CONFIGURABLE KNOWLEDGE-BASED RISK MANAGEMENT PROCESS MODEL WITHIN THE GENERAL CONSTRUCTION PROJECT PROCESS MODEL

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ABSTRACT: Risk management in the construction industry is becoming increasingly important to help projects reach their objectives within the planned schedule and costs and without endangering other key performance indicators. However, it is becoming also more complicated because of the use of multiple technologies and the participation of different specialists from different branches. Therefore, a general method enabling the tackling of the Risk Management Process within the whole construction project process is needed. This paper presents a systematic approach for the description of the Risk Management Process based on the ARIS methodology "Architecture of Integrated Information Systems". The Risk Management Process is sub-structured into three orthogonal views, namely, Organizational, Functional and Data, which are inter-linked in an integrative process model using the extended Event Driven Process Chains approach. As risk is an uncertain event that may occur or not, a specific feature of the developed approach is the use of configurable risk treatment templates. Applying one of the Architectures of Collaborative Scenarios, cooperative risk management enabled by configurable risk treatment templates can be efficiently achieved.

KEYWORDS: process modeling, risk management, configuration management, eEPC, ARIS.

1 INTRODUCTION

Construction shares many common features with other industries but it also has various specific features caused by the unique nature of each construction project. Due to the dynamic and unique character of each construction project, as well as the high influence of the environment, construction has to deal with an extraordinary large number of risks. Additionally, unexpected threats and opportunities may arise during the whole project lifecycle.

The management of predictable and unpredictable risks that may affect the objectives and the outcome of construction projects are becoming increasingly important to the responsible personnel. To answer that growing need, a more reliable systematic risk management methodology is required. One of the main problems in current approaches is that the Risk Management Process (RMP) is dealt with as a stand-alone process, and not as integral part of the general project process. Consequently, neither its influence on the general project process is taken into account, nor the reverse influence of other processes in the project on it. This issue can be handled by designing a standardized RMP using process modeling languages as shown .e.g. by (Sharmak, 2006), and then find a method to integrate the designed RMP model in the overall project process model.

In this paper we present an approach for the achievement of such integration on the basis of the ARIS methodology (Scheer, 1999). ARIS was chosen because of (1) its ability to reduce the complexity in the system by dividing it into different well-defined views, and (2) the ease of use

and interpretation of the represented models. To complete the suggested approach, methods built upon ARIS, namely configurable EPCs and elements of the ArKoS methodology are used. The scope of the presented work is currently limited to the risks that demand changes in the activity sequence of the overall value chain.

2 THE GENERAL RISK MANAGEMENT PROCESS

Risk Management as a systematic process is described in several standards and methodologies (e.g., AS/NZS 4360, 1999; PMBOK Guide, 2000). Although there are differences among risk standards and methodologies in the specification of RM subprocesses, there are also many general similarities in the core of the RMP that are available in any risk management methodology. In fact, any risk management process must contain at least the following subprocesses:

- *Risk identification*: This means to determine which risks may affect the project and to document their characteristics.
- *Risk assessment*: Designates the overall process of risk analysis and risk evaluation (cf. AS/NZS 4360, 1999). The risk assessment process aims to calculate the impact and likelihood of identified risks and to prioritize the risks according to their potential effects on the project objectives. The overall risk ranking result can be used to assign needed personnel and other needed resources in the project.

- *Risk treatment planning*: Describes the process of determining individual or groups of actions to enhance opportunities and reduce threats to the project's objectives.
- *Risk monitoring*: Means to keep track of the identified risks, watch for residual risks and register new risks (PMBOK Guide, 2000).
- *Risk treatment*: Describes the process of executing the planned risk treatment strategies. It is an exceptional process, which means that this process will not be initiated unless risks evolve to actual problems.
- *Risk documentation*: Describes a supplementary process, but one which provides an important information resource for future projects.

The logical sequence of the general subprocesses within the RM process is shown in figure 1 below. However, this generalized sequence does not represent the actual work flow of the risk management process. For example, risk monitoring is a continuous process for the whole construction phase, and it cannot be represented as an event with a specific duration within this phase. It will start when project execution starts and will be finished when the last activity in the construction phase is finished; within this time span several other RM subprocesses may be applied in parallel.
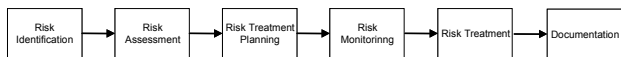

Figure1. Principal sequence of the main subprocesses within the risk management process.

According to their features, RM subprocesses can be classified into the following types:

- *Repeated processes:* The identification, assessment, and treatment planning processes may need to be repeated several times within the project life cycle. This iteration depends on many factors, e.g. new stage started, new available information, demand of more reliable results, or new risks surfaced.
- *Periodic processes*: This includes all documentation processes of the performed RM work. Documentation has to be done periodically, as weekly or monthly reports, or as regular feedbacks to a RM database.
- *Ongoing processes*: Risk Monitoring is an ongoing process for the whole lifecycle of the construction phase; it watches for any deviation in the objectives of the individual activities within the general project process and sends alarm to the responsible (sub)processes to handle the situation if the deviation exceeds the accepted thresholds.
- *Exceptional processes:* Typically the risk treatment process (or the so called exceptional function) will be executed if and only if a probable risk evolves to a problem that *must* be handled. Otherwise, the other subprocesses within RM (so called general functions) will be executed without passing through the risk treatment process, as shown in figure 2.

Furthermore, RM must be undertaken by all parties involved directly in the project in cooperative way. The procedures in the RMP differ according to the reached point in the project span and according to the individual point of view of the project stakeholders. We argue that

more effective management of risks can be achieved if risks are considered from the process perspective of the project lifecycle, and from the cooperation perspective of all project participants. Accordingly, the project span is divided on the high level into three phases, in each of which different kinds of risk procedures are defined and different types and levels of personnel are planned to participate. These phases are: (1) the pre-construction phase, (2) the construction phase, and (3) the post-construction phase. Each of these phases consists of several stages that can be determined in accordance to certain specific factors such as the type of the project, the type of the contract, the perspective of each phase, the particular project objectives, etc. However, according to the experience gained from prior projects, many risks spread through the whole project life cycle and many risks occur at more than one phase, with the construction phase being definitely the most risky one (Patrick et al. 2006)[1]. Therefore, in this research Risk Management is purposely considered without regard to the project phases but holistically taking into account multiple aspects (or views) of the process.
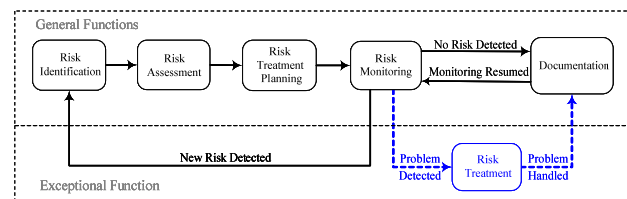

Figure 2. Refined sequence of the general and exceptional subprocesses within the RMP.

3 MODELING THE INDIVIDUAL RISK MANAGEMENT VIEWS

We have chosen the ARIS methodology as baseline for the modeling of individual risk management views because of its specific advantages. ARIS is a method for analyzing processes that takes a holistic view of process design, management, workflow, and application processes (Scheer, 1999). ARIS solves the complexity of business processes by dividing the overall structure into several parallel sub views (organizational, functional, data and control view). This reduces the complexity of the whole system and makes the description of business processes easier. The main principle is to group the components with high interdependency in one view and separate the ones with low interdependency into different views.

The RMP is divided accordingly into: (1) RM organizational view, (2) RM functional view, (3) RM data view, and (4) RM control view. These views are shown in Figure 3.

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[1] Indeed, it is logical to say that a majority of risks occur before the post-construction stage, because a great deal of ambiguity and complexity exists before the physical work on the site is completed, and when the project is transferred into use most uncertainty will be changed to reality, and the possible risks may come only from the satisfaction of the complete facilities, and from environmental sustainability. However, the nature of many risks may nevertheless repeat, at least in principle, within a phase and even between phases.
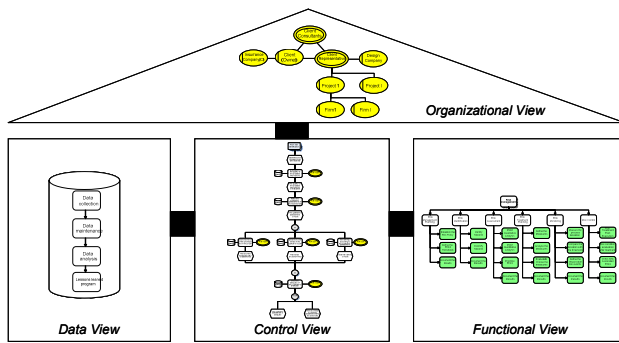
Figure 3. RMP model represented according to the ARIS house view structure.

3.1 *Risk management organizational view*

The organizational view consists of the organizational structures of the participants and the relationships among the organizational units. Because of their large size, most construction projects to date demand the participation of more than one company (main contractor, subcontractors, and many other organizations such as insurance companies, design companies, etc.). All these organizational units have to participate in the RM of the project in some way or other. Therefore, the responsible staff from each organization must be respectively assigned to the RMP, thereby joining the project risk management team. This requires a mapping from the organizational structures of the participating companies to the organizational structure of the RM team, which must be consistently performed and maintained throughout the project life cycle (see figure 4).
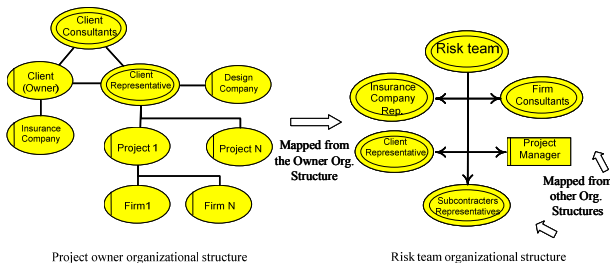

Figure 4. Different organizational structures mapped to the RM team.

3.2 *Risk management functional view*

The functional view contains the description of the activities that need to be performed in order to manage the ex pected risks in a construction project. It is represented using a function tree
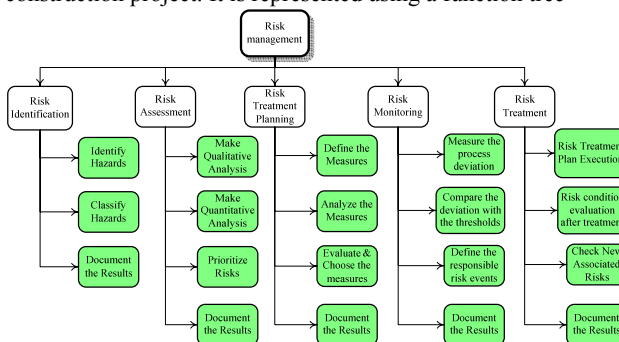

Figure 5. High-level process-oriented RM function tree.

which consists usually of the main functions, sub functions, elementary functions, and the relationships that exist among them. The function tree itself can be process, object or execution oriented. The high-level process-oriented function tree of the overall RMP is shown in figure 5 below.

3.3 *Risk management data view - risk management knowledgebase*

The data view encompasses the information resources needed in the RMP. Indeed, risk management is related to many processes in a construction project. Many activities can carry some amount of uncertainty, and so a lot of relations will exist between the RMP and the internal or external project environment. These complex interrelationships require dealing with a huge amount of information. Therefore, the use of a RM knowledge base is essential.

The needed risk management information can be obtained from a large number of available resources, such as expert judgment, sessions and brainstorming, data from current and prior projects, commercial databases containing infrastructural and environmental data etc. In general, the RM knowledgebase should contain but is not limited to:

- *Risk information,* including the risks themselves, risk factors, risk groups, risk centers (allowing risk teams to see which areas of a project appear to be most at risk and hence assign proper strategies and resources), risk scope, risk thresholds, common risk consequences (i.e. the severity and likelihood of effect for each risk or risk group on the project objectives), expected monetary value, responsible person(s), and expected timing (i.e. a range of dates when the risk is apt to occur).
- *Treatment information,* including common treatment methods for specific risks or risk groups, alternative treatment methods, treatment scope specifying against which kinds of risks is each treatment method effective, treatment center, possible associated risks with each treatment method, change orders to other processes within the project, contingency plans (i.e. the backup strategies or procedures to be followed when the risk event occurs).
- *Environmental information,* which can serve the risk management purposes and can be classified into physical information, social information, economic information, political information and regulatory information (cf. De Zoysa et al. 2003).

3.4 *Risk management control view*

The control view represents the relationships among the different views in the ARIS house; it unites the design results which were developed separately to better manage complexity. This view is typically represented by using eEPCs (extended event-process chains) – see e.g. Wienberg (2001). An eEPC describes business processes by creating a chronological sequence of events, functions and their logical interdependencies using logical connectors, and relating them to the performing actors and the used resources and services (see figure 6).
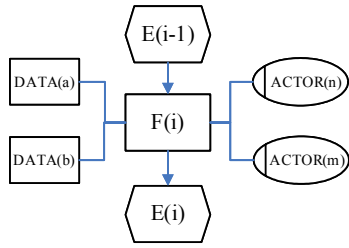
Figure 6.The eEPC Metamodel.

In our approach, each RM subprocess is represented independently via a separate eEPC, even though these subprocesses are not independent but related to each other and to the internal and external project environment. These dependencies are expressed as internal and/or external interfaces, to link a (sub)process integrally to other processes. We believe that, the control flow sequence for each subprocess is the same in all project phases; the difference is in the organizational units participating in each phase, in the available exchanged information among these units, and in the interfaces. To illustrate the control flow of the RM subprocesses easily in this paper, the RM subprocesses are represented without referring to a specific project phase, and without referring to the organization and data views respectively.

Using this approach, the *Risk Assessment* process can be inserted in the general project process model simply as an activity labeled "Risk Assessment", and the detailed Risk Assessment subprocesses can be expressed using the hierarchical EPC concept as a configurable "*EPC building block*" (see figure 7). This method can be applied also for *Risk Identification* and *Risk Treatment Planning*, but it cannot be applied for *Risk Monitoring or Risk Treatment* because of their special characteristics which will be discussed in the next sections.

3.5 *The risk management monitoring process*

As already mentioned, from the contractor perspective *Risk Monitoring* is a continuous process for the whole construction lifecycle. It cannot be expressed as an activity with a specific limited duration within the general project workflow, as its duration is the same as the full construction duration. Therefore, the suggested representation of the *Risk Monitoring* process is as a concurrent function to the whole construction project process (see figure 8).

The details of this function are shown in a hierarchical EPC. The functions *Identification* and *Treatment Planning*, highlighted in light grey on the right side of figure 8, represent a new RM loop. Each of these functions can in turn be expressed with more details as hierarchical EPCs. There is also an interface that links the *Monitoring* process with the post-construction phase, i.e. it continues to be executed in parallel to the main project processes. Of course, this concurrency does not mean that the monitoring process is independent form other construction activities; the dependency is represented by the interface *Alarm*, which will link the monitoring process to other project processes (the grey highlighted elements in the rightmost column). Another interface, needed to resume

the ongoing Risk Monitoring process, is *Monitoring continuation*.
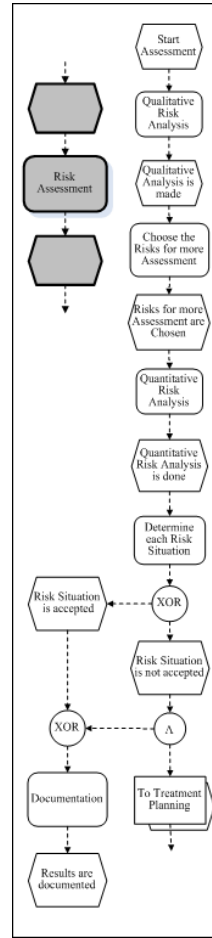
Figure 7. Risk Assessment EPC.
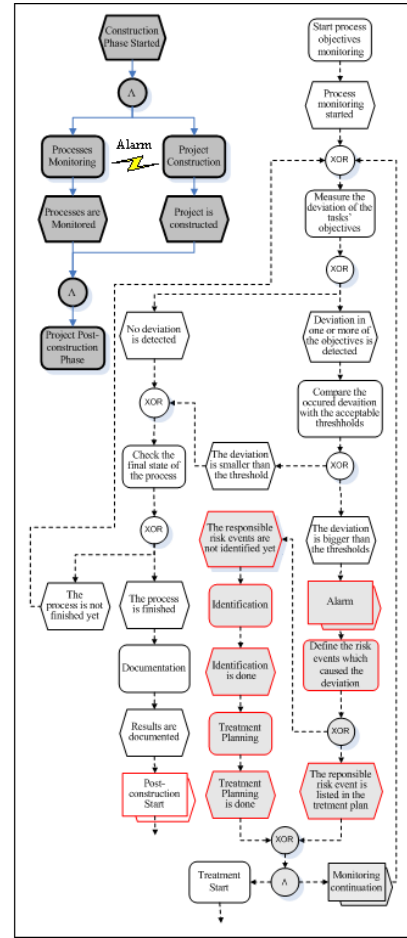
Figure 8. Risk Monitoring EPC.

3.6 *The risk treatment process*

The Risk Treatment Process (RTP) is the *exceptional subprocess* within the RMP. It must be planned, but will not be executed unless an initially uncertain threat evolves to an actual problem. From process modeling perspective, the Risk Treatment process can affect the control flow of the project model in the following three directions:

1. Changes in the control flow are done before the start of the project. This usually happens in the planning stage within the pre-construction phase. It means adopting new construction methods to avoid falling in risks, i.e. using an *avoidance strategy*.

2. The control flow of the general project process will not change, but some changes may occur in the data and/or organizational views. For example, in the case of cost overruns, higher material costs than expected may only require buying these or alternative materials without any changes on the control flow. This means using an *acceptance strategy*.

3. Changes in the general control flow of the project need to be done. Here, some new activities are required to perform the treatment plan in the form of a new control flow sequence. This may require: (1) delay in some other paths until Risk Treatment is performed, (2) concurrent execution with other process paths, or (3) a totally new process sequence substitut-

ing the old one, i.e. using a *mitigation strategy* (cf. Scherer. 2006). This third direction is the most complicated, it is focused in more detail in the rest of the paper.

4 MANAGING UNCERTAINTY IN THE PROJECT PROCESS MODEL

A risk can be defined as an uncertain event that may have positive or negative consequences on the project's objectives. In practice, much more attention is paid to threats because of their negative effects on the project. In the traditional control flow of the general project process model, all processes are expected to be done properly and without any problem or interruption. However, in reality, the construction industry perhaps more than most is plagued by risk (Flanagan and Norman, 1993). Thus it cannot be assumed that the construction project process model will not be interrupted by events stemming from possible risks. Many risks may affect one process in the model, or one risk can affect many processes within the general process model. From process modeling point of view risk as uncertainty can be understood as more than one possibility for execution of the next functions in the project work flow. This kind of multiplicity can be expressed by branches in the control flow to several paths, with the probability of each path expressed as percentage (see figure 9).

Figure 9. Uncertainty in control flow branches.

However, in practice, expressing risks and corresponding treatment activities as new branches within the general construction project process model will make the process model extremely huge and difficult to handle. Numerous paths for probable risks will follow each risky process, and for common risks the same path will be repeated after multiple processes, resulting in a lot of redundancies. Therefore, another way of RM representation is needed which will not neglect probable paths and in the same time will not make the process model inadequately large to use. We argue that this can be achieved through the application of *configurable reference process templates*, establishing well-defined risk modules that can be adapted to specific needs using the content and context knowledge captured in the RM Knowledge Base.

5 USE OF CONFIGURABLE EPCs AS RISK TREATMENT TEMPLATES

The main goal of using reference risk treatment process templates is to enable the organizations in designing their *individual partial risk treatment models*. Each such template will typically contain a project function, the possible

associated risks, and the suggested treatment measures. The information needed to establish such templates will be provided by the RM Knowledgebase, i.e. lessons learned, risk analyses, expert judgment and so on. As these templates are dependent on the RM Knowledgebase, they will be updated and enhanced in parallel with the knowledgebase. This will ensure that the models are reusable and up-to-date, so that they can be effectively applied in other similar areas. With continuous enhancement, a comprehensive risk treatment reference model can thereby be established, providing a repository of potentially relevant risks and measures for various use cases and scenarios.

We suggest using *configurable* EPCs for this purpose. Configurable EPCs (or C-EPCs) extend regular EPC to allow for the specification of configuration connectors and configuration functions in a reference process model. Treatment measures as configurable functions may be included (*ON*), skipped (*OFF*) or conditionally skipped (*OPT*). A configurable *OR* connector can be configured to normal *OR*, normal *XOR*, normal *AND*, or mapped to a single sequence of events and functions (*SEQ*) in the case that no associated risks are detected. All constraints for the configuration of configurable connectors are summarized in table 1.

Table 1. Constraints for the configuration of connectors in a C-EPC (after Rosemann & van der Aalst, 2006).

	OR	XOR	AND	SEQ
OR^C	X	X	X	X
XOR^C		X		X
AND^C			X	

Configurative process modeling is proposed as a method to enable multiple perspectives and avoid redundancies within the construction project model when it is needed to represent the risks and corrective measures associated with each process. In figure 10 an example of such a C-EPC is presented.

Figure 10. Configurative process reference model for the risks and treatment functions associated with F(n).

The column [1] on figure 10 shows the reference risk treatment process model belonging to the generalized project function F(n). While executing function F(n), one or more risks may appear in different contexts. These risks are expressed by the events E(1), E(2) and E(3). Each of these probable risks will require some corrective measures to handle it, e.g. to deal with the risk E(1) the functions F(I) and F(IV) are required. When the corrective measures are performed, it can be said that the func-

tion F(n) is executed and this is expressed by the post-condition event E(n). However, within the corrective measures, another planned activity F(m) may be triggered by the event E(VII) and an interface to another activity package may be required.

The second and third cases in figure 10 represent specifically configured C-EPC instances. For example, in the C-EPC instance [2], only the risk events E(2) and E(3) are expected to occur, and in instance [3] only the consequences of event E(2) need to be considered, the instance [4] shows the case in which E(2) is detected and handled. Finally, instance [5] shows the case when no associated risks are detected during the execution of F(n), i.e. it represents the normal project flow from F(n) to E(n) without any exposed risks. Using such configuretions, a reference risk treatment process model can be quickly adapted to the specific project situation at hand, thereby enabling more efficient, fast and consistent decision making.

6 INTEGRATING CONFIGURABLE RISK MANAGEMENT TEMPLATES INTO THE OVERALL PROJECT PROCESS MODEL

In order to integrate the described configurable risk treatment templates in the overall project process model we suggest using elements of the *Architecture of Collaborative Scenarios* developed in the German project ArKoS, which builds upon the ARIS methodology (cf. Adam et al. 2005). A major objective of ArKoS is to guard local business processes of individual partners in the overall collaborative work process. Use of the ARIS methodology enables different views into business process models and allows a distinction of global process knowledge from local process knowledge. Figure 11 below illustrates the overall concept. The shown vertical axis includes the organizational view and the output view, which are necessary to establish globally oriented collaboration. It represents the global knowledge of all collaboration partners (available for all participants), whereas the horizontal axis represents the local knowledge of the individual partners. Updates of local knowledge do not necessarily influence global knowledge, but changes in global knowledge have to be accessible to all partners at any time.
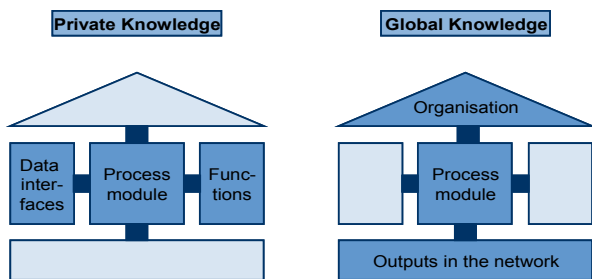

Figure 11. Local and global knowledge concept used in ArKoS.

The ArKoS architecture comprises a *three-tier framework* (see Adam et al. 2005). The first tier focuses on the collaboration strategy. The second tier is the most interesting here. On this tier, each partner considers its own part in the project, thereby designing its local process flows (or local views) within the overall project value chain. The global view is generated in order to manage the common processes and to reduce the complexity of integrating the participating organizational units into a single, complex virtual entity. The main benefit is that the partners can provide access to all relevant information described as global knowledge and at the same time are able to hide their business secrets. The local knowledge is contained in *process modules* which are understood as abstractions for more detailed subprocesses, encapsulating sensible process information. Private process modules are linked within the collaborative scenario using the ArKoS concept *"process interface"*. For the collaboration partners only the data at such interfaces, that is the input and/or output of the respective process modules, are visible and relevant for the realization of the collaboration. Thus it is guaranteed that local EPCs are only visible internally. Finally, the third tier addresses the collaborative business execution, in which the integration of different applications and platforms is established.

This approach can be well adapted for our suggested RMP model. From the risk management perspective, each process module encapsulates the detailed process model of each partner involved in the project execution, and the internal and external relations are determined via the process interfaces. Each partner has the right to hide the details of its work form others, but at the same time is responsible if any delay, cost overruns, or other kinds of problems affecting the project occur in its part of the work. Therefore, the involved parties in a construction project need to cooperate to overcome the potential risks and reach the general and private aimed objectives of the project. This means that some private information *must be shared* with other parties, i.e. risky processes, potential associated risks, and suggested corrective measures. These can be represented as private risk treatment templates associated with specific processes in the local knowledge model of the partner. Using C-EPC templates as suggested in this paper, the whole private knowledge and experience of one partner about the potential risks associated to a specific activity and their possible solutions can be represented. This is illustrated by step 1 in the figure 12 below. The information and steps included in the C-EPC can be tailored according to the needs and the context of the current project (step 2), and then discussed and adapted in the collaborative environment among the involved parties to be agreed as the configurable EPC instance to use (step 3). At the execution time
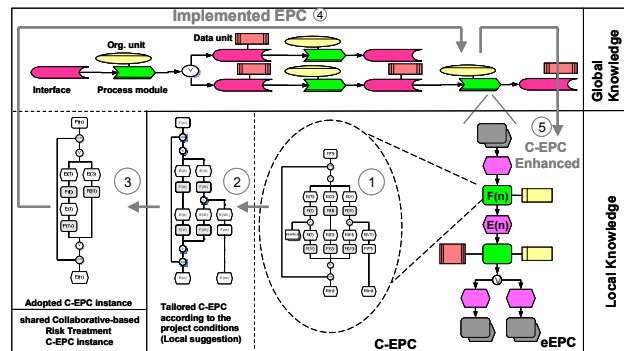

Figure 12. Risk treatment C-EPC lifecycle between the local and global knowledge of the ArKoS methodology.

of the process function, the C-EPC instance will then be used partially or totally according to the actually occurring risks (step 4). Finally, the implemented EPC can be used to further improve the local knowledge and enhance the risk treatment C-EPC (step 5).

7 CONCLUSIONS

An overview of a systematic approach to the Risk Management in construction projects was presented in this paper and a high level RMP model using ARIS methodology was introduced. It was shown how the suggested RMP model can be divided into generic, independent RM *building blocks* (or modules) to reduce complexity and enable re-use. Special emphasis was given to the RTP, represented with the help of risk treatment templates provided as *configurable* EPCs. It was shown how such templates can be flexibly adapted according to the specific project parameters at hand. This allows for high generality, reusability and updatability of the templates which can be used as reference models for the whole construction industry because they can refer to prior risks associated with each construction activity thereby enabling use of best-practice measures to deal with these risks. Further work in this direction is (1) to define and represent the dependencies among the reference models of the RM subprocesses and their relations with the general process model, (2) to model the *Alarm interface* as a bridge between the risk monitoring process and the other processes in a project, thereby enabling automated triggering of the risk treatment procedures when the assigned thresholds are exceeded, (3) to develop a modeling method allowing to modify the sequence and the elements of the project process workflow according to the instantiated risk treatment templates, and (4) to realize a software system as proof of concept and quantification of the benefits of the suggested approach.

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