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An Integrated Performance Prism-Based Framework for Supply Chain Performance Measurement

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Abstract. In this research, an integrated framework for supply chain performance measurement has been designed. The Performance Prism system was employed along with the Analytic Hierarchy Process and the Overall Equipment Effectiveness method to measure the performance of a supply chain. Moreover, the proposed approach addressed the usefulness of combining objective and subjective Key Performance Indicators (KPIs) and demonstrates the efficacy of integrating internal and external measurement contexts as an effective tool for the performance measurement processes. A comprehensive set of non-financial KPIs from the literature and wire/cable industry experts were selected, and classified into five categories corresponding to the five facets of the Performance Prism to help operations managers comprehend holistically performance measurement processes. Findings revealed that capabilities and processes facets have the most significant Performance effect on the SC performance. In contrast, the stakeholder contribution(customers) facet has the most influential impact on the performance measurement processes.

Keywords: Performance Prism, KPIs, AHP, OEE, Supply Chain Management.

1. Introduction

Due to their primary function of transferring energy and information, wire and cable industries have a significant socio-economic impact on all sectors. It is essential therefore, to measure and improve these industries' performance for which a Performance Measurement System (PMS) should be designed.

PMSs have been extensively highlighted by practitioners and academics (e.g. [1, 2]). 'Performance Prism' [3] is considered as one of the amplest PMS introduced so far [2]. It advances a new framework for organisations' performance by its five inter-related facets: Stakeholders satisfaction, Stakeholders contribution, Strategies, Processes, and Capabilities [2]. Also, it offers a new approach towards supply chain (SC)' performance through which different non-financial PM aspects are processing in conjunction with the company strategy. Alternatively, the analytic hierarchy process (AHP) [4] and the overall equipment effectiveness (OEE) [5] are other PM methods that can be embedded in other frameworks due to their flexibility and simplicity. In this paper, to gain advantages of these methods, an integrated Performance Prism-based framework is introduced. Furthermore, a comprehensive set of non-financial KPIs from literature and wire/cable industry experts were selected and classified into five categories corresponding to the five facets of the Performance Prism to help operations managers comprehend performance measurement processes.

It is not evident how firms should measure their SC performances. Several PM frameworks, with many measures, have become more complex tasks[6-8]Moreover, research investigating PM beyond a single firm's borders is still limited [1]. Another grave issue, is that most PMSs used in firms comprise too many different measures, making it hard to comprehend the 'big picture'[7].

Even though Performance Prism is considered one of PM's utmost thorough approaches, unpredictably, it is one of the least studied amongst the modern frameworks[2]. From reviewing the literature, it is proposed that this is the first paper that deals with the wire/cable industries in terms of PMSs using an integrated

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Performance Prism-based framework. Significantly, there is no comprehensive framework for such an industry's PM by considering both subjective/objective measurement methods and internal/external measurement contexts regarding Performance Prism. Also, less effort has been devoted to working out the delicate relationships among different KPIs [6].

In this paper, a novel framework is introduced to fill these gaps and guide top decision-makers and operations managers in improving their SC performance. Due to the flexibility of the Performance Prism, the AHP method and the OEE technique alongside a comprehensive set of selected KPIs based on the literature and expert's opinion, the proposed approach can be implemented for other supply chain scenarios.

The proposed approach deals with both internal and external measurements context dissimilar to the most relevant approaches. This addresses both subjective and objective measurement methods. Furthermore, the complexity of mathematical models have been avoided to simplify using the proposed framework for operations managers.

According to the simplification principle [6, 9-11] operations managers, in general, tend to use more simplistic methods in their operations management. This is despite the fact, that several PM frameworks supported by advanced mathematic/simulation models have been introduced. Nevertheless, their implementation needs a considerable background knowledge in mathematics or software engineering from a practical viewpoint. Therefore, this study aims to offer a practical and straightforward example that operations managers can use in measuring the performance of their SCs. Besides, the AHP and the OEE methods have been applied from the same practical viewpoint of simplicity[6, 12]. Although AHP constitutes an advanced and powerful mathematics model, its application is simple and has a short learning curve [13]. In this line, the OEE method is another effective PM model [14], with high flexibility and simplicity that align with the Performance prism. Furthermore, and to a minor degree, research on SC's PMS has examined how the proposed frameworks can be implemented and made part of practice[15].

A wire/cable company has been chosen to demonstrate the applicability of the proposed framework. Finally, the case company's management decisions are illustrated with the proposed framework's results to improve their SC performance.

2. Literature Review

Kim et al. [15] suggested a new PMS under activity-based costing method and TOPSIS technique. A framework by Gunasekaran et al. [16] was employed in designing a survey to scrutinise performance measures. Arns et al. [17] proposed a hybrid approach that merges algebraic with numerical analysis to extrapolate performance measures like resource utilisations and lead times.

Neely et al. [18] designed a rigorous application of Performance Prism, wherein the company's customers have been categorised based on customer needs. Laihonen and Pekkola [19] utilised a semi-structured interview technique to design a new PMS. focus has been given to the performance information's usage and sharing in a SC. An innovative hybrid BSC-DEA (balanced-scorecard -data envelopment analysis) approach for sustainable SCs has been developed by Motevali Haghighi et al. [20]. Prajogo and Olhager [21] investigated the integrations of information and material flows between SC members and their influence on operational performance.

Nacereddine et al. [22] carried out a cross-sectional study on the PM of a production system. The Performance Prism has given attention. Liu and Liu [23] proposed a PMS for SC, in which they utilised the DEA method and gap-based measurement. Dossou and Nachidi [24] conducted a non-linear approach to demonstrate how the lead-time criterion could increase SC performance. Dissanayake and Cross [25] combined three models, SEM, AHP, and SCOR. The relationship between capacity restrictions and the operational performance of SCs is investigated by Cannella et al. [26]. They conducted simulation techniques.

Ramezankhani et al. [27] proposed a DEA framework to measure a SC's sustainability dimensions' performance. A hybrid method using Quality Function Deployment with Decision Making Trial and Evaluation Laboratory has also been used. Their framework is applied to the automotive manufacturing sector. Based on neuro-fuzzy systems of the ANFIS type and the SCOR level-1 metrics, Lima-Junior and Carpinetti [28] proposed a new SC PMS.

The relevant literature shows minimal research on the PM of SCs using an integrated approach considering both the Performance Prism and AHP method and the OEE technique. The literature further evidences, that applying the Performance prism, the AHP method and the OEE technique is minimal on the wire/cable industries. In addition, The proposed approach deals with both internal and external measurements context dissimilar to the most relevant approaches. Also, it accounts for both subjective and objective measurement methods. Further, the complexity of mathematical models has been avoided to simplify using the proposed framework for operations managers.

A wire/cable company has been chosen to demonstrate the applicability of the proposed framework. Finally, the case company's management decisions are illustrated with the proposed framework's results to improve their SC performance.

3. The Proposed Approach

3.1. Supply Chain KPIs in the Wire/Cable Industry

Relating to a semi-structured interview with a heterogeneous sample of the wires/cables industry's experts, several KPIs from the literature are identified (Table 1).

Table 1: Vital KPIs used in wire/cable industry based on literature and experts 'opinion (internal measurement)

KPIs	References
Products quality	[27]
Customer satisfaction and Customer service	[28], [29]
Time-based performance indicator	[30]
On-time deliveries (orders) and fill rate	[28], [31]
Cost	[32]
OEE metrics(speed/effectiveness)	[33]
Out of stock	[28]
Reliability and Degree of information sharing	[34], [11]
Schedule attainment	[35]
Quality requirements(compliance to regulations, specifications and quality of delivery documentation)	[36]
Finished goods' rejection rate and waste materials	[37], [38]

3.2. Performance Prism System

Performance Prism [3] comprises five interconnected facets [3]; the first facet probes the issue: 'Who are the vital stakeholders and what are their needs?'. The second facet focuses on Strategies. Neely et al. [18] stated that measures had been derived from strategy. According to the same authors, this is the wrong way. They added that an organisation's only purpose is to add value to its key stakeholders. Furthermore, they stressed the key stakeholders' needs as the starting point of strategy formulation. The second facet of the Prism probes: 'What are the strategies we need to guarantee the satisfaction of our stakeholders' needs?'. The third facet probes the issue: 'What are the processes we have to implement to deliver our strategies [3]. For example, an operations manager has to ask: 'Are the processes operating efficiently and effectively?' and 'how we can perceive the sub-components of it are the cause of its inefficiency or ineffectiveness?'. The fourth facet probes the issue: 'What are the capabilities we rely on to operate our processes?' [18]. The final facet is the stakeholder contribution [18]; the authors argue that organisations have to distribute value to their stakeholders and enter into a relationship with their stakeholders, which, in return, should contribute to the organisation.

3.3. Categorizing SC's KPIs into Prism Performance Facets in the Wire/Cable Industry

The KPIs are deployed according to the internal/external measurement contexts and objective/subjective measurement methods according the Performance Prism's facets. In this regard, a questionnaire, as an external measurement context, associated with a semi-structured interview has been designed according to the literature and a heterogeneous sample of the wire/cable industry experts' opinions.

3.4. The AHP and the OEE methods

- *The AHP Method*

Due to its simplicity and flexibility [29], AHP has been employed broadly in almost all applications connected to MCDM techniques. It tolerates subjective aspects; it is considered a progression compared to other MCDMs [30]. Furthermore, it allows to assess the decision-making inconsistency [31], which is considered a significant advancement and a distinguishing feature compared to other MCDM techniques. In this study, AHP incorporated subjective KPIs and objective ones concurrently. Consequently, it allows to embody the experts' subjective judgments. Accounting for these factors would make the proposed model more effective.

MCDM techniques have been broadly employed for supplier's PM (e.g. [29, 32]). Dey et al. [32] argued that there is no best method; each has its positive and negative aspects. They stated that selecting specific supplier PM methods rests on many factors, such as supplier performance implications on overall organisational performance, evaluation concepts, and ease of use. Subsequently, the more optimal approach depends on the context of applying that approach and not only on its robustness. In this paper, the AHP model has been adopted due to its flexibility, ease of use, and simplicity compared to other methods that depend on complex models.

- *The OEE Method*

Nakajima developed the OEE method for evaluating total productive maintenance in the late 1980s [5] . Muthiah, Huang, and Mahadevan [33] consider it as a powerful method that can identify equipment losses in order to improve equipment reliability. The OEE method considers three critical metrics of equipment performance: availability (A), performance (P) and quality rate (Q) of output when evaluating equipment effectiveness using the following formula [34].

$$OEE = P * A * Q \tag{1}$$

Industrial companies have modified OEE to suit their specific requirements ; some of the modified formulations are limited to equipment level effectiveness[34]. In this study, the OEE is modified and adapted to the company's case study. In this context, the formulations are limited to performance (*P*) and availability (*A*) because of data unavailability of the third metric (*Q*). Therefore, the quality rate (*Q*) was measured separately as an overall aggregation of the reject rate. Consequently, formula one is modified as follows.

$$OEE = P * A \tag{2}$$

4. A Real Life Case Study

4.1. Research Methods and Data Collection

The research adopted a case study approach. The triangulation method has taken place as a data collection technique [30], where a combination between a questionnaire and a semi-structured interview with a heterogeneous purposive sample of wire/cable experts and archival research have been conducted alongside actual contacts technique [35]. The experiment strategy [35] using the OEE technique has also taken place dealing with a purposive sample of strategic machines.

4.2. Profile of the focal company and its SC

ENICAB (Entreprise National des Industries des Cables Biskra) is an industrial company specialized in the production of wires /cables. The company was established in 1982 with a production capacity of 14000 tonne /year and 800 employees. On 20/05/2008, ENICAB became a General Cable's subsidiary (GC: an industrial American group). Recently, an Algerian industrial group has acquired all GC shares. The SC understudy consists of four echelons: the first echelon is a set of raw materials' suppliers. The cooper presents the central part of purchased raw materials. The second echelon is the manufacturer (ENICAB). The third echelon is a set of authorized distributors (24 whole distributors), and the fourth echelon is a set of 8 Governmental organizations that buy the wires/cables as end-consumers. The study focused on the suppliers of strategic raw materials as a non-probabilistic sampling method [35]. As far as the distributors and the end-consumers, the whole number of both distributors and end-consumers have been considered.

5. Application of the Proposed Approach

5.1. Parameter and Indices of the Proposed Method

- *Obj_i:* The Objective of each SC's aria /echelon of performance measurement
- *KPI:* Key Performance Indicator
- *M:* Result of measurement
- $\Delta = Obj_i - M$
- *PL:* SC's performance level as a subjective measurement (vsatis: very satisfactory, satis: satisfactory, to imp: to improve, and nsatis: not satisfactory) for a given SC's area/echelon of measurement.

5.2. Internal Measurement Context

- *The suppliers echelon: stakeholder contribution facet*

In this SC's echelon, the AHP has been applied. The AHP includes these major phases: The problem's diagnosis, building the decision model, the Pairwise comparisons and Super matrices developments.

- *The problem's diagnosis and The AHP decision-model building*

ENICAB is in progress to implement the ISO 9001:2008 procedures, which have been updated recently. However, the problem of suppliers' PM is being tackled in a classical way which is a cost-based decision approach. Furthermore, ENICAB does not apply either AHP nor any modern MCDM methods in this area of PM. In these settings, we have conducted all the pairwise comparisons based on the buyer's experience. A decision-making software called 'SuperDecisions' (www.superdecisions.com) has been implemented to carry out all computations and build the AHP structure. The proposed decision model is built and detailed in Figure 1.

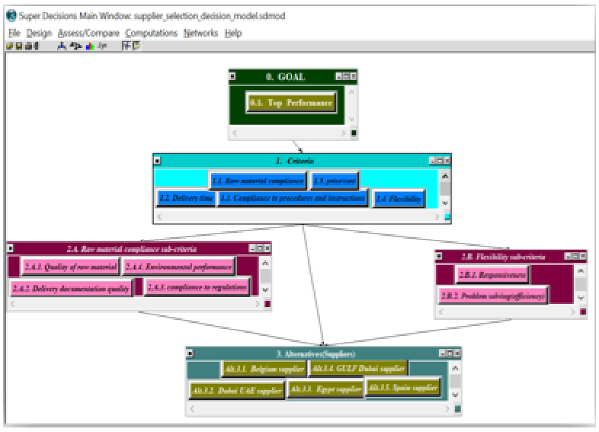

Fig. 1: A Screenshot of the AHP model construction using the super decision software

- *Pairwise comparisons and The super matrices developments (Results and discussion)*

A particular nine-point scale has been employed to conduct pairwise comparisons; wherein even values are intermediate values [36]. The overall number of pairwise comparisons is twelve. Therefore, we have 12 matrices: One matrix for the criteria cluster for the goal node, two matrices for the sub-criteria clusters, the first of which for the sub-criteria under the 'raw material compliance' node, which includes quality of raw material, delivery documentations' quality, compliance to regulations and environmental performance, the other one is for the sub-criteria cluster related to flexibility criteria which comprises responsiveness and efficiency nodes (Figure 1). Therefore, the rest are nine comparison matrices for the five alternatives for all the nine covering criteria. The nine covering criteria are: 1). Quality of raw materials, 2). Delivery documentations' quality, 3). Compliance to regulations, 4). Environmental performance, 5). Responsiveness, 6). Problem-solving (Efficiency), 7). Delivery time, 8). Compliance with procedures and instructions, and 9). Price/cost. (Figure 1)

An eigenvector is calculated for each matrix. Furthermore, matrices' consistency ratio is computed and checked whether the ratios are superior to 0.10 value or not. If the ratio is beyond the limit, it means that the decision process is inconsistent [31]. In this case, questions should be asked again to the buyer to have an acceptable inconsistency ratio. The software computed the limit matrix. Its output can be converted to the relative priorities. i.e., the company's potential suppliers' total preferences which are depicted in Table 2.

The authors suggested that pairwise comparisons should be aligned with the company's strategic objective. In this context, the authors proposed that the buyer should attach more importance to the 'delivery time' criterion and 'raw material compliance' criterion. As a result, the supplier PM process prioritised delivery time and the quality requirements standard. It is noteworthy that the pairwise comparisons were made with the assumption that all five suppliers have relatively the same score in terms of raw material compliance, which is the buyer's hypothesis based on his experience.

Table 2: Priorities and Rankings of ENICAB'S Suppliers Based on 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 3: Priorities of Critical Criteria

Criteria	Priorities
1.1. Raw material compliance(quality)	0.086957
1.2. Delivery time	0.173913
1.3. Compliance with procedures and instructions	0.043478
1.4. Flexibility	0.043478
1.5. price/cost	0.086957

Since the focal company's method has used only the 'price/cost' metric to evaluate their suppliers' performance, the performance level at this SC's echelon is deemed to be not satisfactory; this is the first drawback of the studied SC as it can lead to a lower level of customer satisfaction in terms of quality standards or lead time deliveries. The following KPIs would reveal the related results of this echelon's drawback.

- *The focal company echelon: strategy, capabilities, and processes facets*

The strategic objective of ENICAB is to meet their customers' expectations. Strategies and KPIs have to be designed based on customer satisfaction [37, 38].

- *Rate of deliveries matching the quality and lead time: $kpi_{Rate(Q,T)}$*

The key stakeholder of ENICAB is its customers. In this line, the strategic objective(Objstrat) is to achieve a high rate of deliveries matching the customers' needs and wants. The ENICAB's strategic objective is achieving at least 85% as a rate of deliveries matching the quality(QL) and lead time (T). Therefore, the related KPI model is illustrated in Equation (3) as follows.

$kpi_{Rate(Q,T)}$ = delivered articles on time and matching the quality requirements / Aggregate deliveries (3)

Where, Rate (QL, T): Deliveries' rate matching the QL and T

$$Obj_{strat}: \; Rate_{(QL,\,T)} \geq 85\% \quad (4)$$

$$M = 79\,\%\,,\;\; \Delta = -06\% \xrightarrow{yields} PL{:}\,nsatis$$

The $kpi_{Rate(Q,T)}$ indicates that there is a deviation from the strategic objective. Therefore, the result is deemed unacceptable. On the other hand, the strategic objective of the focal company is not sufficient as a strategic objective due to the new conditions, wherein the Algerian market of wire/cable products has received new international rivals with modern technologies. ENICAB used to occupy the first place in the region as a market leader; now, it occupies second place. Moreover, this KPI is inclusive. Subsequently, more details are needed to scrutinise this inclusiveness and divulge the primary causes of this overall drawback. i.e., this overall drawback is due to the lead time cause or quality factor cause or both of them? The following set of KPIs have been analysed to dismantle the previous KPI.

- *Customer Complaints' number indicator(kpi_{Compl})*

The kpi_{Compl} aims to go in-depth to disclose more detail about the causes behind the abovementioned overall drawback. The objective of ENICAB is to receive less than eight complaints per year. Therefore, the related KPI is as below.

kpi_{Compl}= number of customers' complaints per year (5)

Objective:

$complaints\ number \leq 8\ complaints\ per\ year$ (6)

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

The analysis about the kpi_{Compl} indicated that there were only four complaints related to the quality of cables. These complaints were minor in a minimal amount of products, while the rest were three complaints related to the cables' length, i.e., some customers did not receive the requested length of the required cable. Therefore, the internal analysis as a subjective measurement method shows that ENICAB has a satisfactory PL concerning the quality of its products and this, partially reinforces the buyer assumption about the suitable raw material quality delivered by their suppliers. Even though the product quality's minor faults can be accepted as a marginal error, ENICAB has another drawback related to the cable's length. i.e., in some cases, ENICAB does not deliver the exact length of the demanded cables to their customers. This result is due to the following factors.

- During the study period, the researcher noticed several problems related to the information system(IS), including the delay in updated information from the Final Products Inventory Department to the Marketing and Sales Department. In some cases, the salesperson has had to go personally to check the stored products' state; this is a time-consuming process.
- Even though ENICAB owns a developed information technology system ITS (called AS/400: an IBM operating system implemented by the GC), several practices noticed by the researcher, identified ITS latency issues, wherein the information's receiver, in some cases, does not have the complete information; this is in part, due to the situation of the Algerian internet network by which frequent disconnections occur resulting in the break of all the ITS. However, additionally it was found that the training program for the ITS was not adequate; in some cases, data were provided to the researcher manually, i.e., an amount of data cannot be extracted from the AS/400; also several departments' heads stated that they still have a significant gap of how to utilize perfectly the AS/400. Over these two KPIs, the PL of the ENICAB was satisfactory in terms of product quality. All that remains is to check the deliveries lead time issue. In this regard, the time issue can be measured using a so-called Takt time indicator [39].

- *Takt Time KPI:* $\boldsymbol{kpi_{Tak}}$

$\boldsymbol{kpi_{Tak}}$ = 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:

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

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

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

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

Thus, the SC lead time deliveries trend is late; this reinforces the first kpi($KPI_{(QL,T)}$) result.

The AHP results followed by the three previous KPIs show that the studied SC's performance's general problem is not related to product quality. The overall drawback is related to the delivery lead time save that these KPIs are conveying an inclusive PM. By adopting the combination between the process-oriented approach and the balance 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, the system thinking and Performance Prism lends 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 or the transformation processes, or the 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 quality standards of purchased raw materials ($Q_{nconfraw}$). Therefore,

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

Where,

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

Hence,

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

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

- Purchased raw materials quantity achievement KPI($kpi_{Purch\ raw}$)

The objective is to achieve 100 % of the company's raw materials needs (comp materls needs). Thus,

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

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

This result reinforces the fact that there is a delay in the process of purchasing raw materials. 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,

$$Obj_{OOS}{:}\,0\ day\ out\ of\ stock$$

$$M\ = 19\ day;\ \ \Delta\ =\ -19\ day\ \xrightarrow{yields} PL\ :\ nsatis$$

This kpi gives another 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 below.

- KPI of production management department

This KPI measures the level of commitment of the production management department to the MPS (master production schedule). 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,

$$Q_{pln}: planned\ quantities, Q_{rel}: realised\ quantities$$

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

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

Where,

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

This KPI shows a good PL. Therefore, the production planning department has to be omitted as a principal cause behind the deliveries' latency problem.

- ENICAB Shop floor's KPI 'kpi_{sr}'

The previous KPI (the Takt time KPI: kpi_{tak}) has demonstrated the problem of lead time in general. By employing the OEE technique, which is based on in-depth empirical data, the foremost reasons which result in the lead time pitfall may be identified, largely by referring to data collected via in-depth empirical records of time relating to a purposive sample of machines. The shop floor KPI (OEE) is based on two core criteria relating to the time: the machines' speed 's' and the machines' reliability 'r'. Wherein 'kpi_s' measures the speed and 'kpi_r 'measures the reliability. Therefore, the shop floor's total performance 'kpi_{sr}' consists of these two KPIs. The first is 'kpi_s' and the second is 'kpi_r'.

- 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 '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_i ': theoretical cycle time of a given machine;
'ca_i': machine's actual cycle time;
' d_j ': Machine's downtime;
Where,

$$ca_j = ct_j - d_j \tag{21}$$

- 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,

$$kpi_{sr} = kpi_s * kpi_r \tag{22}$$

Therefore, the suitable kpi is:

$$obj_{sr}: kpi_{sr} \geq 0.50 \tag{23}$$

Where,

$$M = kpis * kpir \tag{24}$$

Under this kpi; to achieve the objective: $obj_{sr}: kpi_{sr} \geqslant 0{,}50$, it should be that both 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.

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

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

Table 4 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 5).

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

Table 4: Total PM of ENICAB' Shopfloor (OEE Results)

Weighed KPIs	obj_{sr}	M	PL
kpi_s	$kpi_s \geq 0{,}7071$	$kpi_s = 0.9413$	sati
kpi_r	$kpi_r \geq 0{,}7071$	$kpi_r = 0.5088$	nsatis
kpi_{sr}(OEE)	$kpi_{sr} \geq 0{,}50$	$kpi_{sr} = 0.4411$	nsatis

Table 5: Weighed KPIs of Each Workshop

Workshop	***M:*** kpi_s	***M:*** kpi_r	***M:*** kpi_{sr}	***PL***
1.Wire/ drawing	0.9410	0.4690	0.4396	nsatis
2. Stranding	0.9433	0.3341	0.3175	nsatis
3. Insulation	0.9466	0.6591	0.6276	satis
4. Assembly	0.9250	0.6250	0.5791	satis
5. Screening / Armouring	0.9000	0.2800	0.2565	nsatis
6. Jacketing	0.9575	0.6800	0.6509	satis

Consequently, the kpi_{sr} provides a significant evidence of ENICAB's shopfloor system' latency. This results in SC slowing time. The kpi_{sr} strengthens the result of the second kpi (tact time *kpi*). The main cause of ENICAB's shopfloor system latency was due to the age of their machines

- The output processes *KPIs*

This KPI consists of the following two sub-indicators

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

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

$$obj_{rej-rate}: \; rej_{rate} \leq 2.5\% \tag{27}$$

Where,

$$rej\, f\, art\, Q = rejected\, finched\, articles\, quantity \tag{28}$$

$$kpi_{rej_{rate}} = rej\, f\, art\, Q/total\, Q\, of\, f\, art \tag{29}$$

Hence, $M = 7.43\,\% \xrightarrow{yields} PL: \; not.satis$

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

This KPI measures the ratio of waste materials quantity(Qwmat) 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.

$$obj_{Qwmat}: Qwmat \leq 2.5\,\% \tag{30}$$

$$kpi_{Qwmat} = aggr\; wmat/aggr\; mat\; quant \tag{31}$$

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

Hence, $M = 2.6\,\% \xrightarrow{yields} PL: n.\,satis$

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

- *External measurement*
  - Distributors and customers echelon: stakeholders' contribution and customers' satisfaction facets

A questionnaire as a subjective measurement method, associated with a semi-structured interview, has been designed and delivered to the entire population of ENICAB's customers, consisting of 24 authorised distributors and 8 state-owned enterprises belonging to the energy sector as end consumers. The analysis of the questionnaire has been conducted based on the ENICAB's strategic objective. Therefore, the adopted KPI is as below.

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

$$obj_{satis-customer} \; : \; ratio_{sati-custmer} \geq 0.85 \tag{32}$$

$$KPI = aggr\; of\; vsatis + satis\; proportions \tag{33}$$

6. Discussion and Performance Improvement Suggestions

Results of the external measurement context (the questionnaire) and the semi-structured interview demonstrated that ENICAB's SC has a high PL in its product quality (corresponds with the internal measurement context). Also, the external measurement context related to order to delivery cycle time kpi corresponds with the internal measurement context. As for the remaining SC's areas that need improvement, focus has given to these area:

- *Products availability and payment terms KPI*

72% of the customers complain about the unavailability of some product types that the organisation cannot produce in terms of technology, which affects the SC's flexibility. The organisation must review its technological capabilities and consider the issues of re-engineering their production processes, analyzing and discussing the technical issue of purchasing new modern machines, or renewing their strategic machines' spare parts. As far as the payment terms, customers are dissatisfied, especially with the trade credit payback period. Key decision-makers should intervene to satisfy their customers about this issue

- *Order to delivery cycle time KPI*

Customers (57%) are dissatisfied with the order to delivery cycle time. The causes are related to the stockout issue and lack of the strategic machines' reliability, as demonstrated by the internal measurement context (Table.V). Key decision-makers can review the status of their strategic machines by; for instance, re-engineering the strategic machines or renewing their spare parts, especially those related to the wire drawing process, stranding and insulation/assembling process. For the stockout issue, they can employ inventory models.

- *Customers' complaints KPI*

Customers (45%) are not satisfied concerning the way the organisation deals with their complaints, while 50% of them are not satisfied with the response time. The IS issues were one of the main reasons which affect the way the company responds to their complaints. The same improvement suggestion can be replicated here, as mentioned in the internal measurement context.

7. Conclusion and Research Perspectives

Given the company's new position, which is its drop to the second position in the market, this situation can be adopted as a core reference for PM on which the subjective measurement is based. Therefore, external measurement's KPIs in which the SC's PL was acceptable must be raised. In this line, the company's strategic objective should be modified. Diagnosing SC's weaknesses and strengths by executive managers is the first step to improve their SC's performances. In this regard, the KPIs categorisation for the Performance Prism facets can present a support roadmap to identify and explore this complex task. Furthermore, findings demonstrated that integrating the external measurement and the internal measurement constitutes a crucial tool for PM process improvement. Also, Findings revealed that capabilities and processes facets have the most significant effect on the SC's performance, whereas the stakeholder contribution facet, which is the suppliers' echelon, has the second influential performance effect on the SC's performance. In contrast, as an external measurement, the other stakeholder contribution facet (the customers) has the most influential impact on the performance measurement processes. The proposed framework would help top decision-makers and operations managers to have a more comprehensive understanding of the SC PM phenomenon. Therefore, it would enhance the PM processes and the SC's performance. Due to the flexibility of the Performance Prism, the AHP method and the OEE technique alongside a comprehensive set of selected KPIs based on the literature and expert's opinion, the proposed approach can be implemented for other supply chain scenarios. Accounting for financial performance measurement can be considered as an appropriate complement for further research. Also, using inventory models or the theory of constraints could improve the SC under study's performance.

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