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MAINTENANCE MANAGEMENT BALANCED SCORECARD APPROACH FOR URBAN TRANSPORT FLEETS

ZARZĄDZANIE UTRZYMANIEM RUCHU W ZAKŁADACH KOMUNIKACJI MIEJSKIEJ W OPARCIU O ZRÓWNOWAŻONĄ KARTĘ WYNIKÓW

Attending the important role of maintenance function in any production or service provider company, the measurement and assessment of maintenance performance is crucial for competitiveness and future survival. That situation is even more critical in urban transport fleets where some specific boundary conditions and special characteristics will affect maintenance policy and implementation. This paper presents a deep review of different studies worldwide to define the most proper and effective maintenance performance indicators, selecting and refining the most important ones to obtain a reduced maintenance management balanced scorecard. That balanced scorecard is proposed as a main tool for urban transport fleet maintenance managers to assess efficiency and effectiveness of maintenance processes and will be used as a basis for a future benchmarking process for this type of companies.

Keywords: *KPIs, balanced scorecard, urban transport fleet, maintenance management.*

Biorąc pod uwagę ważną rolę jaką pełni utrzymanie ruchu w firmach produkcyjnych i usługowych, pomiar i ocena wydajności eksploatacji ma kluczowe znaczenie dla konkurencyjności tych firm i ich przetrwania na rynku. Sytuacja ta jest szczególnie ważna w zakładach komunikacji miejskiej, w których pewne szczególne warunki brzegowe i szczególne cechy floty transportowej mają wpływ na politykę utrzymania ruchu i jej realizację. W niniejszym artykule przedstawiono dokładny przegląd różnych badań prowadzonych na całym świecie w celu określenia najbardziej odpowiednich i skutecznych wskaźników efektywności utrzymania ruchu, wybierając najważniejsze z nich i i udoskonalając je tak aby uzyskać zrównoważoną kartę wyników zarządzania utrzymaniem ruchu z ograniczoną liczbą parametrów. Zrównoważona karta wyników może być stosowana przez specjalistów utrzymania ruchu zakładów komunikacji miejskiej do oceny wydajności i skuteczności procesów konserwacji i stanowić będzie podstawę przyszłych analiz porównawczych dla tego typu przedsiębiorstw.

Słowa kluczowe: *kluczowy wskaźnik efektywności, zrównoważona karta wyników, komunikacja miejska, zarządzanie utrzymaniem ruchu.*

1. Introduction

Maintenance is one of the largest expenditures for the urban transport companies together with fuel (or energy) costs and drivers (personnel) [16], but is the most important one from the view of controllability, attending that fuel and labour costs are more externally driven (crude prices volatility, taxes, personnel policies and salaries, etc.). A proper maintenance policy, managerial processes and planning and optimization of maintenance decisions, scheduling and execution of work can lead to reduce costs, improve vehicle effectiveness, reliability and performance. Consequently, maintenance function is therefore vital for sustainable performance of any urban transport fleet.

Attending the responsibility of ensuring that urban fleet achieves the expected performance, maintenance managers requires a tracking system for maintenance operations performance and results [3, 6, 20, 21]. Furthermore, it is in the interest of maintenance managers to know the relationship between the input of the maintenance process and the outcome in terms of total contribution to vehicle fleet performance and strategic objectives. The measurement of maintenance performance is indeed an essential requirement for any industry of today. This tracking action can be done through development and implementation of a proper and accurate performance measurement system and indicators that are able to quantify important elements of maintenance function performance [5, 15]. Moreover, without having a formal measurement system for maintenance performance, it is difficult to control, plan and improve the maintenance process and consequently can be considered that tracking the performance operations must be a key management issue in any industrial organization.

In summary, a proper maintenance performance measurement system shall contribute to:

- Assess the maintenance function to the strategic company targets.
- Detect the strengths and weaknesses on the maintenance strategy applied.
- Using quantitative and qualitative data for helping to define and stablish a continuous improvement process for maintenance.
- Let us to apply a maintenance benchmarking analysis within and outside the business related with urban fleet transport.

Different frameworks have been defined and used in the past for measuring performance and until the 80s in last century mostly based on financial measures. The original balanced scorecard defined by Kaplan and Norton [14] had four perspectives for analysing: financial aspects, customers, internal processes and innovation and learning. Later, different approaches has been defined by other authors considering other non-financial measurements and intangible assets to achieve competitive advantages [2, 4, 25].

Last, but not least, benchmarking is used for business development and also for improving efficiency and effectiveness of maintenance processes in any type of industry. The analysis performed on this work provides a basis for learning from the top class business companies and offers a road map for performance improvement [12]. As a prior requirement to begin a benchmarking analysis obviously is required a set of proper, reliable, accurate and well defined performance indicators for the industrial sector considered, as it has been previously mentioned.

This paper presents a deep revision of key performance indicators for maintenance management in the specific and very important sector of urban transport fleets in the section 2. In section 3 authors propose a reduced selection of key parameters that can be considered the most important for this application grouped into three main categories. Later, in section 4, those selected parameters are developed and it is presented how can be calculated and managed. Finally, in section 5 the balanced scorecard proposal is presented combining the previous parameters defined.

2. State of the art regarding KPIs for maintenance management in transport fleets.

In order to perform a review of the state of the art regarding maintenance management KPIs, authors have focused firstly on more general documents, mainly international standards, with a more general approach to that problem and later have focused on more specific literature regarding public transport fleets. In this way, publications and documents coming from UITP (Union International des Transports Publics or International Association of Public Transport), and other information from international transport associations have been managed. Next, a complete summary of the review performed is presented.

2.1. EN 15341 Maintenance - Maintenance Key Performance Indicators

This is a European standard [9] and is the most general standard referred to maintenance KPIs. The Spanish version is the UNE EN 15341:2008. As it is stated on the introduction, this standard: "provides Maintenance Key Performance Indicators to support management in achieving *maintenance excellence* and utilize technical assets in a competitive manner. The majority of these indicators *apply to all industrial and supporting facilities* (buildings, infrastructure, *transport,* distribution, networks, etc.)".

This standard defines a set of indicators structured on a three different levels: economics, technical and organizational and mainly are presented such a relation between factors (numerator and denominator) related with activities, resources or events. Maintenance performance and consequently key performance indicators can be affected by internal factors such as group, company, factory, plant that are outside of the maintenance manager control but inside of the company management control. On the other side, external factors such as location, market, laws and regulation, etc. are variable conditions outside company management control also affecting maintenance performance.

Most indicators can be used at different levels depending on whether they are used to measure the performance of plant production, one production line, or a given equipment or item, i.e. are structured from a more general to a more detailed point of view.

On this standard are summarized 24 economic indicators, 21 technical indicators and 26 organizational indicators. Each company must select the most proper indicators attending own characteristics and objectives expected.

As it has been mentioned, that standard is very general and can be applied to any type of industry and consequently perhaps have not into account specific characteristics more related with a urban transport fleet company; but after the analysis of that standard, the Key Parameters Indicators more proper for that companies would be:

Economic indicators: E3, E14, E15, E16 and E17.

Technical indicators: T1. T2, T6 and T21.

Next, as a reminder, general definition of that indicators are presented on Table 1.

2.2. EN 13816- Transportation-Logistics and services – Public passenger transport service quality definition, targeting and measurement.

This standard [8] is mainly focused to promote a quality approach to public transport and focus interest on customers' needs and expectations. This standard collect the quality criteria representing customer view of the service provided divided into eight categories. It can be considered that there are three of them directly related with vehicle maintenance: comfort, security and environmental impact. That general quality criteria are subdivided on more specific items and for those selected previously the next Table 2 present the most important ones from the point of view of authors related with maintenance.

Table 1. Definition of KPIs (following EN 15341) more suitable for urban transport fleets

KPI	Economic	KPI	Technical
E3	$\frac{Total\ Maintenance\ Cost}{Quantity\ of\ output}$	T1	$\frac{Total\ Operating\ time}{Total\ Operating\ time + Downtime\ due\ to\ maintenance} \cdot 100$
E14	$\frac{Total\ Maintenance\ Cost}{Total\ Energy\ Used}$	T2	$\frac{Achieved\ up\ time\ during\ required\ time}{Required\ time} \cdot 100$
E15	$\frac{Corrective\ Maintenance\ Cost}{Total\ Maintenance\ Cost} \cdot 100$	T6	$\frac{Total\ Operating\ time}{Total\ Operating\ time + Downtime\ related\ to\ failures} \cdot 100$
E16	$\frac{Preventive\ Maintenance\ Cost}{Total\ Maintenance\ Cost} \cdot 100$	T21	$\frac{Total\ time\ to\ restoration}{Number\ of\ failures} = MTTR$
E17	$\frac{Condition\ based\ Maintenance\ Cost}{Total\ Maintenance\ Cost} \cdot 100$		

Table 2. Quality criteria and sub-items more related with Maintenance aspects in urban transport fleets

Quality criteria	Sub-items
#6 Comfort	6.1 Usability of passenger facilities
	6.3 Ride comfort
	6.4 Ambient conditions
#7 Security	7.2 Freedom from accident
#8 Environmental impact	8.1 Pollution
	8.2 Natural resources

2.3. Others indicators at international level

A deep review has been performed on scientific papers published, consultancy works, Transport associations, good practices, etc. Next, a summary of the most relevant documents found related specifically with urban transport fleets are presented on Table 3.

Most documents reviewed present a lot of indicators for a complete fleet management, ranging from general company

Table 3. Summary of the most relevant documents managed for that study

Title	Origin / Authors	Brief description	Year	Country
Field study on bus depots and bus maintenance. Similarities between and singularities of different engine technologies and their impact on infrastructure, quality and maintenance. [10]	UITP (Union Internationale des Transports Publics)	UITP study regarding different propulsion technologies (diesel, hybrid, CNG, electric, etc.) and a comparative assessment under different concepts.	2013	Belgium
Managing for Results in America's Great City Schools. [18]	Council of the Great City Schools	This report defines and presents an extensive array of statistical indicators developed by the Council of the Great City Schools and its member urban school districts to measure performance on a broad range of operational functions, including business services, finances, human resources and technology.	2017	USA
A framework for urban Transport benchmarking. [13]	The World Bank	This report summarizes the findings of a study aimed at exploring key elements of a benchmarking framework for urban transport.	2011	USA
The Fleet Management Key Performance Indicators (KPIs) (https://knowledge.fleetforum.org/knowledge-base/article/assessing-your-fleet-management)	Fleet Forum	Excel spreadsheet developed by Fleet Forum (association with more than 40 members including UN; different NGO, academic institutions, donnors and corporative partners).	2013	Switzerland
MBTA Bus Maintenance Efficiency Study. [19]	MBTA (Massachusetts Bay Transportation Authority)	MBTA approach to identify alternatives and develop recommendations for maintenance efficiency improvement.	2016	USA
Fleet owner. KPI's for maintenance: 15 suggestions for numbers that matter. [24]	Fleet Owner	KPIs proposal coming from different associated companies.	2016	USA
Performance Metrics for the New Fleet Manager. Wheels & Wings - Online Newsletter for the Federal Motor Vehicle and Aviation Communities. [11]	Larry Fredrich, Mercury Associates	Paper from a consultant where some fleet maintenance manager performance indicators are summarized.	2014	USA
Developing optimum KPI system for Public Transport Organizations. [1]	SIGMA journal	Egyptian researcher work presenting a study regarding public transport companies' performance indicators.	2016	Egypt
Useful Key Performance Indicators for Maintenance. [23]	www.lifetime-reliability.com	Set of indicators proposed by this Australian web for maintenance management improvement.	2009	AUSTRALIA

International Bus System Benchmarking: Performance Measurement Development, Challenges, and Lessons Learned. [22]	International Bus Benchmarking Group (IBBG)	The IBBG is a comprehensive programme of benchmarking urban bus operations. Currently the consortium is made up of 16 medium and large bus organizations located around the world.	2004	UK

Table 4. Summary of indicators presence on different international studies. Higher presence is a clear clue of relevance and meaningful

Indicator	Number of studies where is mentioned
Average Fleet age *	5
Averaged service speed *	4
Annual mileage *	8
Fleet availability	10
Cost per kilometer (or mile)	10
MTBF	6
CO_2 emission (Tons)	5
Energy Consumption	9
MTTR	3
Accidents per kilometer (or mile)	7
Work orders (WO) per year	2
Fleet Reserve %	1
Preventive Maintenance Program Fulfillment	3
Life Cycle Cost (LCC)	2
Absenteeism	3
Parts list	1
Kilometers (miles) lost service	1

Note (*). These parameters are fleet operational data but are required for assessment and monitoring of other key indicators.

management, customer satisfaction, security, finance, environmental aspects and maintenance. Some of them are very similar, with just a little variation on the definition attending mainly to the data availability in order to obtain the indicator.

For this work, authors have just considered those related with maintenance at economic and technical level. Next, a summary can be observed in Table 4 with those indicators mainly considered and a number representing how many times appears on the ten previous literature sources considered:

It is necessary to mention that the Life Cycle Cost (LCC) more than an indicator is a tool in order to help the decision makers to define if a fleet renovation is required based on real data.

3. Key Parameters Selection

After a deep revision of the state of the art, it is necessary to take into account that KPIs selected must led us to quantify the maintenance process to control and assess its performance and must contribute to process improvements and also for helping decision makers. With that initiative, it would be possible to apply a continuous improvement policy and define control boundaries and "non conformity" limits, with cause's analysis and solutions definitions.

Some major characteristics must be accounted for KPIs selection and definition in order to assure future usability and validity and consequently to obtain a clear, relevant and reliable indicator:

- Easy and quick procurement of data involved on the indicator.
- Proper frequency of data procurement.
- Clarity of the info obtained and showed by the indicator.
- High info interest.
- Graphic trends analysis.
- Easy definition of target or optimal value for such indicator (or limits levels).

Attending previous characteristics, it is proposed to define 3 main indicator groups:

- Structural or own company indicators: this are indicators referring to main fleet general characteristics that are important to take into account for the assessment of others indicators groups, that is, this are boundary conditions affecting maintenance department.
- Basic indicators: That are the indicators defined for technical and economical fleet maintenance management assessment. That indicators led us to evaluate the maintenance execution.
- Advanced indicators. That are the indicators that led us to assess the maintenance repercussion or those consequences derived from our maintenance management.

Next, on Table 5, it is presented a brief summary of each group including indicators considered:

As it can be seen, authors have tried to avoid a vast number of indicators that consequently requires an extensive amount of human resources and financial budget and which may not be feasible for a long-term process. Furthermore, the indicators defined as advanced can be used or bring into play after a first approach with more simple indicators and training people involved on that process, in order to assure success on that more difficult performance metrics.

Table 5. Main parameters defined for BSC proposed

Structural indicators	Basic Indicators	Advanced indicators
Total mileage per year	Maintenance cost / kilometer	Energy consumption kW/km (per powertrain typology: diesel, electric, hybrid, CNG, so on).
Average Fleet age	Availability	Total CO_2 emissions
Averaged service speed	Failures / 10000 Km (related to maintenance)	MTTR
Number of vehicles per maintenance personnel	Accidents / 10000 Km (related to maintenance)	Maintenance delay
Externalization percentage	Maintenance programme fulfilment.	Optimal vehicle period replacement (by LCC)
	Maintenance personnel absenteeism	

4. Indicators definition

Right now, the proposed indicators are going to be defined in a detailed way in order to be comparable between different fleet companies in future benchmarking activities. Attending that data can be obtained by different ways, different alternatives will be defined for a same indicator (if required) that will be noted with different sub index.

For an easier process, we are going to use a record card that will help for simple calculus and future auditing.

4.1. Structural parameters

4.1.1. Total mileage performed

Name	KM-total mileage performed
Definition	Addition of total mileage performed by entire fleet monthly
Formulae	$KM_1 = (\sum total\ mileage\ of\ each\ vehicle\ of\ the\ fleet)km$
Units	Total kilometers (whole number, no decimals: xxx xxx km)
Target value	Unnecessary
Calculus frequency	Monthly measurement and annual monitoring and assessment
Additional comments	Total mileage can be obtained per vehicle models, vehicles types or fuel in order to obtain a more specific indicator.

4.1.2. Averaged fleet age

Name	ED-Average fleet test
Definition	Addition of the age of each vehicle divided by the number of vehicles considered.
Formulae	$ED_1 = \left(\frac{\sum age\ of\ each\ vehicle}{Number\ of\ total\ vehicles} \right) years$
Units	Years with two decimals (xx.xx years)
Target value	Target value should be between 6 and 7 years depending on the optimal fleet replacement value obtained by the LCC analysis.
Calculus frequency	Annual
Additional comments	Average age can be obtained per vehicle models or types and even define different target values depending on that differences assuming a specific LCC analysis.

4.1.3. Average service speed

Name	VM-average fleet speed (
Definition	Addition of average speed of each vehicle per service (urban, interurban, ..) divided by the number of vehicles considered
Formulae	$VM_1 = \left(\frac{\sum average\ speed\ of\ each\ vehicle}{Number\ of\ total\ vehicles} \right) km / h$
Units	Kilometers per hour with two decimals (xx.xx km/h)
Target value	Unnecessary

Calculus frequency	Monthly measurement and annual monitoring and assessment
Additional comments	That average speed can be calculated for each type of service: urban, interurban, mix or others.

4.1.4. Number of vehicles per maintenance personnel

Name	VP-Number of vehicles per maintenance personnel
Definition	Total number of vehicles divided by the number of maintenance personnel (direct maintenance workers, managers and administrative personnel in Maintenance area – own or externalized)
Formulae	$VP_1 = \left(\frac{Total\ number\ of\ vehicles}{Number\ of\ maintenance\ personnel} \right) vehicles / person$
Units	Vehicles per person with one decimal (xx.x vehicles/person)
Target value	Depending on company size and externalization level
Calculus frequency	Annual
Additional comments	That indicator could be calculated just considering direct maintenance workers.

4.1.5. Externalization percentage

Name	PC-Externalization percentage
Definition	Externalized or subcontracted maintenance cost versus total maintenance cost obtained in the indicator of total maintenance cost per kilometer.
Formulae	$PC_1 = \left(\frac{\sum externalized\ maintenance\ cost}{Total\ Maintenance\ cost} \right) x100\ \%$
Units	Percentage with one decimal (xx.x %)
Target value	Depending company structure and size
Calculus frequency	Annual
Additional comments	That parameter must be considered for the assessment of other indicators.

4.2. Basic Parameters

4.2.1. Maintenance cost per kilometer

Name	CM-Maintenance cost per kilometer
Definition	That is the cost for manpower, parts and legal inspections fees devoted to maintenance. It would include: MOD- Direct manpower. Manpower directly related with corrective, preventive, condition monitoring or modification in vehicles. It could be included vehicles cleaning and refueling although usually are externalized tasks it is highly recommended consider it in other specific item. MOI- Indirect manpower. Manpower cost considered but not directly referred to a vehicle such as: maneuvers drivers, interchanging parts repair, so on. TEX- External workshops. Costs related with maintenance actions performed on external workshops and not included in other items (such tires or legal inspections) MAT-Parts. Parts costs related directly to vehicles (not included fuel and ad-blue that are considered operational costs). MAC-General parts. General parts costs not related with specific vehicles such as screws, rags, air conditioner refrigerant charge, etc. ACN-Lubricants, cooling liquid and tires. ITG-Legal required inspections. Cost relates with complimentary legal inspections to be performed on vehicles plus other ones required for some specific design (for instance, high pressure deposit inspection for CNG vehicles). LRC-Vehicle cleaning, refueling and liquids level control. Usually that costs are externalized and not considered in any other previous parameter. GST-management cost. Costs related with management personnel and intermediate level including: maintenance manager, workshop manager, engineering manager, administrative, team manager, warehouse personnel, maintenance purchasing personnel, so on.
Formulae	$CM_1 = \left(\frac{\sum(MOD + MOI + TEX + MAT + MAC + ACN + ITG + LRC + GST}{Total\ fleet\ mileage} \right) € / km$
Units	Euros (€) per kilometer including 4 decimals (xx.xxxx €/km)

Target value	Attending that it will depend on several factors such as: fleet age, type of vehicles, etc.; it should be obtained trends and minimum and maximum values to define a target value.
Calculus frequency	Monthly measurement and annual monitoring and assessment attending the indicator seasonality.
Additional comments	That is a parameter that led us to assess the maintenance efficiency and could be very useful for abnormal situation detection considering that there a lot of different factors affecting it. That parameter of maintenance cost per kilometer and all of the costs considered sorted by different items such as models or vehicle technology can be very useful to help in strategic company decisions.

4.2.2 Availability

Name	DS-Availability
Definition	Percentage indicator representing the time that vehicle is available to perform as and when required for fleet service.
Formulae 1	$DS_1 = 1 - \left(\frac{\sum total\ time\ for\ vehicles\ inmobilization\ in\ hours}{\sum total\ vehicles\ fleet\ required\ time\ in\ hours} \right) x100\ \%$
Formulae 2	$DS_2 = 1 - \left(\frac{\sum total\ time\ for\ vehicles\ inmobilization\ in\ days}{\sum total\ vehicles\ fleet\ required\ time\ in\ days} \right) x100\ \%$
Units	Percentage with one decimal (xx.x %)
Target value	Target value should be higher than 90% and can be considered optimum at 95%.
Calculus frequency	Monthly
Additional comments	That is a great indicator to assess the maintenance policy and management efficiency. Additionally, some variations could be defined for considering vehicles on reserve, vehicles on demand, etc.

4.2.3. Failures per 10.000 km

Name	KA-Failures per 10.000 km
Definition	That is a typical indicator for transport fleet representing the inverse of MTBF. Failures computed are all those that send the vehicle to the workshop and are no related with preventive or predictive maintenance activities.
Formulae 1	$KA_1 = \left(\frac{\sum failures}{\sum km} \right) x10000$
Units	Failures per 10000 km with two decimal (xx.xx failures/10000 km)
Target value	Target value should be lower than 2 and can be considered optimum between 1 and 1.5 failures/10000 km.
Calculus frequency	Monthly but annual monitoring and assessment annual attending that there is a seasonality effect.
Additional comments	That indicator can be customized o modified to obtain more specific info such as: failure type (mechanical, electric, etc.); by vehicle model or powertrain, for a specific period of time or mileage, so on.

4.2.4. Accidents per 10 000 km

Name	SN-Accidents per 10 000 km
Definition	That indicator computes all the accidents reports performed during service for the complete fleet. Typical indicator must take into account all the accidents reports; but for maintenance assessment it can be considered a slightly modification, considering just those reports related with accidents derived from a vehicle failure such as: brakes, direction and suspension, so on.
Formulae 1	$SN_1 = \left(\frac{\sum accident\ reports}{\sum km} \right) x10000$
Formulae 2	$SN_2 = \left(\frac{\sum accident\ reports\ coming\ from\ vehicle\ failure}{\sum km} \right) x10000$
Units	Accidents per 10 000 km with two decimal (xx.xx accidents/10 000 km)
Target value	Target value should be 0
Calculus frequency	Monthly but annual monitoring and assessment annual attending that there is a seasonality effect.
Additional comments	That indicator can be specified for more accurate analysis by parameters such as: vehicles models, service line, for a specific period of time or mileage, so on.

4.2.5. Maintenance plan fulfilment

Name	CM-Maintenance plan fulfilment
Definition	That indicator represents the preventive maintenance program execution versus planning, giving an indication of how far is the real situation versus ideal or complete fulfilment of that program.
Formulae 1	$CM_1 = \left(\frac{\sum Preventive\ Maintenance\ WO\ performed}{\sum Preventive\ Maintenance\ WO\ scheduled} \right) x100\ \%$
Units	Percentage with one decimal (xx.x %)
Target value	Target value should be higher than 95% and can be considered optimum at 100%.
Calculus frequency	Monthly.
Additional comments	That indicator should be analyzed considering also other parameters such as: maintenance WO delay, WO execution time expected vs real, so on.

4.2.6. Maintenance personnel absenteeism

Name	AB- Maintenance personnel absenteeism rate
Definition	That indicator is the relation between absenteeism hours for maintenance work force and total labor hours for maintenance work force.
Formulae 1	$AB_1 = \left(\frac{\sum Maintenance\ WF\ absenteeism\ hours}{\sum Maintenance\ WF\ labor\ hours} \right) x100\ \%$
Formulae 2	$AB_2 = \left(\frac{\sum Maintenance\ WF\ absenteeism\ days}{\sum Maintenance\ WF\ labor\ days} \right) x100\ \%$
Units	Percentage (hours or days) with one decimal (xx.x %)
Target value	Target value should be lower than 4%. Averaged value for Spain in 2000-2016 period has been 4.5% based on data from Statistical National Service.
Calculus frequency	Monthly but annual monitoring and assessment annual.
Additional comments	Absenteeism rate is a classical indicator for any type of industry. Usually is computed considering different shifts of the company and normally is higher for the night shift, which is a very common situation on urban transport fleets.

4.3. Advanced Parameters

4.3.1. Energy consumption kWh/100 km (Diesel, CNG, Hybrid or Electric)

Name	CE- Energy consumption
Definition	That indicator must be obtained following the EN 16258 standard (Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)). It should be considered energy consumption at local level that is referred as tank to wheel and using conversion factors depending on the fuel in use.
Formulae CE_1 (Diesel and hybrids)	$CE_1\left(\frac{kWh}{km}\right) = \left(Average\ diesel\ fuel\ consumption \left(\frac{l}{100\,km}\right) \div 100 \right) \cdot 35.9 \frac{MJ}{l} \cdot \frac{1000}{3600} kJ/s \left(\frac{kWh}{km}\right)$
Formulae CE_1 (CNG)	$CE_1\left(\frac{kWh}{km}\right) = \left(Average\ CNG\ fuel\ consumption \left(\frac{Nm^3}{100\,km}\right) \div 100 \right) \cdot 45.1 \frac{MJ}{kg} \cdot \rho_{NG} \frac{kg}{m^3} \cdot \frac{1000}{3600} kJ/s \left(\frac{kWh}{km}\right)$
Formulae CE_1 (electrics)	$CE_1\left(\frac{kWh}{km}\right) = \frac{Electricity\ consumption\ electric\ buses\ kWh}{Electric\ fleet\ mileage\ performed\ km} \left(\frac{kWh}{km}\right)$
Units	Energy consumption per kilometer with two decimals (xx.xx kWh/km)
Target value	Target value should be defined as a trend, trying to obtain energy consumption reduction as a consequence of fleet renewal or fuel consumption reductions initiatives.
Calculus frequency	Monthly measurement and annual monitoring and assessment attending the indicator seasonality.
Additional comments	That parameter also can be estimated sorting by vehicles models or manufacturers, and additionally can be referred not just to mileage and also to users or passengers transported leading to possible benchmarking comparison with similar companies.

4.3.2. Total CO_2 emissions

Name	EM- Total CO_2 emissions
Definition	That indicator must be obtained following the EN 16258 standard (Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)). It should be considered emissions at local level that is referred as tank to wheel and using conversion factors depending on the fuel in use.
Formulae EM_1 (Diesel)	$EM_1\left(kg\,CO_2\right)=\left(Average\,diesel\;fuel\,consumption\left(\frac{l}{100\,km}\right)\right)\cdot\left(\frac{Diesel\;fleet\,mileage}{100}\right)\cdot 2.67\,kg\,CO_2\,/\,l$
Formulae EM_1 (CNG)	$EM_2\left(kg\,CO_2\right)=\left(Average\,CNG\;fuel\,cons.\left(\frac{Nm^3}{100\,km}\right)\cdot\left(\rho_{CNG}\,\frac{kg}{m^3}\right)\right)\cdot\left(\frac{CNG\;fleet\,mileage}{100}\right)\cdot 2.68\,kg\,CO_2\,/\,kg$
Units	Total CO_2 kilograms emissions (kg CO_2)
Target value	Target value should be defined as an annual reduction target depending of the fleet renewal and other programs for fleet fuel efficiency improvements.
Calculus frequency	Monthly measurement and annual monitoring and assessment attending the indicator seasonality.
Additional comments	That parameter assess the environmental fleet impact and can be sorted by vehicles types and/or models and also be referred to mileage performed or travelers transported for future benchmarking activities.

4.3.3. Mean Time To Repair (MTTR)

Name	TR-MTTR
Definition	That indicator is computed in a discrete way adding all repair times (in hours or days) used on corrective maintenance and divided by the number of failures. Repair time have to consider parts unavailability time. Preventive, predictive or modification activities are not computed as a repair.
Formulae TR_1	$TR_1=\left(\frac{\sum TTR(h)}{Number\,of\;failures}\right)hours$
Units	Hours with two decimals (xx.xx h)
Target value	Attending that this parameter can be affected by so many factors such as: vehicle age, vehicle type, etc.; it is suggested to perform a trending analysis.
Calculus frequency	Monthly measurement and annual monitoring.
Additional comments	MTTR is a technical indicator for maintenance management and led us to obtain as estimation of vehicles maintainability sorting by models or vehicles types.

4.3.4. Maintenance delay

Name	RT- Maintenance delay
Definition	That indicator quantifies the delay regarding real preventive maintenance actions and the theoretical referred to the base reference period for preventive maintenance action expressed in terms of engine oil drain period.
Formulae TR_1	$RT_1=\left(\frac{\sum real\,mileage\,between\;preventive\,maintenance\,actions-\sum theoretical\,mileage}{\sum theoretical\,mileage}\right)x100$
Units	Percentage with one decimal (xx.x %)
Target value	Target value must be lower than 15% and could be optimal lower than 5%.
Calculus frequency	Monthly.
Additional comments	That indicator should be assessed in combination with other ones such as: maintenance fulfilment.

4.3.5. Optimal vehicle period replacement

Name	ER- Optimal vehicle period replacement
Definition	That indicator determines the optimal moment for a vehicle replacement using a Life Cycle Cost Analysis (LCC).
Formulae TR_1	For this indicator, calculus cannot be performed in just one equation. Authors suggest some bibliography for development. [7, 17]
Units	Years with two decimals (xx.xx years)
Target value	Value obtained by LLC analysis.
Calculus frequency	Monthly measurement and annual monitoring and evaluation.
Additional comments	That indicator must be obtained for each vehicle model on the fleet, attending that there are differences between them than can led to different optimum value for each model.

5. Balance scorecard proposal

Attending the previous parameter definition and some important comments, next it is presented a balance scorecard proposal for fleet companies (Table 6).

Table 6. Final structure for the BSC defined

Indicator	Target value	Actual Month	Previous Month	Monthly variation (%)	Assessment	Corrective actions
Structural						
KM						
ED						
VM						
VP						
PC						
Basic						
CM						
DS						
KA						
SN						
CM						
AB						
Advanced						
CE						
EM						
TR						
RT						
ER						

6. Conclusions

This work has presented a balanced scorecard approach for maintenance management in urban transport fleets. Although the BSC defined has not presented the KPIs explicitly in the classical classification attending: financial, costumers, environment, so on, they are presented in an implicit manner. Attending the modern society requirements for a sustainable mobility and the huge importance for that related with urban transport companies in cities, that approach is a contribution step for reaching expected targets. This proposal must be understood such a basis for a subsequent benchmarking approach based on the indicators proposed leading to exchange good practices and collaborations in areas of common interest between different urban transport companies both private and publics.

The final target of that work must be understood as defined by Wireman "performance measurements, when used properly, should highlight opportunities for improvement, detect problems and help find solutions" [26].

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