Article

Application of Near-Miss Management Systems: An Exploratory Field Analysis in the Italian Industrial Sector

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Abstract: Near-miss events are usually identified as adverse events that could have turned into incidents/injuries but, due to an intervention of a safety system or by chance, developed into harmless situations instead. Past and present studies have also outlined the importance of collecting and analyzing near-miss events, as they have same causes of more serious events, thereby allowing for more effective preventative measures at the workplace. Although their importance has been outlined for several years, standard models for designing near-miss management systems (NMMSs) are still lacking and cannot yet support companies in their full-scale application. Despite this condition, NMMSs are applied in several industrial sectors, such as in the construction, mining, chemical, and nuclear industries. The aim of this study is to analyze how companies are developing their own NMMSs. An exploratory analysis was developed through survey analysis; it was provided to a sample of Italian companies in order to evaluate the adoption level of NMMSs as well as current practices applied by companies. The sample included companies of different sizes in the industrial sector. The results extracted from the field analysis outline interesting issues that point out current procedures adopted for the identification, collection, and analysis of near-miss events as well as real benefits and criticalities related to the application of NMMSs.

Keywords: near-miss management system; accident precursor; exploratory analysis; industrial sector; survey

1. Introduction

Near-miss events are an important source of information for improving the safety performance of companies, as they represent a signal from the operational field about the actual safety levels at workplaces. In [1–3], a near-miss event was defined as "An event, not necessarily defined under national laws and regulations, that could have caused harm to persons at work or to the public"; more recently, [4] defined a near miss as "a work-related incident where no injury or ill health occurs, but which has the potential to cause these." Another interesting definition was proposed by Jones et al. [5], in which a near-miss event is a "hazardous situation, event or unsafe act where the sequence of events could have caused an accident if it had not been interrupted". Thus, a near miss and an accident are occurrences; the only difference between them is the gravity of the consequences, as a near miss is an incident that did not result in a fatality or in injury, illness, or property damage. Other studies [6–8] proposed a wider definition (i.e., weak signals or accident precursors) that also includes unsafe acts and unsafe conditions. These represent only potential hazard conditions (not an occurrence like a near miss) that could lead to an accident or an injury. Near-miss events are usually recorded at the workplace via direct or indirect observation. Several past and recent studies [9,10] have outlined the strict connection

between near-miss events and injuries, as near-miss events and accidents often share the same root causes. Near-miss events are usually considered as accident precursors or weak signals. For this reason, recording and analyzing near-miss events and their dynamics could help to avoid accidents and injuries as well, improving the overall safety management process. Thus, near-miss management systems (NMMSs) are an important source of continuous process improvement in the safety domain [2,11–13]. NMMSs are usually designed to analyze the causes and determinants of negative events, thereby supporting, in advance, the recognition of possible causes of future accidents and aiming to apply effective solutions to prevent them [14]. Although no standard process has been defined yet, reporting near-miss events, analyzing their main causes, and learning from them are the main steps that usually characterize an effective NMMS [15,16]. Recently, a literature review of the application of NMMSs in the industrial sector was proposed to identify some potential benefits, main trends, and criticalities that research has pointed out [17]. The aim of this work is to provide findings from an exploratory field analysis in order to evaluate the current practices adopted by companies applying NMMSs in the industrial sector as well as real potentialities and criticalities that occurred during their full-scale application of NMMSs. Thus, based on an analysis of surveys, several issues were explored, starting from the level of adoption of the main tools applied by the companies and progressing to benefits and obstacles outlined with real applications. The structure of the paper is as follows: Section 2 describes the methodology adopted for developing the exploratory analysis; Section 3 discusses the results obtained from the field analysis; finally, Section 4 reports a general discussion about the knowledge acquired from the field analysis.

2. Materials and Methods

2.1. Background and Motivation of the Study

This study was carried out in the context of the national project CONDIVIDO, which is carried out by the University of Salento in collaboration with the Polytechnic of Milan and INAIL, which also funded the activities. The main objective of the project is to develop a tool to support knowledge sharing regarding the management of near-miss events in the industrial sector on a national basis. Thus, an exploratory analysis based on a survey was developed, aiming to point out feedback items derived from the full-scale application of NMMSs in industrial companies. The main purpose of this study is to assess several issues, which have often been theoretically analyzed, through field analysis carried out on a sample of Italian companies. Thus, the survey analysis was constructed based on emerging topics outlined in the literature. Following these findings, a quick overview of these topics is proposed with the related literature analysis.

The first analyzed topic refers to the type of events collected through the NMMS; this is also connected to a still-open issue regarding the definition of near-miss events [18]. Based on how the NMMS is designed, different types of events could be collected, including, e.g., unsafe acts, unsafe conditions, and non-conformity. Unsafe acts and unsafe conditions differ from near-miss events, as in both cases, nothing has occurred. An unsafe condition is a condition in the workplace that is likely to cause injury; unsafe behavior could be defined as any act or behavior that deviates from a safe way of working. Both contribute to increasing the probability of an accident [19]. The main difference is how "close" these events are to an incident: near-miss events are precursors, as they are real occurrences; unsafe acts, unsafe conditions, and non-conformity are antecedents, as they represent potentially hazardous conditions that could lead to an accident. Thus, these events could be defined as early warning signals rather than as actual precursors of an accident [20,21]. It has to be noted that, on one hand, collecting near-miss events as well as unsafe acts and behaviors could increase the efficacy of prevention activities developed by companies based on information derived for their NMMSs. On the other hand, collecting and analyzing different types of events could increase the complexity of the NMMS, thus increasing the effort required to apply it.

Next, the analysis focuses on the main processes that usually characterize an NMMS [22], which are reporting and collection, cause assessment, solution identification, and dissemination. First of all, the reporting and collection process was investigated. This is a very critical activity in the application of NMMSs, as it heavily affects the overall efficiency of the system itself [1,15,23]. Several factors contribute to an increase in the criticality of this process, such as a poor safety culture in the organization [24] or an insufficient involvement of the workers in the near-miss management process [14]. Different systems can be applied for collecting information, like direct reporting, where the person who was somehow involved in the event directly reports information about the occurrence, or indirect reporting, where data are collected by a third party (e.g., a supervisor). Each system is characterized by benefits and criticalities, and they are both applied in several companies. Furthermore, the collection process can be supported by digital tools, aiming at simplifying and increasing the efficiency of the process, or traditional paper-based ones, which can be easier to use by workers and do not need initial investments. Digitalization can also involve other processes, especially dissemination, with the objectives of increasing the process effectiveness and reaching a larger audience.

The cause assessment and dissemination processes are often underestimated in their importance, even by companies applying NMMS [22]. Extracting knowledge, through specific methodologies, about the root causes of a near-miss event or a weak signal (unsafe act and unsafe conditions) can contribute to the outlining of and avoidance of nonconformities or anomalies that, in the future, could lead to more serious events. Several methods are available in the literature, starting from traditional root cause analysis [10] to new emerging approaches, like the Safety II strategy [19], where the focus is more on safety barriers (technical and/or organizational ones) that contributed to interrupting the accident chain. Moreover, the process of diffusion of the knowledge extracted from the cause analysis and the solution identification must be properly addressed to ensure effective management of near-miss events. The aim is twofold: on one side, increasing the safety culture of the company, on the other, improving the awareness of workers of the risks entailed [25,26]. Some recent studies have outlined how digital technologies can contribute effectively to these activities as well [27,28].

Therefore, the objective of this study is to outline the benefits, as well as the criticalities, derived by the real application of NMMSs, aiming to fill the gap present in current literature, which is mainly focused on theoretical studies.

2.2. Research Method

This analysis is intended as a first step for understanding the current level of adoption of NMMSs in Italian companies, highlighting barriers and drivers to the implementation of such systems. According to this scope, the research has an exploratory approach, which is oriented to generate insights and to highlight trends of a phenomenon [29]. Therefore, a questionnaire survey was elaborated, structured in two main parts: the first one collects general features of the companies, such as industrial sector, size, the safety management standard applied, and the eventual adoption of a NMMS. Then, Section 2 is dedicated specifically to companies applying an NMMS. This work presents the results obtained, aiming at providing a field analysis on how NMMSs are applied on a full scale. Companies involved in the study belong to different geographical areas of Italy and different industrial sectors. The survey, developed through the online platform Qualtrics, was sent through email to companies for self-administration. The email was informative about the main objectives of the study and the structure of the survey. Respondents are either internal company personnel or external consultants authorized by the company. Finally, 192 valid answers (i.e., complete in all sections) were collected. However, it has to be noted that the sample may not be representative of the whole Italian industrial sector, as a specific sample design process was not carried out, since this first stage of the study was intended as an exploratory field analysis.

3. Results

3.1. Company Type and Safety Organization Analysis

The first section of the questionnaire has the objective to characterize the sample in the analysis according to general and safety-related features of the companies. The first information regards the company size, which varies from micro-companies (fewer than nine employees) to small (from 10 to 49 employees), to medium (50 to 249 employees) and large ones (more than 250 employees). Another question addressed the company organizational approach towards safety at work: if any standard is applied for safety management (e.g., ISO 45001 [4]) and how this process is managed inside companies, if by an internal representative or an external consultant.

The distribution of respondents according to their size is reported in Figure 1. The two largest groups are small and medium companies, representing about half and a quarter of the sample, respectively; lower participation is outlined for the two extreme groups, large and micro-companies. With the aim of gaining a deeper characterization of the sample, two other issues were investigated: the organization type characterizing the health and safety management model and the eventual adoption of a safety management system (SMS) in the company. For the first issue, it must be considered that Italian legislation allows for organizing the health and safety service with internal resources or with external ones (e.g., consultant firms or experts). The sample is quite equally distributed, as 49% of the companies organize their services with their internal resources.
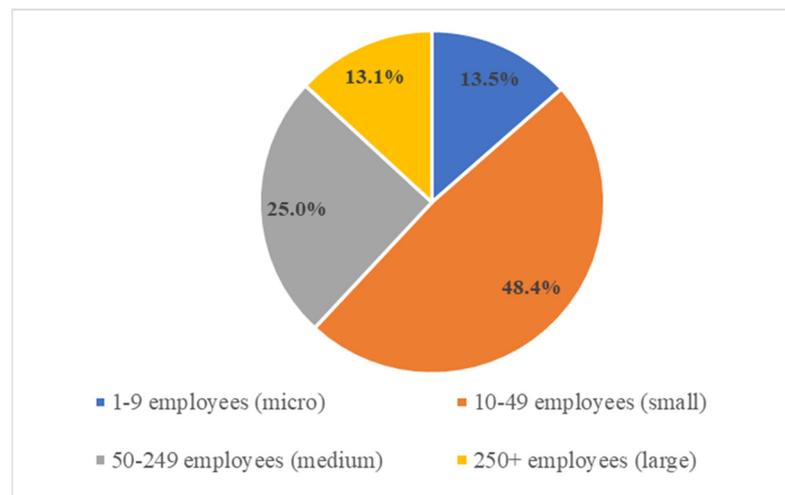

Figure 1. Company size distribution in the analyzed sample.

Considering how many companies adopt an SMS, interesting results are reported in Figure 2. On one hand, almost 46% of the companies in the sample declare that they do have any SMS; on the other hand, about 42% of them adopt a standard model for SMS (defined at international or national level).

In addition, a cross analysis considering both the company size and the eventual adoption of an SMS was performed, pointing out that the percentage of companies adopting standard SMS (like ISO 45001, OHSAS 18000, or based on national guidelines) increases with the size. The results are shown in Table 1. This issue is very important for evaluating the adoption of NMMSs, which is a mandatory requirement of this international standard. However, an additional analysis also highlighted that there are some companies (about 26%) that are not adopting any standard for their SMS but are applying an NMMS as a voluntary activity.
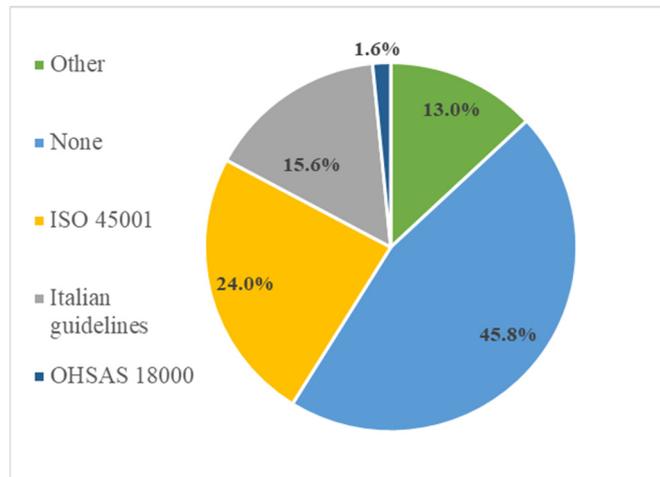
Figure 2. Adoption level of an SMS in the analyzed sample.

Table 1. Cross analysis between company size and SMS adoption (percentages were calculated based on company size, by row).

Company Size	Companies NOT Adopting SMS	Companies Adopting Standardized SMS	Companies Adopting Other Types of SMS	Total
Micro	17 (65%)	4 (15%)	5 (19%)	26
Small	44 (47%)	36 (39%)	13 (14%)	93
Medium	20 (42%)	23 (48%)	5 (10%)	48
Large	7 (28%)	16 (64%)	2 (8%)	25
Total	88 (45.83%)	79 (41.14%)	25 (13.02%)	192

Next, data about the current adoption level of NMMSs are reported in Figure 3: about 45% of the companies interviewed already adopt an NMMS and about 31% have for several years.
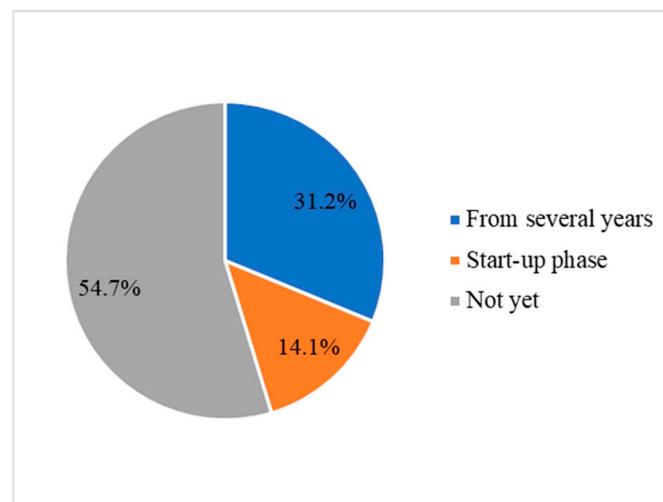

Figure 3. Adoption level of NMMSs pointed out in the analyzed sample.

A cross analysis between the company size and the adoption level of an NMMS was carried out. The results are reported in Table 2. An interesting point emerges from the cluster that already adopts NMMS: the largest group is composed of large companies, but a wide application is also outlined for small and medium ones. This result confirms the trend outlined by several papers and reports in the literature that sees smaller companies dedi-

cating fewer resources to safety management and performing worse than large companies in occupational health and safety (OHS) [30].

Table 2. Cross analysis between company size and NMMS adoption level (percentages were calculated based on company size, by row).

Company Size	NMS Not Yet Adopted	Start Up Phase	Adopted from Several Years	Total
Micro	23 (88.5%)	3 (11.5%)	0	26
Small	63 (67.7%)	8 (8.6%)	22 (23.7%)	93
Medium	17 (35.4%)	10 (20.8%)	21 (43.8%)	48
Large	2 (8.0%)	6 (24.0%)	17 (68.0%)	25
Total	105	27	60	192

Therefore, small and micro-companies should be the target to consider for extending the application of NMMS [25].

3.2. NMMS Adoption: Tools and Methods Adopted

Following this, the analysis was focused on companies that already adopt an NMMS to evaluate operational feedback (procedures, tools adopted, etc.), as well as more strategic ones, like positive feedback and criticalities derived from their real experience. The analysis started by considering the type of events collected by the company's NMMS, for the reasons explained in Section 2: an uncertainty factor derives from the different ways in which current practices of NMMS intend near-miss events, if they only include occurrences or also unsafe acts and conditions and nonconformity. These latter issues are antecedents of an adverse event in a different way compared to near-miss events. The results are reported in Table 3: an interesting result is that most of the companies interviewed collect different types of events, not limiting the analysis to simple near misses but including antecedents, like unsafe conditions and acts. This can potentially increase the effectiveness of NMMSs.

Table 3. Types of events collected in analyzed NMMSs.

Collected Event Type	N° of Companies
Only Near miss	26 (29.89%)
Near miss, Unsafe act, Unsafe conditions	32 (36.78%)
Near miss and Unsafe act	4 (4.60%)
Near miss and Unsafe condition	10 (11.49%)
Other	15 (17.24%)

By analyzing how the collection process is carried out in the companies (see Table 4), the results outline that the most widespread option is to collect data not from the original source but through an intermediary, such as a delegate responsible for this process or the company owner. It must also be noted that in absolute (36%), the most applied option is that the person directly involved in the event reports it without any intermediation. This is particularly true for large companies. Another question regarded the specific tool used for this phase. The results reveal that most respondents rely on physical or digital forms elaborated by the company for near-miss collection (76%), while only 8% use specific software for near-miss management. This denotes a wide variability of procedures and methods adopted in this phase, which can be related to the lack of standardized tools specifically designed for the near-miss management process, which is recognized as a criticality in literature [17].

Data about the type of method/tool adopted for analyzing the potential causes of the collected event were also analyzed. The results show that most companies adopt internal tools developed specifically for this scope: only a few companies declare that they use well-known methods (like the five WHYS or the Ishikawa diagram), confirming the lack of standardized approaches and models also in the analysis phase (Table 5).

Table 4. Responsibility of reporting events in the NMS based on company size.

Responsibility to Report Event	Company Size				
	Micro	**Small**	**Medium**	**Large**	**Total**
Worker directly involved in the event	1	11	8	12	32 (36.78%)
Worker who is responsible for the collection process	1	10	13	3	27 (31.03%)
Company owner	0	1	1	0	2 (2.30%)
Health and safety manager	1	4	5	3	13 (14.94%)
Other	0	4	4	5	13 (14.94%)

Table 5. Models and tools adopted for cause analysis about collected events.

Adopted Cause Analysis Method	N° of Companies
5 WHYS Method to Identify Root Causes of Incidents	8 (9.20%)
Ishikawa Diagram	4 (4.60%)
Company checklist	6 (6.90%)
Italian method for analyzing fatal injury	4 (4.60%)
Structured Interview	8 (9.20%)
Internal company risk assessment model	42 (48.28%)
Other	15 (17.24%)

Another issue regards the diffusion of knowledge derived from collecting and analyzing events in the NMMS: on one hand, the survey outlines the heterogeneity of tools adopted in this phase; on the other hand, there are still companies that do not perform at this relevant activity, losing an important occasion for improving their effectiveness in safety management and safety culture (see Table 6).

Table 6. Reported tools adopted for the information diffusion process.

	Company Size				
	Micro	**Small**	**Medium**	**Large**	**Total**
Training and information meetings	2	15	11	6	34 (39.08%)
Company Bulletin Board	0	5	4	2	11 (12.64%)
E-newsletter	0	3	4	5	12 (13.79%)
Company Module	0	1	3	1	5 (5.75%)
No diffusion	0	0	1	2	3 (3.45%)
Other	1	6	8	7	22 (25.29%)

Another question addressed the level of digitalization characterizing each relevant process in NMMS. The results are shown in Table 7. Data outline that almost 60% of the companies interviewed do not use any software tool for supporting the processes of their NMMS: very few companies (about 7%) currently rely on full-scale digitalization, carrying out the collection, cause analysis, and knowledge diffusion activities with the support of software tools. This can represent a relevant point of improvement for supporting the efficiency of the whole NMMS.

Table 7. NMMS processes developed adopting digital tools.

NMMS Process Involved in Digitalization	N° of Companies
Collection	10 (11.49)
Analysis	3 (3.45%)
Collection and analysis	13 (14.94%)
Collection, analysis, and diffusion	6 (6.90%)
No software tool adopted	51 (58.62%)
Other	4 (4.60%)

3.3. NMMS Adoption: Outlined Criticalities and Benefits

Finally, an analysis of more strategic issues was carried out to highlight the obstacles and benefits that companies have faced during the application of their NMMS. The most outlined critical issue reported from the companies is the development and maintenance of an effective collection and reporting process (26.4%), which is followed by a strictly related issue, that is, the complexity of involving workers in the near-miss management process and increasing their awareness (19.5%). A company culture not specifically oriented towards proactivity is also cited as a relevant obstacle (18.4%). On the other hand, less importance was assigned to the information/communication phase (6.9%), to the costs required for the start-up and application phases (2.3%), and to other minor issues.

As for the benefits, detailed in Table 8, more than half of the companies applying an NMMS declare that they have experienced an increase in the safety level to different extents (resulting in a lower number of injuries or in the improvement of risk identification and prevention, etc.). Other declared benefits are an increased awareness of safety issues among workers and better control of the work conditions.

Table 8. Benefits outlined derived by real-scale application of NMMS in the sample.

Outlined Benefits	N° of Companies
Enhanced safety (less injuries, more control, prevention and risk identification)	48 (55.17%)
More awareness and attention among workers	14 (16.09%)
Control and improvement of processes and procedures	10 (11.49%)
Improved work conditions	4 (4.60%)
Not yet observed	4 (4.60%)
Other	4 (4.60%)
No answer	3 (3.45%)

The last question focused on which possible improvements the company could pursue for its own NMMS. The most shared opinion was that a better involvement and participation of workers in the activities would benefit the performance of the whole near-miss management process (23.0%), as well as specific training supported by proper internal communication (18.4%). Other relevant issues pointed out were the adoption of software tools and digitalization to improve the efficiency (10.3%) and simplification and improvement of the collection phase, which was perceived as critical by 10.3% of respondents.

4. Discussion

The exploratory field analysis highlighted several interesting results, on one hand, confirming issues derived from theoretical studies but, on the other hand, adding new emerging topics derived from the real applications of companies. The level of adoption of NMMSs among respondents is encouraging, since almost half of the involved companies declared that they will adopt an NMMS, either in a start-up phase or a well-established one. The trend confirms a higher diffusion in more structured companies (large and medium ones): this suggests that a possible strategy to foster the diffusion of NMMS in industry could be to support the adoption in smaller and less organized companies, i.e., micro and small enterprises, which represent the largest group in the Italian industrial sector and, in general, in the European context. This is also confirmed by the potential benefits derived by the application of an NMMS outlined by companies. Most respondents adopting an NMMS reported an increase in the global safety level of their organization, confirming the overall effectiveness of applying NMMS for preventing adverse events at the workplace, as defined by several theoretical studies. The largest criticality declared is related to the first process in a NMMS: reporting and collection. Several causes can contribute to this result, from the intrinsic complexity of near-miss definition, raising uncertainty around which events should be reported, to a low awareness of workers, who are not always trained properly for near-miss management, as well as a poor company safety culture. The proposed analysis also outlines that this issue becomes critical, especially in SMEs, where

the organization is more informal than in large companies, and resources to assign to these activities are very scarce.

Another critical point to be considered is that, since no specific standard for the design and management of an NMMS has been defined yet by the global safety community, companies adopt their own models, which can differ substantially from each other, as they can be based on different tools and methods for each of the involved activities. In fact, different types of events are collected and analyzed in different companies; the data analyzed show that the cause analysis is not usually based on a well-known structured method but on internal tools, and that the digitalization of the whole process is typically at a low level. This lack of standardization can also be seen as a barrier for companies that wish to include near-miss analysis in their safety management process, especially smaller companies with fewer resources, and should be addressed through further research.

Finally, it has to be noted that this field analysis has some limitations, mainly related to the sample of companies involved, which is not completely representative of the whole Italian industrial sector.

On the other hand, the aim of the survey was to provide an exploratory field analysis aiming at integrating the theoretical studies currently reported in the scientific literature, rather than to propose a full statistical analysis. Being an exploratory analysis, the results can be considered as a first step in the investigation of this issue, indicating some guidelines that could be verified and validated through future investigations.

5. Conclusions

The paper proposes an exploratory field analysis for evaluating how NMMSs are being applied in the industrial sector in Italy, investigating the current level of adoption, the real procedures adopted in companies as well as the main benefits and criticalities outlined by companies that are applying these systems. The field analysis was developed through a survey carried out in Italian companies from different territorial areas (from Southern to Northern Italy) and industrial sectors (from agricultural to manufacturing and chemicals). Interesting results were achieved, as the aim of the study was to evaluate, from practical experience, how NMMSs are applied in companies, together with real potential benefits and criticalities. The results discussed in this paper confirm some trends outlined in the literature about NMMSs but also outline the main criticalities faced by companies in the implementation of NMMSs, providing a real picture of the analyzed issue that could contribute to an understanding of the level of adoption and fostering of the diffusion of such systems. Further developments will also be oriented to evaluate organizational procedures and tools that can support micro and small companies in adopting NMMSs, based on the evidence collected.

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