

Sustainable Asset Management in urban areas – A contribution to environmental protection and resource efficiency

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Abstract

As part of its sustainability strategy, the City of Münster's Office for Mobility and Civil Engineering (AMT) is pursuing the goal of systematically integrating ecological, economic and technical requirements into municipal asset management (AM). This article focuses on the implementation of an environmental program that combines strategic and operational objectives with concrete measures. Special attention is paid to the integration of scientific research results into existing planning and decision-making processes.

Three research projects are considered: DaRkSeit - Data-based assessment of the resilience of municipal road infrastructure addresses the previously lacking substance-oriented condition assessment of municipal roads through a data-based software solution for the resilient planning of maintenance strategies.

ReKoTi - Resource Plan for Municipal Civil Engineering identifies and evaluates technical, administrative and legal framework conditions for resource-efficient civil engineering practice and develops optimization approaches using Building Information Modeling (BIM). The central result is a municipal

resource plan, which includes approaches for calculating the anthropogenic stock and the monetary valuation of urban infrastructures.

In addition, a research project on web-based excavation management is presented, which enables digital coordination and control of external interventions in traffic areas in order to minimize substance losses and service life shortening.

The article analyses/describes how these findings were transferred into the management and control practices of the AMT and discusses the resulting methodological, organizational and technological implications for sustainable municipal infrastructure management.

Keywords: Sustainability, asset management, municipal infrastructure, civil engineering, resource management, anthropogenic storage, BIM, road maintenance, digitalization, administrative practice

Introduction

The transport infrastructure of municipalities forms the backbone of public life on the one hand and represents a significant municipal asset on the other. Whether it's commuting to work, supply, leisure mobility or freight transportation - all of this is handled via municipal roads. Their importance for the economy and society is correspondingly high.

Driven by the reform impulses of New Public Management (NPM), which has been promoting efficiency, results orientation and proximity to citizens in public administration since the 1980s, the New Municipal Financial Management (NKF) was introduced in Germany. The aim was to make municipal financial management more business-oriented - moving away from a formalistic, input-oriented administration towards greater transparency, efficiency and controllability. The NKF introduced instruments such as double-entry bookkeeping, product budgets, cost-performance accounting and systematic controlling into municipal practice.

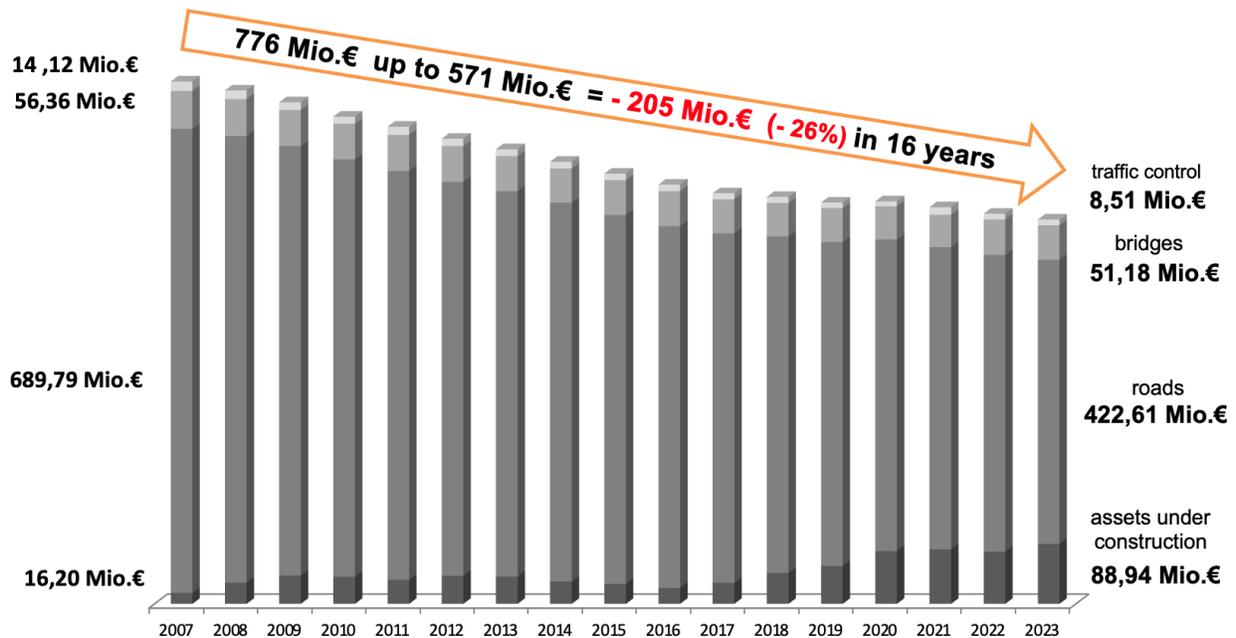
A fundamental element of the NKF is the complete recording and valuation of municipal fixed assets - including road infrastructure. In North Rhine-Westphalia, this process was made mandatory from 2005. In addition to the technical perspective, commercial aspects and life cycle costs were increasingly integrated into maintenance management. Nevertheless, precise determination of the financial requirements for road maintenance remains a challenge. Although pavement management systems (PMS) and modern technologies, including AI-supported forecasts, support planning, they have so far provided reliable results primarily for asphalt or concrete pavements, which only represent part of the areas to be maintained. The higher the desired level of detail, the greater the amount of data required - and in many places it is not feasible to collect and maintain this data due to limited financial and human resources. In addition, strategic urban development policy objectives can often not be adequately reflected in the PMS.

Municipal roads fulfill more than just an access function - they are an elementary component of public services. Interventions in this infrastructure usually have an impact with significant consequences and often affect the quality of life. This results in two central requirements for the road authorities: Firstly, interventions must be minimized as far as possible and unavoidable measures must be sensibly coordinated. Secondly, maintenance work must be planned in such a way that it can be carried out in good time and economically in order to preserve the value and condition of the infrastructure in the long term. This is because an efficient and well-maintained road infrastructure not only represents an important locational advantage for companies, but also has a positive impact on the local community. To meet these complex requirements, holistic asset management systems (AMS) need to be introduced and used sustainably. The city of Münster has been pursuing a strategic approach to data-based and targeted maintenance planning since 2010. This paper presents current findings and transferable results from this practical municipal approach.

Municipal context and development

The city of Münster is a very attractive place to live. The road network, which is currently still in relatively good condition, makes a not insignificant contribution to this. However, there is a risk that the condition of Münster's roads will deteriorate significantly, as in many other cities, if the budget for road maintenance is reduced. In addition, the value of transport infrastructure assets has decreased by around € 205 million (26%) since the introduction of the NKF, from around € 776 million at the start of 2008 to around € 571 million at the start of 2024 (Figure 1).

Figure 1. Development of municipal transport infrastructure



The value of the roads alone has dropped by around € 267 million (39%) since the introduction of the NKF, from around € 690 million at the start of 2008 to around € 423 million at the start of 2024. To counteract this dramatic development, Münster's maintenance management has been gradually improved since 2010.

In order to meet the requirements for systematic road maintenance, the Office for Mobility and Civil Engineering began developing a system for improved road maintenance back in the 1980s. The aim of this system is to improve both administrative processes and structural qualities and to enable effective road maintenance¹.

Since 1996, computerized tools have been used to monitor road safety and the condition of some of the roads has been checked periodically using measurement technology. This makes Münster one of the pioneers in this field. For over 30 years, measures have also been coordinated with utility companies and telecommunications providers (coordinated maintenance planning). For example, extensive coordination between utility companies and the city as the road construction authority in the run-up to planned renewals considerably reduces the disruption to road users. This coordination now begins at an early planning stage and often ends in the joint implementation of construction measures.

Standardized federal guidelines for municipal road maintenance management, which the Office for Mobility and Civil Engineering was and still is involved in developing, have existed to some extent since 2003. The theoretical basis for maintenance management in Münster's road construction has been further developed in recent years in cooperation with Münster University of Applied Sciences since 2008 and has been continuously put into practice. It is then to be reviewed for any potential deficits in a continuous improvement process and optimized if necessary.

At the beginning of the 2000s, controlling gained practical significance in the administration of the City of Münster for the first time as part of the New Management Model, which had been known since 1993. It was introduced as a cross-functional and future-oriented instrument that was intended to interlink planning, organization, control and information supply - with the aim of effectively supporting management in decision-making and control.

The central aim of controlling was to strengthen the efficiency and effectiveness of the management system by improving the information base. To this end, a cost and performance accounting system was set up. In Münster, the services of the responsible office were systematically defined. From the citizens' point of view, the provision of traffic areas and facilities as well as drainage and wastewater disposal were among the relevant products. These products were further subdivided into services and partial services. At these levels, costs and revenues could be recorded in a differentiated manner, resulting in transparency regarding the consumption of resources (input) and the services provided (output) by the office.

Another component of controlling was the development of a reporting system. The first step was to define targets. Derived from this, the first key figures were determined, with which the achievement of the set targets was made measurable through target/actual comparisons. The first target system with corresponding key figures thus supported the office management for the first time and provided a further basis for today's AMS.

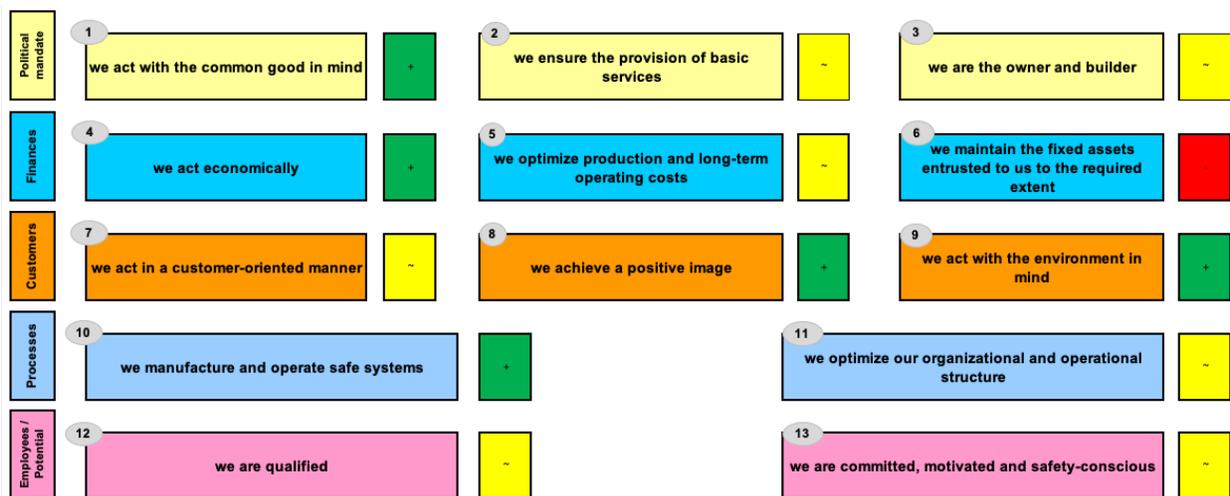
In 2005, the first considerations were made as to how the new legal requirements from the NKF could be integrated into the processes of the AMT. A central component of this work was to obtain as realistic an estimate as possible of the assets of the roads, bridges and canals. In addition, the financial requirements had to be integrated into the municipal PMS in order to avoid redundant work and increase work efficiency. The solution chosen for linking condition values to assets proved to be problematic in 2010, as the depreciation and loss of assets were significantly greater than the deterioration in condition that could be observed on site.

Parallel to this work, the City of Münster's Office for Mobility and Civil Engineering began developing a Balanced Scorecard (BSC) in 2007. The BSC is a strategic management tool that supports organizations in pursuing their goals holistically. Instead of focusing exclusively on financial key figures, it takes four perspectives into account: Finance, customers, internal processes and learning and development. This balanced approach is intended to define strategic goals more clearly, make them measurable and translate them into concrete measures. In Münster, the BSC was thus adapted to the requirements and used as a management tool at the office management level.

The controlling described above provided a solid basis for this. The adapted version of the BSC comprised 13 strategic goals of the office and five defined perspectives (political mandate, finances, customers, employees and processes), to which the goals were clearly assigned. Operational goals were

defined and assigned to the strategic goals at a further level, for which metrics were defined to measure the achievement of the goals. The continuous further development of the metrics and the individual adaptation to new requirements, such as those relating to the environment, digitalization, housing and mobility, has led to the official control system becoming established as a support system (Figure 2). It was ultimately developed into a “certified” AM in the Road Construction and Maintenance department as part of the existing management system. The regular management of the department is based on the strategic objectives, which are visualized in a strategy map using a traffic light system. In the event of a yellow or red traffic light at the strategic level, the operational targets are viewed at the next level. Measures required to improve the achievement of objectives are defined during the analysis and monitored in the further process. Management is supported by a central controlling and reporting system as well as an integrated quality, environmental, health and safety management system.

Figure 2. BSC Strategy map - Overview



The positive developments in recent years in terms of economic and environmental sustainability (see Figure 2) are due in particular to the consistent implementation of a strategically oriented environmental program. This environmental program was developed as part of the existing Asset Management System (AMS) and links the strategic objectives with specific operational measures. It therefore represents a central building block in the further development of office management.

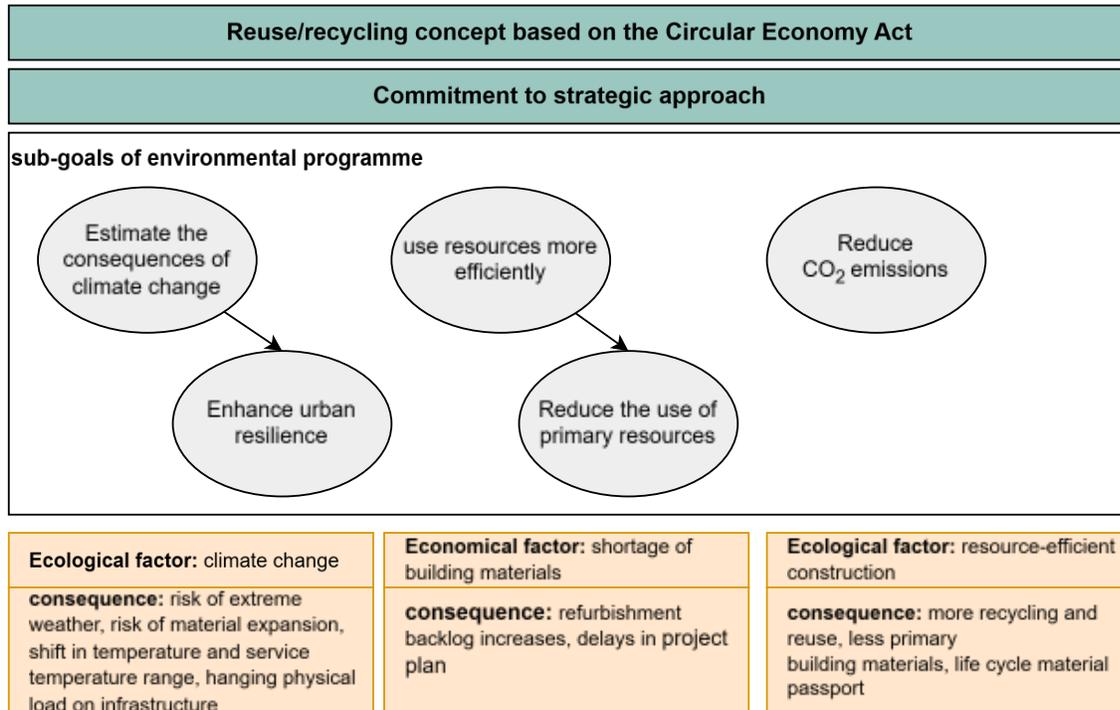
In the following chapter, this environmental program is presented in more detail as a methodological and conceptual basis. It shows how the challenges of municipal infrastructure management can be systematically met through strategic control, professional cooperation and a scientific basis.

Conceptual and methodical implementation of environmental management

The environmental program is a central element of the strategic management of the Office for Mobility and Civil Engineering and is an integral part of the AMS. The systematic consideration of environmental aspects is deeply embedded in the Office's work processes. The aim is to identify environmental impacts at an early stage, promote environmental awareness among employees and consistently take environmental criteria into account when awarding contracts, invitations to tender and procurements. Depending on relevance, feasibility and availability of information, aspects of the entire product life cycle and environmentally sound disposal are also included.

An excerpt of the strategic orientation is shown in Figure 3. Using the example of climate change, four basic requirements for the provision and management of municipal infrastructure facilities are formulated. These requirements serve as guidelines for measures in planning, construction, operation and dismantling - and thus form a binding strategic basis for environmentally oriented action in road construction.

Figure 3: Environmental strategy of the City of Münster's Office for Mobility and Civil Engineering - aspects of climate change

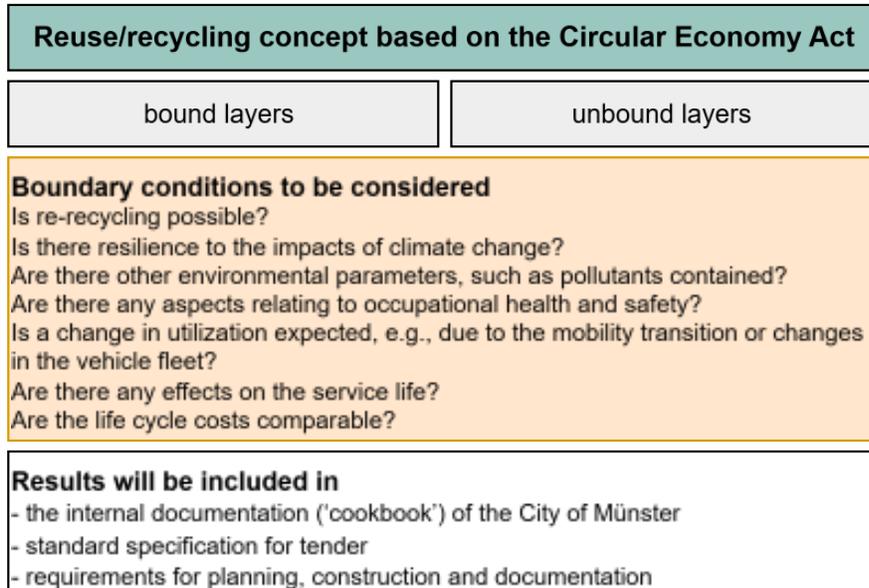


Based on these requirements, a reuse concept was developed that translates the strategic goals of the environmental program into specific issues and action steps. Figure 4 illustrates central considerations for closing material cycles, efficient resource utilization and reducing environmental impacts in municipal road construction.

For a differentiated view, bound and unbound layers are first analyzed separately. Bonded layers are layers of material whose components are firmly bonded together by binders such as bitumen or cement - typically asphalt layers or concrete pavements, for example. Unbound layers, on the other hand, consist of loose aggregates, such as those used in base layers without binders, for example crushed stone or gravel. The separate consideration of these two categories results on the one hand from the different availability of reliable data and on the other hand from considerable differences in the level of scientific knowledge. For bound layers in particular, significantly more and more detailed information is available, enabling more targeted measures for optimization and recycling in the course of maintenance.

Figure 4: Environmental strategy of the Office for Mobility and Civil Engineering of the City of Münster – reuse and recycling concept

The European research project SaferUp! served as an important basis for further analysis of the status



quo and for deriving specific objectives. In addition to the results of the life cycle analysis (LCA) and life cycle cost analysis (LCCA) at network level, three priority objectives for the environmental program were defined: extending the service life of municipal infrastructure, promoting the circular economy - in particular through recycling and reuse - and optimizing asphalt mixtures in terms of resource conservation and environmental compatibility.

As the implementation of these complex requirements went beyond the existing resources and expertise of the office, targeted cooperation was established with external partners from science and industry. Innovative approaches were designed, tested and transferred to regular operations as part of joint development projects. The following three projects are particularly noteworthy: Darkseit, Rekoti and excavation management as part of coordinated maintenance planning. These projects are examples of how viable solutions for environmentally friendly municipal infrastructure planning can be developed and operationalized through cooperation and knowledge transfer.

Results: Integration of scientific research

The three projects outlined here represent a key component of the AM. In addition to environmental issues, technical, financial and planning aspects are also addressed. They are therefore projects of outstanding importance when it comes to future-oriented and sustainable work in municipal AM in civil engineering.

Excavation management

A modern and efficient transport infrastructure is a key location factor and has a decisive influence on the appearance of a city. As part of this analysis, the quality of road surfaces was identified as a key indicator of the state of maintenance. This is significantly influenced both by measures taken by the road authorities themselves and by the control and coordination of external construction measures.

It was found that ensuring a permanently good road condition depends to a large extent on two factors: on the one hand, the availability of sufficiently qualified specialist personnel and, on the other, the use of suitable digital systems to control and document interventions in the road structure. The increasing shortage of personnel and the high number of interventions make it clear that systematic management can no longer be guaranteed without supporting IT solutions. Improperly executed or documented excavations lead to a shortened service life and accelerate the loss of substance in public traffic areas.

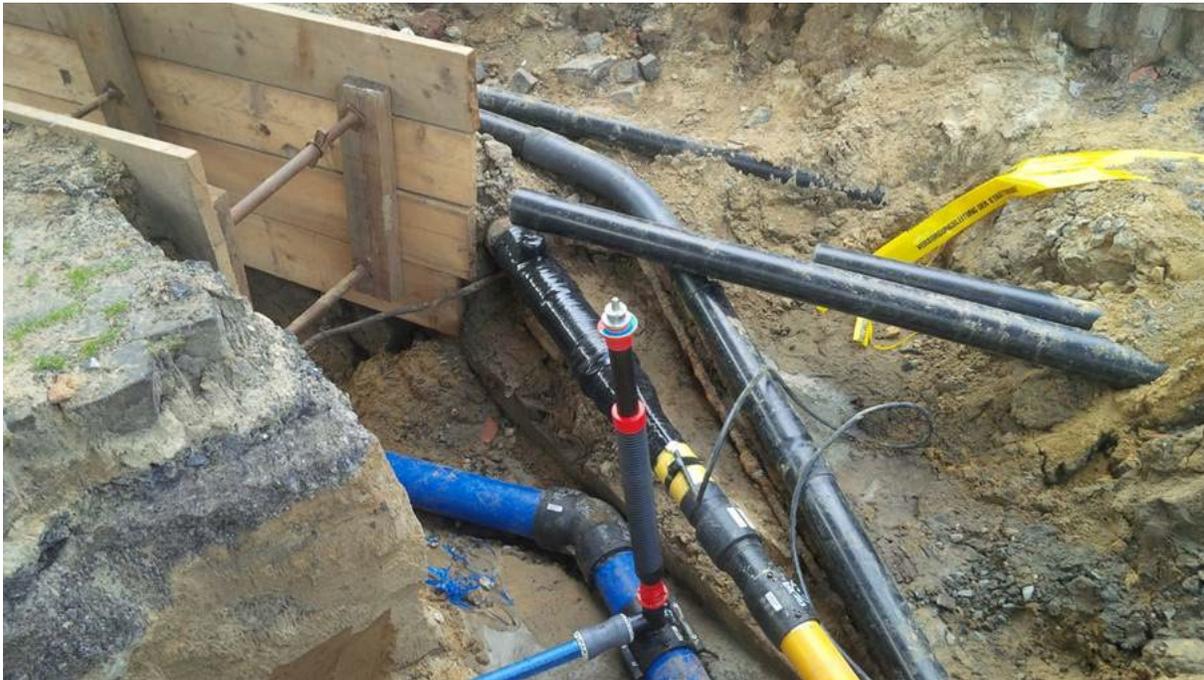
Compared to non-urban roads, which primarily serve a connecting function, municipal roads take on additional tasks. They fulfill access and recreational functions, promote communication in public spaces and make a significant contribution to urban design and thus to the well-being of the population. In addition, they act as a carrier of the underground supply and disposal infrastructure, the relevance of which will increase significantly in the course of planned renovations.

Based on the available studies, it was predicted that the number of excavations - currently around 3,000 to 4,000 per year - will increase significantly in the coming years for the city of Münster. Against this background, the associated administrative processes were comprehensively recorded, analyzed and optimized with the aim of increasing efficiency. At the same time, quality assurance approaches were developed and measures for the permanent implementation of corresponding standards were initiated.

One particular challenge is the fact that the road construction authority does not act as the client for the work of the utility companies. Its influence on the quality of execution therefore remains indirect and is limited to inspection and acceptance. Nonetheless, once the work has been carried out, it bears responsibility for the long-term integrity of the infrastructure.

Another key finding of the analysis was that the fragmentation of execution - particularly in complex excavation measures with several trades involved - often leads to quality deficiencies. The practice of different companies carrying out individual sub-steps (e.g. excavation, pipe laying, backfilling, restoration of the superstructure) independently and without overarching coordination was identified as inefficient and prone to errors. As a result, there is a need to promote more integrated construction work in the future in order to ensure the quality of the restoration and thus the sustainability of the road infrastructure.

Figure 5: Typical underground situation during municipal excavations [Photo: City of Münster]



Based on this, a GIS-based excavation database was developed using existing software from the City of Münster. This was optimized within the first two years after its introduction, but proved itself in practice after only a short time. For this reason, a more modern software solution was to be found that would harmonize well with the existing road information system. The result is the “Excavations” module of the LOGO program system (Geologix, CH), which fully covers the administrative and constructional aspects of excavations. It has a link to maintenance management and project coordination, so that the traffic impact of civil engineering works can also be better managed.

Darkseit

It can be assumed that global warming will cause significant increases in temperature - especially in cities - and thus lead to greater stress on the transport infrastructure. This raises the question of the extent to which today's asphalt roads will meet future requirements and the extent to which today's assumptions for maintenance management forecasts will be valid in the future.

For the municipal road network, there is currently no scientifically sound basis for estimating the future condition development of the structural substance of the superstructure. The condition assessment is currently based exclusively on the recording of visual condition characteristics on the road surface. For a sustainable and economical maintenance strategy in times of climate change, however, knowledge of the expected service life or remaining service life of the individual asphalt layers in the superstructure is essential. By linking data from traffic monitoring, the climate, the road database and our own measurements, the “DaRkSeit” project has developed software that maps the condition of roads in real time for the first time, taking design aspects into account. From this, necessary road maintenance measures can be derived at an early stage, the information system for citizens and companies can be expanded and the organizational and financial framework conditions can be defined. Further details can

be found in the TU Dresden paper (“Calculation of the condition development of urban roads using measurement data to improve asset management”, session PV- Designing, Building and Managing a Sustainable Pavement Network).

Rekoti

In 2009, an initial recycling concept for the use of recycled construction materials (RC construction materials) in civil engineering in the city of Münster was developed as part of a final thesis at Münster University of Applied Sciences. This concept took into account both the geological and hydrological conditions of the city area as well as the regionally available RC construction materials and industrial by-products. The findings led to the Office for Mobility and Civil Engineering's tender documents being adapted and more environmentally conscious standards being established for new construction and maintenance measures. In view of increasing demands for sustainability and resource conservation, there was a need to systematically develop this concept further. This was the subject of the research project RekoTi - Resource Plan for Municipal Civil Engineering.

The aim of the project was to improve resource efficiency in municipal civil engineering using data-based planning approaches. The focus was on the development of a digital resource plan with which material flows in civil engineering can be systematically recorded, analyzed and evaluated. In addition to purely technical considerations, particular emphasis was placed on ecological and economic aspects. Building on existing asset management approaches, an integrated model was developed that provides local authorities with a sound basis for decision-making for sustainability-oriented action planning.

A key result of the project was the investigation of transferability to different infrastructure areas. Using the areas of canals and bridges, it was shown that the methods developed are generally easy to apply, provided a sufficient database is available. At the same time, it showed that there is a considerable need for improvement, particularly in the area of road databases. Deficiencies in the up-to-dateness, completeness and consistency of the available information make reliable planning difficult and limit the informative value of digital models. This realization underlines the need for systematic and quality-assured data maintenance in the municipal context.

Another focus of the project was on dealing with material flows. Practical organizational and logistical solutions are required to enable the reuse of building materials in the sense of the circular economy. In particular, the interim storage and traceability of materials represent key challenges for which initial solutions were developed in the project. In addition, alternative construction methods were identified that have the potential to save primary resources. Their testing and evaluation in practice will be highly relevant for future, resource-saving construction methods.

To assist municipal stakeholders, a structured action guideline has been developed that enables the systematic planning of resource-efficient civil engineering measures. This guideline has a modular structure and can be used regardless of the size or initial situation of a municipality. It also contains recommendations for the integration of reuse potential, the evaluation of alternative construction methods and tips for improving the data situation.

The methods and tools developed in the project enable a well-founded linking of technical, ecological and economic information. On this basis, maintenance and investment measures can be strategically planned, prioritized and coordinated. The digital recording and analysis of material flows also supports resource-conserving construction methods and improves the traceability of interventions. The

application of the concepts in pilot projects, particularly in collaboration with the city of Münster, confirmed their practical suitability. By publishing all key results as part of an open source strategy, the tools developed are also available to other local authorities.

Overall, the RekoTi project shows that data-supported, sustainability-oriented AM is feasible in municipal civil engineering and can make relevant contributions to resource conservation and process optimization. The project results provide a transferable basis for other municipalities to design infrastructures in a sustainable, economical and ecologically responsible manner.

Conclusion and Outlook

The article also illustrates how lengthy the process can be from the development of strategic approaches to their effective integration into municipal administrative action. The example of the civil engineering department of the city of Münster shows that it takes several years between the initial conceptual considerations and the actual implementation of improved procedures, some of which are based on current research findings. This time dimension makes it clear that the transfer of scientific findings into municipal practice requires not only continuity and institutional anchoring, but also targeted pilot applications, experience building and internal organizational learning.

It can be stated that the approaches and tools developed within the framework of RekoTi have already provided concrete impetus for the further development of municipal AM in the Office for Mobility and Civil Engineering of the City of Münster. In particular, the linking of material flow analyses with maintenance strategies provides the basis for more sound planning of measures and more resource-efficient execution of civil engineering measures. Initial applications at property level show that the implementation of these concepts in practical administrative action is possible in principle, but has so far been largely reactive.

The DaRkSeit project has provided valuable results on the expected temperature profile in the road structure in asphalt and new findings on the composition of heavy traffic in a city. Both aspects are being pursued further by the city and the university. For example, the city has already adapted its tender documents so that more heat-resistant asphalt will be built in certain parts of the city in future. This applies to new construction and the maintenance of traffic areas. Dresden University of Technology will use these results, among other things, to further develop the methods of computational dimensioning.

In the meantime, excavation management has become an important part of daily work. Without excavation management, the expansion of high-speed Internet in Münster would not have been so easy to organize. In a short space of time, it was possible to set up a fiber optic network in many parts of the city without any significant negative consequences for residents or businesses. It was also possible to manage the many construction sites very well, so that there were few disruptions to the flow of traffic. The quality of the construction work was also predominantly good thanks to the integrated quality assurance system. Deviations were detected in good time and countermeasures were initiated. Unfortunately, the final rectification of the construction defects is still ongoing.

The next level of development therefore consists of transferring resource planning to network level in order to further develop strategic infrastructure management from reactive to preventive-predictive action. The aim is to enable forward-looking maintenance decisions by aggregating object-specific information at a systemic level and to establish long-term resource protection strategies. The initial

focus will be on the main asset groups that can be directly influenced by the department - roads, sewers and bridges. These form the backbone of the municipal infrastructure and offer a suitable starting point thanks to existing databases and operational access options.

In the long term, the integration of external infrastructures, in particular the networks of supply and disposal companies and telecommunications providers, is also conceivable and reasonable. Such an expansion would not only improve the data situation and control capability, but would also enable greater coordination between the infrastructure players - with the aim of bundling interventions, reducing costs and extending the service life of municipal traffic areas.

In addition, there are open questions regarding data integration, the standardization of material flow recording and the organizational anchoring of such extended resource management within administrative structures. These aspects require further investigation and possibly additional development steps in order to effectively transfer the potentials that have been initiated into the processes of municipal infrastructure management in the long term.

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