

Modelling Supply Chain Performance through an Integrated Performance Prism: A Framework and Empirical study of a Wire and Cable Company

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Abstract:

This study presents an integrated framework for supply chain performance measurement (SCPM). The objective was to design a simple yet effective tool to measure and improve performance. The methodology combines the Performance Prism (PP), Analytic Hierarchy Process (AHP), and Overall Equipment Effectiveness (OEE), which were applied to a set of non-financial Key Performance Indicators (KPIs) derived from expert and literature. Empirical results validated the approach, showing its utility in integrating objective-subjective measures and internal-external context measurement.

keyword: Analytic Hierarchy Process (AHP); Overall Equipment Effectiveness (OEE); Performance Measurement System (PMS); Performance Prism (PP); KPIs; Simplicity.

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1. Introduction :

For several years, the subject of SCPM has been recognised with a growing level of importance within the field of SC management. Intense competition, it is proposed, compels organisations to improve their SCs' performance. Appraising SCP is a compound task, requiring a cross-progression that includes multiple partners contributing to correspondingly multiple challenges such as deficient communication between users and reporters, the deficit of consistency between performance indicators (PIs) and decentralizing historical data (Lima-Junior and Carpinetti, 2017).

Once the PIs are designed, decision-makers should identify the KPIs that must be developed (Cai et al., 2009). However, it is challenging to identify the relationships among KPIs in effect, a lesser degree of focus in prior research has, to date, been devoted to this problem (Cai et al., 2009).

It is suggested, that is unclear how organisations should measure their SCPs. Several frameworks with many measures, exist, as improvement and monitoring SCP have themselves become progressively more complex tasks (Cai et al., 2009). Further to this, research investigating PM beyond a single organisation border is still limited (Anjomshoe et al., 2022; Maestrini et al., 2018). Therefore, performance assessment through a comprehensive framework in the industrial sector still presents a gap in the performance literature (Saleheen and Habib, 2023). Another notable issue with most PMSs is the frequently composition of over-diversification of measures, presenting challenges in comprehending the broad overview (Elrod et al., 2013). The literature review demonstrates minimal research in SCPM using the Performance Prism (PP) (Najmi et al., 2012). Paradoxically, Whilst PP is regarded as one of PM's thorough methodologies, it remains significantly under-researched. (Bouriche et al., 2022, Garengo et al., 2005; Najmi et al., 2012).

Review research piloted by Najmi et al. (2012) and a comparison study carried out by Garengo et al. (2005) among eight known PMSs, including the PP and Balanced Scorecard (BSC), demonstrated that the PP is a powerful PMS when compared to the other PMSs. Garengo et al. (2005) identified twelve key characteristics that should be incorporated into any effective PMS. The PP has gained most of these critical characteristics compared to the BSC. These characteristics are demonstrated in section 2.

In addition to the organization's strategic objectives, PP considers stakeholder needs the first point in building the strategy. Furthermore, the PP considers new stakeholders, such as suppliers, employees, or alliance partners, who are typically ignored when designing PIs (Najmi et al. 2012).

One of a PMS's key functions is corroborating strategies' deployment at multiple tiers (Maestrini et al. 2017). Despite the significant research that has been conducted on the SCPM literature, there appear to be limited opportunities for researchers to examine SCP for the industry sector that addresses SCPM and/or PMS attributes. This includes PIs from cost and non-cost perspective, external and internal measurement context, subjective and objective methods view, assess on strategic, functional or stress the operational level at the same time (Saleheen & Habib, 2023) Most of the studies on SCP do not appear to consider specific strategies (Lima-Junior & Carpinetti, 2017).

To address these issues and to bridge the presented gaps, this paper develops an attempt at a novel Prism-based framework. The framework seeks to offer a new approach toward SCs' PM through which different non-financial PM aspects are processed in conjunction with the corporate strategy. Further, the AHP (Saaty and TL, 1980) and the OEE (Seiichi and Nakajima, 1988) have been incorporated into the proposed framework. Amid the critical attributes of the proposed framework, the prominence of a simplicity-driven rationale stands out as particularly vital, especially within the context of operations management and decision making (Bouriche et al. 2022). The essence of simplicity as a pivotal factor within multidisciplinary modelling frameworks has been emphasized by scholars drawing from diverse fields, including philosophy, mathematics, engineering, econometrics, and economics, as evident in the works of respected researchers such as John (2000) and Zellner et al. (2002). Simplicity-driven frameworks for SCPM are still limited (Bouriche et al. 2022).

This study focused on an Algerian industrial SC of an owned-state company associated with the cable/wire industries, named ENICAB; a subsidiary of the *American General Cable Group* as a case study for this research. Algeria's cable/wire industry is a vital and strategic industry, with impact approaching that of the oil and petrochemical industries. Owing to their key mission for transferring energy/power and

information and their role in sustainable development, the cable/wire industry significantly impacts all economic sectors.

The objective, therefore, is to provide decision-makers and operations managers with a simple and comprehensive tool to facilitate their comprehension and application of the SC's performance measurement (PM) processes. The proposed framework was systematically implemented to measure the performance of the SC case study. This empirical investigation facilitated the discernment of both the strengths and the often less apparent weaknesses of the SC under study.

A thorough review of the literature indicates this to be an initial paper to consider the wires/cables industry regarding PMSs employing an integrated Performance Prism-based framework. Additionally, the framework considers the organisation's strategy when implementing KPIs, distinguishing itself from most frameworks in the existing literature. More importantly, there appears to be a need for a comprehensive framework for SCPM in such an industry, one that simultaneously considers simplicity, subjective-objective measurement methods, and internal-external measurement contexts within the PP. No identifiable, comprehensive framework has considered these factors in conjunction with the AHP method and OEE techniques in the context of the PP system for the cables/wires industry's SC. Furthermore, it is proposed that more emphasis be placed on elucidating the intricate causal relationships among different KPIs. In this context, the paper presents a real-world example proving the usefulness of KPIs relationships, leveraging these methods/techniques and addressing the identified gaps.

The paper is organised as follows. In Section 2, The proposed framework is presented, research methods and data collection are presented in Section 3. Section 4 focuses on the proposed framework's implementation and experimental results. Performance improvement suggestions for ENICAB's SC are displayed in section 5. Section 6 outlines the conclusion.

2. The proposed framework and research methods:

2.1. The proposed framework

Integrating objective and subjective measurements is essential for the effectiveness of PM (González-Benito & González-Benito, 2005). Although objective measures provide accuracy, they may not wholly reflect the system's performance (Beamon, 1999). The AHP has been

applied to address inconsistencies, particularly in subjective assessments. The proposed framework integrates the PP, the AHP, and the OEE, emphasising simplicity. The approaches focused on simplicity and process orientation integrated into the proposed framework are consistent with the company's strategic objectives. AHP evaluates supplier performance through KPIs, including cost, quality, delivery, and flexibility, as informed by literature and insights from industry experts. Other SC echelons utilise supplementary KPIs. OEE is applied to a purposive sample of machines. The evaluation of each PP's facet serves to aid decision-makers and operations managers in enhancing operational performance, as demonstrated in Figure 1.

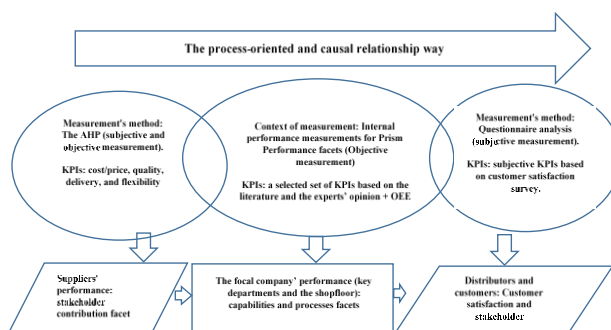


Fig.1. The proposed framework for SC PM.

2.1.1. SC KPIs in the wire and cable industry

Several KPIs are presented based on a review of the relevant literature and insights from semi-structured interviews with a diverse group of professionals in the wire and cable business (Table 1).

Table 1. Vital KPIs used in the wire/cable industry (internal measurement)

KPIs	references
1. Product quality	(Jafarzadeh Ghazi et al. 2023)
2. Customer satisfaction	(Huo et al., 2024)
3. Customer service	(Hosseini-Motlagh et al. 2020)
4. Time-based performance indicator(speed)	(Singh et al. 2021)
5. On-time deliveries (orders)/ delivery schedule	(Ambroszkiewicz and Bylka, 2023; Beamon, 1999)
6. Fill rate	(Castellano and Santillo, 2023)

7. Cost/price	(Jafarzadeh Ghazi et al. 2023)
8. OEE metrics(speed/effectiveness)	(Singh et al. 2021)
9. inventory position /Out of stock	(Ambroszkiewicz and Bylka 2023)
10. Reliability	(Chen et al. 2023)
11. Schedule attainment	(Forghani et al. 2023)
12. Quality criteria (adherence to to regulations and specifications ,alongside the standard of delivery documentation)	(Kaynak & Hartley, 2008)
13. Degree of information sharing	(Thomas and Mahanty, 2021)
14. Finished goods' rejection rate	(Pathania et al. 2021)
15. Waste materials	(Ershadi et al. 2023)

2.1.2. Performance Prism System (PP System)

The PP system (Adams & Neely, 2000) consists of five components: identifying stakeholders and their requirements, formulating strategies to address them, executing processes to implement the strategies, identifying necessary capabilities, and ensuring stakeholder engagement. In contrast to traditional models, the PP initiates strategy formulation with stakeholders as its foundation (Neely et al., 2001). A comparison of the PP with the BSC, revealed that the PP outperformed in stakeholder focus, simplicity, and adaptability (Appendix B: Table 2).

2.1.3. Categorising SC's KPIs into PP facets in the wire/cable industry

The KPIs were categorised according to the five PP facets to ensure comprehensive coverage. They were deployed across internal and external measurement contexts, using objective and subjective methods. A questionnaire and semi-structured interviews, based on professionals' opinions and literature, were used to gather relevant data. The selected KPIs are set out in Appendix A and Appendix C:Table 3.

2.1.4. The AHP and the OEE methods

a. The AHP method

Since its inception by Saaty (1980), the AHP has emerged as a prominent multi-criteria decision-making (MCDM) methodology (Ho & Ma, 2018), renowned for its simplicity, adaptability, and ability to

accommodate subjective evaluations. The AHP's capacity to assess decision-making consistency is significantly improved compared to other MCDM methodologies. This study employs the AHP to evaluate supplier performance using subjective and objective KPIs, integrating expert assessments to improve decision-making.

b. The OEE method

The OEE technique, developed by Nakajima in the late 1980s, functions as a holistic PIs for assessing equipment performance within the framework of Total Productive Maintenance (Seichi & Nakajima, 1988). The OEE method relies on three key metrics: Availability (A), Performance (P), and Quality Rate (Q), evaluated as follows (Muchiri & Pintelon, 2008):

$$OEE=P*A*Q \quad (1)$$

OEE applications are utilised across several industries and tailored to address specific requirements (Muchiri & Pintelon, 2008). In this case study, owing to the absence of data on the Quality metric (Q), the OEE was adjusted to concentrate on Performance (P) and Availability (A). At the same time, the Quality Rate was assessed independently as a compilation of reject rates. Therefore, the revised formula is:

$$OEE=P*A \quad (2)$$

3. Research Methods and Data Collection

3.1. Profile of ENICAB and its SC

ENICAB specialises in producing wires and cables. Established in 1982, it had an initial production capacity of 14,000 tonnes per year with 800 employees. In 2008, ENICAB became a subsidiary of General Cable (GC), an American group, and aims to be a regional leader, fulfilling 35% of national demand for cable products. Recently, Condor Group acquired GC's shares, with the remaining 30% being state-owned.

3.2. Research Methods and data collection

The selected research methodology is a real-world case study approach applied to an SC in the wires and cables sector. The triangulation technique has been utilised as a strategy for data collecting, incorporating a questionnaire, a

semi-structured interview with a heterogenous purposive sample of twelve wires and cables professionals, with actual contacts and archival research techniques. The experimental approach has also been conducted, employing the OEE technique and considering a purposeful sample of strategic machines from the focus company's case study.

The data collection process occurred in six phases. Initially, KPIs from the literature were classified into internal and external categories. The complete population of 32 customers, comprising 24 official distributors and eight additional customers, was evaluated. During the second phase, data for questionnaire design were collected through expert opinions and selected using purposive sampling. Semi-structured interviews with experts modified the KPIs and questionnaire, followed by telephonic communication to resolve overlooked issues in the third step. The fourth stage entailed disseminating the questionnaire over fax to collect customer data. In the fifth stage, a purposive sample of strategic machines was employed for the OEE implementation. The sixth step concentrated on collecting supplier data, employing in-depth interviews, telephonic communication, and archival research for the implementation of the AHP technique.

4. Application of the Proposed Framework

4.1. Internal measurement context

4.1.1. The suppliers' echelon: stakeholder contribution facet

The AHP as a proposed MCDM technique for this echelon involves five principle stages: (A) Problem diagnosis, (B) Model designing (C) Development of the pairwise comparisons, (D) Model assesement; and (E) Super matrix development (Thomas, 2008).

4.1.1.1. The problem's diagnosis

The raw materials of ENICAB are classified into two main categories: strategic raw materials and non-strategic raw materials. The cooper's suppliers as strategic materials are the focus of the suggested AHP. This sort of materials constitutes around 44 % of the total materials ENICAB is adopting the recently upgraded ISO 9001:2008 procedures. Nonetheless, the issue of suppliers' performance measurement is now tackled using a traditional, cost-based decision-making strategy.

Moreover, ENICAB does not utilise AHP or any contemporary MCDM method in this domain of project management. All pairwise comparisons in these circumstances are based on the buyer's experience.

4.1.1.2.The AHP decision-making building

A decision-making computer programme named 'SuperDecisions' (www.superdecisions.com) is employed to carry out all computations. The proposed AHP model is built ; Fig. 2.

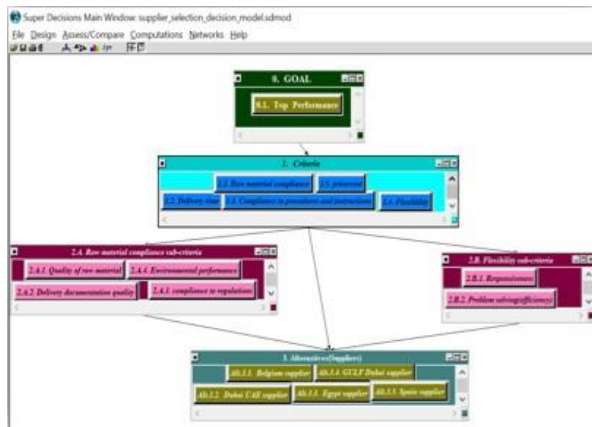


Fig. 2: the AHP model construction by the super decision programme (Screenshot)

4.1.1.3.Pairwise comparisons

A nine-point scale was employed for pairwise comparisons, yielding 12 matrices. The AHP evaluates nodes across various levels to determine priorities through pairwise comparisons and eigenvectors. The conclusive results are extracted from the Limit Matrix, as shown in Table 4, and the evaluation criteria results are presented in Table 5.

Table 4. ENICAB'S suppliers Priorities and rankings by the AHP method.

Suppliers	Priorities	Ranking
Alt.3.1. Belgium supplier	0.148465	2
Alt.3.2. Dubai UAE supplier	0.038657	5
Alt.3.3. Egypt supplier	0.149301	1

Alt.3.4. GULF Dubai supplier	0.049546	3
Alt.3.5. Spain supplier	0.048814	4

Table 5. AHP-derived priorities for the critical criteria.

<i>Criteria</i>	<i>priorities</i>
1.1 Quality/ compliance of raw materials	0.086957
1.2. Delivery timeliness	0.173913
1.3. Adherence to procedures and instructions	0.043478
1.4. Flexibility	0.043478
1.5. price/cost	0.086957

4.1.2. The focal company echelon: strategy, capabilities, and processes facets

The PM's embraced logic is based on selected vital characteristics of the non-financial PMSs (Garengo et al., 2005) and categorised according to the PP facets (Table 1 and Table 3). Focus has been given to several features illustrated in Table 6, along with the parameters and indices.

Table 6. Parameters and indices of the proposed framework for SC performance evaluation

Parameter and indices	Description	
A) The Objective of each SC's area /echelon of performance measurement	Obj _i	i: presents the codification name of a target area /echelon on SC.
B)Method of measurement revealed by KPI	KPI	measure depends on the type of the SC's echelon/area
C)Result of measurement	M	The actual value obtained by applying the related KPI
D)Deviation(objective measurement)	Δ	$\Delta = \text{Obj} - M$ (the planned value of the objective minus the actual value of measurement)
E) SC's performance level (subjective measurement) of the target(i) area/echelon	PL	PL can be measured according to these four levels: Very satisfactory, satisfactory, to improve, and not satisfactory.
F) levels/scores assigned to SC performance's area/echelon level	SAT/N. SAT:	'SAT' presents the satisfactory level of SC's performance, whereas 'N.SAT' signifies PL is not satisfactory.

The strategic objective of ENICAB is to meet its customers' expectations. Therefore, customer satisfaction constitutes the starting point of strategy design.

4.1.2.1.Delivery Rate Conforming to Quality and Lead Time:

$$kpi_{Rate(Q,T)}$$

Given that customers are ENICAB's primary stakeholders, the central strategic objective (Objtstrat) is to attain a high rate of deliveries that fulfil customer expectations. This objective is quantified as achieving a target of at least 85% for deliveries that meet the required quality (QL) and lead time (T) specifications. The related KPI model is consequently defined in the following equation .

$$kpi_{Rate(QL,T)} = \frac{\text{Number of delivered articles on time and matching the quality requirements}}{\text{Agregate deliveries}} \quad (3)$$

Where,

Rate of deliveries matching the quality and lead time = *Rate(QL,T)*

$$\text{Objt}_{\text{strat}} = \text{Rate}(QL,T) \geq 85\% \dots \dots \dots (4)$$

$$M = 79 \% , \Delta = -06\% \xrightarrow{\text{yields}} PL \text{ is } N.SAT$$

The $kpi_{Rate(QL,T)}$ indicates a deviation from the strategic objective, rendering the result unacceptable. In contrast, the strategic objective adopted by the central enterprise needs to be revised due to the new stipulations. New international rivals equipped with modern technologies have emerged in the Algerian market for wire and cable products. ENICAB once held the top position as a regional market leader; it now occupies second place. Furthermore, this KPI is comprehensive.

Consequently, further details are necessary to scrutinize this comprehensiveness and uncover the primary causes of this overarching setback. For example, is this overall drawback attributable to lead time factors, quality-related issues, or a combination? The following set of KPIs has been analyzed to deconstruct the previously mentioned KPI.

4.1.2.2.Indicator for the Number of Customer Complaints (kpi_{compl})

The kpi_{compl} is designed to analyse in greater depth the underlying factors contributing to the aforementioned shortcoming. The company has established an operational target of incurring fewer than eight complaints per annum. Accordingly, the related KPI is formulated as a follows.

$$kpi_{compl} = \text{number of customers' complaints per year} \quad (5)$$

Objective:

$$\text{complaints number} \leq 8 \text{ complaints per year} \quad (6)$$

$$M=7 \text{ complaints, } \Delta = +1 \xrightarrow{\text{yields}} PL: \text{satis}$$

The analysis of the kpi_{compl} indicated that there were a mere four grievances pertaining to cable quality. These related to minor defects in a small number of products. The remaining three complaints concerned cable length; specifically, instances where customers were supplied with an incorrect length of the required cable. Consequently, the internal analysis, albeit a subjective measure, suggests that the factory maintains a satisfactory performance level regarding the quality of its products. This finding lends partial support to the assumption that suppliers are providing suitable raw materials. Nevertheless, whilst these minor product quality faults might be accepted as falling within a marginal error, the factory faces a distinct drawback concerning cable length. That is, in certain instances, the company fails to provide its clientele with the precise requested length of cable. This outcome can be ascribed to the following contributing factors.

Throughout the course of the study, several deficiencies relating to the Information System (IS) were identified. A principal concern was the lag in information being updated from the Final Products Inventory Department and relayed to the Marketing and Sales Department. In some instances, this delay necessitates that sales agent physically verifies the status of stored products themselves. This procedure was observed to be time-consuming.

Whilst the company possesses a developed information technology system (ITS) – specifically, the AS/400, an IBM operating system implemented by the GC – observations made during this research identified significant latency issues. In certain cases, this manifests as personnel not receiving complete information. This problem is partly attributable to the inherent instability of the Algerian internet network, where frequent disconnections were noted to cause total system outages. This, however, was not the only factor identified. It was also determined that the training programme provided for the ITS lacked the required efficacy.

In certain instances, data were manually provided to the researcher. Specifically, certain data could not be extracted from the AS/400. Additionally, heads of various departments have indicated an enduring challenge in effectively utilizing the AS/400, noting a significant gap in its utilization.

Across these two KPIs, ENICAB's performance was deemed satisfactory concerning product quality. The next aspect to scrutinize pertains to the timeliness of deliveries. The elapsed time can be assessed utilizing a Takt time indicator, as introduced by Berrah et al. (2003).

- **Takt Time KPI: kpi_{tak}**

This partial KPI gauges the temporal progressing by computing the difference between the mean production Cycle Times observed in two successive first quarters.

kpi_{Tak} = production cycle time for a given quarter/ number of orders for the same quarter (7)

$\overline{kpi}_n$ = average of former quarter:

$$\text{Hence, } \overline{kpi}_n = \frac{\sum_{i=1}^{n=3} kpi_{Tak}}{3} \quad (8)$$

$\overline{kpi}_{n+1}$ = average of next quarter:

$$\text{Hence, } \overline{kpi}_{n+1} = \frac{\sum_{i=4}^{n=6} kpi_{Tak}}{3} \quad (9)$$

$$M = \overline{kpi}_{n+1} - \overline{kpi}_n \quad (10)$$

If: $M \leq 0$, thus PL: satis

Hence, $M = +0,81 \xrightarrow{\text{yields}} PL: nsatis$

Thus, the SC lead time deliveries trend is late; this reinforces the first KPI's result ($kpi_{QL,T}$)

The AHP results followed by the three previous KPIs show that the studied SC's performance's general problem is unrelated to product quality. The overall drawback is related to the delivery lead time save that these KPIs convey an inclusive PM. By adopting the process-oriented approach and the balanced logic, the causes behind the delivery lead time can be revealed by which the causal relationships are considered. Where the problem arises, and why? Against this background, system thinking and Performance Prism lend an ultimate performance analysis for the whole SC. Hence, is the SC's lead time deliveries pitfall the cause of the processes or capabilities, or does this concern the whole system? i.e., does this issue concern the input processes, transformation processes, or output processes? The following sections deal with these issues.

• **The input processes KPIs of SC's PM**

The input processes KPIs cover three KPIs as follows.

Non-conformity of purchased raw materials KPI

In this area, the objective is to maintain less than 1% of non-conformity to the quality standards of purchased raw materials ($Q_{nconfraw}$). Therefore,

$$kpi_{in-conform} = \frac{\text{quantity of non-conformity of purchased materials}}{\text{aggregated purchased quantities}} \quad (11)$$

Where,

$$Obj_{stra} : (\% Q_{nconfraw}) \leq 1\% \quad (12)$$

Hence,

$$M = 0.67; \Delta = -0.67 \xrightarrow{\text{yields}} PL : \text{satis}$$

This KPI excludes the non-conformity to quality standards of purchased raw materials as a cause of the SC's overall drawback.

○ **Purchased raw materials quantity achievement KPI**
($kpi_{Purch raw m}$)

The objective is to achieve 100 % of the company's needs of raw materials quantities. Thus,

$$kpi_{Purch raw} = 100\% \text{ comp materls needs} \quad (13)$$

$$\text{Where, } M = 85\%; \quad \Delta = -15\% \xrightarrow{\text{yields}} PL : \text{nsatis}$$

This result reinforces the fact that there is a delay in purchasing raw materials process. Failure to obtain materials on time and in required quantities forces the company to pay late delivery penalties for its customers and delay the production system, thus delaying the SC as a whole system.

○ **Out of stock (OOS) raw materials KPI (kpi_{oos})**

The objective is to sustain 0 days out of stock (OOS). Therefore,
 kpi_{oos} = total days being out of stock
 where

Obj_{oos} = 0 day out of stock

$M = 19 \text{ day}$; $\Delta = -19 \text{ day} \xrightarrow{\text{yields}} PL \text{ is } N.SAT$

This KPI gives more evidence for the SC's latency cause. Therefore, it enhances the three previous KPIs ($kpi_{QL,T}$, kpi_{compl} , and kpi_{Tak}).

• **The transformation processes KPIs: processes and capabilities facets**

These KPIs include three subsequent KPIs, which can be deployed according to causal and process-oriented logic. These KPIs are as follows.

○ **KPI of production management department**

This KPI measures the level of commitment of the production management department to the MPS. It depends on computing the difference between what has been planned and what has been realized. According to the focal company's MPS, it is preferable to maintain a margin of error of less than 20%. Hence, the KPI and its result are as follows.

$$Obj_{plan-real} : (Q_{plan} - Q_{real}) \leq 20\% \quad (14)$$

Where,

Q_{pin} : planned quantities, Q_{rel} : realised quantities

$$kpi_{pin-rel} = \sum_{i=1}^{n=12} (Q_{plan} - Q_{real}) / \sum_{i=1}^{n=12} (Q_{plan}) \quad (15)$$

$$M = 1,10 \% \xrightarrow{\text{yields}} PL: \text{satis}$$

Where,

$n = 12 \text{ months (for a given year)}$

This KPI shows a good PL. Therefore, the production planning department must be omitted as a principal cause of the latency problem of the deliveries.

○ *ENICAB Shop floor's KPI (kpi_{sr})*

ENICAB does not apply the OEE technique in this SC's PM area. ENICAB's shop floor consists of six workshops (Table 8). The emphasis is on the strategic machines.

The issue of lead time in a broader context has been illustrated by the prior utilization of the Takt time KPI ($kpitak$) By employing the OEE technique, which relies on comprehensive empirical data, the primary factors contributing to the lead time challenge can be discerned. This is achieved by referencing data derived from in-depth empirical records of time pertaining to a purposive sample of machines.

The shop floor KPI, known as Overall Equipment Effectiveness (OEE), is grounded in two fundamental criteria associated with time: machine speed, denoted as 's,' and machine reliability, represented by 'r.' The speed is measured by ' kpi_s ', while the reliability is quantified through ' kpi_r '. Consequently, the overall performance of the shop floor, denoted as ' kpi_{sr} ' encompasses the combination of these two KPIs. The former is referred to as ' kpi_s ' and the latter is designated as ' kpi_r '.

○ *Measurement's method of ' kpi_s ', ' kpi_r ' and ' kpi_{sr} '*

○ **Speed KPI ‘ kpi_s ’**

- Speed KPI: kpi_s

The kpi_s measures the proportion of the actual speed „sa“ of the machine and its theoretical one „st“.

Thus,

$$kpi_s = \frac{sa_j}{st_j} \quad (16)$$

Equation (16) is for a single strategic machine

$$kpi_{sa_i} = \sum_{i=1}^n (q_i * sa_j) / \sum_{i=1}^n q_i \quad (17)$$

Equation (17) is for a given number „n“ of strategic machines

$$kpi_{st_i} = \sum_{i=1}^n (q_i * st_j) / \sum_{i=1}^n q_i \quad (18)$$

Where,

q_i : quantity of each cable’s type;

sa_j : the machine’s actual speed variable;

n : number of strategic machines of the related process.

st_j : theoretical speed variable of each cable’s type manufactured by the related machine „j“.

- Reliability kpi_r : kpi_r measures the machine’s reliability by calculating the proportion of the machine’s theoretical cycle time and its actual cycle time.

$$kpi_r = \frac{ca_j}{ct_j} \quad (19)$$

Equation (19) is for a single machine

$$kpi_r = \sum_{j=1}^n ca_j / \sum_{j=1}^n ct_j \quad (20)$$

Equation (20) is for a number of strategic machines

Where,

ct_j : theoretical cycle time of a given machine;

ca_j : machine’s actual cycle time;

d_j : Machine’s downtime; Where,

$$ca_j = ct_j - d_j \quad (21)$$

- The total shop floor KPI(OEE): „speed and reliability kpi (kpi_{sr})“

The company’s objective is to maintain at 0.50 as a minimum ratio [7]. Hence,

$$kpi_{sr} = kpi_s * kpi_r \quad (22)$$

Therefore, the suitable kpi is:

$$obj_{sr}: kpi_{sr} = 0.50 \quad (23)$$

Where,

$$M = kpi_s * kpi_r \quad (24)$$

Under this kpi ; to achieve the objective: $\geq 0,50$, it should be that both kpi_s and kpi_r equates to at least 0,7071. OEE results are depicted in Table 4.

It should be noted that (20) applied only for a single machine, but concerning the whole shop floor, it has been used the kpi_{si} average and kpi_{ri} average alongside the kpi_{sri} average of all employed strategic machines. Measurements of 22 strategic machines have been conducted

twice for each machine. Then, to work out the total KPI of the whole shop floor, the following equation has been applied.

$$kpi_{sr} = \sum_{i=1}^n \left(\frac{kpi_{si} + kpi_{ri}}{n} \right) \quad (25)$$

$$n = 2 * (\text{number of employed machines}) \quad (26)$$

Table 7 indicates that the total PL (M: $kpi_{sr} = 0.4411$) was not satisfactory. Therefore, it still lasts the need to discover the in-depth causes behind the issue of delivery lateness. To do that, the workshops have been investigated separately (Table 7).

The kpi_{sr} column indicates that 50% of workshops have unsatisfactory PL: wire drawing, stranding, and screening/ armouring.

Table 7. Total PM of ENICAB'S Shopfloor (OEE Results)

Weighed KPIs	obj_{sr}	m	PL
kpi_s	$kpi_s \geq 0,7071$	$kpi_s = 0.9413$	Satisfactory
kpi_r	$kpi_r \geq 0,7071$	$kpi_r = 0.5088$	Not Satisfactory
$kpi_{sr}(\text{OEE})$	$kpi_{sr} \geq 0,50$	$kpi_{sr} = 0.4411$	Not Satisfactory

It is essential to highlight that Equation (20) is applicable solely to an individual machine. However, when considering the entire shop floor, a composite metric has been utilized, which incorporates both the average KPI denoted as kpi_{si} and kpi_{ri} , alongside the average kpi_{sri} for all strategic machines in operation. Measurements for each of the 22 strategic machines were conducted on two separate occasions. Subsequently, to ascertain the overall KPI for the entire shop floor, the subsequent equation was employed.

Table 7 presents an analysis of the performance metrics, revealing that the overall Performance Level (PL) fell below the desired standard, with a mean score of 0.4411 (M: $kpi_{sr} = 0.4411$) This outcome suggests that the current performance of the shop floor system did not meet the expectations. Furthermore, there was a noticeable deviation ($\Delta = -0.0589$) from the strategic objective, indicating a significant delay in the shop floor system's operations. On the other hand, an inspection of the causal relationship and process-oriented Performance measurement approaches reveals that even with their application, the analysis remains somewhat superficial. It becomes evident that there is a pressing need to

delve deeper into the underlying causes contributing to the issue of delivery lateness. To address this, an investigation was conducted separately for each workshop, applying the causal relationship and process-oriented logic. The findings of these investigations are presented in Table 8, demonstrating the individual PM results for each workshop.

Table 8. Weighed KPIs of each workshop

Workshop/process	M: kpi _s	M: kpi _r	M: kpi _{sr}	PL
1.Wire Drawings	0.9410	0.4690	0.4396	Not Satisfactory
2. Stranding	0.9433	0.3341	0.3175	Not Satisfactory
3. Insulation	0.9466	0.6591	0.6276	Satisfactory
4. Assembly	0.9250	0.6250	0.5791	Satisfactory
5. Screening / armouring	0.9000	0.2800	0.2565	Not Satisfactory
6. Jacketing	0.9575	0.6800	0.6509	Satisfactory

The data in the " kpi_{sr} " column discloses that 50% of the workshops exhibit unsatisfactory performance levels in the processes of wire drawing, stranding, and screening/armouring. This remark substantiates the presence of notable latency within ENICAB's shopfloor system. As a result, there is an observable increase in the time taken for SC processes to occur. It is worth noting that the " kpi_{sr} " reinforces the findings of the second KPI, specifically, the tact time KPI. The primary underlying factor contributing to the latency observed in ENICAB's shopfloor system can be attributed to the age of their machinery.

- **The output processes KPIs**

This KPI can be dismantled into two subsequent KPIs: KPI of finished articles' rejection rate and the waste materials KPI.

- **Finished articles' rejection rate KPI(kpi_{rej-rate})**

The company aims to maintain up to a 2.5 % rate of the finished article's rejection. (rej_{rate}). Therefore,

$$obj_{rej-rate}: rej_{rate} \leq 2.5\% \quad (27)$$

Where,

$$rej\ f\ art\ Q = rejected\ finched\ articles\ quantity \quad (28)$$

$$kpi_{rej_{rate}} = rej\ f\ art\ Q / total\ Q\ of\ f\ art \quad (29)$$

- **Waste materials' error margin KPI (kpi_{wmat})**

This KPI measures the ratio of waste materials quantity (Q_{wmat}) resulting from the production processes. According to the company's experts, a waste materials proportion of less than 2.5 % is a strategic objective based on the precedent year as a reference point.

$$obj_{Q_{wmat}}: Q_{wmat} \leq 2.5 \% \quad (30)$$

$$kpi_{Q_{wmat}} = \text{aggr } wmat / \text{aggr } mat \text{ quant} \quad (31)$$

Where, 'aggr': aggregate; 'mat': materials; 'quant': quantities.

According to the semi-structured interview, the main reasons behind this poor PL measured by the last two KPIs are the machine breakdowns resulting from overuse causes. These KPIs reinforce the measurement result obtained by the kpi_{sr} .

4.2. External measurement context

4.2.1. Distributors and customers' echelon: stakeholders' contribution and customers' satisfaction facets

A questionnaire, serving as a subjective measurement tool (Appendix A), has been designed and administered to the complete clientele of ENICAB, in conjunction with a semi-structured interview. (a total of 32 customers, which are 24 official distributors of the focal company and eight customers: 7 of them are a state-owned enterprise and one Enterprise belonging to the private sector as end consumers).

The analysis has been conducted based on the ENICAB's strategic objective. Therefore, the adopted KPI is as follows.

ENICAB's strategic objective is to achieve at least 85% of its customers' satisfaction (satis-customer). Therefore, the related KPI is as follows.

$$obj_{satis-customer} : ratio_{sati-custmer} \geq 0.85 \quad (32)$$

KPI=aggregation of very satisfactory and satisfactory proportions (33)

Where,

$$0 \leq M \leq 25\% \xrightarrow{\text{yields}} PL: n. satis(\text{Very poor})$$

$$25 < M \leq 49.99\% \xrightarrow{\text{yields}} PL: to impr(\text{poor})$$

$$49.99 < M \leq 84.99\% \xrightarrow{\text{yields}} PL: satis(\text{fair})$$

$$85 \leq M \leq 100\% \xrightarrow{\text{yields}} PL : v.satis(\text{Excellent})$$

Table 9 shows results of the external measurement context arranged in ascending order according to the PL ratios.

Table 9. External PM results (customers contribution)

KPIs	M (=customers' satisfaction degree)	PL
Flexibility(products availability)	28%	To improve
Payment terms (trade credit)	39%	To improve
Communication quality with salespersons	41%	To improve
Order to delivery cycle time	43%	To improve
Support for wire/cable loading process by ENICAB	45%	To improve
Customers' complaints: response time	50%	Satisfactory
Customers' complaints: treatment	55%	Satisfactory
Quotation lead time (responsiveness to inquiry	56%	Satisfactory
Products' packaging quality	72%	Satisfactory
Invoice delivery's lead time	72%	Satisfactory
Delivery order's sheet lead time	75%	Satisfactory
Removal order's sheet lead time	81%	Very satisfactory
Staff's empathy (guard post, sales executives, and salesperson's department)	97%	Very satisfactory
Products quality	100%	Very satisfactory

It should be noted that the external measurement context for product quality corresponds with the internal measurement context. Also, the external measurement context for order to delivery cycle time corresponds with the internal measurement context.

5. Performance improvements suggestions for the ENICA's SC

Results of the external measurement context (Table 9) and the semi-structured interview demonstrate that ENICAB's SC has a high PL in its product quality. As for the remaining SC's areas that need improvement, they are as follows:

5.1. Products availability and payment terms

Significant majority (72%) of customers registered complaints regarding the unavailability of certain product types. This problem stems from the organisation's technological limitations, as it currently lacks the

capacity to manufacture these items, which in turn adversely impacts the flexibility of its supply chain. Therefore, incumbent upon the organisation to review its technological capabilities. This review must address the need for re-engineering production processes, which involves analysing and debating the technical merits of acquiring modern machinery versus renewing spare parts for existing strategic equipment. Furthermore, customers expressed notable dissatisfaction with the payment terms, specifically concerning the payback period for trade credit. Intervention from top decision-makers is required to resolve this matter and enhance customer satisfaction.

5.2. Communication quality with salespersons and quotation lead time

Customers (59%) observed a slow response from the sales officials; they prefer the cell phone to the fax, whereas 44% are dissatisfied with the quotation's lead time. The organisation should improve the lead time of this KPI by applying lean production principles, e.g., the Japanese principal 'Muda'. The company should first improve the IS. The same actions related to Muda and IS can be replicated for the Invoice delivery's lead time and delivery order's sheet lead time.

5.3. Order-to-Delivery Cycle Time

A notable majority of customers (57%) expressed dissatisfaction with the order-to-delivery cycle time. The origins of this dissatisfaction are twofold: issues with stock-outs and the insufficient reliability of strategic machinery, a conclusion supported by the internal measurement data (as detailed in Table 4). It is advisable for top decision-makers to re-evaluate the status of their strategic equipment. This could involve, for instance, re-engineering these machines or, at minimum, renewing their essential spare parts. This applies particularly to equipment involved in the wire drawing, stranding, and insulation/assembling processes. To contend with the stock-out problem, the company might consider employing probabilistic inventory models.

5.4. Customers' complaints

A substantial portion of the clientele (45%) is not satisfied with the manner in which the organisation handles their complaints;

simultaneously, 50% are dissatisfied with the response time. Deficiencies within the IS were identified as a key contributing factor to the company's suboptimal complaint response. The remedial suggestions outlined previously, within the internal measurement context, are therefore equally applicable to this issue.

5.5. Support for products loading process and packaging quality

Customers (55%) believe that the loading process takes a very long time, whereas 18% are dissatisfied with the quality of the product's packaging, which does not provide adequate protection. The factory uses wooden/iron reels for the packaging process. During the packaging and loading process, reels sometimes collide and damage the cables' sheath. Therefore, these operations should be improved by, for instance, adopting the re-engineer process principles of this process.

6. Conclusion

In light of the central Enterprise's recent drop to the second position in the Algerian marketplace. This circumstance can serve as a pivotal reference for subjective assessment. Therefore, external measurement KPIs must be raised in which the SC's performance level was acceptable. Consequently, the organisations strategic objectives should be adjusted if the Organisation plans to regain its former first position.

This study measured the performance of the Algerian wires/cables industry's SC, a subsidiary of the American General Group company, employing an integrated Performance Prism-based framework. The AHP was utilised to evaluate the first echelon of the SC, addressing decision-making issues relevant to vendor performance in alignment with the central enterprise's strategy. For the remaining SC echelons, the framework simultaneously utilised subjective and objective KPIs, accounting for both internal and external measurement contexts across the Performance Prism's five facets.

Diagnosing the SC's weaknesses and strengths is the initial step in improving SC performance for decision-makers and SC managers. In this regard, categorising KPIs for the Performance Prism facets can provide a decision-support roadmap for SC and engineering managers to tackle this complex task. Findings reveal that capabilities and processes facets, especially the ENICAB's shop floor (where the Overall Equipment Effectiveness technique was applied), the inventory

management department, and IS/IT, were the most significant Performance Prism facets. However, the stakeholder contribution facet, which pertains to suppliers in this case, was the second most influential Performance Measurement facet for the studied SC.

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7. Appendices :

Appendix A

KPIs as questionnaire in wire/cable industry

1. Products quality (Persson and Olhager 2002)
2. Order to delivery cycle time (Gunasekaran et al. 2007)
3. Products' packaging quality (White et al. 2016)
4. Flexibility : Product availability (Enrique et al. 2022)
5. Customer service (Pre-sale and post-sale services) (Hosseini-Motlagh et al. 2020)
 - Quotation lead time (Responsiveness to inquiry) (Hammami et al. 2020)
 - Reception quality (staff's empathy) (Aggarwal et al. 2015)
 - Guard post (access to the factory)
 - Sales executives
 - Salespersons' department
 - Communication quality with salespersons (Sengupta et al. 2000):
 - Delivery invoice (lead time) (Gunasekaran et al. 2007)
 - Payment terms (Trade credit) (Wu et al. 2019)
 - Customers' complaints (response time and treatment) (Knox and Van Oest 2014)
 - Other issues related to customer service and delivery time metrics (semi-instructed interview with the experts)
 - Removal order's sheet lead time
 - Delivery order's sheet lead time
 - Support for Wire/Cable loading process by the company

Appendix B

Table 2 The Performance Prism VS. The Balanced Scorecard

	Dimensions	PP Score	BSC Score
Full similarities(A)	Strategy improvement: KPIs should be designed to enhance the company's objectives. Therefore, they help enhance the company's strategy.	1	1
	Depth: KPIs are concerned with each operation.	1	1
	Multidimensional/Balanced: Multidimensional models are described as models that assume various perspectives/contexts of analysis and measurement and manage them in a co-ordinated method (financial / non-financial) or (internal/external measurement)	1	1
	Breadth: All main functions (or macro-processes) are the subject of the measurement	1	1
	Causal relationship: The objective of the KPIs is to reveal the 'causal relationship' between them.	1	1
	Total of full similarities (A)	5pts	5pts
Partial similarities/differences(B)	Strategy alignment: <i>Strategy is the vital dimension in the model. The PMS should guarantee that the KPIs align with the company's strategy.</i>	0.5	1
	Process-oriented: The organization is seen as a unit of collaborated processes constituting a system.	1	0.5
	Total of Partial similarities/differences(B)	1.5pts	1.5pts
Differences(C)	Stakeholder focus: Stakeholders requirements constitute the foundation and the roadmap to formulate the company strategy	1	0
	Clarity and simplicity: the objectives, KPIs and methodology of gathering information are clear, simple and communicated to those involved in the PMS.	1	0
	Vertical: PMSs are firmly hierarchical (or strictly vertical), characterized by cost and non-cost performances on different levels of aggregation.	0	1

Horizontal: PMSs should focus on internal business processes, and based on functional units.	1	0
Dynamic adaptability: KPIs and PMS should be reviewed to respond to environment changes	1	0
TOTAL of full differences(C)	4	1
Total(A+B+C) =	10.5/12	7.5/12

Appendix C

Table 3. KPIs categorisation according to PP facets and wire/cable industry experts' opinion (internal-external measurement methods and objective-subjective measurements context)

PP facets	Key Area of PM in SC	Measurement method/dimension	KPIs (References)
Stakeholder Satisfaction and Stakeholder Contribution	Customer satisfaction	Internal measurement	Objective measurement KPI: satisfied customers (Strategic goal of the company) (Christopher Martin, 2011)
	Customer contribution	External measurement	Subjective measurement: Questionnaire analysis KPI (Neely et al. 2000)
	Stakeholder contribution: Suppliers	Internal measurement: AHP	Subjective measurement + Objective measurement KPIs: Quality requirements (Tîtu and Pop 2022), Delivery time (Noori-Daryan et al. 2019), Flexibility (Enrique et al. 2022), Price/cost (Castellano and Santillo 2023)
Strategies	Focusing on satisfying Stakeholders' needs and wants	Internal measurement: The actual situation of the focal company realisation versus its planned strategic goal	Objective measurement KPI: The deviation between the strategic goal and the actual achievement (Neely et al. 2000)
Processes and Capabilities	The focal company (key departments)	Internal measurement: Set of simple mathematic models	Objective measurement KPIs: lead time and quality requirements (fill rate) (Abbasi et al. 2018), Takt Time (Berrah L. et al. 2003), Quality and Out of stock (Bazrov and Rodionova 2019), Purchases' achievement (Hastings et al. 1982), Schedule attainment (MPS) (Hastings et al. 1982), finished and good article (Hastings et al. 1982), Finished goods' rejection rate (Jafarzadeh Ghazi et al. 2023), Waste materials (Ershadi et al. 2023), Information sharing degree (Thomas and Mahanty, 2021)
		External measurement: Questionnaire method (Customer contribution)	Subjective measurement KPIs: See Appendix A
	Company shop floor	Internal measurement: OEE	Objective measurement KPIs: OEE metrics (Singh et al. 2021)
		External measurement: Questionnaire method (Customer contribution)	Subjective measurement KPIs: Other metrics related to the shop floor: Products 'Packaging quality (White et al. 2016), Loading process (Lead time) (Castellano and Santillo 2023)