Research Article

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# Management of Innovation Ecosystems Based on Six Sigma Business Scorecard

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**Abstract:** In the present context, companies to be competitive must develop high-performance innovation capabilities that enable them to respond quickly to market needs. However, the lack of tools and methodologies to assess the performance of innovation projects in an integrated way remains an obstacle.

The paper begins by discussing the principles of Six Sigma and the Balanced Scorecard for performance evaluation. Next, the advantages of the Six Sigma Business Scorecard are discussed as a tool to support the evaluation of performance in innovation projects. Finally, the advantages of their application in the context of a collaborative ecosystem are discussed.

It is illustrated that the BSC ensures that top management pays attention at any time to the specific elements of the Six Sigma implementation that are not working as planned, providing a link between strategy and quality initiatives assuring customers satisfaction in innovation projects.

**Keywords:** Six Sigma; Balanced Scorecard; Innovation; Collaborative Ecosystems

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## 1 Introduction

Human capital is considered by organizations as the most important asset, and its measurement is fundamental. There is a strong relationship between Human Capital Management, Knowledge Management, Intellectual Capital Management and the Business Scorecard (BSC) learning and growth perspective, specifically in the management of employee retention and workforce planning. The learning and growth perspective involves the changes and improvements to be made to achieve the mission and business vision. The maintenance and development of the know-how are fundamental to guarantee the necessary efficiency and effectiveness to the processes, culminating in the creation of value for the clients and shareholders. Incessant demand for new skills, especially a core competence, should be stimulated. Thus, disinvestment in human resources training can improve short-term financial performance, but in the long term this financial performance will be compromised as the organization lacks the capacity to build the infrastructure needed to support processes that seek the satisfaction of customers and shareholders.

Furthermore, the increase in the globalization of markets, especially in the last decade, has brought about profound changes in the structure, organization and way of operating companies. The methods of work and management inherited from the past are less and less adapted to the turbulence of the modern world [1]. Companies to be competitive need to develop skills that enable them to respond quickly to market needs [2]. The HORIZON 2020 framework program stresses the 'Innovation Union' as a strategy for growth and job promotion supported by a strategy of 'transferring new ideas to the market' [3]. On the other hand, the development of new complex products/services requires access to a distinct set of resources and competencies that companies often do not have [4–6]. Thus, in order to ensure their level of competitiveness, companies are confronted with the dilemma: to develop the skills and resources needed from their own assets, sometimes by making high investments, or alternatively, using the skills and resources that can be available from other organizations in the context of a collaborative ecosystem [1, 2]. The perception of potential links and absent links offers an overview of future relationships that might represent opportunities and threats. The ability to rapidly seek, choose, consolidate and reconfigure links is essential for companies bent on growth.

A collaborative ecosystem is understood as any coalition between a set of autonomous, geographically distributed and heterogeneous entities (specialists and companies) from the operational point of view, who decide to establish cooperative relationships among them, as a process, to achieve common or compatible objectives more efficiently. The collaborative ecosystem perspective of organizational innovation has gained popularity in recent years for investigating the nature of the innovation process, examining how and why innovations emerge, develop, grow and end. This perspective describes innovation as a complex process (not static), produced by interactions between structural influences and the actions of individuals, which occur simultaneously. Thus, the collaborative ecosystem view of innovation is the basis for many conceptual constructions, related to the innovative process, which considers the increase in complexity, the importance of knowledge sources external to the organization and the intra and inter-relationships, fundamental for successful innovation. Innovation is increasingly characterised as an open process, in which many different actors - companies, customers, investors, universities, and other organisations - cooperate in complex ways. As species in a biological system, each member of a business collaborative ecosystem shares the fate of the network, as a whole, despite the soundness of a specific member. The strategy of a company should consider, therefore, the health of the entire ecosystem. A company that acts without understanding the impact on the ecosystem, as a whole, is ignoring the reality of the collaborative networked environment in which it operates. The traditional linear model of innovation with clearly assigned roles for basic research at the university, and applied research in a company, is no longer relevant.

This paper aims to illustrate the role of the Six Sigma Scorecard approach in evaluating the performance of an innovation project. It begins by addressing the principles of the Six Sigma philosophy and the Balanced Scorecard. Next, it is discussed how the two methodologies can be associated as a management tool to improve the performance of innovation projects. Finally, it is discussed how this approach can be applied in evaluating the performance of innovation projects in the context of a collaborative ecosystem thus contributing to customer satisfaction and to the sustainability of organizations.

## 2 Six Sigma Background

Usually, organizations/companies define technical specifications, by quality characteristic, in order to meet the implicit or explicit needs of future customers/consumers. These specifications, defined at the design stage of the products or services and their processes, are almost always quantifiable on a continuous scale. Thus, it is possible to define a procedure for collecting information (data) in each production process, analysing this data and characterizing the process. The meaning of the term “characterization of the process”, which is to be emphasized, has to do with the clear identification of the way in which it takes place, *i.e.*, to know with high reliability that the values of the characteristic under study have a certain average value and a determined dispersion, as well as the type of distribution associated with such data. In order to define and perform a suitable "process characterization", it is common to use a set of tools, such as flowcharts, data logging, control charts and histograms. The analysis of the capacity of the processes to suit their technical specifications is traditionally done using the so-called process capability indexes, such as the $C_p$ index and the $C_{pk}$ index.

Considering that the process for a certain quality characteristic follows a Normal distribution with mean μ and standard deviation $\sigma$, these indices are defined by:

$$C_p = \frac{USL - LSL}{6\sigma} C_{pk} = \min\left(C_{pkL}, C_{pkU}\right) \tag{1}$$

$$C_{pk} = \min\left(C_{pkL}, C_{pkU}\right) \tag{2}$$

$$C_{pkU} = \frac{USL - \mu}{3\sigma} \quad \text{and} \quad C_{pkL} = \frac{\mu - LSL}{3\sigma} \tag{3}$$

Traditionally, for bilateral specifications, it is considered that a process can produce according to its technical specification when the values of $C_p$ and $C_{pk}$ are greater than 1.33. This value of 1.33 means that LSL (lower specification limit) and USL (upper specification limit) are at least $4\sigma$ away from the average μ of the process. The situation of the specification limits are $4\sigma$ apart from the average of the process is found in the ideal process condition, *i.e.*, the process is centred with the specification ($C_{pkI} = C_{pkS}$). For a better understanding of this theme, it is suggested, the consultation of Montgomery [8], Ryan [9], among others.

A process centred with $C_{pk} = 1.33$ produces 60 nonconforming units in one million units produced. This value is calculated considering the location of specification limits (at $4\sigma$ distance from the mean μ), considering that the distribution relative to the characteristic of the study quality is normal. This situation is illustrated in Figure 1.

$$P(LSL \le X \le USL) = P(-4 \le Z \le 4) = 1 - 0,00006 = 0,99994$$

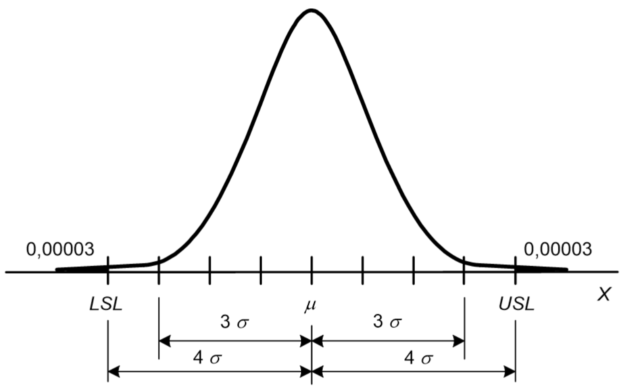


**Figure 1:** Non-conforming production for a process centred with $C_{pk}$ = 1.33.

Whereas a complex product consists of 50 components and all components have $C_{pk}$ = 1.33, nonconforming production shall be equal to $(0.99994)^{50}$ = 0.9970. This means that the proportion of non-conforming production will be equal to 0.003, that is, the production of 3 nonconforming units in 1000 units produced. Although this figure corresponds to the most favourable situation, even so, for certain products it may be considered unacceptable.

At the end of the 1980's the methodology / philosophy known as Six Sigma was developed at Motorola. This methodology presents the limit value of 3.4 per million as an admissible value for non-compliant production. It identifies "two states" in a productive process, the first called "short term" and the second "long term". In the first, it is considered that the process is stable and produces items with mean μ and standard deviation $\sigma$. In the second, it is understood that unidentified variations can occur in the process when the process is in the "short-term" state and, therefore, it is assumed that the process average can range from ± 1.5$\sigma$.

Because of the above recitals, the quality level (sigma level) of a given process is expressed as a function of $\sigma$. In order to identify what level of quality a particular process presents, it is only necessary to determine the number of nonconforming units in one million units produced. In the Six Sigma philosophy, to make it more comprehensive, several metrics are used, such as: Defects Per Unit (*DPU*), Defects Per Opportunity (*DPO*) and Defects Per Million of Opportunities (*DPMO*). Those metrics are defined as follows:

$$DPU = \frac{\text{Total number of defects}}{\text{Number of verified units}} \tag{4}$$

$$DPO = \frac{\text{Total number of defects}}{\text{Number of verified units} \times \text{Number of defect opportunities}} \tag{5}$$

$$DPMO = DPO \times 10^6 \tag{6}$$

Table 1 presents the values in the *DPMO* that allow to identify the quality level of a process (the perspective assumed in this article considers the number of noncompliant units, with 1 *DPMO* = 1 nonconforming unit). For a better understanding of this theme, it is suggested, the consultation of Park [10], among others.

Overall, one of the goals of any company when implementing an innovation project is to ensure that the results initially defined were achieved without defects or failures, *i.e.* customer-defined specifications were obtained, for example, specifications in terms of cost, time, quality and scope were met.

Assuming that defects can occur randomly and independently of each other, we may in these circumstances using the Poisson distribution, proceed to calculate the probability of occurrence of failures/defects in a given time interval, through the following equation:

$$P(x) = \frac{\mu^x . e^{-\mu}}{x!} \tag{7}$$

where: $P(x)$ – stands for the probability of occurrence of defect(s)/failure(s) in the development of an innovation project; and, μ is the average number of defects / failures per innovation project.

Thus, in the context of innovation management, unity is defined as the innovation project. Then, the Defects Per Unit (*DPU*) metric is defined by:

$$DPU = \frac{\text{Number of defects}}{\text{Number of projects performed}} \tag{8}$$

Therefore, by making μ = *DPU* the probability that an innovation project is performed without any defect is given by:

$$P(0) = \frac{DPU^0 . e^{-DPU}}{0!} = e^{-DPU} \tag{9}$$

If we consider that any innovation project consists of a sequence of steps/phases of development, the probability of an innovation project passing through one of the sequential steps/phases of the innovation process, without defects, is given by [11, 12]:

$$P(0) = e^{-DPU} \tag{10}$$

**Table 1:** Conversion table for the Sigma scale.

| Scale Sigma | *DPMO* | Scale Sigma | *DPMO* | Scale Sigma | *DPMO* | Scale Sigma | *DPMO* | Scale Sigma | *DPMO* |
|---|---|---|---|---|---|---|---|---|---|
| 0,00 | 933193 | 1,20 | 617911 | 2,40 | 184060 | 3,60 | 17864 | 4,80 | 483 |
| 0,05 | 926471 | 1,25 | 598706 | 2,45 | 171056 | 3,65 | 15778 | 4,85 | 404 |
| 0,10 | 919243 | 1,30 | 579260 | 2,50 | 158655 | 3,70 | 13903 | 4,90 | 337 |
| 0,15 | 911492 | 1,35 | 559618 | 2,55 | 146859 | 3,75 | 12224 | 4,95 | 280 |
| 0,20 | 903200 | 1,40 | 539828 | 2,60 | 135666 | 3,80 | 10724 | 5,00 | 233 |
| 0,25 | 894350 | 1,45 | 519939 | 2,65 | 125072 | 3,85 | 9387 | 5,05 | 193 |
| 0,30 | 884930 | 1,50 | 500000 | 2,70 | 115070 | 3,90 | 8198 | 5,10 | 159 |
| 0,35 | 874928 | 1,55 | 480061 | 2,75 | 105650 | 3,95 | 7143 | 5,15 | 131 |
| 0,40 | 864334 | 1,60 | 460172 | 2,80 | 96800 | 4,00 | 6210 | 5,20 | 108 |
| 0,45 | 853141 | 1,65 | 440382 | 2,85 | 88508 | 4,05 | 5386 | 5,25 | 88 |
| 0,50 | 841345 | 1,70 | 420740 | 2,90 | 80757 | 4,10 | 4661 | 5,30 | 72 |
| 0,55 | 828944 | 1,75 | 401294 | 2,95 | 73529 | 4,15 | 4025 | 5,35 | 59 |
| 0,60 | 815940 | 1,80 | 382089 | 3,00 | 66807 | 4,20 | 3467 | 5,40 | 48 |
| 0,65 | 802337 | 1,85 | 363169 | 3,05 | 60571 | 4,25 | 2980 | 5,45 | 39 |
| 0,70 | 788145 | 1,90 | 344578 | 3,10 | 54799 | 4,30 | 2555 | 5,50 | 32 |
| 0,75 | 773373 | 1,95 | 326355 | 3,15 | 49471 | 4,35 | 2186 | 5,55 | 26 |
| 0,80 | 758036 | 2,00 | 308538 | 3,20 | 44565 | 4,40 | 1866 | 5,60 | 21 |
| 0,85 | 742154 | 2,05 | 291160 | 3,25 | 40059 | 4,45 | 1589 | 5,65 | 17 |
| 0,90 | 725747 | 2,10 | 274253 | 3,30 | 35930 | 4,50 | 1350 | 5,70 | 13 |
| 0,95 | 708840 | 2,15 | 257846 | 3,35 | 32157 | 4,55 | 1144 | 5,75 | 11 |
| 1,00 | 691462 | 2,20 | 241964 | 3,40 | 28717 | 4,60 | 968 | 5,80 | 9 |
| 1,05 | 673645 | 2,25 | 226627 | 3,45 | 25588 | 4,65 | 816 | 5,85 | 7 |
| 1,10 | 655422 | 2,30 | 211855 | 3,50 | 22750 | 4,70 | 687 | 5,90 | 5 |
| 1,15 | 636831 | 2,35 | 197663 | 3,55 | 20182 | 4,75 | 577 | 5,95 | 4 |
| | | | | | | | | 6,00 | 3 |

Representing this probability by $y$, as the probability of an innovation project pass through the first step/phase of the innovation process without defects, we have:

$$y = e^{-DPU} \tag{11}$$

Thus, if it is known that the first step/phase of the innovation process of the entire sequence of steps/phases defined in the innovation project is successful, that is, without defects, it is possible to determine the value of *DPU* through of the following equation:

$$DPU = -ln\,(y) \tag{12}$$

In global terms and from the macro viewpoint the several sequential steps/phases of an innovation are depicted in Figure 2.

Therefore, the probability of a given innovation project to exceed a set of $k$ steps/phases without any defect in the set of steps/phases can be determined by:

$$Y_{Global} = \prod_{n=1}^{k} y_n \tag{13}$$

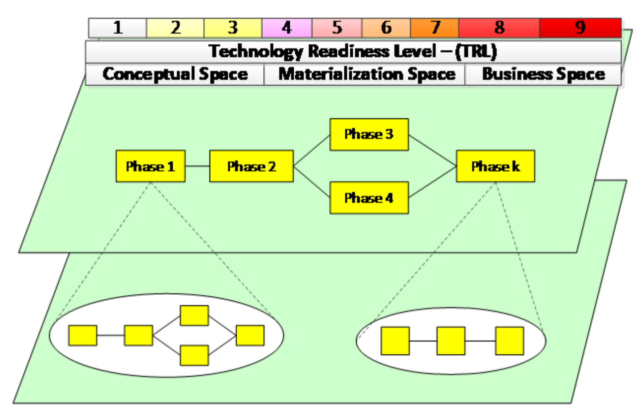


**Figure 2:** Steps/Phases in a generic innovation project.

Hence, the DPU value for the entire innovation project (IP) can be determined by:

$$DPU_{IP} = -ln\,(Y_{IP}) \tag{14}$$

Thus, we have:

$$DPU_{IP} = -ln\,(Y_{IP}) = -ln\left(\prod_{n=1}^{k} y_n\right) \tag{15}$$

## 3 Balanced Scorecard

Nowadays, in an accelerated and highly competitive world, measurement is the first step that leads to control and eventually process improvement. If you do not measure, you do not understand. If you do not understand it, you cannot control it and if you cannot control it, you will not be able to improve. Senior executives understand that their organization's measurement system strongly affects the behaviour of managers and employees. Executives also understand that traditional financial accounting measures like return on investment and earnings per share can give misleading signals for continuous improvement and innovation.

On the other hand, what we measure is not indifferent, not neutral. What we measure reflects what we value and in that sense, is a powerful signal that is transmitted throughout the company. In this sense, the monitoring of the performance of processes based exclusively on financial indicators has become insufficient.

The development of holistic management support tools that allow the evaluation and monitoring of company performance based on the defined strategy is an imperative of modern management. Developed by Robert Kaplan and David Norton [13], the Balanced Scorecard (BSC) is characterized as a structured model that not only complements the traditional financial indicators but also relates the long-term strategy to short-term interventions. The BSC has emerged as a decision support approach at the strategic management level. Many business leaders now evaluate corporate performance by supplementing financial accounting data with goal-related measures from the following perspectives: customer, internal business processes, learning and growth. It is argued that the BSC paradigm can be adapted to assist those managing business functions, organizational units and individual projects.

Thus, the BSC offers a dashboard of business management tools, supported by financial indicators that translate the results of actions and decisions taken, and in non-financial indicators on customer satisfaction, internal processes, innovation activities and continuous improvement of the processes, related to the critical success factors of the business, as shown in Figure 3.

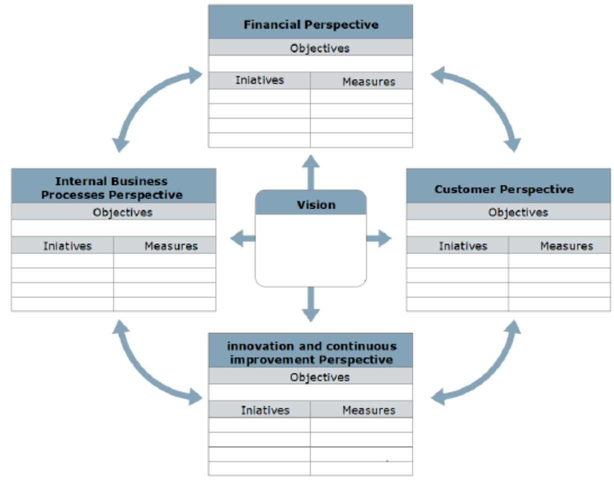


**Figure 3:** BSC control panel.

According to the financial perspective, the indicators developed aim to answer the following question: - How are we viewed by stakeholders? From the perspective of customers, the indicators allow the company to answer the question - How are we seen by customers? From the perspective of internal processes, the indicators allow the company to answer the question - Where do we have to be excellent? From a perspective of innovation and continuous improvement, the indicators allow the company to answer the question - Where should we continue to improve and create value? Thus, the BSC serves as a dashboard, which allows the management has a comprehensive view of the company's performance in the short and medium term. Thus, to put the BSC to work, companies should articulate goals for time, quality, and performance and service and then translate these goals into specific measures.

## 4 Six Sigma Business Scorecard

The Six Sigma philosophy is an evolution of total quality theory, focusing on the ability of organizations to generate value and improve their productivity and competitiveness by eliminating numerous cost-generating activities. The Six Sigma strategy is directly related to obtaining improvements in items such as cost reduction, productivity improvement, market share growth, customer retention, cycle time reduction, defect reduction, cultural change, product and service development, etc. Based on the Six Sigma philosophy and the BSC approach, Praveen Gupta proposed a Six Sigma Business Scorecard methodology [12–14]. This approach aims to build a dashboard that allows management to monitor company performance based on the dimensions of the Balanced Scorecard but through Six Sigma levels.

Based on this approach both the results of actions and decisions taken that are evaluated in financial terms, and the critical success factors of the business that are analysed from a non-financial perspective, their performance is quantified through Six Sigma levels.

Thus, an indicator, called business performance index, was developed as a measure of the overall performance of the system (*IPS*), which can range from a department to the company itself, and from this indicator determine the corresponding Six Sigma level.

Thus, the determination of the sigma level comprises the following steps:

1. Definition of the indicators to be measured.
2. Definition of the weights $W_n$ assign to each of the indicators depending on the relative importance of each of them to the success of the objectives that have been defined. The sum of all weights must be equal to 100.
3. Measurement of the performance of each indicator; for each of the $n$ indicators, performance is calculated by the following ratio:
$$P_n = \frac{\text{Performance achieved} \times 100}{\text{Performance predicted}} \qquad (16)$$
4. Determination of Partial Performance Indices (*PPI*) for each of the $n$ indicators; these indices are determined by the following equation:
$$PPI_n = \frac{W_n.P_n}{100} \qquad (17)$$
5. Determination of the System Overall Performance Index (*SPI*), using the following equation:
$$SPI = \sum_{n=1}^{10} PPI_n \qquad (18)$$
6. Determination of the *DPU* by the following equation:
$$DPU_{Global} = -ln\left(\frac{SPI}{100}\right) \qquad (19)$$
Determination of DPMO by the following equation:
$$DPMO_{PM} = \frac{DPU_{PM}.10^6}{Processes\ number} \qquad (20)$$
7. By definition of the *DPMO* (see equations (5) and (6)) the denominator appears as the number of defect opportunities, *i.e.*, the total number of possibilities for defects or errors. Thus, in an innovation project, from the point of view of operational management, it is assumed that opportunities for defect are associated with non-compliance with the initially defined specifications associated with each stage of the process.
8. Determine the Six Sigma level through Table 1.

In order to illustrate the sigma level associated with an innovation project, Table 2 shows the indicators that were used, as well as the values obtained in this hypothetical case.

**Table 2:** Determination of the Six Sigma level for a hypothetical case of an innovation project.

| **Measured Indicators** | $W_n$ | $P_n$ | $PPI_n$ |
|---|---|---|---|
| I1. Costs | 20 | 80 | **8** |
| I2. Scope | 15 | 70 | **10,5** |
| I3. Deadlines | 15 | 60 | **9,6** |
| I4. Development of new skills | 10 | 60 | **6** |
| I5. Technological capacity | 10 | 70 | **7** |
| I6. Number of patents obtained | 10 | 70 | **7** |
| I7. Hours of work involved | 5 | 75 | **3,75** |
| I8. Defects rate on operations | 5 | 60 | **3** |
| I9. Efficiency level | 5 | 70 | **3,5** |
| I10. Customer satisfaction level | 5 | 90 | **4,5** |
| **Calculations** | | | |
| ***SPI*** | | **62,85 %** | |
| $DPU_{Global}$ | | **0,4644** | |
| ***Processes number*** | | **15** | |
| ***DPMO*** | | **30960** | |
| **Six Sigma Level** | | **3,35** | |

The main difficulty is how to calculate each of the ten indicators mentioned above. Further research and development is required regarding how to collect and record the values without being intrusive in the company "life". As a first approach, for instance, the assessment of each one might be determined based on the perception of the employees involved in the project or alternatively through tools, such as application of fuzzy logic [15], that allow in a more objective way to evaluate the differences between previously planned results and actual results.

On the other hand, if the purpose is to design a simulation model to support the decision-making process, then the values of these indicators will be parameters of the simulation process.

However, based on the values in Table 2, as well as the values obtained from the application of the equations previously defined, we can verify that the closer the real values are to the values initially established the value of $P_n$

is close to 100% and if all the indicators were 100% efficient, the $DPU_{Global}$ value of the project would be zero, to which we would like to state that the innovation project in question had been perfect in all respects compared to the original objectives.

## 5 Increase Performance of Innovation Processes Through Cooperative Relationships

Given the arguments presented above, companies, in order to be competitive in increasingly demanding markets, should adopt strategies that allow them to provide high quality services to their customers. When a company intends to make new products / services available, the company has two possible alternatives: to internally develop the necessary resources both at the level of management competencies and at the level of operational competencies in order to ensure a quality standard that is acceptable to the client and does not compromise its sustainability and survival in the market, or alternatively choose to carry out the innovation project in a collaborative context.

As frequently mentioned by several authors on Collaborative Networks, as well as reports from a growing number of practical case studies, when a company is a member of a long-term networked structure (collaborative ecosystem), such as an industry cluster or industry district, there is the assumption that such involvement brings valuable (potential) benefits to the involved entities [16–20]. Table 3 shows, some examples of associated (intuitive) advantages of co-innovation processes.

However, it is important to realize that, when a company is a member of a collaborative ecosystem, its benefits are not only given by tangible assets – economic capital (*e.g.* cash, resources, and goods). The existence of cooperation agreements, norms, reciprocal relationships, mutual trust, common infrastructures and common ontologies, allows collaborative ecosystem members to operate more effectively in pursuit of their goals [21]. In fact, the existence of a collaborative ecosystem structure enables the increase of knowledge circulation as well as the production of knowledge within the network. In other words, the network acts as a channel to transfer knowledge from one organization to another, and may become the locus of new knowledge creation, rather than within the organizations members of the network [22, 23].

In this context, the choice of the partners to carry out the necessary processes will depend on the identification of the companies that present the highest levels of sigma performance for the set of processes assigned to them. Thus, if this principle is present in the process of creating the collaborative network, companies will be able to increase their competitiveness in the face of competition and in the limit to ensure their own survival in a faster and less impacted way. Figure 4 illustrates from an operational point of view the sequence of steps/phases associated with the collaborative innovation project and the operations associated with the internal innovation project carried out by one of the partners, in order to support the collaborative innovation project.

However, the success of this approach requires the development of a tool that supports the management activities and the existence of mechanisms that act as incentives for collaboration and punish the infractors [24, 25]. Furthermore, the companies involved in a collaborative network must provide to the member coordinator, reliable information in useful time during the execution of the maintenance project; as well as, when was necessary to participate effectively in the recovery of delays.

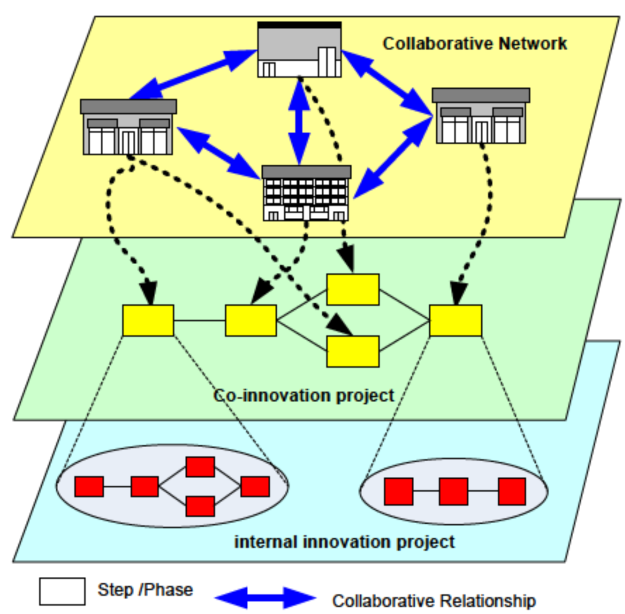


**Figure 4:** Example of a collaborative network in an innovation project.

## 6 Potential Application

To illustrate the advantages of establishing collaborative networks to increase the success rate of innovation

**Table 3:** Example of some associated advantages to co-innovation.

| Type of Benefits | Drivers of co-innovation |
|---|---|
| Savings and cost sharing | • Have access to new markets and/or businesses without the need to make high investments.<br>• Share R&D costs.<br>• Access to equipment and physical facilities<br>• Access to funding from R&D funding programs<br>• Access to industry funding<br>• Ability for SMEs to compete with large competitors. |
| Risk reduction | • Companies operate in changing environments and with limited, therefore imperfect, knowledge. Consequently, in some cases the level of uncertainty may have a negative impact on the decision-making processes. Sharing knowledge among several partners allows a reduction of this uncertainty level.<br>• When several partners are involved in a co-innovation project there is a partition of the responsibilities among them (co-responsibility).<br>• In some cases, solidarity mechanisms can be established among partners.<br>• Also enabling the competition of SMEs in huge innovation projects against large companies. |
| Decrease the dependence level in relation to third party | • In a innovation process all companies depend on others to some extent for products, services, raw materials, tangible and intangible resources and competencies. Through collaboration companies can reduce this dependence by creating privileged links to other companies in an attempt to reduce transaction costs that arise when uncertainty increases.<br>• Also enabling the competition of SMEs in huge innovation projects against large companies. |
| Time reduction | • Increase the capacity of generating new ideas through the combination of the existent resources and diversity of cultures and experiences (critical mass).<br>• Emergence of new sources of value.<br>• Reduction of the life cycle of the products and technologies.<br>• Possibility of developing more robust products fitting the customers' expectations and therefore contributing to an increase of the quality. |
| Defend a position in the market | • Achievement of economies of scale by sharing resources.<br>• Establishment of defensive coalitions with the purpose of building entry barriers in order to defend themselves against a dominant firm or a new player.<br>• Establishment of offensive coalitions with the purpose of developing competitive advantages and strengthening their position by diminishing the other competitors' competitiveness.<br>• Increase the negotiation power in relation to suppliers and/or customers that are outside of the collaborative network.<br>• Also enabling the competition of SMEs with large companies. |
| Increase flexibility | • Share of resources and combination of skills among partners.<br>• Use the core competences from other partners.<br>• Increase the adaptation capacity towards several business environments simultaneously.<br>• Offer a broader range of products / services.<br>• Grow for new segments in a stable way reaching a larger stability. |
| Increase agility | • React in a short period of time to a business opportunity through the redution of innovation time.<br>• Increase the interoperability between several processes and products (establishment of norms) |
| Share social responsibilities | • Obtain recognition from others (intangible value).<br>• Develop social responsibility<br>• Improve public image in society<br>• Increase the qualification level of employees<br>• Develop an innovation culture<br>• Reinforce values that are common. |

**Table 4:** Quality Level provided by each company.

| Project | Required Sigma Level | Processes | Sigma Level Offered by Companies | | | |
|---|---|---|---|---|---|---|
| | | | E1 | E2 | E3 | E4 |
| Proj. 1 | 5 | P1- P5-P3 | 3 | 2.92 | 3.99 | 3.74 |
| Proj. 2 | 5.5 | P1- P2-P1 | 3.97 | 4.81 | 3.97 | 4.99 |
| Proj. 3 | 5 | P5- P2-P1 | 3.97 | 3 | 3.99 | 3.99 |
| Proj. 4 | 4 | P4- P1-P3 | 3 | 3.74 | 3.97 | 4 |

**Table 5:** Quality level of the cooperation process for the various innovation projects.

| Project | Required Sigma Level | Processes | Collaborative Network | Collaborative Sigma Level |
|---|---|---|---|---|
| Proj. 1 | 5 | P1- P5-P3 | E1-E3-E4 | 4.99 |
| Proj. 2 | 5.5 | P1- P2-P1 | E4-E2-E4 | 5.76 |
| Proj. 3 | 5 | P5- P2-P1 | E3-E2-E4 | 5.76 |
| Proj. 4 | 4 | P4- P1-P3 | E1-E4-E4 | 4.99 |

projects, let us consider a scenario inspired on Virtuelle Fabrik that is a real collaborative ecosystem in the metal-mechanic sector, located in Switzerland and Germany.

Let us consider a scenario where we have a collaborative innovation ecosystem which contain four independent firms to accelerate innovation processes, as illustrated by Figure 5; they all have the intention to develop four innovative projects where it is necessary to ensure a certain level of quality according to the sigma level indicated, for the project to succeed, whether at the management level and operational level, thereby ensuring not only the level of competitiveness as well as the sustainability of the company. Please note that the purpose of this example is only to illustrate the potential of this approach. For reasons of simplification, the use of other processes would not be considered, which would also allow the expected results with the same characteristics/functionalities to be obtained.

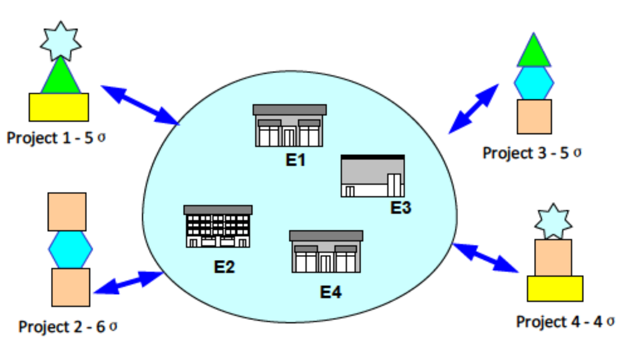


**Figure 5:** Example of cooperation between several companies.

Figure 6 illustrates for the various companies the hypothetical sigma-level matrix for the steps / phases necessary to achieve each of the innovation projects based on the historical performance of organizations in similar projects.

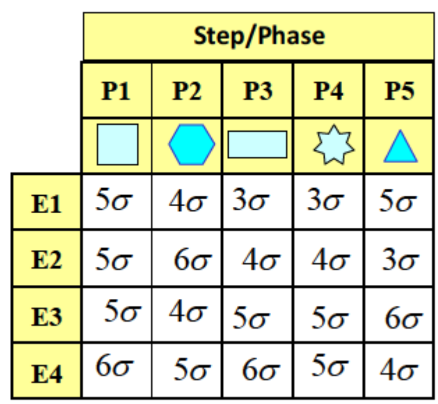


**Figure 6:** Sigma level of the various steps/phases.

In this case, if there is no cooperation agreement between the companies, only company E4 can carry out project 4 (Proj. 4) with the desired quality (level $4\sigma$). For all other projects (Proj. 1, Proj. 2 and Proj. 3) none of the companies have the capacity to carry them out without compromising the company's sustainability, as shown in Table 4.

In the case of establishing a collaborative process between the four companies, all innovation projects can be realized in accordance with the required quality and without any additional effort. Table 5 shows the level of quality in the sigma scale that can be achieved for each of the innovation projects, as well as the network elements involved in the projects in question.

## 7 Conclusions

Currently, there seems to be unanimity on the part of the various actors involved in the business world that, in order to survive, SMEs increasingly have to develop innovation strategies that allow them to move towards a greater appreciation of the products/services provided to their customers.

However, implementation of the strategies described in the previous sections, in many cases requires skills and investments for which companies typically are not prepared, as in the case of small and medium-sized enterprises.

In this context, as an alternative, it was shown how, through dynamic cooperation networks, a company can significantly increase its level of competitiveness, at a reduced cost and in a practically instantaneous time, which in turbulent socio-economic scenarios represents an additional advantage in relation to traditional innovation processes.

It was shown that the BSC is a tool with great capacity to integrate and interact, in a logical and coherent way, with a set of other tools used by organizations, such as de Six Sigma approach. The use of the Six Sigma strategy with the BSC presupposes a process of continuous improvement and, consequently, assists the process of evaluating the performance through the identification of problems, their causes and the actions to be carried out to solve them. The BSC was seen as an instrument to assess the degree of alignment of the organization with its strategic direction. The Six Sigma strategy worked as a way to operationalize the necessary improvements for this strategic alignment.

Furthermore, this paper illustrates that the BSC ensures that top management pays attention at any time to the specific elements of the Six Sigma implementation that are not working as planned, providing a link between strategy and quality initiatives. Thus, the BSC provides a mechanism for top management to track success in implementing a Six Sigma process, and the opportunity to make changes considering the results achieved. It has been observed that the Six Sigma philosophy fits perfectly into the BSC's internal perspective. Six Sigma has included financial aspects (costs and profitability) in the quality management system, seeking to create value for the customer and the investor.

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