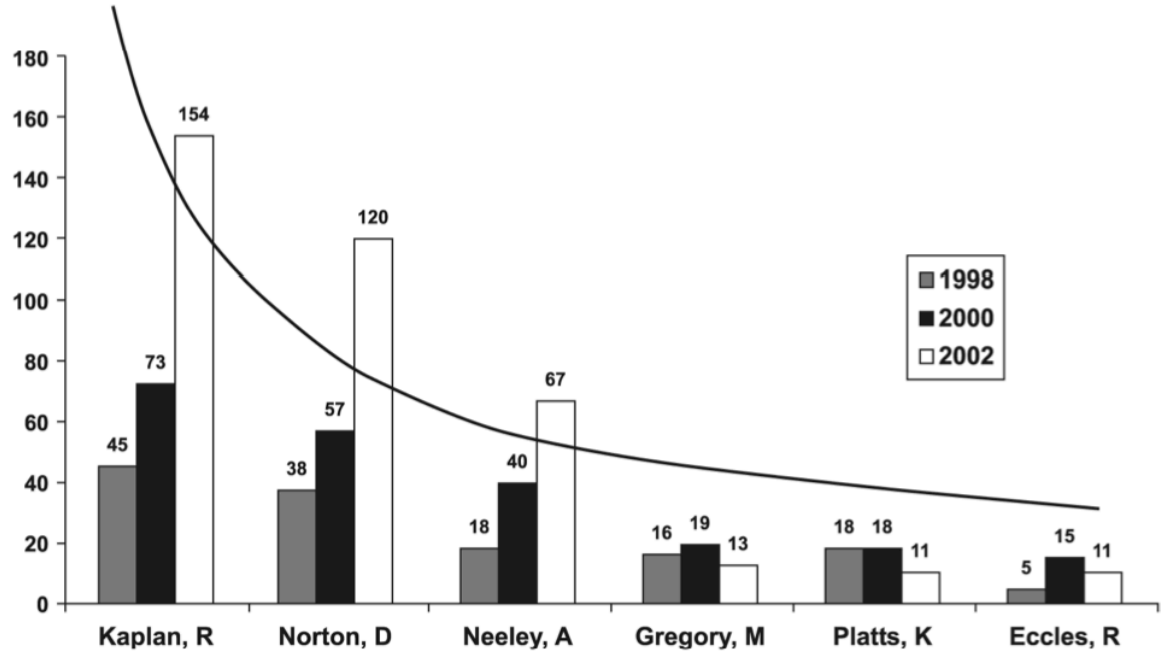

Figure 3: Most frequently quoted authors by year[38]

2000 papers	Citation – frequency
Kaplan and Norton (1996a)	35
Kaplan and Norton (1992)	26
Kaplan and Norton (2000b)	19
Kaplan and Norton (1996c)	12
Neely and Adams (2001), Kaplan and Norton (1996b, 1993)	8
Olve *et al.* (1999), Eccles (1991)	7
Sveiby (1997), Johnson and Kaplan (1987)	6
Neely *et al.* (1995), Kennerley and Neely (2000), Kaplan and Norton (2000a), Lynch and Cross (1991), Lev (2001), Keegan *et al.* (1989)	5
Neely (1998; 1999), Roos *et al.* (1997), Brooking (1996), Stewart (1997), Maskell (1991), Ittner and Larcker (1998), Yin and Campbell (1994), Prahalad and Hamel (1990)	4

Figure 4: Most frequently quoted references in 2002[39]

This can be seen also analysing the other most modern PMSs: all of them starts from the achievements of the BSC and they try to fix and improve some critical points of the BSC itself. [40]

Among the most common PMSs can be anyway seen a common path that derived from the BSC itself.

[38] Marr, B., 2003, pp. 681-683
[39] Marr, B., 2003 pp.682
[40] cf. Striteska, M., 2012

As effectively summarized by Striteska and Spickova in their paper, every PMS[41]:

- Must reflect non-financial information based on key success factor of each business
- Should be implemented as a means of translating strategy and monitoring business results, must be aligned and fit within a strategic system
- Should be based on organisational objectives, critical success factors, and customer needs and should monitor both financial and non-financial aspects
- Must accordingly change dynamically with the strategy
- Must make a link with the reward system

In the following sub-sections the most important performance measurement models (a part the BSC, to which an entire section has been reserved) will be summarized and their strengths and weaknesses will be briefly pointed out.

2.3.2 European Foundation for Quality Management (EFQM)

The EFQM model was generated in the early 90's, almost contemporary with the BSC.

"The EFQM Excellence Model is a non-prescriptive system, proposed to help organizations to assess their progress to excellence and continuous improvement"[42].

It is based on eight fundamental concepts of excellence[43]:

1. Results orientation;
2. People development and involvement;
3. Customer focus;
4. Continuous learning, innovation and improvement;
5. Leadership and constancy of purpose;
6. Partnership development;
7. Management by process and facts;
8. Public responsibility.

Quoting from Striteska and Spickova*:*

> *"The core of the EFQM model is the RADAR methodology which is cyclical and continuous. The methodology consists of five steps: determine required results, plan and develop approaches, deploy approaches, assess and review achieved results. Thus designed model is used as a self-assessment tool, which enables a comprehensive, systematic and*

[41] cf. Striteska, M., 2012, pp.3
[42] Striteska, M., 2012, pp.5
[43] cf. Striteska, M., 2012, pp.5

regular review of an organization's activities and results."[44]

Summarizing the good and the bad points:

	Enumeration:
STRONG POINTS	• systematic and non-prescription model • using of self-assessment approach in order to organization excellence • strengthen the sense of quality • recognition of strong and weakness points of organization • consist of criteria hierarchy • allow shortlist of indicators based on "Good example" of practice • creating conditions for comparative analysis of business processes with external business • feedback from results helps to improve enablers
WEAK POINTS	• no focus / priorities - no links • criteria are not specific within the company – no possibility for differentiation • is not strategic management tool (systematic setting and achieving goals) - therefore, is not instrument for strategy implementation • is not suitable for enterprise communication • tendency to bureaucracy • did not give quidelines how to design and conduct effective performance measurement

Figure 5: Strengths and Weaknesses of the EFQM[45]

2.3.3 SMART Performance Pyramid

The SMART Performance Pyramid has been introduced in 1991 by Cross and Lynch in their work: *Measure Up! Yardsticks for Continuous Improvement*.[46]

The acronym SMART means: Strategic Measurement Analysis and Reporting Technique.

"*The primary aim of the performance pyramid is to connect through organization's strategy with its operations by translating objectives from the top-down (based on customer priorities) and measures from the bottom-up*" [47].

Four levels compose the pyramid:

1. Overall corporate vision
2. Short term targets (profitability) and long term goals (market, financial)
3. Day to day operational measures
4. Four key indicators: quality, delivery, cycle time, waste[48]

[44] Striteska, M., 2012, pp.5
[45] Striteska, M., 2012, pp.6
[46] cf. Lynch, R. L., 1991
[47] Striteska, M., 2012, pp.7
[48] cf. Striteska, M., 2012, pp.7

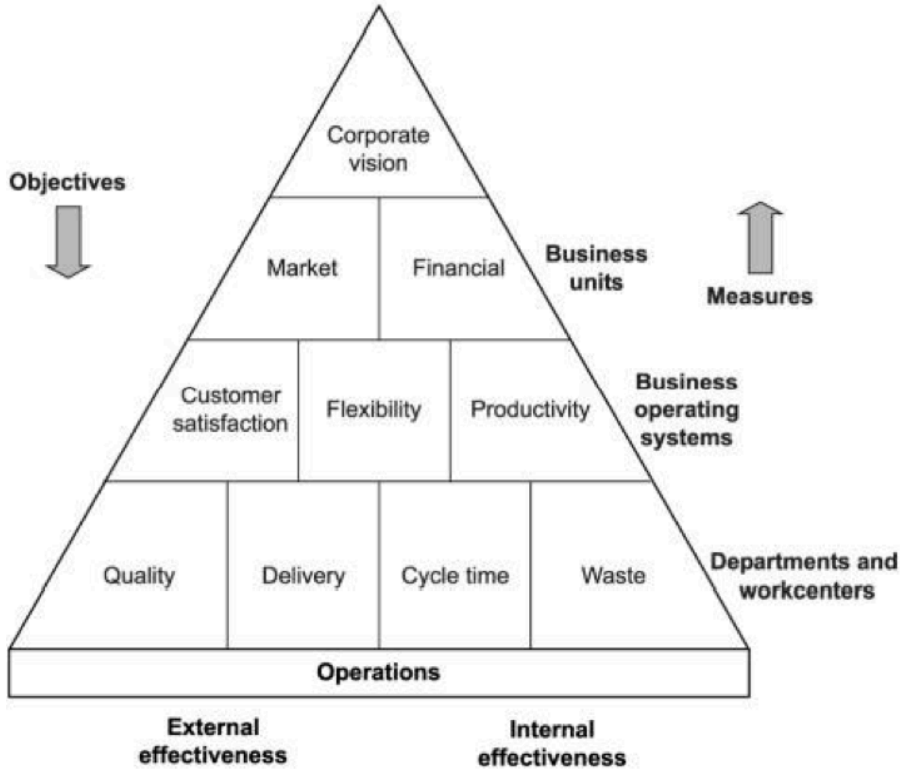

Figure 6: Performance Pyramid by Lynch and Cross (1991)[49]

As did before it is important to summarize some good and bad points:

	Enumeration:
STRONG POINTS	• attempt to integrate corporate objectives with operational performance indicators • manage PM strategically
WEAK POINTS	• does not provide any mechanism to identify key performance indicators • fails to specify the form of the measures • does not explicitly integrate the concept of continuous improvement

Figure 7: Strengths and Weaknesses of the SMART Pyramid[50]

2.3.4 Performance Prism[51]

The Performance Prism or PP, is the youngest PMS presented here and therefore one of the most comprehensive.

It has been developed by a group of researchers (Neely, Adams and Kennerley) in the 2001 and it is based on the strengths of the other existing performance systems.

[49] Tangen, S., 2004, pp.733
[50] Striteska, M., 2012, pp.7
[51] cf. Neely, A., 2001, pp. 6-13 and Neely A., 2002

In particular it stems deeply from the BSC, but it adds to it another important dimension: the stakeholders. Among them there are also the employees, suppliers, alliance partners and intermediaries.

> *"In the first place, the organizations should think about the wants and needs of all of their key stakeholders as well as how to deliver value to each of them. Secondly, organizations have to harmonize and integrate strategies, processes, and capabilities in order to deliver real value to its stakeholders. Thirdly, the relationship between organizations and their stakeholders is reciprocal – stakeholders expect the fulfilment of their wants and needs on the other hand they have to contribute to organizations"*[52].

It can be represented through a prism thanks to its five perspectives of performance[53]:

1. Stakeholder satisfaction
2. Strategies
3. Processes
4. Capabilities
5. Stakeholder contributions

Another interesting aspect regards the strategy, which should not be the source by which the measurements are derived; in the words of their developers:

> *"strategies should be put in place to ensure the wants and needs of the stakeholders are satisfied"*[54].

In other words, the need of the stakeholders come first, then the strategy can be formulated*:*

> *"it is not possible to form a proper strategy before the stakeholders and their needs have been clearly identified"*[55]

The good and the bad points:

[52] Striteska, M., 2012, pp.7
[53] Striteska, M., 2012, pp.7
[54] Striteska, M., 2012, pp.8 (quoted from: Neely A., 2001)
[55] Tangen, S., 2004, pp.734

	Enumeration:
STRONG POINTS	• reflects new stakeholders (such as employees, suppliers, alliance partners or intermediaries) who are usually neglected when forming performance measures • considers the stakeholders' contribution to performance • ensures that the performance measures have a strong foundation
WEAK POINTS	• offers little about how the performance measures are going to be implemented • some measures are not effective in practice • short of logic among the measures, no sufficient link between the results and drivers • no consideration is given to the existing PMSs that companies may have in place

Figure 8: Strengths and Weaknesses of the Performance Prism[56]

[56] Striteska, M., 2012, pp.8

2.4 The Balanced Scorecard

In this section it will be explained more in depth the system of the Balanced Scorecard.

First of all it is fundamental to point out, why it has been decided to analyse in depth this system and not more modern ones:

1. The BSC is clearly the most influencing model in the literature about performance measurement systems in the modern times (as we showed before, see chapter 2.2.1) and it is also the most implemented one in real companies among the other models quoted before. [57]
2. Its great importance resides, as already said, in the innovative perspective that it brought towards the performance measurement problem: it has been a breakthrough.
3. Moreover, since it can be considered the basis (at least conceptual) for many other PMSs, it is clear that a deeper analysis of this model allows a broad applicability of the concepts in many other contexts.
4. In the end it has to be considered that this model represents really well a top-down approach towards the measures design and, as it will be more clear later, this is an important aspects to be analysed for the developing of this work.

At this point it is to understand why this model had so much influence and so much success (much more than any other). The answer to this question is quite simple: it met the needs of the managers.

As stated by Kaplan and Norton themselves in 1992:

"Managers want balanced presentation of both financial and operational measures" [58]

Even though a lot has been written about the balanced scorecard (by the authors themselves, and also by others), it has never been clearly specified *what* a BSC is: the authors have never defined it, preferring to explain how it works and how it can be implemented; moreover the model itself faced few evolutions during the years. [59]

Lawrie and Cobbold tried anyway to identify some clear attributes of the BSC[60]:

- A mixture of financial and non-financial measures
- A limited number of measures
- Measures clustered into four groups called perspectives (see below)

[57] cf. Striteska, M., 2012, pp.4 and Lohman, C., 2002
[58] Kaplan, R., 1992, pp. 71
[59] cf. Lawrie, G., 2002, and Kaplan, R., 2010
[60] cf. Lawrie, G., 2002, pp. 3

- Measures chosen to relate to specific strategic goals; usually documented in tables with one or more measure associated with each goal
- Measures should be chosen in a way that they gain the active endorsement of the senior managers of the organisation, reflecting both their privileged access to strategic information, and the importance of their endorsement and support of the strategic communications that may flow from the Balanced Scorecard once designed
- Some attempt to represent causality: causality should be between *performance driver (lead)* measures and *outcome (lag)* measures

The central aspects of the model proposed by Kaplan and Norton was, since the financial measures (DuPont) were no more enough to guarantee the success of a company, that they had to be flanked, in a balanced way, by measure regarding operations.

In particular the original model prescribes four perspectives[61]:

1. Financial
2. Customer (or External Business)
3. Internal Business
4. Innovation and Learning

Each one of them was supposed to bring answer to four fundamental questions[62]:

1. How do we look to shareholders?
2. How do customers see us?
3. What must we excel at?
4. Can we continue to improve and create value?

As it has been just said, the first version of he BSC has shown from the beginning a great utility, in particular in the approach, but some critics were made; in particular some weak points were noted[63]:

- At the beginning it was not explained so well how to implement the model and design the measures: because of this, many “how to” books followed.
- Secondly some definitions of the BSC and its parts were vague
- And finally the previously quoted questions were not all clear

In particular the question: “To succeed financially, how do we look to shareholders?” was considered *weak*. Because of this, it has been substituted in 1993 by the concept of “*strategic objectives*”[64]. This step introduced the concept of *mapping* the

[61] cf. Kaplan, R., and Norton, D., 1996
[62] cf. Lawrie, G., 2002, pp. 4
[63] cf. Lawrie, G., 2002, pp. 5-6
[64] Kaplan, R., 1993, pp. 136; Kaplan, R., 2010, pp. 18-21

goals of the measures of the different perspectives according to the strategic goals.

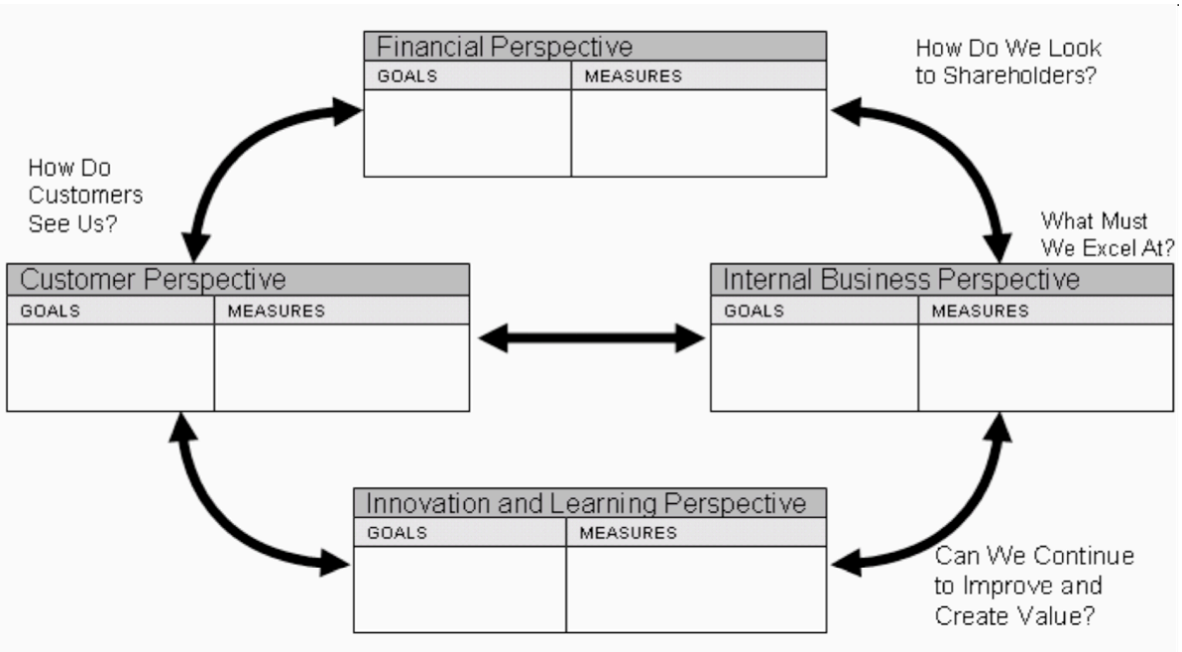

Figure 9: Example of the first model of the Balanced Scorecard[65]

Moreover a clearer concept of "causality" between measures was introduced; this causality concept evolved in the following years till reaching the point, in which the entities connected by causality were no more the measures themselves, but this causality was among the different strategic objectives even of different perspectives. These linkages between objectives have been called in the following time as *strategy maps* (Figure 10). [66]

These innovations made the BSC model evolve from a PMS into a management system, or better a *strategic management system.*

At the end of its evolution, we can say that a basic BSC looks like the one in Figure 2: the vision and the mission are at the centre of the model and they lead the design of the performance measures with the purpose of aligning their goals to the strategic objectives; the different perspectives are balanced through cause-effect connections among the measures themselves.

It is now important to describe better the four basic perspectives and other important methodological aspects of the BSC.

[65] Lawrie, G., 2002, pp. 4
[66] Kaplan, R., 2010, pp. 21-22

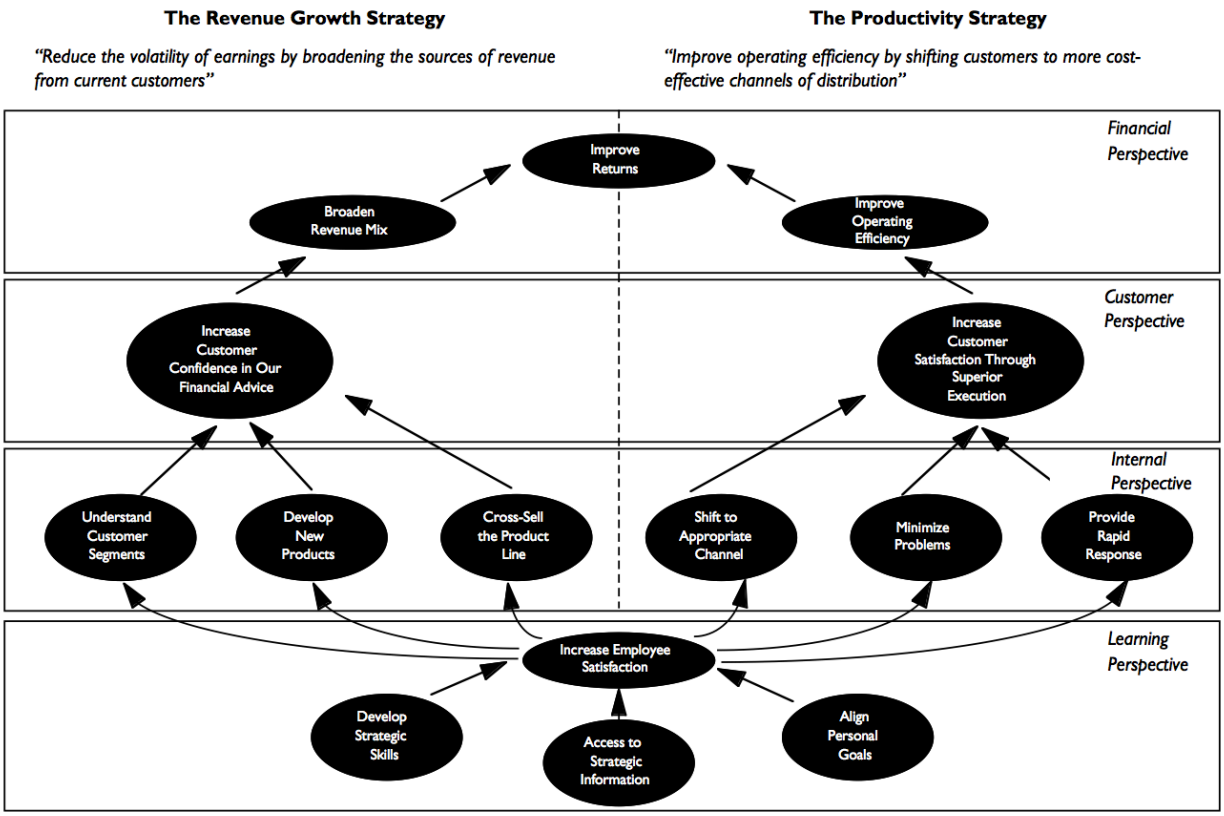

Figure 10: Example of Causality-Linkages in the case of Metro Bank[67]

2.4.1 Financial Perspective

In this perspective, the measures define the long-run objectives of the company, according to each business unit; there is not a standard set of financial measures to apply to each business, but according to the nature of the business, the type of measure required can be different.

As proposed by Kaplan and Norton themselves three different stages for each business can be identified[68]:

- Rapid Growth
- Sustain
- Harvest

For the business in the *rapid growth* phase, more than profit and financial measures, the ones of interested are more the metrics regarding sales number and market share growth. [69]

[67] Kaplan, R., 1996, pp. 71
[68] cf. Kaplan, R., 1996, pp. 56
[69] cf. Kaplan, R., 1996, pp. 56

Most of the businesses of a company should be found in the *sustain* stage: they are expected to be profitable and the investments regard continuous improvement rather than long term growth perspective. The financial objectives related to this stage emphasize the traditional financial measurements like return on capital, gross margin and so on. [70]

For the *harvest* phase instead, since companies want to earn the maximum profits from the investments previously made in this business, the financial measures and therefore objectives will stress a lot on the cash flow. The ROI is no more a valuable metric, because investments for this business are not planned. [71]

Moreover some companies have organized their financial measures according to three themes[72]:

- Revenue Growth and Mix
- Cost Reduction/Productivity Improvement
- Asset Utilisation/Investment Strategy

These three financial themes can be used with any of the previous three business types: of course the kind of measures will change. (cf. Figure 11)

		Financial Themes		
		Revenue Growth and Mix	**Cost Reduction/Productivity Improvement**	**Asset Utilization**
Business Unit Strategy	**Growth**	Sales growth rate by segment Percentage revenue from new product, services, and customers	Revenue/Employee	Investment (percentage of sales) R&D (percentage of sales)
	Sustain	Share of targeted customers and accounts Cross-selling Percentage revenues from new applications Customer and product line profitability	Cost versus competitors' Cost reduction rates Indirect expenses (percentage of sales)	Working capital ratios (cash-to-cash cycle) ROCE by key asset categories Asset utilization rates
	Harvest	Customer and product line profitability Percentage unprofitable customers	Unit costs (per unit of output, per transaction)	Payback Throughput

Figure 11: Example of Financial Measures according to Business Units and Financial Themes[73]

2.4.2 Customer Perspective

In this perspective the managers are used to identify the customers and the market sections related to each business unit.

[70] cf. Kaplan, R., 1996, pp. 57
[71] cf. Kaplan, R., 1996, pp. 57-58
[72] cf. Kaplan, R., 1996, pp. 58
[73] Kaplan, R., 1996, pp. 58

Normally the measures connected with this perspective relate with the success of the products and with the customers; among these we can quote some of them like: number of new customers, customer satisfaction, customer profitability and market share. [74]

These measures are quite generic, but they are normally customised on the targets of each business unit.

This section and especially its measures, even though they cover an important role in the concept of the BSC (which tries also to make the company more customer-oriented), are not of particular interest for this work, since it is more focused on the internal perspective and the operations measures.

Because of this the analysis will not go further and we will pass directly to the next perspective.

2.4.3 Internal Perspective

This is the section of the operations/executive measures, because it refers directly to every internal process. In particular the core of this section are all the processes in which the company must excel in order to reach the following corporate objectives:

- "*Deliver on the value propositions of customers in targeted market segments, and*
- *Satisfy shareholders expectations of excellent financial returns"* [75]

In other words, objective of this perspective is to control and measure the performances of the key processes, which are fundamental to reach the financial and customer goals/objectives.

Therefore the executive managers have to identify the key processes for the satisfaction of customers' expectations and financial objectives and establish which kind of measure is the best to assess their performances.

Among these there will be for sure also technical information, but, in order to respect the purpose of the BSC of constraining the number of measures, it is better to choose synthetic measures, which can be a clear and straightforward representation of the internal performances. Any of them will try to express performance in the mean of: cycle time, quality, employee skill, productivity etc. [76]

Anyway, as clearly pointed out by Kaplan and Norton themselves:

[74] cf. Kaplan, R., 1996, pp. 58
[75] Kaplan, R., 1996, pp. 62
[76] cf. Kaplan, R., 1996, pp. 63

> ”*Since much of the action take place at the department and work station levels (the shop-floor), managers need to decompose overall cycle time, quality, product and cost measures to local levels. That way, the measures link top management's judgment about key internal process and competencies to the actions taken by individuals that affect overall corporate objectives. This linkage ensures that employees at lower levels in the organisation have clear targets for actions, decisions and improvement activities that will contribute to the company's overall mission”*[77].

In this statement there are two important aspects to be underlined:

- At first the clear top-down process of assigning the measures and the goals
- Secondly the fact that the improvement process is directly incorporated in the internal perspective and it is delegated to the lower levels, as in a CIP (Continuous improvement process).

The top-down approach in this perspective is the image of the approach of the overall model[78]:

- from the strategy it is important to identify the key elements of the production system, the key activities which clearly give competitive advantage,
- then it is fundamental to determine few synthetic measures (and the relative goals) of the performances, which also represent the alignment to the strategy
- in the end it is necessary to transfer the goals and the measures to the lower hierarchical levels

This structure is similar to most of the nowadays management systems and it is difficult to be avoided. The top-down approach will be better explained in its proper section

In the end, the fact that process improvement activities are incorporated in the internal perspective is perfectly coherent with the approach of the BSC, which sees the feedback loop or Deming cycle as a fundamental tool to reach and assess the strategy.

2.4.4 Learn & Growth Perspective

The last perspective is maybe the less straightforward, but it is still of great importance for the good functioning and the profitability of the company.

[77] Kaplan, R., 1992, pp. 75
[78] cf. Kaplan, R., 1996

As it is likely to expect, in the other perspectives, few or more discrepancies between the goals and the results will be evidenced. This because, as we know, the goals have to push the improvement of the performances in order to succeed in fulfilling the strategy and in fostering a continuous development of the company. [79]

These improvements (or growths) and the way in which the company *learns* are exactly the subjects of the measures of this perspective.

There are typically three main sources for these discrepancies[80]:

- People
- Organisational Procedures
- System

In order to close the gaps, the company will have to invest in *re-skilling* the employees, enhancing information technology and aligning organizational routines and procedures.

Each of these aspects will be measured in different ways and the proper measures will be different for any company.

2.4.5 Cause and Effect Relationship – Lag and Driver Measures

As we said previously (see chapter 2.3), the cause-effect relationship is a very important concept in the designing and implementation of a BSC.

The strategy in fact can be resumed as a series of *if-then* statements.

In a simpler way: “if we reach the goals in the customer satisfaction performance, then we will have outstanding profitability” and continuing the chain “if we reach this goal in the product quality, then we will certainly gain a lot of points in the customer satisfaction”.

These connections have to be found and established by the management and it constitutes the main structure of the BSC.

Because of these relationships, the measures to be reported in a BSC has been divided in two different kinds[81]:

- Lag or outcomes measures
- Lead or drivers measures

As it can be easily guessed the firsts represent the “*effects*” or consequences of the

[79] cf. Kaplan, R., 1996, pp. 63-64
[80] cf. Kaplan, R., 1996, pp. 64
[81] cf. Kaplan, R., 1996, pp. 65; Kaplan, R., 2010

results of the others. In a well designed BSC it is needed a good mix of these two types:

> *"outcome measures without performance drivers do not communicate how the outcomes are to be achieved. Controversially, performance drivers without outcomes measures may enable the business unit to achieve short-term operational improvements, but will fail to reveal whether the operational improvements into enhanced financial performance or in expanding the business"*[82].

In the end we report a brief summery of the strength and weaknesses of the BSC.

	Enumeration:
STRONG POINTS	• clarity of vision and strategy adopted • consistent monitoring of strategy • concentration on strategic, in the competition environment critical business objectives • cross-disciplinary and hierarchy traversing communication process • integration of performance measures for operational objectives at an appropriate level • cause/effect relationships as instrument for management
WEAK POINTS	• does not express the interests of all stakeholders • lack of long-term commitment and leadership for management • too many/few metrics – development of unattainable metrics • lack of employee awareness or a failure to communicate information to all employees • constructed as a controlling tool rather than an improvement tool • no relationships´ quantification • inappropriate to benchmarking

Figure 12: Strengths and Weaknesses of the Balanced Scorecard[83]

[82] Kaplan R., 1996, pp. 66
[83] Striteska M., 2012, pp.5

2.5 Key Performance Indicators (KPIs)

After having discussed and explained what a Balanced Scorecard is, it is important, for the prosecution of this work, to deepen another topic: the Key Performance Indicators.

Before explaining what they are, how they can be used and how to design them, it is necessary to explain why this topic will be faced.

As it has been already said, they will be important for the prosecution of this work, but why?

As it was explained in the Abstract and the Introduction (see chapter 1), the objective of this work is to develop a flexible, effective and coherent systematic for the development of operational performance measures in manufacturing companies. The flexibility is an important aspect of the work: it has not to be developed for a specific company, but it has to be adaptable to the biggest number of them.

It is according to this need and also other considerations that the BSC has been chosen as the main example of PMSs; for the same reason the explanation of what KPIs are is of fundamental importance for a work about performance measurements.

As the BSC or methods deeply correlated with its features are applied in almost every company, the KPIs are broadly implemented as a support of PMSs or as stand-alone performance measurement/management methods.

As it has been just said, they can be considered as a proper managing system or they can be integrated in other Performance Measuring Systems or Management models as a useful tool. Sometimes they are not used in a whole as the method/model would prescribe, and they are presented with different names or variants, but the basic concept is always more or less the same and it is very useful and easy to use.

But, what are the KPIs? We will try to give an overview in the following section.

2.5.1 What are the KPIs?

Moore has described the term KPI as:

> "*Performance targets given to individuals or organisations indicating how performances will be measured, and the target must adapt to meet business situations*." [84]

[84] http://www.kmice.cms.net.my/ProcKMICe/KMICe2008/Pdf/221-225-CR116.pdf, pp. 221 (quoting from: Moore J., 2004)

Moreover it is possible to say:

> *"Key Performance Indicators (KPIs) are quantitative and qualitative measures used to review an organisation's progress against its goals. These are broken down and set as targets for achievement by departments and individuals. The achievement of these targets is reviewed at regular intervals"*[85]

Substantially, according to these definitions, they do not look so different from the main performances measures indicated in the four or more perspectives of the BSC. It is their similarity, which gives them the possibility to adapt quite easily to this kind of holistic system.

In some literature the KPIs have been seen as:

> *"The missing link between the balanced scorecard work of Kaplan and Norton and the reality of implementing performance measurement in an organization."*[86]

On the other hand they are not completely dependant on the development of a BSC.

The KPIs are strictly related with strategy and vision and they are thought as nothing else then the metrics of the success of the company. [87]

As it is shown in the Figure 13, the KPIs depend from the Critical Success Factors (CSF); we can say that they are the measures of the CSFs themselves.

But what are the CSFs?

> "*Critical success factors are those few things that must go well to ensure success for a manager or an organization, and, therefore, they represent those managerial or enterprise area, that must be given special and continual attention to bring about high performance. CSFs include issues vital to an organization's current operating activities and to its future success*." [88]

[85] FinPa New Media 2009, *Key Performance Indicators*, FinPa New Media, Melbourne, viewed 24 February 2009, http://swinburne.projects.finpa.com.au/toolbox10/releases/final/toolbox/resources/res4040/res4040.htm (visited on the 5/09/2014)
[86] Parmenter, D., 2007, pp. ix
[87] cf. Parmenter, D., 2007, pp. 3
[88] Boynton, A.C., 1984, pp. 17

Figure 13: Strategic Alignment Pyramid[89]

The difference between the CFSs and the KPIs can be seen in the following way[90]:

- The CFSs are the answer to strategic questions/problems, for example: "Why would customer choose us?"
- The KPIs on the other hand are the metrics of the management objectives, which enables the measurement of the strategic performances.

Defining more specifically which are the characteristics of the KPIs is not easy, because the literature can be really diverging on this topic. This is because, as we said, they are a quite flexible tool, but also because sometime the managers misunderstand their real meaning and they call with the term KPI any sort of performance measures of a certain importance. [91]

Looking at the work of Parmenter, he underlines that there are three different types of Performance Measures. As we pointed out at the beginning of this work (see chapter: 2.1), the distinction and organisation of the different measures can vary a lot; this division shall be taken as an opinion of the author (Parmenter), nothing more, but it is useful to identify better the characteristics of the KPIs.[92]

[89] Bauer, K, 2004, (quoted from http://prov.vic.gov.au/wp-content/uploads/2011/05/1010g3.pdf, pp. 8)
[90] cf. Parmenter, D., 2007, pp. 3
[91] cf. Parmenter, D., 2007, pp. 3
[92] cf. Parmenter, D., 2007, pp.1-36 and Dumbrowski, U., 2013, pp. 27-31

He uses an “onion analogy”, which can be quite straightforward[93]:

- The external layer is the one of the Key Result Indicators (KRIs): they tell you how you have done (in a perspective). They are similar to the lag/outcome measures of the BSC.
- Between the external layer and the core there are the Performance Indicators (PIs): they tell you what to do. They can be seen as the lead/driver performance measures.
- At the core of this “onion” there are the KPIs: they tell you what to do to increase your performance dramatically. They are still lead/driver performance measures, but they look at the main performances to be increased, the ones which are really important.

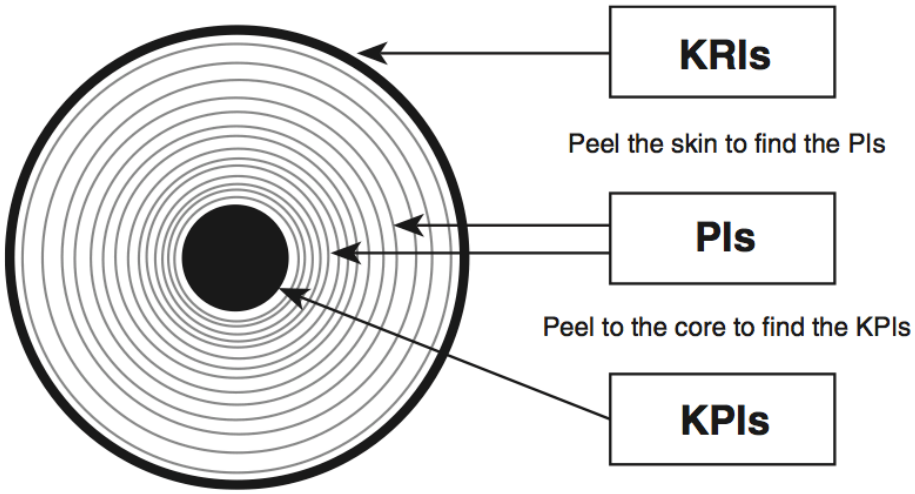

Figure 14: Three types of Performance Measures[94]

Looking at this division we can clearly see the analogy with the lag/lead performance measures of the BSC, and we can understand that among all the important indicators just a few of them are KPIs. [95]

So, when we speak about KPIs, we have to keep in mind that they are very few in quantity, but of really great importance. For example there can be just one KPI per department and this department can be evaluated from the top management, according just to that single indicator.

[93] cf. Parmenter, D., 2007, pp. 1-2
[94] Parmenter, D., 2007, pp. 2
[95] cf. Parmenter, D., 2007, pp. 7

All the other measures are used to monitor the good performance of the other parameters, which contribute to the result of the KPI.

In other words, according to Parmenter and also to part of the modern literature, the KPIs are measures, not mainly traditional (most of the time they are new), which have been developed to synthetically indicate the status of the key performances of the company. [96]

According to this vision the author identifies other seven characteristics typical of the KPIs:

1. *"Non-financial measures (not expressed in dollars, yen, pounds, euros, etc.)*
2. *Measured frequently (e.g., daily or 24/7)*
3. *Acted on by the CEO and senior management team*
4. *Understanding of the measure and the corrective action required by all staff*
5. *Ties responsibility to the individual or team*
6. *Significant impact (e.g. affects most of the core critical success factors [CSFs] and more than one BSC perspective)*
7. *Positive impact (e.g. affects all other performance measures in a positive way)"* [97]

Almost all these characteristics are valuably recognised by all the other literature about the topic; just the second one is a point of discordance: according to Parmenter the KPIs have to be measured and reported directly to its responsible with a daily frequency or 24/7. In other words the daily (short term) progress (or status) is extremely important. [98]

On the opposite sides, many other authors see the KPIs as long-term measures (sometimes even including financial measures), whose results have to be reported maybe once a month. This is a big difference and it is difficult to say which one of the two is wrong or even if one of the two is wrong.

From one side the vision of Parmenter is correct:

> *"A monthly, quarterly, or annual measure cannot be a KPI, as it cannot be 'key' to your business if you are monitoring it well after 'the horse has*

[96] cf. Parmenter, D., 2007, pp. 1-36
[97] Parmenter D., 2007, pp.5
[98] cf. Parmenter, D., 2007, pp. 5

bolted.'"[99]

If an indicator is a key for the success of the company it should be monitored with the highest frequency as possible; it is useful to measure it if we could be able to act according to it if the things are not going properly, not wait until it is too late (*after 'the horse has bolted'*).

On the other side, since the KPIs are a flexible tool, with a broad field of application, it is possible that some measures take some time to "evolve" and therefore a daily or 24/7 measuring and report is just a waste of money and time.

For some businesses (especially the manufacturing industry) the Overall Equipment Effectiveness (OEE) can be considered as a KPI. [100]

The OEE, can be defined as[101]:

OEE= Availability x Effectiveness x Quality Rate

Formula 3: Overall Equipment Effectiveness (OEE)

This measure is subjected to a large series of parameters and the variability can be quite high. Therefore, a daily report cannot show the real progress of this performance: a certain time, thanks to which all the different variables are compensated, is necessary to evaluate the results. In cases like this (very common in the manufacturing industry) the vision of Parmenter results not correct.

In the end it is possible to say that neither of these two visions is to be considered the preferable one: every company, which wants to use the KPIs, have to develop their own indicators keeping in mind, what has been explained before, and in the end choose the most coherent vision to their needs and to their business. [102]

Before examining briefly how to develop the KPIs, it is important to underline other two characteristics of these indicators, which make them one of the most used tools in the performance management.

1. Possibility of usage also in the compensation/reward system
2. Possibility of KPIs of different hierarchical levels

Since the KPIs refer to really important (as we said key) processes, their usage can be not just the one to control and monitor the related activities, but it can be used as the parameter according to which is possible to calculate the variable part the

[99] Parmenter, D., 2007, pp. 6
[100] cf. Johnsson, P., 1999, pp. 55-77
[101] VDMA 66412-1, October 2009, pp.19
[102] cf. VDMA 66412-1, October 2009, pp.19

compensations of an employee. This aspect of the KPIs can be also really useful in the motivation of the responsible employees to reach determined goals. [103]

The second aspect to keep in mind is the fact that the structure of the KPIs can be considered “recursive”: what we have said till now in this chapter is referred to highly hierarchical levels of the organisations. Therefore the KPIs are intended to be indicators useful for the upper management to evaluate the performance of the organisation in a whole, but also to evaluate the work of the responsible for these measures.

If for example the OEE (choosing a typical production measure) is seen as a KPI by the upper management, its responsible (for example the production department manager) is the one who has to guarantee the achievement of the goals and he/she will be evaluated on that.

This, on the other hand, does not prevent the production manager himself/herself to establish a system of KPIs internal to its department according to which he monitors the performances of the department itself in order to achieve the goals connected with the OEE. It could be useful to see the analogy of these last words with the already quoted PIs. [104]

This last aspect has to be kept in mind also for the prosecution of this work.

2.5.2 How to design a KPIs system

In this section we will try to give some hints and some direction for the design and developing of KPIs.

As we said, the KPIs are a flexible tool, because they can be adapted to pre-existing PMSs (e.g. the BSC), but they can also be used “stand-alone”. This makes difficult to identify a general procedure to develop them: if they have to be integrated in a BSC, they have to be categorized according to the different perspectives of the scorecard and moreover they have to follow the steps required to develop a BSC itself. [105]

If on the other hand they are used as a “stand alone” management system, the ways to develop them have to deal more with the different kinds of business, in which the company operates.

[103] cf. Parmenter, D., 2007, pp. 1-36, Wouters, M., 2008, pp. 64-78
[104] cf. Parmenter, D., 2007, pp. 1-36
[105] cf. Parmenter, D., 2007 and http://prov.vic.gov.au/wp-content/uploads/2011/05/1010g3.pdf (visited on the 05/09/2014)

In this case there can be different approaches, as it is explained in a document from the Victoria State in Australia, in which the guidelines to deal with the KPIs are given.[106]

For some businesses or “agencies” it is preferable an approach to KPIs, which starts from the regulatory requirements; for others, especially services companies, the risk based approach could be more useful. [107]

Other methods more likely to be implemented in manufacturing companies are[108]:

- Life cycle approach: here the KPIs are connected with the fundamental stages of the life (or production life) of the product
- Cause & Effect: similarly to the relationship model of the BSC, here the KPIs are determined following logical chains of cause and effects; fundamental in this approach is the identification of the main processes to analyse.
- Levels: according to this approach the KPIs have to be divided into strategic and operational ones: the strategic KPIs have to answer to the management/strategic needs; the operational ones instead has to focus more on the operations and are built from the ground up.

As it can be seen, every approach make the KPIs derive form the strategy and the vision; just the “levels” approach admits that some KPIs of different levels can be built bottom-up. This is interesting for the prosecution of the work.

On the other hand, since most of the approaches look at KPIs as strategic indicators, it is straightforward to assess, that the main responsible for the designing of these indicators are the managers who sit in high hierarchical position and who, thanks to this position, have a broader view of the company and of its critical (or key) points.

They have to identify the CSFs and from them derive the measures or KPIs.

As we already said the KPIs have the characteristic of being, most of the times, new measures, which are developed time by time, to represent at best the key performances of the company. Because of this, the measures are normally extremely synthetic (therefore they would require many other data/measures) and with its own particular metrics.

The designing of these measures is an extreme conceptual job and it has to be carried out through several workshops and meeting and also with the help of an external facilitator. It is not in the interest of this work to go into more details about the

[106] cf. http://prov.vic.gov.au/wp-content/uploads/2011/05/1010g3.pdf
[107] cf. http://prov.vic.gov.au/wp-content/uploads/2011/05/1010g3.pdf, pp. 13
[108] cf. http://prov.vic.gov.au/wp-content/uploads/2011/05/1010g3.pdf, pp. 13-14

designing itself of the KPIs; for this we would remind to the literature on the topic. The *"12-step Model"* of Parmenter is a valuable example.[109]

In third chapter of his book, Parmenter develops a methodology to design the KPIs of a company, which is composed by 12 steps[110]:

- *"Step 1: Senior Management Team Commitment*
- *Step 2: Establishing a "Winning KPI" Project Team*
- *Step 3: Establish a "Just Do It" Culture and Process*
- *Step 4: Setting Up a Holistic KPI Development Strategy*
- *Step 5: Marketing the KPI System to All Employees*
- *Step 6: Identifying Organization-Wide Critical Success Factors*
- *Step 7: Recording Performance Measures in a Database*
- *Step 8: Selecting Team-Level Performance Measures*
- *Step 9: Selecting Organizational "Winning KPIs"*
- *Step 10: Developing the Reporting Framework at All Levels*
- *Step 11: Facilitating the Use of Winning KPIs*
- *Step 12: Refining KPIs to Maintain Their Relevance"*[111]

According to the author of this model, its great strength is in the fact that it has solid basis and it also spends most of its time in the "environment preparation", than in the developing the KPIs themselves.

In his words:

> *"Like painting the outside of a house, 70% of a good job is in the preparation. Establishing a sound environment in which KPIs can operate and develop is crucial. Once the organization understands the process involved and appreciates the purpose of introducing KPIs, the building phase can begin."*[112]

Therefore he stresses a lot on the support and commitment of the management, as well as the understanding and preparation of the nature of KPIs and their developing methodology from the employees.

Before passing to the next session, it is important to underline that the KPIs, as any other measure, have to be updated during their life according to two aspects: [113]

- The goals
- The nature of the measure itself

[109] Parmenter D., 2007, pp. 37-100
[110] Parmenter D., 2007, pp. 37-100
[111] Parmenter, D., 2007, pp. vi
[112] Parmenter, D., 2007, pp. 37
[113] cf. Parmenter, D., 2007, pp. 111

Sometimes the goals can be out of date: they have to be coherent to the strategy and respect the SMART (Specific, Measurable, Achievable, Realistic, Time-Related) principles. On the other hand, sometimes, the measure itself or its metric has to be modified, because it does not fit anymore the nature of the business of the company.

Given the great importance of the KPIs for the company, being out of date in this field can compromise the future of the organisation.

2.6 Designing Approaches

In the following section the two principal approaches for the designing of measures will be explained and analysed; the choice of which one of these approaches depends strictly on the kind of management style implemented in the company, but also on the kind of PMS or, more in general, management system, which has been adopted.

These two approaches are the Top-Down and the Bottom-Up: each one of them has some advantages, but also some defects: we will try to point these out.

Moreover they have their own field of application; therefore it is not possible to determine which one of the two is absolutely better.

It has been decided to introduce this section in the chapter regarding the theoretical foundation, because the knowledge of these approaches is really important for the comprehension of the conceptual model, which will be explained in the following chapter (see chapter 3).

2.6.1 Top-Down Approach

In this subsection we will face the top-down approach.

First of all, what does it mean? As suggested by its "title", this approach is supposed to have a "command chain", which flows from the top (the management) down to the lower hierarchical levels (till the most operative one: the shop floor). [114]

This means that the decisions (in particular the strategic ones) are held by the top management and to the lower level is delegated just to the applications of the "measures" imposed from above.

In the words of Willaert and Willems:

> *"Often this is the point view where the internal processes are often looked at by the top management and parties external to the company. This can be referred to as the strategic top-down approach for evaluating overall core processes and their strategic contribution to the corporate goals. Typical strategic questions in this top-down approach are: "Which processes are creating value?", "Which processes should we improve?", "Who are the stakeholders of this process?", "What is the goal of each process", "Who could take responsibility and/or ownership over which process?", etc."* [115]

[114] cf. Crespi, V., 2005, pp. 1159-1160
[115] Willaert, P., 2006, pp. 741

The responsibility of the lower levels is therefore constrained to the fruitful application of the decisions taken by the upper levels.

This system can be in a certain way recursive: the inference of the top hierarchical level can be limited and it may not go too deep in the hierarchical structure, constraining its influence to some intermediate managers.

These have to answer to the request of the management above, but, on the other hand, have the possibility to replicate the same structure. This allows to the strategy, imposed from above, to go deeper and deeper through the organization, but, at the same time, this allows the top management to keep a solid control of the organisation and its behaviour.

Quoting Willaert and Willems again:

> *"To be sure that KPI's, deducted from the strategy, are surely process oriented, it seems valuable to formulate specific process goals for each of the identified core processes,"* [116]

This approach has been really appreciated by the management in the past to years, because, as we said, it allows to keep easily the control of the organisation, but it makes all the structure much more rigid.

This kind of management approach makes the decision-making longer, because every decision at a lower level has to pass before to the responsible person, who maybe is some levels upper. Moreover the passage of information is more difficult and the communication more formal. [117]

The discussion about the management style can go much further and it can contemplate many other factors: this is not the interest of this work, therefore it is better to stick on the implications of a top-down approach on the performance measures design.

Most of the PMSs that we have discussed before (included the BSC and the KPIs) follow mainly a top-down approach: the performance measures are decided by the top management following the strategy that they have chosen. [118]

This is perfectly coherent with what we have said before (see chapter 2.3) for example of the BSC: the scorecard in fact is nothing else than a "table" on which the managers control the performances of the company in the departments that they consider of crucial importance and their alignment with the strategic objectives.

[116] Willaert, P., 2006, pp. 742
[117] cf. Adler, P.S., 1996, pp. 61-84
[118] cf. Crespi, V., 2005, pp. 1159-1160

We can say mostly the same for the KPIs systems: the CSF are identified by the top management following the strategy and the key activities, and therefore the indicators, are chosen accordingly, again by the top management. [119]

Coherently there can be the establishing of "second level" KPIs, introducing the already cited recursive structure. In any case the performance measures are imposed from the responsible manager.

Looking at the big amount of literature on these methods and their vast application, we can say that a top-down approach works pretty well in the measures designing.[120]

On the other hand it can leave some doubts about its efficacy on the lower levels of the organization and its rigidity can constitute a source of problems and delays in the new businesses, which require faster procedure, more delegation and flexibility. [121]

In the following table it has been tried to summarize the advantages (strengths) and disadvantages (weaknesses) of this approach.

ADVANTAGES/STRENGTHS	DISADVANTAGES/WEAKNESSES
• Clear hierarchical organization • Effectiveness on the control and application of the strategy • Clear distribution of the responsibilities • Easy decomposition of the tasks	• Low efficiency in communication • High rigidity of the decision making procedure • Long feedback loops • Low delegation → Low motivation • Poor effectiveness at the lowest level of the hierarchy

Figure 15: Advantages and Disadvantages of the Top-Down Approach[122]

2.6.2 Bottom-Up Approach

Proceeding like for the top-down, we can identify the main characteristic of this approach analysing the title: the approach focuses on the needs of the bottom lines of the hierarchy and at first attempts to answer to these needs independently, then it tries to aggregate the different solutions in higher hierarchical clusters, attempting to build up the most coherent organisation as possible.

[119] cf. Parmenter, D., 2007, pp. 1-36
[120] cf. Neely, A., 2005, pp. 1228-1263 and Kaplan, R., 1996, pp. 53-79
[121] cf. Parmenter, D., 2007, pp. 58
[122] cf. Crespi, V., 2005 pp. 1159-1160 and Adler, P.S., 1996, pp. 61-84

Describing better and in a more systematic way the bottom up approach is not an easy task, because the consensus towards it and the examples of application are developing in the current times: its importance is increasing in the recent years, in particular with the aim of supporting new kinds of flexible business. Therefore historical examples of its fruitful application are missing. [123]

Anyway we will try to underline the most important and useful aspects of this approach, especially related to our focus: the measures design.

First of all it is important to notice that, since the starting point is the bottom line of the organisation, this approach tries to separate as much as possible from the strategy: the design of measures (or any other action) and the strategy of the management is not imposed from above, but they start and have impulse from the needs of the lower levels themselves.

> *"Combining and aggregating these sub-parts and units to get a more general view on the core processes is rather a bottom-up approach. Questions that can be asked in this approach are: "How can we improve this specific process?", "Which department or function is having a role in this process?", "Where and when are customers involved in this process?", "What are the specific drivers in the process that influence the outcomes?", etc."* [124]

In this kind of approach the different hierarchical parties are independent and completely responsible for the choices they make, not just for not achieving of a goal. In other words we can say that the responsibilities are very spread through the organisation and the delegation is a central aspect of this approach. [125]

Moreover the bottom-up approach is characterised by the fact that the organisation, the goals, the strategic objectives and so on are deeply connected with the needs of the lower levels: in other words we can say that the bottom-up approach tries to build up a strategy making it *emerge* from the inside (the shop-floor level). [126]

It is clear from the beginning that this is not an easy task, mostly because fundamental for the success of this approach is the culture of the company and its employees: among the common values, it has to be shared that every action of any employee should be focalized towards the good of the company, because making the good of the company means making the good of the employee himself.

[123] cf. Crespi, V., 2005 pp. 1159-1160; cf. Willaert, P., 2006, pp. 740-744
[124] Willaert, P., 2006, pp. 741
[125] cf. Adler, P.S., 1996, pp. 61-84
[126] cf. Willaert, P., 2006, pp. 741

This kind of culture makes the workers extremely propositive and aware of their actions: this motivates them in doing their best and consequently the best for the company. [127]

Anyway, establishing a culture like this is not an easy task, especially in the mature businesses like the manufacturing one; normally this kind of approach is more doable in young businesses, not only because the culture is not entirely developed yet, but also because the age of the employees is lower: older employees are harder to convince to change their habits and the way they perform at work. These kind of worker is the typical one of manufacturing companies in which their experience and knowledge is extremely valuable and difficult to replace.

Despite the problems of implementing a bottom-up approach from an organisational point of view, it is also important to understand which can be the negative sides of it.

As we said, the culture is a fundamental aspect of this approach and especially it should be shared at all levels: if it is not, applying this kind of approach can lead to poor results. [128]

Beside this problem it is also to keep in mind that a great delegation both vertical and horizontal can affect any project (developed in this way) with poor coherence among the different parts.

In fact it is likely that, even if the commitment of the different development groups is high, the results diverge, especially in the goal setting. This can request a big effort in assessing the coherence among the different goals in order to assess an effective strategy through the whole organisation.

The opponents of this approach underline also how difficult it is to build an effective strategy starting from so low in the organisation and just looking at the inside.

For example, building up a coherent PMS and the connected strategy looking just at the inside of the company is really difficult and dangerous, because it can prevent from seeing important threats or opportunities coming from the outside; in this way the profitability and the competitiveness of a company can be put in danger.

In conclusion we can say that the bottom up approach can be really valuable in motivating the employees and assessing a more flexible and modern organisation; on the other side it results to be difficult to be applied completely from the very bottom to the very up. [129]

[127] cf. Adler, P.S., 1996, pp. 61-84
[128] cf. Willaert, P., 2006, pp. 740ff
[129] cf. Willaert, P., 2006, pp. 740ff; cf. Adler, P.S., 1996, pp. 61-84

Its usage can be limited to certain parts of a project: for example it can be a valuable method to design the measure at an operational/executive level. [130]

This is an interesting point, which we will deepen in the following chapter, in which we will discuss the model/systematic proposed by the author.

Like before in the following table it has been tried to summarize the advantages (strengths) and disadvantages (weaknesses) of this approach.

ADVANTAGES/STRENGTHS	DISADVANTAGES/WEAKNESSES
• High communication efficiency • Short feedback loops • High flexibility in the decision making procedure • High delegation → high motivation	• Less clear distribution of responsibility • Low control of the formulation and application of the strategy • Low coherence of the objectives • Poor effectiveness at the highest level of the hierarchy

Figure 16: Advantages and Disadvantages of the Bottom-Up Approach[131]

2.6.3 Conclusion and Remarks

As it has been already pointed out, these methods can be applied in order to build the organisation structure and the management polices (but this is not our aim), but also as approaches to face any kind of process.

It is exactly in this sense that we needed to explain them. In fact the performance measures designing can be seen as a project, which has been developed internally by the company itself, whose output is not a material product, but are the measures themselves.

Moreover the process of developing measures is a quite special one, which can even deviate from the normal procedure of the company. Therefore, it means that, in this case, each one of the to approaches can theoretically be applied to whichever company's structure. It is just a matter of choosing the most appropriate one.[132]

[130] Willaert, P., 2006, pp. 741
[131] cf. Crespi, V., 2005 pp. 1159-1160 and Adler, P.S., 1996, pp. 61-84
[132] Neely A., 1997, pp. 1140

3 Conceptual Model

In this chapter it will be introduced the conceptual model developed by the author.

Before getting into details of the different parts of the model/systematic, it is important to understand which theoretical knowledge from the previous section (see chapter: 2) has been used and it is important to set some premises.

What is important to keep in mind in the work are the basic information about the PMSs and the measures as well (see chapter: 2.2 and 2.2).

Moreover we have to keep in mind that the objective of this work is to develop a flexible systematic, which can be adapted to any kind (at least to a major number) of PMSs; that is why the BSC and the KPI systems have been treated more in detail (see chapter: 2.4 and 2.5): the first represents the conceptual basis of the modern PMS, the second is really deeply spread in almost all the nowadays organisations, even if sometimes with different names or particular features.

In other words we can say that they give the right basis, in particular the right state of mind, in order to face the designing of a systematic for operative performance measures.

The other theoretical foundations that have been discussed before are the different kinds of approaches in organisations and, more in particular, the kinds of approaches adoptable in order to design performance measures (see chapter: 2.6.1 and 2.6.2).

We have spoken about two different methods to intend the organisation, but also to design the measures:

- the top-down approach, which is the one that is very suitable (at least at the strategic levels) for implementing PMS like the BSC and KPIs on a whole company and
- the bottom-up approach, which in the past has been less explored and adopted, but it is showing good potential in modern businesses, in particular in the design of low hierarchical levels (operational and executive) measures.

3.1 Premises

As we said in the previous introduction to this chapter, before starting with the description of the model, it is relevant to make some assumptions, in particular to justify the choice of which one of the design approaches.

As already stated in the introduction (see chapter: 1), this work has its focus on the low hierarchical measures of a manufacturing company, especially in the production department; this leads us to an important question: what importance has strategy at this level?

To give an answer to this question is not easy, but it is relevant: if the strategy influence is negligible, consequently we could try to avoid a top-down approach, and we could rely on a pure bottom-up one, which would have to relate with other strategic measures on higher hierarchical levels. [133]

On the other side, if the strategy has anyway a predominant role, the use of a traditional top-down approach could not be avoided: in fact if the measures are too bounded to the strategy, trying to build them up with a bottom-up approach could be not effective at all; it could even be dangerous. [134]

According to the main literature on this topic, in particular the several works of Neely (who effectively summarise also other works in this field), the measures should be always derived from the strategy. [135]

This assumption should have lead this work towards the application of a top-down approach, in perfectly coherence with almost all the modern PMSs. On the other side, one of the aims of this work was also to explore, if it was possible to develop a "new systematic" using the bottom-up approach, because the measures objective of the model were at a low hierarchical levels.

Therefore it is important to have a better understanding of the nature of the performance measures at a shop-floor level: as reported by Mark Wouters[136] (quoting one of his works in collaboration with Lohman[137]), on an operations level there is a bunch of other "unofficial" measures and reports, which "live" beside the approved PMS measures.

[133] cf. Willaert, P., 2006, pp. 740-744
[134] cf. Willaert, P., 2006, pp. 741; cf. Crespi, V., 2005 pp. 1159-1160
[135] cf. Neely, A., 1997; cf. Neely A. 2000; cf. Neely, A. 2001; cf. Neely, A. 2005
[136] cf. Wouters M., 2008
[137] cf. Lohman et al., 2004

These unofficial measures are usually not related to data requested by the managers or derived by strategy, but they are naturally developed on the shop floor in order to answer to its particular needs. [138]

It is quite straightforward to understand now, that it is impossible to lead a production department just relying on the measures derived by the strategy: there are in fact many operational figures, metrics and reports needed to effectively lead such an operative department in which also machines have an important role.

This aspect was considered by almost all the quoted literature, but, since these works were more focused on the developing of an overall PMS, this problem never been faced directly. [139]

These “unofficial” measures were just quoted as a possible threat for the containment of the measures themselves: the fact that they are unofficial makes them impossible to control. This means that they are used to justify some actions at the bottom levels, but the top management does not know them; this can cause misunderstandings and also conflicts. [140]

Moreover, since they are not “official”, also the “horizontal” communication is prevented: they can multiply in many duplicates all along the production department without knowing that a similar measure already exist; in this way their number explode and the coherence of the PMS drops significantly.

For this work, instead, this is a very relevant aspect: it shows that at this level, the measures derived by strategy are not enough. The strategy covers for sure a really important role, but it cannot tell everything; the needs of the shop floor have to be listened to and they should be coherently satisfied at the moment of the PMS design also in order to contain their unofficial proliferation.

This dichotomy has been solved in this work with the application of a hybrid systematic, which tries to combine both the two approaches: this will be the main topic of the next section.

[138] cf. Wouters M., 2008
[139] cf. Wouters M., 2008; cf. Neely A., 1997; cf. Neely A. 2000; cf. Neely A. 2005; cf. Bourne, M. 2000
[140] cf. Wouters M., 2008 pp. 64-78; cf. Neely A., 1997, pp. 1131-1152; cf. Neely A. 2000, pp. 1119-1145; cf. Bourne, M. 2000, 754-771; cf. Willaert, P., 2006, pp. 740-744

3.2 A Hybrid Model

This section will be focalized on the description of the hybrid model, which is the core of this work. As the title suggests and as it has been already explained before (see chapter 1), this model makes use of both the top-down and the bottom-up approach, trying to make an effective and efficient synthesis of them both, using the strengths of the one to cover the weaknesses of the other.

Before getting into details of the description of the model itself, it is better to start setting the limits of its applicability.

By request, this has to be a flexible model, adaptable to the biggest number of PMSs as possible: as we already explained in the chapters 2.4 and 2.5, we chose as basis of our work the BSC and the KPI systems, because they cover a broad spectrum of applications. As already said, many different PMSs have been derived from the BSC and the KPIs (even if maybe with different names) are spread in almost every company, sometimes even integrated with a BSC. [141]

Moreover we have to remark once again that the focus of this work is on the low levels of the measures hierarchy: mostly the shop floor. This means that we concentrated in particular on the executive, operational and tactical measures of a production department.

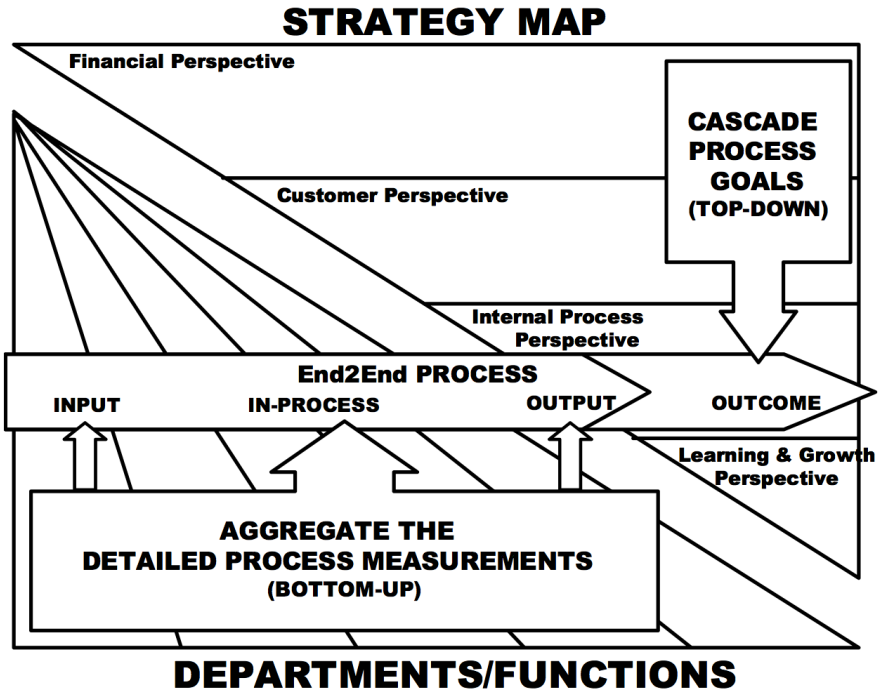

Figure 17: Example of Linking the Top-Down and the Bottom-Up Approach[142]

[141] cf. Parmenter, D., 2007, pp. 1-36; Striteska M., 2012, pp.1-10
[142] Willaert, P., 2006, pp. 743

The aim of this work is therefore not to develop a systematic for a whole PM system, but more a designing systematic for a part of it: in particular, given what we said before, this systematic can be used as tool to develop a specific kind of measures for “compatible” PM systems.

3.2.1 A Hybrid Model – Top-Down

In this sub-section, we will start explaining more in details the components of this Hybrid Model.

First of all we will face the part concerning the Top-Down approach: as we said (see chapter 3.1), the strategy has a certain influence even on the design of the low hierarchy measures; what has not be said, is in which extent and in which modalities.

Looking at Figure 15 the explanation will be clearer.

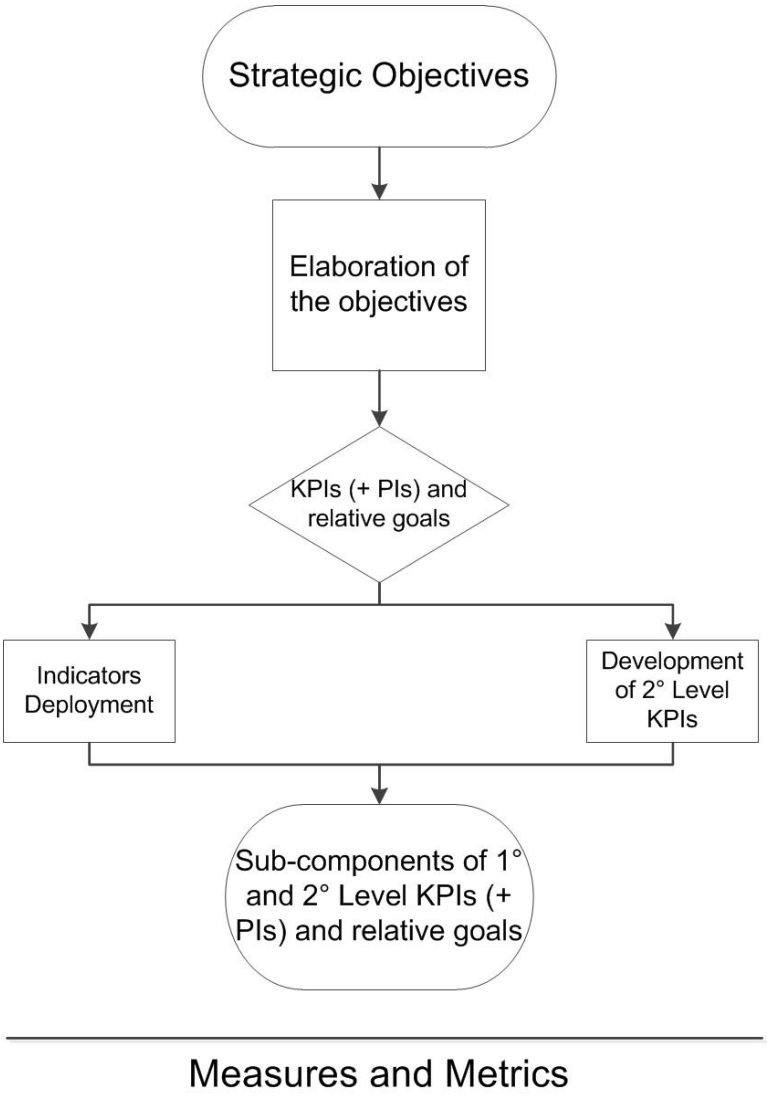

Figure 18: Scheme of the Top-Down Approach

The aim of this systematic is that it can be applied in many different PMSs, provided that they put the Strategy at the centre of their system (like the BSC); therefore the starting point of our top-down approach are the strategic objectives of the company.

In this point of the explanation, it is important to clarify, that the way by which they have been decided is not of our concern, but let us say that they represent our starting point.

It is still a task of the top/upper management to elaborate these strategic objectives and then provide a series of "fundamental measures". [143]

These fundamental measures can be (e.g. in a BSC) the indicators that have been inserted in the different perspective of the BSC or the measures to report on the "report sheets"; in this work it has been decided to call them KPIs and PIs (following the distinction made by Parmenter, cf. Figure 15) in order to make clear that they are key measures, which directly come from the strategy. [144]

Moreover, as we stated, the KPIs are not necessarily distinct by the BSC and the term KPI is actually used in the companies' terminology. [145]

These fundamental measures, which from now on will be called KPI of 1° level, are always combined with their goals, as a good procedure for performance measure determination requires. [146]

The activity of the model starts at this point: "from above" (the management) these KPIs have been determined and they are referred to the different parts or departments of the company, now our model gets involved with the objective of translating them at lower levels.

Taking into consideration the department of our interest, the production, these KPIs can be referred to the overall performances of the department in term of productivity, quality and so on, or even to specific production lines or machines.

As already said (see chapter: 1), it is not interest of this work suggesting the specific measures to be used in a production department, but just propose a systematic for their design.

It is through these key indicators and their goals that the strategy's influence propagates through the company even at the lower levels. [147]

[143] cf. Parmenter, D., 2007, pp. 1-36; cf. Neely, A., 1997; cf. Neely, A., 2001, Kaplan, R., 1993, pp.134-147
[144] cf. Parmenter D., 2007, pp. 1-2
[145] cf. Parmenter D., 2007
[146] cf. Neely, A., 1997, pp.1131; cf. Neely, A., 2000, pp. 1119ff
[147] cf. Parmenter, D., 2007

This can happen in different ways[148]:

- If the KPI refers to the overall performance of the department, they give the strategic directions to the entire division and this strategy is translated to the shop floor through the sub-goals connected with the sub-measures, that these synthetic indicators require.
- On the other hand, if the KPIs are more specific, they directly affect strategically the focused machine/line/worker prescribing him/her definite objectives.

In both cases these kind of KPIs push the responsible party for that performance to try any way to reach the goals required by the management; in addition, the performance indicators and their goals achievement can be used as parameters for the retribution of the responsible employee: this can be a source of motivation for reaching the strategic objectives. [149]

Pushed by this, the responsible employee can desire to establish (if they have the authority) another KPIs system of "second level"[150]: we can say that these 2° level KPIs share mostly the same characteristics of the 1° level KPIs; the only difference is that the latter derive directly from the strategy (the are even the indicators of the strategy implementation), the former on the other hand are more operative and their dependency from the strategy is indirect.

Anyway both of them have a top-down structure and they have to be faced in this part of the model.

Given what we have just said, the model consider two different topics to focus on:

- The KPIs of first level have to be deployed in all the sub-components they required
- The second level KPIs, instead, since they are proper of the department of interest, should also be developed.

In the following lines these to statements will be made clearer.

As we said (see chapter: 2.4) the first level KPIs are strategy-determined; they focus normally on a big portion (sometimes the whole) of the department and they are normally extremely synthetic.

This last aspect is the most important for us in this moment: being synthetic means that they are measures composed by many different factors, arithmetically formulated

[148] cf. Parmenter, D., 2007; cf. Kaplan, R., 1993; cf. Kaplan, R., 1996; cf. Kaplan, R., 2010
[149] cf. Parmenter D., 2007; cf- Neely, A., 2000
[150] cf. pp. 33 of this work - the recursive structure

by different sub-measures. Therefore they require the establishment of a series of sub-measures together with their metrics and goals:

- The metrics are chosen according to the metric required by the correspondent KPI
- The “sub-goals” are normally straightforward derived by the KPI goal, but this is an aspect that will be faced later.

On the other side, the people responsible to achieve the first level ones, in order to keep record and control of the performances of their department, normally introduce the second level KPIs.

In order to be clearer, it could be useful to make an example: from the top management a quality KPI for the overall production department is established; the division’s director is the responsible for achieving the goals imposed by the management, therefore he/she would need to have all the relevant information/measure concerning quality of the department. This can lead him to have to establish another KPI system of second level with the purpose to fulfil the strategic goals, managing the production system in the most efficient and effective way.

It should be clearer now that these second level KPIs have much more an operative nature, but they still stem from strategic needs. Even if they are of a lower hierarchical level, by nature the KPIs are mostly synthetic measures: this means that even the second level KPIs could require a deployment process.

Given the different nature of the KPIs deployment and KPIs (second level) development, these two processes have been separated in the systematic modelling, but they should be developed by the same group of people and also trying to limit at most the possible overlapping of measures.

The result of this approach is a series of Measures and Metrics: they will be the expression of the sub-components of the first level KPIs, the second level KPIs themselves (and their subcomponents) and their goals.

This part will no further describe the procedure of top-down design, because it is mostly the KPIs procedure and it is no interest of this work to stress on it: there is a plenty of literature about it (e.g. Parameter’s work) [151]. More interesting is instead how to proceed in case of a bottom-up method: this will be faced in the next section.

3.2.2 A Hybrid Model – Bottom-Up

The other component of the model is composed by a Bottom-Up approach.

[151] cf. Parmenter, D., 2007, pp. 105-164

If with the top-down approach we wanted to translate the strategy needs at the low hierarchical levels, with this method we intend to intercept the needs of the shop floor with the aim of translating them into a coherent measurement system built up from the bottom.

In Figure 17 is reported the scheme of this part of the model.

As we said before, the bottom-up approach has been contemplated with the aim of giving more “voice” to the instances of the low level workers. Given the hierarchical distance between the top management and the shop floor (especially in traditional business like the mid/big-size manufacturing industry), it is possible that what has been seen as good for the strategy form the top management, is not everything that the shop floor needs: it is difficult to look so in depth throughout an organisation. [152]

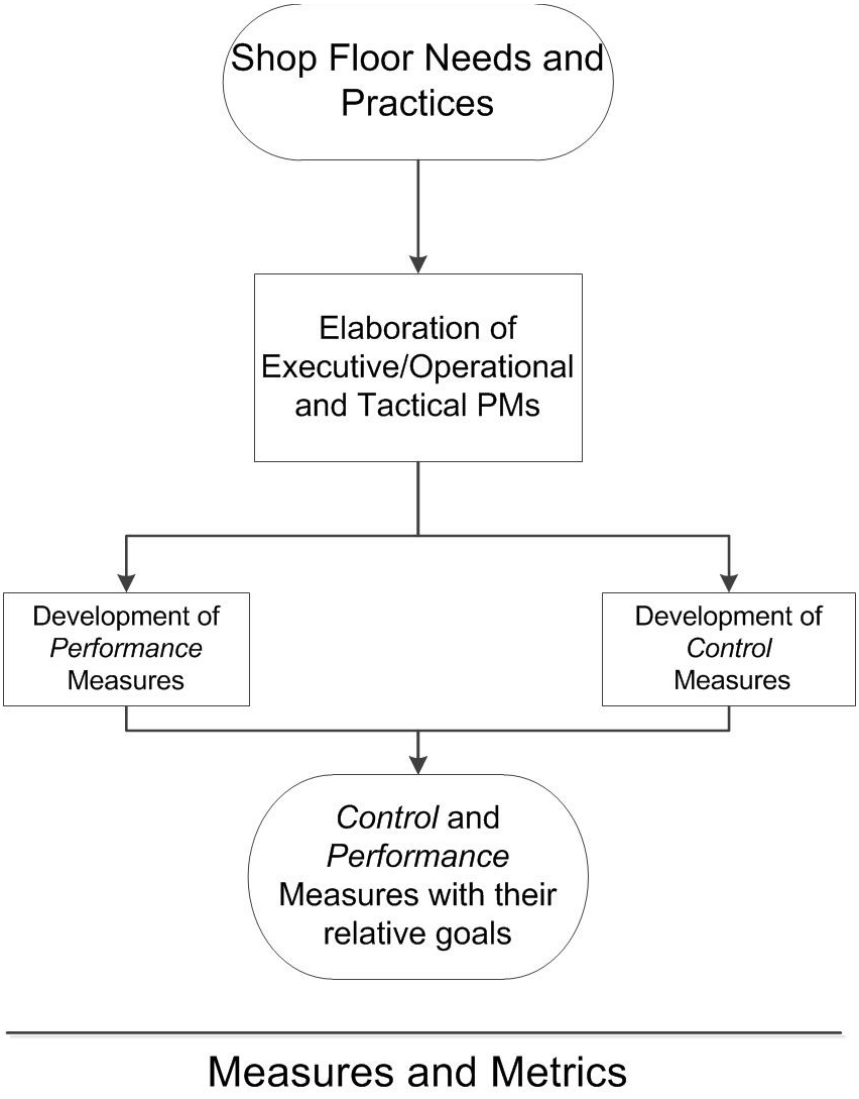

Figure 17: Scheme of the Bottom-Up Approach

[152] cf. Willaert, P., 2006, pp. 740ff

Because of this, the first step of this model is to start from these unnoticed needs, which normally drive to the practice of establishing unofficial measures together with all the problems connected (proliferation, lack of control and so on). The purpose of this step is exactly to make these needs emerge from the shop floor workers; thanks to their great on-field experience they are the real experts of the production system: they have a deep knowledge of the machines, their weaknesses and also how to extract the useful data from them.

They may leak of a global and strategic vision and this is also an aspect that we would try to fix.

The second step is the actual elaboration and development of the measures themselves: this step will be deepened in a further section (see chapter: 3.2.2.1), now we limit to say that the main sources of inspiration for the shop floor measure design are:

- The Experience and the past used measures
- The benchmarking of other companies or other department of the company itself (e.g. another production site)
- The literature and the normative.

At this point, it is important to make a distinction between the possible measures that will be designed: in this work it will be made a differentiation between *performance* measures and pure *control* measures.

Kaplan has already made this distinction, even if with different terms[153]: there the author speaks about a distinction between *strategic* and *diagnostic* measures for the BSC perspectives (high hierarchy level), but the background meaning is the same.

Using the words of the author:

> *"the diagnostic measures are those ones that monitor whether the business remains "in control" and are able to signal when unusual events are occurring that require immediate attention"*; [154]

on the other side:

> *"the strategic ones are those that define a strategy for competitive excellence".* [155]

Translating these two definitions at our interest levels, the control measure are the ones which has the task of controlling the good operation of the machines and to

[153] cf. Kaplan, R., 1996, pp. 68
[154] Kaplan, R., 1996, pp. 68
[155] Kaplan, R., 1996, pp. 68

signal if some inconvenience has occurred; moreover they can be used to empirically (thanks to the experience) forecast the possible problems or breakdowns of the machines in the presence of particular conditions.

For example in a milling machine it could be useful to record the working time of a tool coupled to a particular material in order to forecast the next tool breakdown and therefore plan a preventive maintenance/substitution and avoid an unplanned intervention. This can make the difference in fulfilling the results of particular performance measures: depending on how measures like the technical availability have been defined, avoiding unplanned maintenance can push the performance, reducing the discrepancy between the planned and the real busy time.[156]

Other control measures can be also very technical: temperature of the tool, vibrations, and so on. Many of these can be just measures required/provided by the machines themselves, but coupling them with the experience of the shop floor workers, their utility can dramatically increase.

On the other side there are the *performance* measures: which are they? and how are they different from the KPIs?

First of all they are operational measures, so they track the operational and technical performances of the machines; of course they also give some *control* information, because a bad performance is a useful feedback to control if the process is proceeding well, but they are not imposed by the strategy.

The philosophy beneath them is that they should express the performance not looking after the strategic objectives and metrics, but following once again the needs or propositions of the shop floor.

In the following lines some examples of these *performance* measures will be given. Most of them could be found in the literature: especially the norms regarding the performance measurement system of a MES. [157]

The MES or Manufacturing Execution System is "*a process-close, operating system for the manufacturing management or business management*". [158]

Just to make some examples of the different measures (of low hierarchical level) that is possible to find in this normative, we could quote:

[156] cf. pp. 53 of this work
[157] cf. VDMA 66412-1, 2009
[158] cf. VDMA 66412-1, 2009, pp.3

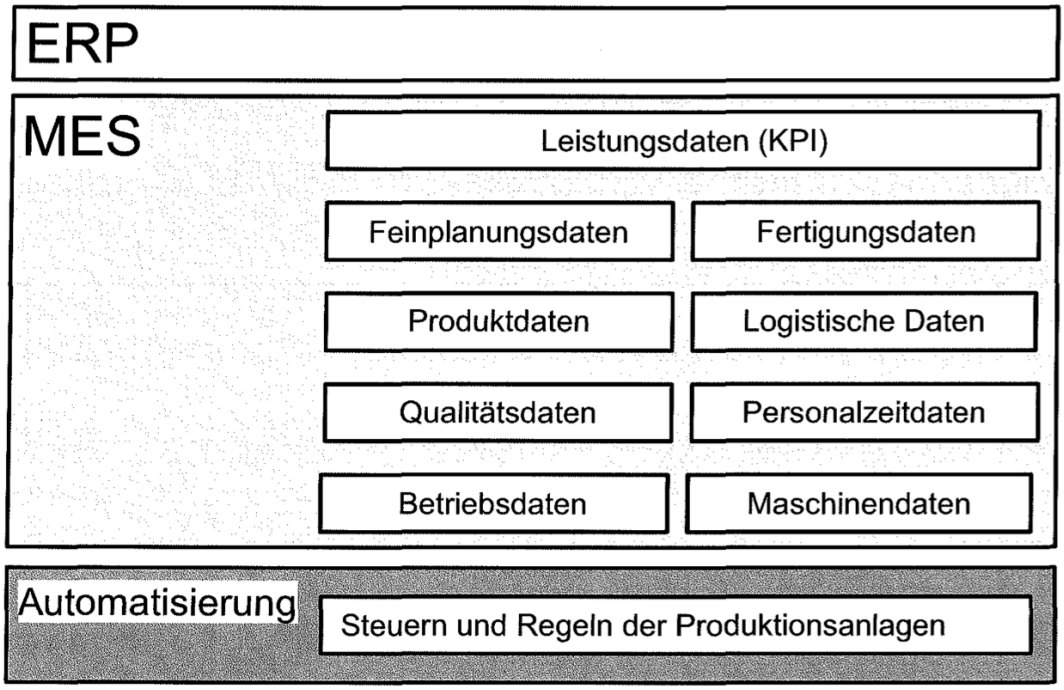

Figure 18: Scheme of the MES[159]

- Technical Availability, defined as[160]:

$$\text{Technical Availability} = \frac{\text{Production Time [s]}}{\text{Production Time [s]} + \text{Delay Time [s]}}$$

Formula 4: Technical Availability

In which the delay time is considered the time lost due to unexpected events. This measure is a ratio and can even be calculated as a percentage. The higher the value, the better it is.

This measure can be designed as a “Productivity” measure.

- First Pass Yield, defined as[161]:

$$\text{FPY} = \frac{\text{Good Inspected Pieces [\#]}}{\text{Inspected Pieces [\#]}}$$

Formula 5: First Pass Yield (FPY)

Also this measure is a ratio and therefore can be also calculated as a percentage. In this measure the units with rework are not considered: this

[159] VDMA 66412-1, 2009, pp.3
[160] VDMA 66412-1, 2009, pp.25
[161] VDMA 66412-1, 2009, pp.28

peculiarity make it different from the quality rate, in which the rework can be admitted. The higher the value, the better it is.

This measure can be designed as a “Quality” measure.

- Effectiveness, defined as[162]:

$$\text{Effectiveness} = \frac{\text{Production Time per Unit [s]} \times \text{Production Quantity [\#]}}{\text{Production Time [s]}}$$

Formula 6: Effectiveness

As the two before, also this measure is a ratio and therefore it can be calculated as a percentage. It can be considered also an indirect measure to determine the time lost in dysfunction of the process. The higher the value, the better it is.

This measure is by definition the “Effectiveness” measure.

These indicators are all composed measures (they are not absolute values), but still of very low hierarchy level: they can be as useful directly on the shop floor as on management levels.

As reported from the Normative (Figure 19), these measures are interesting from the workers to the management level.

Unternehmensebene	Werker, Meister, Leiter, Management

Figure 19: Levels of Interest for these Measures as Reported by the Normative VDMA 66412-1[163]

In analogy with the top down approach, these two different kinds of measures (performance and control) that we have identified have not to follow different developing paths, but they have to be designed by the same group-work following the same steps, in order to guarantee a certain level of coherence to the overall set of measures.

In other words, we can say that this distinction is needed in order to make clear that at operational level these two kinds of measure are needed and none of them has to be forgotten; moreover this distinction can be useful to give a better and neater categorisation of the measures.

At this step it is important to ask if this distinction is enough to lead the process of measures design or not. In the author’s mind, also other “directions” for their organisation are needed.

[162] VDMA 66412-1, October 2009, pp.21
[163] VDMA 66412-1, October 2009, pp.21

As we said, the strategy and its implications should be neglected in this approach in order to give space to the needs of the shop floor and to avoid “suffocating” them under the strategic prescriptions. On the other side it is reasonable to think that at least some strategic perspectives/visions should be considered.

Therefore in this bottom-up approach, some strategic concepts have been introduced as “directions” to lead the measures design and help in their categorisation.

It is important to have clear that these directions do not reduce the innovative power of a bottom-up approach, but they are just needed in order to “canalise” better its results.

Moreover these “strategic concepts” are not peculiar for each organisation, but they are common to any manufacturing company, which wants to compete in the modern times.

At first it is important to remark that any action and improvement in the company in order to improve its competitiveness have to follow the “Magic Triangle” [164]: Cost-Quality-Time.

Everything, especially in a production department, should tend towards the objectives of reducing the costs, increasing the quality and also reducing the time needed to transform the inputs into outputs.

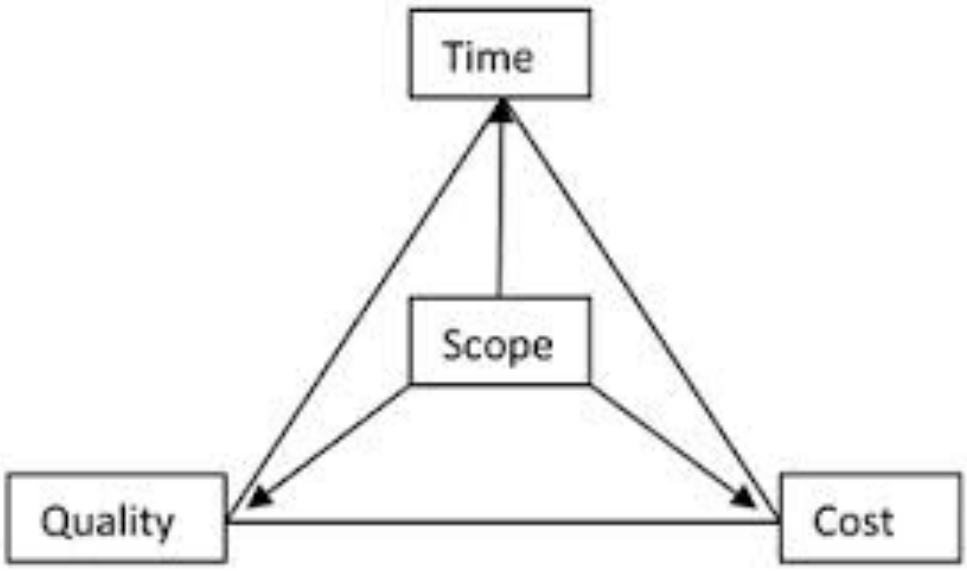

Figure 20: The Magic Triangle[165]

Trying to be more specific, it is possible to identify each measure in one particular category (or direction).

[164] cf. http://tachenn.co.uk/Project_Management.html (read on the 26/09/2014)
[165] http://tachenn.co.uk/Project_Management.html (read on the 26/09/2014)

A part from the already quoted:

- Quality
- Effectiveness and
- Productivity

We could add[166]:

- Efficiency
- Timeliness
- Flexibility

Just giving these directions cannot be considered enough, since the aim of this work is to establish a usable systematic to design measures.

Because of that, in the following section we would try to propose in details a design process suitable for a bottom-up approach.

[166] cf. Parmenter, D., 2007, pp. 15

3.2.2.1 A Hybrid Model – Bottom-Up – Design Process

At first it is important to underline a concept that has been quoted at the beginning of this work: the *modern* usefulness of performance measures resides not just in the control activity, but also in the continuous improvement circles.

It is useful to make this remark now, because it is especially at the low hierarchical levels, where the activity of continuous improvement takes place. Of course it is not a prerogative of the shop floor: in fact the KPIs (for example) have the objective of informing the top management about the alignment to the strategy and according to this information the management can take its actions, aiming to reduce the gap between the reality and the goals. [167]

On the other side it is also to say that, because of the fact that the information have to climb many hierarchical levels before coming to the management, the activity of improvement can require more time and therefore has to be centred on long-term objectives.

The feedback loops of low hierarchy measures instead are usually much "shorter" and therefore more effective in the day-by-day improvement. Anyway the level of bureaucracy and the communication style of the company can always make the difference. [168]

Given that it is much easier to understand that these measures have to be designed in order to fit inside a feedback loop; this means that they have to be accompanied by the relative goals and also the information related to the responsible parties, which have to take care of their collection and reporting as well as the ones, which has the authority and the task to take corrective decisions. [169]

Schematising in a "basic feedback loop" what it has been just said could be helpful.

This basic feedback loop (Figure 21):

> *"presents a systematic series of steps for maintaining conformance to goal/standards by communicating data back to the responsible worker and/or decision maker to take the appropriate action"* [170].

The basic elements of the feedback loop and their interrelations are:

1. *"The Sensor evaluates actual performance.*
2. *The Sensor reports this performance to a Responsible Worker.*

[167] cf. DIN EN ISO 9001, 2008, pp.7
[168] cf. Adler, P.S., 1996, pp. 61-84
[169] TRADE, 1995, pp.1-9
[170] TRADE, 1995, pp.1-8

3. *The Responsible Worker also receives information on what the goal or standard is.*

4. *The Responsible Worker compares actual performance to the goal. If the difference warrants action, the worker reports to a Responsible Decision Maker. (This could signal a need for corrective action)*

5. *The Responsible Decision Maker verifies variance, determines if corrective action is necessary, and, if so, makes the changes needed to bring performance back in line with the goals."*[171]

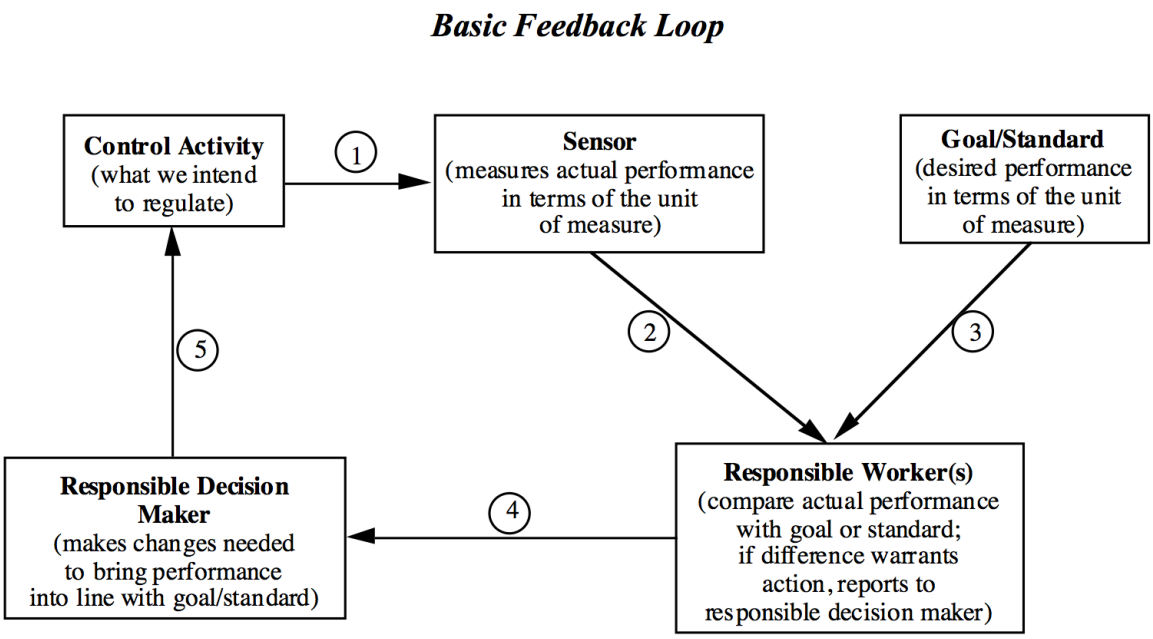

Figure 21: Basic Feedback Loop[172]

As it can be seen in Figure 21, this feedback loop has the positive point of identifying the responsible parties and to involve directly the employees in the process of measuring the performances.

Anyway this has been called a "basic" feedback loop, because it takes care just of the running process of measuring, not of the measures design. [173]

Because of this, it is possible to insert this feedback loop into an overall process for measure design (and more broader a process for the measurement activity): in this way we will have a complete overview of the different steps that can be followed to

[171] TRADE, 1995, pp.1-8
[172] TRADE, 1995, pp.1-9
[173] cf. TRADE, 1995, pp.1-1 – 1-9

establish the measures directly integrated with a control loop, which guarantee a continuous activity of improvement and also of measures maintenance.

The process that will be explained in the following lines should not be taken as prescriptive and unchangeable; it is more a

> "*guideline, intended to show the process generically. Different organisations, who best know their own internal process should feel free to adapt the guidelines where necessary to best fit within their operations.*" [174]

This process has not be thought specifically for a bottom-up approach, but due to its high "generality" it could be used as a valuable basic for the design systematic. What is fundamental is to change the prospective according to which this has to be intended; every step has to be seen always from the perspective of the worker, not of the manager; if sometimes the vision seems a bit short sighted it is normal, because this is intrinsic in the bottom-up approach. That is why it has to be integrated with another one with an overall vision: this will be made in the next sub-session.

The process is shown in Figure 22 is described as a "*High Level Block Diagram*": this does not mean that it has been thought just for high hierarchical levels design, but just that for each step, it does not go too much into details.

This diagram is organized in eleven steps; their order can be changed according to different needs of different organisations, anyway in these lines we will take care of presenting the process as it is shown in Figure 22, without avoiding of pointing out some remarks, where and when needed.

Another last premise: we will use just the structure of the reported scheme, not the contents, which were more aligned to a strategic vision.

Step 1: Identify Process[175]

In the first step, the critical processes have to be identified. This statement can sound extremely similar to a top-down approach, but what radically changes is the perspective: in this step "critical" does not refer to what is considered of great importance for the strategy, but it refers to what is seen as precarious or even problematic for the shop floor.

The criticality in this perspective is therefore more technical-oriented than strategic-oriented. In other words here we look for those processes, which cause technical problems or are of particular importance for the correct technical transformation of inputs into outputs.

[174] TRADE, 1995, pp.1-9
[175] cf. TRADE, 1995, pp.1-12

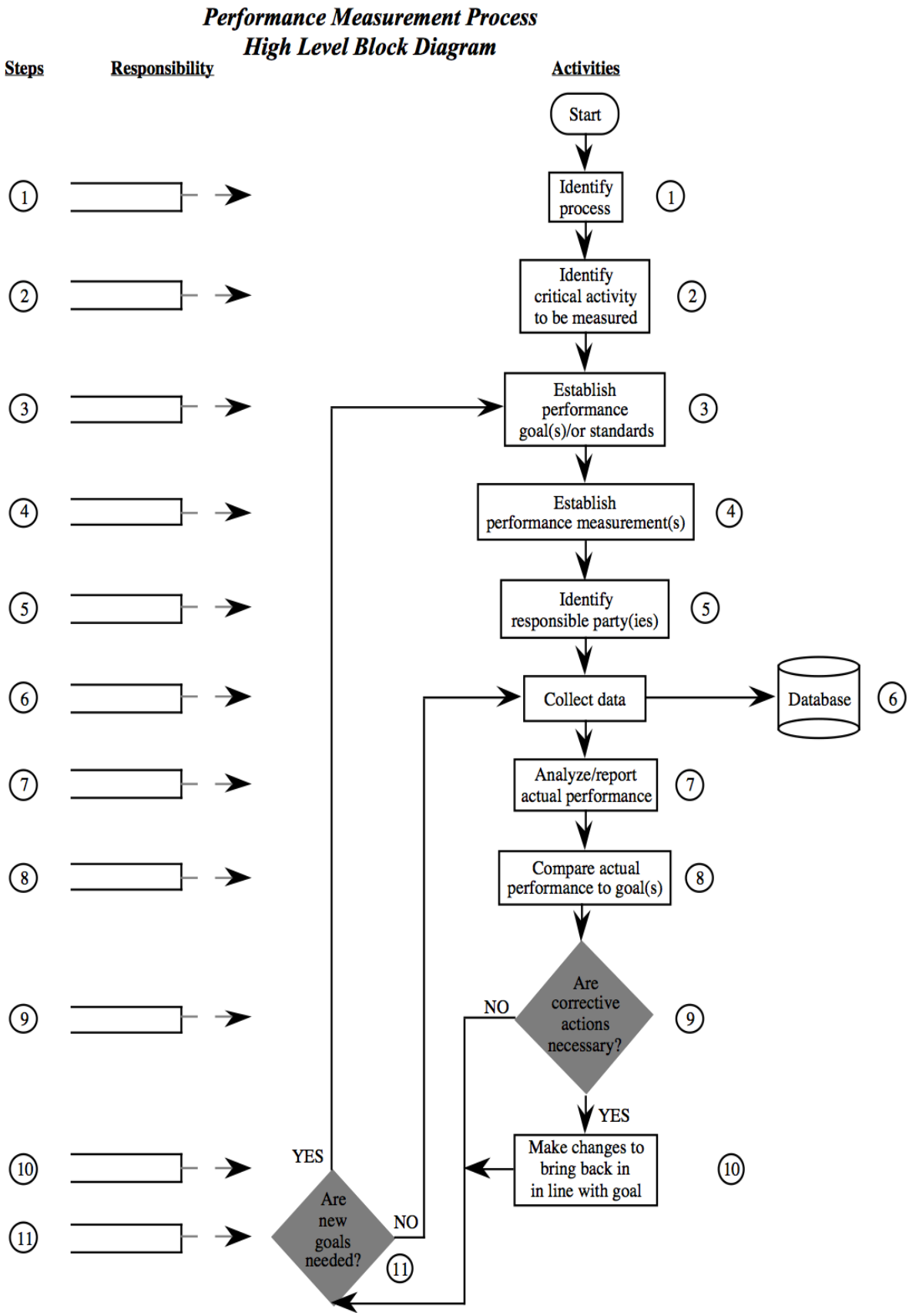

Figure 22: Performance Measurement Process[176]

[176] TRADE, 1995, pp.1-11

In a bottom-up approach a “critical process” in a manufacturing industry could be for example the metal stamping process: this is the process in which some metal sheets are printed (or formed) in order to create some semifinished products (e.g. car doors). [177]

In fact the workers can be aware of problems in quality, which force some reworking activities and some other problems in following the scheduled orders.

Probably in this process there is some margin for improvement in many sectors (the previously called “strategic directions” needed to canalise the bottom up activity), which can be connected with some specific activities that will be investigated in the following step.

As an output of this step we have a list of processes, which have been categorised as critical and which will be further examined.

Step 2: Identify Critical Activities to be Measured[178]

In this step we receive as an input all the processes, which have been categorised as critical; now it is the moment to investigate them more in detail, which activity (or activities) is responsible for the criticalities quoted before.

Identifying each critical activity is fundamental, because “*each one of them becomes the hub around which a feedback loop is constructed*”.[179] (cf. Figure 21)

Following the examples introduced before we could make this step clearer: before we have underlined problems in timeliness and quality, therefore now we have to identify the causes.

It is possible that the two effects are in reality related with the same cause: an inefficient method or procedure of exchanging the dies. It could happen in fact that this press is loaded almost at the maximum of its capacity, but the procedure by which the dies are substituted is so inefficient (time consuming) that it pushes the workers to rush dealing with it, in order to keep up with the schedule. This attitude may not give the hoped results (keep up with the schedule) and it may even introduce other problems: for example the alignment of the die could be not correct and so some quotations may not be respected; this introduces problems of quality.

It is at this point that we have to sate precisely what it is important to know about the activity that is going to be measured. Without this knowledge it is impossible to perform the measurement activity.

[177] TRADE, 1995, pp.1-9
[178] cf. TRADE, 1995, pp.1-13
[179] cf. Maskell, B.H., 1991

In the same paper from which the eleven-steps model has been borrowed, a simple sub-model for the generation of information is proposed (cf. Figure 23). Here it will be reported just few words; for more details we suggest to refer to the paper.[180]

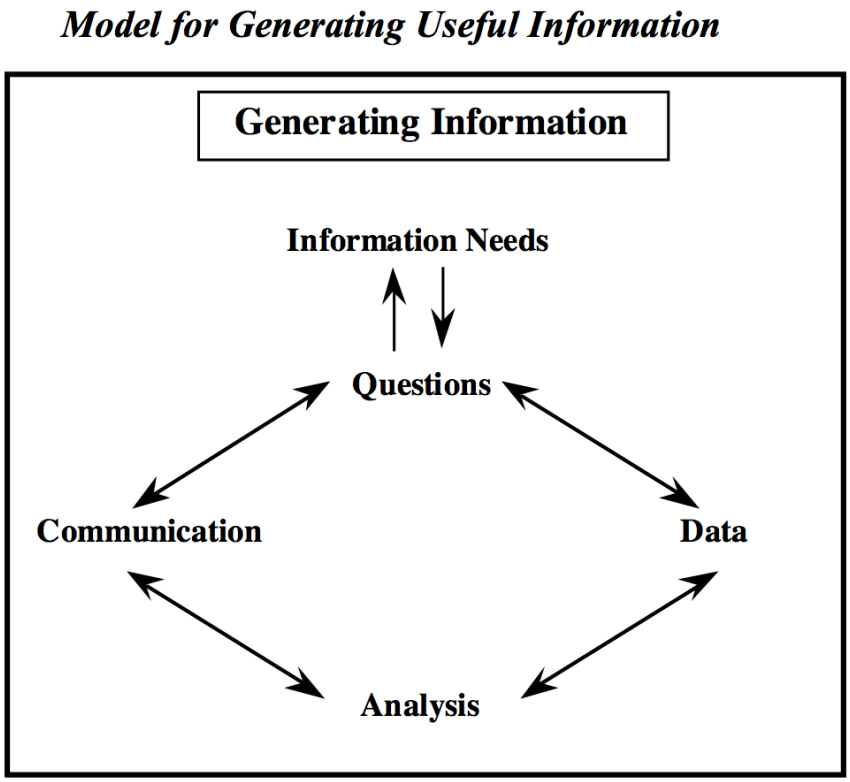

Figure 23: Information Generation Model[181]

According to this model it is fundamental to be able to answer to the question: "What do we want to know (about this critical activity)?". The central issue is then: "How do we generate useful information?"

To answer to this question we could follow the directions proposed by this model, but since we are in a bottom-up approach, we can also start relying on that great practical experience that the shop-floor workers have developed throughout the years, maybe not just in our company.

Moreover it is at this point where the previously quoted "unofficial practices" or "unofficial measures" can become useful basis on which we can construct a more reliable and efficient measure.

[180] cf. TRADE, 1995, pp. 1-14
[181] TRADE, 1995, pp. 1-14

As output of this step we have a series of critical activities for each critical process. These activities have to be monitored and measured in order to establish the feedback loop process and solve the criticalities identified before.

Before the exact identification of the measure (together with its formula) another step is needed: determining the goals.

Step 3: Establish Performance Goal(s) or Standard(s) [182]

Without a meter of comparison or an objective to aim at, the measures are useless.

Because of this, after having identified the critical activities and before designing the measures, there is the step of setting the goals.

As general, in order to be good, the goals have to be SMART[183]:

- Specific
- Measurable
- Achievable
- Relevant
- Time-Bound

Anyway it is not just a matter of goals, which assume a continuous improvement process: sometimes also standards or thresholds are sufficient for some activities or processes, which have already reached a high grade of efficiency, but whose discrepancy from standard performance could cause a domino effect.

In the activity of determining goals and standards, it is not always easy to choose the right ones, which can guarantee good performances without being too difficult to be reached.

In this environment relying on the experience of the shop floor workers and also on the benchmarking of other companies or even other internal departments can be a good way to establish fair goals/standards.

On the other hand there could be the tendency, looking from the bottom-up, of aiming not high enough and therefore agreeing on “too reachable” goals or “too confortable” standards. Moreover there is the risk of not aligning these goals to the company strategy; because of that the successive integration of the two approaches cannot be avoided (see chapter 3.2.3).

Trying to be more practical and following the previous example we could try to suggest some goals for the pressing activity. Even if the identified critical activity is

[182] cf. TRADE, 1995, pp. 1-15
[183] cf. Rohana, A., pp. 223

just one, the problems caused by it are two; therefore two different problems mean two different goals. Anyway, since the critical activity is single, we will try to solve it just with one corrective action that will be evaluated by the two different goals set before.

These two goals: improving the quality and reducing the time (cf. Figure 20) are discording at a first sight: improving the quality and contemporary reducing the setup times can be seen as conflicting in this activity. In fact, if the quality is affected by the not correct alignment of the dies exchanged during the setups, being more precise would require more time and so the objective of reducing the setup time can be even more difficult to be reached. It is here where resides the challenge of finding a new procedure for setups, which can allow reaching the two objectives. Anyway set priorities among them two, especially at the beginning can be fundamental.

Prioritizing between the two aspects, we could say that the quality one stays at the top, while the timeliness, even if important, is secondary; because of this we could set the first goal as an increase of the 20% of the quality compared to now and as a secondary goal we can set for example a monthly time reduction for this activity of the 1% starting after three months of assessment.

The objective of these goals is to stress more on the precision of the die montage (the objective of quality improvement is quite high), even to detriment of the timeliness, whose objective is less binding. On the other hand the timeliness has to be regained through the time.

In the end, as an output of this step we have a list of goals for each critical activity, within the focused process.

Step 4: Establish Performance Measurement(s) [184]

In this step of the process we will focus on the effective setting of the performance measures, with their:

- unit of measure
- frequency
- sensor

This is the core point of our process and it can be organised in several subsequent activities, which will be analysed one by one[185]:

1. translate “what do we want to know” into a performance measure
2. identify raw data
3. determine where to locate them

[184] cf. TRADE, 1995, pp. 1-16
[185] cf. TRADE, 1995, pp. 1-16 – 1-22

4. identify the sensor
5. choose the measuring frequency

In the previous step we have decided, which information we need in order to answer to the questions we have and we have also decided which goals or standards we want to reach.

In this step, we have instead to “translate into numbers” the answers we gained before.[186] In other words, in this step we determine the formula and the metrics of the measure; this decision can be still affected to some modifications according to which data we can collect. This process of translation can be done easily if the goals have been already quantified and they did not remain just qualitative ones.

For example in the case presented above we have stated that the goals for the time reduction should be of the 1% every month, while the quality indicator should reach an increase of the 20% in the good production. These goals are already represented by numbers, they are not just statements: this can help a lot in designing the measure; on the other side the precise formulas and metrics are yet to be decided.

Moreover the “same” measure can be expressed in many different variants: the choice of one measure or another can be made according to which data are more easily available or also according to which measure better conveys the data to the interested party.

After we have chosen the better way to express the needed information, we pass by to the second point of this list: identify the raw data. [187]

Which raw data do we need in order to express what we want? This step is particularly important, when the measure, that is needed to be expressed, is synthetic, it makes use different simple (or raw) data and then it combines them together in order to better express the information it carries.

The identification of raw data is more complex when the measures are of high level, but it is also true that even simple measures are composed by absolute data. In our example, in fact both the two measures are ratios: this means that they have at least two different data to be identified; moreover they both required “historical” data in order to show the improvement in comparison with the previous month.

After the identification of raw data, it is the time to determine where we can find and extract them[188]: this is not just a problem of determining the location of the data, but it also a matter of identifying where it is possible to extract the data in the easiest and most economic way, without hindering the production process.

[186] cf. TRADE, 1995, pp. 1-17
[187] cf. TRADE, 1995, pp. 1-18
[188] cf. TRADE, 1995, pp. 1-19

Before rushing in the research of data, it is also important to look in the already available ones and see if the needed data are already accessible or at least achievable from the ones we already possess.

Going back to the previous example, we had two different measures: one about quality and another one about timeliness (or productivity according to the perspective). The first one is composed by data we already possess, the production quantity and also the good quantity (we could possess just the bad production, but the good one is obtainable with a simple arithmetic operation); the second one instead could have never been recorded. Therefore it is necessary to define where and how the minutes (or seconds) needed by the operation can be collected.

This leads us to the next step Sensor Identification. [189]

In this step it is still to be practically defined how we can extract the data; in other words, where do we have to put the “sensor” and which “sensor” is to be used. With this word (sensor) it is not to be intended just a device: in fact, potentially the sensor could be also a person. In a broader sense we identify the sensor as the responsible party for the measuring or data collection: in the most automated system, this sensor is normally built in the machine and the collection is done automatically by the information software, in other systems instead it could be necessary the intervention of a person.

As a general rule, in the technical environment, in which the precision of the measure is normally of vital importance, the automatic measure should be preferred to the one which requires the man intervention: this is because dealing with human requires always to keep in mind a possible bias in the activity. The choice of automatic system, on the other hand, involves other problems connected with the technical feasibility and the costs.

In our example, sticking to the time measure, there could be two possible solutions: let us explore both.

The simplest choice is that one of the machine operators is made in charge also of:

- starting and stopping a chronometer when the procedure starts and ends,
- later reporting on a chart the time needed every time
- at the end of the month making the calculation and writing a report

The second choice could be instead of inserting a sensor (device), which detects that the procedure of exchanging die has started; it has to interact with the information system, starting a chronometer and at the end of the procedure stopping it automatically. In this solution, the data are already inserted in the information system,

[189] cf. TRADE, 1995, pp. 1-20

which can provide an immediate feedback and can also make automatically the calculation and the report when requested.

This solution is clearly more elegant and also more precise and probably more effective; on the other side it requires a performing information system and the installation of a sensor on the machine: bigger investments. This could be also difficult for technical reasons.

At last we have to determine the frequency of the measure activity[190]: how often do we have to collect the raw data and how often do we have to calculate the performance measure. This last one usually coincides with the report frequency, but it may not always be true. Therefore it could be necessary to determine three different frequencies:

- raw data collection
- performance measure calculation
- performance reporting

With this last activity the step of establishing the performance measures is completed: from the step before we have obtained the goals, now we also have a better description of the measures formula, where and how we can collect the data and also how often the measuring activity is performed.

As an output we have the performance measures and their components; in the next step we will identify the responsible parties.

Step 5: identify Responsible Parties[191]

After having defined also the measures, we have arrived at the point to determine who are the responsible workers and the decision makers.

Their main tasks are:

- Collecting the data
- Analysing the actual performance
- Comparing the results with the goals/standards
- Determining the corrective actions
- Making changes

This step should be tailored on each company, because it is difficult to prescribe something without knowing the management style of the company or the composition of its employees force and their authority.

[190] cf. TRADE, 1995, pp. 1-21
[191] cf. TRADE, 1995, pp. 1-22

On the other hand it is possible to give some guidelines in order to approach this step bottom-up. As we already said, as a management style the bottom-up approach focuses a lot on the delegation of the responsibilities; however approaching the measure designing bottom-up does not mean that also the management style consider an extreme delegation as an effective solution; sometimes the management likes to maintain the control on the organisation choosing the different responsible parties by itself. In this way they can choose the people who they trust and for the top management is easier to identify the responsibilities.

Approaching this topic bottom-up can anyway involve much more the shop-floor employees in the decisional process, probably increasing their motivation and also their engagement.

This step could be therefore the occasion for the workers to propose themselves or some colleagues for these tasks, according to their aspirations and also their self-confidence.

Especially for the decision maker, there could be a problem of authority: this responsible party needs to be able to take decisions with a certain level of independence, whose authority has to be recognised by the workers, but also by the other employees.

The output of this step is therefore a list of people (mostly proposition of names which have to be accepted by the management) with their area of responsibility.

After this step we have accomplished the pure process of performance design: now we have in fact all the instruments to perform our measurements. We know in fact the data we need, where to get them, how to collect them, how to composed them and how often to perform this activity; moreover we know all the responsible parties, not only for the measurement activity, but also the decision makers for closing the feedback loop.

Since with the next step we will be into the measurement activity itself and even if it is not exactly our focus to investigate the process of measuring, we would like to give for completeness an overview of the following steps and how they relate to a feedback control loop.

Step 6: Collect Data[192]

It is straightforward to understand that this is the step in which the data are gathered and directly organised in different collections in order make them available for the different measurements and also for the workers.

[192] cf. TRADE, 1995, pp. 1-23

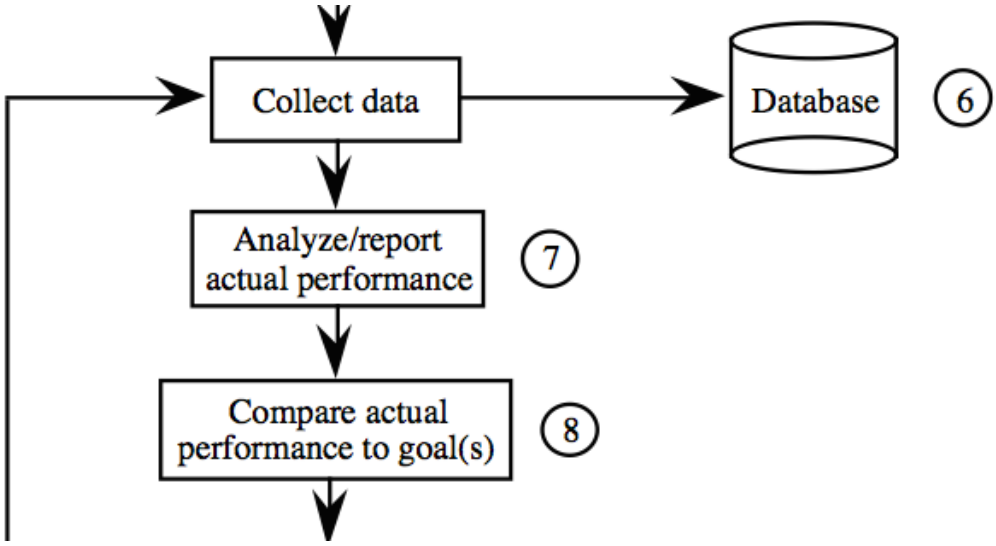

Figure 24: Performance Measurement Process – Zooming on the Measuring Activity Part[193]

As a general remark it is important that, once a single data is collected it should be made available to all the possible interested parties in the company. This is important in order to give to the biggest number of people to check the performance and also to bring improvement ideas; moreover it is important to keep them available for all the life of the PMS, because the system will not remain completely the same for all its lifespan. Some new measures could be in fact introduced (other updated and so on) and these may require the same data already used by other measures: having them available in a common database can simplify all these processes and avoid the duplication of the same information.

Another important aspect is the collection form: the data, as we said, have to be made achievable by all the people who need them; moreover it is of crucial importance that these data are offered in comprehensible and easy-to-use forms. The data do not have to show any kind of bias: they have to be objective.

As output of this step we have an increasing number of data organised in their sheets or forms. These data have to be kept monitored along the collection process.

Step 7 & 8: Analyse and Report Actual Performance & Compare Actual Performance to Goal/Standards[194]

In this step of the process the raw data collected at the step before are assembled in order to create the performance measures requested; once the data are assembled and the measures formed, they need to be analysed: in fact, as we said before, the

[193] TRADE, 1995, pp.1-11
[194] cf. TRADE, 1995, pp. 1-26

measures themselves without a comparison with their goals or standards are useless.

This step was divided in two different ones in the original paper, but in the opinion of the author this made no sense, because the activity of analyse and comparison are too bounded to be divided: moreover this was making the understanding too laborious and muddled. [195]

The performance measures are therefore compared with their goals and then a discrepancy analysis has to be made, in order to determine which are the problems causing the gap (if present) and therefore suggest the actions to be taken from the responsible parties.

Because of that normally synthetic reports are produced: in these reports the results are presented and normally complementary data are shown together in order to give the most complete view of the situation.

Of course there are different ways to display these results and speaking about them is not the aim of this work, but we can at least say that the representation changes according to the level of detail requested[196]:

- at the higher level of the hierarchy the data are summarized synthetically making use of intuitive cockpits
- at lower level instead, the focus is more on the details of the information (making use of tables, spreadsheets and diagrams), with anyway the use of simple indicators to show the status of the performance: good, fair, bad (or green, yellow, red)

As we said for the data, also the reports have to be made available to all the workers (at least the reports of the performance of their department) in order to push them to do better if the results are not satisfactory and also to recognise their good job if the goals have been accomplished.

As an output we have a series of reports of the actual performance in which a gap analysis between the results and the goals has been provided. Moreover the causes of the performances are analysed and these should be the most important inputs for the next step.

Step 9: Determine if Corrective Action(s) is necessary

This step is the one in which the decisions are taken: either the goal has to be update or it is time to take actions.

[195] cf. TRADE, 1995, pp. 1-15
[196] cf. Lohman, C., 2002, pp. 267ff

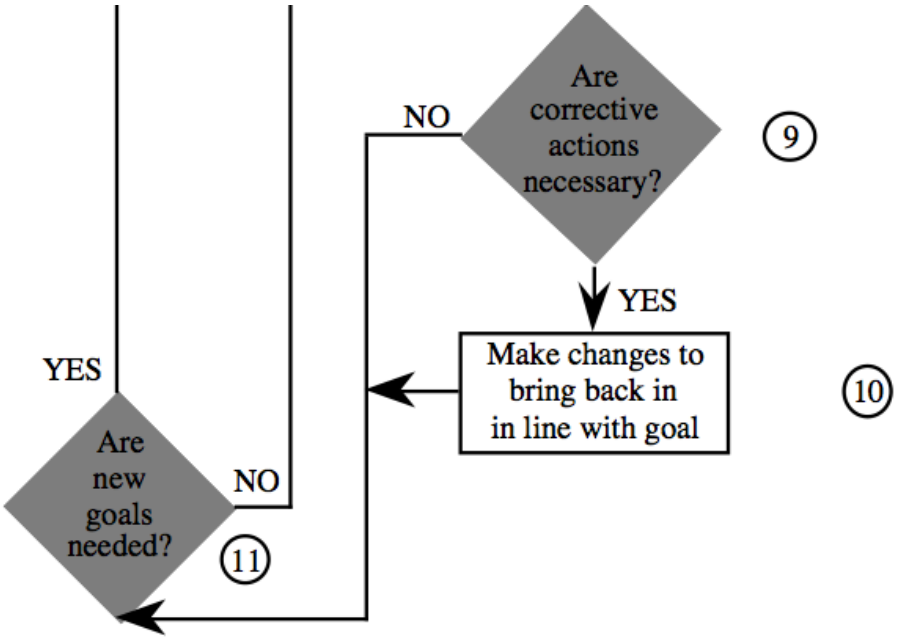

Figure 25: Performance Measurement Process – Zooming on the Feedback Activity[197]

In fact, out of the previous step we can fall in two different situations:

- the goal has been reached
- the goal has not been reached

As an answer to the first situation, the goal can be update in order to stimulate a continuous improvement.

In the second case instead, the answer can be of two different types: either the goal is recognised as too challenging and impossible to be reached even if improvements have been made, or the process is still too inefficient and therefore it is needed to take further improvement actions.

As output of this step we have an action plan to be implemented (Step 10) or a series of changes concerning the goals (Step 11).

Step 10: Make Changes to Bring Process Back in Line with Goals or Standards

This is the step, which closes the feedback loop: the plan implementation.

The changes decided at the previous step are brought into action in order to successfully push the process towards its goals. The whole control loop should continue and pass through this step until a gap between the results and goals is identified.

[197] TRADE, 1995, pp.1-11

Step 11: Determine if New Goals or Standards are Needed

Out of Step 9 (but it can be decided also after step 10, cf. Figure 25) we know if the chosen action following the gap analysis is to change/update the goals or not. If yes, this is the step designated to perform this action.

In this step it has to be decided if the goals identified as unreachable or out of date and if thy need to be updated: if yes we return to Step 3, if not the loop restarts with the collection of data (Step 6) cutting out all the measure design process.

Conclusions and Remarks

As we tried to make clear in the previous line (see chapter 3.2.2.1), the most important part of this process goes from step 1 to step 5 included: it gives a solid basic structure for a bottom-up measures design. The other steps give on the other hand an overview of the other stages to be completed to fully implement a feedback loop in a performance measurement system.

The most important thing to understand is that potentially the measures design is a continuous process, which stems from the needs evidenced by the gap analysis. Besides this continuous process, it is periodically fundamental to make an overall maintenance of the PMS, which restarts the process from the beginning.

3.2.3 A Hybrid Model – Integration of the Two Approaches.

Now that we have completed the overview on the process of Performance Measurement it is time to go back to the purposed systematic for the measures design.
As it has been already shown two different approaches are possible: Top-Down and Bottom-Up (see chapters: 3.2.1 and 3.2.2).

Each of them has some peculiarities and some particular sectors of interest; even speaking of measure design for the same hierarchical level, the perspective is different and the focus can be not the same.

On the other hand, the output of the two approaches is the same: measures defined in metrics, frequency and goals.

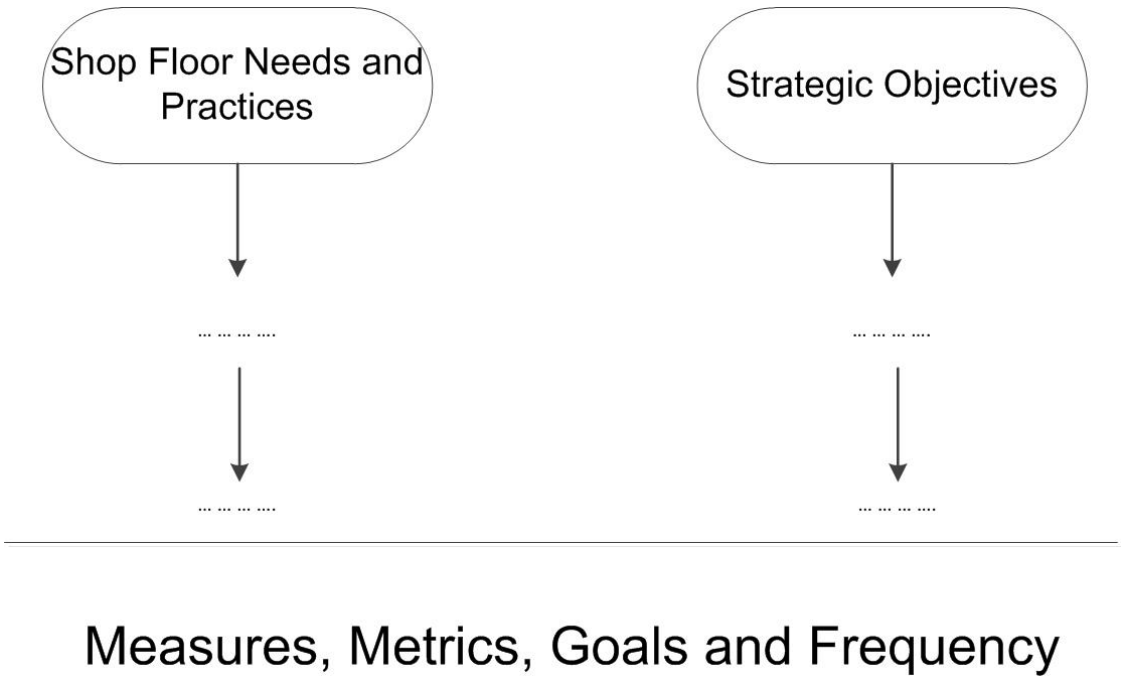

Figure 26: Résumé of the Models and its Outputs

Now there is just one step left in order to complete the systematic and produce a coherent system of measures: the integration of the results.

Why do we need a process of integration and cannot we just keep the measures as they have been designed by the two approaches (see chapters: 3.2.1 and 3.2.2)?

In order to answer to this question we have to analyse the different inconveniences that this hybrid systematic could bring.

Everything stems from the fact that the purposed systematic is basically composed by a “double” measure design, which face the project of building a PMS (for the lower hierarchical levels) according to two different perspectives[198]:

- The Top-Down bases its results on the alignment with the strategy and the measures respond just to the implementation of strategic objectives
- The Bottom-Up instead tries to put in the first position the direct workers of the shop-floor

This can be the cause of several facts, which need to be discussed:

- Some measures may have been developed *equally* by both approaches, but with some differences in metrics, frequency, etc.
- Some measures may have been developed *similarly* by both approaches, but with some more consistent differences
- Some measures may have been developed *differently* (sometimes the measures are totally different) by both approaches, but their aim or objective is the same: in other words they are two different answers to the same question
- The designed measures are flanked by different and sometimes conflicting goals, since they respond to different needs

Now we will proceed to face the problems one by one.

The first situation that we could have to face is also the easiest to solve: it can happen that from the two processes, two very similar measures have been developed. In this case we refer to very small or secondary differences, which could unreasonably duplicate the amount of measures; for example there could be differences in the frequency of collection or report (hourly and daily), or there could be a discrepancy in the metric (pieces/second and pieces/hour), etc.

These are minor differences, which could be dictated by different needs from the perspectives, but they can be easily solved[199]:

- If the PMS is strictly connected with the information system, these differences can be solved choosing one of the two and then derive the other one automatically performing a simple calculation
- If, on the other hand, the measurement activity is very delegated to the workers, it has to be chosen the best compromise among the two, in order not to stress too much the responsible party in the collection activity and the production of reports.

[198] cf. Willaert, P., 2006, pp. 740ff; cf. Parmenter, D., 2007, pp. 1-36
[199] cf. VDMA 66412-1, 2009; cf. Lohman, C., 2002, pp. 267ff

As a general remark it has to be kept in mind that in the design of a PMS should always try to contain the number of measures.

The second possible situation is that the discrepancy is a bit bigger and the solution of the problematic is not that simple. For example it can happen that measures like the Technical Availability, even if expressed by the same name and with the same purposes, are characterised by different accounting of the different time-spans: in some cases in fact the time spent in planned maintenance is considered as part of the planned busy time, sometimes not. [200]

This affects a lot the output values of the measures and therefore make the two results incomparable: one of the two has to be chosen after a comparison of the strengths and weaknesses of the two propositions. Keeping them both is not advisable, because the too much quantity of measures, especially carrying different information, can:

- cause confusion in the decision maker who has to beware in choosing always the same measure, and
- create conflicts on the results analysis among different hierarchical levels just because they look at different results for the same measure (namely)

Moreover it can happen that different measures have been developed in order to measure the same quantity or better the same activity: in this cases, it is not compulsory to choose one of the two measures, because in their difference can reside the need of divergent purposes.

For example, speaking of quality measures, there can be three different indicators, which look at the same object (the quality of the production), but they are all kept in the PMS system in order to show all the different aspects of this problem.

Beside the

$$FPY = \frac{\text{Good Inspected Pieces [\#]}}{\text{Inspected Pieces [\#]}}$$

Formula 7: First Pass Yield (FPY)

that we already explained before (see Formula 3, pp. 59), there are at least other two possibilities:

- the Quality Rate and
- the Rejects Quote

[200] cf. VDMA 66412-1, 2009; cf. Lohman, C., 2002, pp. 267ff

The Quality Rate (QR) is expressed by the following formula[201]:

$$\text{Quality Rate} = \frac{\text{Good Parts [\#]}}{\text{Produced Parts [\#]}}$$

Formula 8: Quality Rate

It simply compares the overall good parts with the overall produced parts; it makes no distinction between good parts produced with or without reworking as instead is done by the FPY.

The Scrap Quote instead is expressed as[202]:

$$\text{Scrap Quote} = \frac{\text{Scrap Parts [\#]}}{\text{Produced Parts [\#]}}$$

Formula 9: Scrap Quote

This measure can be seen as the dual of the previous one: it considers in fact all the bad parts, which do not pass the quality checks and have to be recycled or eliminated, not considering the reworked ones.

All these three measures say mostly the same thing, but they put the accent on different details that can be essential or preferable in one department or in another[203]:

- the FPY, in fact, is looking just at the parts which pass the first check; it gives a good impression of the performances of the production system. It is in fact to be remembered that the reworking of components is generally an expensive process
- the Quality Rate instead is a general index of the quality, which gives an overall view of the quality performance, putting the accent on the good parts. This index can be useful at the top management, which does not need to get into details
- the Scrap Quote instead has the same characteristics of the QR, but it looks at the problem from the other side: not “how many good parts do we produce?” (how good are we?), but “how many bad parts do we produce?” (how bad are we?)

These can seem negligible differences, but each one of these measures has a proper dignity and a reason why it has been chosen: they can be all kept, on condition that the metrics are homogeneous.

[201] VDMA 66412-1, 2009, pp. 23
[202] VDMA 66412-1, 2009, pp.27
[203] cf. VDMA 66412-1, 2009, pp.23, 27, 28

Finally we have to discuss the most important discrepancy that can arise in this double measure design: the goals divergence.

As we said, since two design processes with different approaches have been performed (see chapters: 3.2.1 and 3.2.2), it is possible (probable) that the there is discordance in the goals or standards assigned to the various measures.

The general situation can be that the goals proposed by the top-down approach, following the strategy demands, are too demanding: in the top-down approach in fact the goals are normally assigned through the deployment of the strategic objectives, preventing some freedom to the production department in their choice. [204]

On the other hand the goals established through the bottom-up approach can be too easily reachable and sometimes even discording with the strategy. (cf. chapter 3.2.2)

Besides these “simple” cases, which can be treated simply looking for a compromise between the two parties, there can be also other cases in which the compromise are not enough: the goals in fact can be conflicting, showing diametrically different solutions to the same problems. [205]

This difference in the goals setting is not to be considered exclusively as a bad thing: in fact having a double view of the same topic can be always enriching, giving hints to the both sides on how the solutions can be different. On the other hand a decision has to be taken and not always a compromise between the two is possible. In these cases, the proposition of the strategy is anyway hierarchically superior, since it is normally based on a broader view of the company and its objectives.

On the other side, if the goals are very distant and almost conflicting, it means that either there is a problem in transmitting the strategy to the lower levels, or it can sound as an alarm to the top management showing them that their vision is too distant from the real situation of the shop floor and its needs.

It is therefore necessary a harmonization (win-win solution) of the different conflicts, which will try not to impose one on the other, but which will try to find a fruitful compromise. [206] Anyway the arisen of conflicts has not to be seen as a disgrace or a bad signal: it is better in fact that, especially speaking of performance goals, the conflicts show up in the design stage than during (or, even worse, after) the normal production process flow.

Until now we have just focused on the procedure of the systematic proposed by this work, but it has not been said, who will take care practically of following the systematic.

[204] cf. Willaert, P., 2006, pp. 740ff; cf. Parmenter, D., 2007, pp. 1-36
[205] cf. Fry, T.D.; Cox, J.F., 1989, pp.52-56 (quoted from: Neely, A., 1997, pp. 1132-1134)
[206] cf. Willaert, P., 2006, pp. 740ff; cf. Parmenter, D., 2007, pp. 1-36

This aspect is not to be neglected, moreover it covers a fundamental part of the model; therefore it will be discussed in the following section.

3.2.4 A Hybrid Model – The Participants

Who will have to participate into the design of the measures for the PMS? This is the question that we will try to answer in this section.

First of all it is important to keep in mind how important is to involve the more workers as possible in the performance measures design. Essentially for two reasons[207]:

- The more participants are involved, the more ideas can emerge from the discussion: in this way having different points of view can sensibly enrich the final solution
- The more the workers are involved in this process, the more their commitment and their motivation increase

This is the reason why this work wants to propose a combined systematic, which includes also the employees of the shop floor that normally are forgotten in the measures design process. [208]

On the other side it is not even possible to think that all the employees of a company should be able and called to participate to this activity. In fact the performance measures design is a time consuming process, which has to follow some steps and needs a certain amount of time in order to reach its final definition. [209]

The examples reported in literature require always a long time span because many difficulties can occur and also because the time in which the human capital is available to participate to these kinds of projects is always limited. Moreover it always takes longer to fully implement a whole PMS and see all the needed measures correctly designed, collected and visualized.

As an example, the work of Bourne et al. (Figure 24), which has developed and implemented an entire PMS in three different UK companies, reports:

> *"In all three cases, the initial performance measurement system design was completed over a period of four months in four or five facilitated half-day workshops. However, it then took another 9 to 13 months before the performance measures reached the stage of being regularly measured, reviewed and displayed."* [210]

[207] cf. Adler, P.S., 1996, pp. 61-84; cf. Willaert, P., 2006, pp. 740ff; cf. Parmenter, D., 2007, pp. 1-36
[208] cf. Willaert, P., 2006, pp. 740ff
[209] cf. Parmenter, D., 2007, pp. 1-36; cf. Neely, A., 1997, pp. 1131ff; cf. Neely, A., 2000, pp. 1119ff; cf. Lohman, C., 2002, pp. 267ff
[210] Bourne, M., 2000, pp.760

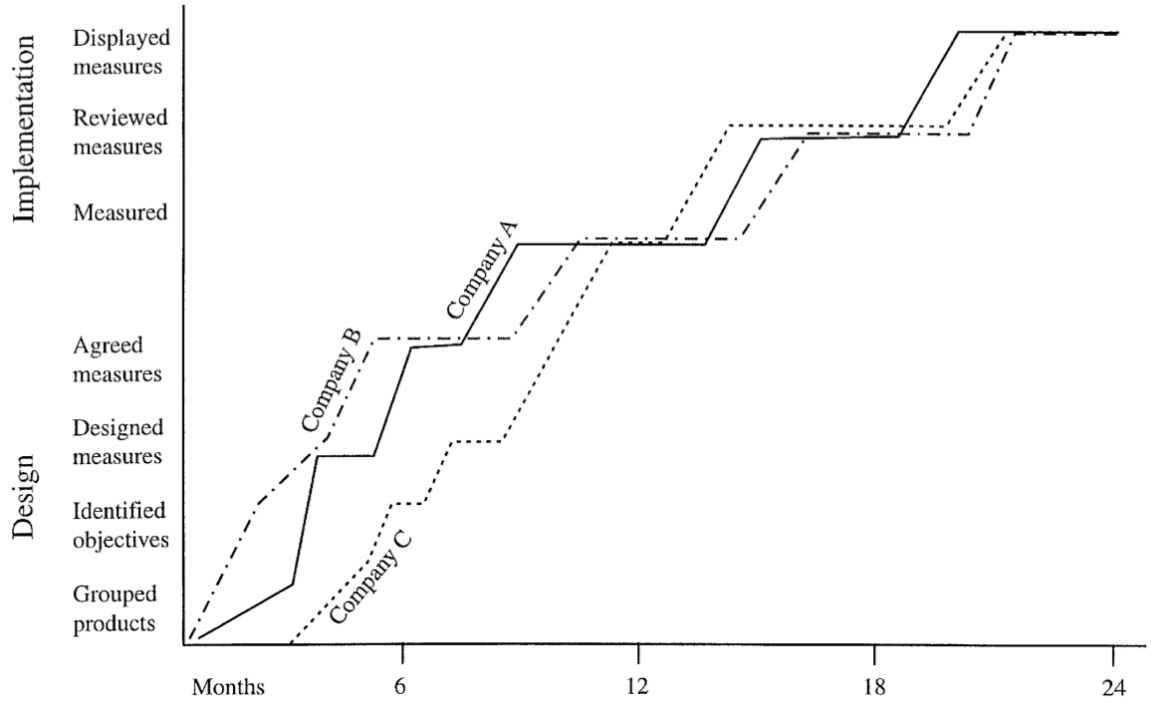

Figure 27: Performance Measurement System Implementation[211]

Another example of a project developed by Lohman et al. in a full-time activity by a research group took six months[212]: in this case it has to be underlined that the PMS design has not been developed by the company managers, but they were used just as "consultants" for the research group. This has for sure reduced the time needed: in fact if the same job were made by the managers and workers themselves as a part-time activity, it would have taken more or less the double.

These examples are here to underline that there is a trade off between involving in this process as many people as possible and the needs of the company, which cannot afford to employ so much workforce in this project.

Given the previous consideration we would like to propose now a solution for this model.

As stated by Bourne et al. and reported also by Azavedo, the activity of performance measures design is *cognitive* or *conceptual*: they therefore require an "environment", which stimulates the cognitive performance and the emerging of ideas. [213] [214]

The proposition of this work is to develop the measures in workshop sessions internally to the company, with, as participant, employees of the company itself; this

[211] Bourne M., 2000, pp. 760
[212] cf. Lohman et al., 2004
[213] cf. Bourne M., 2000
[214] cf. Azevedo S., 2013

solution is quite common to many works in the literature and it is also at the base of some interesting papers like the ones by Lohman, Bourne, Neely, Parmenter and many others. [215]

The workshops allow the participants to share their ideas and propositions using all the method typical of group-work (brainstorming, the 635 method, the De Bono's six hats, etc.); moreover they can be a good meeting point among different hierarchical levels of the company. In fact normally the managers and the shop floor workers struggle to meet each others, because of different working places and different working tasks; "forcing" them to meet and work together can be an important opportunity to share the different views.

As stated before the chosen number of people involved in this process should not be the result of the trade-off between as many people as possible and the money lost from the reduction of capacity due to the reduction of available workforce. Moreover the number of people in workshops, especially in team working, should not exceed the limits: a minimum number of 3, 4 and a maximum number of participants of 7, 8. The lower boundary is necessary, because otherwise the process has not enough "minds" and, according to the theory of team working, the problem of too few ideas produced could appear: this because of the little number of participants but also because some phenomena like "group thinking" can arise and affect the workshop results. On the other side, instead, increasing too much the number of participants can make the group work sterile, because the possible many different perspectives can be hardly canalise towards a productive output.

In this work it will be proposed the institution of two distinct groups, one for each approach, with a number of 4, 5 members. This number does not want to be prescriptive, but it is just a suggestion for an optimal compromise. On the other hand this number has to be discussed company-by-company according to the own needs and also to the own restrictions.

In fact, this number is referred to big/medium size companies; if on the other hand this systematic is adopted in smaller organisation, in which 10 people are too many, it is of course possible to reduce the number of the group members. In other words this parameter can be tailored on specific needs.

On the other hand there are some specific characteristics, which have to be maintained in order to do not invalidate the process.

First of all it is fundamental to keep the hybrid structure of the systematic also in the structure of the workshops. How does this translate in practice?

[215] cf. Parmenter, D., 2007, pp. 19-104; cf. Lohman, C., 2004, pp. 267ff; cf. Bourne, M., 2000, pp. 754ff; cf. Neely, A., 2000, pp. 1119ff

The membership of the participants in each group should be split in:

- One half representative of the management
- One half representative of the shop floor

The first ones should bring the “strategic vision” proper of the high hierarchical levels into the group, while the second ones should bring their operational experience.

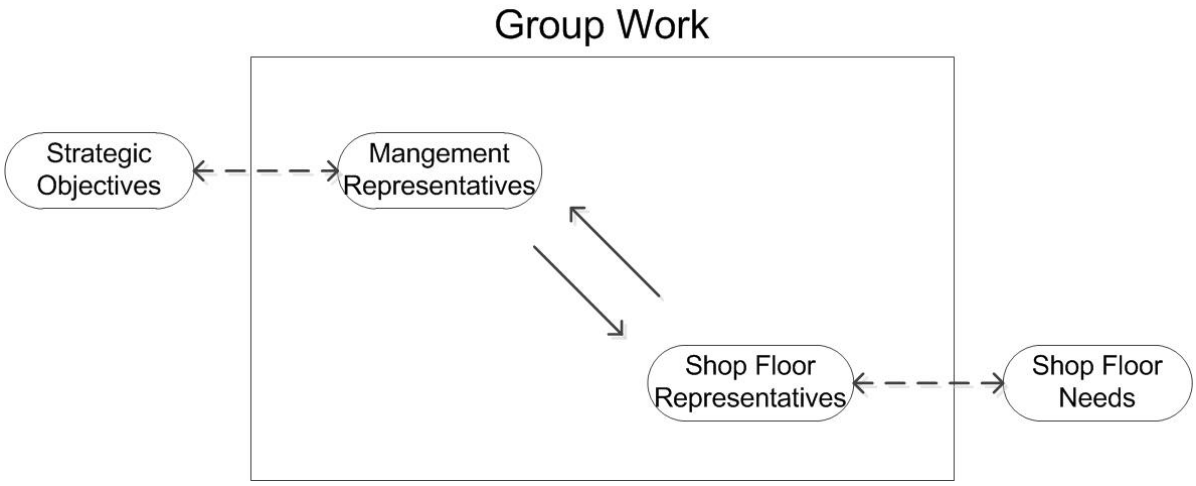

Figure 28: Scheme of the Group Works

The question that can directly arise is why we should make “mixed” (hybrid) groups if the model is already hybrid: “isn’t it a repetition?”.

In the view of the author it is not, moreover it is coherent with the approach of the whole project and it is even necessary for the success of the systematic: in fact making mixed groups has the objective of mitigating the differences of the two perspective.

If we had separated the participants in:

- Representative of the management in the top-down approach
- Representative of the shop floor in the bottom-up one

the two groups would have been too much inward-looking giving as results measures, metrics and goals that could have shown too many differences: these differences could be complicated to be solved with any compromise.

In other words we can say that the presence of representatives of the shop-floor in the group in charge of developing the top-down approach are there to mitigate the request of the strategy and also to give an insight in which are the constraints of the real production site. On the opposite side, the representative of the managers in the bottom-up group have the purpose of giving strategic hints to the shop-floor workers.

Now we will try to give a better look inside the work of the workshops.

In the top-down one (see chapter 3.2.1) the objective is to deploy the 1° level KPIs imposed from the strategy to the lower levels and, if required, to develop a system of 2° level KPIs, which can support the production director in achieving the strategic objectives. As we will better explain later, the production manager should not be involved directly in the workshops; he/she has to delegate to his/her representatives the implementation of the strategy. [216] In this environment the shop-floor workers do not have the purpose to contest every strategic decision, but, as already said, they have to fully support them with the scope, at the same time, of mitigating the requests, which seem out of range according to their previous experience.

Speaking more factually, they should try to mitigate too high demanding goals or, given their better practical knowledge of the machines, they have to point out questions of feasibility for some particular measure collections or sensor positioning.

On the other side, in the bottom-up approach the roles revers themselves: the operative level representatives should be in this case the spokesmen of the shop-floor needs and they should be the ones leading the procedure of measures design. The management representatives, on the other hand, should sustain the process putting themselves in the position of the workers, but giving an insight in which the strategic objectives are.

Trying to be more practical, their objective should be the one of trying to push as far as they can the goals set bottom-up and then, always speaking about goals, trying to avoid that the objectives diverge too much from the ones that a coherent strategy could require. [217]

The consequent important aspect is that, the two groups do not overlap in the process running: they need to be independent, otherwise too much influence from one side or the other can badly affect the results and prevent a sort of "*double check*" of the results proposed form the two approaches.

Making a brief summary of the lines before, at this point some aspects about the participants in the process should be clear:

- There should be a mixed composition of the participants either from the management side, either form the shop floor side
- The number of participants is limited
- There should not be any super position of the members between the two groups

[216] cf. Parmenter, D., 2007, pp. 31, 45, 77ff
[217] cf. Parmenter, D., 2007, pp. 77ff

- The direct responsible of the department should not directly take part to the workshops

This last aspect is till to be deepened: why should not the manager take directly part to the workshops? The answer can be very easy: it has not so much time to dedicate to this single project even though it is very important. Beside this superficial, but true, answer, there is also another argumentation: the process of performance measures design should remain (in a first moment) as much "independent" as possible. [218]

The presence of the department head-manager can affect the decision and the discussion during the group work, but mostly it is important that he/she remains external to the design process till the integration phase.

It is important that his/her contribution arrives in the second phase of the design process, when it is the moment to take the final decisions and also some compromises have to be taken. [219]

It is important to remember that the results of the two designing processes are not definitive measures, but they are mostly propositions of measures and in some cases there could be overlapping or conflicts between them and their goals.

In those situations, the only responsible to take decisions is the department manager and nobody else, therefore it is fundamental that he/she will face the integration phase in a totally objective way: it is also to remember that one of the good aspects of this systematic is the fact that same problem is observed from two different perspectives, which can bring good and new ideas that the other would have never considered. It is therefore fundamental to face them without any bias.

In order to help the manager in this activity it is also to consider the recourse to an external facilitator: an expert in the field of performance measuring, who is external to the company and who has the task of helping in the integration phase.

He has two main purposes:

- Make the negotiation fruitful among the two parts, helping them to reach a fruitful compromise in the case of conflicts or discordant visions
- Help the responsible manager in maintaining fully objectivity

The use of an external facilitator is quite common in this kind of projects: we find them in the work of Bourne as academic facilitators, in the works of Neely and also in the work of Wouters. [220]

[218] cf. Parmenter, D., 2007, pp. 44ff
[219] cf. Parmenter, D., 2007, pp. 44ff
[220] Bourne, M., 2000, pp. 759ff; Neely, A., 1997, pp. 1150; Neely, A., 2000, pp. 1120ff; Wouters, M., 2009, pp. 64ff

As reported in the work of Wouters:

> "*An outsider can be instrumental to unearth existing experiences and to help people expressing new ideas. But the facilitator is not just ''taking notes''. The facilitator also brings the ideas of employees to a next level: the facilitator knows about utilizing information systems and tools, can find data in the organization's information systems, makes prototypes of concrete measures, and gently brings fresh ideas to the table. The facilitator needs to be an expert on PMS design, but this expertise is for the most part used to ask questions, to clarify, to compare and challenge ideas, to sometimes make suggestions, to build things, and to ask for feedback. The facilitator/expert is not there to ''Design and Implement'' nor to deliver a ''turnkey PMS''*"[221].

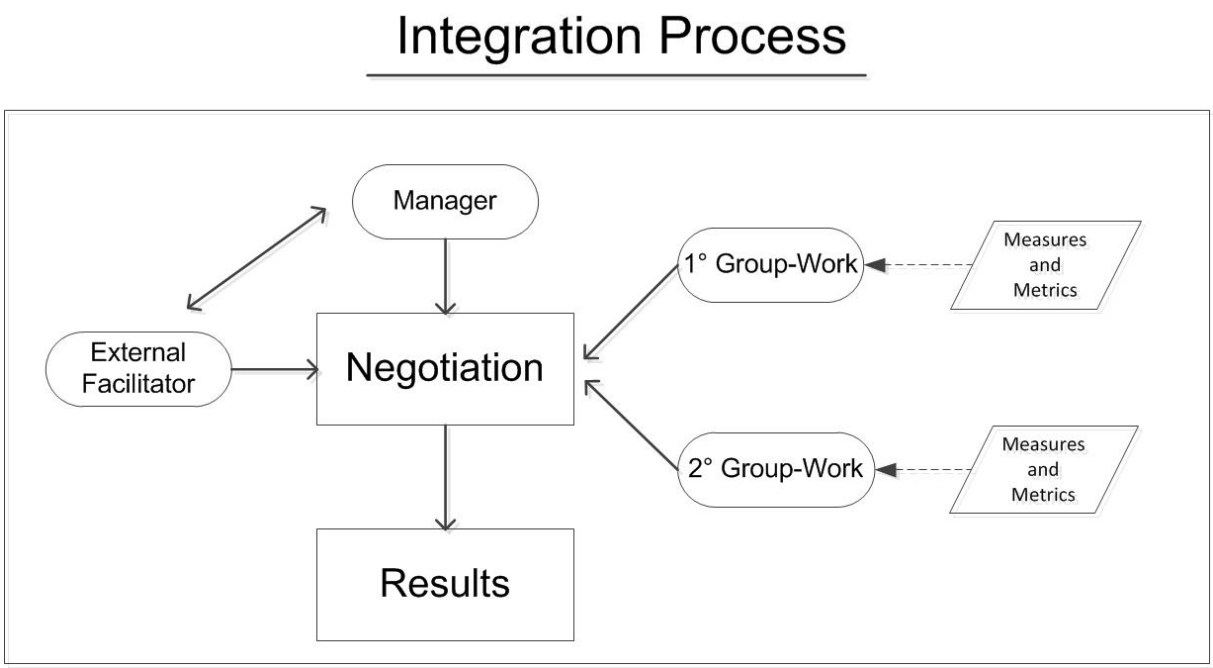

Figure 29: Integration Process with the External Facilitator

The contribution of the external facilitator can be very useful also in the process of of measure designing; the choice of not involving him/her in there is due to the fact that normally (if he/she is not an academic involved in a research project) has to be paid for his/her contribution. Since the model is "double" it would have required the facilitator for the double of the time (or two facilitators), therefore, in order to contain the possible cost, it has been chosen to limit his/her presence just to the second phase of the work, where it is essential.

[221] Wouters, M., 2009, pp.72

The last aspect that we would like to examine, before making some conclusions and remarks about this section, regards how the members of the two groups have to be chosen.

Concerning the representatives of the management, since they should be in quite high hierarchical positions in the department, the choice is not that broad: they should be chosen from the department manager among his/her staff.

On the other side it becomes more complicated to choose the members among the shop floor workers; in order to maintain a complete bottom up approach the representatives should be chosen on a voluntary basis by the workers themselves. Anyway it is important that they satisfy some conditions like:

- A certain experience in the production department (a fixed number of years)
- A broad knowledge of the entire production process (previous job rotation)

They have to be as “delegates” of the shop floor workers: that is why, even during the performance measures designing, they should keep a tight relationship with the shop floor in order to have the broader base of ideas as possible.

3.3 Useful Tools

Before passing to the section in which we will draw some conclusion and remarks about this model, we would try to propose some useful tools, obtained from the literature, which can be really helpful in the accomplishment of the process of measures designing.

In this chapter, we would like just to give an overview of their main treats and their utility. For a better and detailed description, we will remind to the Appendix (see chapter 5) and further more to the original papers.

The tools identified have to be taken as suggestions, not as prescriptions: the usage or not of these tools/methods does not prevent the good performance of the systematic and moreover they might be substituted by other similar tools, which better suit to the needs of the specific company or which result more advanced to the responsible of performing the measures design.

The critical parts of the methodology are, as the reader can have already noticed, the actual running of the two approaches for the measures design and the following integration of the specific measures, metrics and goals.

In this framework, according to the author, two aspects seem of primary importance:

- The possibility of an effective comparison of the different measures
- The capacity of choosing among them some measures to eliminate, because they have been found useless or in order to contain their number [222]

In order to face the first aspect, a framework developed by Neely exactly for the performance measures development and categorisation will be introduced, while regarding the second problem some other analytical tools like the Analytical Hierarchy Process and the Interpretative Structural Modelling will be explored. [223]

The Performance Measures Record Sheet, proposed by Neely in 1997, helps in comparing the different measures, because it gives a complete and straightforward framework for their categorisation, in which, not only the main traits, but all the characteristics of the performance measure are made explicit. Moreover, applying this as a support in the measures design, also the process itself becomes easier. [224]

[222] *It is useful to remember that the aspect of containing the measures number is of primary importance, in order to not create a PMS composed by too many measures. A PMS, in which it would result impossible to have a clear vision of the company performance, because the decision maker would be confused or overwhelmed by their number.*
[223] cf. Neely, A., 1997, pp. 1131ff; cf. Saaty, T.L., 1980; Azevedo, S., 2013
[224] cf. Neely, A., 1997, pp. 1131ff

Beside this, as we said, we would like to propose two other tools: they have been not developed specifically for the performance measures design, but, since they are less methodological and more analytical, they can be easily applied to our situation.

The first is the Analytical Hierarchy Process. As its name can suggest, it is a method based on mathematical procedure, which has the purpose to suggest a hierarchy among some options, basing itself on input values given by the user. It is normally used for decision-making and in our case can be extremely helpful in hierarchically categorise the different measures obtained as output of the two work-groups. [225]

The second one is instead the Interpretative Structural Modelling (ISM). This is another analytical model, based on mathematical rules, which aims to identify the hidden structure and relations among the measure themselves. In the process of measures integration (see chapter 3.2.3) the structure and relation behind them cannot appear always clear, making the decision of keeping or discarding some measure even more difficult. With this process, instead, applied to our cases and in general to a PMS, we have the possibility of developing the understanding of the relations among the performance measures and identifying indispensable ones from the ones in surplus. [226]

[225] cf. Saaty, T.L., 1980; cf. Rangone, 1996
[226] cf. Azevedo, S., 2013; cf. Attri, R., 2013

3.4 Conceptual Model - Conclusions and Remarks

In this chapter we have tried to explain the model in its details; we have started with some premises necessary for the understanding of the model itself, we defined also the boundaries of its application and then we have faced the model.

As it has been explained the model is *hybrid* and it combines the two possible approaches in the performance measures design: the top-down and the bottom-up.

With the first we have tried to accomplish the need of transmitting the strategy even at the shop floor level and with the latter we tried to build a brand new systematic for developing performance measures starting from the needs of the production workers. This bottom-up approach is the most interesting among the two, because it is one of the first times in which it has been attempt to start from the bottom and build up the measures needed by a PMS (See chapter 3.2.2).

This work has not limited yet to introduce these two approaches, but it has also consider the need of the integration of the two; it is in this step, where the strength of this research resides: trying to exploit the strengths of the both two approaches in order to fix each other weaknesses or limits.

In order to help the participants to this process and the manager, some useful tools have been identified: they have been briefly introduced in the previous section and they are extensively explained in the appendix (see chapter 5).

4 Conclusions

In this last chapter we would like to draw some considerations and some remarks about this work; moreover would like to underline the new research paths that it will open.

First of all, it is better anyway to make a brief summery of what it has been treated in this work, starting from reminding the initial requests and showing the obtained results.

This work has stemmed from the need of investigating which are the most modern forms of Performance Measurement Systems and in particular how these Systems can be compiled; in other words, how to design performance measures. These measures, as already said in the introduction (see chapter 1), should be seen as the foundation of a bigger decision support system. In fact, as should be clearer now (cf. chapter 2.3), the PMSs are no more just control tools, but holistic systems, whose final purpose is to be managing and decision support systems.

As explained in chapter 3, the focus of this work has not been the whole performance measurement system, but it has been circumscribed just to the operational, executive and tactical measures of the production department of a manufacturing company.

In particular the objective of this work has been to focus on the operational measures, mainly because of two reasons:

- The strategic measure design has been already fully investigated in the field literature and a further work on this topic would have not brought the aimed innovation
- Moreover, nowadays, it is even more and more clear that in order to improve the efficiency, effectiveness and flexibility of manufacturing companies it is needed to close the gap between the top management and the shop floor workers: involving the last ones in the process of performance measures design through a bottom-up approach is a first step in this direction.

As just said, the scientific research on the strategic driven measures is already at an advanced stage, while a general study in the operational levels has been always obstructed by the peculiarities of these departments in the different companies.

It is in this frame that this works inserts itself and tries to bring new energy to the research in the field: in fact it tries, founding itself on the most modern literature, to develop a flexible and coherent systematic for the design of the performance measures of the bottom levels of the organisation.

Moreover this work has not just limited on refocusing the attention of the research in the field to the lower levels, but it has also tried to introduce a new way of designing the measures, which separates itself form the traditional top-down strategy driven approach.

This work in fact has tried to combine the two possible approaches (top-down and bottom-up) in a hybrid model, which, as already said (see chapter: 3), tries to cover the weaknesses of the one with the strengths of the other.

This aspect represents the great newness of this research: in fact the bottom-up approach applied to a systematic for the performance measure design represents an *unicum* in the scientific research.

This represents a great virtue of this work, but it also represents one of its criticality: in fact, because of the lack of literature background on this topic, the systematic has been developed brand new, trying to apply the most modern concepts in the operative levels of the organisation. Concepts derived from the *World Class Manufacturing*[227] and the *Lean Production*, which have been very useful for the developing of the bottom-up systematic, have been a great source of inspiration.

Anyway the challenge of the work was not just limited to the developing of the bottom-up systematic, but also to the integration with a top-down one: building a hybrid model. One of the conclusions of this work is in fact that, even at the shop floor level, avoiding the strategy is almost impossible, if the objective is to create a coherent PMS.

The strategy in fact has a very dominant position in the modern PMSs (BSC, KPIs, …); forgetting about its existence in designing part of them would be an error that could hinder the success of the company itself.

The PMSs have changed their nature since the birth of the BSC: from simple *control systems*, they have become the executive instruments for managing a company, aligning all the departments of the organisation to the needs of the strategy. Because of that the strategy has permeated in all the levels of the organisation reaching also the shop floor.

On the other side, at the lower levels, the strategy is not everything, and the contribution of the experience of the workers could be extremely valuable in developing operational measures. Therefore creating a structured bottom-up systematic, which allows this experience to emerge, can help in closing the gap between the top management and the shop floor, creating many positive effects on the PMS and also on the employees in terms of motivation, involvement and commitment.

[227] Maskell B.H., 1991

Despite the difficulties connected with the conceptualisation of the hybrid systematic, another critical part of this work has been the development of the practical organisation of its participants. The literature in this field has given a marginal help, because in many works this topic was not deepened enough (or not even touched), while in others the organisation was extremely tailored on the specific characteristics of the company.

Because of that, the author has produced a workshop model (cf. chapter 3.2.4) relying on general theories of team/group work and analysing the few examples present in the literature (especially regarding the need of an external facilitator), basing its result on a rigorous process of induction and deduction.

Therefore this section (cf. chapter 3.2.4) has been meant to be mostly a suggestion (not a prescription), which can be (or has to be) tailored on the specific needs of each company.

About this, two aspects appeared to be anyway unavoidable for the good performance of the systematic:

- The total separation of the two group works
- The presence of an external facilitator at least in the integration phase

The first, as already said (see chapter 3.2.4), in order to maintain the independency of the two results; the second, in order to bring an objective point of view in the discussion, helping the department manager to look at the trade off more objectively.

In conclusion we can say that the biggest achievement of this work are:

- Having produced a brand new systematic for the performance measures design, which theoretically answer to the needs of flexibility, effectiveness and coherence, putting in this way the foundation for an effective decision support system.
- Filling a lack in the field literature: for one of the first times trying to create a systematic with the bottom-up as the approach for the measures development
- Making a first step in this direction, giving new impulse to the research in this topic

On the other side we cannot consider this work exhaustive: as already said, this is just a first step forward in this research field, but a long way has yet to be done.

In particular, as already said, this work has shown the potentiality of this new hybrid approach just theoretically: in fact, because of delays and also time constraints, it has been impossible to test/implement it practically or even have a confrontation with the company’s experts in the field.

Introducing in this work a practical application of the systematic and also having the possibility to confront the developed ideas with the experience of companies' employees could have added a significant value to it.

This should be the natural next step stemming from this work, because, we have not been able yet to close our feedback loop, which is essential to evaluate the effectiveness of this work.

Moreover, because of the potentialities underlined previously (cf. chapters: 2.6.2, 3.2, 4) in this thesis, more work should be done researching the possible applicability of the bottom-up approach in measures design, involving especially those companies, which base the most of their business on the activity of shop floor and which wants to finally try to close the hierarchical gap between the top management and the shop floor.

5 Appendix

In the appendix to the work we treat more in details some useful tools, obtained from the literature, already quoted in chapter 3.3, which can be really helpful in the accomplishment of the process of measures designing.

We will focus on each method in details and we will reserve for each one of them its own section.

5.1 Neely's Performance Measures Record Sheet

Before getting into details of what this Performance Measure Record Sheet (or Framework for measures design) is, it is important to explain which are the reasons that require its usage.

As it can be understood from its name, it consists of a predetermined sheet in which all the measures and their characteristics are recorded in order to compose a uniform framework for the performance measures categorisation.

In our two systematics we have focused on how to achieve the results, but we have not introduced a way to represent the obtained measures; the focus here is not in terms of reports visualisation, but in terms of measures description.

This aspect is not to be underestimate in the process of measure design:

> *"Designing a performance measure, however, involves much more than simply specifying a robust formula. For issues such as the purpose of the measure, the frequency of measurement and the source of data all have to be considered. Despite the high level of academic and industrial interest in performance measurement, no one appears to have addressed the simple, yet fundamental question, what does a well-designed performance measure constitute?"*[228]

Previously in this work (see chapter: 2.2), we already stressed on the fact that the *performance measure* is not to be considered just as a formula, but many other aspects like the metrics, the frequency (of collection and reporting) and the goals make it complete; anyway we did not face this aspect in its whole extent and complexity.

Moreover, as we will see later, filling in all the elements required by this framework helps in looking at all the important aspects for a measure definition. At last, this record sheet shows its utility if we think that the measures developed by the two

[228] Neely, A., 1997, pp. 1131-1132

approaches have to be compared and integrated: a common framework helps considerably in this operation.

Now we will pass to give an overview of this framework, for more details it is advisable to refer to the original paper.

	Recommendation	Source
1	Performance measures should be derived from strategy	[1,5,13,23-27]
2	Performance measures should be simple to understand	[21,23-28]
3	Performance measures should provide timely and accurate feedback	[1,13,24]
4	Performance measures should be based on quantities that can be influenced, or controlled, by the user alone or in co-operation with others	[13,23,24]
5	Performance measures should reflect the "business process" – i.e. both the supplier and customer should be involved in the definition of the measure	[13,23,24]
6	Performance measures should relate to specific goals (targets)	[13,24,28]
7	Performance measures should be relevant	[23,24,26]
8	Performance measures should be part of a closed management loop	[5,13]
9	Performance measures should be clearly defined	[13,24]
10	Performance measures should have visual impact	[21,24]
11	Performance measures should focus on improvement	[21,23]
12	Performance measures should be consistent (in that they maintain their significance as time goes by)	[23,24]
13	Performance measures should provide fast feedback	[24,25]
14	Performance measures should have an explicit purpose	[13]
15	Performance measures should be based on an explicitly defined formula and source of data	[13]
16	Performance measures should employ ratios rather than absolute numbers	[13]
17	Performance measures should use data which are automatically collected as part of a process whenever possible	[13]
18	Performance measures should be reported in a simple consistent format	[23]
19	Performance measures should be based on trends rather than snapshots	[23]
20	Performance measures should provide information	[24]
21	Performance measures should be precise – be exact about what is being measured	[24]
22	Performance measures should be objective – not based on opinion	[24]

Figure 30: Recommendations Summery for Performance Measure Design[229]

[229] Neely, A., 1997, pp. 1137

The author (Neely), after having performed a deep literature review (performed also in other independent papers), has tried to recollect some common recommendations, which have been made by different authors about the characteristic of *good* performance measures (cf. Figure 30). [230]

Starting from this list of recommendations, the author proposed a framework consisting of ten elements, which refers to the different requirements of these recommendations.

The ten elements are[231]:

1. Measure
2. Purpose
3. Relates to
4. Target
5. Formula
6. Frequency
7. Who measures
8. Source of data
9. Who acts on the data
10. What do they do

The element *measure* can be translated as "title" of the measure. According to Neely:

> "*The title of the measure should be clear. A good title is one that explains what the measure is and why it is important. It should be self-explanatory and not include functionally specific jargon*." [232]

With the second element (the purpose), we ensure that it is clear why the measure has been introduced: if in fact a measure lacks of any explicit purpose, it can be questioned quite easy, why it has been developed and introduced in the PMS.

In this third element of the framework, according to Neely, the business objectives to which the measure is related to have to be specified; this responds to the recommendation (number 1 in Figure 30) by which the measures have to be derived from strategy: this can seem conflicting with our purpose of avoiding the strategy influence from the measure designing, but first of all this framework could be adopted also in the top-down approach and even in the bottom-up one, if we translate the *business objectives* with the *needs of the shop floor*, the apparent conflict is directly solved.

[230] cf. Neely, A., 2005, pp. 1228ff
[231] cf. Neely, A., 1997, pp. 1136-1140
[232] Neely, A., 1997, pp. 1136

The fourth element is the measure target: it is nothing else then the explication of the measure goals. It should be clear now that the goals have always to accompany a well-designed measure. Their definition can be quantitative (always) or qualitative (sometime): this is the place to make it explicit.

The fifth element is the core of the measure description: the formula with its metric. As underlined by Neely the characteristics of the formula can deeply affect the behaviour of the employees themselves and also the profitability of the company. If, in fact, the measure, together with the goal, is wrongly specified and wrongly perceived by the employee, it can lead the worker to act in a totally opposite way to the one imagined by the performance designer. Extremely significant in this topic is the example reported in Neely's work, proposed by Fry and Cox in their work *Manufacturing performance: local versus global measures.*[233]

The sixth element of the framework is the already quoted aspect of the frequency: it is important that it is underlined not only the frequency of collection, but also the one of reporting. As we already said (see chapter: 2.2 and 3.2.2.1 Step 4), they are distinct and they, most of the time, do not match; therefore it is important to make them explicit.

As seventh element, the responsible of the measure collection and reporting has to be identified. Not necessarily the two people coincide, so if they are different, they both have to be specified.

After that, it is important to report the source of the raw data:

> "*The importance of this question lies in the fact that a consistent source of data is vital if performance is to be compared over time.*" [234]

The ninth and tenth elements regard who has to act and what he/she has to do with them. In other words the people responsible for closing the feedback loop are identified here. Quoting Neely:

> "*This is probably the most important element contained on the performance measure record sheet, not because it contains the most important information, but because it makes explicit the fact that unless the management loop is closed, there is no point in having the measure*"[235]

In the paper some different applications of the framework are proposed; in Figure 31 we take one example table to show how a complete framework looks like.

[233] cf. Fry, T.D.; Cox, J.F., 1989, pp.52-56 (quoted from: Neely, A., 1997, pp. 1132-1134)
[234] Neely, A., 1995, pp. 1140
[235] Neely, A., 1995, pp. 1140

Title	New business won
Purpose	To enable us to track cumulative progress versus plan
Relates to	Business objectives – "achieve sales targets", "increase market share" and "achieve financial returns"
Target	100 per cent of contracts targeted
Formula	Orders received versus orders targeted (expressed as percentage)
Frequency	Monthly
Who measures?	Sales manager
Source of data	Order book
Who acts on the data?	Sales director
What do they do?	Identify shortfalls in performance and investigate reasons
Notes and comments	This measure will require us to introduce a new management process – namely the screening of contract opportunities

Figure 31: New Business Won – Performance Measure Record Sheet[236]

In the end the author has asked two questions:

- *"Are the measures that are produced good measures?*
- *Does the record sheet simplify the process of designing measures?"*[237]

The answer to both of these questions is yes: even if not all the recommendations could have been accomplished (some of them were not good recommendations), the most important aspects of the measures were fulfilled.

According to the second question, as we said, the answer is positive, because it allowed the participants of the different applications reported in the paper to have a better insight in the nature of the measure itself, even leading them to change their first impression/idea.

In conclusion, as we have seen, this framework can provide a useful tool for the measure designing: it covers all the notable aspects of the measures and, as the results of the work show, the measures produced exploiting the framework are good, complete and clear.

Moreover this framework is perfectly compatible with our systematic, since they both cover the same aspects (see chapter 3); in addition it shows a notable utility for the comparison and integration of the measures obtained as outputs of the two different group-works: exactly what we were looking for (see chapter 3.2.3).

[236] Neely, A., 1997, pp. 1144
[237] Neely, A., 1995, pp. 1141

5.2 Analytical Hierarchy Process

The second tool presented in this chapter is the Analytical Hierarchy Process (or AHP). It has been presented by Thomas Saaty in 1980 and it is an effective tool for dealing with complex decision making, and for aiding the decision maker to set priorities and make the best decision. [238]

Saaty developed this process, not for a specific application, but in general for all the cases in which making a decision can be difficult and therefore there is a need of an analytical (and therefore objective) help. Its wide range of usage makes it useful also in the performance measurement field and it can help to compare different measures and set priorities among them. The work of Rangone is a clear example in this topic[239]:

> "*The purpose of this article is to contribute to address this problem, by showing the application of the analytic hierarchy process (AHP) to measuring and comparing the overall performance of different manufacturing departments on the basis of multi-attribute financial and non-financial performance criteria*". [240]

In Rangone's view the AHP helps to integrate different measures into a single score for ranking decision alternatives; in particular the AHP can be used to compare and make decisions about the performance of different departments, but given its broad applicability, it can also be used to prioritize the performance measures themselves. Quoting Rangone again:

> "*Recently the AHP has been applied to several and heterogeneous decision problems, e.g. investments appraisal, projects selection, human resources evaluation, vendor rating. However, little attention has been given so far to the application of the AHP to performance measurement, although the AHP seems to be suitable also to compare the overall results of different responsibility centres within a company when multi-attribute performance criteria are used.*" [241]

In its work Rangone uses this process to compare the overall performances of different factories of a multinational firm; we will limit to suggest the AHP as a tool for prioritizing the performance measures outcome from the systematic.

Before getting more in details into the description of this process, it is important to recall its utility for this work: after that the two different workshops have performed

[238] Saaty, T.L., 1980
[239] Rangone, A., 1996
[240] Rangone, A., 1996, pp. 105
[241] Rangone, A., 1996, pp. 106

their process and have “produced” the measures, it is the moment of running the integration of the measures themselves, in order to integrate them in a coherent and effective PMS. This operation is normally delegated to the department manager (or the one in charge of it), who, with the help of an external facilitator, has to solve the possible problems or discrepancies between the two sets of measures.

As already said, this is not an easy task and the help of an analytical tool can be extremely useful.

The AHP can perfectly absolve this task: in fact its structure considers a set of evaluation criteria (priorities) and a set of alternative options (the measures) among which a decision is to be made. It is important to note that, since some of the criteria could be contrasting, it is not in general true that the best option is the one, which optimizes each single criterion, rather the one, which achieves the most suitable trade-off among the different criteria.

In the following lines we will try to give a brief overview of how the AHP works.

First of all we have to say that the AHP works on the basis of pairwise comparison, it generates a weight for each evaluation criterion according to the decision maker’s pairwise comparisons of the criteria. The higher the weight, the more important is the corresponding criterion.

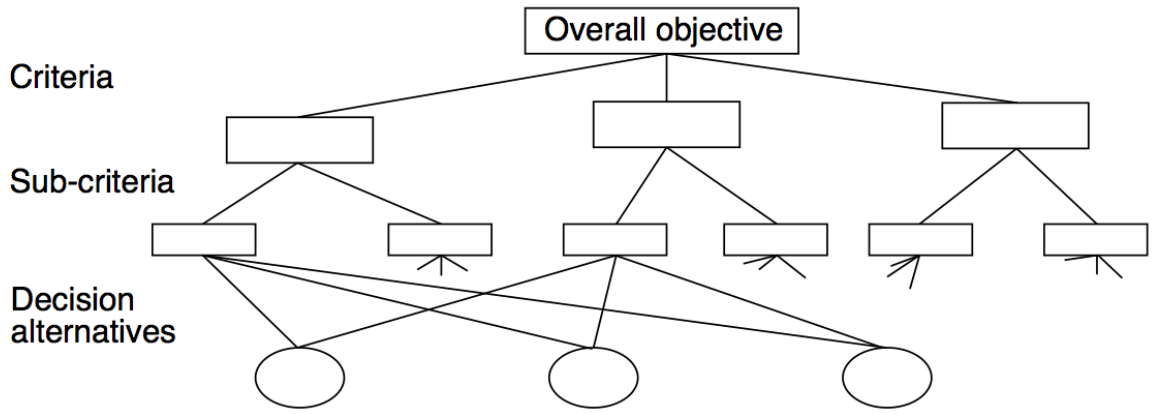

Figure 32: Hierarchical Structure of a Decision Problem[242]

Next, for a fixed criterion, the AHP assigns a score to each option according to the decision maker’s pairwise comparisons of the options based on that criterion. The higher the score, the better the performance of the option with respect to the

[242] Rangone, A., 1996, pp. 106

considered criterion.

In the end the AHP combines all the different weights and it creates a global score for each decision alternative; based on each global score, it composes a consequent ranking of the options. The global score for a given option is a weighted sum of the scores it obtained with respect to all the criteria.

The proper formulation of the method is quite extensive and in this work it is not of our interest to describe it in every details; therefore in the following lines we will show the basis of its formulation, some spotlights as example and we will make some consideration about its features. For more information and an extensive application we remind to the already quoted works of Saaty and Rangone. [243]

The AHP can be performed following three consequent steps:

- Computing the vector of criteria weights
- Computing the matrix of options scores
- Ranking the options

Everything starts with the computation of the pairwise comparison matrix **A**: it has dimension *m*x*m*, where m is the number of the evaluation criteria considered.

Each entry a_{jk} of the matrix **A** represents the importance of the *j*th criterion relative to the *k*th criterion. If $a_{jk} > 1$, then the *j*th criterion is more important than the *k*th criterion. If two criteria have the same importance, then the entry a_{jk} is 1. The entries a_{jk} and a_{kj} satisfy the following constraint: $a_{jk} \cdot a_{kj} = 1$. Obviously, $a_{jj} = 1$ for all *j*. The relative importance between two criteria is measured according to a numerical scale from 1 to 9.

Value of a_{jk}	***Interpretation***
1	*j* and *k* are equally important
3	*j* is slightly more important than *k*
5	*j* is more important than *k*
7	*j* is strongly more important than *k*
9	*j* is absolutely more important than *k*

Figure 33: Values and Interpretations of a_{jk} [244]

[243] cf. Saaty T.L., 1980; cf. Rangone A., 1996
[244] Mocenni, C.: The Analytic Hierarchy Process
http://www.dii.unisi.it/~mocenni/Note_AHP.pdf (read on the 27/09/2014)

The phrases in the “Interpretation” column of Figure 33 are only suggestions, and they may be used to translate the decision maker’s qualitative evaluations of the relative importance between two criteria into numbers.

Once the matrix **A** has been calculated its values can be normalized (a_{jk}) as well as the criteria weights vector **w**.

Reporting an illustrative example from the literature, the comparison matrix **A** and the corresponding weights vector can look like this[245]:

$$\mathbf{A}=\begin{bmatrix}1 & 3 & 5\\ 1/3 & 1 & 3\\ 1/5 & 1/3 & 1\end{bmatrix} \quad \mathrm{w}=\begin{bmatrix}0.633\\ 0.261\\ 0.106\end{bmatrix}$$

After this step, the matrix of options scores **S** has to be calculated: before we have to calculate a pairwise comparison matrix **B**, which is built for each of the *m* criteria. It has dimension *nxn*, where *n* is the number of options evaluated and each of its entry represents the comparison between two options: the value one means that the importance of the two options is the same.

Following the previous illustrative example, the **B** matrices would look like this[246]:

$$\mathrm{B}^1=\begin{bmatrix}1 & 3 & 7\\ 1/3 & 1 & 5\\ 1/7 & 1/5 & 1\end{bmatrix} \quad \mathrm{B}^2=\begin{bmatrix}1 & 1/5 & 1\\ 5 & 1 & 5\\ 1 & 1/5 & 1\end{bmatrix} \quad \mathrm{B}^3=\begin{bmatrix}1 & 5 & 9\\ 1/5 & 1 & 3\\ 1/9 & 1/3 & 1\end{bmatrix}$$

In order to build the vectors constituting the **S** matrix each entry is divided by the sum of the entries in the same column, and then the entries are averaged on each row, thus obtaining the score vectors $\boldsymbol{s}^{(j)}$, *j=1, ... ,m*. The vector $\boldsymbol{s}^{(j)}$ contains the scores of the evaluated options with respect to the *j*th criterion.

Finally we can compose the matrix **S** as: $\mathbf{S}=[\boldsymbol{s}^{(1)} \ldots \boldsymbol{s}^{(m)}]$[247].

$$\mathrm{S}=[s^1 \quad s^2 \quad s^3]=\begin{bmatrix}0.643 & 0.143 & 0.748\\ 0.283 & 0.714 & 0.180\\ 0.074 & 0.143 & 0.072\end{bmatrix}$$

As third step we have to rank the different options, by doing this we have to multiply the obtained matrix **S** with the vector of weight obtained before: $\boldsymbol{v}=\mathbf{S}\cdot\boldsymbol{w}$, where the vector **v** is the vector of the global scores.

As last step, the components of the vector have to be organised in a decreasing

[245] cf. Mocenni, C.: The Analytic Hierarchy Process http://www.dii.unisi.it/~mocenni/Note_AHP.pdf (read on the 27/09/2014)
[246] cf. Mocenni, C.: The Analytic Hierarchy Process http://www.dii.unisi.it/~mocenni/Note_AHP.pdf (read on the 27/09/2014)
[247] cf. Mocenni, C.: The Analytic Hierarchy Process http://www.dii.unisi.it/~mocenni/Note_AHP.pdf (read on the 27/09/2014)

ranking, in order to facilitate the understanding of the results. [248]

$$v = S \cdot w = \begin{bmatrix} 0.523 \\ 0.385 \\ 0.092 \end{bmatrix}$$

In the illustrative example the first option results to be the most preferable.

In order to conclude this presentation it is important to make some remarks[249]:

- The AHP is a very powerful and flexible tool, because the results are obtained according to the criteria and options proposed by the user: this allows a great control on the tool itself from the decision maker, which guides any decision according to its experience. In other words it does not take away decision power to the responsible, but it helps him in conveying its ideas.
- On the other hand it requires many calculations and their number can exponentially explode due to the dimension of the problem. Normally for our application, this should not be an issue, because the options proposed should be limited to two or one or two more (double systematic)

In conclusion we can say that the AHP can be a useful tool in the integration decision-making process.

Before passing to the next session, it is worth to underline that beside the AHP there is a similar analytical method, which, instead of providing a hierarchy among the options considering the criteria completely independent, tries to establish a similar framework for the decision making admitting the interdependences among the choices and the criteria. This method is called: Analytical Network Process (ANP).

The choice between one and the other depends on the nature of the decision that has to be made: are the criteria independent? Use the AHP. Are the criteria interconnected? Use the ANP.

[248] cf. Mocenni, C.: The Analytic Hierarchy Process http://www.dii.unisi.it/~mocenni/Note_AHP.pdf (read on the 27/09/2014)
[249] cf. Mocenni, C.: The Analytic Hierarchy Process http://www.dii.unisi.it/~mocenni/Note_AHP.pdf (read on the 27/09/2014)

5.3 Interpretative Structural Modelling

At last, in this section it will be introduced another methodology, which can be extremely useful in the process of integration of the two sets of measures produced by the two work-groups.

With the previous section, we have investigated a method, which can help a lot in the building of the hierarchy among the different measures; now this work wants to propose another method, which aims more to identify the hidden structure and relations among the measure themselves.

Quoting from the work of Azevedo et al.:

> *"Its (of the ISM) basic idea is to use experts' practical experience and knowledge to decompose a complicated system into several elements and construct a multilevel structural model. ISM can also be used to identify and summarize relationships among specific variables, which define a problem or an issue."*[250]

In particular the work of Azevedo shows how these *specific variables, which define a specific problem or an issue* can be exactly the performance measures (in this case of supply chain) of a PMS. [251]

The applicability of this methodology is anyway very broad, and it has been applied in many different fields:

> *"ISM can be used at a high level of abstraction such as needed for long range planning. It can also be used at a more concrete level to process and structure details related to a problem or activity such as process design, career planning, strategic planning, engineering problems, product design, process re-engineering, complex technical problems, financial decision making, human resources, competitive analysis and electronic commerce."*[252]

In the following lines we will try to investigate more deeply what the ISM is and how it can be useful for our purposes.

The first time this approach was proposed is in the 1973 by Warfield and, taking inspiration from his words, it is possible to say that:

> *"The ISM approach is normally deployed to uncover shared mental models. The shared mental models can be treated as a tentative*

[250] Azevedo, S, 2013, pp. 215
[251] Azevedo, S, 2013, pp. 215
[252] Attri, R., 2013, pp. 6

> *theoretical framework because it captures how respondents commonly understand and explain a phenomenon under consideration."*[253]

In other words the ISM can be defined as a process, which helps the human beings to understand better what he/she knows and what he/she does not; it tries to show the structure of related elements and therefore it helps to develop a structured model of their relations.

This capability applied to our cases and in general to a PMS helps a lot in developing the understanding of the relations of the performance measures and can help to identify indispensable ones from the one in surplus.

Before looking into the results of the work of Azevedo and their importance for this work, it is important to see how it practically works.

Quoting Attri again:

> *"ISM starts with an identification of variables, which are relevant to the problem or issue, and then extends with a group problem-solving technique. Then a contextually relevant subordinate relation is chosen. Having decided on the element set and the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of variables. In the next step, the SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived."*[254]

Some points have to be clarified:

- What it is a Structural Self-Interaction Matrix (SSIM)
- What it is a Reachability Matrix (RM)

The SSIM is a matrix, normally built from an experts group or anyway by the responsible for the ISM, which explains the relation among the different variables. In particular it works comparing pairs of variables each time; therefore it shows the relationship between variable *i* and *j.* In particular four different symbols are used to explain the possible nature of the relationship:

- V: measure *i* will help achieve measure *j*
- A: measure *j* will be achieved by measure *i*
- X: measure *i* and *j* will help to achieve each other

[253] Azevedo S., 2013, pp. 215
[254] Attri R., 2013, pp. 3

- O: measure *i* and *j* are unrelated

In order to understand better these signs it can be useful to look at Figure 34.

	8	7	6	5	4	3	2	1
1. Inventory level	O	V	V	V	X	V	V	
2. Operational costs	O	O	O	O	V	A		
3. Lead time	V	V	V	O	O			
4. Business wastage	O	O	O	X				
5. Environmental costs	V	O	O					
6. Delivery time	V	V						
7. Customer satisfaction	V							
8. Cash-to-cash cycle								

Notes: V – measure *i* will help achieve measure *j*; A – measure *j* will be achieved by measure *i*; X – measure *i* and *j* will help achieve each other; O – measure *i* and *j* are unrelated

Figure 34: Example of a SSIM for PM of the Supply Chain[255]

This SSIM is then converted in the Reachability Matrix (RM): the symbols A,V,X and O are substituted by values of 1 or 0 according to the following rules:

- If the (*i, j*) entry in the SSIM is V, then the (*i, j*) entry in the reachability matrix becomes 1 and the (*j, i*) entry becomes 0.
- If the (*i, j*) entry in the SSIM is A, then the (*i, j*) entry in the reachability matrix becomes 0 and the (*j, i*) entry becomes 1.
- If the (*i, j*) entry in the SSIM is X, then the (*i, j*) entry in the reachability matrix becomes 1 and the (*j, i*) entry becomes 1.
- If the (*i, j*) entry in the SSIM is O, then the (*i, j*) entry in the reachability matrix becomes 0 and the (*j, i*) entry also becomes 0.

The result can be seen in the Figure 35.

Once the reachability matrix is obtained, the method prescribes to make a partition of the previous matrix: this partition is made for each measure and it is made between a "reachability set" and an "antecedent set."

> *"The "reachability set" for a particular variable consists of the variable itself and the other variables which it may help achieve. The "antecedent set" consists of the variable itself and the other variables which may help in achieving it. Subsequently, the intersection of these sets is derived for all*

[255] Azevedo, S., 2013, pp. 218

variables."[256]

Measure number	Measure description	1	2	3	4	5	6	7	8	Driving power
1	Inventory level	1	1	1	1	1	1	1	0	7
2	Operational costs	0	1	0	1	0	0	0	0	2
3	Lead time	0	1	1	0	0	1	1	1	5
4	Business wastage	1	0	0	1	1	0	0	0	3
5	Environmental costs	0	0	0	1	1	0	0	1	3
6	Delivery time	0	0	0	0	0	1	1	1	3
7	Customer satisfaction	0	0	0	0	0	0	1	1	2
8	Cash-to-cash cycle	0	0	0	0	0	0	0	1	1
	Dependence power	2	3	2	4	3	3	4	5	

Figure 35: Example of a RM for PM of the Supply Chain[257]

From the Figure 36 it is possible to see the measure 8 is found to be at level 1. Thus, it would be positioned at the top of the ISM model.

Measure number	Reachability set	Antecedent set	Intersection	Level
1	1, 2, 3, 4, 5, 6, 7	1, 4	1, 4	
2	2, 4	1, 2, 3	2	
3	2, 3, 6, 7, 8	1, 3	3	
4	1, 4, 5	1, 2, 4, 5	1, 4	
5	4, 5, 8	1, 4, 5	4, 5	
6	6, 7, 8	1, 3, 6	6	
7	7, 8	1, 3, 6, 7	7	
8	8	3, 5, 6, 7, 8	8	I

Figure 36: Partition of the RM: Level I[258]

This process is then repeated until the levels of all the measures are found. The identified levels aid in building the diagram and the final model of the ISM.

When this process comes to a conclusion it is possible to draw the interpretative model, showing with arrows, the sequence of dependence.

This is visible in Figure 37 and in this particular case it can be seen how the Lead Time, but most of all the Inventory Level are the performance measures at the base of everyone else.

[256] Azevedo S., 2013, pp. 219
[257] Azevedo S., 2013, pp. 219
[258] Azevedo S., 2013, pp. 219

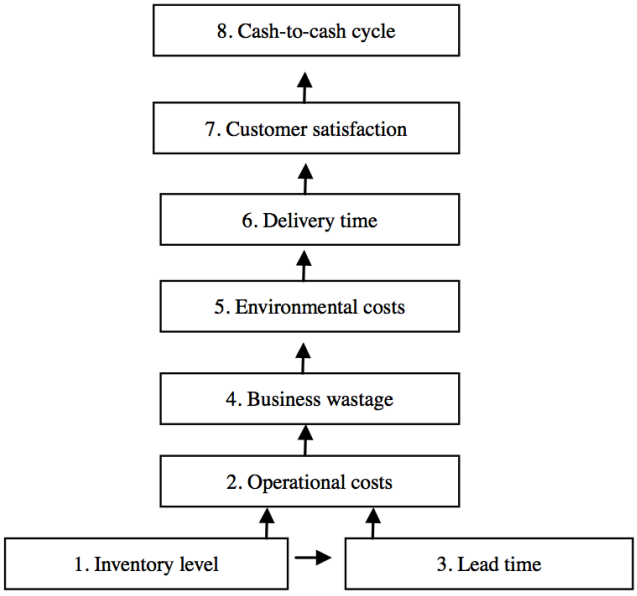

Figure 37: Final Diagram of the ISM[259]

Moreover, by each measure the Driving power and the Dependent Power is calculated as the sum of zeros and ones in the reachability matrix. Thanks to the driving and the dependant power is possible to draw another useful graph in which the measures are divided in four possible clusters (Figure 38):

- Driver Measures: high driving and low dependant power
- Autonomous Measures: both the powers are low
- Dependant Measures: high dependant and low driving power
- Linkage Measures: both the powers are high

It is possible to recognise in this second result, the same indications given by the ISM final model: in fact, in the particular case of the example, the measure 1 and 3 are the base of the ISM model as well as they can be found in the driving cluster (even showing less driving power for measure 3).

At the same time the measure 8, which is at the top of the hierarchy in the ISM model (it drives no measure), is the only measure that we can see in the cluster of the Dependent measures.

It can be quite clear now how powerful, but at the same time easy to use this method can be: at the end of it we have no new information, but all the ones that we had before are better organized and at the same time well represented in straightforward diagrams.

[259] Azevedo, S., 2013, pp. 221

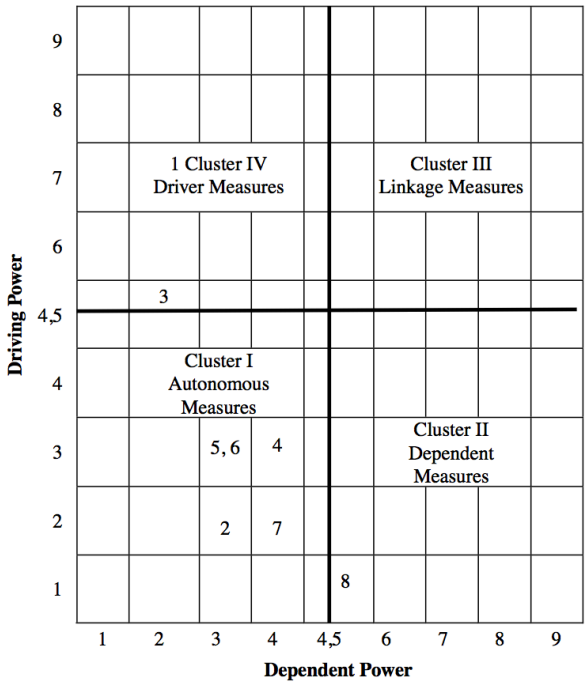

Figure 38: Example of Clusters of Performance Measures[260]

Moreover, thanks to the work of Azevedo, it is possible to say that this method is quite adapt to deal with performance measures and it can be quite useful in the identification of their relations.

According to Azevedo et al.:

> *"The set of performance measures proposed in this paper for the automotive supply chain is quite different from others because it provides a representation of operational, economic and environmental performance measures in a hierarchical manner and clusters them into driver and dependent categories. Accordingly, the ISM-based model proposed in this study for identifying and ranking of performance measures can provide the decision maker with a more realistic representation of the problem. The utility of the proposed ISM methodology in imposing order and direction on the complex relationships among the suggested performance measures is of considerable value for decision makers."*[261]

According to the authors themselves, anyway, this model has to be statistically proven and show yet some shortcomings. It is not of our interest to discuss the problematic of the specific model, but to show how useful it can be in situations, in which decisions about performance measures have to be taken.

[260] Azevedo, S., 2013, pp. 222
[261] Azevedo, S., 2013, pp. 224

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7 Picture Index

8 Summery of the Formulas

9 Abbreviations

e.g.	Example given
cf.	Confront/compare
pp.	Page/pages
PM	Performance Measure
PMS	Performance Measurement System
BSC	Balanced Scorecard
KPI	Key Performance Indicators
EFQM	European Foundation for Quality Management
PP	Performance Prism
CSF	Critical Success Factors
KRI	Key Result Indicators
PI	Performance Indicators
MES	Manufacturing Execution System
AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
ISM	Interpretative Structural Model
SSIM	Structural Self-Interaction Matrix
RM	Reachability Matrix
PDCA	Plan Do Check Act
JIT	Just in Time
TQM	Total Quality Management
KVP	Kontinuierliche Verbesserung Prozess
CIP	Continuous Improvement Process
ISO	International Organization for Standardization
VDMA	Verband Deutscher Maschinen- und Anlagenbau
DIN	Deutsche Institut für Normung
FPY	First Pass Yield
ROI	Return on Interest
OEE	Overall Equipment Effectiveness
€	Euro

#	Number
etc.	Et cetera