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Sustainability Assessment of the Operation of the BUGA23 Ropeway

Prof. Dr.-Ing. Jürgen Follmann

Thomas Marx M. Eng.

Sebastian Bruns B. Eng.

Accompanying study for Doppelmayr Seilbahnen GmbH and Bundesgartenschau Mannheim gGmbH

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Darmstadt University of Applied Sciences,

Department of Civil and Environmental Engineering

Haardtring 100, 64295 Darmstadt

www.fbbu.h-da.de/forschung/projekte/urbane-seilbahnen

Authors

Prof. Dr.-Ing. Jürgen Follmann	E-mail: juergen.follmann@h-da.de
Thomas Marx M. Eng.	E-mail: thomas.marx@h-da.de
Sebastian Bruns B. Eng.	E-mail: sebastian.bruns@stud.h-da.de

on behalf of Doppelmayr Seilbahnen GmbH and Bundesgartenschau Mannheim gGmbH

Konrad-Doppelmayr-Straße 1, Postfach 20, 69225 Wolfurt, AUSTRIA

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Summary

Although the densely populated areas have a good transport infrastructure, this is mostly oriented towards motor vehicle traffic. There are capacity bottlenecks on roads and railways. At the same time, the population is growing. The potential for redensification of neighborhoods is being exploited. Climate protection, sustainability, noise reduction, quality of life and health are shaping a changing mobility behavior.

Urban ropeways help to close gaps in the public transport network. They glide above obstacles almost silently and do not compete with other traffic areas. They are considered faster and more cost-effective to implement than rail lines and can attractively transport around 5,000 passengers per hour and direction at a speed of 25 to 30 km/h over a distance of up to roughly 5 km. They can also be dismantled quickly. This study presents the results of an investigation carried out by Darmstadt University of Applied Sciences on behalf of Doppelmayr GmbH. The aim of this study was to compare the sustainability aspects of operating ropeways and buses for passenger transportation between the BUGA Mannheim 2023 event sites. In the context of the fictitious bus operation, a distinction was made between diesel-powered and electrically powered vehicles.

In terms of sustainability, the social, economic and ecological pillars were given equal consideration and analyzed. The results show that the ropeway is a sustainable solution for the temporary connection of the two BUGA sites. Both diesel and electric buses are less suitable. The ropeway proves to be more socially and ecologically sustainable, especially due to its direct route.

It is important to note that the study did not produce a comprehensive life cycle assessment, but only took into account the CO2 footprint of the systems considered during operation.

Keywords

Sustainability; Ecology; Economy; Social; Comparison; Urban ropeway; E-bus; Bus; Transport planning; Urban mobility

1. Initial Situation, Methodology and Aim of the Study

The Federal Horticultural Show (BUGA) took place in Mannheim from April 14 until October 8, 2023. A total of over two million visitors were expected. According to the BUGA company's press release, a total of more than 2.2 million people actually visited the BUGA (BUGA23 2023-10-09). To handle the flow of visitors between the two main sites Spinelli and Luisenpark, the construction works for a continuous monocable gondola lift from Doppelmayr started in June 2022 (Ragge 2022). The gondola was built exclusively for the BUGA23 and is to be completely dismantled after the horticultural show (Figaj und Scharff 2024).

Some of the system components come from the ropeway built for the Floriade in Almere. This installation was in operation until October 2022. The required components were then brought to Mannheim. The costs for planning, approval, construction, operation and dismantling of the ropeway in Mannheim amounted to eight million euros. The total length of the connection is around two kilometers. It forms the basic framework of a comprehensive transport concept for the "most sustainable BUGA of all time" (BUGA 23 2024). Passengers are transported with a maximum of 64 cabins, which can also be attached to or detached from the rope as required (BUGA23 2023). The maximum operating speed on the line (outside the stations) is 6.5 m/s (23.4 km/h), resulting in a trip time of seven minutes. In practice, the ropeway runs at a reduced speed whenever possible (Doppelmayr Seilbahnen GmbH 2020) to save energy and optimize costs and to provide a longer experience for guests, thus achieving longer travel times. Operation is powered by green electricity (BUGA23 2022).

The decision to construct a temporary ropeway infrastructure was based on the aspects of sustainability, reliable transportation of visitor flows and the required transport capacity. The sustainability criterion was given the highest weighting in the selection process.

In the study, three transport systems for connecting the two event locations Luisenpark and Spinelli Park of BUGA23 in Mannheim were compared and evaluated for sustainability:

- the actual BUGA ropeway,
- a fictitious electric bus connection alternative and
- a diesel bus connection alternative.

The data required for this was requested or obtained from available literature. Further data such as random passenger counts and the design of the stops were gathered on site.

This study does not claim to be a generally applicable guide for evaluating the sustainability of local public transport systems. However, it can serve as a guide.

In order to examine the combination of the fictitious bus service for the event with the existing scheduled public-transit bus service, the existing local public transport system and its infrastructure were examined. In addition to examining options from the route network, stops were documented on site and random passenger counts were carried out.

The feasibility of a fictitious bus service was assessed on the basis of the number of vehicles and drivers required.

For the detailed evaluation of fictitious bus transport and the implemented ropeway, the sustainability categories of social, economic and ecological aspects were divided into further sub-areas. The diesel and electric drive systems were always considered together if their different drive systems did not lead to differences in their impact on the corresponding sub-area.

Various methods were used to gauge the sub-areas. These included literature research, on-site inspections, evaluations of public transport passenger information, evaluation of the energy consumption provided and calculation of the required driving personnel (bus) and energy requirements.

A detailed evaluation matrix was created for the final assessment of the social, ecological and environmental sustainability categories. This was intended to make the qualitative classification of the various sub-areas visible. Specific factors were defined that play a decisive role in the sustainability of the aspects under consideration and enable a comprehensive assessment with weighting of the individual elements. This structured approach allows for a comprehensive and meaningful recognition of the different dimensions of sustainability.

In addition to sustainability, this study also includes a greenhouse gas balance for the operation.

2. Results

2.1 Analysis and evaluation of existing public transport connections

The first step was to examine whether the existing public transport system had sufficient capacity to transport the additional BUGA guests. To this end, all relevant connections in the vicinity of the two BUGA locations Spinelli and Luisenpark were first identified and then examined on site. The focus was particularly on accessibility at the relevant stops.

As a result, only one connection in each direction was considered for the transportation of visitors. All other potential connections either had travel times of more than 30 minutes or required more than one change. This made them unattractive and less suitable. They therefore did not meet the service and quality level of BUGA Mannheim gGmbH.

The remaining capacities of these two connections were determined by means of random passenger surveys. For this purpose, the number of passengers was recorded during the relevant peak traffic times (1:00 p.m. to 3:00 p.m.) and compared with the total capacity of the respective scheduled buses. To determine the theoretical total capacity, the information on the number of seats and standing room in the respective buses was documented.

The travel times of more than 30 minutes in some cases, transfers and the coverage adapted to the existing demand during the course of the day make the lines unattractive for transporting guests during the BUGA. In addition, the remaining capacity would not be sufficient.

The BUGA transport concept derives a required transport capacity between Spinelli and Luisenpark of 2,800 passengers per hour per direction (pphpd) from a forecast number of 2.1 million visitors. However, the analyzed residual capacity in the existing public transport system on the Spinelli - Luisenpark route is less than 100 passengers per hour, which means that smooth passenger transport is not feasible.

2.2 Determination of fictitious bus traffic

Due to the lack of capacity of the existing public transport service, an additional service must be developed for the BUGA. To examine a fictitious bus transport solution instead of a ropeway, the required number of buses to be used and the resulting personnel requirements are determined. If regular buses with a length of 18 m are used, they have a transport capacity of 91 passengers (41 seated and 50 standing).

In order to be able to transport 2,800 pphpd at peak times, as assumed in the preliminary planning for the design of the ropeway, a bus service with a capacity utilization of up to 65% would have to run every 2 minutes.

Taking into account an estimated time loss of around six minutes per one-way trip to serve the stops and turn the bus around, this results in a total of around 30 minutes for the round trip, including passenger changeover, with a travel time of around nine minutes per direction. The provision of reserve buses required in the event of the failure of individual vehicles does not appear to be mandatory, as additional vehicles from the existing fleet of Rhein-Neckar-Verkehr GmbH (rnv) could be provided if necessary. This is particularly justified as the peak demand of 2,800 pphpd can only be expected in exceptional cases. Mathematically, this results in a number of 24 buses to be procured in order to be able to handle the transport of 2,800 pphpd in the event of peak demand. The current shortage of drivers is considered to be much more problematic. For this purpose, the order of magnitude was determined using the actual transport figures.

The actual passenger numbers provided by Doppelmayr for the entire BUGA period (2023-04-14 to 2023-10-08) were used to determine the hourly distribution of transportation between the event sites. The average number of passengers per hour (Figure 1) is used to determine the average number of buses that would have to be used in the respective hour. The analysis of the actual passenger numbers results in an average maximum number of 1,250 passengers per hour and per direction (pphpd) during the particularly busy period from 11:00 a.m. to 1:00 p.m.

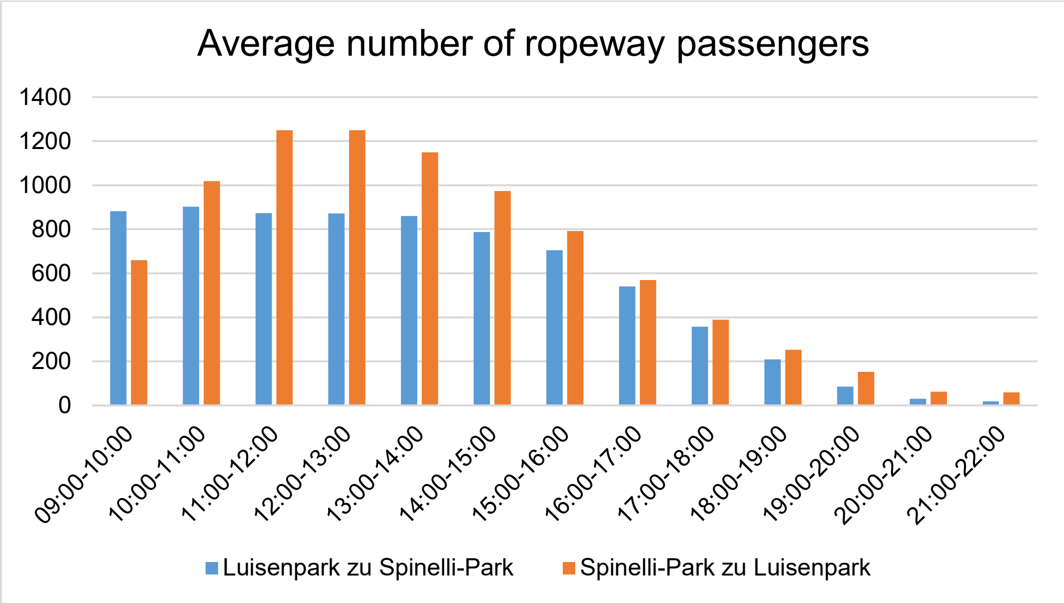

Figure 1: Average daily passenger curve, ropeway passengers per hour (BUGA period 2023-04-14 to 2023-10-08, source: Doppelmayr, own illustration)

At least 11 people are required as drivers to cover the period between 11:00 a.m. and 1:00 p.m., while fewer drivers are deployed during off-peak times. In the period from 8:00 p.m. to 9:00 p.m., the efficient use of vehicles, i.e. the use of a single vehicle, leaves only 30-minute coverage.

If employment contracts are drawn up for 160 hours per month, this results in a minimum number of 22 persons to be employed in order to cover the average demand at all times. In order to absorb peaks above the average workload, appropriate deployment planning must be carried out and, for example, vacations should preferably be planned on days with a low expected number of passengers. Due to the assumed target utilization of the vehicles of 65%, there is free capacity to absorb unexpected passenger peaks. In extreme cases, particularly heavy additional loads on the system could lead to increased waiting times. In practice, there is additional working time for the driving personnel apart from the timetables, but this is not taken into account in this calculation.

Sustainability Assessment of the Operation

2.3 Social aspects

In the comprehensive analysis of the transportation systems under consideration and their social effects, subjective aspects such as ride sensation, comfort and the experience are examined in addition to the quality of the connection. Aspects such as accident risk, social safety and accessibility are also considered. Social impacts also include potential sociological functions that can be fulfilled by the means of transportation and potential for possible conflicts with stakeholders.

In principle, urban construction and transportation projects must be integrated into the respective urban (residential) environment. This aspect is not considered in the present study due to the short operating time of only around half a year and the resulting tight time limit of the transport projects.

For a qualitative classification of the various sub-areas, these are weighted with the help of factors. Figure 2 shows a sample.

Fulfillment of the criterion	Valuation
outstanding	10
very good - outstanding	9
very good	8
good	7
rather good	6
satisfactory	5
sufficient	4
rather poor	3
poor	2
very poor	1
not fulfilled	0

Figure 2: Evaluation key for social aspects

The ropeway performs well to outstandingly in all areas except social safety and acceptance. In particular, the connecting function with the virtually clock-free operation and the guaranteed barrier-free accessibility even during periods of high demand offer outstanding quality. Social safety is rated somewhat lower due to reduced accessibility in emergencies and the lack of operating personnel in the cabins. Although the lack of acceptance among neighbors is not unusual for a local public transport project, it is more intense than with fictitious bus operation due to the visibility of properties, for example.

Like diesel bus transport, electric bus transport is in the good mid-tier in almost all sub-areas, which is to be expected due to the widespread use of buses in local public transport. When it comes to avoiding potential conflicts with stakeholders, bus transport, and electric bus transport in particular, stands out from ropeways. One reason for this is that no new route would have had to be built in the case of this study. Only a rededication of a car lane to a bus lane would have taken place at the expense of motorized private transport. In addition, the BUGA has little overlap between the peak times of everyday traffic and visitor traffic. Electric bus transport also benefits from its low-emission drive system in this aspect.

Bus transport has to make concessions in the assessment of its social function due to its spaciousness, the number and arrangement of seats as well as noise emissions, in particular due to driving noise. It has further weaknesses compared to the ropeway in the areas of ride sensation, comfort and experience. The minor difference between the two types of bus transport can be explained by the reduced noise pollution and lower vibrations of the electric drive.

In the overall assessment of social sustainability, the ropeway is ahead of the two bus services by around 1.5 points. These in turn differ from each other by only 0.2 points. According to this assessment, the ropeway is the more socially sustainable means of transport.

2.4 Economic aspects

Sustainability considerations in economics encompass more than just investment and operating costs. Potentially critical issues for the present and future, such as energy consumption, personnel requirements and structural footprint, must be taken into account. Downstream processes with economic relevance, such as dismantling, flexibility and recycling, must also be included.

The total costs of the various transportation systems differ significantly. At eight million euros, the ropeway is the most cost-efficient, followed by diesel bus transportation at around ten million euros. At around 22 million euros, electric bus transport is by far the most cost-intensive option.

In order to be able to classify economic effects for future generations, long-term economic, social and ecological effects are more important than the immediate costs when considering the sustainability of a project. Consequently, the economically sustainable treatment of the three transport systems examined was evaluated by means of the economic sub-areas. A positive assessment of economic sustainability means that the transport system in question will continue to be economically viable in the future.

The ropeway performs well to very well in all sub-areas with the exception of land requirements as, in contrast to the bus alternatives, new land is required. The comparatively low energy consumption is particularly advantageous, also compared to electric bus transportation. The assessment of the social costs also benefits indirectly as, unlike diesel, electrical energy is not dependent on individual raw materials such as climate-damaging mineral oil or biomass. Instead, it can be obtained from a variety of energy sources, including various renewable ones, and therefore offers a more reliable and price-stable option.

In the following, the term transportation describes the movement of a person in one direction (see Figure 3).

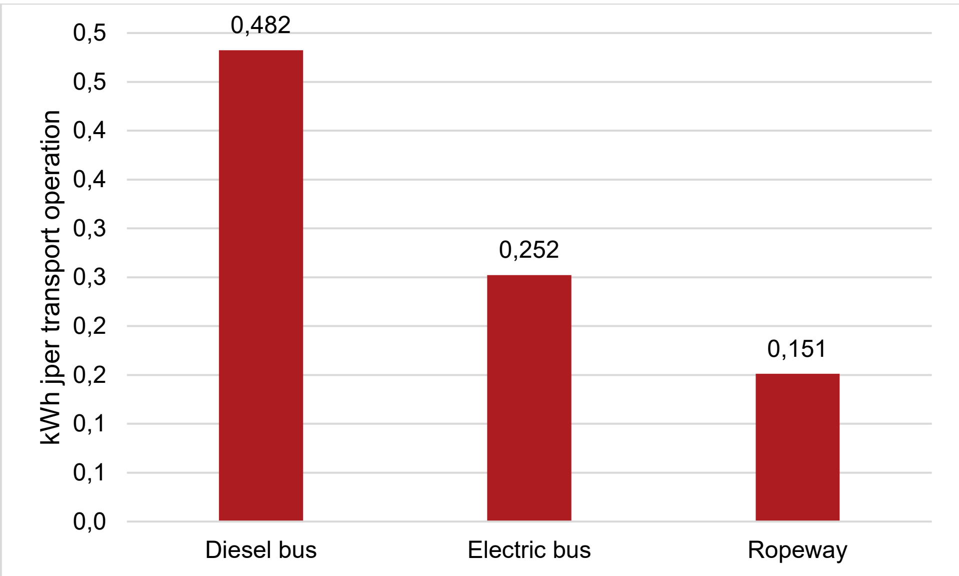

Figure 3: Energy requirement of the means of transport considered in kilowatt hours per journey (own calculation based on (Cox & Althaus, 2020; Statistisches Bundesamt, 2022c))

It should be noted, however, that no explicit data is available for the social costs of a ropeway and the assessment is therefore only comparable to a limited extent. The sufficient assessment of land consumption can be explained by the new infrastructure to be built for the ropeway. It should be noted here that, although the ropeway takes up new space compared to bus transportation, this is limited to the station and tower locations. Just under 3,500 m² of land were built on for the ropeway. In comparison, the construction of a new asphalt road with a 3.50 m wide lane in each direction on the existing route of the fictitious bus connection would have required around 37,450 m², i.e. ten times as much surface area, to be sealed.

Electric bus and diesel bus transportation differ in their evaluation for the categories of energy and social costs. The significantly higher energy consumption due to the lower efficiency of a diesel engine leads to a poor rating for diesel bus transport as opposed to a satisfactory rating for electric bus transport. The assessment of the social costs of electric bus transport is also based only on estimates. In the different assessment of the two drive systems, it is assumed that electric buses perform significantly better in reality and diesel buses slightly worse than the average bus in Germany. The personnel requirements are assumed to be the same for both drive systems. No additional space is required due to the existing infrastructure. As a result, there will be no dismantling after the BUGA and the buses can be handed over to their new destination.

With the evaluation key comparable to Figure 2, the ropeway is just one point ahead of electric bus transport and just under three points ahead of diesel bus transport in the overall evaluation of economic sustainability. The overall assessment of economic sustainability is primarily due to the expected differences in social costs, for which specific data on the individual transportation systems is lacking. This makes a conclusive assessment of economic sustainability difficult.

2.5 Ecological aspects

Urban transportation projects have extensive ecological impacts. The biosphere in the vicinity of transportation systems is an important sub-area here. Soil sealing and noise muisance are also part of a comprehensive consideration of the ecological sustainability aspect. In densely populated regions, there are also impacts on air quality.

This study initially focuses attention on the creation of a GHG balance for the operation of all three transport systems. Responsible and sustainable operation of means of transport is closely linked to the GHG emitted by them.

The BUGA ropeway has rather moderate to no impact on the environment in all areas of environmental sustainability. It has no or very little impact in the sub-areas of noise, air quality and the GHG balance of transportation operations. It only has a relevant impact on the biosphere and soil sealing due to the construction of the required infrastructure and the resulting traffic route. However, it should be noted that, after dismantling the plant and recultivating the area and biosphere taken up, no impairment will remain.

Electric bus transport also has a rather low impact on the environment at most. This is the case in the categories of noise and the GHG balance of the operation. The reason for this is the high demand for electrical energy compared to the ropeway. In all other sub-areas, there is no significant impact on the environment.

The situation is different for diesel bus transport. In the areas of biosphere and land sealing, its assessment is the same as that of electric bus transport, but in the areas of noise, air quality and the GHG balance of the operation, the assessment differs greatly. Although the impact on air quality is only moderate due to the modern design of the diesel drive, the noise pollution caused by diesel bus traffic is comparatively high. The GHG footprint of bus operations is considered unacceptable. In times of advancing climate change, a 1.7-fold or even 34-fold increase in CO2-equivalent emissions compared to alternative transport systems is unacceptable (see Figure 4).

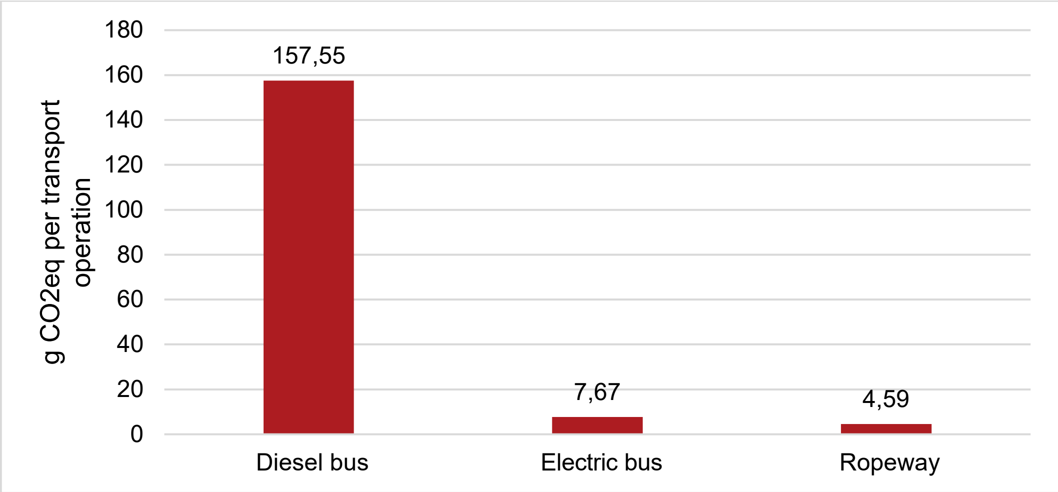

Figure 4: GHG emissions caused by operation (own calculation based on (Zemo Partnership 2023), (Umweltbundesamt 2022) and (Icha und Lauf 2023; Hauser et al. 2019))

In the overall evaluation (evaluation key as shown in Figure 2) of ecological sustainability, the BUGA ropeway is almost five points and the electric bus transport about four points ahead of the diesel-powered bus transport, which represents the clearest difference in all three main areas of sustainability examined. The ropeway is 0.65 points ahead of electric bus transport and can therefore be classified as the most ecologically sustainable choice.

3. **Conclusion**

Confirmation of the choice of the ropeway as a sustainable means of transportation

In this sustainability study, the BUGA23 ropeway was compared with a fictitious bus service powered by electricity or diesel. The result confirms the decision in favor of the ropeway as a sustainable means of transport for the temporary connection of the two BUGA sites. Meanwhile, diesel bus transport is considered unsustainable in all three areas and therefore unsuitable for the declared aim of the BUGA.

Three pillars of sustainability

Sustainability was assessed equally in the social, economic and ecological pillars (see Figure 5).

In terms of social sustainability, the ropeway can be classified as significantly more sustainable than the two alternatives. It also performs better in the area of ecological sustainability, although electric bus transport is also considered to be ecologically sustainable. The assessment of economic sustainability primarily shows the importance of collecting comprehensive data in order to be able to determine the effects of transport projects. A cautious assessment is made in favor of the ropeway.

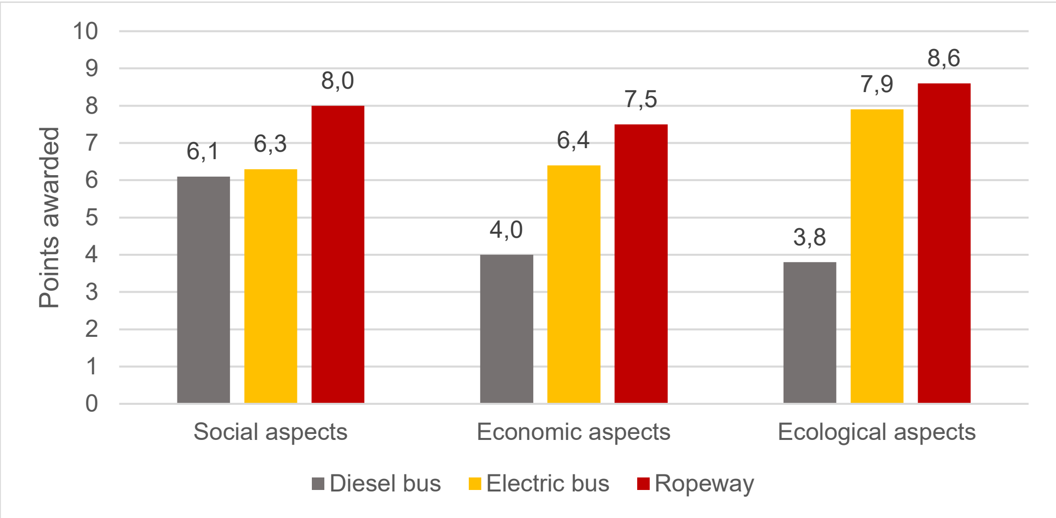

Figure 5: **Overall rating**

In the case of BUGA23, the assessment of the ropeway benefits above all from the direct route and the thus significantly shorter connection. Passenger numbers also play an important role. Lower passenger numbers lead to lower capacity utilization and therefore higher relative energy consumption values (kWh/passenger). The actual energy consumption depends on factors such as the operating speed.

For example, halving the number of passengers almost doubles the relative energy consumption values. Conversely, the energy efficiency of the ropeway increases as the number of passengers increases.

The assessment of the sustainability of the bus transport systems benefits from the existing bus stops and the assumption that the capacity of the road infrastructure does not need to be adjusted for this major event due to the different peak times. Therefore, if necessary, vehicles from an external depot could also be used for bus transportation.

Uniqueness of the study

The presented examinations and assessments refer exclusively to this particular case. Differences such as changes to the route, lack of existing infrastructure or lower expected passenger numbers would lead to different results in the assessment.

In addition, the weighting of the factors identified in the course of this study was based on the discussion and assessment by the team of authors. At the same time, it must be acknowledged that the evaluation of factors in the area of sustainability in general is often characterized by individual values and contexts. The transparent approach chosen enables critical reflection on the interpretation of the results and underlines the need for an open debate.

Limited data available

This study is partly based on limited data. This particularly affects the areas of traffic safety and social costs.

Although the calculated GHG balances for the operation are available, further data such as raw material extraction, production, maintenance and disposal are missing for a comprehensive assessment of the climatic impact of a transport infrastructure project. Operation is only one element of a complete GHG balance.

Potential of urban ropeways

In summary, it can be said that there is great potential for urban ropeways in public transport. In view of climate change and other pressing social challenges, particularly those relating to energy and mobility, it is essential to consider and develop alternative transport systems. During the BUGA23 in Mannheim, the ropeway proved that it is financially, ecologically and socially attractive.

Ropeways have decisive advantages over conventional local passenger transport in all three main areas of sustainability, particularly for connections with high passenger volumes where no direct routes for bus (or streetcar) transport are possible. The willingness to integrate technologies such as ropeways into comprehensive local public transport concepts, to adapt them to existing urban structures and those currently being planned, and to continuously develop them further, requires openness and courage.

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