

Handheld-Assisted Field Data Collection for Occupational Risk Assessment

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A computerized handheld procedure is presented in this paper. It is intended as a database complementary tool, to enhance prospective risk analysis in the field of occupational health. The Pendragon forms software (version 3.2) has been used to implement acquisition procedures on Personal Digital Assistants (PDAs) and to transfer data to a computer in an MS-Access format. The data acquisition strategy proposed relies on the risk assessment method practiced at the Institute of Occupational Health Sciences (IST). It involves the use of a systematic hazard list and semi-quantitative risk assessment scales. A set of 7 modular forms has been developed to cover the basic need of field audits. Despite the minor drawbacks observed, the results obtained so far show that handhelds are adequate to support field risk assessment and follow-up activities. Further improvements must still be made in order to increase the tool effectiveness and field adequacy.

occupational health and safety hazard identification risk assessment field data collection
database handheld

1. INTRODUCTION

1.1. Context of the Study

In Switzerland, systematic assessment of work-related risks in activities involving significant hazards has been required by law since 1996. In regards to other standards, the Swiss occupational health policy is very similar to the ones in use in a number of industrialized states, such as European Union countries. Fulfilling this obligation in companies involving numerous hazards and work activities requires significant resources. Either through field investigation or questionnaires, a large quantity of data must be collected in order to get a global and comprehensive view of the risks within the

company. Furthermore, resources must be dedicated to risk analysis follow-up activities (data updating, follow-up of preventive measures, etc.).

The use of databases to support risk analysis management is quite common. Once the data is formalized and introduced into a central database, it may be easily used for analysis and follow-up purposes. As a matter of fact, numerous commercial tools are available, most of them being customizable to the specific needs of your study. Less support exists however in regard to field data collection and transfer to the database. Despite this lack, any practitioner understands the difficulties of recording data on a laptop while performing investigations in a

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“hostile” work environment, or the drawbacks of manual form filling.

A computerized handheld procedure is presented in this paper. It is intended as a database complementary tool, to enhance the implementation and follow-up of prospective risk analysis in the field of occupational health. Its role is to allow on-field storage of the data in a structure and formalism directly importable into a central database. Although the study is focused on data collection in the context of global risk assessment, it also opens development perspectives for specific risk assessment techniques. Specific computerized models have been developed to assess risks based on multiple variables, such as musculoskeletal injuries [1]. Interfacing global workplace assessment with specific risk quantification modules may, in the future, significantly enhance the tool.

1.2. Use of Handhelds in Occupational Health Applications

Personal Digital Assistant (PDA) devices are becoming ubiquitous and, as their processing and memory capacity are growing, they may be an interesting alternative to laptop computers. In addition, increased workforce mobility has brought about new, more efficient ways of collecting data from geographically distributed sources. Most distributed data is still recorded using pen and paper and then it is typed into a document or a database application.

Because of the variety and quantity of data to be collected by occupational health and safety (OH&S) practitioners, the use of PDA data collection applications is very interesting. Moreover, occupational health management relies heavily on field investigation and follow-up capabilities.

Traditionally, field data is collected on a paper form such as a predefined hazard list or table. The hazard list technique is adequate when applied to a narrow field (a specific hazard or activity) but its application becomes difficult in wide prospective investigations. Tables or open lists

are convenient for any field requirements but transferring the data afterwards to a computer may be time consuming. It must also be pointed out that with both manual methods, the data transfer process (coding, data cleaning) may be a source of error. The use of computerized data collection with oriented forms or procedures may significantly increase both acquisition efficiency and data transfer reliability.

A large number of ready-to-use applications are available and may be found on Internet websites. Some tools have also been proposed by previous authors to address medical, safety, hygiene or ergonomics issues. A field data collection system on a Newton MessagePad 120 was reported by Cohen in 1997 [2]. Handhelds' capabilities at the time of the study were limited and difficulties were encountered when trying to implement large checklists (time delays). Significant tool developments have been carried out since and capability limitations are no more reported by recent authors as a major drawback. The recurrent challenge however is to develop a pertinent and easy-to-use data acquisition process [3, 4].

However, some difficulties should be stressed, such as the handhelds' screen size limitation. It requires more awareness and slows navigation between fields, which may be perceived by users as a waste of time and reduce their willingness to use the computerized tool. Despite this feeling, it is interesting to note that, due to data transfer, a significant time reduction has been observed when comparing computer-assisted and manual data collection [2, 3, 5, 6].

2. METHOD

2.1. Risk Assessment Strategy

The hazard and risk scaling considered in this study are based on the risk analysis method in use at the Institute of Occupational Health Sciences (IST). This method, developed by Parrat [7], is an adaptation of classic risk approaches (such as Hazard Analysis and Critical Control Point,

HACCP) to the field of OH&S. As shown in Figure 1, the whole process of about nine steps includes hazard identification, risk evaluation as well as risk mitigation phases. Hazards and risk profile are associated with groups of workers performing similar activities in similar conditions, also called Homogenous Exposure Groups (HEG).

Similarly to other methods, risk is defined as the product of the frequency or probability of an event and the gravity of its associated health effects. One of the main interest of this OH&S-oriented method is the occurrence ranking system and the acceptance matrix (see Figure 2), which allow a quantitative comparison between chronic and acute (accidental) risks.

Various scales may be used to establish the severity and occurrence rates. It must be pointed

out that, in the case of chronic risks (exposure), determining the occurrence is complex because the assessment criteria depend on the hazard source. When the dose-response is known and there is a threshold limit, rating is obtained by comparing effective exposure to the standard (percentage of the standard, see Figure 2). This scale is, for instance, used in the case of exposure to chemicals. A direct comparison between the exposure level and a standard is not always possible, either there is no accepted simple standard or there is no known exposure/dose level. In this case, semi-quantitative scales, in which the relevant factors are classified by “bands”, may be used. Postural work problems, which relate to several qualitative factors, are typical examples requiring specific assessment scales. Specific scales can be set following

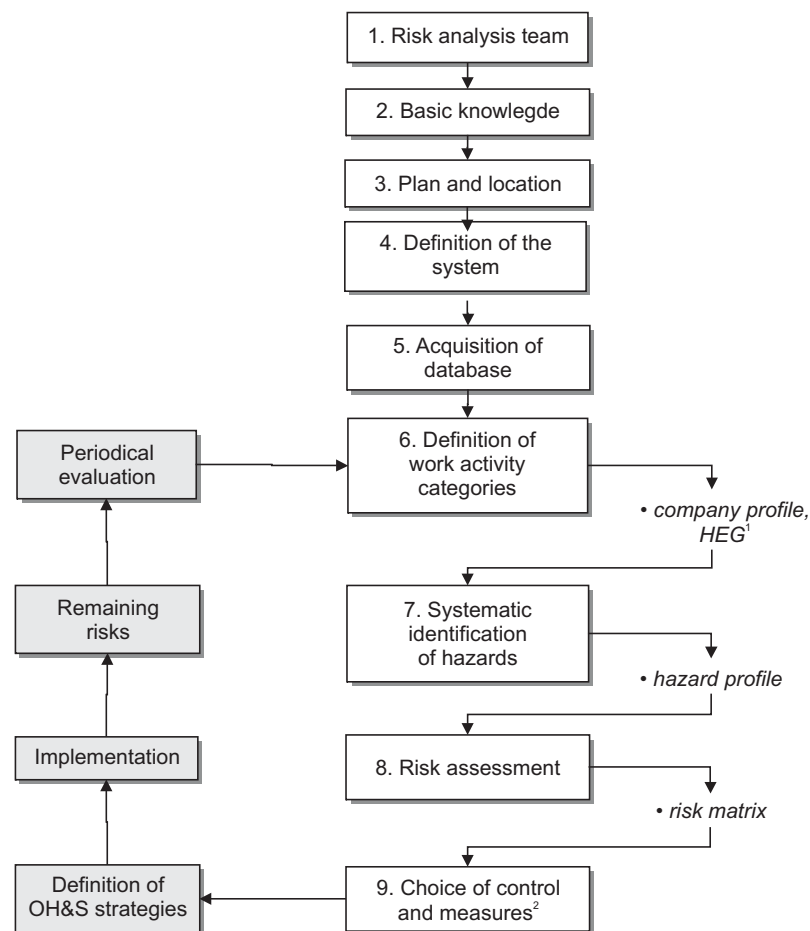


Figure 1. Risk management process. Notes. 1—Homogenous Exposure Groups, 2—similar critical points in Hazard Analysis and Critical Control Point (HACCP), OH&S—occupational health and safety.

Occurrence									
		Accident (accident/year)	Exposure (% of standard)						
Very high	5	>10/year	>100%	5	10	15	20	25	
High	4	<10/year	<100%	4	8	12	16	20	
Moderate	3	<2/year	<50%	3	6	9	12	15	
Occasional	2	<1/2/year	<25%	2	4	6	8	10	
Rare	1	<1/10/year	<10%	1	2	3	4	5	
		no harm expected	small injury (≤3-day stop)	medical treatment needed (>3-day stop)	physiological impairment (<15%)	physiological impairment (>15%)	Accident		
		no harm expected	discomfort, irritation	reversible harm	irreversible harm	severe harm, death	Exposure		
		1	2	3	4	5			
		Negligible	Marginal	Important	Critical	Catastrophic			
		Severity							

Figure 2. Risk matrix used in the Parrat method.

international recommended criteria, such as the ones proposed by the Finnish Institute of Occupational Health [8].

Risk assessments in the OH&S field tends to be based on repetitive schemes because of the large number of possible hazards and workplaces to take into account. This quantification process (step 8) must, for instance, be repeated systematically for each identified hazard source, which tends to be time-consuming. Moreover, later transcription of the field data collected may be a significant source of error.

2.2. Tool Requirement

The key issue in the development of a field acquisition tool is the automation and simplification of the reproductive schemes used in the OH&S risk assessment process. The tool should therefore:

- focus on hazard identification assessment and control (steps 6–9). For obvious reasons, preliminary procedural steps such as basic knowledge, plan and location (system boundaries, flow diagram) (steps 2–3) are to be processed separately. Descriptive information on the tasks or processes

performed is useful complementary information, although it does not constitute a key element of the tool developed;

- integrate the key methodological features of the risk assessment process currently in use at the IST, whereas:
 - the categorization of work activity should be compatible with the concept of HEG, or groups of workers encountering similar exposure conditions [7];
 - each HEG can be linked with a qualitative hazard profile (a list of hazard sources or hazard phenomena). The hazard profile must be understood as a summary of potential exposures or accidents which may be encountered by the corresponding group of workers. All occupational hazards, including safety, ergonomics and occupational hygiene factors, should be considered in the hazard profile set-up;
 - each hazard can be quantified, according to the occurrence and severity scaling proposed (see risk matrix, Figure 2). The quantification of the hazard profile produces a risk profile, which gives a summarized view of the risk level assessed for the corresponding to a set of workers;

- support field data collection in providing a systematic acquisition procedure and a convenient data storage (uploadable without further treatment into a central database). Collecting pertinent data is of primary importance to ensure a sound OH&S management. This is especially true in our case, as the data acquired will supply a central database, the core of the OH&S management system. The final purpose of the database is to:
 - store the data collected during the field investigations;
 - assist analysis and decision making by providing hazard and risk overviews and, at a later development stage, provide an exchange platform for all the OH&S actors involved.
- Hazard identification. All the potential health hazard sources are identified and indexed during this process. Information collected at this stage is mainly qualitative (hazard characterization), but semi-quantitative data about the potential health effect (severity ranking) may also be considered. At the end of the hazard identification process, each group of similar workplaces should be linked to a listing of hazard sources, also called a hazard profile.
- Risk analysis. This procedure is linked with the hazard identification process. The hazard data previously collected is implemented with quantitative values. Accordingly to the methodology developed by Parrat [7], the occurrence of health damage due to an accident as well as chronic exposure are ranked using semi-quantitative scaling. The resulting profile gives an overview of the occupational risks undertaken by a group of workers exposed to given working conditions.
- Hazard or risk checking. Once established, the hazard and risk profiles should be periodically updated. Specific audits may be performed in order to check the validity of the data. This may also be done in the course of other survey procedures (i.e., post-incident intervention, problem solving). Investigators should be able to perform the checking quickly without having to build the profiles from scratch.
- Decision taking. Decision taking is a common outcome for field investigation processes. Technical, individual or organizational preventive measures may be resolved in order to eliminate an undesirable hazard or to mitigate an unacceptable risk. Records about a decision should be unambiguously linked to a specific work activity and place(s) and must include a time limit.

2.3. Implementation Method

A structured and systematic approach is required to computerize field acquisition, some adjustments have therefore been made to the manual method used so far. The main methodological changes undertaken are (a) enhancement of the hazard identification list and (b) the setup of the acquisition process and procedures.

2.3.1. Field data acquisition

A field investigation may be initiated for many reasons or purposes. It may take place as an a posteriori analysis in order to fix an existing problem or investigate the causes of a previous accident/incident. It may also be performed in an a priori way in the context of an audit (external or internal), an inspection, a systematic hazard identification process or a systematic risk analysis. These last two reasons, which have been required by law since 1996 in Switzerland, are the most frequent purposes of a priori investigations.

Four possible field acquisition processes have been considered in this study. It is assumed that these processes cover the basic requirements of a prospective workplace survey:

A set of modular procedures has been developed in this study. The main investigation processes are carried out using appropriate sequence of procedures. The choice of a modular structure is based on practical as well as on methodological considerations, i.e., reusability.

Database implementation is indeed easier and the different sub-procedures may be conducted independently. This last advantage is of significance because field acquisition processes may be adapted to a wide range of needs. Although their primary goal was to support on-site hazard identification and risk analysis, the checking or decision procedures may, for instance, be also used to support auditing or post-incident investigations. Moreover, the structure used allows the introduction of additional procedures at further development stages of the study. The logic structure of the procedures is presented briefly in section 3.

2.3.2. Hazard identification

An accurate identification of hazards is required prior to any serious risk assessment and management strategy. In a general sense, failing to identify a potential risk may have severe consequences in terms of risk exposure and/or cost-benefit effectiveness. It may indeed lead to an unexpectedly high residual risk or to the inadequate allocation of resources for prevention. Previous comparative studies of risk assessment methods [9] suggest that even with skilled practitioners a significant amount of hazardous situations are overlooked during the analysis.

As occupational risks are characterized by numerous hazard sources, the use of hazard lists to assist identification is quite common in the OH&S field. The lists intended to assist the identification process must be very short in order to fit on a printout support. Although adequate to be used as a reminder to avoid critical omission, they are usually not exhaustive enough to be implemented as such in an automated acquisition procedure. Moreover, the very structure of these hazard lists is often inadequate for a systematic classification. This is, for instance, the case when hazard sources, hazardous events and worsening factors are at the same hierarchical level.

2.3.3. Tools

The acquisition system has been developed on a Palm Pilot device (m515, Palm Inc., Santa Clara, CA USA). The size, weight and touch-screen facilities of handhelds make their use appropriate to support field activities in a wide range of conditions. Moreover, a large number of commercial handheld-software is available.

The Pendragon forms software (version 3.2, Pendragon Software Corporation, Libertyville, IL, USA) has been used to support field data acquisition in this study. This database allows the setup of field entry sequences and scripting actions (calculations, Boolean logic) on the handheld support, while providing a Microsoft MS-Access platform on the desktop. The scripting and formats depicted in this paper are specific to Pendragon formalism, although it must be stressed that the general structure and implementation strategy may be applied to other software. The primary requirements being of limited complexity, several other databases may indeed be used to support the field data acquisition process.

2.3.4. Key fields

One can make use of a wide range of data to support OH&S management: risk assessment data, accident reports and statistics, human resources (absenteeism, turn-over, etc.), questionnaire data, hazard product management, etc. In a sense, the coverage and size of the central database is only limited by the data and resources available. For the handheld however the number of procedures and fields to be used is limited by the duration of the investigation. It must also be kept as straightforward and easy-to-use as possible because field conditions usually do not favour work concentration.

A set of key fields has been defined for each acquisition procedure, all of them being mandatory to perform the investigation. The minimal information about the investigation undertaken, the company profile or the work activity are, for instance, considered as key

fields. It is also true for the field used to define HEG (workplace locations, work activities) and to establish hazard and risk profile (hazard phenomena, occurrence and severity). The basic idea is that users not familiar with the handheld or with limited time should be able to introduce core data as quickly as possible. Depending on their needs, users should decide to fill the other non-mandatory fields directly into the central database or on the handheld (if available).

3. RESULTS, ACQUISITION TOOL

3.1. Acquisition Forms

Because of both software requirements and practical purposes the data acquisition process has been split into procedures, or so-called forms, in Pendragon formalism. Basically, each form contains a linear sequence of fields. Only one-to-one relationships are allowed into a form (a field of a form is related to only one field of the same form). Separate forms are required in order

TABLE 1. Forms to Be Used for Different Auditing Processes

Form Name	Description/Content	Mandatory Fields
Audit	Contains contextual information related to the auditing process and audited company. One audit form must be filled for each field investigation. Audit-related data is unique while company data is recorded as an external lookup list and may be re-used in other audits forms (next audits in the same company).	audit date, auditor, audit goals, company name, address, contact person
Company profile	Depicts the basic company structure. This form is used to create an intermediate hierarchical level between the company and its workplaces (or work activities). Several departments may be associated with a company.	company name, departments/sector
Work Activity	Work activity groups exposed to similar risks may be created in this form. A work activity group is defined as a concatenation of the <i>company</i> , <i>department</i> and <i>activity</i> fields. Several activity groups may be associated with each department/sector.	company name, department/sector, activity (work description), location
Hazard identification	The hazards to be associated with a specific work activity are depicted in this form. Each new identified hazard must be entered into a new form. Cascading selection lists (cascading lookups) are used to facilitate the hazard description (see Figure 5) although the <i>hazard source</i> and <i>hazardous events</i> fields must be filled manually.	hazard, hazardous event, hazard source description
Risk assessment	Quantitative values are associated with the hazard to characterize the risk. Gravity and occurrence values are to be associated with each identified hazard. The use of predefined popup lists (occurrence and severity scales) and calculation scripts facilitates the quantification process.	hazard description, occurrence, severity, risk
Decision	Decisions worked out during an audit are recorded into this form. It is directly linked to a work activity group and may be used independently of the hazard and risk identification processes. The decision is associated with a due date and responsible in order to allow its use in follow-up planning.	decision description, due date, responsible
Control	Control actions such as the follow-up of a decision, a hazard or risk identification update are recorded into this form. It is directly linked to a work activity group and may be used independently of the hazard and risk identification processes.	control description, control date

to depict one-to-multiple relationships between fields. A good example of this is the relationship between the *company* and *department/section* fields, as several departments may be linked to the same company name. On the handheld, these two fields appear into two distinct forms linked through a form-to-subform hierarchy. A handheld form usually corresponds to a table into the corresponding MS-Access database structure. The number of forms and their content is largely determined by the structure to which the acquired data will be uploaded.

As shown in Table 1, seven forms have been considered in this study. They cover the most relevant fields and relationships which may appear in the central database. Anyone of the four possible auditing processes may be obtained by a combination of appropriate acquisition forms. This modular structure is convenient in the

perspective of further developments as it facilitates the introduction of new procedures and/or new combinations of procedures.

3.2. Field Data Acquisition

Once implemented on the handheld, modular forms must be filled following a predefined procedure. As shown in Figure 3 the acquisition procedures links the various forms in a logical order. Scripting and form-to-subform functions are used to ensure the user's navigation between forms. Following the correct procedure is straightforward as the fields and forms are displayed in a chronological order. Once the key fields of a form are filled, the user may proceed to the next subform(s), either by selecting the appropriate button or using a selection list (when several subforms are available).

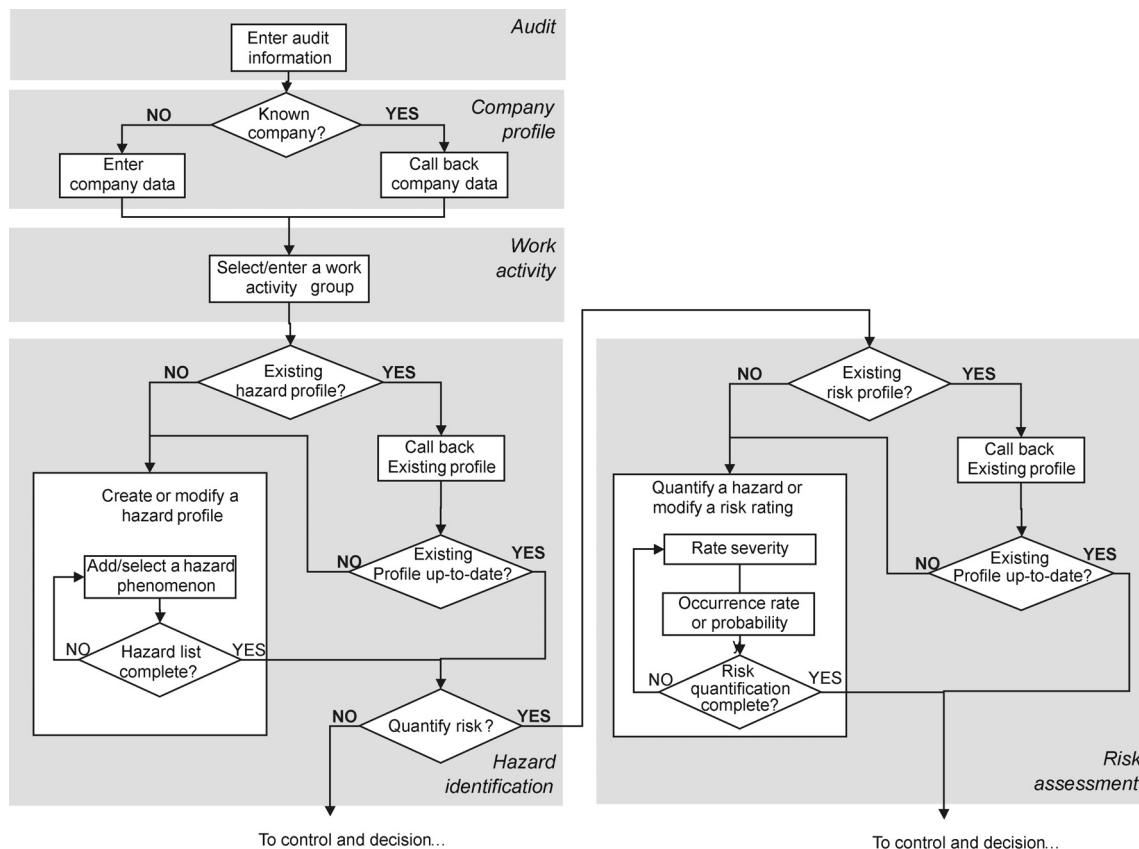


Figure 3. Data acquisition procedure on a handheld.

3.3. Forms Navigation and Control

Several handheld embedded functions and scripting possibilities have been used to facilitate form filling and to ensure their coherency. Specific examples are given in Figure 4. The main functions/scripting action used are as follows:

- Boolean tests and mandatory fields, to ensure that the minimal required information is provided (key fields of the database) and to facilitate navigation inside forms (sending the user to the appropriate field);
- subform functions and button/popup lists facilities, to allow navigation between forms and to ensure the setup of one-to-one and one-to-multiple relationships between forms and subforms;
- lists, lookup lists and cascading lookup lists, to facilitate data entry in providing preset items lists to the user (cascading hazard lists, severity and occurrence scales lists, etc.).

acquisition procedures are required. This is especially true during the hazard identification phase, which relies on a repetitive use of a predetermined list.

A specific hazard list has been designed to be implemented on a handheld. The list proposed relies on a systematic hierarchical classification of about 75 hazards. Such a structure is required in order to allow the use of cascading lists on the computerized tool. The classification used is also intended to avoid redundancies or overlapping between the list fields and equivoque entries in the database. An example of hazard selection using the cascading lookups is presented in Figure 5. Its generic structure is intended to cover the whole range of work-related hazards, including chronic and acute physicochemical risks, biomechanics risks (load lifting, repetitive movements) as well as psychosocial factors (mental and emotional stresses). However it must be pointed out that if this last category may be easily implemented in the qualitative assessment

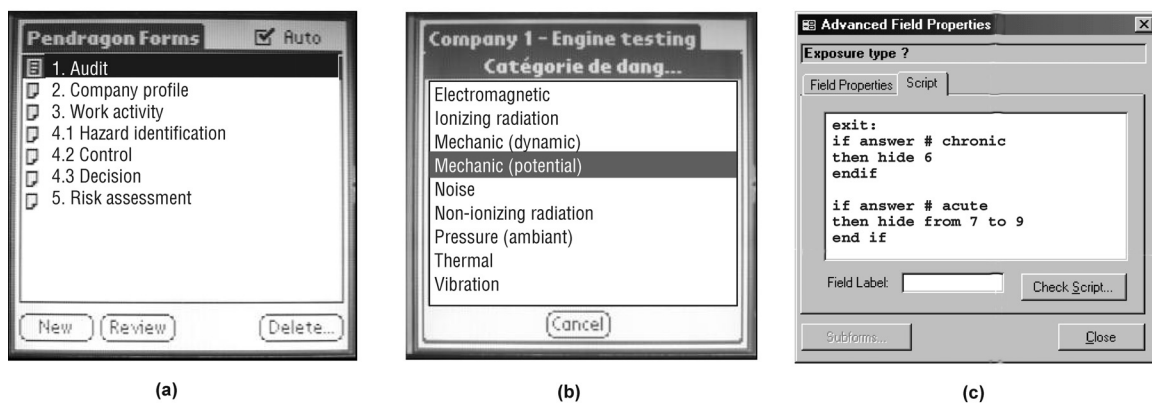


Figure 4. Examples of handheld displays within forms: (a) Pendragon main menu (display forms available), (b) one of the available hazard lists (physical hazard lookup), (c) a popup menu and its related script (risk assessment form).

3.4. Hazard Identification List

Acquiring data on a handheld in field conditions differs notably from usual data collection performed in computer-based programs. Because of the limited space available on the handheld display as well as the lack of spare time during an investigation, quick and straightforward

phase (hazard identification), its quantification remains difficult.

The screen size being limited, the hazard list is implemented on the handheld using lookup lists of limited size (between 3 to 8 items each). To select a specific hazard, the user must go through a hierarchical sequence of cascading lookups.

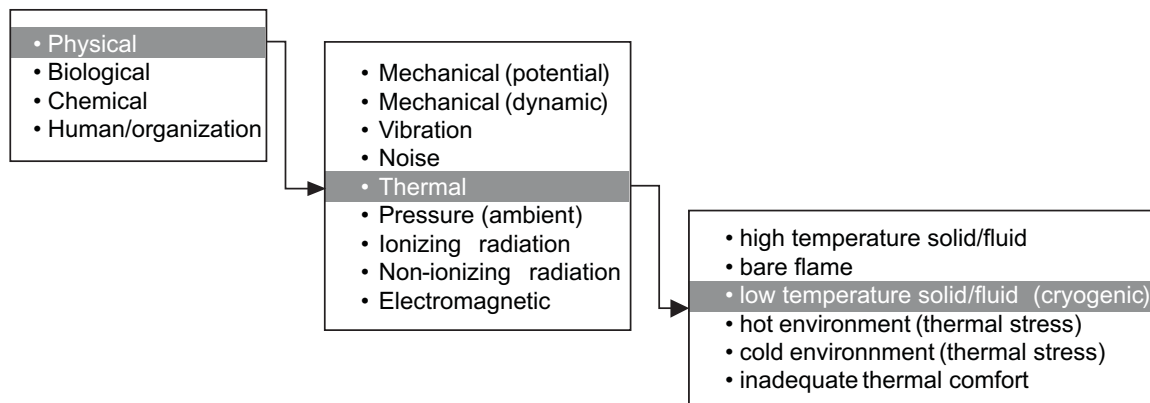


Figure 5. Partial view of the hazard list.

3.5. Database Mapping

The data collected on the handheld is uploaded on a computer using the palm desktop synchronization feature. Each form is entered as an independent table (in an MS-Access format) in the Pendragon software, which constitutes the prime recipe of the imported data. From there, the data can be sent to a functional database, in which the relationships existing between the database table (or handheld forms) will become effective.

The data may be sent to a wide range of databases, using exportation or direct mapping functions.

An example of a database structure to be used with a PDA is shown in Figure 6. The data collected in a handheld form usually appear as a single MS-Access table. It is interesting to note that the database structure may be more complex than straightforward form-to-subform relationships used on the PDA. Moreover, the central database

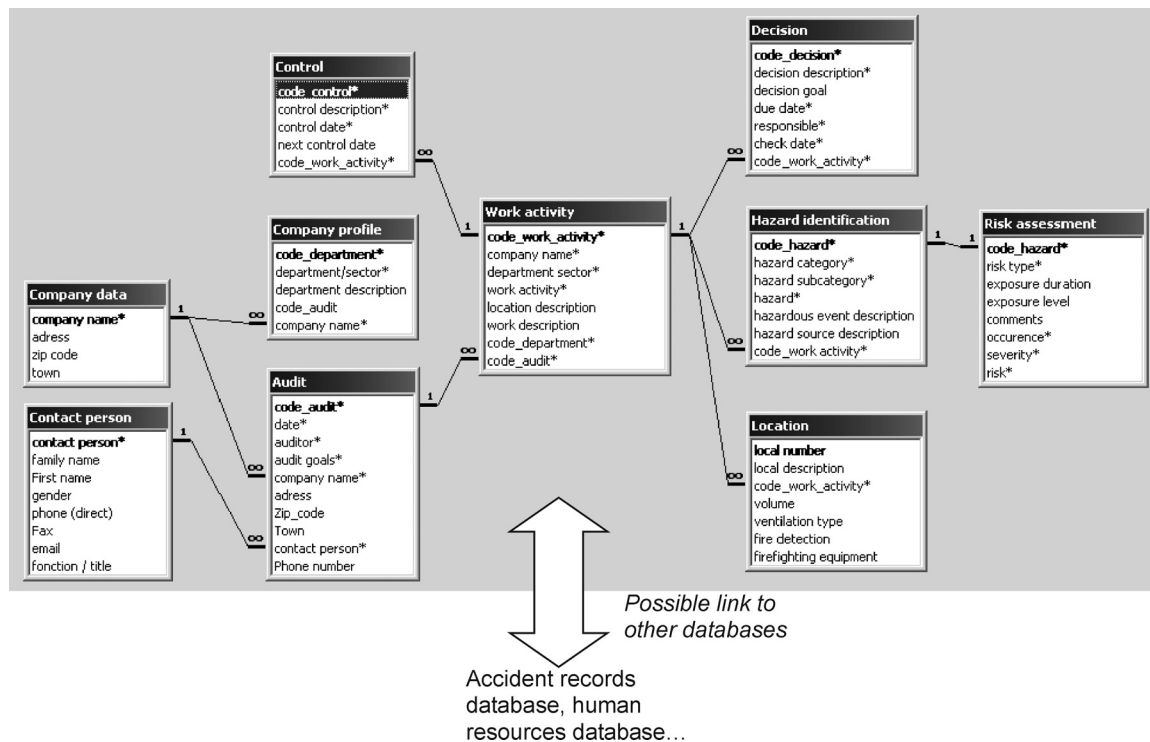


Figure 6. Example of database structure.

may contain many more fields and tables than the handheld. Additional data may be either entered on the desktop or through importation from related data sources. Some examples of additional tables (location, contact person) and links with other OH&S data sources are also suggested in Figure 6.

4. CONCLUSIONS

4.1. Comments

The tool developed in this study is being tested and refined at the OH&S department of IST. Several observations can be made about the preliminary tests undertaken so far. These observations are based on an internal evaluation: four colleagues not involved in the development of the tool but familiar with the risk assessment method were asked to test the acquisition procedure. It must be pointed out that these trials did not constitute tool validation, for which large-scale tests are still required.

- The advantages of handheld tools with regard to data integrity are somehow limited. On the one hand, systematizing the acquisition procedure and automating the data transfer makes the investigation more reliable (complete, no data alteration). On the other hand, electronic devices, being more sensitive to mishandling and environmental conditions, are intrinsically less safe than manual forms. The risk of complete data loss may not be excluded, for instance, in case of mechanical damage, serious thermal or electromagnetic stress. However, it must be stressed that the risk of major loss may be noticeably reduced using organizational and technical measures (regular backups, use of removable data storage).
- The setting-up of acquisition procedures on Pendragon is time-consuming as handheld forms cannot be emulated on the computer. After each change, all the forms must be frozen and sent to the handheld. Besides, the correct implantation of the forms must be

checked after downloading as occasional transfer failures have been encountered (forms not downloaded onto the handheld). The most sensitive part of the acquisition process is still the transfer into the central database. Mapping mismatch preventing a complete transfer of data has been encountered while uploading handheld data to the Pendragon database or transferring it to an external database (the central MS-Access database). Despite the software's in-built exporting and importing facilities, the mapping configuration is not intuitive. The user should be careful to avoid any mismatch between the properties of corresponding fields.

- The duration of field investigation appears to increase (by 10–30%) with handheld acquisition procedures compared to the manual procedure used previously (based on the same assessment method). The global balance remains attractive because of the time gained while uploading data into the central database. Moreover, disregarding the global duration of the process, one should also stress that the induced activity shift has positive side effects in terms of public perception and motivation for the OH&S specialist. More time is indeed spent in “observable” field activities and less in tedious and “hidden” office work (data cleaning and transfer).
- Handheld forms, which use a large proportion of predefined lists and lookups, can be filled quickly and are therefore adequate for field activities. Open text fields, which must be filled by hand (using handheld sign recognition), are less adequate and tend to discourage unfamiliar users. Fortunately, risk assessment relies heavily on predefined scales and hazard lists. No handwriting is therefore required for the mandatory fields used in the risk identification and assessment forms.

4.2. Further Use

Despite the minor drawbacks observed, the results obtained so far suggest that handhelds are

adequate for supporting field risk assessment and follow-up activities. Further developments must be made to allow their integration with existing risk management methods, such as specific forms to support quantitative assessment of complex hazards. Further testing is also required to refine and validate the tool. Some refinements are specific to the tools used or the risk assessments application (database field mapping, lookups lists), while others relate to the general use of handheld tools in field conditions (user-friendliness, reliability, field entry speed). It is interesting to note that the strength and limitations encountered in this latest category are similar to the ones reported by previous authors in other application conditions. From our point of view, these recurrent concerns are key issues to be addressed to make the use of field data acquisition tools more attractive and widespread.

The handheld tool is not intended to be used in an independent way. It must be understood as merely part of the OH&S data system, which itself belongs to a global occupational health management system. The database may, for instance, be used in a direct way to insert or extract relevant information such as accident statistics, measured exposure levels or medical surveillance planning and follow-up actions. Although discussing the management strategy is outside the focus of this paper, the complementary role of the proposed tool must be emphasized. For practical reasons (mapping with Pendragon), an MS-Access central database has been considered in this study. Further developments are going to be undertaken in order to use the handheld tool with OH&S management systems that use other databases, such as Oracle.

REFERENCES

1. Kumar S. Computers in delivery of ergonomic technology for safety in the workplace: ErgoRisk©, an example. *Human Factors and Ergonomics in Manufacturing* 2002;12(3):321–30.
2. Cohen MA, Cotey MR. IH interface. The use of a hand-held pen computer for field data entry. *Appl Occup Environ Hyg* 1997;12(12):792–6.
3. Tudor JR. IH interface: collecting industrial hygiene field data: practical experiences with a handheld computer. *Appl Occup Environ Hyg* 2001;16(4):426–31.
4. Malter DE, Davis TJ. Data collection and “real-time” learning using handheld computers. *Appl Occup Environ Hyg* 2003; 18(5):321–30.
5. Koop A, Mösges R. The use of handheld computers in clinical trials. *Control Clin Trials* 2002;23:469–80.
6. Zankl A, Molinari L. Abase—a tool for the rapid assessment of anthropometric measurements on handheld computers. *Am J Med Genet* 2003 Aug 30;121A(2):146–50.
7. Parrat J, Mann S, Loth S, Droz P-O. Risk Analysis of Occupational health and safety hazards. A semi quantitative approach. *Occup Hyg* 2001;5(3): 209–30.
8. Mauno A, Martti L, Tuulikki K. Ergonomic workplace analysis (Report No. ERG 3/84). Helsinki, Finland: Ergonomics Section, Finnish Institute of Occupational Health; 1997.
9. Suokas J, Pyy P. Evaluation of the validity of four hazard identification methods with event descriptions (Research Report No. 516). Tampere, Finland: VTT Technical Research Centre of Finland; 1988.