

# Comparison of Asset Management Practices in Norwegian Oil & Gas and Road Infrastructure: Results from Industry Survey

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**Abstract**— Road tunnels are a cost center of an infrastructure due to the high capital and operating expenditure involved. The long design life and increasing demands from stakeholders present a challenge for efficient management of road tunnels. Asset Management is an effective approach for systematically managing the lifecycle of assets, which is increasingly recognized in various industries, including Road infrastructure. The Norwegian Road authorities have initiated recent projects to implement this concept. Asset Management practices in the Norwegian Oil & Gas (O&G) industry are believed to be mature, and there exists a potential for a cross-industry knowledge exchange that is yet to be explored. Available literature shows that Asset Management awareness and implementation is insufficiently documented for the O&G and Road infrastructure. As part of the ongoing Ph.D. study, a survey was conducted to map these practices in both industries and other major industries in Norway. This paper presents the survey findings and compares the O&G and Road infrastructure industry to assess the current status of Asset Management. The survey further identifies key areas of improvement for implementing Asset Management in both industries. The results are based on input from well-experienced respondents from large organizations. Respondents from O&G acknowledged Asset Management in their organization despite the gaps showing inconsistencies in the underlying details. Limited asset awareness is seen in both industries, particularly in the Road infrastructure. Both sectors are highly focused on improving safety, lowering maintenance costs, and increasing asset availability. However, the overall results indicate a relatively superior level of practice is established in O&G industry. This creates an opportunity to emulate the Asset Management practices from O&G to Road infrastructure, which could only be the start of the Asset Management journey.

**Keywords**—asset management, oil & gas, road tunnels, best practices, knowledge transfer, cross-industry comparison, survey

## I. INTRODUCTION

A well-planned Road infrastructure is vital to the growing economy and healthful living. Road tunnels are crucial for bypassing traffic in dense cities and connecting scattered lands. Norway is one of the most tunnel-dense countries, where the reason being its uneven topography comprising of numerous fjords and islands. To this date, the Norwegian road authorities were challenged with constructing and operating more than 1250 road tunnels. The list includes the world's longest Lærdal tunnel (24.5 km), the longest subsea tunnel, Ryfast tunnel (14.3 km), and the ongoing Rogfast tunnel project, which will become the longest and deepest subsea tunnel in the world NPRA (2023). An overview of Norwegian road tunnels is presented in Table 1. The expected tunnel design life of 100 years requires tunnels to comply with new

regulations and upgrade with advanced technology. The useful design life of tunnel equipment in Norway is 25 years (NPRA, 2022) and significant value can be realized from optimally maintaining these equipment, which is an under-researched topic with growing interest. In Norway, nearly 200 tunnels are on the European and National roads were to be upgraded to comply with the minimum safety regulations NPRA n.d. Comparing today's tunnel with the past, major differences in the complexity, safety, risks, and cost are noticed, making modern tunnels a complex system that often resembles a small process plant (Norwegian Tunnelling Society, 2008). The complexity is further expanding with the newly built and upgraded tunnels incorporated with advanced communication systems, state-of-the-art cameras and sensor technology, and extensive safety and fire prevention systems. These technologies allow tunnels to be monitored through traffic control centers, which is another example of increasing complexity due to human-machine interaction. Besides, the current experience-based practices are gradually being replaced by technology-enabled risk and data-driven decisions. Furthermore, the cost of tunnel construction was estimated to have increased tenfold in 2017 compared to the year 2000 (Norwegian Tunnelling Society, 2017). This cost has further escalated with the recent events of the COVID-19 pandemic and the Russia-Ukraine conflict, where the economy seems to be nearing towards recession. Apart from the physical assets, it is equally important for organizations to effectively manage the individually growing human, financial, information, and other intangible assets in an integrated manner.

With all these developments, and the continually growing road traffic, rising public expectations, increasing digitalization, and enforced safety & sustainability regulations, a systematic and structured approach is vital to manage tunnels optimally throughout their lifecycle. In general, it can be said that modern assets require a modern management approach.

Table 1. Overview of road tunnels in Norway NPRA (2023)

Single-tube tunnels	Multi-tube tunnels	Subsea tunnels	Tunnels managed by NPRA	Total no. of tunnels
1075	134	40	587	1266

The Norwegian Public Road Administration (NPRA) is responsible for managing tunnels on the European and National roads in Norway. Managing a large number of tunnels of varying lengths, types, and geographic locations

can be demanding for the road authorities. For instance, the maintenance backlog for national and county roads in Norway is estimated between 28 and 46 billion (NOK Consulting Engineers' Association, 2021). Tremendous efforts are required to settle the accumulated work and manage the additional infrastructure projects. The current strategy in managing road tunnels in Norway is widely believed as 'traditional', and a shift towards a systematic approach has been realized.

Oil & Gas (O&G) is one of Norway's major and mature industries which has been operating since oil was first discovered in 1969 (Ministry of Petroleum and Energy, 2020). In recent years, the complex processes in O&G have advanced with evolving technology and the surfacing of new methods of managing assets. Moreover, safety has progressed significantly on the Norwegian Continental Shelf (NCS) as the industry learned from past incidents and abide by the strict regulations enforced by the Petroleum Safety Authority. The tumbling oil prices of 2015 compelled the industry to realize its unhealthy cost structure and high break-even prices (Equinor, 2017). Since then, the O&G industry has reformed substantially, and the 2014 break-even prices were reported at 35% lower in 2020 (Rystad Energy, 2020). Although there is always room for further improvement, yet the established practices of the O&G industry can be exploited in other industries, such as the Road infrastructure.

Comparing O&G to Road tunnels, a list of similarities and differences are observed. Significant capital investments, similar lifecycle of electrotechnical equipment, safety, high Operation & Maintenance (O&M) cost, dispersed asset location, etc. are some of the similarities.

Looking at the differences, both industries have separate business models, where O&G is profit-oriented, the tunnel industry is based on funding from the government. Moreover, the asset users vary in both industries as qualification and training are mandated for offshore personnel, tunnel users are general public who are expected to self-rescue in case of unwanted incidents. Another aspect is the complexity, where O&G has large-scale assets constituting of numerous systems requiring onshore-offshore coordination, road tunnels have relatively fewer systems and are less complex. Criticality is one of the key differentiators in this comparison as oil installations are subjected to devastating consequences in case of a major incident, which is not too hard to occur. The stakes are further high if there is drilling going on the platform. An overview of both industries in terms of similarities, trends, risks, and challenges from an asset management perspective is found in Taha *et al.* (2021).

#### *A. Asset Management*

The concept of Asset Management emerged in the O&G and Public sectors in the 1980s (Institute of Asset Management, 2015). It was driven by a change in the traditional thinking towards a lifecycle approach by balancing of safety, cost, and value. It is a relatively new field that is still gaining global recognition. The first International Standard for Asset Management, ISO 55000 series, was published in 2014 and enables organizations to assess their performance and follow guidelines to initiate or implement Asset Management. ISO 55000 series is based on PAS55, a Publicly Available Standard developed by the British

Standard Institute in 2004 (Institute of Asset Management, 2015). A prominent Asset Management manual in the infrastructure industry is the International Infrastructure Management Manual (IIMM), which guides the implementation of ISO 55000 standards. Since its existence, Asset Management has been adopted by various industries, where its mandate or legal requirements are still at its infancy. The scope of Asset Management is vast, and is well-presented by the 39 subjects in the Asset Management Landscape, prepared by the Global Forum for Maintenance and Asset Management (GFMAM) (2014). Industries may have non-identical consideration for the various Asset Management subjects, which might be harmonized disproportionately to achieve their business objectives. However, to maximize value through Asset Management, organizations should consider each subject with the required depth in an integrated manner.

The general approach of asset-intensive industries today is more leaned towards *Managing Asset*, as opposed to Asset Management. To elaborate on this, the managing asset approach is based on what you do to your assets, often a manager's personal understanding, interpretation, and experiences on how to run the asset with optimum value. It is more of a department-centric approach that is decentralized and lacks integration (ISO, 2017). Although with this traditional approach organizations continue to deliver and achieve their objectives, but with the maximum potential untapped. On the contrary, Asset Management is a more holistic and structured approach that involves various departments and business units to accomplish the organizational objectives by balancing safety, cost, risk, and opportunities. It is a combination of technical and business knowledge for effectively and efficiently meeting the asset-related needs of a business (Hastings, 2015). According to ISO 55000, Asset Management is "a coordinated activity of an organization to realize value from assets". Asset Management focuses on deriving value throughout the asset life cycle, i.e., from conceptual design to disposal. Moreover, alignment with organizational objectives, leadership & organization culture, and assurance of assets fulfilling their required purpose are the fundamentals of Asset Management as per ISO 55000. The benefits of implementing Asset Management include improved safety, informed decisions, increased efficiency as well as demonstrating compliance and social responsibility. Looking specifically at the Road infrastructure, the benefits from implementing Asset Management will firstly, give better control of assets to road authorities, have a clear future investment plans and justified funding needs, cost-saving from efficient Operations & Maintenance (O&M), systematic follow-up of activities, as well as safe and reliable travel through the road tunnels. In this paper, the term 'Asset' is devoted to Offshore installations and Road tunnels.

## II. LITERATURE REVIEW

Asset Management practices and implementation in the Norwegian industry are scarcely documented. This paper is part of a Ph.D. study that aims to establish a cross-industry knowledge & technology transfer between the Norwegian O&G and Road tunnel industry. Early on in the project, it was realized that Asset Management practices in the Norwegian

industry are unexplored. The review of existing literature shows very few Asset Management surveys, that too map practices in larger geographical regions.

#### *A. Asset Management Surveys Conducted in Norway*

For the Norwegian Oil & Gas industry, although the practices are believed to be well-developed, the overall assessment of the Asset Management concept is insufficiently documented. A holistic survey for benchmarking Asset Management in Norwegian O&G does not exist; however, different areas within Asset Management have been surveyed previously. Some relevant surveys include measuring the impact of Production and O&M with the use of integrated operations design (Moltu & Nærheim, 2010), challenges and evaluation of implementing Reliability Centered Maintenance (RCM) analysis on the Norwegian Continental Shelf (NCS) using mixed methods (Wattum, 2014), factors which affect the Installation and Maintenance in the Norwegian subsea industry (Moreno-Trejo *et al.*, 2012), and the relationship between Health, Safety, & Environment (work), and its link to offshore accidents (Bjerkan, 2010).

For the Road infrastructure, Asset Management is currently explored under the ‘Virksomhetsutviklings’ (VU004) project in Norway, which was initiated in recent years NPRA (2019). The need for an Asset Management approach is also acknowledged in the recent proposal of the National Transport Plan (NTP) for 2022–2033. It focuses on five goals, where the first one is to create better value for money (NTP, 2021). This also indicates the awareness of opportunities in the existing system and confirms the support from the governmental level. NPRA has contributed to several reports prepared by the World Road Association (PIARC). However, practices for managing road tunnels in Norway have not recently been benchmarked from an Asset Management perspective. Asset Management surveys, in which NPRA participated, were conducted in 2004 and 2008. The 2004 survey report is based on Asset Management implementation for all assets, including bridges, pavement, and tunnels (PIARC, 2004). The response from NPRA showed that the Asset Management System was not implemented, but expressed their interest in having one in the future. The 2008 survey focuses on Asset Management practices (PIARC, 2008). At that time, Norway was in the process of implementing a tunnel management system. The survey indicated that there were no plans for defining a formal framework for Asset Management in Norway. These surveys were conducted in the same year when PAS 55 was published and revised, in 2004 and 2008, respectively. No such survey has been conducted with the Norwegian authorities after the release of the ISO 55000 series in 2014. Survey related to infrastructure Asset Management in Norway was found for the maintenance of parks and roads, and was conducted in 2015 (Lindholst & Holt, 2017).

For general industries, the most relevant Asset Management survey in Norway was conducted in 2021 by Ernst & Young (EY Norway) Eckhoff (2021), which took place after the survey conducted by the authors of this paper. The EY Survey was conducted from a pandemic perspective, focusing on the trends and challenges in the industry. The overall response to their survey showed that a higher focus on the trends and value drivers within Asset Management is on

technical aspects, such as reliability, availability, safety, information & data, technology, etc., where the most pressing challenges are encircling around aligning Asset Management plans with business objectives, coordination of Asset Management activities across the organization, effective use of asset information, competency building, etc. It can be simply said that the trends and value drivers are focused around Managing assets, whereas the pressing challenges are more related to Asset Management ISO (2017). Also, the support and commitment from organization’s senior executives is seen furthest in the list of most critical challenges, a similar attitude seen in the Norwegian government’s NTP as mentioned above. The future of asset-intensive organizations seems to be highly dependent on technology as the respondents regard big data, predictive analytics, IoT, data visualization, AI, etc., as having the biggest impact on Asset Management activities. Other findings from the EY Survey are compared to the results from this paper and are presented in Survey Results and Analysis.

#### *B. Asset Management Surveys Conducted Globally*

At a global level, the United States has embarked on the Asset Management journey since the nineties, and numerous projects have since been conducted by the National Cooperative Highway Research Program (NCHRP) to integrate Asset Management in the various US Department of Transportation (DOT). In the NCHRP report 545, several survey studies are presented encircling Asset Management implementation in the US National Academies of Sciences, Engineering (2005). NCHRP has also presented surveys of state practices to analyze Asset Management practices in the US DOT Cambridge Systematics *et al.* (2002). The survey focuses on practices around databases, management systems, performance measures, etc., and the results showed a shift towards a strategic Asset Management approach. The report also presents the challenges in implementing Asset Management, such as nonintegrated decision-making, silo-based working, improving lifecycle analysis, etc., which are also relevant for many organizations today. A similar survey has been conducted by the American Water Works Association American Water Works Association (2015).

The Organization for Economic Co-operation and Development (OECD) conducted a survey in 2001 regarding the implementation of Asset Management System in the Road sector OECD (2001). An important observation was that the elements of Asset Management System varied from one country to another.

A cross-country survey was conducted to identify the barriers in implementing Asset Management System in the US and Libya Beitelmal *et al.* (2017). Out of the 28 barriers identified from the literature, 14 barriers were regarded as ‘important’ by the respondents from both countries. These were merely non-technical and more related to organizational and management aspects as seen in the EY survey.

The risks and challenges, along with the maturity of risks in Asset Management activities, were assessed in a global survey for Energy and Resources companies by Deloitte (Deloitte, 2015). The top two risks indicated by the respondents were the deterioration or aging of assets and the mechanical/electrical breakdown of assets. Other relevant observations are compared with our survey findings in the

### Survey Results and Analysis section.

Numerous other surveys have been conducted within the Asset Management domain with varying objectives, such as evaluating the importance of the 39 subjects from GFMAM J. K. & T. A. (2015), the impact of implementing ISO 55000 standard on organizational performance (Alsyof *et al.*, 2021), the European Federation of National Maintenance Societies (EFNMS) survey for assessing asset management practices EFNMS (2012), Asset Management challenges in the UK highways (Shah *et al.*, 2017), and Asset Management best practices in the US (Hawkins & Smadi, 2013) Transportation Research Board (2011).

A major breakthrough in technology and work processes is seen in recent years. As a result, modern tools and techniques are better equipped with capabilities for improving efficiency and overall improvement. Therefore, the Asset Management views, awareness, and practices need to be reassessed and benchmarked with recent practice for constant improvement.

Realizing this need for and importance of Asset Management, a survey was conducted in the major Norwegian industries, such as O&G, Road infrastructure, Power generation, Fisheries, and Maritime industries. The underlying objective of the survey is to determine the awareness, maturity, and the performance of Asset Management in each industry, and compare practices within and among the individual industries to highlight gaps, challenges, synergies, and opportunities. The results from this survey may also offer opportunities for these industries to monitor their individual progress and evaluate against the industry leaders. Due to the relevance and limitation of the content of this paper, key results from O&G and Road infrastructure are presented in this paper.

### III. METHODOLOGY

The survey is conducted to present an overview of Asset Management and is not exhaustive. The overall process starts with collecting data, analyzing it, and observing the relationships to understand how organizations have worked with Asset Management in recent years. The questionnaire is generally based on Value, Alignment, Leadership, and Assurance, which are the fundamentals of Asset Management as stated in ISO 55000 standard. Moreover, industry experience and the 39 Asset Management subjects from GFMAM were utilized in setting up the questionnaire. Although several maturity assessment tools exist, such as those developed by the Institute of Asset Management (Institute of Asset Management, 2016) and the Asset Institute (the Asset Institute, 2021). However, these are highly detailed questionnaires with intense use of Asset Management terminologies, which are often incomprehensible for those unaware of the standards. The intent of the conducted survey is to benchmark Asset Management practices using a simple sentence structure, which is easily understandable by those not involved directly with Asset Management. The survey was active for responses between December 2020 and February 2021.

Comparative analysis analyzes the qualitative data and compares the O&G and Road infrastructure based on inductive reasoning. Background information about the Ph.D. project and the purpose of the survey was delivered to the respondents over the survey tool and via invitation emails.

The confidentiality of demographic data was assured through the Norwegian Centre for Research Data (NSD) application. Additionally, definition of Asset and Asset Management from ISO 55000 was presented.

Asset Management is a broad concept, and the most relevant respondents include asset managers, maintenance engineers, and those aware of management and technical subjects, such as project managers, etc. For this survey, the targeted audience were invited through purposive sampling. Using Google, LinkedIn, and company websites, participants were approached based on their position, location, and industry. Using convenience and snowball sampling, personal contacts were requested to distribute the survey to their relevant colleagues. From the respondents' long industry experience, it is believed that they are well aware of their organization's practices.

The questionnaire was designed in three thematic sections: Demographic information, Organizational practices such as leadership, standardization, etc. (14 questions), and Technical knowledge such as O&M practices, root causes analysis, etc. (12 questions). Questions in the second and third section assess the maturity of Asset Management and are mainly designed as closed-ended. Almost all questions were given option to respond with a text. The survey questions were designed with a Yes/No/Don't Know, as well as unipolar ordinal Likert scale and Ratio scale with percentage intervals. The data collected is qualitative and primary. The questionnaire was adjusted after piloting with a university professor, a graduate student, and one respondent each from O&G and Road infrastructure industry.

The results from this survey will be validated using mixed methods through follow-up interviews and will be presented at another instance. The survey was prepared in Norwegian and English, and to the best of our knowledge, it was one of a kind that was conducted in Norway in recent years.

### IV. SURVEY RESULTS AND ANALYSIS

This paper presents some demographic information and focuses on the survey results that determine the awareness of the Asset Management concept in O&G and Road infrastructure. A varying number of respondents completed each section of the questionnaire, and a downward trend was noticed towards the survey completion. To base results on a maximum number of responses, each section was analyzed separately. The response summary for O&G and Road infrastructure, with response rate (in parenthesis), is shown in Table 2. It is important to note that the respondents from Road infrastructure belong to various departments of an organization, whereas respondents from O&G industry belong to several Operator organization from Norway.

The drop in respondents between the sections could be due to various reasons, such as respondent's interest and awareness of Asset Management, confidentiality issues, assigning less priority, too lengthy to complete, non-managerial/technical background of the respondent, etc. Although the response rate for this survey was low, especially for the technical part, the respondents are believed to be highly relevant to the study. This paper, therefore, provides a useful insight on Asset Management practices in Norway's O&G and Road infrastructure industry.

A. Demographic Information

The demographic data provides an insight into the industry workforce and reflects the respondents' background, which also derives confidence towards the reliability of results. A summary of key demographic results is presented in Table 3.

Female employment of about 12% and 18% in the O&G and Road infrastructure, respectively, shows that both industries are male-dominant. Comparing with the international figures, the numbers vary slightly at 22% and 11% for major oil-producing nations and the construction industry, respectively the Boston Consulting Group (2017). Moreover, the study shows that female employment decreases with seniority, which is 17% for the O&G industry. In Norway, 21% of females were employed in the energy sector in 2020, with top positions mainly held by males Centre for Research on Gender Equality (2020).

Table 2. Overview of the survey response

	Total distb.	Demographic data	Organizational practices	Technical knowledge
<b>Oil &amp; Gas</b>	69	34 (49.3%)	24 (34.8%)	20 (29.0%)
<b>Road infrastructure</b>	174	49 (28.2%)	34 (19.5%)	30 (17.2%)

Table 3. Overview of the demographic data

	Oil & Gas	Road infrastructure
Female employment	12%	18%
Higher education (Bachelor & above)	80%	59%
Position (Project manager & higher)	73%	80%
Respondents from a large organization	74%	86%
Age (mean)	48.6 years	51.9 years
Experience within the organization (mean)	15.5 years	16.8 years
Total experience (mean)	25.4 years	27.9 years

With an almost equal gender ratio in Norway's working population (Statistics Norway, 2018), female employment is well below reasonable.

For the respondent's education, the survey shows that the majority of the employees in both industries are Masters graduates, which is almost 60% for the O&G and 35% for the Road infrastructure. Bachelor and high school graduates are the second most employed in both industries. Respondents who are doctorates are only seen from the O&G industry. Overall, the comparison shows a higher level of education in the O&G industry than in the Road infrastructure and the Norwegian statistics of 2012 Statistics Norway n.d.

The high proportion of senior employees and their long experience show that the responses are from participants who have a good understanding of the work processes and the general industry practices. The age and experiences in both industries are similar statistically, that is an average age of 50 years, almost 16 years of experience in their current organization, and a total experience of nearly 26 years. Also, the majority of participants are employed with large organizations; thus, the results represent practices of organizations employing over 250 people.

B. Organizational Practices and Technical Knowledge

This section presents 10 out of the 26 questions with key

findings focusing on overall awareness of Asset Management.

1) Working with asset management

A noticeable number of respondents quit the survey when asked if their organization is working with Asset Management. Those who responded to this question are split into three sets, as shown in Fig. 1.

The figure shows that the majority of respondents from the O&G industry believe that their organization is currently working with Asset Management principles, which is the same for almost one-third of the Road infrastructure. This shows that Asset Management is a common approach in the O&G, which was also expected since the industry has long been working with such principles.

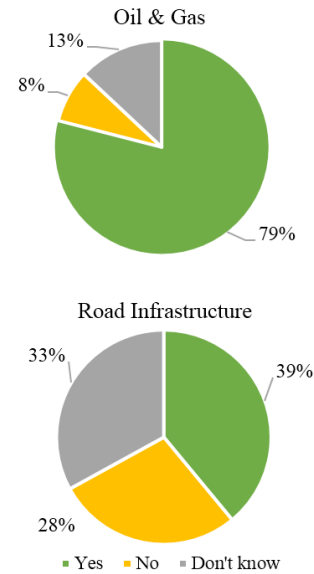


Fig. 1. Asset management in the Norwegian O&G and road infrastructure.

It is also noticed that those who are not working with Asset Management in the O&G industry are medium-sized organizations (between 50–249 employees). For the Road infrastructure, it is interesting to see the contrasting views of the respondents, which are almost equally split. Such difference could be due to the newness of Asset Management in the industry, with some people working with it and others not. People may also have a unique understanding of Asset Management, which may be reflected here. Moreover, a lack of awareness among respondents indicates the possibility of a siloed working environment with insufficient information flow, which is seen as one of the biggest threats to effective Asset Management in the Norwegian industry in the EY (Survey Eckhoff, 2021).

Overall, the O&G seems to implement Asset Management fairly, where Road infrastructure has at least started the journey.

2) Asset management standards

As mentioned earlier in sub-section I.A, various standards and models are adopted by different organizations. Fig. 2 shows the awareness of standards and models in the O&G and Road infrastructure.

Familiarization with ISO 55000 standards in both industries is limited to about a quarter of the respondents. A common among these respondents is that they agreed to work with Asset Management (sub-section '1)'), with few

exceptions. The majority of respondents in both industries are either unaware of the main standards or completely uninformed of any standard. An interesting point to notice is the complete obliviousness of the IIMM in the Road infrastructure. Those who chose 'Others' indicated ISO 9001 standard for Quality management, NORSOK N-005 for Condition Monitoring, and N-006 for Assessment of Structural Integrity for Load Bearing Structures.

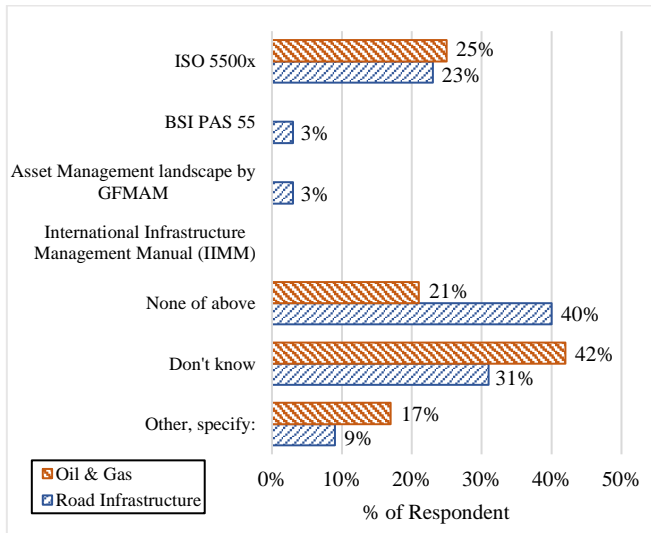


Fig. 2. Familiarization with asset management standards.

Comparing the awareness of Standards to working with Asset Management (sub-section '1)'), it is seen that some respondents from both industries acknowledge the existence of Asset Management in their organization but are unaware of the Standards. This shows that Asset Management is known by the term, and little information about the underlying Standards is known, which is more relevant for the O&G industry. Only about 32% and 43% of the respondents in the O&G and Road infrastructure, respectively, agreed to work with Asset Management and are also aware of the Standards. Overall, a lack of awareness regarding relevant Standards is noticed in both industries, with a significant proportion of respondents unfamiliar with any Asset Management Standards.

### 3) Development in asset management

The progress in the Asset Management journey can be documented by evaluating the establishment of a separate department or key documents within an organization. Asset Management is a structured approach with a set of orderly documents necessary for successful planning and implementation. These documents are staged at different levels and are described in clause 2.5.3.4 of ISO 55000. Fig. 3 shows very contrasting responses for the O&G and Road infrastructure, where the former shows higher progress in establishing the documentation and a department for Asset Management.

Just above half of the respondents in the O&G industry agreed to have a separate department for Asset Management in their organizations, which is 17% for the Road infrastructure. Generally, a particular position of Asset Manager and Tunnel Manager is assigned for offshore platforms and road tunnels, respectively, which does not necessarily confirm the implementation of Asset

Management principles. Respondents who agreed to have a separate department in both industries are mostly those who work with Asset Management (sub-section '1)'), although some exceptions exist for the O&G industry.

For the documentation, an increasing trend is observed from the establishment of Asset Management Policy to Asset Management System in the O&G industry, as seen in Fig. 3.

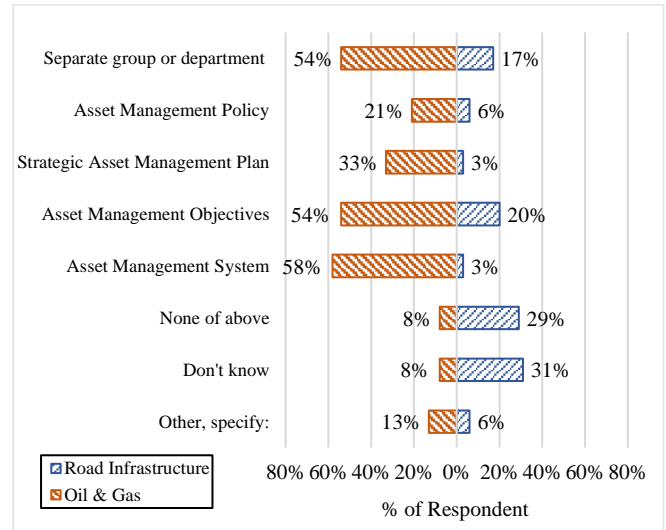


Fig. 3. Level of asset management documentation.

However, the reverse of such order is expected to implement an Asset Management system as per the ISO 55000 standard, where Policy is set first before moving to Asset Management Plans, Objectives, and System. For the Road infrastructure, very few documents are established, among which the Asset Management Objectives are most documented. More than half of the respondents have not established or are unaware of the documentation in the Road infrastructure, which is very insignificant for the O&G industry. An in-depth analysis shows that some respondents in both industries agreed to be aware of the ISO 55000 series, yet they did not establish the documents as per the Standard. In the Deloitte survey Deloitte (2015), ISO 55000 was also seen as of limited interest, as 70% of respondents did not plan to certify with some uncertain about the value it offers. The biggest challenges for effective Asset Management seen in the EY Survey are aligning Asset Management plans and activities with priorities and targets, and Coordinating/integrating Asset management activities across the company. This is also visible in Fig. 3, as where there is a lack of documentation, the presence of documentation is also in reverse order. Moreover, it is seen that some of those who agreed to work with Asset Management stated that no document or department had been established. This may be due to the informal implementation of Asset Management or a sign of unclarity between Asset Management and *Managing assets*. It is also noticed that the establishment of a specific department, to some extent, has resulted in progress in Asset Management. Overall, very few respondents implement Asset Management based on ISO 55000, which is about one-fifth in O&G and none in Road infrastructure. A lack of formal implementation of Asset Management is seen where both industries have progressed scantily with the documentation. Where the O&G industry's weakness lies in

the systematic order of documentation, the Road infrastructure falls behind in setting the key documentation.

4) Progress in asset management implementation

The progress in Asset Management can be tracked by the extent to which it is implemented across the organization. Fig. 4 shows the various organizational levels and the degree to which each industry is implementing Asset Management.

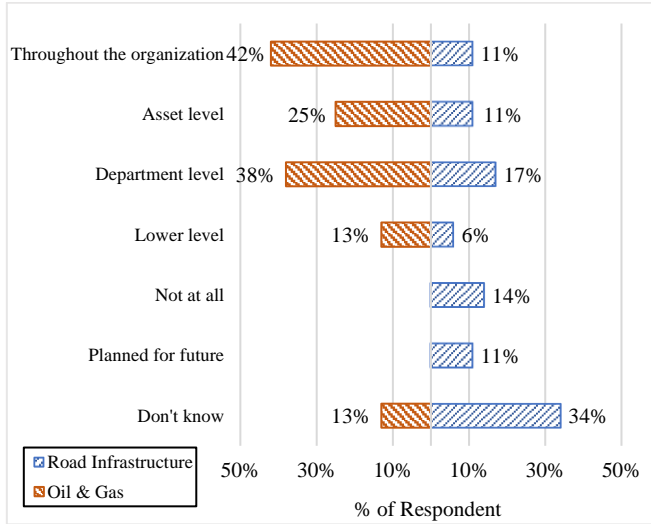


Fig. 4. Asset management implementation across the organization.

All the respondents from the O&G industry believe that Asset Management is implemented at some level within their organization. Where the most popular responses indicate that it is implemented at the departmental level and throughout their organizations. Whereas for the Road infrastructure, a notable proportion of respondents believe in the complete absence or future implementation of Asset Management. The highest percentage of respondents from Road infrastructure are those who are unaware of Asset Management implementation. This consists of respondents who are unaware of Asset Management in their organization (section 1)), Asset Management standards (sub-section '2)'), and Asset Management documentation (sub-section '3)').

The overall results show that Asset Management is more broadly implemented in the O&G industry than in the Road infrastructure. It can be said that Asset Management is being implemented in O&G, whereas for the Road infrastructure, a lack of clarity among respondents is observed.

5) Asset data

The importance of data and the potential value it can deliver is becoming a major interest to asset managers and has generally been realized by industry practitioners. The data quantity, quality, and usage often vary based on the asset strategy. Having the right data with sufficient quantity is essential to bring value from data-driven analytics. Fig. 5 shows insights from the respondents of both industries.

The respondents from both industries generally believe that the data quantity is good enough, although there are some who believe that the data quantity is insufficient in the Road infrastructure. The data quality lies between good and moderate for the O&G where it is more leaned towards moderate for the Road infrastructure. The utilization of data is mainly moderate in both industries and yet to achieve its

merits. A quarter of respondents from the O&G industry seem to be good at utilizing data, where a similar proportion in the Road infrastructure is at moderate. Comparing the asset data with the EY Survey, a similar response is observed, where data quantity is an important trend, data quantity and information quality is an important value driver, and the information quality and its effective usage is of top challenge (Eckhoff, 2021).

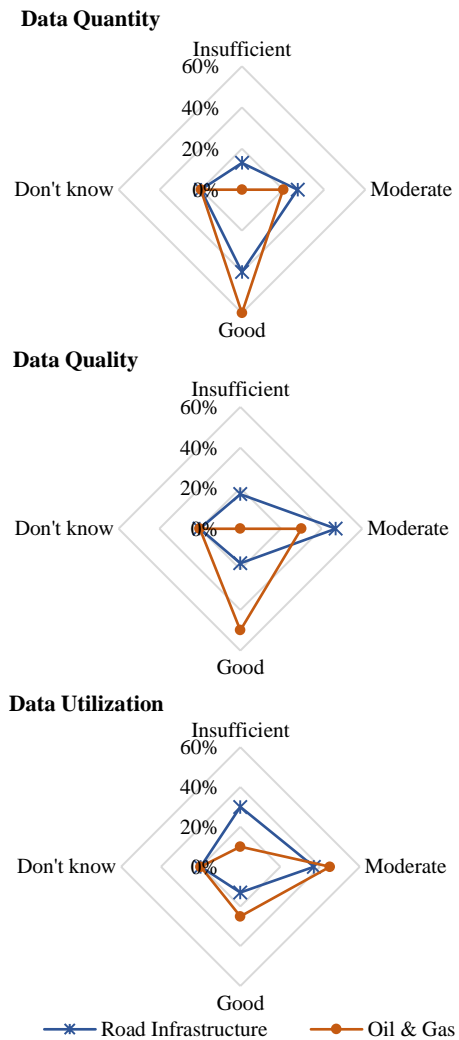


Fig. 5. Overview of data quantity, data quality, and data utilization.

6) Asset awareness

Essential information for managing any asset comes through the awareness of its capabilities, limitations, and performance. Opportunities in enhancing asset efficiency can be unlocked with good upkeep of data and available asset information. Mean Time Between Failures, energy consumption, etc., hold potential value in managing performance. Asset capabilities and limitations can assist in optimal operating regimes, developing maintenance plans, and preparing for future demands. The response to Asset awareness is presented in Fig. 6.

Almost three-quarters of the respondents are good and moderately aware of their assets in the O&G industry, compared to just below 50% in the Road infrastructure. A very similar proportion of all three criteria for asset awareness is seen, where the Asset limitations are most known in the O&G industry. Another point to notice is that none of the

respondents from O&G indicated that their organization is entirely unaware of their assets, which was otherwise seen for Road infrastructure. In general, asset awareness in Road infrastructure is dominated by moderate and little understanding. One of the reasons for such a difference could be due to the varying levels of outsourcing maintenance tasks, which is significant for Road infrastructure. Moreover, the availability and utilization of data may also increase the proximity to asset, which is an underdeveloped competence and is majorly outsourced in both industries. Significant unawareness in such senior respondents highlights the improvement needed in communication, transparency, and integrated working practices. Overall, it can be seen that O&G industry have better asset awareness compared to the Road infrastructure, yet both industries need to acquire asset information throughout their hierarchy and utilize the existing data to get a better sense of intimacy with their asset.

7) Maintenance strategies

Maintenance is a key element in Asset Management as the majority of the lifecycle cost is associated to the O&M of assets. Appropriate maintenance strategies can deliver significant value, which may result in improved safety and huge cost savings. The EY Survey shows that effective Predictive and Reactive maintenance is one of the most pressing challenges for the respondents; where the former is highly regarded, the inclusion of the latter shows the importance and high level of Reactive work. The percentage of equipment maintained using various maintenance strategies today in the O&G and Road infrastructure is presented in Fig. 7.

It is interesting to see that a significant proportion of respondents from both industries are unaware of the maintenance strategies used. For the Calendar based, Run-time based, and Corrective maintenance, a similar trend is seen in both industries, where the larger part believes that up to 50% of their equipment is maintained using these strategies. For Condition-Based Maintenance (CBM), it is surprising to see such a contrasting result where only a few in O&G, compared to half of the respondents from Road infrastructure, believe more than 51% of their equipment is maintained using CBM. It is either that CBM is unclear to the respondents or that the Road infrastructure’s strategy is heavily Condition-based, regardless of the equipment’s criticality. Looking at Data-driven maintenance, there is still a long way for both industries to implement and gain benefits from their data.

The Deloitte survey showed that the majority of respondents (39%) said their preventive maintenance is 60%–80%, and reactive maintenance is 20%–40%. This was followed by 32% respondents with an equal ratio of preventive to reactive maintenance. These observations align well with our findings, as more than half of the respondents believe each preventive maintenance strategy, except data-driven, is at least applied to their equipment. The Corrective maintenance in our study could be either planned or unplanned, hence, cannot be compared to Reactive maintenance.

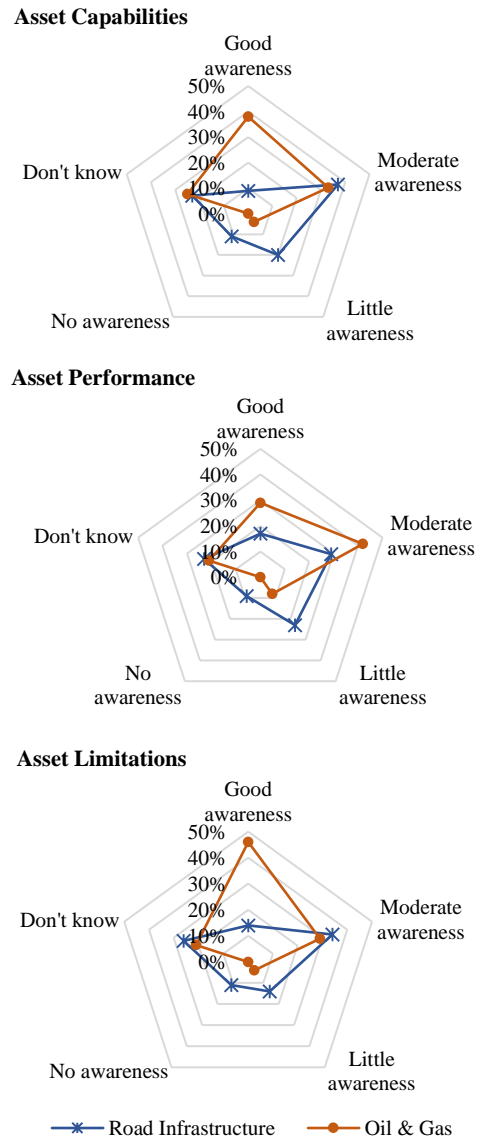


Fig. 6. Awareness of asset capabilities, performance, and limitations.

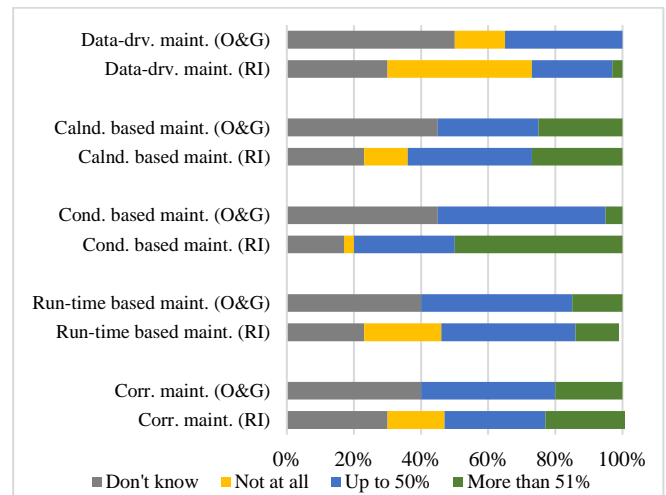


Fig. 7. Maintenance strategies currently employed on assets (RI is an abbreviation for Road Infrastructure).

8) Benchmarking of asset management practices

Benchmarking is a common practice for organizations to audit its performance against the industry leaders. Fig. 8 shows a highly contrasting response from both industries.



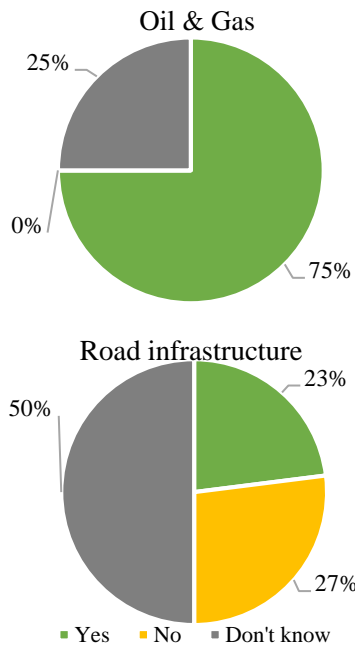


Fig. 8. Benchmarking asset management practices.

Three-fourths of the respondents have benchmarked their practices in O&G, whereas the rest are unaware. For the Road infrastructure, just below a quarter of the responses show that their practices are benchmarked. The high percentage of inconsistent and uninformed respondents reveals that Asset Management is in inception. Results from O&G show that the industry is progressing in implementing Asset Management and that the industry has high consideration towards improvement.

Practices in the Road infrastructure might be benchmarked by those implementing Asset Management in their department.

9) Current status of asset management

Having self-awareness is essential for achieving the set targets. Fig. 9 shows the overall progress in implementing Asset Management in both industries. The respondents have rated their practices on a scale where 'non-existence' is the least and 'Best practice' is the most advanced level of implementation.

The most popular response in the O&G industry shows that Asset Management practices are integrated. None of the respondents indicate the 'Non-existence' of Asset Management in O&G, where some believe they established Best practices. For the Road infrastructure, almost half of the respondents believe that their practices are 'In development', where about one-third did not rate. An equal portion of 7% and 3% of respondents are on both sides of the majority.

Compared to the EY Survey, just over half of their respondents consider their organization to be at a 'Developing' stage in compliance with ISO 55001 standard, whereas a quarter believe it is 'Competent'. The overall Asset Management in the Norwegian O&G and Road infrastructure is in the implementation phase, where the improvements are ongoing, best practices are yet to be achieved.

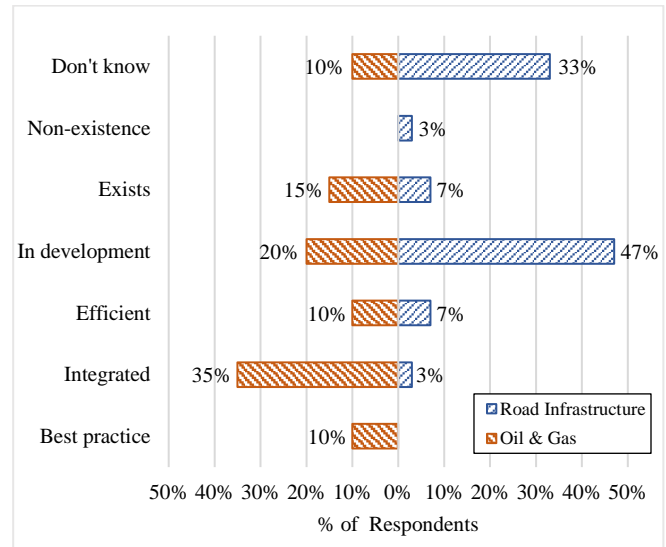


Fig. 9. Current status of Asset Management in the respective Organizations.

10) Most value to the organization

The fundamental of asset management is to realize value from assets. Based on the organizational objectives, asset managers prioritize the values that offer greatest benefits. The five topmost values to respondents are shown in Fig. 10.

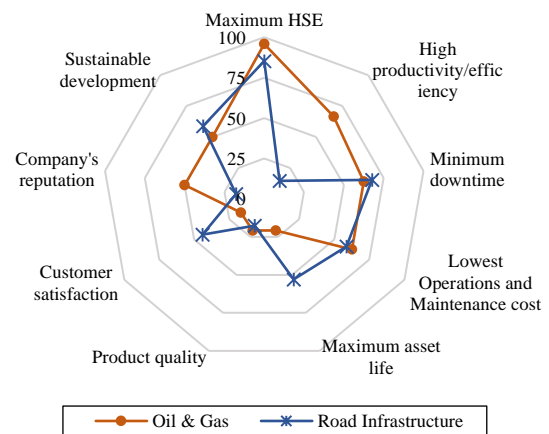


Fig. 10. Topmost values as indicated by the respondents of both industries.

As expected, maximizing the Health, Safety, and Environment (HSE) remains the highest value for most respondents, followed by minimum downtime and lowest O&M cost. This corroborates with the EY Survey findings where Safety and Reliability were of top concerns for the respondents. This might be a reason why Asset Management is closely linked with Maintenance. Surprisingly, improving safety performance was ranked low in the most important value drivers for Asset management Eckhoff (2021). It is interesting to observe a notable difference among the industries for value towards maximum asset life, which is value to only 21% of respondents in the O&G. It seems like few organizations in the O&G industry look from a lifecycle perspective and that the long-term approach may not be favored, which could be due to the high focus on production. Although sustainability is an ongoing shift, yet Sustainable development is averagely valued in both industries, especially the highly pressured O&G industry. Similar results are seen for Environment, Climate, and Sustainability in the

EY Survey. For the Road infrastructure, just above half of the respondents consider maximizing asset life as value, which shows the presence of a correct mindset. Another interesting observation is regarding Product quality and High productivity/ efficiency, which were the least value to many respondents from the Road infrastructure. This shows some contradiction in terms of practicality, as Product quality has the potential to influence the Maximum asset life. Generating efficiencies from CAPEX and OPEX were in the top five value drivers for Asset Management in the EY Survey, which do suits well for the O&G, but do not comply with Road infrastructure. High value for increased customer satisfaction in the Road infrastructure shows the difference in the business model of public and private organizations.

Overall, both industries share some common values, where few differences are observed. The O&G seems to be leaning towards high productivity with a short-term focus, where Road infrastructure tends to focus on lifecycle. Although industries differ in setting priorities, values should be considered wisely.

## V. CONCLUSION

The survey outcome identifies key insights of Asset Management awareness among the respondents from O&G and Road infrastructure in Norway. The literature shows that the challenges outlined in the late nineties studies in the US are still relevant today, especially in the Norwegian industries. The survey results indicated that Asset Management is commonly acknowledged and is moderately implemented within the O&G industry. Moreover, O&G seems to have greater awareness of their assets compared to Road infrastructure, where better asset proximity is yet to be achieved. The varying responses in Road infrastructure indicate some uncertainty among the respondents in understanding Asset Management, and the NPRA should prioritize harmonizing Asset Management throughout the organization. Understanding of the underlying standards and documentation is in infancy in both industries, and a systematic approach to implement Asset Management is vital. In general, both industries focus on lowering the OPEX and aim for higher asset availability. Compared to Road infrastructure, the O&G seems to focus on high returns with a slight gravitation towards short-term gain. The survey also reveals that the majority of respondents tend to implement Asset Management in their own capacity, where some are still unclear in differentiating between Asset Management and *Managing assets*.

This paper implies that there is a potential of knowledge transfer between the two industries. The similarities in both industries indicate that proven techniques in O&G which are based on long experiences can be adopted in Road infrastructure. Moreover, the differences in business models, complexity, and criticality show that robust practices from large-scale assets in O&G can be transferred to relatively simpler Road infrastructure. As observed from the survey, there are two maturity levels of Asset Management, one from where the knowledge could be transferred (O&G), and the other as knowledge receiver (Road infrastructure).

For successful implementation of Asset Management, the survey results showed that both O&G and Road infrastructure should focus on the basic activities. This starts with realizing

the need for Asset Management, communicating awareness of Asset Management effectively throughout the organization, formally embarking on the Asset Management journey by referring to relevant Standards and models, good understanding of asset technicalities, knowledge exchange visits to successful executors, and establishing a dedicated group which can perform these activities with complete support from top management. In a more specific context, the O&G industry requires better focus on maximizing asset life, sustainable development, asset performance, and data utilization. Whereas the Road infrastructure needs to focus on Asset Management concept and its documentation, high productivity and efficiency, asset awareness, proper benchmarking of current practices as well as the data quality and its utilization.

Overall, the survey revealed that O&G seems to be somewhere around midway in the Asset Management journey, where the Road infrastructure has recently departed. This confirms the initial industry-wide belief of O&G having higher Asset Management maturity and that the chances of emulating O&G practices in the Road infrastructure hold potential for considerable improvement.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

S.M.T has conducted the overall study including preparing and conducting the survey, analyzing the results, and writing the draft article. J.R. contributed to assisting in the ideation, survey preparation, and analyzing the results. O.N. contributed to guidance in designing and conducting the overall study, providing input and feedback for the survey, and reviewing the article. All authors had approved the final version.

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