



Digital transformation in municipalities for the planning, delivery, use and management of infrastructure assets: Strategic and organizational framework

Nawel Lafioune^{a,*}, Anaïs Desmarest^b, Érik Andrew Poirier^a, Michèle St-Jacques^a

^a Department of Construction Engineering, École de Technologie Supérieure (ÉTS), University of Quebec, Quebec City, Canada

^b Department Smart and Resilient Cities, Hautes Études d'Ingenieur (HEI), University of France, Lille city, France

ARTICLE INFO

Keywords:

Digital transformation
Municipality/city
Government
Barriers and challenges
Urban infrastructure
Asset management

ABSTRACT

As the acceleration of technological development in the built asset industry brings on waves of digital transformation (DT), traditional ways of doing and organizing are being disrupted, especially on the part of large public owners such as municipalities. For these owners, these waves of transformation require constant adaptation as they compete with existing initiatives and embedded legacy practices.

This paper presents the results of the second part of a longitudinal research project aimed at framing digital transformation within municipalities to improve urban infrastructure lifecycles. More specifically, the paper presents the results of work undertaken to operationalize, extend and further validate the digital transformation framework that has been developed in part 1 and which is presented elsewhere. The theoretical framework acts as a guide and analysis tool for the digital transformation of municipalities and aims to help them reduce and/or eliminate the barriers and challenges in this digital transformation. To do so, the results from a survey conducted within 44 municipalities and interviews conducted with 13 municipalities of different sizes are presented and discussed through the theoretical framework.

The results show that data and information management remain the key issues, especially in a siloed organizational context such as those found within municipalities. Moreover, a significant amount of organizations remain unaware of how to approach digital transformation which in turn leads to disinterest or disengagement in digital transformation, which results in localized or fragmented initiatives. This in turn can cause delays in implementing transformational initiatives and contributes to maintaining a low level of digital maturity. The study also highlights the critical lack of human resources, expertise and appropriate training to support digital transformation.

1. Introduction

Municipalities across Canada, like many municipalities around the world, are often forced to play catch up and do more with less, due to the increasingly poor condition of urban infrastructure assets and a stagnation or reduction in available funds [1]. Despite considerable investment, the rate of asset maintenance deficits continues to grow [2]. Moreover, and as discussed elsewhere, municipalities are at the forefront of combatting climate change and ensuring resilience of the built environment.

Digital transformation is advanced in many sectors in Canada, such as aerospace, which is a testament to the expertise and skills available in

the country. By leveraging this expertise, Canadian cities will be able to benefit from an effective and beneficial digital transformation. In addition, there is a growing interest in digital transformation from Canadian provincial and federal governments, with initiatives such as the Canadian Digital Adoption Program, the NovaScience program, and the Ministry of Economy, Innovation and Energy's Offensive Digital Transformation Initiative. However, despite these government initiatives, there is a lack of structured digital transformation initiatives at the local government level, which represents a significant challenge.

Digital transformation within municipalities can potentially help overcome these challenges, yet this transformation is rife with challenges [3]. Indeed, as with other domains, municipalities are facing the

* Corresponding author.

E-mail address: nawel.lafioune.1@ens.etsmtl.ca (N. Lafioune).

Table 1
Profiles and number of survey respondents.

No. of: Cities in Quebec by size / Cities with respondents / Respondents by city size						No. of respondents / level of asset management		
City size	No. of living	No. of cities in Quebec	No. of cities with respondents	No. of cities with respondents	% of respondents	Level	No. of respondents	% of respondents
Big	> 100 000	10	9	40	29.63	Strategic	34	25
Medium	10 000 < X < 99 999	96	27	83	61.48	Tactical	28	21
Small and very small	X < 2 000 < X < 9 999	290 + 711	7	11	8.14	Operational	46	34
Not indicated	-	-	1	1	0.75	Not indicated	27	20
Total	8 426 075 hab	> 1100	44	135	100	3	135	100
Portrait of cities in Quebec						Survey Respondent Profiles		

Source: Décret 1214–2019 du 11 décembre 2019.

Note: In Quebec, city and municipality each have their own definition. The word "city" designates both for the present research.

Table 2
Interview respondent profiles.

No. of respondents / city size		No. respondents / sex		No. respondents / age		No. respondents / year of experience		No. Interviews					
Size	No.	%	Sex	No.	%	age / year	No.	%	year experien	No.	%	interviews	No.
Big	5	38.46	Man	16	66.66	20–30	4	16.66	< 5 ans	4	16.66	Individual	20
Medium	6	46.15	Women	8	33.33	30–40	10	41.66	5/10 ans	6	25	in pairs	2
Small & very small	2	15.38				40–50	7	29.16	10/20 ans	8	33.33		
Total	13	100	Total	24	100	50–60	3	12.5	> 20 ans	6	25	Total	22

Table 3
Preliminary framework.

06 Categories		22 Subcategories	
1	Strategy / Governance / steering / leadership / Financial resources	Lack of guidance and/or leadership	1
		Lack of a strategic plan	2
		Unmanaged external pressure	3
		Lack of governance	4
		Lack of support from senior management	5
		Funding issues	6
2	Process / practice / management	Lack of collaboration	7
		Absence of data management	8
		Misalignment of current practices and management	9
3	Organization / Structure / Culture	Absence of organizational change management	10
		Lack of communication	11
		Lack of training	12
		Non-conducive organizational culture	13
		Inadequate policy and support from elected officials	14
4	Policy / standards / regulations / laws / contracts	Lack or incompatible standards / contracts	15
		Incompatible laws and regulations	16
5	People / Community / Network	Limited vision	17
		Resistance to change	18
		Lack of human resources	19
		Perceptions from the citizens	20
6	Digital / Information Ecosystem	Inadequate technologies and tools	21
		Incompatibility and/or inadequacy of existing information systems	22

Source: From Lafioune & al. [11]. Reproduced with the permission of Lafioune N.

considerable rise in the use of technology to support a variety of business processes [4]. While these tools allow the collection of data on different assets and specific types of technologies are increasingly being used, municipalities lack the skills to store, process and use the data effectively [5]. This means that the potential wealth of data and information that is captured, goes largely unused [6]. Part of the reason for this is that municipalities tend to undertake a digital transformation in a haphazard

and fragmented manner. Indeed, digital transformation of urban infrastructure assets lifecycle activities rarely find their way into the strategic planning process within municipalities. To this effect, digital transformation has been shown to require a long-term vision and holistic understanding of an organization’s needs which is often not the case in most municipalities.

The research presented in this paper is part of a longitudinal study on the digital transformation to support integrated urban infrastructure asset planning, delivery, management and use within municipalities. This paper focuses on the operationalization, further validation and extension of a theoretical framework that aims to articulate the criteria of successful digital transformation supporting urban infrastructure assets lifecycle activities within municipalities. More specifically, this paper builds on and extends a preliminary theoretical framework that focused on the identification of barriers and challenges constraining digital transformation in the municipal context, especially with regards to urban infrastructure assets lifecycle activities for existing and yet-to-be-constructed built assets, such as buildings, roads, railways, sewer and water systems, etc.

The objectives of the research presented in this paper are: (1) to further validate and refine the barriers and challenges identified within the preliminary theoretical framework, (2) to operationalize and extend the constructs within the framework, and (3) to identify and evaluate trends concerning digital transformation within Canadian municipalities. To achieve this, a mixed-method approach is employed which includes both survey and interview data. Using data from 135 survey respondents covering 44 municipalities and 22 interviews covering 13 municipalities of different sizes, the theoretical framework is operationalized and extended to understand the current state of digital transformation within Canadian municipalities.

Material and method are first presented. Theory follows including the summary of the digital transformation theoretical framework used for this study. These results obtained through by category of framework are compared and discussed. Subsequently, their implications for research and practice are exposed. This comparative work is integrated into the framework to extend it with recommendations for action, which gives rise to the final framework. Finally, the article concludes with the importance of the findings of the study, namely for municipalities in their digital transformation. Potential future research are discussed and

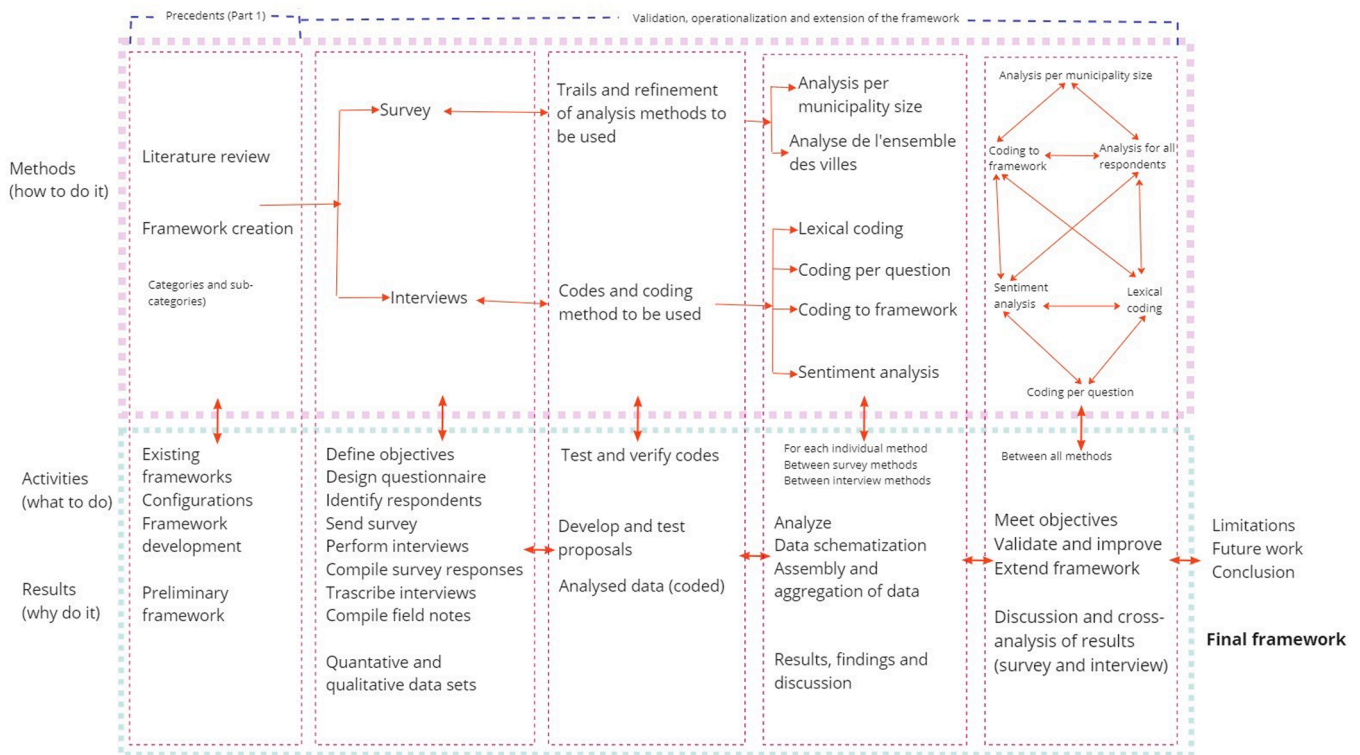


Fig. 1. Analysis sequences from a pre-structured framework.

the limitations of the study are exposed.

The paper contributes to the field of research in digital transformation in the built environment through the operationalization of a theoretical framework and its extension. While other frameworks for digital transformation have been developed, none have focused on the urban infrastructure asset management domain. It provides a guide and analysis tool for the digital transformation of public organisations and shows the potential to be applied in practice. Using the framework as such a tool, the results show that management of data and information consistently rank as the main issue for municipalities. The results also show that there is a critical lack of human resources, expertise and appropriate training to support digital transformation.

The description of the methodology and the different methods is another contribution among others. It shows, in detail, how to draw reliable conclusions from qualitative data, which is beneficial to both the theoretical and practical community.

2. Material and method

2.1. Survey

The survey targeted respondents selected according to the following criteria:

1. Employees from municipalities of all sizes (large, medium, small and very small).
2. Employees working in different departments within a municipality.
3. Employees holding a position that includes at least one asset management activity. The distribution of respondents' functions should cover an identical portion, ideally, in the three levels of asset management: strategic, tactical and operational.
4. A minimum number of 40 respondents per asset management level, i. e. $40 \times 3 = 120$ targeted respondents.

The survey consisted of 25 multiple choice questions designed

around the sub-categories of the framework, each with a specific purpose. These questions are presented with the results in Section 4.1.1. The questionnaire was verified, improved and validated through a pre-test. It was then reformatted using an online platform to facilitate data collection. The survey was designed to take a maximum of 10 min.

2.1.1. Profile of survey respondents

The number of survey respondents exceeded the target number. The survey resulted in a high return rate (112.5%), with 135 respondents working in 44 municipalities instead of 120 respondents working in 40 municipalities. Table 1 summarizes the portrait of municipalities in Quebec, the number of municipalities and their sizes according to Ministère des Affaires Municipales et de l'Habitation [7]. It presents the profile of survey respondents with the distribution rate between the three levels of asset management.

2.2. Interviews

Semi-structured interviews were conducted in parallel with employees from several targeted municipalities across Quebec. At the end of the survey, respondents were asked if they would agree to the interview. Those who accepted and passed represent the sample of interviewees. The interviews served to provide more depth of coverage to the data collection, which in turn served to operationalize the framework as an analysis tool. Due to the health measures related to COVID 19, the interviews were conducted remotely. Interviews lasted an average of 20 min and were conducted over a 4-month period.

The first interviews were used to adjust the questionnaire and refine it accordingly. The interview questions (Section 3.2.3) are organized according to the framework (Table 3). There are six open-ended questions that encourage respondents to expand on their responses for each category.

Data collection was done by taking notes and recording the entire interview. Before the interview began, the interviewer insists on the confidentiality of the information, as well as the anonymity of the

Table 4
Results of the analysis of survey responses.

Category /Subcategory	Question	Results
Strategy / Governance / Steering / Leadership	Vision 1/ Do your managers have a common vision on the digital transformation of urban infrastructure assets?	65% of respondents say that their managers do not share a common digital transformation view of urban infrastructure assets.
	Strategy 2/ Does your municipality have a strategic plan for digital transformation of urban infrastructure assets or related to digital?	67% of respondents said that their municipality does not have a strategic plan for urban infrastructure assets.
	Application of the strategy 3/ Is this strategic plan reflected in the municipality's activities (actions)?	82% of respondents who answered "yes" to question 2 said that the digital transformation 's strategic plan is reflected in actions.
	Action follow-up 4/ Is there accountability (performance evaluation) for the activities of this strategic plan?	Even for those municipalities that have taken action, 70% have no follow-up.
	Financing 5/ During the planning of your municipality's project portfolio, is there any funding in the Three-Year Capital Program for the digital transformation projects?	For 67% of respondents, digital transformation is not included in the Three-Year Capital Program, it is not considered a priority for investment, digital transformation is unknown and the benefits are not identified.

municipality and the respondent. The complete and automated transcription of the audio was done at the same time as the interview. The result of the transcription was adjusted immediately after the interview to be as accurate as possible.

2.2.1. Interview respondent profiles

22 semi-structured interviews were conducted with 24 respondents working in 13 municipalities of different sizes from across the Province of Quebec. The interviewees worked in different departments, for example: public works, urban planning, engineering, environment, information technology, general management, etc. Table 2 presents the profiles of the interview respondents.

3. Theory

Digital transformation has become a key issue for organizations and governments around the world. The COVID-19 pandemic has highlighted its importance, especially with the increasing use of big data, cloud computing and other digital technologies [8]. "As a core strategy of many enterprises, digital transformation is no longer a multiple-choice question but rather a survival issue" [9].

Digital transformation offers many opportunities to improve the quality of life in cities, notably by improving the operational efficiency of urban infrastructure, reducing costs and improving the quality of services.

Digital transformation has become a key area offering new opportunities but also significant challenges (Nguyen et al., 2018), such as data security, privacy and digital disparity. Implementing digital

transformation of urban infrastructure can be complex and costly, especially for smaller cities. In addition, local governments may lack an understanding of the benefits and risks of this transformation, as well as the technical knowledge to implement it. The lack of theoretical frameworks for digital transformation compounds these challenges. Liu et al. [8] believes that the implementation of digital transformation does not work well in China because of this lack of theoretical framework. Moreover, proper preparation and a supportive organisational culture have a direct and significant impact on the success of digital transformation [10].

Developing a framework for digital transformation aims to provide a clear structure for organisations and governments seeking to undertake digital transformation initiatives by identifying key issues and best practices to follow. Based on a review of existing literature and existing digital transformation frameworks, the framework presented in 3.1 is specifically tailored to Canadian municipalities but can also be applied in other countries and regions of the world.

3.1. Preliminary framework

The framework developed is the result of a broader doctoral research than the subject of this scientific article. The latter is designed to improve and validate the components of the framework in the practical environment and at the same time to draw up a portrait of Quebec cities in terms of digital technology. Following this stage of the research, a case study is launched to verify and monitor its applicability.

The research presented in this paper builds off a preliminary theoretical framework that identifies the barriers and challenges to digital transformation that municipalities face. The framework contains 22 sub-categories structured into six broad categories as shown in Table 3. This framework was used to design the survey and interview questions.

Each category addresses an issue that can prevent a planned and structured digital transformation. By unpacking each issue and proposing possible solutions for each element, digital transformation can succeed. This will enable municipalities to benefit from the full potential of technology for the benefit of citizens.

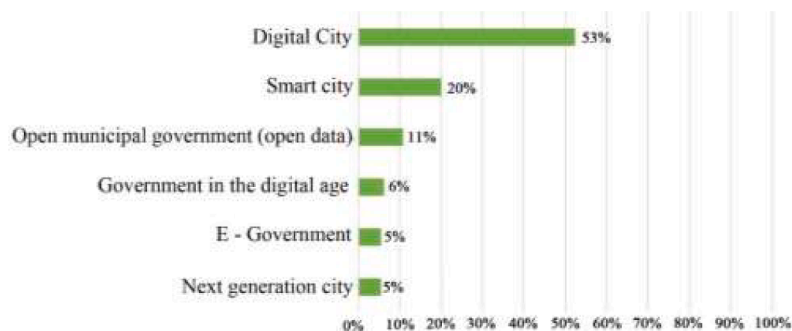
With regard to the validation of the framework, it is derived from a review of the existing literature on digital transformation, as well as frameworks developed by other researchers in this field. Empirical data collected from interviews with city employees and policy makers. Throughout the research, we ensured that our framework was consistent with current best practice and trends in the field of digital transformation.

The validity of our framework lies in its adaptability to different city sizes and its ability to help local governments implement digital transformation in a structured and effective way. By providing specific practices and assessment measures, this framework can help local governments address the challenges of digital transformation of urban infrastructure assets.

The validity of the research leading to the design of the framework is ensured by the type of participatory research, the provision of a wide range of validation procedures and the monitoring of the methodological approach. With regard to participatory research, action research is characterised by a process of knowledge production carried out together with the actors in the field. Its corollary is that it highlights the potential of the participants and strengthens the awareness of those involved of their own capacities to initiate and control action. The fact that the research is replicated in several Quebec cities increases the external validity of the research. Internal validity is ensured by the collaboration of the researchers. The data collected is compiled and analysed by two researchers, each in turn. The results are then compared, discussed and heard in a single final result, which was presented to the third researcher, and validated together. In terms of supporting the validity of the analysis, this research has drawn on a range of strategies and techniques proposed by various authors, principally Huberman and Miles [12,13] and Van der Maren [14]. In addition, technological innovations

Table 5
Results of the analysis of survey responses.

Category /Subcategory	Question	Results
Process / Practice / Management	6/ Does your municipality have a set of predefined tasks and activities for initiating, executing and analyzing digital transformation of urban infrastructure assets projects?	67% of respondents say that there are no predefined tasks or activities for initiating digital transformation projects.
	Validation of activities 7/ Does your municipality have a central team that validates all digital transformation of urban infrastructure assets activities?	79% of respondents said that there is no team that validates digital transformation activities.
	Validation of activities 8/ In your municipality, do employees have access to professional training to familiarize them with the digital transformation of urban infrastructure assets?	60% of respondents do not consider that employees have access to training to become familiar with digital transformation.
	Training 8.a / If yes, do you think that the content of the trainings is appropriate for digital transformation of urban infrastructure assets? (Trainings in the areas of professional development and not only introduction to functionality software like Microsoft Project)	37% of those who answered "yes" to question 8 think that the content of the training is appropriate. However, despite the ownership of the content, 54% of respondents believe that not enough employees have access to it.
	8.b / If yes, do you think that the number of employees who have access to these trainings is sufficient for the implementation of digital transformation of urban infrastructure assets?	60% of respondents don't think that the number of employees who have access to these trainings is sufficient for the implementation of digital transformation of urban infrastructure assets
Collaboration	9/ In your municipality, are there teams that use interdisciplinary collaborative approaches (e.g. LEAN Management, Integrated Design Process)?	50% of respondents say that teams use interdisciplinary approaches in the municipality. Among the approaches cited, LEAN Management was in first place, mentioned by 42% of respondents, followed by Integrated Design Process for 13% of respondents, and continuous improvement for 8%.
Existing concepts	10 / Are any of the following concepts used (at least one service or activity that advances this concept) in your municipality? More than half of the respondents consider the digital city concept as the most used in municipalities. 61% of respondents associate their municipality with one concept, and one in two associate their municipality with several concepts. To better understand the logic behind these responses, during the interviews, respondents were asked for their definition of smart city and digital city, as it was found that their definition was either limited or incomplete compared to the definition in the literature.	



and their contributions to the processes facilitate the analysis and measurement of the validated data.

The applicability of such a framework depends on a number of factors specific to each municipal organization, such as its size, budget, priorities and objectives, whether it is already engaged in digital transformation or is considering doing so. It depends on the ability of the municipal organization to identify and implement digital transformation initiatives that meet the needs of the community and improve the efficiency, service quality and transparency of the organization.

3.2. Analytical methods and tools

The analysis of the survey data was done for each municipality and were then reanalyzed according to the size of the municipality. Indeed, this indicator was often mentioned during the interviews. The data collected is compiled and then analyzed by two researchers, each on his own. The results are compared, discussed and heard in a single final result which was exposed to the third researcher and validated.

The analysis of the interview data was done using four methods, as shown in Fig. 1. A systemic random analysis of the textual data resulting from the interview transcripts and grouping by the same meaning was performed (lexical coding). A content analysis and its measurement by lexical statistics was done according to the answers to the survey questions (per-question coding) and according to the framework (per-barrier coding). An analysis of the opinions, judgments, and emotions of

the discourse, followed by the measurement of the content (sentiment coding) was also performed.

3.2.1. Sentiment analysis

Sentiment analysis, also known as 'opinion mining', involves determining the opinion, judgement and emotions behind the natural and spontaneous language of respondents. It assesses feelings about services, issues, individuals, subjects and their properties and other entities [15]. Its main purpose is to analyze opinions and test emotional scores. Currently, sentiment analysis is a very popular field of study according to Elmurngi [16]. For this purpose, Thomas [17] divides this analysis into three levels: word/term level [18] or aspect level [19], sentence level [20] and finally, document level [21].

The classification of emotions into fear, frustration, joy, hope, etc. is based on readings of the existing literature on the psychology of emotions and how they are expressed in natural language. We have identified these emotions as the most common and relevant to our study on digital transformation. Of course, there are many other ways of classifying emotions and our approach may not be suitable for all studies.

For textual sentiment analysis, it is possible to identify sentiment through artificial judgement using natural language processing algorithms, such as Naive Bayes methods and neural networks. Sentiment analysis in the context of a survey can be difficult, especially in a specific context such as the Quebec municipal sector. We noticed that the language used was different from academic French, with particularities in

Table 6
Results of the analysis of survey responses.

Category /Subcategory	Question	Results
Organization / Structure / Culture	Human resources capacity and organization 12/ Does your municipality have a sufficient number of competent staff in the field of digital transformation?	The majority of respondents (80%) consider that there are not enough competent employees in the field.
	Structural and organizational change management 11/ In your municipality, is there a management plan for resource development in the area of digital transformation of urban infrastructure assets? (e.g. employment, promotion, reward, etc.)	Only 7% of respondents say that their municipality has a resource development management plan in place for digital transformation.
	13/ Does your municipality have a list of the skills needed to effectively advance digital transformation of urban infrastructure assets?	80% of the respondents (99 people), say that their municipality does not have a list of skills to move forward in digital transformation.
	15/ Is a change planning adapted and concretely put into action (including identification of functional and technical needs) for the digital transformation of urban infrastructure assets?	There is no planning for change for 65% of respondents. Cities do not identify their needs regarding the digital shift.
	14/ On a scale of 1 to 5, what is the level of support for the digital transformation change projects of the urban infrastructure perceived within your municipality? (1 = no support, 5 = fully supports). Across all municipalities (of all sizes), almost half of the respondents consider that there is no support for digital transformation projects. Only 3% responded that there was full support. Regardless of municipality size, the response rate is similar for each level of support.	

Level	All cities	Big cities	Medium cities	Small and very small cities
Level 1	~48%	~50%	~47%	~55%
Level 2	~18%	~22%	~17%	~22%
Level 3	~32%	~27%	~36%	~22%
Level 4	~8%	~10%	~6%	~14%
Level 5	~8%	~8%	~9%	~8%

Table 7
Results of the analysis of survey responses.

Category / Subcategory	Question	Results
Policy / Standards / Regulations / Laws / Contracts	Guides and guidelines 16/ Has your municipality developed its own guides to support digital transformation of urban infrastructure assets? (e.g. BIM deployment guide, e-permit delivery guide, GIS user manual).	72% of respondents said that their municipality does not have a guide supporting digital transformation.
	Contracts 17/ Has your municipality revised its bidding criteria, contract clauses including intellectual property (IP), property rights to harmonize with digital transformation of urban infrastructure assets projects?	The tender criteria have not been revised for nearly 67% of respondents; 25% are not sure that this has been done.
	Norms and standards 18/ Does your municipality use its own norms and standards or does it rely on established national or international norms (e.g. ANSI, BS, AS or ISO)	63% of respondents say that municipalities do not use their own norms and standards or national and international standards.

vocabulary, expression and pronunciation, as well as a linguistic diversity of respondents’ profiles. They also found that hierarchical levels influenced discourse. According to Elmurngi [16], existing software for sentiment analysis generates results that are 85% accurate, which is insufficient.

In this study, we examined some approaches to sentiment analysis and finally opted for manual sentiment detection and ranking of text units for better speech interpretation. Each word in a text was assigned a positivity or negativity score and these scores were aggregated to obtain an overall measure of the sentiment expressed. We also used the revisualisation of video recordings to observe gestures and voice intonation to avoid misclassification of comments.

“NVivo version 12” was used for the analysis of the collected interview data. It helped identify the frequency, order of words or phrases used by the respondents.

Fig. 1 presents the methodology and methods of analysis for this operationalization and extension of the framework.

4. Results

4.1. Overview of results by category

4.1.1. Category 1. Strategy / governance / steering / leadership / financial resources

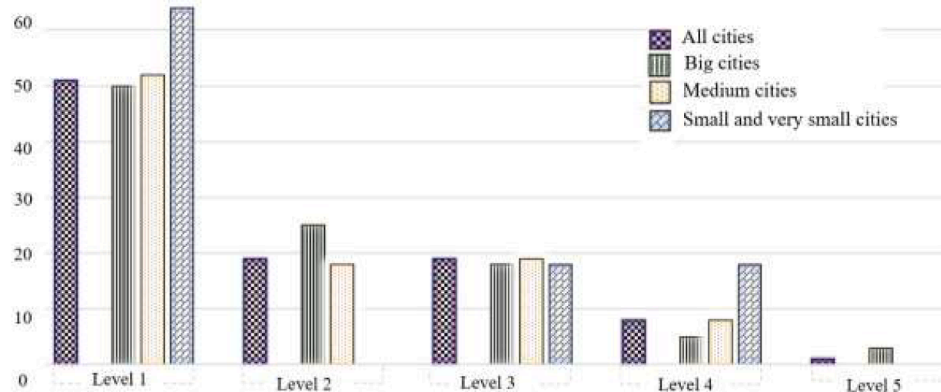
Category 1 includes management and support, leadership, defining a strategic plan, taking steps to mitigate external pressures, developing effective governance, and addressing funding issues. All of these factors contribute to an organization’s ability to structure and succeed in its digital transformation (Table 4).

Question 1: Please explain in your words the extent and current state of digital transformation in your municipality concerning its urban infrastructure assets?

The majority of respondents have a limited understanding and vision of digital transformation for municipal urban infrastructure assets and/or do not see the benefits. Indeed, almost the majority of respondents (18

Table 8
Results of the analysis of survey responses.

Category /Subcategory	Question	Results
People / Community / Network	Citizen involvement 20/ Is the digital transformation vision of your municipality’s urban infrastructure and the value they generate communicated to citizens?	Only 1% of respondents consider that the vision of the digital transformation is communicated to citizens. 73% say it is not and 23% are not sure.
	External collaboration 21/ Does your municipality belong to a group that works on the digital transformation of urban infrastructure assets?	57% of respondents say that their municipality is not part of a group working on digital transformation.
	Resistance to change 19/ On a scale of 1 to 5, at what level do elected officials show leadership and support for the digital transformation of urban infrastructure assets? (1 = no support, 5 = ongoing support). In all municipalities (all sizes), more than half consider that elected officials do not support digital transformation, and only 1% speak of continuous support. For large and medium-sized municipalities, the response rate for levels 1 to 3 is close. For small and very small municipalities, the response rate for the rest of the levels is slightly different.	



out of 24) limit digital transformation to the digitization of data. This needs to be considered in the activities of the developed framework. Addressing this issue requires awareness raising and training to raise the level, skills and capacity.

Respondents mentioned the digitization of data or certain asset management activities, but none mentioned the term "transformation" as a major change or planning in current practices. Therefore, this is an important issue, so there needs to be a clear definition and agreement on what digital transformation is for municipalities before steps are taken to achieve it. 'Nothing done' is a contribution and a big gap detected and confirmed by the results that the government must take into consideration.

Here are some definitions given by the respondents:

"digital transformation is the act of transposing paper data into digital or computerized data."

"Have digital databases of municipal urban infrastructure assets. Try as much as possible to digitize the data as a database, so it's more easily manipulated."

"Having a tool that allows us to go and get all the 'live' information there, really live, there, that's my definition."

"I'll be honest, I manage a large department but I'm not very "technological". This element brings an additional management to implement the system which can be quite complex. I understand that afterwards it makes management easier, but I don't have anything concrete to show us how it will make day-to-day management easier."

However, the implementation of a digital transformation strategy is not an end in itself. Although 8 respondents said that digital transformation is a necessity, whether planned in advance or done in an as hoc fashion, respondents agreed that it was inevitable:

"I'm sure it's coming. It's an obvious move. Except they don't know how to do it."

"All our archival systems are taking the whole paper vault and putting it in digital."

"At the governance level, the strategy is not well defined because it is not a priority for the municipality's leadership."

However, two municipalities in Quebec (large and medium) have already begun the digital transformation of their urban infrastructure assets in a more or less structured manner. Compared to other municipalities, they stand out, and it seems clear that their level of maturity is quite advanced. The following is an excerpt from an interview conducted with a pair of respondents, one of whom is the Director of Information Technology and the other the Director of Asset Management in the Geomatics department.

"The objective in relation to digital transformation is to digitize the information that the municipality has on its assets and centralize it for use in databases. To structure the information and to be able to retrieve functions, replacement values or life cycle times to be able to plan in future investments."

"Information management is important for further automation (urban lighting, citizen services, traffic control, etc.). The goal is to modulate and measure the service provided."

4.1.2. Category 2. Process / practice / management

Category 2 involves the review of the organization's processes, practices and management methods. It aims to improve collaboration between different stakeholders, to implement effective data management and to align the organization's practices with its overall management strategy (Table 5).

Question 3: Please explain how processes / practices / management have been transformed through digital tools and technologies, if applicable?

The data from the interviews highlight the fact that processes and practices have not been transformed. 33% of responses indicate that nothing has yet been done, and this is more evident in large municipalities as it represents 50% of responses. The responses are more

Table 9
Results of the analysis of survey responses.

Category / Subcategory	Question	Results
Digital/ information ecosystem	Systemic technology watch	24/ Does your municipality have a systemic technology watch? 54% of respondents say that their municipality does not have a systemic technology watch.
	Dedicated data management team	25/ In your municipality, is there a team that ensures the sharing of data on the built environment between departments? 67% of respondents say that there is no team in place to oversee data sharing.
	Systemic technology watch	22/ Please indicate the technologies most used by employees involved in the delivery and management of urban infrastructure in the municipality. Autocad and GIS are the most used technologies, with about 15% of responses each, followed by 11.2% for the query and complaint management system. The latest technologies used for BIM, CIM, 3D modeling, etc. are almost not used in municipalities. To better understand this distribution of responses, it was necessary to ask respondents in the interviews: why? Here is the range of answers: not seeing the usefulness; not knowing the benefit; not knowing the tools; or "employees prefer to work as usual and don't like change, it's easier and faster". So, according to them, the current workload is enough, they don't want to be burdened with new learning, etc.
Existing information systems	23/ On a scale of 1 to 5, how supportive is the Information Technology (IT) department of the digital transformation of urban infrastructure assets (1 = no support, 5 = ongoing support). Across all municipalities (regardless of size), almost half of the participants consider the IT department to be unsupportive of the digital transformation. The majority (>85%) of large municipalities, as well as small and very small municipalities think that the IT department does not support the digital transformation enough. But there is an exception for medium-sized municipalities where 26% of respondents think that IT provides regular or continuous support.	

nuanced are more nuanced for medium-sized municipalities, with 41% of responses where nothing is being done, and 33% where digital transformation is said to be in progress.

“Processes are being adapted even though most practices are still paper based.”

“Processes are going to be developed in the next few years in asset management but for now there is nothing concrete.”

Although there is little or no change in processes and practices, the pandemic has been an accelerator of the digital transition within municipalities. Indeed, 17% of respondents identify the pandemic and the shift to remote working as an accelerator of the transition.

“With COVID, we have made it possible to have more certificates and authorizations for construction permits available online for applications. Citizens can now do it directly from their homes on the Internet and we receive the digital documents they file when they

make their request. It makes it easier, it reduces the traffic at the department.”

“In terms of management, it is more telework that has changed management. We’ve gone virtual and that’s required a lot of adaptation for our managers.”

However, 12.5% of the responses indicate that practices and processes are being changed for the implementation of digital either voluntarily or randomly by the city.

“The city starts with the processes and then the software implementation follows. The development is done in-house which helps propel management to integrate asset management into the process.”

4.1.3. Category 3. Organization / structure / culture

Category 3 is about anticipating and solving problems related to the organization, structure and culture of a company. It provides guidelines in implementing effective organizational change management,

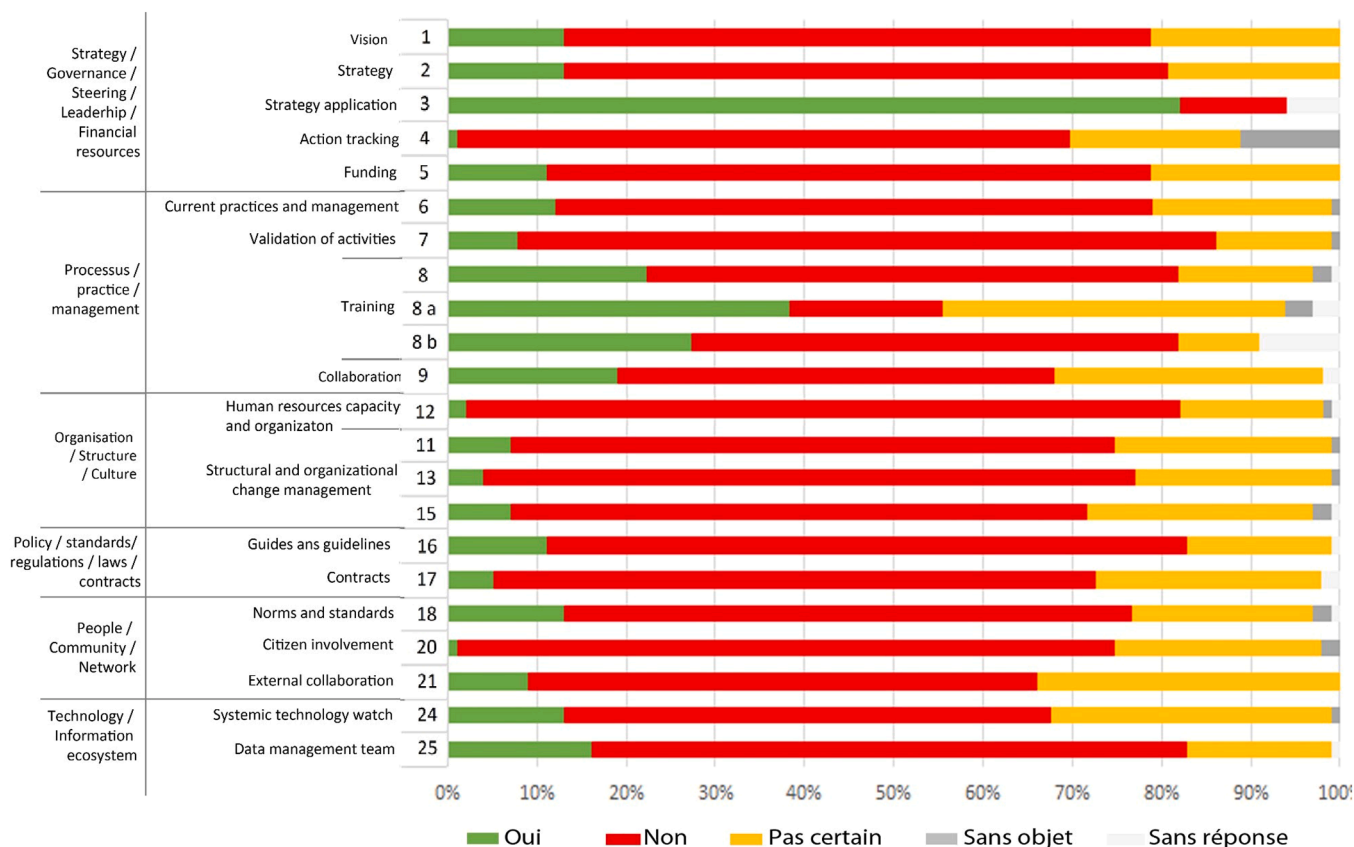


Fig. 2. Compilation of survey responses (all municipality sizes).

improving internal communication, providing training tailored to the needs of the organization, and creating an organizational culture conducive to business success (Table 6).

Question 4: Does your municipality have a specific structure in place to support digital transformation?

The answer to this question is overwhelmingly "no". The most frequent answer (54%) is that it is not something that is being thought of at the moment. The proportion of this answer is 40% in large municipalities, 66% in medium-sized municipalities and 100% in small and very small municipalities. The establishment of a specific structure is underway in some municipalities, representing 20% of responses for large municipalities and 33% of responses for medium-sized municipalities.

"No there is no structure, that's the problem."

"No, it's really all individual initiatives. Everyone does a little bit of initiatives like I do, I do like public works did to give way, to improve their management, but there's nothing that federates the whole."

"Maybe there's something coming, but to my knowledge, at our level, there's nothing. For the last 10 years we've been hearing: we're going to do it."

No municipality has a structure in place to support digital transformation. At best, the establishment of the structure is under consideration, but there is little concrete action. There is no structure in place and it is still too distant a goal for the municipalities interviewed.

4.1.4. Category 4. Policy / standards / regulations / laws / contracts

Category 4 aims to address the legal and regulatory issues that limit the implementation of a structured digital transformation. It seeks to identify, review, improve, and develop the contractual and regulatory context with the objective of establishing an environment conducive to

the implementation of a structured digital transformation. The sub-categories aim to establish transparent and consistent policies, accurate and comprehensive contracts and agreements, and regulations that facilitate digital transformation (Table 7).

Question 2: In what ways has your municipality changed its regulations, policies or contractual documents to facilitate digital implementation?

"Nothing has been done to date - it's not a priority," said one respondent from a large municipality, which sums up the general thinking. There are no changes, and when there are changes, they are minimal. The other testimonies confirm this:

"No. We're not there yet."

"At present, we have no policy for conversion to digital. We have nothing."

"On the digital implementation side there is nothing that has been done yet."

"I think we're still far, far, far, far away. It's all about organization and purpose."

80% of the responses from large municipalities and 67% from medium-sized municipalities state that nothing is in place regarding digital transformation in terms of regulations and contracts. There is a need to revise policies, regulations and contracts to enable the different sectors of the organization to move forward with their digital transformation.

"Currently, building permit application plans are submitted in paper form. After they are received at the city, they are sent to a company that does document scanning and then we receive it on disks or a flash drive. We can't simply ask citizens to file it digitized because we don't have the right. We have to change the regulations on permits

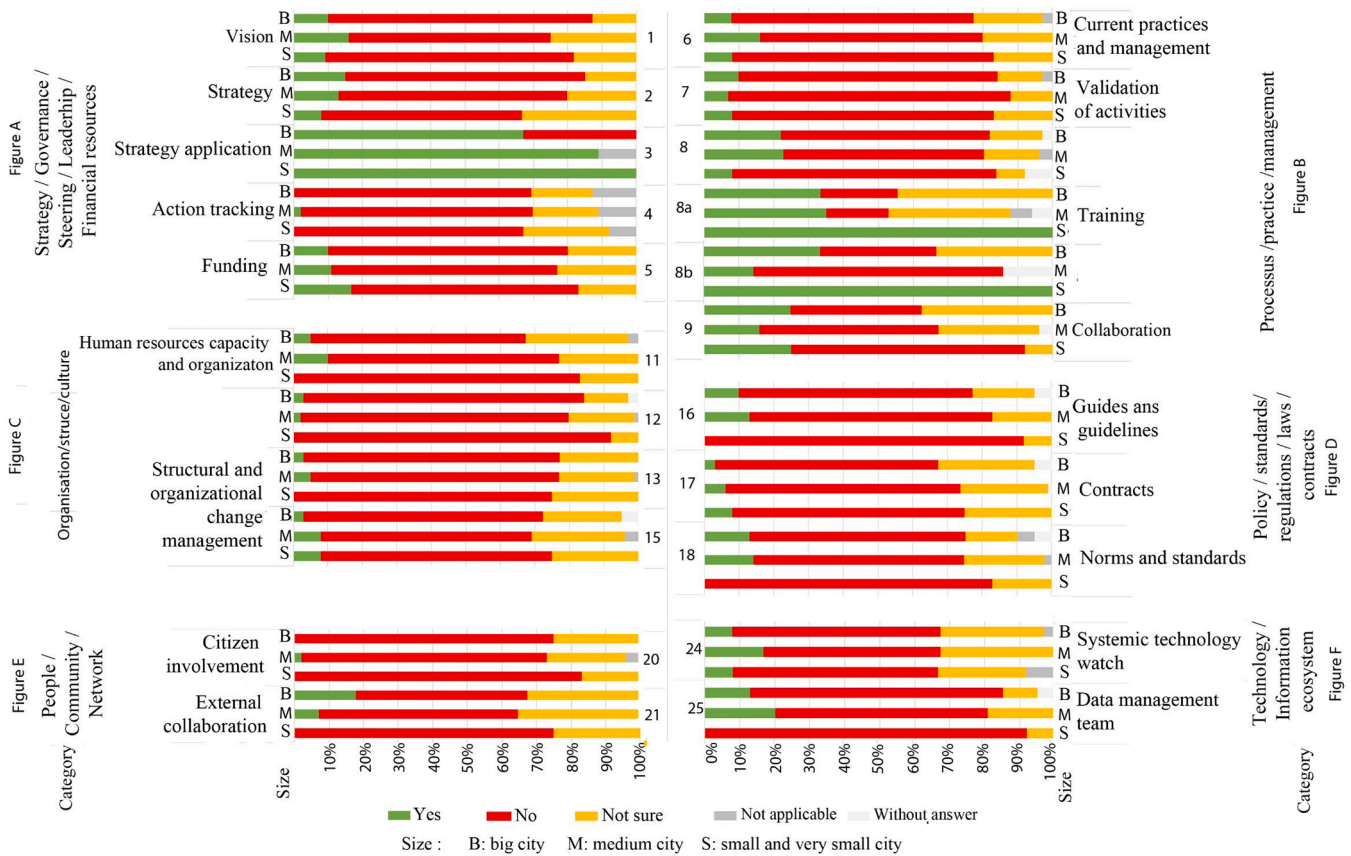


Fig. 3. Compilation of survey responses analyzed by municipality size.

and certificates to require that it be written in. We want to have a digital copy, right now it says 2 copies, we need to change that regulation.”

There is no structure in place, it is not a priority according to the respondents. However, there is a will to change that comes from employees and citizens (also known as a bottom-up or grass-roots approach). None of the municipalities participating in the survey have specific policies or regulations in place to facilitate implementation of digital practices.

“This change is not happening through a request from the board but is happening through employee initiative. So there are no processes or policies that drive the digital transition.”

“It’s the citizens’ demand to be faster and to know the data better but for the moment nothing legal. No regulation but a political wish.”

“It would be a political thing because it would be the Council that’s going to have to approve those kinds of changes there, those requirements there. Because they have to be written into the bylaw.”

According to 40% of respondents, the data format is specified and imposed in contracts. However, only five respondents mentioned the need to change regulations to facilitate digital implementation.

4.1.5. *Categorie 5. People / community / network*

Category 5 addresses a variety of people, community, and network issues such as limited leadership and staff vision, resistance to change, lack of human resources, and negative citizen perceptions. It proposes the establishment of mechanisms to engage and support all stakeholders in planning while monitoring their progress and evaluating their performance.(Table 8)

Question 5: What is the impact of digital transformation of urban

infrastructure assets on employees? And the services offered to citizens?

75% of respondents see a positive impact of digital transformation on their municipality. However, the interviews did reveal some resistance or obstacles. These include resistance to change due to advancing age, lack of staff and lack of expertise. 58% of respondents identify lack of staff as an important reason holding back digital transformation, this represents 30% of respondents from large municipalities, 75% from medium municipalities and 100% from small and very small municipalities. Here are some excerpts from the interviews:

“Some people are a bit lost, it stresses them out, especially people who are close to retirement. They didn’t know what a computer was. There are many of them. I have a few colleagues who have rushed into retirement because there are too many changes. It stresses them out, they are used to writing on a piece of paper, it’s not their business. There are many who are starting to think about retirement because of this.”

“Small towns are not able to have their own staff. We can’t afford to pay them for five days, but we don’t have any work to give them for five days anyway.”

“The lack of manpower. We digitize but what do we do with it? How do we manage it afterwards?”

4.1.6. *Categorie 6. Digital / information ecosystem*

This category aims to create a reliable, efficient and state-of-the-art digital and information ecosystem. It refers to the set of digital and technological components that interact with each other to enable the operation of an information system. The ecosystem may include software, hardware, networks, data management practices, methods and workflows, and end users (Table 9).

Question 6: How has digital transformation of urban infrastructure

Table 10
Occurrence of Barriers from Interviews by the theoretical framework.

Categories and subcategories	No. of references	% of responses
Strategy / Governance / steering / leadership / Financial resources	48	9%
Lack of guidance and/or leadership	2	0%
Lack of a strategic plan	16	3%
Unmanaged external pressure	6	1%
Lack of governance	9	2%
Lack of support from senior management	0	0%
Funding issues	15	3%
Process / practice / management	151	29%
Lack of collaboration	25	5%
Absence of data management	90	18%
Misalignment of current practices and management	36	7%
Organization / Structure / Culture	42	8%
Absence of organizational change management	13	3%
Lack of communication	8	2%
Lack of training	15	3%
Non-conducive organizational culture	6	1%
Policy / standards / regulations / laws / contracts	36	7%
Inadequate policy and support from elected officials	8	1%
Lack or incompatible standards / contracts	12	2%
Incompatible laws and regulations	16	3%
People / Community / Network	95	18%
Limited vision	37	7%
Resistance to change	22	4%
Lack of human resources	35	7%
Perceptions from the citizens	1	0%
Digital / Information Ecosystem	57	11%
Inadequate technologies and tools	6	1%
Incompatibility and/or inadequacy of existing information systems	51	10%
Intrants	85	16%
Maturity level / Lack of internal expertise	31	6%
Asset management / valuable creation	11	2%
Rhythm / long term / life cycle	34	6%
Terminology	9	2%
Total général	514	100%

assets impacted the municipality’s digital ecosystem?

20% of respondents think that digital transformation has had a positive impact. This represents 20% of responses from large municipalities and 40% from medium-sized municipalities.

“These are still relatively small municipalities, but I think that at the municipal level it would be an added value to have all the information digitized.”

A quarter of respondents say that digital transformation is neglected or not deployed in a structured way due to a lack of expertise on its implementation.

“There aren’t many vendors, and I’m very concerned about our dependence on IT vendors. We’re stuck with one vendor’s technology for a long contract.”

“It makes us more efficient, I really believe that, but my fear is also that it can make us vulnerable. I have a fear in terms of the vulnerability of organizations, whether it’s a municipality or whatever.”

4.2. Overview of compiled results

4.2.1. Analysis for all municipalities Vs Analysis by municipality size

The first observation is the high rate of negative responses across all categories. The second highest response rate was "Not sure". These responses tend more towards the negative according to the majority of respondents (interview section) who said, "We didn’t want to answer 'no' to all the questions." However, one exception was noted: response 3 is positive because the strategic plan is reflected in actions when present.

Results of the analysis by municipality size. The survey data was re-analyzed to account for the size of the municipality, as this factor, a municipality’s size, was frequently mentioned during the interviews. Fig. 3 summarizes the responses from this re-analysis.

When the same response is compared across scales, there is little difference for the majority of responses. Nevertheless, question 25 (on the presence of a team to manage and share data) is mostly negative for small municipalities. However, three responses to questions 3, 8a and 8b concerning small municipalities were positive, namely, respectively: whether the strategic plan is reflected in the municipality’s activities; whether the content of training is appropriate; and whether the number of people trained is sufficient. These answers differ from one size municipality to another, and this is understandable, as the smaller the municipality, the smaller the number of employees and therefore, in theory, the easier to manage.

When the set of responses analyzed by municipality size is compared to the set of responses analyzed for all sizes combined, the number of negative responses dominate in both Figs. 2 and 3. Thus, there is little difference between the responses, which leads to the conclusion that municipality size does not have a significant impact on digital transformation of municipal urban infrastructure assets lifecycle practices.

4.2.2. Coding results by framework category

Table 10 shows the categorization and count of coded instances organized per the theoretical framework. Subcategories with too low a percentage are assigned to "Extrant" and can be removed from the framework. "Intrants" are subcategories that were frequently mentioned in the interviews and were not included in the original framework.

As shown, analysis and categorization of the coded responses from the interviews indicate that the most frequently mentioned consideration is "data management". The second consideration is "existing information systems". The third consideration is "limited vision". The fourth consideration is "compatibility of current practices". Finally, the last important consideration is "availability of human resources".

Asset management, as a process, is not well known or mature enough in Quebec municipalities. Moreover, among the respondents, those who think they are familiar with it focus on asset management at the

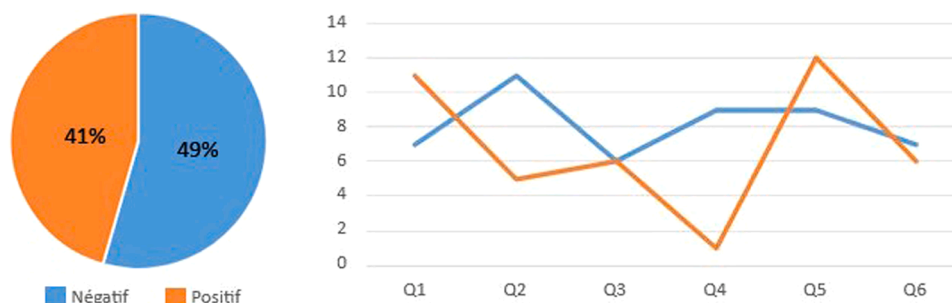


Fig. 4. Portion and analysis of feelings according to the interview questions.

Table 11
Responses to survey and interview objectives.

Survey objectives	Responses to the objectives
To provide an overall picture of digital transformation efforts for urban infrastructure assets in the Canadian municipal environment.	Few efforts are made, it is not a problem of resistance to change but mainly a lack of knowledge of the process to follow and its benefits. None of the 44 municipalities surveyed in Quebec, regardless of size, have undertaken digital transformation in a systemic and structured manner. The level of maturity of urban infrastructure assets management and the level of maturity of digital transformation do not seem to be advanced enough in these municipalities. The brakes categorized in the framework are all confirmed and accentuated.
Identify the barriers and challenges of digital transformation (buildings + urban infrastructure) faced by Canadian municipalities.	
Understand the organizational structure in place and whether there are any initiatives taken or thought of to drive organizational change.	No organizational structure is put in place. A few separate initiatives are undertaken such as the digitization of data. These initiatives are undertaken as pieces of a puzzle scattered in different departments of the municipality with no structure to bring it all together. No strategic plan, no strategy is undertaken or planned and therefore no impact is identified.
Understand the scope of digital transformation's strategy for urban infrastructure assets in the municipality and identify gaps and impact on the following: - regulations, policies and contracts - current processes and practices - human resources - the municipality's digital ecosystem	No review, so impossible to identify. No adopters, so impossible to identify. A glaring lack of human resources in the field. No initiative is undertaken to train, develop internal skills, or to undertake a recruitment plan. It is based on the needs of each department and is considered outdated or obsolete by respondents. There are also problems with the interoperability of tools, and those that exist do not keep up with the evolution of technology.

operational level.

“Everything is to be done, people mix up asset management and project management. Initiatives are only taken if direction comes from above.”

In addition, the notion of time came up very often, with more than half of the interviewees referring to it. The pace and length of initiatives related to digital transformation urban infrastructure assets demotivate municipal employees. Digital transformation urban infrastructure assets is a project that generates its benefits in the long term, whereas most managers are focused on concrete results in the short term.

Terminology is also an issue with the specific language of the municipal environment, employees must agree on the same definitions and names of assets and processes.

4.2.3. Sentiment analysis

Sentiment analysis reveals several elements pertaining to digital transformation of urban infrastructure assets within municipalities. The number of positive and negative feelings is very close, 41% and 49%, respectively. Negative feelings include fear, frustration, misunderstanding, anger and reluctance. Positive feelings include joy, hope, motivation and desire. However, the detection of feelings according to the interview questions is very different (Fig. 4).

Thus, a varying number of reactions and emotions were expressed. There is no great variation in the number of negative feelings between all questions (blue line). While the number of positive feelings (orange line) clearly varies from question to question from its minimum in Q4 to its maximum in Q5.

Q1 on the definition and vision of digital transformation elicits contrasting reactions between hope and incomprehension. For instance, a respondent indicated that:

“Be able to look up all the information live there. Cool! It's ideal but hard to pinpoint what's really important in the face of total disarray in our business units.”

Q2 on changing the regulations, as well as Q4 on setting up a digital transformation support structure, provoked much more negative reactions that tended towards frustration and anger.

There is a meeting point of feelings in Q3 where respondents express opposite emotions. On the one hand, there is satisfaction with the acceleration of digital transformation generated by the pandemic. On the other hand, there was dissatisfaction, as processes and practices were slightly transformed. Moreover, digital transformation is done in a random, unstructured and unfederated way by the municipality.

Q5, on the impact of digital transformation on employees and

citizens, elicits many mixed responses, seemingly dominated by age-related fear.

“There are colleagues who are lost, it stresses them out, especially those close to retirement. I have a few colleagues who have rushed into retirement because they are afraid.”

However, after reflection and discussion with the respondents, most of these negative emotions are not a form of resistance to change. It has more to do with dissatisfaction with the current situation because it is not being addressed:

“...especially, it's not their role at all, and worse, nobody's role.”

Therefore, it is a form of municipal employee protest that can really push towards positive change.

The analysis of the feelings reveals several findings and conclusions. This analysis allowed us to gain a better understanding of the human being and the issues at stake in the digital transformation. We noted the variation in emotions and reactions from one question to another. We wanted to better understand why frustration and anger is a form of resistance to change. After reflection and discussion with the respondents, most of these negative emotions are not a form of resistance to change.

It has more to do with dissatisfaction with the current situation, as it is not being addressed. Therefore, it is a form of protest by city employees that can really push for positive change. Sometimes this anger is related to the administrative burden in the municipal environment, which has an impact on the behavior of the employees. Time is therefore an indicator to be taken into consideration to keep employees engaged and motivated. On the one hand, there is contentment with the acceleration of the digital transformation generated by the pandemic. On the other hand, there is dissatisfaction, as processes and practices are slightly transformed. In addition, the digital transformation is done in a random, unstructured and unfederated way by the city. Without the analysis of feelings, we would never have known the true interpretation of the respondents' behavior. Sentences expressing anger would have been associated with resistance to change, contrary to reality. Also, the municipal organization must pay attention to its employees and their behaviours and concerns. Finally, it is the employees who will apply the activities mentioned in the framework developed in the article.

Sentiment analysis has given us a better understanding of employees' reactions and attitudes towards digital transformation. This helps us to identify the main barriers to digital transformation and to propose effective solutions to overcome them. Using sentiment analysis, it is also possible to evaluate the effectiveness of different communication and

Table 12
Validation and extension of the framework.

	Initial framework (Table 1)	Final framework (Table 10)	
1	Strategy / Governance / steering / leadership / Financial resources 1. Lack of guidance and/or leadership 2. Lack of a strategic plan 3. Unmanaged external pressure 4. Lack of governance X 5. Lack of support from senior management X 6. Funding issues	Strategy / Governance / steering Systemic vision .1 Strategic plan .2 Funding .3 Steering and coordination .4 External pressure .5	1 ✓ Intrant X Extrant
2	Process / practice / management 7. Lack of collaboration 8. Absence of data management 9. Misalignment of current practices and management	Process/Practice/Management/Organization/Structure/Culture Collaboration .1 Current practices and management .2 Structural and organizational change management .3 Communication .4 Training .5 Organizational culture .6	2
3	Organization / Structure / Culture 10. Absence of organizational change management 11. Lack of communication 12. Lack of training 13. Organizational culture	Data management ✓ Quantity and storage .7 ✓ Ownership and accessibility .8 ✓ Reliability and updating .9 ✓ Security and control .10 ✓ Format and share .11	3
4	Policy / standards / regulations / laws / contracts 14. Inadequate policy and support from elected officials 15. Incompatible standards / contracts 16. Incompatible laws and regulations	Policy /standards/regulations/laws/contracts Politics and support of elected officials .12 Standards/contracts .13 Laws and regulations .14 ✓ Guides and Guidelines .15 ✓ Terminology .16	4
5	People / Community / Network 17. Limited vision 18. Resistance to change 19. Lack of human resources 20. Perceptions from the citizens X	People/community/network Leader/Champion .17 Resistance to change .18 Human resources .19	5
6	Digital / Information Ecosystem 21. Technologies and tools 22. Existing information systems	Technology / Digital / Informational Ecosystem Existing technology and tools .20 New technologies and collaborative tools .21	6

awareness strategies for digital transformation. Sentiment analysis is an important tool to better understand the behaviours and concerns of employees. Organisations need to pay attention to their employees and their behaviours to keep them engaged and motivated. Ultimately, it is the employees who implement the changes, and their satisfaction and commitment are essential for a successful digital transformation.

4.3. Responses to survey and interview objectives

The responses to the survey and interview objectives are summarized in Table 11.

5. 4. Discussion

As shown throughout the paper, the preliminary framework served to structure and guide research activities aimed at operationalizing, validating and, if applicable, extending it. In large part, the results from both the survey and interviews confirms and validate the categories developed in the preliminary framework. However, in an effort to extend and make the framework more applicable, category and subcategory titles, which were originally developed as barriers and challenges, were changed using more neutral terms in the final framework. For example, "lack of guidance" is replaced by "Guidance and coordination". Also, some categories were moved and reorganized. Some elements were removed while others were added based on the research process. Table 12 presents the mapping between the initial and final framework.

The encoding of subcategories 1, 4 and 5 (Table 11) is not clear enough because of the proximity of meaning. In addition, these subcategories had very low representation in the analysis of the results

from the workshops and interviews. Therefore, it was decided to combine them into one subcategory, "Guidance and coordination". The leadership portion of subcategory 1 refers to a trait and was moved to category 5 by adding the term "champion". This trait is already observed in some leaders who are seen to drive municipal innovation.

All of the analytical methods used have identified subcategory 8: "Data Management" as a key issue in the digital transformation of urban infrastructure assets in Quebec municipalities. However, as this is an ever-evolving field, the stakes of digital assets continuously grow as sources of data grow and reliance upon them becomes more and more important. New considerations also emerge, namely the evolution of technologies and the context, especially in the post-COVID period. The world is now facing massive digitization, especially with respect to asset data. To this end, some respondents expressed that the pandemic has accelerated some of the digital transformation processes in their municipality. Most of the feedback relating to this aspect relates to collaboration tools and the ability to work remotely, which has allowed the use of digital technologies to grow within municipalities. Furthermore, data management includes many aspects that cover a broad number of domains. As such, it was introduced as a category of its own.

Categories 2 (Process / Practice / Management) and 3 (organization / Structure / Culture) are merged, but sub-categories 7 (Collaboration) and 11 (Communication), although close in meaning, were not merged. However, it is necessary to make these clarifications: Collaboration is the action of working with someone to accomplish a certain task or benefit each other, through cooperation, alliance, association, etc. Communication means the exchange of information, feelings, etc., transmission by speech, writing, gestures, etc. Communication may or may not be beneficial, but collaboration has benefits or expectations.

The subcategory 17 "limited vision" became "systemic vision". In fact,

Table 13
Digital Transformation Framework supporting the planning, delivery, use and management of municipal urban infrastructure asset.

Category	Subcategory	Proposed actions/solutions/guidelines	Results
Strategy / Governance / Steering	Systemic vision Strategic plan Financing Steering and coordination External pressure	<ul style="list-style-type: none"> • Develop a common vision on DT of urban infrastructure assets and promote this vision to all levels and departments of the municipality. • Verify the existence of actions supporting DT of urban infrastructure assets in existing strategic plans. • Design an implementation strategy for DT of urban infrastructure assets. • Define the activities (actions) of the strategy. • Schedule these activities over time. • Implement activities (actions) of the strategy. • Develop a strategic plan or adapt and enrich the one related to DT of urban infrastructure assets. • Follow-up of actions. • Evaluate the performance (accountability) of the activities of this Strategic Plan for DT of urban infrastructure assets. • Include funding for DT of urban infrastructure assets in the Three-Year Capital Program during project portfolio planning. • Seek and provide for various sources of funding. 	<p>A shared and communicated vision.</p> <p>A clear strategy and action plan well undertaken, monitored and rigorously followed.</p>
Process / Practice / Management / Organization / Structure / Culture	Collaboration Current practices and management Structural and organizational change management Communication Training Internal expertise / maturity level Organizational culture	<ul style="list-style-type: none"> • Review current processes/practices and identify what reinforces siloed work. • Identify and re-implement existing interdisciplinary collaborative approaches in the municipality (e.g. LEAN Management, Integrated Design Process). • Establish and incorporate interdisciplinary collaborative approaches. • Join groups (e.g. committee, association) working on the DT of urban infrastructure assets or related topics and develop strategic partnerships. • Define tasks and activities to initiate, execute and analyze DT of urban infrastructure assets projects. • Circumscribe and define new roles and responsibilities supporting the implementation of DT across the urban infrastructure assets life cycle. • Establish a core team that validates all activities relating to DT of urban infrastructure assets. • Prepare criteria for measuring and monitoring performance, maturity and organizational capacity. Gökalp & Martinez [22] have developed a DX-CMM process capability maturity model based on 18 maturity models. Their model is based on a holistic and integrated approach applicable to all sectors. • Plan the change and put it into concrete actions (including identification of functional and technical requirements) for the DT of urban infrastructure assets. • Develop a list of skills needed to effectively advance the DT of urban infrastructure assets. • Develop a successful communication strategy: develop a detailed communication plan, set up clear communication channels, develop an engaging message. • Ensure continuous motivation and communication with stakeholders. • Plan professional trainings to familiarize them with the DT of urban infrastructure assets. The content of the trainings should be appropriate to the DT of urban infrastructure assets (trainings in the areas of professional development, not just introduction to software functionality). • Ensure that a sufficient number of employees have access to these DT of urban infrastructure assets implementation trainings. • To develop recognized and certified training offers, covering all aspects of NL, in conjunction with key players in the academic world. 	<p>Harmonized practices, processes and management areas with an efficient flow of information allowing employees to generate maximum value for the citizen.</p> <p>Optimized approaches supported by a continuous improvement process: from planning, to implementation and maintenance, to life cycle maintenance.</p> <p>A framed, structured and organized change.</p> <p>An increase in competence and capacity to succeed in the DT of urban infrastructure.</p>
Data management	Quantity and storage Ownership and accessibility Reliability and updating Security and control Format and sharing	<ul style="list-style-type: none"> • Understand asset information management and differentiate it from document management. • Identify information management practices that are consistent with the urban infrastructure assets management. • Designate and/or train a dedicated data management team. • Learn about examples of digital models generated from a physical model and plan for the beneficial need of the municipality's assets. Develop the municipality's own components. • Thoroughly study and implement an effective data management strategy including: the need for level of detail 	<p>Managed, reliable and up-to-date information, accessible at the click of a button, secure, necessary for the assets built or to be built throughout their life cycle.</p> <p>Sustainability of information and assets.</p> <p>Effective management of construction projects, and sound management of urban infrastructure, digital assets and data as an asset.</p>

(continued on next page)

Table 13 (continued)

Category	Subcategory	Proposed actions/solutions/guidelines	Results
Policy / Standards / Regulations / Laws / Contracts	Policy and support from elected officials Standards / Contracts Guides and guidelines Laws and regulations Terminology	<ul style="list-style-type: none"> and quantity of data, its accessibility, reliability, security, format, updating, cost, etc. • Work in collaboration with the different departments of the municipality, the data requirements for better decision making. • Develop information requirements and uses. • Define roles and responsibilities for information management. • Put in place the necessary procedures and mechanisms to ensure data security. 	<p>Clear and consistent policies governing the implementation of DT and regulations to facilitate its application across the industry.</p> <p>Clear and comprehensive contracts that facilitate the use of DT in collaborative ecosystems.</p> <p>Up-to-date, relevant guides, documents and standards that facilitate and support effective, quality work.</p>
		<ul style="list-style-type: none"> • Focus on the parameters that frame the various policies and directions for DT and Asset management both supporting the shared vision and implementation goals. • List the norms and standards used by the municipality, including established national or international standards (e.g., ANSI, BS, AS or ISO). • Develop guides and documents to support the application of the DT of urban infrastructure assets (e.g., a BIM deployment guide, an e-permit delivery guide, a GIS user manual). These guides and documents should take into consideration the specific context of the municipality and communicate best practices, techniques and strategies. • Identify and learn about standards covering information management and data creation for built assets (e.g. ISO55000 and ISO19650). • Adapt and adopt standards to facilitate asset management and asset information management. • Revise the City's bidding criteria, contract clauses including intellectual property (IP), property rights to align with DT of urban infrastructure assets projects. • Develop contractual and financial mechanisms adapted to the new business models supported by the DT of urban infrastructure assets and clarify data ownership, insurance and other issues. 	
People / Community / Network	Leadership / Champion Resistance to change Human Resources	<ul style="list-style-type: none"> • Develop a dictionary (unify the language) of municipal terms, especially those appropriate to the workforce. • Identify and empower leaders and champions for DT of urban infrastructure assets implementation while preparing the necessary resources to coordinate and develop DT of urban infrastructure assets activities. • Develop strategic partnerships to exchange complementary skills and provide mutual support and motivation, (local, national and international partnerships). • Develop a network of professional relationships that benefit the municipality. • Increase the municipality's skills in asset management and information management. This can be achieved by implementing a support plan with a holistic approach. • Prepare a plan to increase human resource capacity in sufficient numbers (bank of experts). • Develop a resource development management plan for DT of urban infrastructure assets (e.g. employment, promotion, reward, etc.) 	<p>Dedicated and competent actors leading DT and GAUI.</p> <p>Resilient actors with a capacity for progressive adaptability.</p>
Technology / Digital / Information Ecosystem	Existing technology and tools New technologies and collaborative tools	<ul style="list-style-type: none"> • Mapping existing technologies and identifying needs and development paths to be prioritized. • Develop a systemic technology watch that allows for the integration of information throughout the urban infrastructure assets lifecycle (potentially affecting service quality). • Establish requirements for the implementation of collaboration platform(s) based on open and neutral formats. • Learn about "common data environments" and see the utility and applicability to the municipality. 	<p>A collaborative work environment supported by reliable technologies that allow employees to collaborate effectively, to deliver the best service in less time.</p>

the analyses revealed that the systemic vision of digital transformation of municipalities is not developed or well thought out. In addition, its location in the preliminary framework is not appropriate for category 5, so it has been moved to category 1. Finally, subcategory 22 has been renamed "new technologies and collaborative tools".

It is necessary to explain the difference between sub-category 12 "training" and the input "internal expertise/maturity level". Although lack of expertise is related to lack of training in some respects, it is better to include lack of expertise as a new sub-category in its own right.

The need for "guidance and guidelines" is an emerging input especially at the survey level, so its importance is paramount. "Terminology" is also an emerging input, but at the interview level. The need to create a dictionary and agree on a common vocabulary is paramount for all parties to understand each other and for the digital transformation of urban infrastructure assets to be successful. These two inputs are added as sub-categories under the category of "policies/standards/regulations/legislation/contracts".

The input "rhythm/long term/life cycle" refers to the notion of time,

which came up very often in the interviews and workshops. Respondents pointed out that the pace of public administration is very slow, in addition to all the hierarchical procedures. They also believe that it is difficult to sustain digital transformation, being a long-term project throughout the life cycle of the asset. Therefore, it is not possible to incorporate this input into the framework, but it is clearly an issue to be considered and addressed in action planning.

After analysis, the "conviction of citizens" was reconsidered and removed because its score is zero in different analyses. Previously considered as obstacles to digital transformation, citizens are, on the contrary, important elements in the change and the transition to digital. In most of the municipalities studied, it was found that the change was brought about by a desire on the part of citizens

From this analysis and subsequent reconfiguration emerged a final framework that is presented in [Table 13](#).

6. Conclusion

This paper presents the results of the second stage of a longitudinal research project aimed at helping cities conduct a planned, and structured digital transformation. This digital transformation will lead to the integration of information sources and implementation of digital twins to better meet the needs of citizens and maintain the quality of service over the long term. The research presented in this paper provides further insight into the challenges municipalities face today with respect to the successful digital transformation of urban infrastructure assets. It provides a framework that outlines in a systemic way how to reduce and/or eliminate these barriers and challenges. The analyses revealed that data management is one of the key issues with digital transformation. Moreover, the findings relate that digital transformation is not well defined and the systemic vision of digital transformation is not developed and thought through within municipalities. The analyses show that little is done to operate digital transformation in a structured and organized way to accommodate and support change.

The majority of the municipalities analyzed, regardless of size, do not understand the benefits of digital transformation. They remain relatively ignorant on the subject and their lack of knowledge leads to a lack of interest in digital transformation. All this leads to fragmented initiatives that hinder effective digital transformation. This lack of effort on the part of the municipalities generates a backlog and a lack of digital maturity that is becoming more and more urgent to overcome.

This study also highlights the critical lack of human resources, expertise and appropriate training to support digital transformation, regardless of the size of the municipality.

In Canada, municipalities are under the jurisdiction of the provinces, which make the laws. From the digital transformation perspective of municipalities, some restrictive laws and regulations do not allow for simple decisions. They must be revised and adapted. Urban sprawl, being a characteristic of the Canadian context, further increases the amount of urban infrastructure to be managed. It is therefore difficult to implement a systemic approach covering all urban infrastructure, which justifies the use of technology, such digital twin for municipalities.

Limits

A first limitation of this research is the maturity level of digital transformation and asset management within the organizations studied. On the one hand, these two areas are emerging and on the other hand, the municipal/public sector underestimates digital transformation and is lagging in digital transformation and urban infrastructure assets management.

A second limitation of the interviews and workshops was that they were conducted remotely due to the health context of COVID-19. This method has its limitations, as the absence of a physical meeting sometimes prevents us from properly observing and taking into account the respondents' non-verbal language. This can lead to a possible bias in the

interpretation that can be made by the researchers.

The framework developed provides guidelines that governments can benefit from by anticipating monitoring in advance. However, this analysis could not address the prioritization of actions within the framework. This framework has not been tested given the long time frame for digital transformation. Future research is needed to test and adapt it to a specific municipality. The creation of specific guides to accompany this framework should also be envisioned to support it.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors are unable or have chosen not to specify which data has been used.

References

- [1] E. Champagne, C.É. Beaudry, The special status of large municipalities in Canada: promises and limitations, *Górnosl. Stud. Socjol.* 256 (2018).
- [2] Pourreaux, S., & Galipeau, R. (2016). Addressing the infrastructure maintenance deficit. *Le Québec économique* 06: Le défi des infrastructures, 303.
- [3] Creusé, E. (2021). The new challenges of the digital transition of municipalities.
- [4] Kaufmann, V. (2014). *Back to the City: Motility and Urban Transformations*. PPU Press.
- [5] D.J. Caron, E. Lyall Nelson, S. Bernardi, Municipal governance and information: an exploratory study of the optimal use of 311 data, *Can. Public Adm.* 63 (4) (2020) 602–619.
- [6] Moritz, M. (2016). Big data and eco-intelligent municipalities. *I2D-Information, data documents*, 53(1), 62–63.
- [7] Ministère des Affaires municipales et de l'Habitation. (2020). Décret 1214-2019 du 11 décembre 2019.
- [8] W. Liu, J. Zhang, Y. Shi, P.T.W. Lee, Y. Liang, Intelligent logistics transformation problems in efficient commodity distribution, *Transp. Res. Part E Logist. Transp. Rev.* 163 (2022), 102735.
- [9] W. Liu, S. Wei, K.W. Li, S. Long, Supplier participation in digital transformation of a two-echelon supply chain: monetary and symbolic incentives, *Transp. Res. Part E Logist. Transp. Rev.* 161 (2022), 102688.
- [10] N. Halpern, D. Mwesiuno, P. Suau-Sanchez, T. Budd, S. Bråthen, Ready for digital transformation? The effect of organisational readiness, innovation, airport size and ownership on digital change at airports, *J. Air Transport Manag.* (2021) 90, <https://doi.org/10.1016/j.jairtraman.2020.101949>.
- [11] N. Lafioune, E.A. Poirier, M. St-Jacques, Managing urban infrastructure assets in the digital era: challenges of municipal digital transformation, *Digital Transformation and Society review* (2023).
- [12] M. Huberman, M.B. Miles, *Analyse Des Données Qualitatives: Recueil De Nouvelles Méthodes*, De Boeck Université, Bruxelles, 1991.
- [13] Miles, M.B., & Huberman, A.M. (2003). Analysis of qualitative data. De Boeck Supérieur.
- [14] Van der Maren, J.-M. (1995). *Méthodes de recherche pour l'éducation*. Montréal: presses de l'Université de Montréal/De Boeck Université.
- [15] Liu, B. (2012). "Sentiment analysis and opinion mining. Synthesis lectures on human language technologies," 5(1), 1–167.
- [16] Elmurugi, E. (2020). "Approaches based on sentiment analysis and supervised learning techniques for robust reputation systems in the e-commerce environment" (Doctoral dissertation, Graduate School of Technology).
- [17] Thomas, B. (2013). "What Consumers Think about brands on social media, and what businesses need to do about it", Report, Keep Social Honest.
- [18] N. Engonopoulos, A. Lazaridou, G. Paliouras, K. Chandrinou, ELS: a word-level method for entity-level sentiment analysis, in: *Proceedings of the International Conference on Web Intelligence, Mining and Semantics, 2011*, p. 12.
- [19] Zhou, H. & Song, F. (2015). "Aspect-level sentiment analysis based on a generalized probabilistic topic and syntax model," *The Twenty-Eighth I.*
- [20] N. Farra, E. Challita, R.A. Assi, H. Hajj, Sentence-level and document-level sentiment mining for arabic texts, in: *Proceedings of the IEEE International Conference on Data Mining Workshops, 2010*, pp. 1114–1119.
- [21] A. Yessenalina, Y. Yue, C. Cardie, Multi-level structured models for document-level sentiment classification, in: *Proceedings of the Conference on Empirical Methods in Natural Language Processing, 2010*, pp. 1046–1056.
- [22] E. Gökalp, V. Martinez, Digital transformation maturity assessment: development of the digital transformation capability maturity model, *Int. J. Prod. Res.* 60 (20) (2022) 6282–6302.