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CONSIDERATIONS FOR THE USE OF RAG SYSTEMS IN SMALL MUNICIPALITIES IN SELECTED USE CASES

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Abstract
Using artificial intelligence (AI) and retrieval-augmented generation (RAG) systems in municipal administrative processes opens up new opportunities to increase efficiency and improve the quality of public services. This article focusses on the analysis of selected municipal use cases, including application procedures for social benefits, economic development, emission control permits, and the introduction of digital twins using the example of the municipality of Hofbieber. AI-based systems automate routine activities, support plausibility checks and enable data-driven decision-making. In particular, Hofbieber's digital twin shows how AI-powered analytics can contribute to CO_2 monitoring, risk assessment, and sustainable urban planning. Despite technical, organizational and legal challenges, the case studies illustrate the potential of AI solutions to promote sustainable development and citizen participation even in small municipalities. The results underline the need for holistic approaches to ensure acceptance, data protection and continuous qualification of employees, and thus fully exploit the advantages of AI in public administration.
Keywords: Digital Twins, RAG Systems, Technical and organizational Challenges, Use Cases

INTRODUCTION

The application of artificial intelligence in municipal application procedures offers numerous advantages. There are some barriers and obstacles to using artificial intelligence to optimize administrative procedures in municipalities that need to be taken into account. Using AI requires access to large amounts of data, which are often not available in the required quality and quantity in municipal administrations or cannot be used for data protection reasons. In many municipalities, there is a lack of sufficient expertise and skills in these areas to successfully introduce and operate such systems. The introduction of AI in administration is a complex and interdisciplinary endeavor that requires expertise from various areas such as IT, law, and personnel development. The lack of coordination between these areas can be a hurdle.
In addition to considerable financial and human resources, which are limited in many municipalities, the introduction of AI systems also requires the clarification of legal and ethical issues. For example, basic regulations must be made with regard to discrimination, explainability of decisions, and liability issues. The implementation of AI in public administrations requires a holistic approach that takes into account technical, organizational, and personnel aspects.
The acceptance and trust of citizens and employees in AI systems are crucial for their successful implementation. Concerns about transparency, fairness, and accountability must be addressed. In order to overcome these barriers, suitable framework conditions must be created and awareness of the opportunities and challenges of AI in public administration must be clarified in order to be able to enable the necessary tangible benefits.
This also represents a signal to create and support an AI-friendly organizational culture by involving employees and teaching AI skills in interdisciplinary teams with data and subject matter experts as a personnel component. However, this also means an ongoing program for the qualification and further training of employees across the workforce to use AI systems. At the same time, attracting and retaining AI talent through attractive working conditions and career opportunities is an important prerequisite for long-term change..

THEORETICAL BASICS

Retrieval Augmented Generation (RAG) systems mark a paradigm shift with using artificial intelligence for knowledge-intensive tasks. Particularly in the context of the public procurement of administrative services, RAG architectures offer the potential to significantly increase the quality, efficiency, and transparency of digital administrative services. This scientific paper sheds light on the concept, functionality, and opportunities of RAG systems for public administration, discusses challenges and provides an outlook on future developments.

Retrieval Augmented Generation (RAG) refers to an architectural concept that combines large language models (LLMs) with external, often organization-specific sources of knowledge. While classic LLMs are based exclusively on their training data, RAG extends these models with a retrieval mechanism: relevant information is retrieved from databases, documents or knowledge systems and integrated into the response generation as a context (Databricks, 2025).

This allows RAG systems to provide up-to-date, fact-based and domain-specific answers without the need for time-consuming retraining of the model. The typical process is divided into three steps:

1. Retrieval: Identification of relevant documents or text passages by means of semantic search.
2. Augmentation: Enrichment of the LLM input with the retrieved information.
3. Generation: Creation of a response by the LLM taking into account the extended context.

In contrast to classic information retrieval systems, which usually only provide document lists, RAG generates a directly usable summary response text (TU Dresden, 2025).

In the public sector, the provision of accurate, up-to-date and comprehensible information is essential. RAG systems address key challenges of classic LLMs, such as outdated training data, lack of explainability, and the risk of hallucinations (SSRN, 2025).

By integrating up-to-date legal bases, administrative regulations and policies, citizen inquiries or internal information can be answered with a high level of factual accuracy. The automation of citizen requests, the provision of self-service portals, and the support of clerks through RAG-supported knowledge engines lead to considerable efficiency gains. Routine inquiries can be answered automatically, quickly, and consistently. At the same time, there remains the possibility of escalating complex cases to human experts (Databricks, 2025).

A central concern of the public administration is the traceability of decisions. RAG systems can be designed in such a way that they disclose not only answers, but also the underlying sources and lines of argumentation. This strengthens citizens' trust in digital government services and supports accountability (SSRN, 2025).

The possibility of operating RAG models locally and feeding them with organization-specific data allows data protection requirements and specific regulatory requirements to be met. Data processing remains within the official infrastructure, sensitive information is not transmitted to external cloud services (TU Dresden, 2025).

While the potential of AI solutions in metropolises is intensively researched, it is increasingly becoming apparent that even small municipalities can benefit from AI – despite technical, organizational, and legal hurdles (Isagah & Ben Dhaou, 2024). Based on current case studies, the following examines how AI can promote sustainable development and citizen participation in small communities.

Small municipalities often have limited IT infrastructures and specialist staff. The integration of AI requires investment not only in hardware and software, but also in the qualification of employees (Viale Pereira et al., 2023). In addition, there is the need to make local data available in sufficient quality and quantity (Isagah & Ben Dhaou, 2024).

METHODS

Digitalization represents a challenge and at the same time an opportunity, especially for micro-municipalities. The case study method is particularly suitable to analyze the possible applications of digital solutions in these specific contexts, as it provides context-dependent, detailed and practical insights (cf. Wiechmann 2008).

According to Yin (2009), a case study consists of five central building blocks: research question, theoretical framework, case selection, data collection, and data analysis. The most important steps are:

1. Formulate research question: Focus on "how" or "why" questions, e.g.: "How can digitization improve administrative processes in micro-municipalities?"
2. Theoretical framework: Embedding in existing research and concepts.
3. Case selection: Conscious selection of a relevant, typical or particularly interesting case.

4. Data collection: Using various methods such as interviews, document analysis, and observations to get a comprehensive picture.
5. Data analysis: Systematic evaluation and interpretation of the data with regard to the research question.

A good case study tells a relatable story, focuses on a specific problem and its solution, and concludes with an evaluation of the results.

The selection of a micro-municipality as an object of investigation should be targeted, for example because it has already implemented the first digitization projects or faces special challenges. The case study can help to identify specific barriers and success factors.

The data sources used are:

1. Interviews with administrative staff and citizens
2. Analysis of project documents and digital applications
3. Observation of administrative processes

The analysis focuses on questions such as:

1. What digital solutions have been introduced?
2. What challenges did you face during implementation?
3. What effects did they have on administration?

The following examples are thematic as well as methodological reference cases for the survey and interpretation methodology.

Digital twins in Lower Austria: The SCiNDTiLA project shows how digital twins are used as a reflection of the community to simulate sustainable development strategies and support decision-making processes. Especially in small municipalities, resources can be used more efficiently and citizens can be better involved (Viale Pereira et al., 2023).

AI-powered citizen participation in rural areas: AI-based platforms have been introduced in several small European towns, enabling citizens to submit concerns digitally and participate in decision-making processes. This increases the acceptance of municipal measures and strengthens trust in the administration (Isagah & Ben Dhaou, 2024).

RESULTS

The analysis shows that digitization and innovative approaches such as digital twins offer considerable potential for increasing efficiency and modernizing municipal tasks. At the same time, there are challenges posed by federal structures, limited resources, and the need to build up technical know-how. Successful implementation depends largely on strategic embedding, the provision of resources, and the creation of suitable legal and organizational frameworks.

The following administrative procedures appear to be critical to success from the consultations:

1. Application process for social benefits

To Guarantee social benefits is a core task of the municipalities. Sponsorship and organization vary considerably between the federal states and municipalities, which is reflected in different administrative structures and expenditures (Bertelsmann Stiftung, 2015).

Independent cities and districts bear the main burden of social benefits, while municipalities belonging to districts concentrate primarily on areas such as daycare centers. The digitization of these application procedures can increase efficiency, shorten processing times and minimize sources of error. Nevertheless, challenges remain due to federal differences, data protection requirements, and the need to adequately reach disadvantaged groups.

2. Municipal economic development

Economic development at the municipal level has gained in importance in recent years, especially against the background of difficult labor market and budgetary situations in many municipalities (IWH, 2004).

The aim is to promote business settlements and increase local value creation. Rather, important influencing factors are the transport infrastructure, regional agglomeration effects, and national and European structural policy. Digitalization can improve the visibility and accessibility of funding offers, but it does not replace the fundamental location factors.

3. Emission permits and environmental management

The approval of emissions is a complex administrative process that is regulated by legal requirements such as the Greenhouse Gas Emissions Trading Act (TEHG) and the Federal Immission Control Act (BImSchG). As a rule, the state authorities are responsible, which both issue emission permits and approve monitoring plans (DEHSt, 2018).

The digitalization of approval procedures can increase transparency and traceability, make it easier

to meet deadlines and speed up communication between operators, inspection bodies and authorities. The integration of monitoring systems also enables continuous monitoring and reporting.

4. Introduction of digital twins using the example of a municipality

Digital twins (DCs) are virtual images of real urban infrastructures and processes. They offer municipalities the opportunity to simulate complex relationships, optimize planning processes and make data-based decisions (Weß, 2023). Examples of applications range from traffic control to urban development and resource management. Practical projects such as "TwinBy" in Bavaria show that both small and medium-sized municipalities can benefit from the introduction of digital twins, provided that know-how, resources, and suitable use cases are available (DKSR, 2024).

The greatest potential lies in efficiency increases, better planning security, and the possibility of playing through scenarios for crisis management and sustainable development.

DERIVATION OF A SAMPLE TRANSFER PROJECT

The following case study on a use case of the municipality of Hofbieber in Hesse has set itself an ambitious goal: it intends to achieve climate neutrality by 2030. To support this endeavor and to preserve the unique qualities of the municipality, Hofbieber has invested in an innovative approach – a digital twin of the entire municipality and its surroundings. A digital twin is a precise virtual replica of a real-world object or system. In the case of Hofbieber, it is a detailed digital representation of the entire community, including its infrastructure, buildings, and natural environment.

Figure 1. CO2 monitoring of the municipality of Hofbieber

This approach allows the municipal administration to closely monitor and analyze various climate-influencing factors. The technology for the digital twin was provided by Hexagon's Safety, Infrastructure & Geospatial Division. It uses a combination of geospatial baseline data, environmental data and 3D land use classifications provided by AI analyses to model CO2 emissions as well as natural and artificial CO2 sinks. This provides the decision-makers in Hofbieber with a comprehensive overview of the climate situation in the municipality and enables them to make informed decisions to achieve their climate goals. Although digital twins have so far been used mainly by larger cities for environmental modelling and urban planning, Hofbieber, with its 6,300 inhabitants, shows that smaller municipalities can also benefit from this technology. Therefore, this could be a model for other small communities pursuing similar climate goals.

The use of the digital twin in Hofbieber goes beyond pure CO2 monitoring. It provides a platform for various simulations and analyses:

1. CO2 monitoring: The digital twin enables precise tracking of CO2 emissions in the municipality. This not only helps to monitor progress towards climate neutrality, but also allows comparisons with other municipalities.
2. Flood risk: Flood risks have already been calculated on the basis of data from the digital twin. This can help the municipality to take preventive measures and adapt the infrastructure accordingly.
3. Future applications: In the future, Hofbieber plans to use the digital twin for further simulations, including the analysis of heat islands, urban air currents, and traffic flows.

A special feature of the project in Hofbieber is the way in which the data for the digital twin was collected. Due to the relatively small area of 87 square kilometers, Hexagon used drone instead of aerial photography from specially equipped aircraft. This method could prove to be more cost-effective and flexible for smaller municipalities. The use of a digital twin in Hofbieber not only promises benefits for climate protection, but could also have a positive impact on other areas:

1. Real estate values: Improved environmental conditions and a more sustainable infrastructure could increase real estate values in the municipality.
2. Insurance premiums: A better understanding and management of risks such as flooding could

lead to lower insurance premiums for residents.
3. Economic development: Hofbieber's innovative approach to environmental and urban planning could make it more attractive to companies and investors.
4. Tourism: A sustainable and environmentally friendly approach could promote ecotourism in the region.

The project in Hofbieber is funded by the state of Hesse with 170,000 euros (Kommunalwiki, 2025). This underlines the importance that the state government attaches to the use of innovative technologies for climate protection. The support could also encourage other Hessian municipalities to tackle similar projects.

The use of artificial intelligence (AI) also plays an important role when using the digital twin (Digital Ministry of Hesse, 2025). AI algorithms can analyze and interpret the enormous amounts of data that the digital twin generates. They can identify patterns, make predictions, and make optimization suggestions that human analysts might miss. This enables the municipality to proactively respond to potential problems and develop innovative solutions for climate protection.

Hofbieber's digital twin is part of a larger trend in urban planning and environmental management. Similar projects have already been implemented in larger cities such as Klagenfurt and Villach in Austria and in the canton of Zug in Switzerland. However, the success in Hofbieber could show that this technology is accessible and useful for smaller communities as well.

Implementing a digital twin also comes with challenges. These include:

1. Data protection: Comprehensive data collection and analysis raises questions about the protection of residents' privacy. It is important that the municipality develops and adheres to transparent guidelines for data use.
2. Technical expertise: Managing and interpreting the data from the digital twin requires specific technical know-how. Hofbieber must ensure that it has the necessary skilled workers or access to external expertise.
3. Continuous updating: To keep the digital twin useful, it needs to be fed with up-to-date data on a regular basis. This requires a long-term commitment and continuous investment. AI processes will play a decisive role in this regard, especially in the future, in order to work cost-efficiently.
4. Citizen participation: It is important to involve the residents of Hofbieber in the process and to communicate the benefits of the digital twin to them. Transparency and communication are key factors here.

Despite these challenges, Hofbieber's digital twin offers enormous potential for the sustainable development of the community. It enables data-driven decision-making that can lead to more effective climate action. It can also serve as a tool for citizen participation through visualising complex environmental processes and making them understandable.

Hofbieber's approach shows that even small communities can use innovative technologies to tackle major challenges such as climate change. By taking advantage of the digital twin, the municipality is positioning itself as a pioneer for sustainable development in rural areas. The success of this project could have far-reaching implications and inspire other communities to take similar initiatives.

In summary, Hofbieber's digital twin is a promising tool to achieve climate neutrality by 2030. It not only provides the ability to accurately monitor CO2 emissions, but also to simulate different scenarios and predict the impact of measures. With integrating AI and advanced analytics methods, the community can make informed decisions and use its resources effectively. The success of this project could have far-reaching consequences for urban planning and environmental management in small communities. It shows that advanced technologies are not only reserved for large cities, but can also be successfully used in rural areas. If Hofbieber achieves its climate goals with the help of the digital twin, this could serve as a model for other municipalities in Germany and beyond.

Ultimately, the project in Hofbieber is not just about technology, but about creating a sustainable and livable future for the residents. The digital twin is a tool that allows the community to preserve its unique qualities while making a significant contribution to climate action. It is an example of how innovation and environmental awareness can go hand in hand to bring about positive change at the local level.

Overall, the conclusion can be drawn that the use of AI in municipal application procedures has the potential to accelerate processes, improve the quality of decisions, and optimize services for citizens and companies. However, aspects such as framework conditions, acceptance formation, and level of performance in correctly selected use cases must be taken into account in order to ensure responsible and trustworthy use of AI.

CHALLENGES, LIMITATIONS AND PERSPECTIVES

Despite the advantages mentioned, RAG systems face specific challenges in the administrative environment, which were derived as challenges in the cases examined:

1. Data quality and maintenance: The effectiveness of RAG depends to a large extent on the timeliness and structuring of the integrated knowledge sources. Outdated or incorrect data can lead to incorrect information.
2. Complexity of integration: The connection of heterogeneous data sources and the assurance of interoperability with existing specialist procedures require technical and organizational adjustments.
3. Transparency and bias: Even RAG systems are not free of prejudice, especially if the underlying data sources are not diverse or representative. In addition, the traceability of response generation remains a challenge, although it is improved compared to pure LLMs.
4. Legal and ethical aspects: The use of AI-based systems in administration raises questions regarding liability, data protection, and algorithmic fairness.

In the empirical studies considered, a significant improvement in task management, perceived explainability and user satisfaction was shown compared to basic models. At the same time, it became clear that while fine-tuning can increase stylistic consistency with standard answers, it can also increase the risk of hallucinations. Gov-RAG systems can improve factual consistency and reduce inconsistencies, outperforming basic models and alternative frameworks in government applications.

Further comprehensive surveys are still necessary and valid statements must be substantiated.

RAG systems are only at the beginning of their development and implementation in the public sector. Future research and development will focus on the following aspects:

1. Improvement of retrieval algorithms: Combination of dense and sparse vector retrieval with domain-specific hierarchizations.
2. Automated evaluation: Development of methods for the automated evaluation of factual accuracy and reduction of hallucinations.
3. Expansion of explainability: Integration of explanation modules that make decision-making processes transparent.
4. Participatory development: Involvement of citizens and administrative staff in the design and evaluation of RAG-based services.

CONCLUSION

Retrieval augmented generation systems offer public administration the opportunity to make digital services more efficient, precise and closer to the citizen. They address key challenges of classic LLMs and open up new paths for transparent, comprehensible, and adaptive administrative digitization. However, successful implementation requires careful data maintenance, technical integration and consideration of legal and ethical framework conditions.

The analysis shows that AI solutions also offer considerable potential to prompt sustainable development and citizen participation in small municipalities. Despite existing technical, organizational, and legal challenges, case studies show that the advantages – from more efficient processes to resource conservation and greater proximity to citizens – outweigh the disadvantages. However, the prerequisite is responsible, participatory, and transparent implementation.

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