

Assessment of economic effectiveness of the technical facilities development of a railway carrier

based on the example of screw (Kuttruff) jacks purchase for the maintenance of electric multiple-unit sets

Increasingly modern generations of new traction units dedicated to the passenger traffic and the carried out modernisation of those already used force regional railway carriers to incur costs related to the necessary inspections or repairs. On the other hand the competition on the transport market (road carriers and individual motorisation) or local governments (ordering the performance of regional transport) exert pressures on the carrier in the field of the operating cost optimisation, also with respect to the rolling stock maintenance facilities.

Text **ARKADIUSZ DREWNOWSKI, TOMASZ KWARCIŃSKI, PIOTR SIEDLECKI**

So it is possible to refer to opposite trends. On the one hand we have increasingly higher costs of keeping the maintenance facilities, resulting from more and more modern rolling stock¹, on the other hand the pressure to optimise them in the company. In this situation carriers undertake various actions, which could be broken down into two basic groups: reduction or development of own maintenance facilities.

The reduction of facilities is intended to cut the costs of their operation, obviously not at the cost of lowering the standards for rolling stock maintenance. The following trends can be distinguished in this case:

- 1) spinning out a part of own maintenance facilities as a separate entity (entities), starting their own business, but carrying out the hitherto tasks²;
- 2) reducing own maintenance facilities and outsourcing services that require a greater repair potential;



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Screw (Kuttruff) jacks

Streszczenie

W artykule poruszono problematykę rozwoju zaplecza technicznego przewoźnika kolejowego, na przykładzie zakupu podnośników śrubowych typu Kuttruffa dla oddziału zachodniopomorskiego spółki Przewozy Regionalne, która to inwestycja została zrealizowana. Dokonano analizy ekonomicznej, która wykazała, że w analizowanym przypadku rozwój zaplecza technicznego taboru (a nie jego ograniczenie) jest korzystne. Pozwala to z jednej strony zmniejszyć koszty utrzymania taboru, a z drugiej zapewnić odpowiednią jakość jego utrzymania. Oprócz wymiernych korzyści ekonomicznych realizacja analizowanej inwestycji dała również niewymierne korzyści dla przewoźnika.

Słowa kluczowe: koszty organizacji komunikacji, bezpłatny transport, preferencje komunikacyjne

Summary

Assessment of economic effectiveness of the technical facilities development of a railway carrier

The paper addresses the issues of technical facilities development based on an example of screw (Kuttruff) jacks for rail vehicles installation in the repair workshop of rolling stocks in the West Pomeranian branch of Przewozy Regionalne company. An economic analysis was performed, which showed that in the analysed case the development of technical facility (and not its limitation) is beneficial. This allows on the one hand to reduce the costs of rolling stock maintenance and on the other hand to ensure an appropriate quality. In addition to measurable economic benefits, the analysed investment project provided the carrier also with immeasurable benefits.

Keywords: rail transport, passenger transport, rolling stock maintenance facilities, screw (Kuttruff) jacks

3) liquidating own maintenance facilities and outsourcing all the maintenance-repair services.

The third of the aforementioned cases so far has not occurred among railway passenger carriers in Poland. Always, to a greater or smaller extent, there are rolling stock maintenance facilities, although there are already operating companies, for which the rolling stock maintenance is the basic task. Nevertheless, the market of entities providing services of comprehensive rolling stock maintenance is not that well developed as it is the case for the road transport, where among carriers a clear trend can be observed, related to total liquidation of own maintenance facilities in favour of services outsourcing.

The development of rolling stock maintenance facilities applies to the situation, where a carrier decided to perform as large as possible number of maintenance-repair activities, to reduce thereby their outsourcing, which will result in the maintenance cost savings. In this case it is obvious, that the implementation of such option is related to incurring the necessary capital expenditure, which links with the necessity to raise funds for that.

However, irrespective of actions undertaken by the carrier with respect to the maintenance facilities development or reduction, the economic effectiveness calculation should be always the key issue for any actions, where the overall benefits and costs (expenditures) related to such action are compared.

The paper raises the issues of maintenance facilities development, based on the example of screw (Kutruuff) jacks purchase for the maintenance of electric multiple-unit sets in the West Pomeranian branch of Przewozy Regionalne company. In this case the carrier decided to develop the maintenance facilities on its own, to carry out independently the rolling stock repairs in all areas and in this way to become independent of external entities, whose services had to use beforehand³.

Basic information about the Kutruuff type screw jacks from the rolling stock maintenance point of view

The passenger rolling stock owned by the West Pomeranian branch of Przewozy Regionalne company, to ensure its functionality and safety for the carried passengers, must be subject to the maintenance-repair process, pursuant to the provisions of the *Maintenance System Documentation* (DSU). For each of the possessed EN57, EN57AL, ED72, and ED78 traction units a separate DSU is determined, which specifies the maintenance-repair actions related to the three maintenance levels, i.e. P1, P2, and P3 as well as to running repairs (NB), and emergency repairs (NA).

Actions performed during the maintenance-repair work carried out in the repair shop⁴ are related both to the vehicle's superstructure, of which primarily roof⁵, and also to the undercarriage. Proper performance of those actions requires the use of specialised equipment, including:

- inspection pits with lowered floor,
- Kutruuff type screw jacks,
- inspection platforms,
- workshops⁶.

Kutruuff type screw jacks (Fig. 1) are used at the work related to the vehicle's undercarriage⁷. They are built of a heavy stable base, with a wormshaft mounted on it. On the

shaft a bearing plate is situated, moving vertically together with the vehicle by a mechanical action on the shaft by means of a lever. The screw jack principle of operation consists in applying a small rotational force to the shaft, which converts into a high linear force applied to the vehicle. Screw jacks are most frequently arranged in sets comprising four pieces, synchronised together to ensure uniform lifting of the vehicle. A possibility of their smooth movement, depending on the needs, is a major advantage⁸. In addition, they feature a high level of use safety, because due to their structure they lock themselves, making free fall of the vehicle impossible.

Information about the implemented investment

The investment project discussed in the paper consisted in purchasing 16 pieces (4 sets) of Kutruuff type screw jacks for the Rolling Stock Operation and Maintenance Section in Szczecin (hereinafter referred to as PRS1).

The necessity to carry out the investment was related to the maintenance of the owned rolling stock (EN57AL, ED72), to the rolling stock (EN57) modernisation as well as to the purchase by the Marshall Office of the West Pomerania Voivodeship in the years 2012-2013 of 12 vehicles from ED78 series⁹, which required specialised equipment necessary to carry out inspections and repairs, pursuant to procedures included in the DSU for the given series of the rolling stock. The Section formerly owned only one set (4 pieces) of Kutruuff type screw jacks, which enabled carrying out the maintenance-repair process only on levels P1 and P2. While to carry out the P3 process and running and emergency repairs it was necessary to outsource such tasks. The purchase of Kutruuff type screw jacks enabled independent implementation of the above tasks. So this is an example of developing the rolling stock maintenance facilities potential to achieve savings related to the possibility of extending the scope of independently performed inspections and repairs.

The paper presents below the assessment of economic effectiveness of the discussed investment project, which preceded the making of decision on its implementation.



Fig. 1. Kutruuff type screw jacks. Source: *Catalogue of equipment and measuring instruments. MTL ASCO RAIL Sp. z o.o. (www.ascorail.eu)*

| No | Series | Estimated number of P3 inspections in years | | | | | | | | | | |
|----|------------|---------------------------------------------|------|------|------|------|------|------|------|------|------|------|
| | | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| 1 | ED78 | 3 | 5 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 4 |
| 2 | EN57AL | 0 | 0 | 4 | 6 | 4 | 6 | 6 | 6 | 6 | 6 | 6 |
| 3 | EN57, ED72 | 9 | 8 | 9 | 8 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

Table 1. Source: Own study based on the internal data of 'Przewozy Regionalne' Sp. z o.o. West Pomeranian Branch in Szczecin

| No | Rolling stock series | Inspection type | Unit cost of P3 inspection 'outsourced' [PLN] | Unit cost of P3 inspection in the Szczecin section [PLN] | Difference (4) - (5) [PLN] |
|----|----------------------|-----------------|-----------------------------------------------|----------------------------------------------------------|----------------------------|
| 1 | ED78 | P3 | 63 512,95 | 42 487,68 | 21 025,27 |
| 2 | EN57AL | P3 | 39 332,79 | 27 389,76 | 11 943,03 |
| 3 | EN57, ED72 | P3 | 35 332,79 | 27 389,76 | 7 943,03 |

Table 2. Source: Own study based on the internal data of 'Przewozy Regionalne' Sp. z o.o. West Pomeranian Branch in Szczecin

◆ The investment economic effectiveness assessment was carried out based on the comparison of total measurable benefits and expenditures (costs) of this investment, using the economic effectiveness indices known from the literature¹⁰.

The investment was entirely completed in the first half of 2015. Kutruff type screw jacks are used in the Section PRS1 from July that year. The analy-

sis of effectiveness assessment was carried out for the years of 2015-2025¹¹, although the period of screw jacks operation will be longer (the planned period is 30 years)¹².

Investment related expenditure

- Total expenditures, related both to the implementation and to further operation of the investment,

| No | Year | Rolling stock series | Number of inspections | Difference in unit maintenance costs [PLN] | Total for individual rolling stock series [PLN] (4) x (5) | Total for the year [PLN] |
|----|------|----------------------|-----------------------|--------------------------------------------|-----------------------------------------------------------|--------------------------|
| 1 | 2015 | ED78 | 3 | 21 025,27 | 63 075,81 | 94 847,93 |
| 2 | | EN57AL | 0 | 11 943,03 | 0 | |
| 3 | | EN57, ED72 | 9 | 7 943,03 | 31 772,12 | |
| 4 | 2016 | ED78 | 5 | 21 025,27 | 105 126,35 | 168 670,59 |
| 5 | | EN57AL | 0 | 11 943,03 | 0 | |
| 6 | | EN57, ED72 | 8 | 7 943,03 | 63 544,24 | |
| 7 | 2017 | ED78 | 4 | 21 025,27 | 84 101,08 | 203 360,47 |
| 8 | | EN57AL | 4 | 11 943,03 | 47 772,12 | |
| 9 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |
| 10 | 2018 | ED78 | 4 | 21 025,27 | 84 101,08 | 219 303,50 |
| 11 | | EN57AL | 6 | 11 943,03 | 71 658,18 | |
| 12 | | EN57, ED72 | 8 | 7 943,03 | 63 544,24 | |
| 13 | 2019 | ED78 | 3 | 21 025,27 | 63 075,81 | 182 335,20 |
| 14 | | EN57AL | 4 | 11 943,03 | 47 772,12 | |
| 15 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |
| 16 | 2020 | ED78 | 4 | 21 025,27 | 84 101,08 | 227 246,53 |
| 17 | | EN57AL | 6 | 11 943,03 | 71 658,18 | |
| 18 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |
| 19 | 2021 | ED78 | 4 | 21 025,27 | 84 101,08 | 227 246,53 |
| 20 | | EN57AL | 6 | 11 943,03 | 71 658,18 | |
| 21 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |
| 22 | 2022 | ED78 | 4 | 21 025,27 | 84 101,08 | 227 246,53 |
| 23 | | EN57AL | 6 | 11 943,03 | 71 658,18 | |
| 24 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |
| 25 | 2023 | ED78 | 4 | 21 025,27 | 84 101,08 | 227 246,53 |
| 26 | | EN57AL | 6 | 11 943,03 | 71 658,18 | |
| 27 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |
| 28 | 2024 | ED78 | 4 | 21 025,27 | 84 101,08 | 227 246,53 |
| 29 | | EN57AL | 6 | 11 943,03 | 71 658,18 | |
| 30 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |
| 31 | 2025 | ED78 | 4 | 21 025,27 | 84 101,08 | 227 246,53 |
| 32 | | EN57AL | 6 | 11 943,03 | 71 658,18 | |
| 33 | | EN57, ED72 | 9 | 7 943,03 | 71 487,27 | |

Table 3. Source: Source: own study based on figures from Tables 1-2

| No | Series | Estimated number of NB in years | | | | | | | | | | |
|----|------------|---------------------------------|------|------|------|------|------|------|------|------|------|------|
| | | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| 1 | ED78 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2 | EN57AL | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 3 | EN57, ED72 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

Table 4. Source: Own study based on the internal data of 'Przewozy Regionalne' Sp. z o.o. West Pomeranian Branch in Szczecin

| No | Rolling stock series | Repair type | Unit cost of a running repair 'outsourced' [PLN] | Unit cost of a running repair in the Szczecin section [PLN] | Difference (4) - (5) [PLN] |
|----|----------------------|-------------|--------------------------------------------------|-------------------------------------------------------------|----------------------------|
| 1 | ED78 | NB | 10 185,50 | 2 166,40 | 8 019,10 |
| 2 | EN57AL | NB | 8 280,60 | 1 272,40 | 7 008,20 |
| 3 | EN57, ED72 | NB | 6 272,60 | 1 472,40 | 4 800,20 |

Table 5. Source: Own study based on the internal data of 'Przewozy Regionalne' Sp. z o.o. West Pomeranian Branch in Szczecin

can be divided into three groups:

- capital expenditure,
- operating expenditure,
- replacement expenditure.

The capital expenditure comprised:

- expenditure related to the investment preparation,
- expenditure related to the shop preparation to the screw jacks use,

- expenditure related to screw jacks purchase and assembling.

The expenditure related to the investment preparation was not considered, because it was related to normal duties of the carrier administration employees.

In accordance with the investment task sheet the total capital expenditure related to the shop prepara-

| No | Rok | Rolling stock series | Number of running repairs | Difference in unit NB costs [PLN] | Total for individual rolling stock series [PLN] (4) x (5) | Total for the year [PLN] |
|----|------|----------------------|---------------------------|-----------------------------------|-----------------------------------------------------------|--------------------------|
| 1 | 2015 | ED78 | 2 | 8 019,10 | 16 038,20 | 39 655,00 |
| 2 | | EN57AL | 2 | 7 008,20 | 14 016,40 | |
| 3 | | EN57, ED72 | 2 | 4 800,20 | 9 600,40 | |
| 4 | 2016 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 5 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 6 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 7 | 2017 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 8 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 9 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 10 | 2018 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 11 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 12 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 13 | 2019 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 14 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 15 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 16 | 2020 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 17 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 18 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 19 | 2021 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 20 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 21 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 22 | 2022 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 23 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 24 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 25 | 2023 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 26 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 27 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 28 | 2024 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 29 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 30 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |
| 31 | 2025 | ED78 | 3 | 8 019,10 | 24 057,30 | 71 290,90 |
| 32 | | EN57AL | 4 | 7 008,20 | 28 032,80 | |
| 33 | | EN57, ED72 | 4 | 4 800,20 | 19 200,80 | |

Table 6. Source: own study based on figures from Tables 4-5

tion to the screw jacks use and to their purchase and assembling amounted to PLN 1,643,000.

An assumption was made in the economic analysis that the total capital expenditure was incurred in 2015.

The **operating expenditure** of Kutruff type screw jacks was estimated on the basis of operating expenditure of the same type screw jacks, used in the PRS1 section in Szczecin.

The following operating costs of new screw jacks (16 pieces – 4 sets) were assumed:

- current operation and maintenance – PLN 500 per year (for 2015 – PLN 250),
- Transport Technical Inspection – PLN 700 per year.

The calculations of screw jacks operating costs did not include the **electricity cost**, because its value, related to the screw jacks use, as compared with the energy used for the entire shop operation, can be considered marginal.

Also the **labour cost** was not considered, because the investment will not result in an increased number of persons employed. The human resources had some reserve of capacity and the persons already employed could use the new screw jacks within their hitherto nominal working time.

The screw jacks were handed over to use in July 2015, hence the forecast operating cost for this year was adopted for calculation as a half of average current operating and maintenance value assumed for the next years.

Because the forecast number of inspections and repairs will stay on a similar level in the next years, it is possible to assume that individual operating cost amounts will not change in the analysed period.

Average operating expenditure for new screw jacks taken for calculations:

- 2015 = **PLN 950**,
- next years (2016-2025) = **PLN 1200**.

With respect to the **replacement expenditure** an assumption was made in the analysis that in the reference period (years 2015-2025) repairs of screw jacks will be carried out every five years, i.e. in **2020** and in **2025**, related to the wear of certain sub-assemblies. The value of individual replacement expenditures in the years adopted above (expressed in fixed prices) is **PLN 5000**. The depreciation rate for Kutruff type screw jacks is 10%, however the actual period of such screw jack use substantially exceeds the analysis period.

Investment effects (benefits)

The effect related to the investment project implementation, consisting in purchasing Kutruff type screw jacks for Section PRS1 Szczecin, was defined as a difference between the cost of carrying out P3 inspections, running repairs (NB) and emergency repairs (NA) of specified rolling stock by external companies (outsourcing) and a similar cost in the case of performing them independently in Szczecin as a result of screw jacks purchase. This effect may be expressed by the following general formula:

$$E = KC_z - KC_w$$

where:

E – total effects related to the use of purchased Kutruff type screw jacks,

KC_z – total cost of outsourcing P3, NB, and NA inspections,

KC_w – total cost of carrying out P3, NB, and NA inspections independently in the Szczecin shop.

The total cost of P3, NB, and NA inspections was defined as the product of a unit cost of specific P3, NB, and NA inspection and their number in the given year.

At the calculation of the total cost of outsourced and in-house P3, NB, and NA inspections, the economic analysis included the inspection type and the number of rolling stock units, which will be serviced only as a result of the project implementation.

The effects were analysed with a breakdown into the rolling stock maintenance P3, running repairs (NB), and emergency repairs (NA).

P3 maintenance

The estimated number of performed P3 inspections in individual years (Table 1) and a unit cost of outsourced inspection and carried out in-house in section PRS1 in Szczecin (Table 2) was estimated based on the data of 'Przewozy Regionalne' Sp. z o.o. (Ltd.), West Pomeranian Branch in Szczecin.

Table 3 presents the effects resulting from the Kutruff type screw jacks operation in individual years.

Running repairs – NB

The number of performed running repairs in individual years (Table 4) and a unit cost of NB outsourced and carried out in-house in section PRS1 in Szczecin (Table 5) was determined based on the data of 'Przewozy Regionalne' Sp. z o.o. (Ltd.), West Pomeranian Branch in Szczecin.

Table 6 presents the effects resulting from the Kutruff type screw jacks operation in individual years.

Emergency repairs – NA

The estimated number of performed emergency repairs in individual years (Table 7) and a unit cost of NA outsourced inspection and carried out in-house in section PRS1 in Szczecin (Table 8) was determined based on the data of 'Przewozy Regionalne' Sp. z o.o. (Ltd.), West Pomeranian Branch in Szczecin.

Table 9 presents the effects resulting from the Kutruff type screw jacks operation in individual years.

Total effects (benefits)

Total effects (benefits) resulting from the operation of newly purchased Kutruff type screw jacks are the effects obtained from the performance of P3, NB, and NA inspections in section PRS1 in Szczecin, which may be expressed by the following general formula:

$$E = EU_1 + EU_2 + EU_3$$

where:

E – total effects related to the operation of repair shop in section PRS1 in Szczecin in the given year;

| No | Series | Estimated number of NA in years | | | | | | | | | | |
|----|------------|---------------------------------|------|------|------|------|------|------|------|------|------|------|
| | | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
| 1 | ED78 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 2 | EN57AL | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | EN57, ED72 | 2 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

Table 7. Source: Own study based on the internal data of 'Przewozy Regionalne' Sp. z o.o. West Pomeranian Branch in Szczecin

| No | Rolling stock series | Repair type | Unit cost of an emergency repair 'outsourced' [PLN] | Unit cost of an emergency repair in the Szczecin section [PLN] | Difference (4) - (5) [PLN] |
|----|----------------------|-------------|-----------------------------------------------------|----------------------------------------------------------------|----------------------------|
| 1 | ED78 | NA | 11 256,60 | 2 567,40 | 8 689,20 |
| 2 | EN57AL | NA | 9 542,50 | 1 846,60 | 7 695,90 |
| 3 | EN57, ED72 | NA | 7 325,30 | 1 648,80 | 5 676,50 |

Table 8. Source: Own study based on the internal data of 'Przewozy Regionalne' Sp. z o.o. West Pomeranian Branch in Szczecin

- EU₁ – effects related to the performance of P3 inspections in section PRS1 in Szczecin in the given year;
- EU₂ – effects related to the performance of running repairs (NB) in section PRS1 in Szczecin in the given year;
- EU₃ – effects related to the performance of emergency repairs (NA) in section PRS1 in Szczecin in the given year;

Table 10 presents total effects resulting from the Kutruff type screw jacks operation in individual years of the analysis period.

Economic effectiveness assessment for the investment

The economic effectiveness assessment for the project was expressed by means of the following indices.

| No | Year | Rolling stock series | Number of emergency repairs | Difference in unit NA costs [PLN] | Total for individual rolling stock series [PLN] (4) x (5) | Total for the year [PLN] |
|----|------|----------------------|-----------------------------|-----------------------------------|-----------------------------------------------------------|--------------------------|
| 1 | 2015 | ED78 | 1 | 8 689,20 | 8 689,20 | 27 738,10 |
| 2 | | EN57AL | 1 | 7 695,90 | 7 695,90 | |
| 3 | | EN57, ED72 | 2 | 5 676,50 | 11 353,00 | |
| 4 | 2016 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 5 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 6 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 7 | 2017 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 8 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 9 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 10 | 2018 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 11 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 12 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 13 | 2019 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 14 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 15 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 16 | 2020 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 17 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 18 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 19 | 2021 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 20 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 21 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 22 | 2022 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
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| 24 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 25 | 2023 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 26 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 27 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 28 | 2024 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 29 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 30 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |
| 31 | 2025 | ED78 | 2 | 8 689,20 | 17 378,40 | 55 476,20 |
| 32 | | EN57AL | 2 | 7 695,90 | 15 391,80 | |
| 33 | | EN57, ED72 | 4 | 5 676,50 | 22 706,00 | |

Table 9. Source: own study based on figures from Tables 7-8

- Net Present Value (NPV),
- Internal Rate of Return (IRR),
- Simple Payback Period (OZ),
- Discounted Payback Period (OD),

Net Present Value (NPV)

The basis for the NPV calculation comprised the data related to the capital expenditure, replacement expenditure, operating expenditure, and the effects. At the same time category C_t , consisting of capital and operating expenditure, needs clarification – which can be determined by the formula $C_t = C_{t1} + C_{t2} + C_{t3}$. Table 11 presents the calculations.

$$NPV = \text{PLN } 1,114,375.04$$

Internal Rate of Return (IRR)

The calculation of the internal rate of return IRR was carried out in Excel spreadsheet. The calculated rate of return is: **IRR = 18.11%**

Simple Payback Period (OZ)

The calculation of the simple payback period OZ was carried out in Excel spreadsheet, based on the data presented in Table 11 (column 7).

The incurred capital expenditure will payback in August 2020, so after 5.09 years of screw jacks commissioning.

The simple payback period will be: **OZ = 5.09 years**

Discounted Payback Period (OD)

The calculation of the discounted payback period OD was carried out in Excel spreadsheet, based on the data presented in Table 11 (column 9).

The incurred capital expenditure will payback in April 2021, so after 5.80 years of the facility commissioning.

The discounted payback period will be: **OD = 5.80 years**

Conclusions

The example discussed in the paper shows that in this case the development of the rolling stock maintenance facility is favourable, and not its reduction. On the one hand it allows to cut the costs of the rolling stock maintenance, and on the other hand to ensure appropriate quality of its maintenance.

The carried out effectiveness assessment of the investment, consisting in purchasing 16 pieces (4 sets) of Kuttruff type screw jacks for section PRS1 Szczecin for the rolling stock maintenance clearly shows, that it is financially profitable for the enterprise 'Przewozy Regionalne' Sp. z o.o. West Pomeranian Branch in Szczecin, which is proven by values of economic effectiveness indices.

Apart from indicated measurable benefits a number of immeasurable effects may be distinguished, related to the implementation of the assessed investment. The following can include the main ones:

- improved conditions of repair staff work;
- improved safety of repair staff work;
- improved quality of carried out rolling stock repairs and inspections;

- shortened time of performed repairs and inspections, which is related to increased effectiveness of the rolling stock use from the transport and operating work point of view;
- avoided rolling stock downtimes, resulting from the lack of emergency repair performance;
- possibility to provide maintenance-repairs services to external entities¹³.

It is also worth emphasising that the electric multi-unit sets operated by the Przewozy Regionalne were modernised with the support of the EU funds and therefore they must be in working order from the technical and operational point of view during the project duration. If these requirements are not met, this can mean the necessity to return a part of or the total obtained financing. Because of the Kuttruff type screw jacks purchase it is possible to carry out running and emergency repairs of those vehicles and thereby to meet the requirement of their working order in the period of project duration.

The considerations presented in the paper, related to the economic effectiveness of the carried out project, are confirmed even more distinctly by the fact, that the management board of Przewozy Regionalne company made the decision about the investment implementation and it was completed in accordance with the adopted schedule. ■



Arkadiusz Drewnowski, Ph.D. Eng. | Faculty of Management and Economics of Services, Department of Transport Systems and Policy, University of Szczecin
e-mail: arkadiusz.drewnowski@wzieu.pl



Tomasz Kwarciniński Ph.D. | Faculty of Management and Economics of Services, Department of Transport Systems and Policy, University of Szczecin
e-mail: tomasz.kwarcinski@wzieu.pl



Piotr Siedlecki | 'EURO-PROJEKTY PIOTR SIEDLECKI' Company
e-mail: piotrsiedlecki@wp.pl

¹ Resulting from stricter requirements related to the rolling stock maintenance-repair process, in accordance with the provisions of the *Maintenance System Documentation* (DSU).

² This allows *inter alia* to carry out the restructuring in the established entities, downsizing the unnecessary employment and/or changing the hitherto terms of employment.

³ In this case: the investment was also related to the technical progress in the field of the rolling stock maintenance.

⁴ Because they require ensuring appropriate conditions of work, such as constant temperature, easy access to sub-assemblies installed in vehicles, hard pavement to ensure the transport within the company. It is especially important during the winter time, when snow is deposited on the vehicle roofs, and the undercarriage may be ice-covered.

⁵ Including related to pantographs, A/C systems, air reservoirs, resistance of electric brakes, cooling systems etc.

| No | Year | P3 | NB | NA | Total [PLN] |
|----|------|------------|-----------|-----------|-------------|
| 1 | 2015 | 94 847,93 | 39 655,00 | 27 738,10 | 16 2241,03 |
| 2 | 2016 | 168 670,59 | 71 290,90 | 55 476,20 | 29 5437,69 |
| 3 | 2017 | 203 360,47 | 71 290,90 | 55 476,20 | 33 0127,57 |
| 4 | 2018 | 219 303,50 | 71 290,90 | 55 476,20 | 34 6070,60 |
| 5 | 2019 | 182 335,20 | 71 290,90 | 55 476,20 | 30 9102,30 |
| 6 | 2020 | 227 246,53 | 71 290,90 | 55 476,20 | 35 4013,63 |
| 7 | 2021 | 227 246,53 | 71 290,90 | 55 476,20 | 35 4013,63 |
| 8 | 2022 | 227 246,53 | 71 290,90 | 55 476,20 | 35 4013,63 |
| 9 | 2023 | 227 246,53 | 71 290,90 | 55 476,20 | 35 4013,63 |
| 10 | 2024 | 227 246,53 | 71 290,90 | 55 476,20 | 35 4013,63 |
| 11 | 2025 | 227 246,53 | 71 290,90 | 55 476,20 | 35 4013,63 |

Table 10. Source: own study based on figures from Tables 3, 6, and 9

| No | Year | Capital expenditure C_{t_1} [PLN] | Replacement expenditure C_{t_2} [PLN] | Operating expenditure C_{t_3} [PLN] | Effects (benefits) B_t [PLN] | $B_t - C_t$ (col. 6 - col. 3 - col. 4 - col. 5) | Discount factor (discount rate $i = 5.0\%$) | NPV_t (col. 7 x col. 8) | |
|----|------------------|-------------------------------------------|-----------------------------------------------|---------------------------------------------|-----------------------------------|----------------------------------------------------------|----------------------------------------------------|------------------------------|--------------|
| 1 | 2015 (t = 0) | 1 643 000,00 | | 950,00 | 162 241,03 | -1 481 708,97 | 1 | -1 481 708,97 | |
| 2 | 2016 (t = 1) | | | 1 200,00 | 295 437,69 | 294 237,69 | 0,952380952 | 280 226,37 | |
| 3 | 2017 (t = 2) | | | 1 200,00 | 330 127,57 | 328 927,57 | 0,907029478 | 298 347,00 | |
| 4 | 2018 (t = 3) | | | 1 200,00 | 346 070,60 | 344 870,60 | 0,863837599 | 297 912,19 | |
| 5 | 2019 (t = 4) | | | 1 200,00 | 309 102,30 | 307 902,30 | 0,822702475 | 253 311,98 | |
| 6 | 2020 (t = 5) | | 5 000,00 | 1 200,00 | 354 013,63 | 347 813,63 | 0,783526166 | 272 521,08 | |
| 7 | 2021 (t = 6) | | | 1 200,00 | 354 013,63 | 352 813,63 | 0,746215397 | 263 274,96 | |
| 8 | 2022 (t = 7) | | | 1 200,00 | 354 013,63 | 352 813,63 | 0,710681330 | 250 738,06 | |
| 9 | 2023 (t = 8) | | | 1 200,00 | 354 013,63 | 352 813,63 | 0,676839362 | 238 798,15 | |
| 10 | 2024 (t = 9) | | | 1 200,00 | 354 013,63 | 352 813,63 | 0,644608916 | 227 426,81 | |
| 11 | 2025 (t = 10) | | 5 000,00 | 1 200,00 | 354 013,63 | 347 813,63 | 0,613913254 | 213 527,40 | |
| 12 | Total (NPV) | | | | | | | | 1 114 375,04 |

Table 11. Source: Own study based on figures from section II, III, and Table 10

- ⁶ Enabling the performance of sub-assembly tests by means of specialised equipment, necessary for the air conditioning systems, engine diagnostics, auxiliary equipment (testers, measuring instruments, sub-assembly testing stands) diagnostics.
- ⁷ Including those related to the brake system and the running gear, high-voltage equipment, converters, high-speed circuit breakers, pneumatic system etc. Apart from the rolling stock maintenance and repair needs the screw jacks may be used at a change of track gauge (bogies exchange).
- ⁸ Although they can be permanently fixed to the floor, e.g. in the case of only one type of rolling stock maintenance.
- ⁹ 'Impuls' type electric multiple-unit sets, manufactured by the rolling stock producer, company Nowag from Nowy Sącz. The vehicles purchased by the Marshall Office were handed over for use by the West Pomeranian branch of Przewozy Regionalne company in the form of a lease.
- ¹⁰ See e.g. J. Engelhardt, *Zasady analizy i oceny działalności gospodarczej przedsiębiorstw kolejowych*. CeDeWu, Warszawa 2014.
- ¹¹ Where 2015 was taken as the basic year.
- ¹² The investment effectiveness was assessed only for the years of 2015-2025, because the requirements of the company ordering the experts opinion, i.e. Przewozy Regionalne, were such.
- ¹³ This effect was classified right now as immeasurable, because it is difficult to estimate the size of demand for such services, because so far the West Pomeranian branch of Przewozy Regionalne was not providing such services to external entities. Nevertheless, taking into consideration on the one hand the possessed experience of the maintenance group employees, and the potential, which will increase after the purchase of Kuttruff

type screw jacks, and on the other hand observing a growing number of entities providing passenger regional transport, it is possible to assume, that such effect could occur.

References

1. Baumgartner J.P., *Prices and Costs in the Railway Sector*. Ecole Polytechnique Federale de Lausanne, January 2001.
2. *Katalog urządzeń i przyrządów pomiarowych*. MTL ASCO RAIL Sp. z o.o. (pobrano ze strony firmy: www.ascorail.eu).
3. Materiały wewnętrzne „Przewozy Regionalne” Sp. z o.o. Oddział Zachodniopomorski w Szczecinie.
4. Engelhardt J., *Zasady analizy i oceny działalności gospodarczej przedsiębiorstw kolejowych*. CeDeWu, Warszawa 2014.
5. *Niebieska Księga, Sektor kolejowy. Infrastruktura kolejowa*. Jaspers, wrzesień 2015.
6. Wytyczne Biura Infrastruktury, Logistyki i Zaopatrzenia „Przewozów Regionalnych” Sp. z o.o. (pismo PBL2c-Pl-223-04/1/2014, Warszawa 8.07.2014).