Determination and Analysis of KPIs in the Production Flow of a Manufacturing Environment: A Power BI-Based Approach

Hélder Pinho [1], Luís Cavique [2]
[1] Mestre IST-UL em associação Universidade Aberta, Portugal,
helderdepinho@tecnico.ulisboa.pt
[2] Universidade Aberta e Lasige FCUL, Lisboa, Portugal,
lcavique@uab.pt

Abstract

The manufacturing industry rapidly evolves to meet higher demands, customization, and global competitiveness. Key Performance Indicators (KPIs) are essential for monitoring and optimizing production efficiency. With Industry 4.0 advancements, including AI, IoT, and Big Data, integrating AI with Business Intelligence (BI) and real-time KPIs enables proactive, data-driven decision-making. However, many industries still need more awareness or expertise to harness these innovations. This research will review the role of KPIs in modern industry and develop a Power BI tool to optimize production control for a metallurgical company, enhancing decision-making and productivity.

Keywords: Key Performance Indicators, Business Intelligence, Industry 4.0, Microsoft Power BI.

Título: Determinação e análise de KPIs no fluxo de produção de um ambiente de fabrico: uma abordagem baseada em Power BI

Resumo: A indústria transformadora está a evoluir rapidamente para satisfazer as maiores exigências, personalização e competitividade global. Os indicadores-chave de desempenho (KPIs) são essenciais para monitorizar e otimizar a eficiência da produção. Com os avanços da Indústria 4.0, incluindo IA, IoT e Big Data, a integração de IA com Business Intelligence (BI) e KPIs em tempo real permite uma tomada de decisões proativa e baseada em dados. No entanto, muitas indústrias ainda precisam de mais consciência ou conhecimentos especializados para tirar partido destas inovações. Esta investigação irá rever o papel dos KPIs na indústria moderna e desenvolver uma ferramenta Power BI para otimizar o controlo de produção de uma empresa metalúrgica, melhorando a tomada de decisões e a produtividade.

Palavras-chave: Indicadores Chave de Desempenho, Business Intelligence, Indústria 4.0, Microsoft Power BI.

1. Introduction

Manufacturing companies face several challenges these days. Globalization, shorter products, innovation cycle times, and the growing volatility of production orders cause production systems to change. Because of this, production management requires transparent knowledge of the ongoing processes [Walzel et al., 2019].

Organizations use performance management systems to verify whether they are going in the right direction. Indicators are the physical values used to measure, compare, and manage organizational performance [Bhatti et al., 2014].

Industry 4.0, enabled by the Internet of Things (IoT), Big Data, and its industrial application, focuses on having machines and tools connected, either together or via central management, to have enough data to create a better decision for the high-levels of the decision chain [Samir et al., 2018].

Industry 4.0 emphasizes automation and enhancing production efficiency. AI (artificial intelligence) plays a key role by supporting tasks such as predictive maintenance, production optimization, and customer experience personalization. It achieves this by analyzing vast amounts of data and detecting real-time anomalies [Moutinho & Cavique, 2023].

Integrating manufacturing engineering, decision-making, and information technologies in this new era of industry is a must. For example, applying business intelligence (BI) concepts using key performance indicators (KPIs) helps make proactive decisions. Naturally, therefore, data integration is required. However, with frequent changes in processes and resources, machines, interfaces, and communication protocols, it is becoming hard to conglomerate these various aspects [Walzel et al., 2019].

The primary objective was to identify and understand key performance indicators (KPIs) commonly used in the industrial sector, specifically within the manufacturing environment. The insights from this review served as the foundation for developing a Power BI-based dashboard in a genuine factory that facilitates daily analysis of factory floor conditions and enables timely reactions based on the data provided by these KPIs.

1.1. Problem

The company has advanced manufacturing machinery but needs more control over production efficiency, causing waste and higher costs. Implementing KPIs and data visualization tools is essential for tracking metrics, optimizing processes, and staying competitive.

1.2. Objectives

Develop an affordable, user-friendly tool to analyze data gathered from various sources and calculate key performance indicators (KPIs). Additionally, propose a KPI monitoring solution that meets the needs of both the shop floor and the production management team.

1.3. Proposed Solution

The objective is to create a dashboard-like platform using Power BI for effective daily management of the factory floor, utilizing data extracted from the organization’s existing information systems. Key Performance Indicators (KPIs) will focus on Availability, Performance, and Quality, which are essential for calculating Overall Equipment Effectiveness (OEE), a crucial metric for the factory.

In addition to these primary KPIs, the dashboard will incorporate other vital indicators, including Lead Time, Average Delay Time, Cost of Poor Quality, Average Production Time, Stockout Rate, and additional factory-specific KPIs.

2. Data Sources and Data Model

The BI system uses the company's ERP database, Microsoft Excel, and a calendar table from Power Query's M language. Excel files come from reports generated by pressing and grinding machines in CSV format. The ETL process uses Power Query, with reports created in Power BI Desktop. Figure 1 illustrates the key data sources, and the processes needed to generate the KPI report.

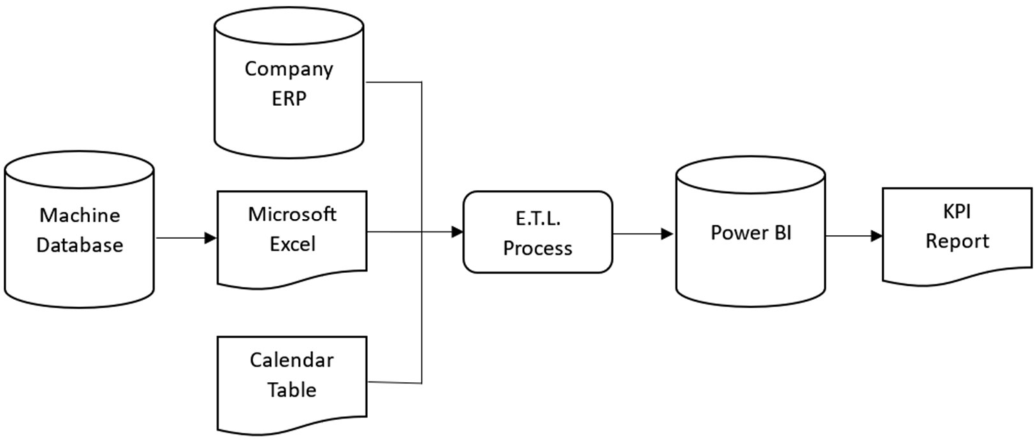


Figure 1. Data Sources Schema is detailed with the Machine Database.

2.1. Data Sources for the Data Warehouse

All data originates from the company's ERP SQL database, except for the data in the "OEE" table. The OEE table data comes from reports sent daily in CSV format by the machines in the pressing and grinding section. This data is then opened in Excel and processed in the ETL process.

Table 1 below illustrates how the data imported from the data sources is structured in the data warehouse.

Table 1. Data Sources for the Data Warehouse

Factory Area	Table	Data Source
Pressing and Grinding Machines	OEE	Microsoft Excel
Planning management	*Fluxo_WIP*	SQL Database
Coating sector	*Revestimentos*	SQL Database
Warehouse	Stocks	SQL Database
Quality control	*Rejeitados*	SQL Database
Production management	Leadtime	SQL Database

2.2. Data Tables

The following parameters represent critical tables in the database that provide essential insights into the manufacturing process:

OEE: Tracks Overall Equipment Effectiveness parameters linked to production shifts and dates.
Lead Time: To identify potential delays and record lead times for completed manufacturing orders, including promised and actual delivery dates.
FLX_WIP: Provides data on current production status and workload, aiding in planning and management to ensure production meets objectives.
Rejeitados: Contains information on rejected and non-conforming products, including quantities, monetary value, and reasons for rejection.
Revestimentos: Manages finished products needing a coating before packaging, keeping records of loads and quantities finalized and stored.
Stocks: Maintains records of completed materials ready for sale, identifying high-demand items for timely replenishment and preventing lost sales opportunities due to stockouts.

2.3. Calendar Table

A custom calendar table was created using Power Query's M language, as shown in Figure 2. This table enhances flexibility and accuracy in representing periods and performing time-related calculations. It allows users to manage data hierarchies, offering more profound insights into trends.

```
let
// Defining the start and end date for the calendar
StartDate = #date(2000, 1, 1),
EndDate = #date(2030, 12, 31),

// Creating a list of dates
ListDates = List.Dates(StartDate, Duration.Days(EndDate - StartDate) + 1,
#duration(1, 0, 0, 0)),

// Converting the list of dates into a table
Calendar = Table.FromList(ListDates, Splitter.SplitByNothing(), {"DataE"}),

// Adding additional columns
AddColumns = Table.AddColumn(Calendar, "Semana", each
Date.WeekOfYear([DataE], Day.Monday)),
AddYear = Table.AddColumn(AddColumns, "Ano", each Date.Year([DataE])),
AddMonth = Table.AddColumn(AddYear, "Mês", each Date.Month([DataE])),
AddDay = Table.AddColumn(AddMonth, "Dia", each Date.Day([DataE])),
AddDayOfWeek = Table.AddColumn(AddDay, "DiaSemana", each
Date.DayOfWeek([DataE]) + 1)
in
AddDayOfWeek
```

Figure 2. Creation of the calendar table using the Power Query M language

2.4. Data Model

The Data Model (see Figure 3) is a widely used approach in data warehousing and business intelligence. It organizes data into fact and dimension tables, optimizing querying and reporting. This work created a similar data model using tools like Microsoft Power Query to simplify analysis, improve performance, and enhance data clarity.

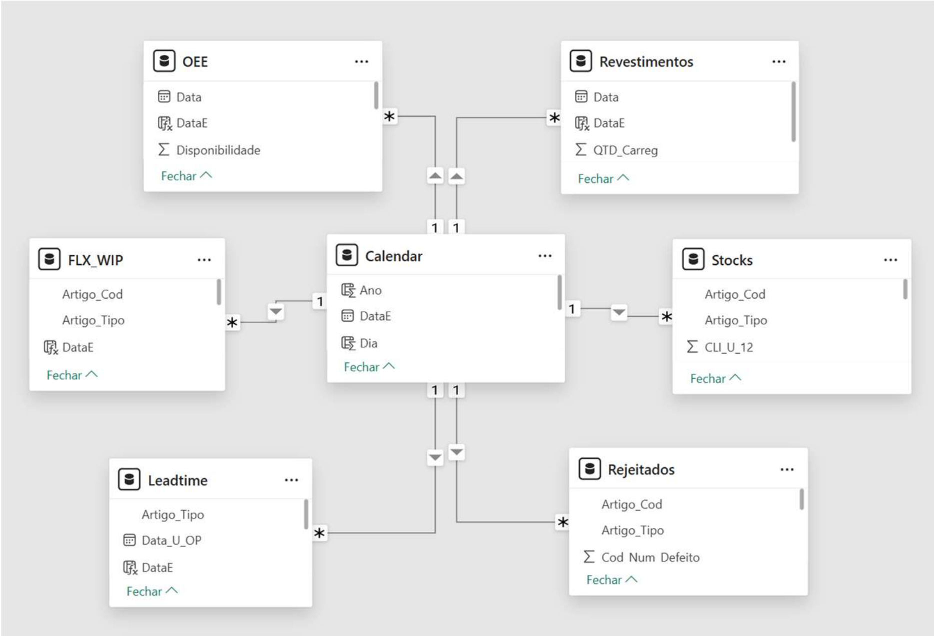


Figure 3. Data Model of this Project

3. Proposed KPI's Dashboard

This chapter covers the creation of a dashboard for monitoring Key Performance Indicators (KPIs) on the shop floor, built with Microsoft Power BI, which combines data preparation, modeling, and visualization into a single application for interactive reporting.

3.1. Data Analysis Expressions (DAX)

DAX is a formula language used in Microsoft Power BI and Excel for data modeling and analysis, allowing users to create custom calculations, aggregate data, and perform complex analyses.

```
ProduçãoSugerida =
VAR NecessidadeProducao =
    IF(
        SUM(stocks[QTD_STK]) <= SUM(stocks[Stock_min]),
        SUM(stocks[Stock_max]) - SUM(stocks[QTD_STK]),
        0
    )
RETURN
    NecessidadeProducao
```

Figure 4. DAX expression is used to calculate the required quantity to produce

The DAX expression in Figure 4 calculates the ideal production quantity by checking if the warehouse quantity is at or below the minimum stock level, returning the difference to the maximum stock level or 0 if above.

```
Classificacao_ABC =
VAR Ranking =
    RANKX(
        ALL('stocks'),
        CALCULATE(SUM('stocks'[Vendas_Eur_U_12])),
        ,
        DESC,
        DENSE
    )
RETURN
SWITCH(
    TRUE(),
    Ranking <= 100, "A",
    Ranking <= 400, "B",
    "C"
```

Figure 5. DAX Expression to classify items based on their sales performance

The measure in Figure 5 categorizes items based on sales using the RANKX function to rank items in the stocks table. The SWITCH function assigns classifications: "A" for items ranked 100 or below (top performers), "B" for ranks between 101 and 400 (mid-level performers), and "C" for ranks above 400 (lower performers).

3.2. Dashboard's Structure

As seen in Figure 6, the proposed dashboard features a main menu that grants access to charts and indicators crucial for managing the factory floor.

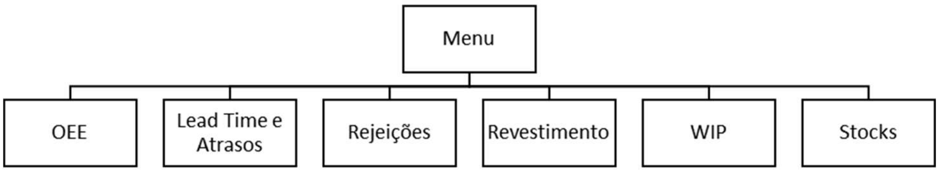


Figure 6. Dashboard's Structure

3.3. OEE Chart

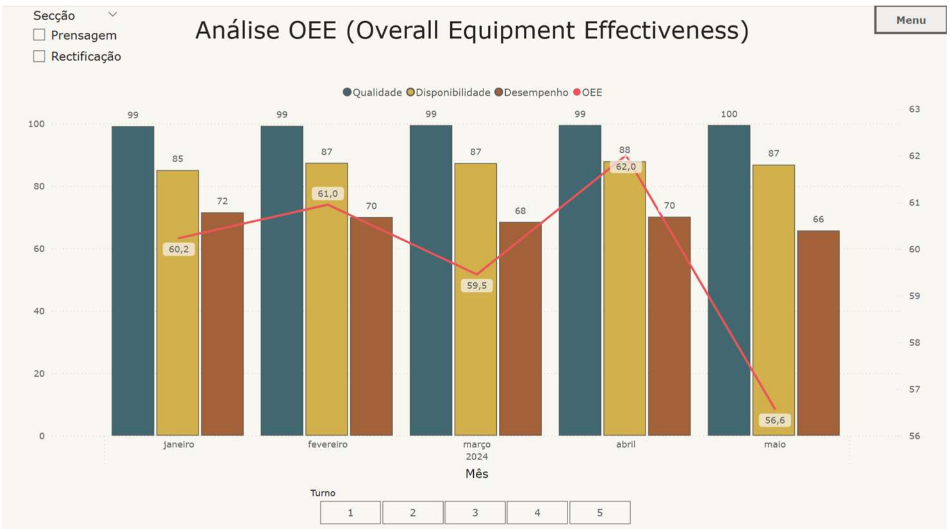


Figure 7. OEE Chart

Figure 7 shows the OEE (Overall Equipment Effectiveness) for the Pressing and Rectification sections. OEE is calculated from its three components: availability, performance, and quality. The line graph displays the average OEE, while colored bars indicate each component's contribution. Users can drill down by date to view monthly and daily graphs.

The Overall Equipment Effectiveness (OEE) KPI is calculated using three main factors:
OEE = Availability × Performance × Quality.

Performance measures how fast equipment produces parts, availability checks how much time it's working, and quality assesses how many products are defect-free. Together, they determine the Overall Equipment Effectiveness (OEE) in manufacturing, where 100% means perfect production. A good OEE is 60% or higher, while 55-59% is poor for the company in this study.

3.4. Lead Time e *Atrasos* chart (Lead Time and Delays chart)

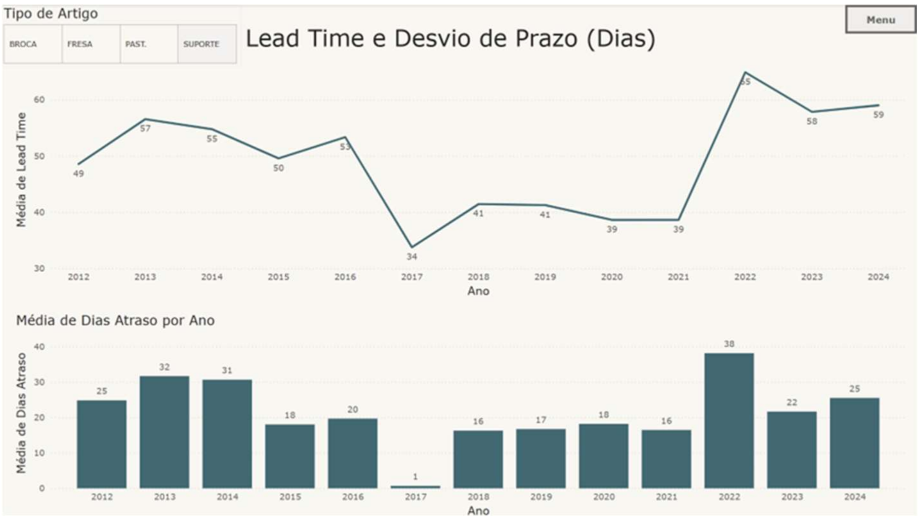


Figure 8. Lead Time and *Atrasos* chart

Figure 8 shows delivery and customer satisfaction indicators, including Lead Time and Delay Deviation KPIs. Users can click on a year for monthly analysis and filter by product type. Lead Time measures the time from order placement to product delivery. At the same time, the Delay in Deviation Days KPI tracks the difference between promised and actual delivery times, assessing production and supply chain performance. Monitoring these indicators boosts customer satisfaction, improves operational efficiency by identifying bottlenecks, and aids better decision-making.

3.5. *Rejeições* chart (rejections chart)

Figure 9 analyses rejections from a macro perspective, highlighting lost production time and potential sales loss. It shows rejected items by defect type, their percentage of total rejections, and estimated costs. Users can filter by production section and item type and limit the analysis period. Rejection analysis aids in improving quality, reducing costs, and supporting continuous improvement.

Cost of Poor Quality (COPQ) KPI represents costs from products or services that fail to meet quality standards. This chart analyses defect types and rejections, highlighting sections contributing to high COPQ, measured in euros.

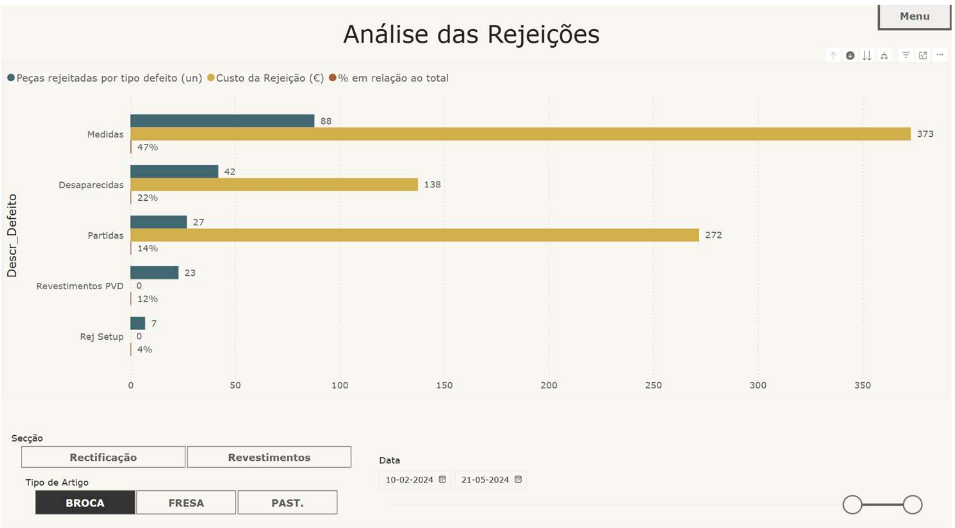


Figure 9. Rejeições Chart

3.6. Revestimento chart

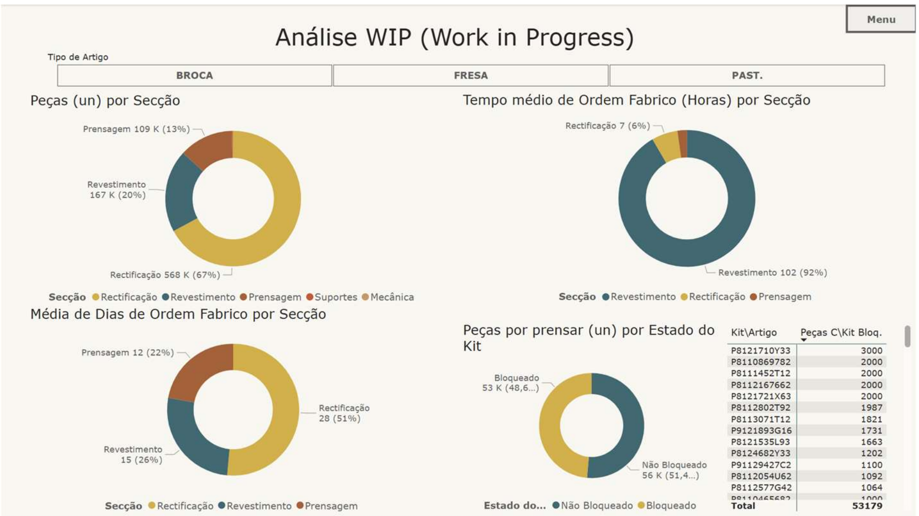
Figure 10. Revestimento chart

This section analyses the coatings department chart (Figure 10), which tracks the number of materials transferred to the warehouse **(Stock Inflow KPI = Total Good Products Received)** to ensure a steady flow and meet management objectives, each with different demands and storage needs. Users can filter by coating type and date range and drill down from year to month to day for detailed analysis.

3.7. WIP chart (Work in Progress chart)

Figure 11 evaluates the WIP and allows filtering by item type. This KPI is crucial for management as it provides visibility into the quantities of semi-finished items.

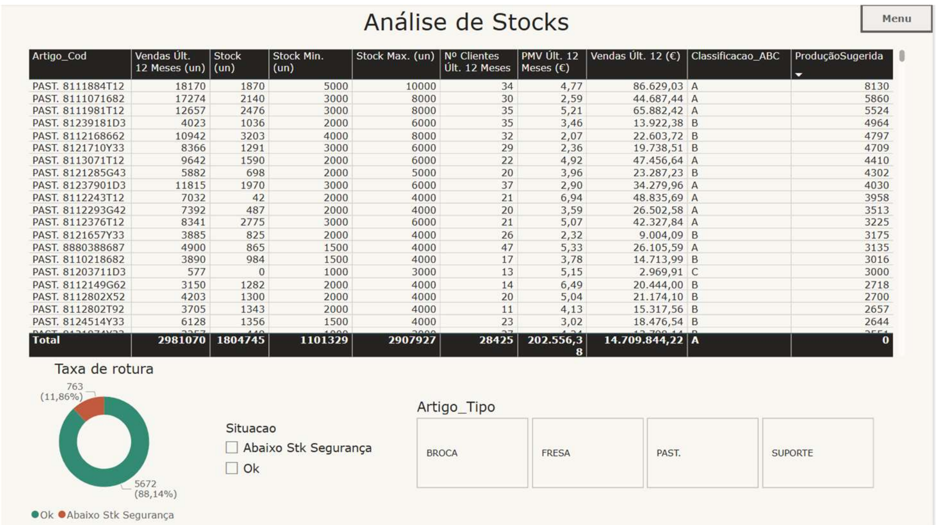
WIP Quantity KPI: Measures semi-finished items in production, helping identify bottlenecks.
Production Status and Progress Visibility KPI: Shows the real-time status of production orders, highlighting areas needing attention.
Average Time in Section KPI: Tracks how long orders spend in each section, indicating efficiency and potential delays.
Average Days in Section KPI: Calculates the time orders remain in a section, aiding in forecasting and process optimization.



Kit\Artigo	Peças C\Kit Bloq.
P8121710Y33	3000
P8110869782	2000
P8111452T12	2000
P8112167662	2000
P8121721X63	2000
P8112802T92	1987
P8113071T12	1821
P9121893G16	1731
P8121535L93	1663
P8124682Y33	1202
P91129427C2	1100
P8112054U62	1092
P8112577G42	1064
Total	53179

Figure 11. WIP Chart

3.8. Stocks Chart



Artigo_Cod	Vendas Últ. 12 Meses (un)	Stock (un)	Stock Min. (un)	Stock Max. (un)	Nº Clientes Últ. 12 Meses	PMV Últ. 12 Meses (€)	Vendas Últ. 12 (€)	Classificacao_ABC	ProduçãoSugerida
PAST. 8111884T12	18170	1870	5000	10000	34	4,77	86.629,03	A	8130
PAST. 8111071682	17274	2140	3000	8000	30	2,59	44.687,44	A	5860
PAST. 8111981T12	12657	2476	3000	8000	35	5,21	65.882,42	A	5524
PAST. 81239181D3	4023	1036	2000	6000	35	3,46	13.922,38	B	4964
PAST. 8112168662	10942	3203	4000	8000	32	2,07	22.603,72	B	4797
PAST. 8121710Y33	8366	1291	3000	6000	29	2,36	19.738,51	B	4709
PAST. 8113071T12	9642	1590	2000	6000	22	4,92	47.456,64	A	4410
PAST. 8121285G43	5882	698	2000	5000	20	3,96	23.287,23	B	4302
PAST. 81237901D3	11815	1970	3000	6000	37	2,90	34.279,96	A	4030
PAST. 8112243T12	7032	42	2000	4000	21	6,94	48.835,69	A	3958
PAST. 8112293G42	7392	487	2000	4000	20	3,59	26.502,58	A	3513
PAST. 8112376T12	8341	2775	3000	6000	21	5,07	42.327,84	A	3225
PAST. 8121657Y33	3885	825	2000	4000	26	2,32	9.004,09	B	3175
PAST. 8880388687	4900	865	1500	4000	47	5,33	26.105,59	A	3135
PAST. 8110218682	3890	984	1500	4000	17	3,78	14.713,99	B	3016
PAST. 81203711D3	577	0	1000	3000	13	5,15	2.969,91	C	3000
PAST. 8112149G62	3150	1282	2000	4000	14	6,49	20.444,00	B	2718
PAST. 8112802X52	4203	1300	2000	4000	20	5,04	21.174,10	B	2700
PAST. 8112802T92	3705	1343	2000	4000	11	4,13	15.317,56	B	2657
PAST. 8124514Y33	6128	1356	1500	4000	23	3,02	18.476,54	B	2644
Total	2981070	1804745	1101329	2907927	28425	202.556,38	14.709.844,22	A	0

Figure 12. Stocks Chart

The stock analysis chart in Power BI, illustrated in Figure 12, is essential for managing inventory effectively. It provides a comprehensive view of stock-related metrics, enabling informed decision-making and helping to avoid issues like overstocking and stock outlooks. The Stockout Rate measures the percentage of items currently out of stock compared to the total number of items available. This KPI is essential for understanding the current state of inventory and how it can affect sales and customer satisfaction.

4. Drill through

Drill-through in Power BI allows users to click on a data point to see detailed information. For instance, you can drill down to monthly and even daily figures from annual production totals, revealing trends, peak days, and operational issues, aiding in better resource and capacity planning.

4.1. Manage by exception example: Dashboard Drill-Trough

This dashboard applies 'management by exception' to OEE, starting with a yearly review to spot performance issues (see Figure 13). 'Manage by exception' means focusing on significant deviations from set standards, addressing only issues outside acceptable performance levels.

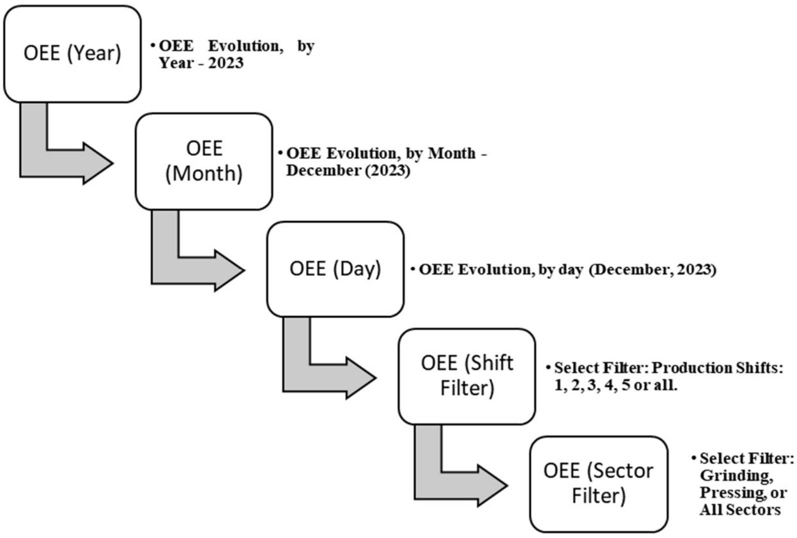


Figure 13. Drill through example (management by exception)

Using management by exception, the manager reviews the OEE chart for key factory sectors and spots a notable performance drop 2023 that continues into 2024 (see Figure 7), deviating from previous steady results.

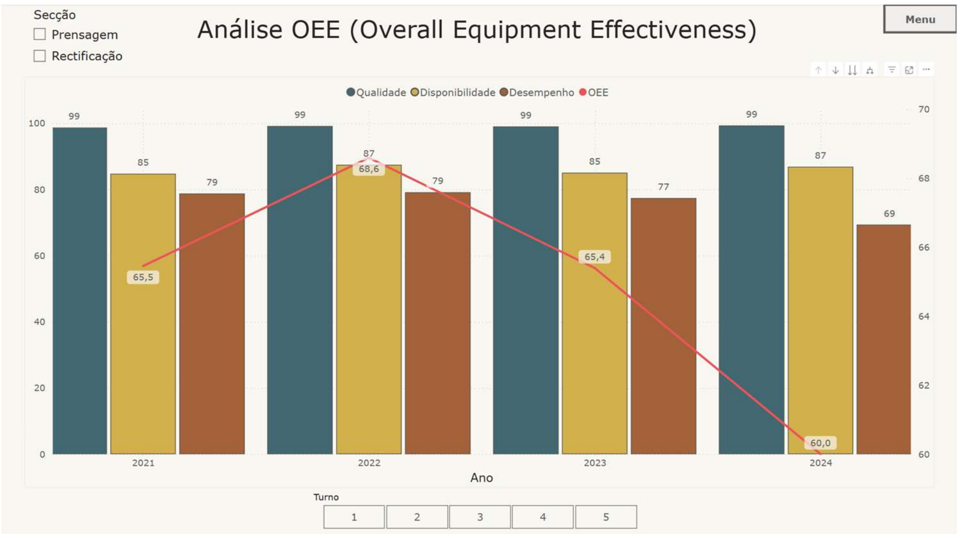


Figure 14. Drill Trough (Year): Performance drop starts in 2023 and continues into 2024

Drilling down into December 2023, he finds OEE fell sharply. The drop is mainly driven by reduced machine efficiency (performance factor). Further analysis reveals that Shift 1 (*Turno* 1) and specifically the pressing sector (*Prensagem*) are primary contributors to the decline, especially on December 13 and 26 (see Figure 15). In 2024, the low values of OEE persist, with low performance (see Figure 16). This ongoing trend highlights the need for further investigation into potential causes, such as machine maintenance or operational changes.

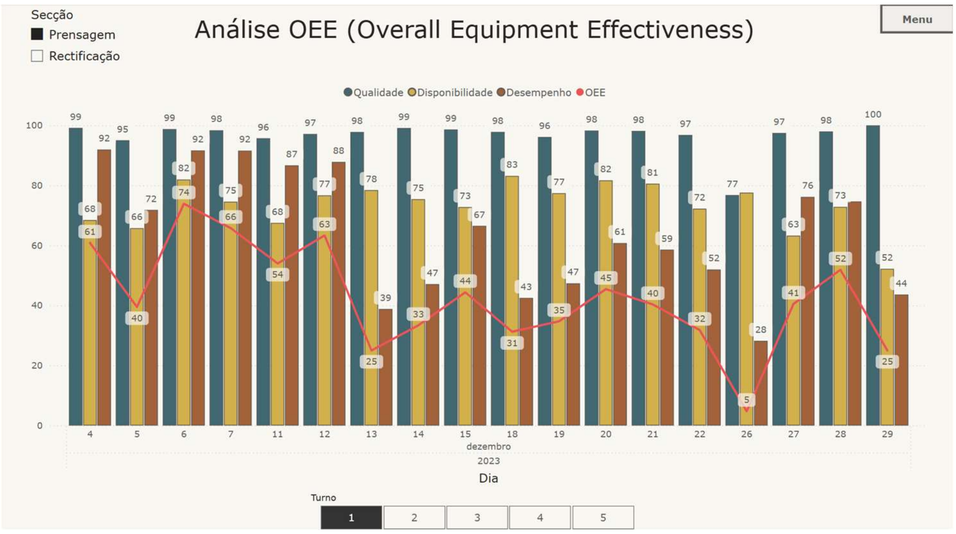


Figure 15. Drill-Trough (Day - December 2023: Shift Filter + Sector Filter)

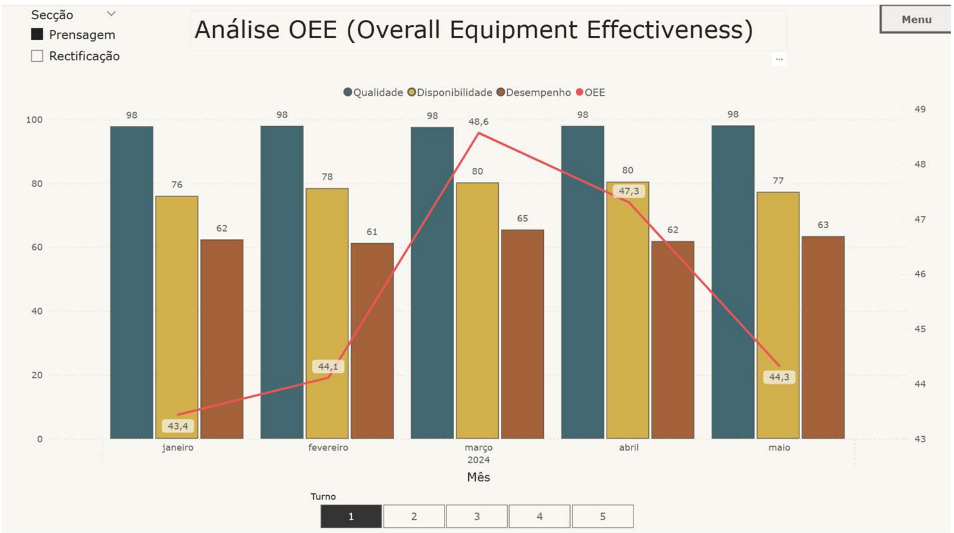


Figure 16. Drill-Trough (Month - 2024: Shift Filter + Sector Filter)

5. Conclusion

The paper explores the integration of Key Performance Indicators (KPIs) with Business Intelligence (BI) tools to optimize production processes in Industry 4.0. It focuses on developing a Power BI-based dashboard for a metallurgical company to monitor factory performance.

The system enhances decision-making and operational efficiency by analyzing KPIs like Overall Equipment Effectiveness (OEE) and Lead Time. Features such as drill-through and management by exception enable detailed analysis and proactive problem-solving. The research showcases the potential of BI in driving data-driven strategies and improving competitiveness in modern manufacturing.

The paper contributes to management by exception with BI tools that focus on significant deviations from standard KPI values, streamlining managerial attention to critical issues. Drill-through functionality allows detailed analysis of specific shifts, days, or production sectors to identify root causes of inefficiencies. It ultimately improves resource allocation and supports data-driven decision-making in line with Industry 4.0 principles.

REFERENCES

Bhatti I., M., Awan, H. M., & Razaq, Z. (2014). The key performance indicators (KPIs) and their impact on overall organizational performance. Quality & Quantity, vol. 48(6), pp. 3127-3128.

Moutinho L., & L. Cavique (2023), Impact of Artificial Intelligence in Industry 4.0 and 5.0, in Artificial Intelligence, in Philosophy of Artificial Intelligence and Its Place in Society, Eds. L. Moutinho, L. Cavique, E. Bigné, IGI-Global, (ISSN: 2328-1316; eISSN: 2328-1324), pp. 358-376.

Samir, K., Khabbazi, M. R., Maffei, A., & Onori, M. A. (2018). Key performance indicators in cyber-physical production systems. Procedia CIRP, 72, 498-501.

Walzel, H., Vathoopan, M., Zoitl, A., & Knoll, A. (2019). An approach for an automated adaption of KPI ontologies by reusing systems engineering data. In 2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), pp. 1693-1694.

Helder Pinho holds a Bachelor's degree in Industrial Engineering and Management (2014) from Instituto Superior de Engenharia de Coimbra and a Master's degree in Information and Enterprise Systems (2024) from Instituto Superior Técnico associated with Universidade Aberta. He currently works in the metallurgical industry and has previous experience in the automotive and textile sectors. His primary interests include promoting and developing simple technological solutions to optimize production flows, ultimately translating these improvements into operational profits for manufacturing industries.

Luís Cavique is a Tenured Assistant Professor at the Department of Science and Technology (DCeT), Section of Informatics, Physics and Technology (SIFT). Graduated in Computer Engineering from FCT-UNL. He obtained a Master's and Doctorate in Systems Engineering from IST-UTL in 2002. His areas of interest are the intersection of Informatics with Systems Engineering, namely the area of Data Science. He has authored more than 200 scientific papers in peer-reviewed journals and conferences. He is an integrated member of LASIGE at the Faculty of Sciences.