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Ontology based risk self-assessment and mitigation for teleworkers

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Abstract. The COVID-19 health crisis has forced many people to work from home, exposing companies and workers to the various risks brought about by teleworking. In order to raise awareness and enable better management of these risks, we have built an ontology for the control and mitigation of teleworking risks as well as a tool for self-assessment of individual worker risk profiles. We have conducted a literature review and interviews about corporate practices to manage telework's negative impacts. The resulting ontology allows us to link the risks with adaptations provided by the employers and employees. In order to circulate this self-assessment tool, we have integrated the ontology into a user-friendly website, where people can fill out an anonymous survey to establish their personal risk profile and get recommendations about further adaptations that could be beneficial in their situation.

Keywords: Risk assessment, remote work, telework, ontology, decisions support system.

1 Introduction

The health crisis has forced many employees to work from home (Mori, 2021). While some have had a positive experience, enjoying the new freedom to work in the quiet of their homes and save the commute time, others have had a more nuanced experience (Dubey & Tripathi, 2020). This research aims to raise awareness and disseminate best practices for teleworking risk management.

Our motivation for this research is to better control the broader impacts of teleworking on society as a whole. In the literature on organizational risks, impacts of telework on people are rarely correlated with the organizational and private context of the workers (Buomprisco, Ricci, Perri & De Sio, 2021). However, from a business continuity and risk management perspective, this problem is worth considering (Savić, 2020). Identifying specific risky contexts and devising targeted mitigation measures will allow the employer who wishes to ensure the smooth running of activities in an inclusive perspective to reduce risks inherent to specific work contexts. In this paper,

we address the following research question: how to design and implement an ontology for teleworking risk assessment and control.

In order to tackle this issue, we have created an ontology and a survey tool allowing for self-assessment of teleworking risks and data collection about the mitigation measures provided by employers. Employees can better understand the risks they face and identify potential solutions. Employers can see how they compare to other companies and get an assessment of the perceived risk level of their employees.

2 State of the art

First, we present the definition of telework and the other forms of remote work. Second, we present the relevant concepts from teleworking risks and risk breakdown structure. Third, we present the mitigation measures and adaptations regarding teleworking risks. Fourth, we present the ontology of risks and control measures that allows us to model risk control and mitigation for teleworkers. Finally, we present the ontology transformation literature relevant to our project.

2.1 Definitions of telework and other types of remote work

There are many terms that are used interchangeably but that do not necessarily refer to the same reality. Often the characteristics related to telework will depend on the context and the situation of the employee (Sullivan, 2003). While telework is traditionally defined based on geographical and temporal boundaries – the worker being in a telework situation when outside the company's own boundaries – this concept can encompass different forms of work such as mobile work, work at home, telecommuting, satellite office or detached unit (Kniffin et al., 2021; Bailey & Kurland, 2002; Olson, 1983). With the rise of these new forms of work, Allen et al. (2015) and Savić (2020) define telework and work from home as two interchangeable terms that describe the work situation of employees working outside the company's own premises. In the rest of this paper we will use telework to represent the situation of workers performing their activity outside the company's own premises without distinction of the place of work.

2.2 Teleworking risks

The World Health Organisation (WHO) declared a global health emergency following the outbreak of the Covid-19 (Velavan & Meyer, 2020). Many populations saw their movements restricted, which greatly increased the number of people involved in teleworking (Mori, 2021). While a significant portion of workers reported satisfaction with this new form of work, a sizable number of teleworkers expressed mixed feelings (Dubey & Tripathi, 2020). For this study, we selected the main risks related to telework considered in the recent literature: social interactions, societal issues, physical health, mental health, infrastructure and productivity (Bloom, 2021; Fílardí, de Castro & Zaníní, 2020; Purwanto et al., 2020; Tavares, 2017).

The first risk family considered relates to social interactions. The increase of family conflicts and domestic violence can be partly tied to telework, as we see a blur of the boundaries between work life and family life. This blurring often results in overwork and stress (Tavares, 2017). Societal issues are related to promotion and demographic inequalities. Workers fear that promotion opportunities will decrease with telework, negatively impacting their career (Baert, Lippens, Moens, Sterkens & Weytjens, 2005). Moreover, as women are more likely to work from home when given the opportunity (Bloom, 2021) they will have fewer opportunities to pursue their careers. Finally, workers over 60 are less likely to telework (Morilla-Luchena, Muñoz-Moreno, Chaves-Montero & Vázquez-Aguado, 2021), creating new inequalities based on age. Inadequate workplaces, uncomfortable working positions and reduced activity are associated with an increase in musculoskeletal problems among teleworkers (Buomprisco, Ricci, Perri & De Sio, 2021). This, and the lack of breaks, account for most of the physical problems directly related to telework. Mental health risks are induced by diverse causes, but recent studies demonstrate the link between mental health issues and telework. Wang et al. (2021) found that loneliness and isolation are induced by reduced social activities and long working hours while Chong et al. (2020) demonstrated that task setbacks caused by peers are most likely to create exhaustion. On the other hand, overwork and stress can be caused by long working hours and skewed work-life balance (Okubo, Inoue & Sekijima, 2021). Infrastructure risks encompass all technical and financial issues related to working outside the company's premises. Fílardí et al. (2020) consider factors such as lack of appropriate equipment, insufficient technical support or hindered access to data. Financial issues are related to the additional costs that workers incur for their internet access or the increased electricity consumption (Austin, 2021).

While the previous risks mainly impact the workers, productivity risk impacts companies more strongly than teleworkers. During the Covid-19 health crisis Okubo et al. (2021) found a decrease of 20% in productivity among workers who started teleworking. Multiple factors were found to contribute to the drop in productivity. The main factors are the inefficiency of online communication (Wang et al., 2021) and extended response time due to the asynchronous nature of telework (Fílardí et al., 2020).

2.3 Teleworking risks breakdown structure

We have organized the main categories of risks associated with teleworking in a hierarchical risk breakdown structure (Hillson, 2003). For this study, we consider six main risks families: social interactions, societal issues, physical health, mental health, infrastructure and productivity (Bloom, 2021; Fílardí et al., 2020; Purwanto et al., 2020; Tavares, 2017). For each risk family, we identified the related risk factors. A risk factor is a source of risk from the internal or external environment of the person in a remote working setting. The risk breakdown structure is shown in Table 1. These risk families and risk factors will be used to structure the classes of our ontology and to characterize their instances.

Table 1. Risk breakdown structure for teleworking

Top level	Risk family	Risk factors
Teleworking risk	Social interactions	Family conflict
		Customer & stakeholder
	Society	Decrease in promotion opportunities
		Increased gender and age inequalities
	Physical health	Musculoskeletal problems
	Mental health	Loneliness and isolation
		Increased exhaustion
		Overwork and stress
	Infrastructure	Inadequate equipment
		Incapability to use the equipment
		Data access problems
		Data security issues
		Increased internet and electricity cost
	Productivity	Lack of communication
		Non-adaptation
		Loss of efficiency and commitment
		Task setbacks
		Procrastination
		Loss of motivation
		Loss of focus

2.4 Mitigation measures and adaptations

Companies and individuals can introduce adaptations and implement mitigation measures to facilitate remote working and reduce its impacts (Bentley et al., 2016; Buomprisco et al., 2021; Chong et al., 2020; Lazăr, Osoian & Raţiu, 2010; Wang et al., 2021). The control measures gathered through our literature review were structured in a typology where the top level is defined by the originator of the change and the second level defined by the type of adaptation. The adaptations can be considered in terms of working tools (such as technical equipment and support, private equipment and working space) or work practices such as organizational measures regarding processes, decision-making or individual working habits. The typology of mitigation measures and adaptations is presented in Table 2.

2.5 Ontology for teleworking risks and control measures

In information systems (IS), ontologies are used to describe concepts and their relationships in a given domain (Guarino, 1998). Ontologies support the description of the entities and their interrelationships in order to structure the knowledge of a particular domain of discourse. They can be used to build a 'web of data' understandable by machines to support the Semantic Web (Berners-Lee & Fischetti, 2001), identify similarities between concepts (Gomez-Perez, Fernandez-Lopez & Corcho, 2004) or to model a specific domain of knowledge (Bedini & Nguyen, 2007).

Facing the task of ontology creation, researchers put efforts into fully or at least partially automating the generation process (Bedini & Nguyen, 2007). Ontology learning is associated with techniques supporting the extraction of content from structured or semi-structured data (Asim, Wasim, Khan, Mahmood & Abbasi, 2018). This presupposes the existence of data sources covering the domain of interest. In the case where these data are not available or are only partially available, a traditional way of ontology creation is recommended.

2.6 Ontology transformation

Our ontology will be used for creating an online risk self-assessment and recommendation tool. While conceptual data modelling and ontology modelling present several similarities (El-Ghalayini, Odeh & McClatchey, 2007), fundamental differences exist between ontologies and databases, as regards the way information is structured and stored (Martinez-Cruz, Blanco & Vila, 2012). In our project, we chose to transform and store the ontology in a relational database to allow for a tight integration with the existing architecture of the recommender system (Zemmouchi-Ghomari, Ghomari, Adjir & Belaala, 2017).

Implementation of an ontology into a relational database implies a mapping of constructs. Constructs from the ontology field such as classes, properties, data types, inheritance and others have to be transformed into relational database related constructs such as tables, columns, data types, constraints and others (Astrova, Korda & Kalja, 2007). We applied the mapping rules proposed by Astrova et al. (2007) to successfully transform our ontology of risks into a relational database.

3 Ontology driven self-assessment risk evaluation

The risk breakdown structure and typology of control measures allow us to frame the concepts composing the ontology for teleworking risks and mitigation measures presented in this section. An important aspect of every ontology lies in the objectives underlying its development (Doty & Glick, 1994). In this research, our goal is to allow for the assessment of risks caused by teleworking and recommendations of appropriate mitigation measures based on the respondent's situation.

Software tools for risk analysis and management fall into four categories: risk identification aids, risk status monitors, decision-making aids and simulation models (Webb, 2017). These categories are not mutually exclusive and software can support multiple functions related to risk analysis and management. Our goal is to support the first three categories with our self-assessment tool. First, the system should support the worker in identifying and evaluating risks relevant to their situation. Second, the system should consolidate all the data generated by the users in order to compute the aggregate risk level. Finally, the system should be able to recommend relevant supplemental mitigation measures and adaptations based on the user's risk profile.

In order to successfully implement such a system, we need to model the relationship between risk factors and mitigation measures. We also need evaluation

questions regarding all risk factors, as well as evaluation questions for the mitigation measures and adaptations in all the individual situations. The relative importance of risks also plays a key role in creating aggregate risk profiles. For this reason, each risk factor is weighted.

Table 2. Typology of control measures for teleworking risks

Source of measure	**Type of measure**	**Description**	**Individual measures**
Employer driven	Technical equipment and support	Providing employees with all the necessary equipment and support to perform their tasks remotely	Ergonomic equipment, IT support and training, Company VPN, Provide digitized documents, Provide phone and internet connection
	Organizational measures	Adapting work processes, decision rules or task allocation to take into account the constraints and opportunities of telework	Flexi-time, Compressed work weeks, Part-time work, Job sharing, Mandatory office presence days, Holacracy, Transparent salary scale, Catch up calls between employees, Daily newsletter, Encouraging interactive communication, Decision-making authority, Training on remote collaboration, Short daily business catch-up meetings
Worker driven	Private environment and equipment	Employees adapting their private environment and equipment to better integrate the constraints of telework	Dedicated work area, Removing all personal devices from the room, Creating a conducive work environment
	Working methods and habits	Employees changing their work methods and private habits to better adapt them to the constraints of teleworking	Breaking tasks into small steps, Having tasks set by priority, Blocking out ambient noise, Extra-professional activities, Taking breaks, Having physical activity

The data collected with our system can be used to analyse the risks of teleworking and the response of companies and employees at a large scale. We have created a taxonomy of companies which allows for data drill-down along four dimensions: company size, economic sector, geographical location and legal status.

3.1 An integrated database for self-evaluation and recommendations

In order to support both self-evaluation and recommendations, we need to integrate our ontology into an online tool that will present the ontology, assist employees in evaluating their exposure to telework risks and provide recommendations based on the risks identified by the worker. These constitute the three main parts of the software developed to support our research.

First, the ontology will be used to inform users of risks and adaptations. For this, we need to integrate risk families, risk factors and mitigation measures. By linking risk factors and their mitigation measures, we can present the mitigation measures that reduce a risk, or the risks that are impacted by a mitigation measure.

Second, to allow employees to do their self-assessment, we need indicators to measure each risk factor. These indicators will in turn be presented in the form of a question to the users. During the self-assessment we also collect a list of mitigation measures provided by the company of the teleworker.

Finally, based on the measure of each risk factor, we are able to evaluate the self-assessed exposition of the teleworker to all risk families. Based on this assessment and the mitigation measures deployed by the company, we are then able to propose new mitigation measures to reduce exposure to the risks identified by the teleworker.

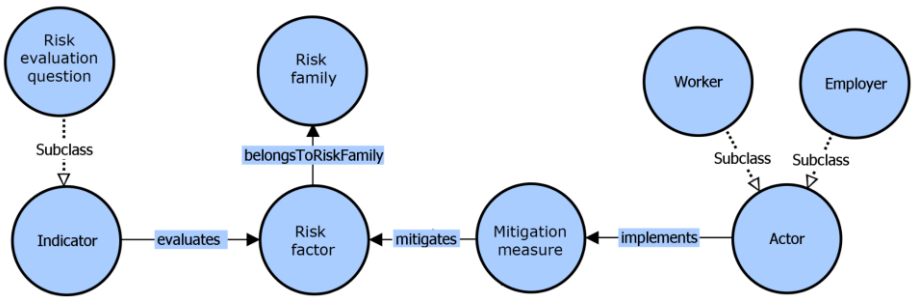

Fig 1. Ontology for evaluation and mitigation of teleworking risks

Starting from our ontology, depicted in Figure 1, we first built a conceptual model of the data in the form of an entity–relationship (ER) diagram, depicted in Figure 2. For this transformation, we applied the transformation rules formulated by (Astrova, Korda & Kalja, 2007). Each ontology class was represented by an entity. The properties of the classes were converted to attributes in the corresponding entities. The inheritance relationships composing hierarchy of risks in our risk breakdown structure were represented by one-to-many relationships in the ER diagram. Finally, a logical data model was created based on the conceptual one. This model is implemented in the self-assessment system, named “welcome”.

3.2 A tool for risk evaluation

Based on the implementation of the ontology, we can now include the necessary elements to support the self-evaluation. This involves collecting all the answers to the assessment questions in the form of a score from 1 to 5 (Likert scale), as well as the list of the implemented mitigation measures. Finally, since one objective of this research is to allow individuals to compare their evaluation with those of other teleworkers in different sectors, sizes and legal forms of companies or regions, we have added a taxonomy of companies based on the definitions of the Federal Statistical Office. The elements of the taxonomy were added to the data model.

The final data model comprises all data needed to store the self-assessments, compute the risks families exposure and recommend mitigation measures. The scoring

is based on the users' responses and weighting of the risk factors in a risk family. Owing to the structure of the data model, all the processing can be done at the database level as soon as the self-assessment is completed.

Each self-assessment is presented in the form of a spider chart that represents the individual exposure to the risk families as well as the average exposure of the teleworkers of the activity sector to these same risk families. In addition, based on the calculated risk exposure and the mitigation measures that have been put in place by the employer, we can recommend additional mitigation measures to reduce risk exposure.

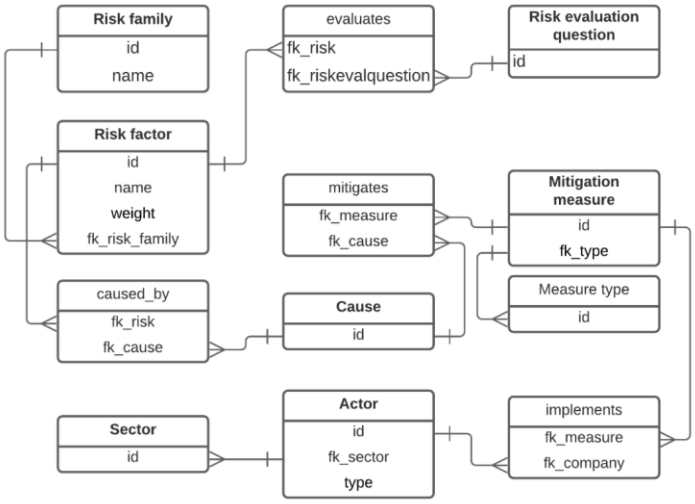

Fig. 2. Conceptual model of risk self-assessment and mitigation database

Mitigation measures are presented based on the already existing mitigation measures and the risk exposure. The recommender system tries to find the not already used mitigation measures that would have the highest impact in lowering the risk exposure. If a given mitigation measure affects two risks that are significant, it will be preferred over a mitigation measure that affects only one risk. Finally, in order to test and calibrate the recommender system, we have conducted interviews with a set of local companies to gain more insight into the risk perception and the mitigation measures that have been deployed specifically to mitigate the effects of telework during the crisis.

4 Discussion

This research aims to raise awareness and disseminate best practices for teleworking risk management. Raising awareness about teleworking risks requires getting managerial attention on this topic. For Davenport and Harris (2007), managerial decision is supported by "the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions." Our approach is to tightly integrate self-assessment of risks at the individual

level with recommendation of adaptations that should help reduce those risks in the same application. Following Webb's (2017) recommendations, we designed a risk analysis and management artefact to support both workers and decision-makers. Collecting data about adaptation measures put in place by the respondents' employers allows us to not only make recommendations based on the existing work context but also to create a dataset enabling benchmarking at different scales. The workforce's perceived level of risk and the adaptations can be visualized along different dimensions: geographical, economic sector, company size and legal status. This level of benchmarking makes the relative effort of decision-makers in the economic fabric visible.

5 Conclusion

In this paper, we propose a type of risk assessment and mitigation approach that leverages the power of ontological conceptualisation. Our ontology of risks and adaptations can be used to allow for effective self-assessment of risks and the recommendation of mitigation adaptations. In order to disseminate our risk ontology and raise awareness about teleworking risks, we transformed the ontology into a relational database for risk analysis and mitigation. As this ontology has been built for this specific application, the transformation was possible and resulted in a database allowing for the evaluation and mitigation of a number of risk factors. The data collected about existing mitigation measures can also be used for benchmarking of best practices across economical sectors. These tools are integrated in a user-friendly website where all workers can perform a self-evaluation of risks relative to the adaptations provided by their employer.

This tight integration between the risk evaluation and mitigation ontology and the multidimensional benchmarking is expected to support decision-makers in effectively reducing the impact of teleworking risks by taking appropriate preventive measures and providing employees with adequate mitigation adaptations. In the long run, this will allow for the creation of a panorama of the remote working risks in Switzerland.

6 Future work

Future studies could fruitfully explore this issue further by designing a maturity model for telework mitigation best practices. This model could be based on the data collected through the self-assessment tool and will aim at providing companies with objective guidelines to improve the working conditions of their teleworkers.

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