Final Newsletter
September 2015

Innovative strategies, methods and tools for occupational risks management of manufactured nanomaterials (MNMs) in the construction industry

Overview of Scaffold results

Content

Context and objectives

The construction industry is the biggest industrial employer in the EU, with 13,9 million jobs, representing 6,4 % of total employment and 29 % of industrial employment. The use of MNMs and nano-enabled products (NEP) in construction is an increasing reality, mostly in cement or concrete products, coatings or insulation materials and to a lesser extent in road-pavement products, building glass, flame retardant or textiles. Most workers and employers in the construction sector (~75%) are not aware of working with MNMs and NEP. Detailed information about product composition and possible nano-specific health and safety issues is generally lacking: the information available for the raw MNM is often lost while stepping down the user chain. As a consequence, it is very difficult for average construction companies to conduct a proper risk assessment and organize a safe workplace for its employees.

The SCAFFOLD research aimed at providing practical, robust, easy-to-use and cost effective solutions for the European construction industry, regarding occupational exposure to MNMs.

Release and exposure, assessment

The Scaffold project measured particle release and occupational exposure (inhalation, dermal) at pilot scale, lab scale and in real scenarios, considering: 5 MNMs (TiO_2, SiO_2, carbon nanofibres - CNF, cellulose nanofibres – CeNF, and nanoclays), 6 applications (depollutant mortars, self-cleaning coatings, self-compacting concretes, fire-retardant panels, coating laminates and insulations) and 5 scenarios (manufacture of NMs, manufacture of products containing MNMs and application, machining (drilling, sawing), demolition and fires).

Workers were not overexposed to MNMs in the processes monitored and the measured exposure was below limits selected by Scaffold for the five MNMs. The highest mass concentration of MNM was measured in tasks where nano-powders were handled directly and in significant quantities e.g. cleaning of the reactor and of filters in the nano-TiO_2 manufacturing process, or spraying dispersions of self-cleaning coatings. The highest total particle concentrations were measured while machining hard materials like self-compacting concrete and laminates filled with CNF, with no clear difference between conventional and nano-enabled materials and with no observation of free nano-object. Dust peaks were also observed during e.g. manual adding of powder additives or demolition tasks, with average 8-hour exposure still below the limit value, and a large and complex variety of particles of all sizes, mainly bound in the matrix. In construction, exposure to mixed types of dust and to chemical compounds (including carcinogenic asbestos, crystalline silica, and solvents), is common and may often be of higher relevance than the exposure to MNMs, which are typically included in the products at concentrations below 1,5 %.

Fire tests performed with conventional and nano-enabled materials showed differences in fire behaviour in the presence of the nano-objects. However, none of the nano-objects introduced in the materials was identified in the combustion effluents, with the possible exception of nano-clays from the fire retardant panels.

Protection equipment

Experimental investigations of collective protection were carried out in nine rooms with different ventilation systems. Particles from the processes were prevented from reaching the room air only when works were conducted in the glove box or with positive pressure room ventilation.

The efficiency of different types of current respiratory protective devices intended for use in construction industry and of three types of clothes generally used by workers on construction sites were tested with different nanoaerosols in to enable a proper selection for different workplaces and hazards. The Total Inward Leakage (TIL) of nanoparticles was measured with a breathing manikin simulating natural human movements and speech. The highest TIL was found for simulation of speech and of up and down head movement. The highest effectiveness of protection was recorded for the full-face mask used with P3 filters and the TH2 powered filtering device incorporating a hood.

The observation of PPEs involved in real scenarios at industrial partners' workplace showed that the current gloves, masks and Tyvek clothes are efficient towards NPs incorporated in a material at realistic concentrations (between 0,4 and 1,7%). Whether in powder form (synthesis of NPs, manufacturing of the mortar) or in solid state (mortar with water, applying on a wall) or in sol-gel state (liquid mortar), we never observed SiO_2, TiO_2, nanoclay or nanocellulose inside PPEs. Regarding the nature of the clothes, the rain coating was the most efficient material, with no diffusion observed at all (aerosol and liquid). The polyester 65%/cotton 35% material was efficient only for SiO2 aerosol and the fleece jacket for SiO_2 aerosol and TiO_2 aerosol.

Library of Solutions, management

As a main outcome, the project SCAFFOLD has released a Library of Solutions including:

- 4 **quick guides** (risk prevention, risk assessment, risk protection and risk management) **for OSH managers** in construction,
- a **Toolkit** (software) to facilitate the diagnosis, implementation and audit of nano-risk management in large and small construction companies.
- **a handbook for risk management** (new deliverable in preparation).

Standardization

CEN/TC 352 "Nanotechnologies" (WG3/PG5) is preparing a Technical Specification (TS) based on Scaffold's results: "Manufactured nanomaterials (MNMs) in the construction industry. Guidelines for occupational risk management".

European strategy

Considering the state of the art and of the praxis and the regulatory and research context at the end of the project, Scaffold proposes a European strategy to further improve the management of occupational risks related to MNMs in construction.

Jesus López de Ipiña, Tecnalia, Coordinator
jesus.lopezdeipina@tecnalia.com

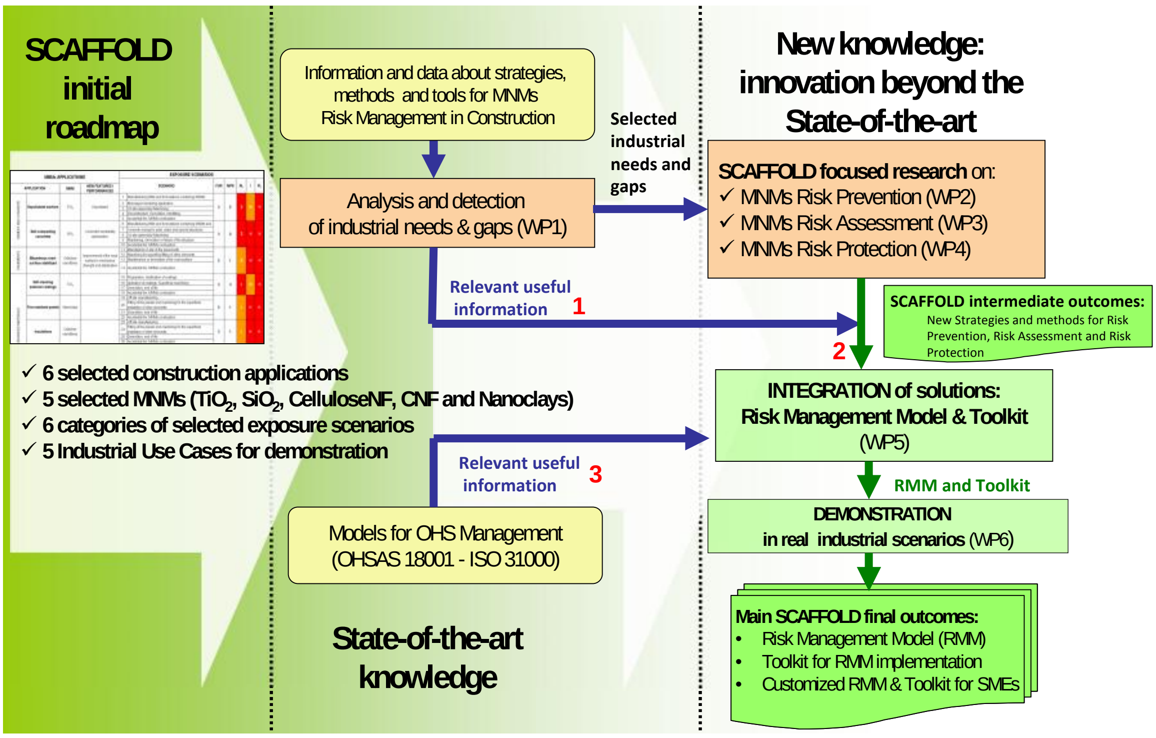
Partners

1. TECNALIA Research and Innovation, Spain
2. CEA, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, France
3. DEMOKRITOS, National Centre for Scientific Research "DEMOKRITOS", Greece
4. CIOP-PIB, Centralny Instytut Ochrony Pracy - Państwowy Instytut Badawczy, Poland
5. ACCIONA, Acciona Infraestructuras S.A., Spain
6. AENOR, Asociación Española de Normalización y Certificación, Spain
7. MOSTOSTAL, Mostostal Warszawa S.A., Poland
8. ROSSAL, ROSSAL SRL, Romania
9. TECNAN, Tecnología Navarra de Nanoproductos S. L., Spain
10. NETCOMPOSITES, NETCOMPOSITES Limited, United Kingdom
11. ICECON, Institutul de Cercetari Pentru Echipamente si Tehnologii in Constructii, Romania
12. EU-VRi, European Virtual Institute for Integrated Risk Management, Germany
13. FIOH, Tyoeterveyslaitos, Finland
14. UMN-PTL, Regents of University of Minnesota, United States of America

International Advisory Board

Eusebio Rial (†), Emmanuelle Brun	EU-OSHA (Spain)
Domenico Campogrande	FIEC (Belgium)
Rolf Gehring	EFBWW (Belgium)
Olivier Salvi	ETPIS (Germany)
Martie Van Tongeren	IOM (UK)
Steffi Friedrichs	NIA (Belgium)

Structure of the project



Point of view of the construction industry

The FIEC (European Construction Industry Federation) and the EFBWW (European Federation of Building and Wood Workers) are the European sectoral social partners for the construction industry, representing respectively the employers and the workers.

Despite the improvements observed in OSH statistics over the last few years in our sector, further efforts are needed and this explains why OSH issues have an important place in our social dialogue agenda. In particular our joint work programme mentions specifically the need to adequately address new possible hazards, including those linked to the use of nano-materials.

A study that we undertook in 2009 showed that nano-materials are more and more used in construction, but also that detailed information about them is generally lacking. As a consequence, for the average construction company it is very difficult to conduct a proper risk assessment and to organise a safe workplace for its workers.

For this reason the toolkit and the various outcomes developed in the framework of the Scaffold project can provide an extremely valuable support to construction companies, and in particular SMEs, as regards the prevention and management of occupational risks related to nano-materials.

After the intensive work undertaken in the framework of this project, the main challenges now will be the promotion and the dissemination of the outcomes, as well as the needed feedback from users in view of future adaptations and improvements.

In this respect both our organisations can provide an important link with such users, both the companies, but also the workers of the sector, through the network of our national affiliates.

Our common goal is a continuous improvement of prevention and management of OSH and the tools developed in the framework of this project will certainly help us in achieving such a goal.

Domenico Campogrande, FIEC   Rolf Gehring, EFBWW

Stakeholder consultation in Scaffold

Scaffold‘s key outputs (guides, toolkit, roadmap & strategy) were prepared following extensive consultation with a range of stakeholders (via workshops, meetings, surveys, interviews and document reviews):

- Representatives of the construction sector, including:
  - European Construction Industry Federation (FIEC);
  - European Federation of Building and Wood Workers (EFBWW);
  - OHS Managers from several construction companies.
- Manufacturers of construction products;
- European and Spanish agencies for occupational safety;
- Manufacturers of personal protection equipment;
- Experts in nanosafety;
- Policy makers at European and national (Spain) levels.

The authors would like to place on record their thanks all those who contributed. In particular the authors would like to thank Domenico Campogrande (FIEC) and Rolf Gehring (EFBWW) for their advice and assistance throughout the Scaffold project.

The views expressed in these outputs are solely those of the authors.

Scaffold final conference

OPEN WORKSHOP

Operational occupational Risk Management Models and tools for MNMs in the industry

Hosted by: SENN2015

Organized with the support of: EU-VRi

Scaffold's final conference was organized as a Joint event with the two other industry-orientated projects NanoMicex and Sanowork. It took place on 15.04.2015 in Helsinki, at the SENN conference. About 40 persons attended the workshop, coming from scientific research, expertise institutes, public authorities and industry. The agenda of the workshop and the presentations are available on Scaffold's website (http://scaffold.eu-vri.eu).

The workshop provided an extended (if not complete) overview of the issues at stake when implementing applied nanosafety in the industry: from safety by design (of MNMs or of MNM-enabled products) to insurance of occupational nanorisks, *via* risk protection, risk assessment and risk management. The following overall conclusions can be drawn from the presentations and discussions:

- Safety-by-design must be undertaken upfront with the producer of MNMs or MNM-enabled products, balancing the often antinomic factors "performance" and "safety". For instance, for the molecular Safety-by-design, within and not after the design of the MNM.
- Even in a context of large uncertainties concerning the risk assessment and of gaps in the available tools, it is possible to provide sound recommendations and even risk management tools, which are based on the best available knowledge.
- The followings are keys for the transfer from research into practical tools for the industry:
  - Communicate and disseminate information on risks and risk management of MNMs through Material Safety Datasheets (MSDS) and Standards;
  - Use simple (simplified) rules in the Risk Management Model (RMM);
  - Translate the practical tools for risk management into national languages;
  - Have the industry on board to drive the development of practical tools.
- The long term maintenance, update and further developments of a risk management tool for MNMs and of its components is a major challenge. This requires a sustainable EU-wide coordination of pluri-disciplinary expertise institutes, who can transfer science and knowledge gained through research into operational tools for industry and the regulators.
- The current regulatory framework is considered as sufficient for nanosafety in the construction sector; efforts should be made to develop guidelines or guidance documents that support practical implementation of risk management (smart regulation).

Risk Prevention – Safe by Design (SbD)

Scaffold (WP2) has developed innovative strategies for Risk Prevention in selected scenarios and products of the construction sector. The main conclusions and outputs on this issue can be summarized as follows:

(1) There is not a well-established methodology for **Risk Prevention** in the use of MNMs in the construction sector. However, several strategies can be applied in the different stages of their use, from the design to their incorporation in matrixes.

(2) Scaffold has proposed and demonstrated **Risk Prevention** strategies for the 5 nano-objects in its scope, as reported in Table 1 below.

(3) It is possible to start the **Risk Prevention** from the design of the MNMs. For instance in the case of TiO_2 spherical nanoparticles, Figure 1 below, by supporting them on sepiolite microfibers. This way, the risks associated to the matter in the nanoscale are minimized and the photocatalytic effects are improved.

(4) For some products with very low density, such as n-SiO_2, it is possible to prepare highly concentrated stable aqueous suspensions for their further use in cementitious matrixes. This has been considered **Risk Prevention** by safe handling.

(5) Clay nano platelets need to be organically modified in order to favour their compatibilization with polymeric matrixes. However reducing the degree of organomodification can lead to a reduction in smoke and heat release.

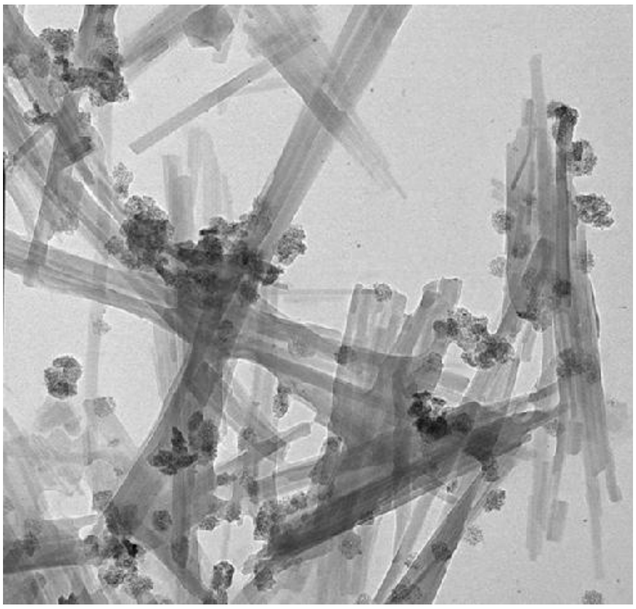


Figure 1: Spherical TiO_2 nanoparticles supported on sepiolite microfibers. Scale is 100 nm.

Table 1: MNMs description and properties used for Scaffold WP2

NMNs	Producer	Comments
SiO_2	TECNAN	10-15 nm Surface area approx. 206 m^2/g
TiO_2	TECNAN	15-20 nm Surface area approx. 80 m^2/g 80/20 Anatase/Rutile
Nanoclay (Dellite 67G)	Laviosa Chimica Mineraria S.p.A, modified by TECNAN	Reduce the organic content and therefore the toxic smoke when burned
		Additional inorganic compound (silane)
TiO_2 supported on sepiolite fibers	Tolsa S.A.	µ-particle size The n-spheres are supported on micro fibers in order to reduce the nano-risks and increase the photocatalytic effect
Carbon nanofibers	Pyrograf Products, Inc.	7-8 µm length
Cellulose nanofibers	Celluforce	The fibers form agglomerates, necessary to disperse prior to their use

Table 2: MNMs applications and risk prevention strategies proposed by Scaffold WP2

MNMs	Application	Strategy	Impact
TiO_2	Self-cleaning and depolluting mortar	Concentrated and stable dispersions	Reduce volumes transported and related risks
		n-TiO_2 supported on sepiolite microfibers	Reduce potential emission of free nanoparticles
SiO_2	Self-compacting concrete	Concentrated and stable dispersions	Reduce volumes transported and related risks
Nanoclay	Fire resistant polymeric panels	Thermal treatment	Reduce the smoke (and slightly heat release) from the panels in case of fire
		Low energy mixing processes	Reduce particle release (with equivalent fire performance)
Cell NFs	Insulating polyurethane foam	Good dispersions and MNM-binding to the matrix	Reduce the likelihood to release free MNMs from solid matrix
CNFs	Composite materials for electro-magnetic interference shielding		

Risk Assessment

The main objective of WP3 was to develop strategies and methods for risk assessment in selected scenarios in the construction sector. Three main results have been achieved:

1. Proposition of Occupational Exposure Limits (OELs) for the 5 nano-objects of the project;
2. Data on measurements at lab and pilot scale in scenarios in the sector;
3. Methods for risk assessment of the selected nano-objects in construction have been proposed.

The OELs proposed by Scaffold are summarized in Table 3 (Stockmann-Juvala H et al, 2014). Due to the limited amounts of data on the hazards no OEL could be proposed for nanoclays at this stage. In addition to the substance-specific OELs, Scaffold recommended 8 h OELs for general, inert dust of 0,3 mg/m3 for the respirable fraction, and 4 mg/m3 for the inhalable fraction. These values can also be applied to nanoclays.

Table 3: OELs proposed by Scaffold

Nano-object	OEL (mg/m3) or fibers/cm3 (1)	Reference Values particles/cm3 or fibers/cm3(1)
nano-TiO2	0.1	40.000
nano-SiO2	0.3	40.000
nano-clay	0.3 (respirable) & 4 (inhalable)	40.000
Low toxicity dust	0.3 (respirable) & 4 (inhalable)	
nano-cellulose	0.01 (1)	0.01 (1)
Carbon nano-fiber	0.01 (1)	0.01 (1)

General benchmark exposure levels for nanomaterials have been recommended by different institutes, e.g. the IFA in 2009 (IFA 2014a). The values recommended by the IFA were also adopted as provisional reference values for engineered nanomaterials by the Social and Economic Council (SER) in the Netherlands in 2012 (SER 2012). These values are also recommended as reference values for engineered nanomaterials by the Finnish Institute of Occupational Health (FIOH 2013). These values are mainly based on experiences in exposure measurements and on the detection limits of the available measurement methods, and are not substantiated toxicologically.

Occupational exposure measurements have been performed on selected scenarios in construction. Table 4 below shows the scope of the assessments, which cover the life cycle of the 6 nano-enabled applications selected for their relevance in the sector. In general, the results of the measurements are encouraging: nearly no occupational issues related to MNMs have been identified in the scenarios investigated.

Finally, WP3 has developed a Best practice guide for risk Assessment which aims to help Occupational Health and Safety managers assess the potential risks derived from the use of nano-objects in the construction sector.

Table 4: Scope of the assessments performed in WP3

	Nano-object and application					
Life cycle step	**nano-TiO2** depollutant mortar	**nano-TiO2** self-cleaning coating	**nano-SiO2** self-compacting concrete	**nano-Clay**(fire retardant panels	**carbon nano-fibers** coating laminates	**nano-cellulose** insulations
Nano-object manufacturing	X	X	○			
Manufacturing nano-enabled products and application	X	X	○	○	X	X
Use/maintenance: Machining	X	X	X	(X)	X	X
Demolition	X	X	X	(X)	X	X
Accidental fires	X	X	X	X	X	X

Scenarios marked with X have been measured in WP3; scenarios marked with the red round have been measured in the Industrial Case Studies (WP6).

References:

Stockmann-Juvala H. et al (2014). Risk management in the construction industry – derivation of occupational exposure limit values for nanomaterials NanoTox 2014 Conference, April 23-26 Turkey.

IFA (2014a) Criteria for assessment of the effectiveness of protective measures. Available at: http://www.dguv.de/ifa/Fachinfos/Nanopartikel-am-Arbeitsplatz/Beurteilung-von-Schutzmaßnahmen/index-2.jsp (sited 17.2.2014).

FIOH (2013) Teollisestituotettujennanomateriaalientavoitetasoperustelumuistio [Target levels for engineered nanomaterials].Työterveyslaitos. (in Finnish)

SER (2012) Provisional nano reference values for engineered nanomaterials. Advisory report 12/01.The Netherlands.Social and Economic Council. http://www.ser.nl/~/media/Files/Internet/Talen/Engels/2012/2012_01/2012_01.ashx.

Risk Protection

Applying the precautionary principle, we should first assume that all the NPs are isolated, even if it is not always realistic. That's why employers must take action both for the engineering controls and for the personal protection in order to reduce the risk to a minimum. Generally speaking, employers must give appropriate instructions to workers by providing information and training for the exposed employees.

In Scaffold (WP4), the efficiency of collective and personal protection equipments (used in or intended for the construction sector: Table 5) were characterized in order to give clear conclusions and recommendations for the construction sector. For PPEs, the aim was to determine if NPs can diffuse or leak through PPEs and clothes in different states (liquid, powder, solid and aerosolized NPs) during different steps of their life cycle (synthesis, handling, manufacturing, using and end of life. The three main routes of exposure to nanomaterials at the workplace were considered: inhalation, dermal penetration and ingestion.

For Respiratory Protective Devices (RPDs), a robotic head and torso manikin was developed, built and deployed to measure the Total Inward Leakage (TIL) of NPs in nanoaerosols.

The main conclusions obtained are listed below:

- For **indoor working**[1], when risks cannot be eliminated at the source, the **engineering control** has to be considered before any personal protection. For example, if the environment is confined (as in a glove box2), no personal protection equipment and no engineering control systems against NPs are required.
- Multistage **air filters** with high efficiency (F7+H14 or H14) are the best engineering control systems because they provide air purifications from nano-size particles with efficiency more than 98 %. But the efficiency of fine air filters of classes F7 strongly depended on the particle's size (higher than 90 % for sizes less than 30 nm, decreasing to 60-70% for larger sizes).
- **Masks with P3 filters** show the highest filtering effectiveness against all the tested types of nanoaerosols. P3 filters need to be used with the best fitted face pieces (half masks or full-face masks, fitting well with the face of the worker).
- Concerning clothes used by workers in the construction sector, the **polyamide & polyurethane rain coating** was the most efficient (against aerosol diffusion and liquid diffusion). But it is only used when it rains.
- **Woven materials** are recommended for NPs in **hydrosols** because they do not swell in the liquid.
- **Non-woven clothes** are recommended for **aerosolized NPs** because they trap NPs.
- Generally speaking, **thicker materials** are recommended because they limit the NPs diffusion.
- **Chemical protective clothing category 3** (type 5 and 6) is recommended for the manipulation of liquid materials containing NPs when the work cannot be performed in a fume cupboard (for example: cleaning of filters and reactor, or spraying on a building site).
- Wearing **protective glasses** is highly recommended against liquid splash and dust.

Besides, Scaffold (WP4-Risk Protection) developed a **customized Control Banding approach** for the construction sector, implemented in a fully functional XML-based macro-enabled **Microsoft Excel workbook**. The tool considers the materials and construction processes treated during the project, but can be applied to other construction scenarios as well.

---

[1] For outdoor working, only PPEs come into consideration (masks, gloves and clothes).
[2] Seldom used in the construction sector, due to the large quantity of NPs and MNMs handled.

Table 5: Examples of protective devices investigated

Enclosure/containment systems used by Scaffold partners, from natural ventilation to the glove box. Pictures: • Natural Ventilation (left) • Closed reactor with regular opening (right)	 
Most commonly used respiratory protective devices: • FFP2 and FFP3 filtering half masks (left picture) • Half masks • FFA1P2 and FFA2P3 filtering half masks against (among others) particles • Full face masks • Powered filtering device with hood (right picture)	 
Gloves (A, B, C, D) Pictures: B (left) and D (right)	 
Clothes: • Fleece jacket 100% polyester (left picture) • Jacket composed of 65% polyester and 35% of cotton (picture in the middle) • Rain jacket composed of polyamide coated with polyurethane • Chemical protective clothing category 3, type 5 and 6 (right picture)	  

Risk Management

From the viewpoint of management systems, OSHAS 18001 is the worldwide recognized and adopted standard for Occupational Health and Safety. OSHAS 18001 implements an approach based on the PDCA model (Plan–Do–Check–Adjust), fully compatible with and easy integrable in other management standards like ISO 9001 and ISO 14001.

In this respect, the European project SCAFFOLD with the **Risk Management Model (RMM)** answers two questions: the capability of OHSAS 18001 to deal with “nano-risks” and eventually its suitability for being implemented by SMEs.

The RMM presents itself an innovative conceptual work (Figure 2). It has been designed using requirements of OHSAS 18001 as skeleton (structure, elements, etc.), includes additional requirements derived from guidelines established in ISO 31000 and integrates specific elements developed by the project in the areas of risk prevention, risk assessment, risk protection and risk management.

Scaffold's RMM can be applied in any type of organization irrespective of size and type, in all its areas and levels. Every subsector involved in construction cycle can use this model but with different necessities, perceptions and criteria (manufacture, building and civil construction, demolition). In addition, this design allows the integration of RMM with the other management systems (e.g. ISO 9001, ISO 14001) especially for the common requirements (systems requirements as document control, audits, training, etc).

The RMM includes specific considerations on initial review, monitoring and audit and can be certificated. The implementation of this RMM will allow the organization to consider nano-risks in OHSAS system. On the other hand, if the organization has no experience on a systematic approach for managing its occupational health and safety risks, the implementation of the RMM could be the first step for a more complete and organized perspective of OHS risks. An organization that proves the successful implementation of this model could ensure all interested parties that it has an appropriate management of nano-risks.

The RMM requirements have been analyzed with a specific attention to SMEs particularities In this respect, a specific guide to establish criteria for interpreting the RMM and facilitate implementation in the SME construction companies in the entire life cycle of the construction sector, has been drafted and additionally implemented in the Toolkit (Customized approach for SMEs).The guides are complemented by a complete check list with a customized version for SMEs.

One of the key aspects of the management system is the continuous improvement, which allows companies to improve their performance in a continuous way, taking into account the technical and economical limitations, but also the possibilities brought by the new technology, new knowledge and new risks. This is a key issue, as nanotechnology knowledge is subject to continuous changes due to technical and scientific advances. Therefore it is necessary to provide companies with an evolutive tool capable to integrate new knowledge on risks, on their detection and on their mitigation.

The launching of the future standard ISO 45001 on occupational health and safety management systems is expected in late 2016, beginning 2017. It will transform OHSAS 18001 in an International Standard supported by ISO and will represent a very important milestone in the implementation and certification of H&S management systems. The future standard will also be aligned with ISO 9001 and ISO 14001. In this sense, elements developed by project SCAFFOLD will be easily integrated in the new standard.

Depending on the evolution of the new ISO 45001 project, the future EN TS (CEN TC 352 / WG-3 PG5 Scaffold), currently in preparation, could be easily adapted to the ISO high-level structure for management system standards (included in new ISO 45001), in order to facilitate integration.

The additional result of SCAFFOLD/WP 5 is the **RMM-Toolkit** (Figure 3) that represents the integration of all the solutions developed for risk management during the project in a software tool, friendly, easy to use and customizable for SMEs. It consists in a standalone desktop application for the Windows platform structured with two operational modes (learning and risk management), two setup (large or advanced companies in risk management and SMEs) with five operational modules (Library, Customization, Risk management, Tools and Help).

The main tools integrated in the Toolkit are:

- **Risk management**: guides the diagnostic, implementation and audit of the RMM by using a set of interactive and customized check lists. The check lists enable the user to enter comments and generate bar charts. The Toolkit includes two check lists depending on the set up decided by the company: general check list (275 questions) for large companies and reduced check list (150 questions) principally for SMEs.

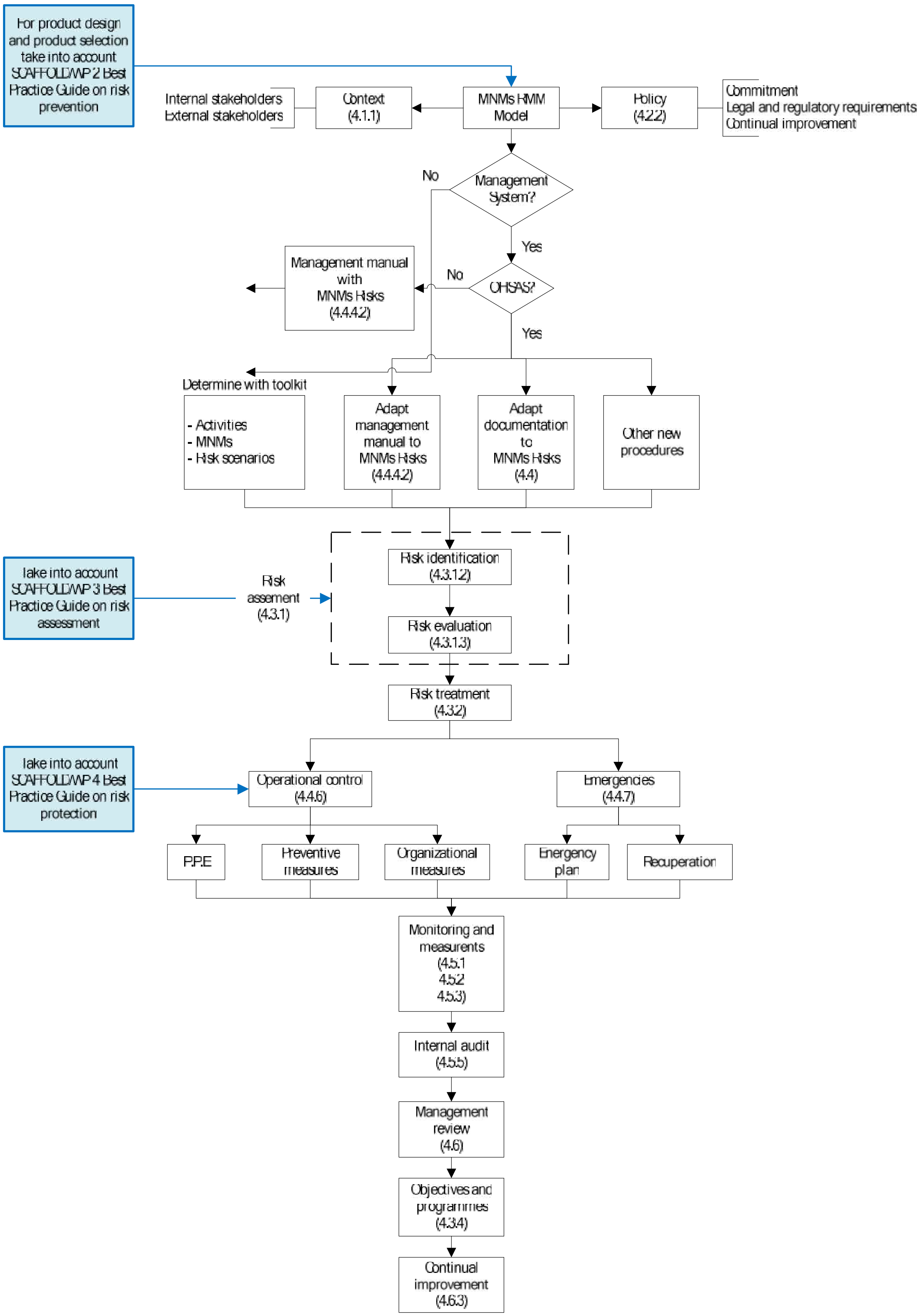


Figure 2: Scaffold's Risk management flowchart

- **Risk assessment**: guides the qualitative and quantitative risk assessment of the occupational exposure to MNMs and monitors the implementation of the control measures. This tool opens the risk evaluation tool with a list of processes, tasks and scenarios. Each scenario can be characterized with both quantitative and qualitative methods. The quantitative method allows the user to enter the exposition and reference values. The tool then calculates the exposure value and, according to the configured thresholds, the risk level. The qualitative method implements the control banding approach ISO 12901-2. The user can navigate through these charts to get a hazard band (A – E) and an exposure band (1 – 4). This characterization leads to another risk level. For each scenario, a set of control measures can be selected, allowing the user to specify whether they are already implemented or not.
- **Planning**: opens a tool to schedule the implementation of the control measures specified in the risk evaluation tool. For each control measure, the user can select the expected implementation date, the actual implementation date, the progress, the responsible and the associated cost. This planning can be exported to Excel.
- **KPIs**: allows the definition, customization, calculation, visualization and monitoring of Key Performance Indicators.
- **Documents and templates**: gives access to a list of Word templates with procedures, instructions, registers and OHS manuals that can be customized by end-users to facilitate the implementation of the RMM.
- **Scaffold's Library of Solutions**: includes several quick guides to facilitate the diagnosis, implementation and audit of the management of nano-risks in construction companies (large and small).
- **Training tools:** allows to customize training in nano-risks according to the different levels of the company (workers, supervisors and the high direction)

The Toolkit enables companies with an OSHAS model implemented to consider the management of nano-risks into this model, but also to companies with no experience in health and safety management systems, particularly SMEs, to initiate the path to a complete OHS management with the implementation of RMM as first step.

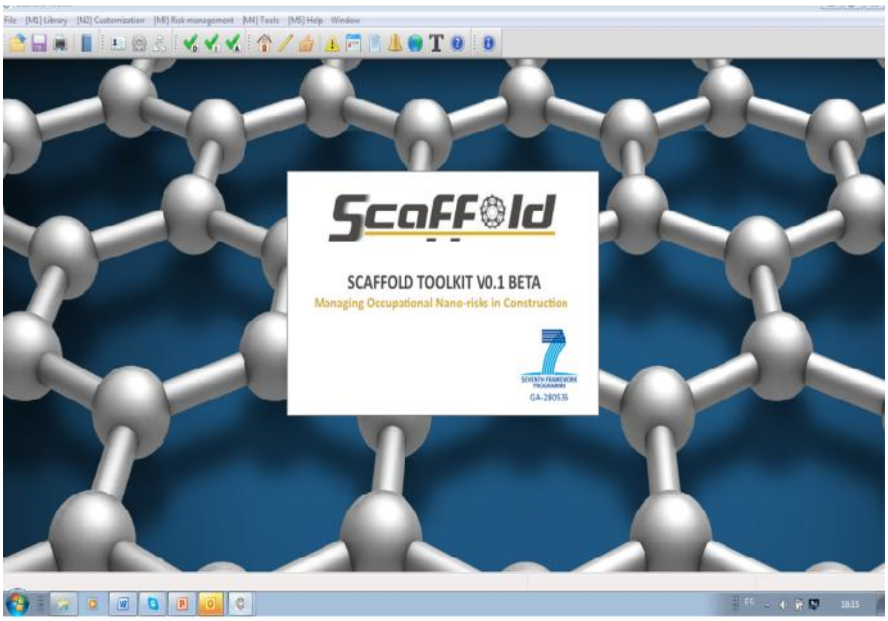


Figure 3: Introductory screen of the RMM Toolkit

Implementation on construction sites

One of the integral parts of project was to test Scaffold's risk management model in real work with manufactured nanomaterials (MNMs) in five Industrial Use Cases (IUC). Exemplary companies were selected for this demonstration for different steps of the life cycle of construction products:

- IUC 1: production of nanoparticles at TECNAN (Spain),
- IUC2: production of building materials with nanoparticles at ICECON (Romania),
- IUC 3: application of coating in real construction site with subcontractors, by MOSTOSTAL Warszawa S.A. (Poland),
- IUC 4: construction elements containing nanomaterials at ACCIONA (Spain),
- IUC 5: end of life of the construction products with MNMs at ROSSAL (Romania).

The selected companies implemented Scaffold's risk management model for work with manufactured nanomaterials. The developed system complemented the companies' existing systems of risk management. Also, an important element of the project was to verify whether the created solutions can be applied in very different environments (laboratories, construction sites) and in countries of various climate conditions, legal requirements and work safety culture.

First step of the implementation was an initial diagnosis of the systems already in use in each of the company. It allowed to point out an optimal way of complementing them with new elements about safe work with materials with MNMs. In all industrial cases, a diagnosis was carried out with a desktop software integrating all of the solutions developed in Scaffold's Toolkit. A special checklist from the Toolkit (Figure 4) was used for identification of gaps in management systems regarding work safety with nanoparticles. In a second step, companies complemented their systems with new documents (instructions, procedures etc.) to be used at work place. New documents were created using Scaffold's risk protection or risk assessment guides, a new Scaffold template or the templates from Scaffold's management system.

Figure 4: Workers in Romania and Poland performing various works involving materials with MNMs, with simultaneous measurement of the NP concentrations in air.

After the implementation, an external audit was carried out in each of the company. This allowed to check and improve the versatility of solutions proposed by the Scaffold project. In addition during the audits a monitoring of the presence of nanoparticles was made through the above selected processes for case studies. It allowed to check if the assumptions of exposition for MNMs obtained during the pilot works in the previous work packages were appropriate for the real work with MNMs(Figure 5). The results of the audits will be used not only for companies in the successful implementation of the new system, but will also serve in the further improvement of developed risk management system.

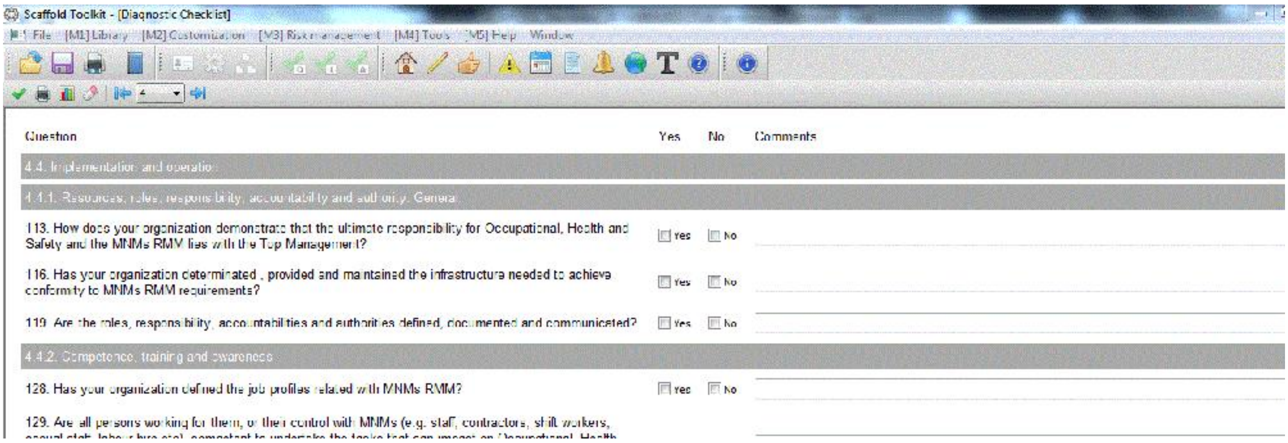


Figure 5: Scaffold Toolkit – a sample screenshot of checklist used in initial diagnosis of the management system already used in company.

Benefits for the companies involved in Industrial Use Cases (IUCs)

TECNAN (Spain): *"The enterprise has increased its knowledge about the risk assessment of nanoparticles production during the IUC1 (SiO_2). This knowledge can be extrapolated to other nanoparticles produced by the company. The information obtained during the quantitative risk assessment in our facilities has been used to improve the workers safety, elaborating an internal document where it is specify the safety measures needed to produce safely. Moreover, the new information will be used in our technical data sheet in order to guarantee to our customers that we produce the nanomaterials safely. These new guides will be useful for the customers in order to ensure their safety in handling the nanoproducts acquired".*

ICECON: *"1) Developing the range of products manufactured by the company, by including new recipes using nano-clays; such a product is fire-resistant panel containing MNMs for cladding flat surfaces of buildings elements, 2) Implementation in the company the Risk Management System on manufacturing processes of panels based on bentonite nano-clay and plaster, 3) Improving working conditions related to occupational safety and health, 4) Alignment and compatibility of the RMM with other management systems previously implemented, 5) In 2015 the company registered a new patent for fire-resistant panel containing MNMs for cladding flat surfaces of buildings elements".*

MOSTOSTAL: *"The company gained a vast knowledge about risk management of MNMs during IUC3. Extended information about risk assessment and risk protection can now be used for future safer work with state of art materials. It will allow the company to safely and confidently use materials that aren't yet widely known and used on our national market. Potentially it can lower costs of use of these novel materials and add the enterprise an advantage in the very difficult and competitive construction sector. Additionally gained knowledge can be used for generating revenue from consultancy about risk protection and* *prevention in use of MNMs on Polish market. During the IUC we created a new document that will allow us to hire contractors or subcontractors for work involving MNMs: "Requirements of integrated environmental and OHS management system for work with nanomaterials". This document implements the Scaffold results into the current management system in the company".*

ACCIONA: *"1) Communication and awareness actions: the employees implied in the work were aware of the materials that they were handling and the associated potential risks. 2) Risk prevention actions: the onsite manager as well as the personnel in charge of the risk prevention plan were also aware of the potential risks of the used nano-additive and could carry out their work more efficiently and in a safer way. 3) Use of new tools: the toolkit as well as the Best Practices Guides are at the disposal of the all the above mentioned employees and will be used, if needed, in further works. This gives to the company the possibility to implement a new tool in its risk management system, which is specific for MNMs".*

ROSSAL: *"For the enterprise, who has already implemented the standard OHSAS 18001 for a range of activities in the services field, but didn't have, yet, request or opportunities to work with MNMs, the implementation of the SCAFFOLD approach was the perfect occasion to check, one more time, the validity of his own Management System and to develop preventive actions in a new field. The company watched valorization of theoretical potential and practical experience provided by SCAFFOLD project for improving an integrated management system already certified and expanding its applicability to other activities not addressed yet: demolition of buildings containing nano-clay".*

Proposal for a European strategy

Considering the state of the art and of the praxis and the regulatory and research context at the end of the project, Scaffold proposes a European strategy to further improve the management of occupational risks related to MNMs in construction.

Five key issues and strategic objectives, 12 operational objectives and 30 strategic actions are proposed, prioritized and commented (Table 6). Natural leaders of the actions are suggested at European and national levels, e.g. from the construction industry, from the European Commission or European Agencies or from the Scaffold consortium itself. Five further options are discussed but were not selected as propositions for the construction sector.

The proposed European strategy includes the long term maintenance, update and further development of science-based operational tools at the European level, and their translation and transcription into national tools. These tools include:

- Guides and a toolkit;
- A training and certification programme;
- Consolidated measurement strategies;
- An emission and exposure database;
- Occupational Exposure Limit values (OELs).

The sustainable maintenance, update and further development of these tools represent a considerable effort. Many of the actions proposed are inter-linked and not specific to the construction sector. Therefore, for the sake of efficiency and sustainability, the efforts should be joined and coordinated at the European level and across industrial sectors, ending up with European multi-sectorial tools including sectorial modules and translated into national versions operated at local level. For some actions (e.g. the development of OELs), a European coordination is already in place. For others, the efforts are scattered and duplicated or strongly attached to temporary funding (project-based research). This situation calls for the creation of a European platform of expertise institutes all over Europe that would coordinate the sustainable development, maintenance and update of operational tools for the risk management of MNMs in the industry.

Table 6. Excerpt of the proposed European strategy for occupational nanosafety in construction

Strategic Action	When?	Prio-rity
Strategic Objective 1: **Raise awareness, disseminate information on MNMs in construction products**		
Op. Objective 1.1: ***Improve the information on MNMs and related safety issues in Safety Data Sheets, labels and Technical Sheets of construction products***		
1. Launch an evaluation study of Safety Data Sheets (SDS) and labels for relevant construction products regarding MNM-related information, update ECHA's guide on SDSs and produce a note for the construction sector	2016	1
2. Launch a regular control of SDS for relevant construction products regarding MNM-related information, report defaults to the competent national authorities	2017-	1
3. Launch an evaluation study of Technical Sheets (TS) for relevant construction products regarding MNM-related information, produce a note and/ or a guide for the construction sector	2016	2
4. Launch a campaign towards manufacturers of construction products promoting clear MNM labelling	2016	2
Strategic Objective 2: **Disseminate and implement best practices regarding MNMs in construction**		
Op. Objective 2.2: ***Disseminate actively Scaffold's guides and tools within the construction sector: large & small companies, relevant OSH actors...***		
1. Inform key actors on the issue and on Scaffold's results, guides, tools	2015	1
2. Translate, adapt the Scaffold toolkit and handbook and integrate them into national tools / guidance	2015-17	1
3. Ensure regular updates of the scaffold tools and their integration into national tools / guidance	2017-	1
4. Promote social dialogue in construction companies on collective and individual prevention and protection measures regarding MNMs	Always	1
5. Require from OSH controlers to explicitely include nanosafety in the proof of compliance for OSH requirements	2015-	2
Strategic Objective 3: **Establish OELs and other reference values for MNMs relevant in construction**		
Op. Objective 3.1: ***Promote needs and priorities from construction on MNMs towards actors in charge of OELs***		
Op. Objective 3.2: ***Support on-going works on OELs for construction's priority MNMs, incl. background research***		
1. Include priority MNMs of the construction sector into the work program of SCOEL and national equivalents	2016-	1
2. Support operational research to provide the data needed to derive the priority nano-OELs for construction	2016-	1
3. Support operational research to provide the alternative toxicology data for MNMs used in construction	2016-	2
Strategic Objective 4: **Ensure better adequacy of measurement capacities with assessment needs**		
Op. Objective 4.1: ***Develop strategies and standards to measure the different MNMs with the relevant metrics (number, mass or surface concentration) and at relevant levels for comparison with available occupational limits***		
1. Prioritize the needs as a function of MNMs of concern and of gaps between measurement capacities and OELs	2015-16	1
2. Support the development, harmonization, validation of measurement strategies adequate in regard to exposure limits, focusing on the priorities	2016-	1
3. Support the standardization of the measurement strategies developed	2016-	1
Op. Objective 4.2: ***For some MNMs, develop R&D to design more accurate devices***		
1. Evaluate the needs and priorities for new developments	2016-17	1
2. Support operational research to develop the priority measurement devices currently missing	2017-	1-2
Strategic Objective 5: **Make available typical exposure data for key construction activities**		
Op. Objective 5.1: ***Develop an operational public database on emission of and exposure to MNMs in construction***		
1. Evaluate the options to constitute an operational public database on MNM emission and exposure in construction	2015-16	1
2. Support the development of an operational public database on MNM emission and exposure in construction	2016-	1
Op. Objective 5.2: ***Feed this database with data from the literature and/or with new experimental data on emission of and exposure to MNMs in construction***		
1. Support a review of scientific and technical literature on emission of and exposure to MNMs in construction, so as to feed in the database	2016-17	1
2. Evaluate the remaining key gaps and define R&D actions to fill them	2016-17	1
3. Support operational research to provide key missing data on emission of and exposure to MNMs in construction	2017-	1-2

Op. Objective: Operational Objective RM: Risk Management OEL: Occupational Exposure Limit value

Scaffold Public Documents (online!)

The following "Scaffold Public Documents" can be uploaded from Scaffold's website (http://scaffold.eu-vri.eu/home.aspx?lan=230&tab=2633&pag=1566):

Main Guides & Tools

Scaffold's quick guides:
- Risk prevention
- Risk protection
- Risk assessment
- Risk management.

Scaffold's Toolkit for the Risk Management of manufactured nanomaterials (MNMs) in the construction sector:
- Operating manual
- Toolkit (software, v2 version including case studies, coming Oct. 2015).

Scaffold's Handbook (new deliverable, coming Dec. 2015).

Other Guidance

Risk Protection
- Guidance on health surveillance in relation to MNMs for workers in the construction industry.
- Exposure register model for MNMs in the construction industry.

Risk Management
- Guide for the implementation of a Risk Management Model in relation with MNMs in the construction sector.
- Guide for the initial review, the monitoring and the audit of Scaffold's Risk Management Model in relation with MNMs in the construction sector.
- Guide for the implementation and the audit of Scaffold's Risk Management Model for SMEs in relation with MNMs in the construction sector.

Background Reports

General
- Life Cycle Analysis of project-selected MNMs.
- Background information on exposure, use, and hazard of manufactured nanomaterials in the construction sector.

Risk Assessment
- Formulating Occupational Exposure Limits Values (OELs) (Inhalation & Dermal).
- Review on the toxicity of manufactured nanomaterials applied in the construction sector.
- Emission of toxic gases and MNMs during a fire of construction products containing nano-objects.
- Applicability of the DREAM model in estimation of dermal exposure to MNMs during several construction related tasks.

Risk Protection
- Results of application of the Stoffenmanager Nano-tool in the construction work area.
- Selection of representative PPEs used in construction for efficiency tests (coming*)
- Efficiency assessment of current alternatives for personal dermal protection (coming*).
- New device for MNMs trapping (coming*).
- Procedure for testing dermal PPE (coming*).
  * after scientific publication

Risk Management
- Customized control banding approach for potential exposure to MNMs in the construction industry.

Training & Info

- Info Leaflet by FIOH: Nanomaterials in the construction industry - Guidance for protecting and monitoring health of workers.
- Training modules for the Risk Management of manufactured nanomaterials (MNMs) in the construction sector (included in the Toolkit, version v2 coming Oct. 2015).
- Workshop "Operational occupational Risk Management Models and tools for MNMs in the industry". With Nanomicex & SanoWork.

The Scaffold research has received funding from the European Community's Seventh Framework Programme (FP7/20072013) under grant agreement number 280535.