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Maintenance Management – a Module in Asset Management in a Medium-Sized German City as an Example

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Abstract

Since the development of public administration management in the 1980s into the New Management Model, the principles of asset management have found their way into the management of public administrations. This enabled the already existing systematic maintenance management of roads to be integrated as an element of asset management. Systematic road maintenance today ensures the provision of a well-functioning infrastructure. The requirements for maintenance management - especially for municipal infrastructure - are becoming increasingly complex. In addition to the purely technical view, the commercial view and life cycle cost considerations have also been incorporated into maintenance management. The available financial resources should be used optimally in such a way as to achieve the useful lives of the assets, ensure the value retention of the fixed assets and implement the new infrastructure requirements. When renewing existing infrastructure today, it is therefore necessary to address issues that will become relevant tomorrow. These include, for example, an ageing society, increased e-mobility, a child and disability-friendly society, flood protection, reduced noise and a reduction in air pollution. These and other aspects are therefore integrated into the existing management system and must also be considered during maintenance. Municipal asset management (AM) is a suitable controlling method for this. This paper intends to show how modern maintenance management of municipal infrastructure as an element of asset management can be achieved by changing the way it is viewed and approached, without generating additional costs in the medium term.

1 Introduction – What is the additional benefit of Asset Management?

The Pavement Management System (PMS) or systematic road maintenance is an important tool for road authorities to choose the right measure at the right time from a road construction perspective and to estimate the short and medium-term financial requirements. Furthermore, it makes it possible to monitor the success of the measures implemented and the maintenance strategy over longer periods of time (Schmuck, 1987). Long-term considerations and the consideration of changing requirements are not or hardly possible in PM systems. It therefore has a strong operational focus and is only suitable for the management level of an organization to a limited extent.

Asset management is intended to support the management at all levels of an organization in carrying out their leadership and management tasks. It is used for task- and result-oriented controlling under economic aspects based on targets, metrics and key figures. The objectives and requirements defined in asset management are to be achieved through measures and projects. In contrast to project management, asset management makes it possible to consider an asset from the initial planning stage throughout its entire life cycle. While quality management describes the process flow for completing tasks in accordance with predefined goals and standards, asset management is concerned with the organization of tasks in accordance with the predefined goals and standards. Asset management therefore means (strategic) control over the life cycle of an organization's assets.

The requirements for asset management are regulated in E DIN ISO 55001:2017-02. According to DIN ISO 55000 (DIN, 2016), the benefits of asset management over the life cycle can include the following:

- Improved economic performance (maintaining asset values despite cost reduction),
- fact-based decisions on asset-related investments (easier decision-making by weighing up costs, risks, opportunities and performance),
- planned and controlled handling of risks (reducing financial losses, improving occupational health and safety, improving image),
- improved performance and earnings (ensuring performance leads to better services and products),
- proven compliance with regulations,
- enhanced reputation (customer satisfaction increases),
- improved sustainability,
- increased efficiency (the review and the resulting improvement increases effectiveness and leads to the achievement of the organizational goal).

An asset management system can also be used to manage and control the assets of a municipal road infrastructure through a series of business processes for decision-making that promote continuous improvement in maintenance management.

The following characteristics are therefore decisive for a functioning maintenance management system as part of asset management:

- The nature and purpose of the organization (organizational goals),
- the inventory of all infrastructure assets,
- knowledge of the age, condition and changes to the assets,
- availability of information for carrying out a life cycle cost analysis,
- information to perform risk management analysis,
- information on the development of the financial plan to support investments and
- the development of investment strategies,

to manage the road network over its entire life cycle. Furthermore, a repeatable definition of characteristics is essential to the overall assessment process. It is also necessary to define what is to be achieved in the future.

In order to be able to manage efficiently in terms of AM, it is important to define targets, measures for target fulfillment and associated key performance indicators (KPIs). The values, metrics and KPIs can be used to objectively, quantitatively and qualitatively assess whether the strategic objectives are being achieved. When developing KPIs, the collection of new data should be minimized and the consideration of already collected data should be maximized. To monitor and document success, an annual review is prepared at the end of the year to identify which processes still need to be improved. There are two things to be considered regarding the informative value of key performance indicators. First, the data must be tested to check whether it is suitable for the measurements and calculations. Second, the validity of the results must be checked to ensure that they reflect actual performance.

A performance framework should consider who is affected by the performance of the installations. Here, a distinction is made between three broad groups: external stakeholders (usually more interested in what happens on the network than the average customer; have an interest in the transportation system), customers (anyone who uses parts of the transportation network) and partners (stakeholders who share strategic objectives with the transportation agencies). Partners can help deliver or fund projects.

2 How can Asset Management be set up?

Based on the common management function circle (see Figure 1), management models for road maintenance can be developed in a similar way, in which the various tasks for the safety and performance, construction and maintenance of road pavements are combined and linked.

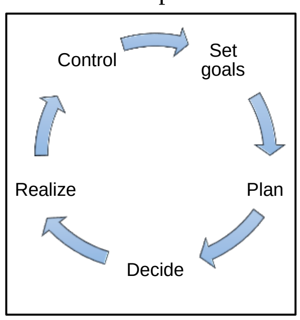

Figure 1: Schematic illustration of the management circle (Münster b, 2020)

Different organizational forms are conceivable depending on the administrative structure, tasks, task weighting and standards. It is therefore a misconception that the asset management standard describes an organizational form or structure. The series of international standards ISO 55000 Asset Management describe the international standard of asset management. They have not yet been implemented in German standards or regulations for road maintenance management. The asset management system is well aligned with the life cycle considerations of the New Control Model for Municipalities (NSM) and New Municipal Financial Management (NKF). This can be used as a guide when setting up an AM system.

In Germany, current systems for systematic road maintenance are based on condition-based target determination. This means that the planning of maintenance activities over the life cycle is geared towards optimizing the condition and achieving the service life.

The management of road maintenance is a special "planning task" in which both the strategic decisions on maintenance measures or measure strategies are made network-wide and the preparation of a maintenance program as well as the preparation and implementation of maintenance measures are carried out on an object-by-object basis at the operational level. These two levels are linked by a tactical level, which supports the decision-making process to achieve the strategic objectives (Fig. 2).

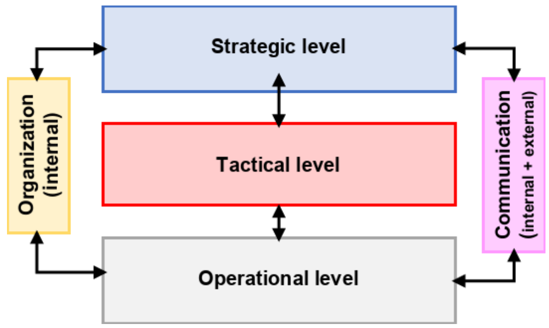

Figure 2: Decision-making levels in asset management AM (Buttgereit et al., 2016)

The basis for this is the road network that has been recorded and prepared in a corresponding database. In order to better integrate financial aspects into construction-related decisions in maintenance management, asset management should also take into account information from asset accounting.

To be able to control efficiently in terms of asset management, it is important to define goals, measurements and key performance indicators. Long-term and short-term management options can be developed based on the defined goals and key performance indicators, which are explained in more detail using an example from the area of finance.

Long-term management (strategic level) should create intergenerational justice, i.e. not place a burden on future generations but be sustainable. To achieve this, it is necessary to achieve an even distribution of resource consumption over the life cycle.

Short-term management (operational level) is primarily concerned with achieving a balanced annual result, i.e. the resource consumption of the financial year is covered by the resource revenue of the same financial year. Efficiency control can be carried out, for example, through time comparisons, operational comparisons or target/actual comparisons. The short-term control of the budget should be carried out with the help of target agreements as part of contract management. The prerequisite for this is that product information on monetary values, quantities and qualities is known, which is mapped and controlled in a management system.

3 Approach to Asset Management Münster

Considering the previous principles, the asset management of the "Construction and Road Maintenance" department of the City of Münster's Office for Mobility and Civil Engineering will be explained below. For this purpose, it is necessary to determine the organizational goals of the company. The objectives of the Office for Mobility and Civil Engineering, which is responsible for the maintenance of municipal roads, are important. The desired sustainable maintenance management as part of asset management is based on all topics that are relevant for a functioning, future-oriented infrastructure and should consider the three columns of sustainability, ecology, economy and socio-cultural aspects.

Ecological sustainability essentially means actively influencing environmentally harmful factors from the construction and operation of road networks. Influence can be exerted, for example, through traffic avoidance, multimodal offers or the optimization of transport chains, the conservation of natural resources during construction or the avoidance of traffic jams.

The economic sustainability of road maintenance must therefore be geared towards economic efficiency: It must be ensured that the resources expended (investment and maintenance expenditure) are matched by appropriate social and economic benefits (e.g. in the form of time or cost savings or changed service life and reduced maintenance expenditure as part of value retention).

Social sustainability means the organization of socially acceptable transport that can satisfy the existing demand for mobility. In particular, the supply of the population with daily needs, but also education or healthcare, must be taken into account. In addition to the needs of MIT (motorized private transport), the needs of those affected, e.g. residents, must also be integrated.

This approach and perspective thus follow the triple-bottom-line approach of asset management and is cross-organizational, as many organizations have an impact on the asset "street" through their actions. For this reason, numerous strategy papers of the City of Münster must be considered in AM and maintenance management.

Thanks to the implementation of asset management, it is possible to manage road maintenance in a target- and task-oriented manner from an economic perspective. In the medium term, this means a significant increase in the quality of road maintenance. Instruments are thus available to achieve specified or self-imposed goals through active planning, control, implementation and monitoring of our tasks consistently and sustainably over time.

3.1 Derivation of strategic goals at various organizational levels

A central point in the development of asset management is the definition of objectives at a strategic, tactical and operational level. In the public sector, laws and regulations generally form the basis or foundation for action. They often already contain targets and standards from which measurements can then be derived. Consequently, the content of the target system is already fed by these requirements and can be expanded to include local targets that are based on the applicable regulations (legal and technical) (Fig. 3).

The strategic goals of the Office for Mobility and Civil Engineering have been derived from the long-term corporate goals of the City of Münster and a vision has been formulated, which is visualized in Figure 4.

The goals cover the tasks and responsibilities of the Office for Mobility and Civil Engineering Münster. In the sector of mobility, these include the provision of public traffic areas and facilities, i.e. the planning, construction, maintenance and financing of public roads, paths, squares, bridges, tunnels, noise barriers, lighting, traffic signal systems (traffic lights), parking ticket machines and the parking guidance system, as well as the sovereign tasks of the road construction authority.

Based on the vision and objectives of the department, the following three key objectives have been formulated in the asset management of the "Construction and Road Maintenance" department.

- We preserve values.
- We manage 640 million euros of the city's assets.
- We create infrastructure and the conditions for the future.

These key objectives can be specified in the following strategic goals and express selected requirements for the infrastructure, also in relation to the interested parties (external stakeholders, customers and partners):

Value preservation, mobility, safety, environment/sustainability, collaboration, communication and digitalization (Münster b, 2020).

On the one hand, the trick is to identify the relevant goals, formulate them clearly and focus on them. On the other hand, the quality of an AM is determined by its flexibility, i.e. how it deals with changes, new requirements or competing objectives.

Figure 3: Goal levels of the Office for Mobility and Civil Engineering of the City of Münster (Münster b, 2020)

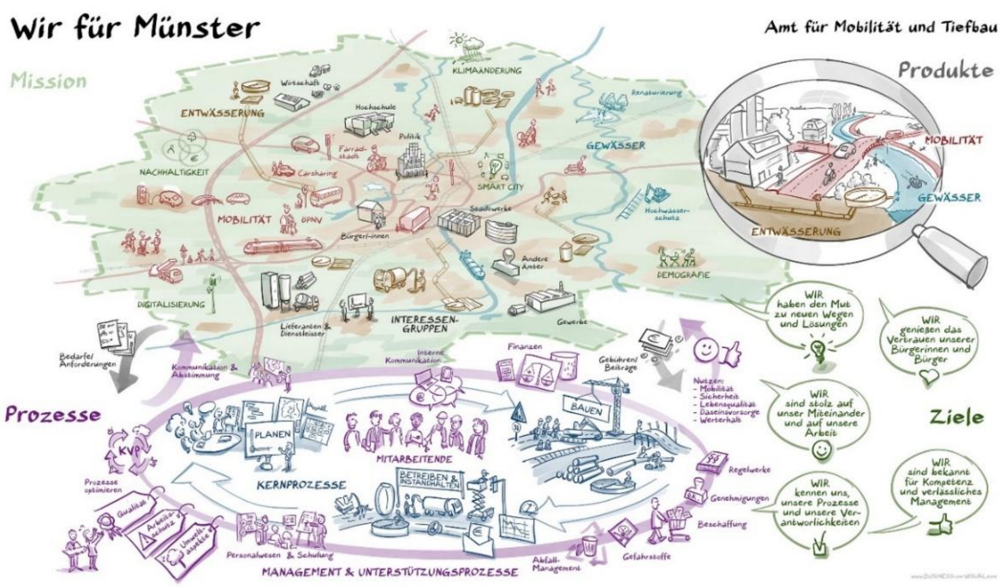

Figure 4: Vision and goals of the Münster Office for Mobility and Civil Engineering (Münster a, 2020)

3.2 Development of operational goals and measurements

The strategic objectives of the organizational unit were operationalized and provided with key performance indicators (KPIs) relevant to management (Buttgereit et al., 2016). Some examples are listed below:

Increasing the mobility of every individual is justified by the operational goals of keeping the infrastructure barrier-free for everyone and increasing access to public transportation. Citizens must be connected barrier-free from their front door and integrated into a barrier-free infrastructure at all stages of their lives. They must be free to choose their means of transportation. The goal implies local mobility, i.e. distances of up to two kilometers, such as journeys to public facilities. Measures include, for example, bus stops with raised kerbs, guidance systems for the blind, signal heads for the blind, traffic signal control, special bus lanes, access to electric mobility and bicycle parking facilities at bus stops.

The next goal is environmental compatibility/sustainability. The operational goals of reducing noise and acting more sustainably form the basis of this goal. This involves the careful use of resources, materials and energy as well as everything that surrounds people, affects them and influences their living conditions. Measures such as the construction of noise barriers, the use of noise-optimized asphalt, the use of recycled materials, crossings on main roads, a detour-free footpath network and speed reduction to reduce noise are considered.

Another goal is to maintain the traffic infrastructure. The necessary maintenance and renewal measures are to be carried out in accordance with the selected maintenance strategy. Measured variables such as assets, reinvestment rate, depreciation rate, asset utilization rate, average total and remaining useful life, unscheduled asset disposals and condition values are considered.

Another goal is the safe operation of the facilities. Road safety is an important asset that must be protected. The strategic goal of making the infrastructure safe is aimed at the safe use of the facilities for all road users. Safety is reflected in the operational objectives of increasing road safety, creating capacity, flood protection and speed reduction as a safety concept, road and structure monitoring, traffic light operational readiness and flood protection.

Finally, improving accessibility. This is not primarily about mobility. Rather, the focus here is on the surrounding communities and the associated commuters. They should be able to reach the city center easily and conveniently. The operational objectives of creating a multimodal offering in the city and increasing the general flow of traffic are in line with this strategic objective.

All objectives, key figures and metrics are described and brought together in the strategic asset management plan. This is operationalized in annual asset management plans and programs.

4 A holistic view of the life cycle

A holistic approach to asset management means infrastructure management in the sense of responsibility for the entire infrastructure or “asset portfolio” (“sewers, roads, bridges, traffic control and parking guidance systems”) over the life cycle by bringing together the technical, planning and commercial aspects towards intergenerational equity (Fig. 5). It is therefore a sustainable asset management system that is firmly integrated into the overarching control and communication framework of the organization.

Based on network-wide concepts of strategic maintenance planning (strategic level), work programs are derived at the tactical level and summarized in a concrete maintenance program. This concrete maintenance program is then implemented in the form of projects at the operational level.

Infrastructure management requires a proper combination of engineering planning, economic evaluation and political objectives. This addresses different decision-making levels. The political decision-making level decides on plans that set the framework for the road authorities' actions. The technical levels decide on prioritization and action plans based on engineering and economic considerations, while the operational level implements the specific maintenance program in the road network, considering implementation issues and traffic considerations. What all levels have in common is that such decisions and considerations can only be made based on meaningful and transparent data.

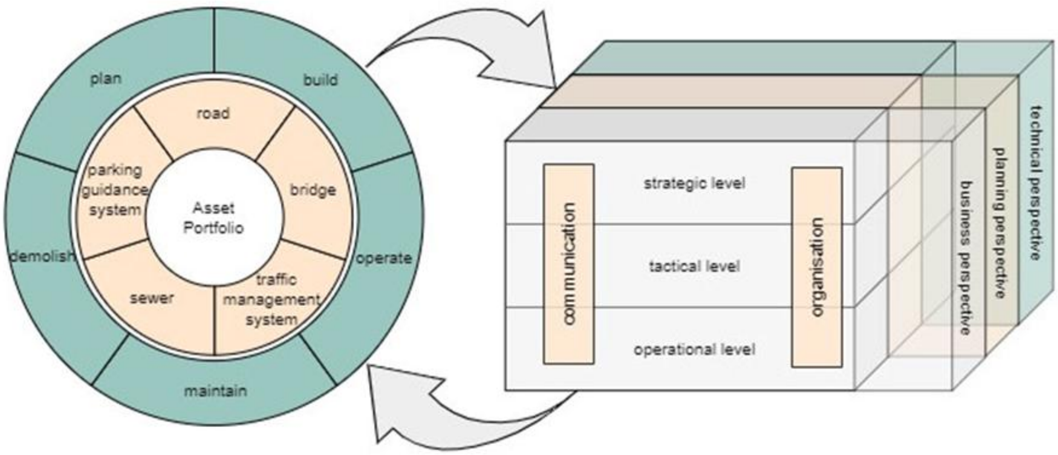

Figure 5: Continuous effect of the maintenance management organization (right) on the asset portfolio to be managed depending on the respective life cycle phase (left)

Various projects have been carried out in Münster in recent years, focusing on the road network. A concept for road maintenance management has been developed at a strategic, tactical and operational level and implemented in the LOGO road information database. The next step is to develop maintenance management for sewers, as significant synergies are seen in the coordinated maintenance planning of roads and sewers. Parallel to this, work is also being carried out on the maintenance management of structures and traffic facilities. Finally, the pumping stations, sewage treatment plants and bodies of water will be considered before finally defining a maintenance management system that covers all facilities. The concepts will initially be tested for small sub-networks. The data required for this, which is still missing or insufficient, will be successively completed. This will then be followed by expansion within the overall network, which in turn requires the collection, completion and continuation of the missing or insufficient data.

At a strategic level, the processes and their factual and content-related design in TIMM were examined under scientific supervision. The analysis was based on the current state of science and research and regarding the current state of the art in terms of quality assurance measures and with a focus on expected future requirements. The long-term financial requirement forecast at the grid level, considering various maintenance strategies over the life cycle, is a key component here (see (FGSV, 2019), (Buttgereit et. al, 2019)). Current developments such as building information management (BIM) and asset management were also taken into account. The condition survey and assessment (ZEB) for depicting the network condition and the consistent use of ZEB data for maintenance management were also identified as important components.

Key performance indicators (KPIs) relevant to management were also defined at the strategic level. The results of the statistical analysis of the status values are referred to as key performance indicators and are also among the most important pillars of any strategic (asset) management. Furthermore, questions were formulated from the perspective of strategic management, some of which are listed below as examples. A distinction must be made between fundamental questions in AM and more specific ones with a focus on maintenance management:

- Are/were stakeholder inputs, concerns and expectations considered?
- Are there planned modifications?
- Is outsourcing an issue?
- How do we pursue the approach of sustainable value retention over the life cycle of the assets?
- How has the condition of the network changed?
- How has the condition developed at section level?
- How will the condition develop in the future if no maintenance measures are carried out?
- How efficient were the individual maintenance programs in the network?
- To what change in condition have they contributed?

At a tactical level, a practice-oriented concept for a network-wide condition survey and assessment (ZEB) was also developed with scientific support. On carriageways of the main roads, the metrological ZEB is continued in a four-year recording cycle. On carriageways of the subordinate road network and on secondary areas, either the visual-image-based or the visual-sensitive ZEB is used. The asphalt pavements of the main roads that have been measured and assessed every four years to date only correspond to approx. 8% of the total road surface, meaning that currently approx. 92% of the road surface has not been recorded and assessed. On the one hand, this means a major financial risk, but on the other hand it also means that there is great potential for improvement.

For this reason, visual image-based sample surveys have been commissioned to complete the data in the future. The aim is to gain insights into the various measurement and evaluation techniques and the use of the results to evaluate the facilities for the inventory. Essentially, cycle paths will be surveyed to gain insights into their condition as well as to provide a basis for future planning (e.g. on cycle routes).

The results of the previous ZEB measurement campaigns in 2009, 2013 and 2017 were quality-assured and synchronized, providing a data basis for numerous further evaluations and analyses. The statistical analyses have provided insights into the effectiveness of the selected conservation strategies (the conservation measures implemented). The data basis thus created forms a necessary basis for the development of a model for forecasting the condition of asphalt pavements in the main road network.

The tactical work and maintenance programs are implemented through projects at the operational level.

5 Produce in civil engeneering infrastructure management Münster (TIMM)

The theory described in the first part will be put into practice using the example of the strategic objective of value retention. Maintaining the value of the infrastructure is essential for a municipality, as a reduction in assets ultimately leads to a reduction in equity. The preservation of equity and thus the preservation of assets is of central importance for the sustainable fulfillment of municipal tasks and the expectations of our stakeholders.

5.1 Initial situation Development of assets

The starting point was the analysis of the development of assets in civil engineering infrastructure since the introduction of the NKF on 01.01.2008. In 16 years, there has been a 16,4% reduction in assets on the balance sheet. This corresponds to a loss in value of € 252 million. Wastewater disposal assets lost 6% of their original value and transportation areas and facilities lost 26% (Fig. 6).

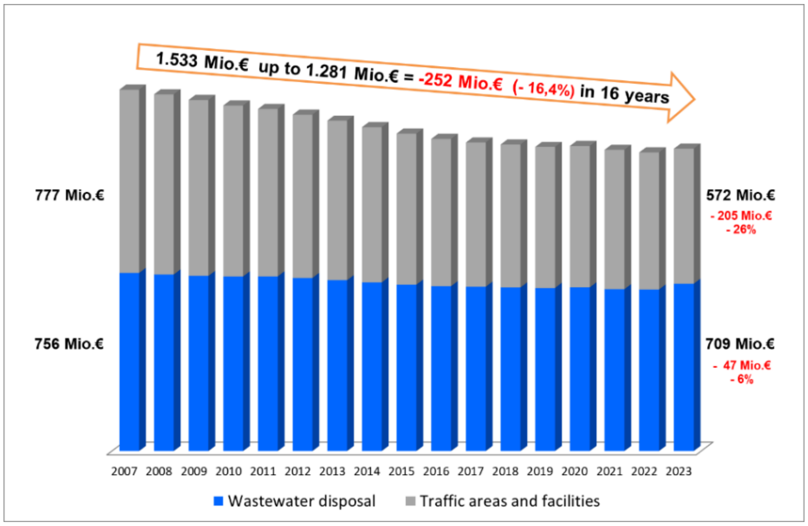

Figure 6: Development of civil engineering infrastructure assets

The greatest loss in value over the past sixteen years was suffered by the municipal road network at 39%. The value of the opening balance sheet of around € 690 million fell by around € 267 million to around € 423 million (Fig. 7).

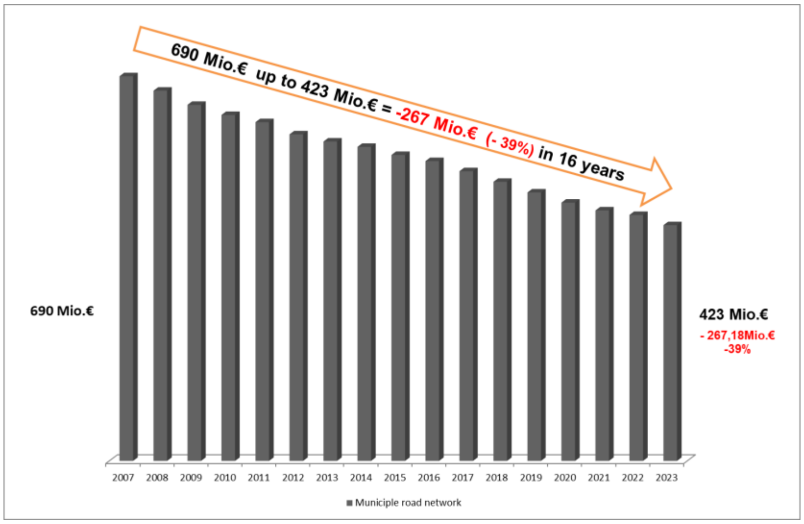

Figure 7: Development of municipal road assets

5.2 What are the reasons for the loss of value? How can countermeasures be taken?

The reason for the high loss in value is the imbalance between depreciation and replacement investments. The loss in value resulting from depreciation cannot be offset by replacement investments. Replacement investments are at a good level and only need to be increased slightly. The main reason for the imbalance is excessive depreciation. This results from insufficient useful lives.

5.3 Which assets are important? What are the most important factors with the greatest leverage?

In the data analysis of the road network, the components of the road network were analyzed. The road network is divided into road categories and the road system is subdivided into carriageway and secondary area. Residential streets make up a significant proportion of the road network, accounting for almost 50% of the total road area. The subordinate network is therefore of particular importance, as are the secondary areas. The data analysis was thus able to identify the important assets of the road infrastructure (Fig. 8).

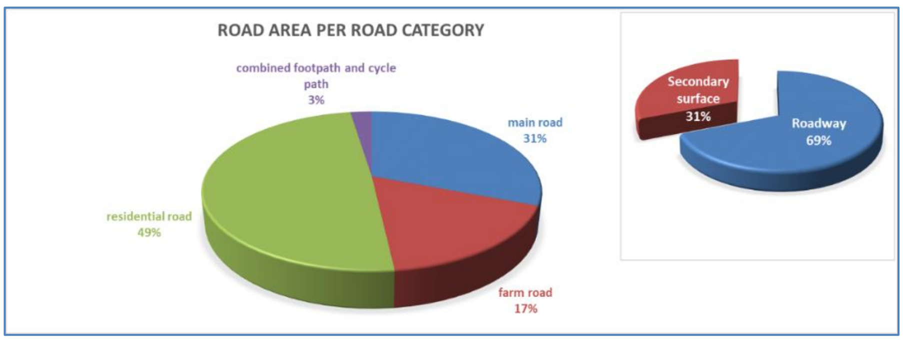

Figure 8: Components of the municipal road network

5.4 Technical versus balance sheet useful life of roads

The “useful lives from optimized maintenance strategy” for roads are to be extended to 40 - 80 years (depending on the road category). The initial assessment according to NKF as of 01.01.2008 was carried out with useful lives for roads of 40 - 60 years as stipulated in the NKF Act. The extension is based on extensive studies of Münster's road network and the experience of recent years. These longer service lives correspond more closely to the technical service lives and should therefore be incorporated into the maintenance strategy. The “Guidelines for the planning of maintenance measures on road pavements” (FGSV, 2001) and the “Ordinance for the calculation of redemption amounts in accordance with the Railway Crossing Act, the Federal Trunk Road Act and the Federal Waterways Act” (BMDV, 2010) also confirm service lives of the individual layers of up to 80 years.

Particularly for the residential street category, which comprises around 50% of the network in Münster, an optimized maintenance strategy should increase the service life to 80 years in line with the underlying sewer. There are clear economic and ecological advantages for the entire road network.

5.5 Effects of extending the useful life

As can be seen from the previous explanations, the technical useful life of the assets plays a key role in maintenance management. The following two simple questions therefore arise: What is the impact of longer useful lives? How do I achieve longer useful lives?

In financial terms, longer useful lives can lead to reinvestments being stretched out, annual road maintenance funds being reduced, and balance sheet depreciation also being reduced. Positive effects from an environmental point of view include lower carbon dioxide emissions, reduced resource consumption, less traffic disruption due to a smaller number of roadworks and less noise emissions due to defective roads, construction work or congestion caused by roadworks.

But how can longer service lives be achieved? At this point, material and construction technology as well as engineering must be analyzed in detail. For example, longer service lives can be achieved by changing material properties or improving quality assurance.

In asphalt road construction, asphalt granulate has been added for years, which comes from roads that are already in use and whose binder has lost its adhesive strength due to the influence of the weather, for example. In order to extend the service life, solutions must be found to improve the adhesive strength. In addition to the addition of fresh bitumen, this can be achieved using rejuvenators. But which one is the right one? Extensive investigations have been carried out in the laboratory, which have subsequently been implemented in pilot projects in Münster. In the meantime, the laboratory tests have shown that a larger quantity of asphalt granulate can be added than in the current regulations, meaning that an additional positive environmental aspect can be achieved by increasing the recycling rate.

Optimized "quality assurance" can be achieved, for example, by ensuring that employees receive regular training. It is conceivable that the previously defined annual number of training days per employee could be increased by 2 days in future. After all, an organization is only able to do its work efficiently through good training and further training as well as an exchange with other colleagues. Another idea as a metric or key figure would be, for example, to set the target of reducing the number of failed inspections by around 5% per year.

If we add up the above statements and draw a conclusion, we conclude that the measures and fields of action described together serve all three columns of sustainability - ecology, economy and socio-cultural concerns (Fig. 9). It is therefore entirely justified to speak of sustainable asset management in Münster.

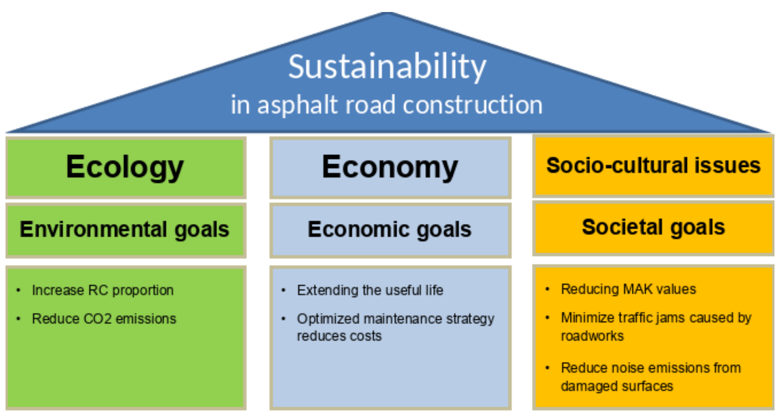

Figure 9: Three columns of sustainability in asphalt road construction

5.6 Coordination of road and sewer service life

As a final example, the cross-asset synchronization of maintenance and renewal schedules for roads and sewers is considered. The aim is to coordinate the planning of measures for both assets. The intersection of the road condition data with the sewer condition data is seen as an essential support here (Fig. 10). Based on individually defined criteria, this makes it possible to form meaningful maintenance sections across all assets so that traffic disruptions in the road network are minimized. This information can also be used to coordinate the work with the utility companies and thus achieve further optimizations. In addition to the ecological benefits, this also has economic advantages.

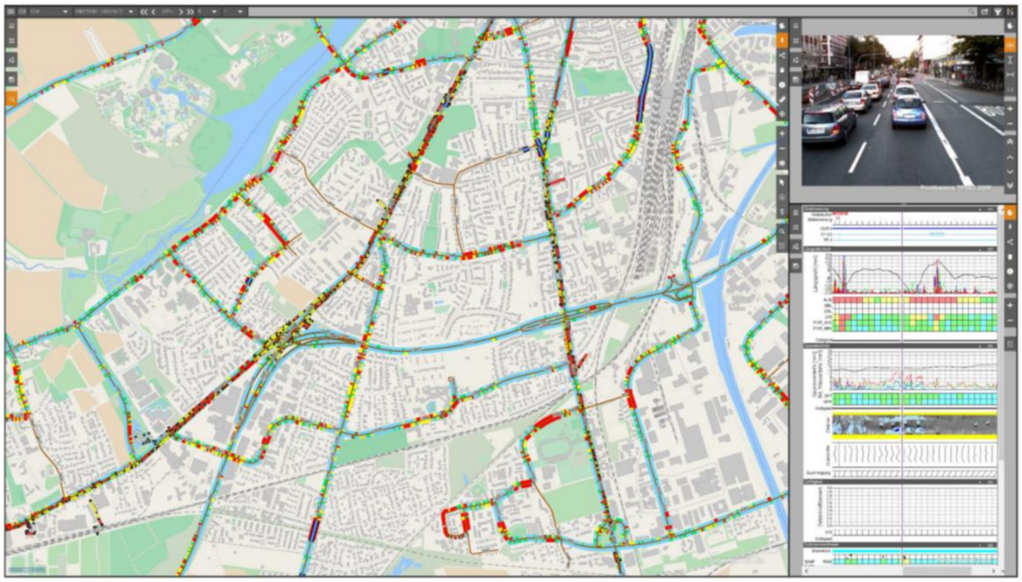

Figure 10: Visualization of road and sewer condition data (Heller, 2019)

6 Conclusion and outlook

A holistic approach to asset management means infrastructure management in the sense of responsibility for the entire infrastructure or “asset portfolio” (“sewers, roads, bridges, traffic control and parking guidance systems”) over the life cycle by bringing together the technical, planning and commercial aspects towards intergenerational equity. This is therefore sustainable asset management, which forms the framework with organization and communication.

Using the example of the “Road Construction and Maintenance” department of the City of Münster's Office for Mobility and Civil Engineering, it was shown how an AM can be built up to the department level, considering the city's corporate objectives, and how key figures and metrics can be defined for the municipal infrastructure.

The introduction of the AM has necessitated a readjustment of tasks and standards, which could be explained and communicated to employees in a simple and transparent manner. On the one hand, AM offers managers support in their day-to-day work. On the other hand, strategic planning can be tackled more effectively, the effects of new requirements can be recognized and evaluated more quickly, and any necessary corrections can be made promptly. It quickly becomes clear where, at what point, what risk exists in the completion of tasks or the quality of performance. The introduction of AM has also made it easier to answer questions relating to occupational health and safety or sustainability in road construction, for example, in addition to the further development of systematic road maintenance.

In the opinion of the authors, asset management is a useful tool in public administration. Asset management helps in the development of investment decisions. At the same time, it makes it possible to create quick forecasts and thus enables the administration to react to current political topics or issues. Asset management can also be used to better analyze relevant topics in the future and implement them in the existing working environment. The same applies to the consideration of new technologies.

To be able to answer questions in asset management, it is often necessary to obtain new or additional information. This effort is often shied away from. However, people lose sight of the fact that this new or additional information can also be used to answer more far-reaching questions, e.g. from technical areas - such as smart city or digitalization. The information can also be used to answer financial questions.

For us, asset management means sustainable management in the sense of intergenerational justice, a responsibility for the infrastructure over the entire life cycle in which we bring together the technical planning and commercial aspects as well as the political and legal framework conditions and the expectations of our stakeholders. Ultimately, it is a valuable tool for decision-makers, as it is within their immediate reach, and they can therefore access the information they need for efficient management quickly and easily.

In Münster, strategies and concepts have been developed to supplement the existing regulations, and some have already been tested and implemented in pilot projects. The potential identified here is enormous. Without the courage to carry out pilot projects and experiments, no progress can be made. That is why Münster is continuing to work boldly on innovations.

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