Using inter-enterprise architecture as an instrument for decision-making under the arrival of unexpected events in hierarchical production planning

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Abstract: The use of inter-enterprise architecture (IEA) facilitates the generation of collaborative networks (CNs) since its tools guide enterprises step by step in the implementation of collaborative processes, in both strategic and tactical levels. At the strategic level, companies that make up CN begin the process of defining the collaboration domain, teams, people, objectives, processes, among others, to achieve common goals. At the tactical level, in a specific context of hierarchical production planning (HPP), companies could find advantage in using of decision-support systems (DSSs) that allow the management of unexpected events that affect production planning. This paper describes the main elements of the IEA proposed: framework, methodology and modelling language. To validate the correct definition of the different elements of our proposal and their relation with one another, we proposed a relationship meta-model.

Keywords: IEA; inter-enterprise architecture; collaborative networks; DSSs; decision-support systems; unexpected events; collaborative production planning; CN; HPP; hierarchical production planning; decision-making; engineering management.

Reference to this paper should be made as follows: Vargas, A., Boza, A., Cuenca, L. and Ortiz, A. (2015) 'Using inter-enterprise architecture as an instrument for decision-making under the arrival of unexpected events in hierarchical production planning', *Int. J. Engineering Management and Economics*, Vol. 5, Nos. 1/2, pp.73–88.

This paper is a revised and extended version of a paper entitled 'Inter enterprise architecture as an instrument for decision-making under unexpected event in hierarchical production planning' presented at *CIO-ICIEOM-IIIE 2014, '8th International Conference on Industrial Engineering and Industrial Management' (XVIII Congreso de Ingeniería de Organización), 'XX International Conference on Industrial Engineering and Operations Management' and 'International IIE Conference 2014'*, Málaga, Spain, 23–25 July, 2014.

1 Introduction

Inter-enterprise architecture (IEA) facilitates the integration of collaborative business processes of different enterprises in line with their information systems/information technology (ISs/IT), to support joint processes, reduce risks and redundancies, increase customer service and responsiveness, reduce technology costs and allow for alignment on multiple levels (Vargas et al., 2013a). An IEA should be conformed for: framework, modelling language and methodology. Because this is a wide field of study, we want to focus on a specific context of HPP supported by DSSs, when unexpected events happen that threaten business continuity.

The objective pursued by this paper is based on the analysis done in the ongoing research, reported in previous papers. Vargas et al. (2011, 2013a, 2013b, 2014a, 2014b) propose solutions that guide collaborative networks (CNs) that use collaborative HPP and help them with the design of DSS tools for managing non-programmed decisions caused by the arrival of unexpected events. The paper is structured as follows: Section 2 describes briefly the related work in the fields of collaborative planning, DSSs and enterprise engineering/enterprise architecture (EI/EA). Section 3 presents our proposal of the use of IEA as an instrument that enables the design and creation of CN in both strategic and tactical levels. In the tactical level, the focus is through the use of IEA as a mean of creating DSS tools in a specific context of collaborative HPP under the arrival of unexpected events and how DSS can help to handle and manage this kind of situations. A relationship meta-model has been designed to validate the correct definition of the elements in our IEA. Finally, Section 4 presents the main conclusions and future steps in this research.

2 Related work

Companies should be able to achieve two separate objectives: manage the increasing technological complexity of their IS/IT value generation to the business processes, and must concurrently achieve, integrate and coordinate their processes with their chain partners in the search for efficiency and competitiveness to ensure survival in the global market. At the moment that companies implement inter-enterprise collaboration systems, strategic changes start to happen allowing the development of joint planning processes, incrementing efficiency, synchronisation and coordination of joint activities and the improvement of customer service. Achieving these goals in principle independently, it can be possible in conjunction with the use of the enterprise engineering (EE) and enterprise architecture (EA) (Cuenca et al., 2010, 2011a), which provides concepts, models and tools that enable organisations to meet the challenges of the integration of strategic areas and business processes with IT areas, achieving greater value for the companies, improving their performance, communication and degree of integration, which ultimately give rise to the creation of competitive advantage through the effective support of IT to compliance strategies and objectives. Although the use of the EA is implemented and studied in depth in the individual firm, these concepts can be extended to the SC or CN. However, research in this area is very limited. This raises the concept of IEA (Vargas et al., 2013a, 2013b), which seeks the implementation of EA tools and methodologies developed for the individual firm, adapting to an environment of collaboration between several companies that make CN, with the aim of facilitating the integration of collaborative processes of companies in line with their IS/IT to harmonise the joint processes, reduce risk and redundancies, increase customer service and responsiveness, reduce technology costs and align the joint business strategy with IS/IT. An IEA should facilitate the integration of collaborative processes of companies in line with their IS/IT, which has an extensive field of study. To narrow the field of study and address in depth a particular aspect, we will focus on a specific problem: the collaborative production planning and the arrival of unexpected events.

Collaborative planning can be seen in different hierarchical levels of organisations and should start from a strategic communicating decision across the organisation at the highest level that will modify processes to both tactical and operational levels.

Specifically, decisions and processes affect different activities in terms of production planning, purchase planning, distribution planning, logistics planning, among others. And, all these decisions involve a complex selection among a large number of alternatives. Therefore, formulating the general problem as a single model is extremely complex. In this sense, HPP systems facilitate decision-making decomposing the problem into sub-problems, in the context of an organisational hierarchy where decisions of the higher levels impose restrictions to the lower levels (Alemany, 2003). The use of support systems for decision-making in the field of HPP has increased the potential of these systems providing better information management and the use of computer tools to solve mathematical models to aid decision-making (Boza et al., 2010). Additionally, production-planning systems face unexpected events that force non-programmed decision-making causing, for instance, manual changes in the amounts committed or modifications to the master production plan (Acevedo and Mejia, 2006; Alvarez, 2007). However, the difficulties and costs, which implies remake of these changes and plans, occur often as a result those plans have not come to run or the manual changes turn out in inefficient decisions that affect the performance of the SC. These approaches result generally in long production stops, which reduce productivity and business continuity, as well as decrease customer service. In other words, lack of proper management of unexpected events in production planning creates a bottleneck that must be addressed in a timely and efficient manner (Van Wezel et al., 2006). The disregard of taking into account unexpected events in production planning means that response times and inventories often are excessive, while resource utilisation is low and end dates of the products cannot be accurately controlled (Palacios and Álvarez, 2007). Thus, potential benefits are lost because organisations do not know how to respond appropriately to unexpected events.

3 Proposal

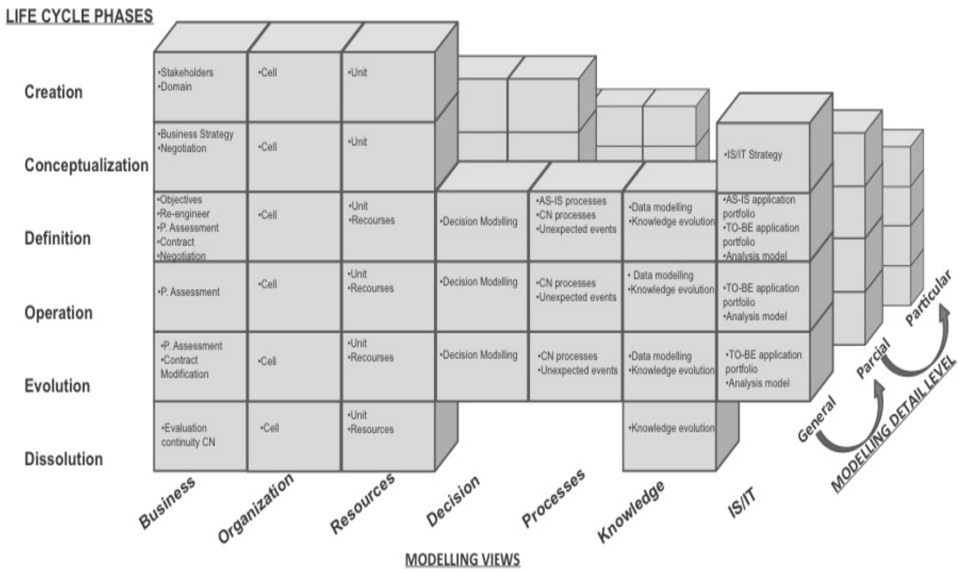
We encourage the reader of this paper, to read our previous papers (Vargas et al., 2011, 2013a, 2013b, 2014a, 2014b) to completely understand the conceptual bases of our proposal. Throughout our ongoing research, the need to use tools of enterprise architectures has been evident in a collaborative environment or, because today, more than ever, organisations are grouped into CN to face the current environment of globalisation and competition. Collaborative processes start at a strategic level within organisations that decide to collaborate, and run on the tactical and operational levels, following the steps of the proposed collaborative process. At the tactical level, to run the process of production planning and decision-making among different companies, it makes sense to use the HPP to decompose the problem into sub-problems, thereby allowing minimisation of its complexity.

So far, research has shown the importance of the use of HPP in conjunction with DSS, which supports the decision-making processes, however this research focuses on the tactical part of the operation of the production planning, without having into account the importance of the strategic vision of collaborative processes. Additionally, it does not contemplate the use of IEA as a tool that can facilitate the modelling of the processes of planning and decision-making in collaborative context. On the other hand, in the research conducted around HPP and DSS, the importance of creating flexible systems that take into account different unexpected events that may occur and affect the planning generated has been mentioned causing inefficiencies in processes, failing to comply with delivery dates, excess of inventory, lack of stock, among others. Some research has been considered in its fundamentals certain types of interruptions, providing solutions to a limited and specified, so far no research evidence to propose an integrated management of different types of events that can affect the production planning has been provided. Taking into account this big picture, and the main elements of an IEA described in, we propose a framework, a modelling language and a methodology for IEA in collaborative HPP responsive to unexpected events.

3.1 *Framework for hierarchical production planning under unexpected events (FHPPUE)*

FHPPUE, its structure and elements are shown in Figure 1. Previous works on the field of EA and specifically IE-GIP (Ortiz et al., 1999; Cuenca et al., 2010) and GERAM (FORCE, IFIP-IFAC Task, 1998), frameworks in context of collaboration and specifically ARCON (Camarinha-Matos and Afsamanesh, 2008) and the works of Váncza et al. (2011) and Boza et al. (2009) in hierarchical DSS have been taken into account in this proposal, which includes the following perspectives: modelling views, lifecycle phases and modelling detail level.

Figure 1 FHPPUE – Framework for hierarchical production planning under unexpected events



Modelling views: The definition of the modelling views took into account two approaches: the architecture IE-GIP (Ortiz et al., 1999; Cuenca et al., 2010) and the framework for a decision-support system in a hierarchical extended enterprise (FDSSHEE) proposed by Boza et al. (2009, 2010). Table 1 shows a comparative analysis of the origin of the views of our framework.

Table 1 Origin modelling views FHPPUE

Modelling views	*IE-GIP*	*FDSSHEE*	*FHPPUE*
Function	■		*Business
Information	■		*Processes
Data	■	▨	*Knowledge
Resources	■		≈
Organisation	■		≈
Decision		▨	≈
Applications	■	▨	
Technology	■		*IS/IT
Conventions:			
■	IE-GIP framework view		
▨	FDSSHEE element that represents a modelling view		
≈	Modelling view included in FHPPUE with the same name and structure		
*	Modelling view evolution		

Seven modelling views have been proposed, to assure a complete and integral model for CN in the context of HPP under unexpected events. The classical function view (FORCE, IFIP-IFAC Task, 1998) has been split into two different views: business and process, to facilitate the modelling, because the business view is focused on strategic issues, and the process view is focused on tactical and operational aspects. The knowledge view is an evolution of information and data views. The main elements proposed in the FDSSHEE have been taken into account in the FCPUE in the decision view, knowledge (data modelling) and IS/IT (model analysis and research).

Business view: This view represents the strategic aspects that must be taken into account in the CN, including stakeholders, domain, business strategy, negotiation, reengineer, contract, objectives, performance assessment, contract modification and evaluation continuity of CN. *Organisation view*: This view allows the representation and modification of the organisational and hierarchical structure and the teams (cells) involved into the CN (FORCE, IFIP-IFAC Task, 1998). *Resources view*: This view represents the capabilities and resources to complete business processes and the roles and responsibilities of individuals and organisational units within the CN. This view includes physical and human resources (FORCE, IFIP-IFAC Task, 1998). *Decision view*: This view refers to the decision-making system that has to be adopted for the business process managers. This view is invaluable to determine how the decisions are made in the planning process (Chen et al., 1997). *Process*: This view represents the processes performed for each enterprise in its local domain and the CN processes in the global domain, as well as the unexpected events that affect the production planning and how those have to be handled. *Knowledge*: Data is information for organisations. In the continuous learning process where organisations are involved, the information that they handle becomes knowledge. Thus, it is a differentiating asset of CNs (Boza et al., 2010). *Information Systems/Information Technology (ISs/IT)*: This view defines what kind of applications and technology are relevant to the CN, the IS/IT strategy that must follow the CN that is aligned with the business strategy (Cuenca et al., 2011b) and finally the analysis model that seeks to link the decision modelling and data modelling.

Lifecycle phases: The lifecycle phases are a state of development in the life cycle of a CN. FCPUE considers in its design the proposals of ARCON and GERAM, in this aspect, because these two architectures are complementary to each other. A brief description of each phase for the CN scope is given here: *Creation (CR)*: This phase represents the motivation of collaboration from stakeholders and its incubation. In this phase are defined the teams evolved, organisational units structure and roles and responsibilities. *Conceptualisation (CO)*: This phase represents the strategic definition of the CN, the IS/IT strategy and its implicit negotiation. *Definition (DE)*: This phase represents the definition of business process, contract, objectives, re-engineer, performance assessment, decision modelling, unexpected events, data modelling, knowledge evolution, application portfolio and analysis model, as well as the relationship between these elements. *Operation (OP)*: This phase is surely the most important; it occurs when the CN operates directly towards achieving its goals. *Evolution (EV)*: During the CN's operation, it may be necessary to make some changes to its membership, process, contract, structural relationships and roles of its members if its performance is not at a desirable level. *Dissolution (DS)*: A CN will typically dissolve after accomplishing its goal. However, this CN could evolve into a new structure where the knowledge acquired could generate collective learning and trust in the collaborative process.

Modelling detail level: This perspective has to do with the detail level of the modelling, the general modelling being the most neutral that it could be for any kind of CN, partial modelling occurs when the model is developed for a specific cluster and the particular modelling is developed for a specific industry.

Each cell in the FCPUE represents the intersection of a particular lifecycle phase with one modelling view. Not all views include all lifecycle phases. For instance, the views of process, knowledge and IS/IT do not require the definition of elements in the beginning of the life cycle because their core is in the definition, operation and evolution of the CN life. Each framework's element represents a building block in our modelling language.

3.2 Modelling language for hierarchical production planning under unexpected events (MLHPPUE)

To implement the FHPPUE, the instantiation of its elements has to be completed. These elements in modelling language are called building blocks. A building block can be fed in different lifecycle phases with information that is related with the same building block in other phase or with different building blocks in the same or different phases. We followed the guidance of the standard (ISO/CEN 19440, 2008) for generation of building blocks in enterprise modelling context. The instantiation done is shown in Table 2; for each building block, the lifecycle phases associated and its modelling view are listed; additionally, a brief explication of its instantiation is described. The template used for each building block maintains the following structure:

- *Header*: the header background is demarcated in different colours to separate the head from the body. The header contains the attributes related to the identification of the building block and its context modelling, and includes the following elements: building block tag, identifier, name and unit responsible for design.
- *Body*: the body contains the particular attributes that are specific to each building block. The body is divided into two parts: descriptions that contain the descriptive attributes of the building block, among which are those that are predefined in the template or those that can be added by the user to meet specific needs, and relationship of attributes, which may include operational relations, specialisation relationships and partnerships, among others.
- An example of the template designed for modelling the building block 'Unexpected event' is shown in Table 3. This template is used in the lifecycle phase 'definition' to determine the historical of events that have affected the production planning and the solutions provided to those events. According to Darmoul et al. (2013), unexpected events are originated by: customers, suppliers, production or resources. Resource in this category includes machinery, tools and people. To be consistent with our architecture, we have split resources in: unit (workers) and resources (machines and tools). For each category is necessary to design tables with vital information, which are going to feed the building block through the listed questions.

Table 2 Instantiation of building blocks

Building block	*Life cycle phase*	*Modelling view*	*Building block's instantiation*
Stakeholder	CR	Business	Number or nodes in the CN that decide to participate in a collaborative process. Minimum number of nodes must be two
Domain	CR	Business	The domain represents the boundaries of the CN in the collaborative context.
Cell	CR, CP, DE, OP, EV	Organisation	Cells represent teams of the CN. Those cells form the organisational structure of the CN, taking into account the know-how that each enterprise can provide
Unit	CR, CP, DE, OP, EV, DS	Resources	Units represent members of the CN and its roles. Each unit must belong to at least one cell and each team must have at least one member of each node
Resources	CP, DE, OP,EV, DS	Resources	Resources represent all those physical resources necessary to carry out the operation of the CN
Business strategy	CP	Business	The mission, vision, values, goals, strategy, plans, critical success factors, policies and parameters of the CN are agreed on at a business level, which have to be aligned with the IS/IT strategy

Table 2 Instantiation of building blocks (continued)

Building block	*Life cycle phase*	*Modelling view*	*Building block's instantiation*
Negotiation	CP	Business	Consists of defining the information exchange plan as well as the exception handling and the compensation system of the CN
IS/IT strategy	CP	IS/IT	The mission, vision, goals, plans, critical success factors, policies and parameters of the CN are agreed on in a technological level, which have to be aligned with the business strategy
Objectives	DE	Business	The objectives of the CN have to be specified in quantitative terms, in order to evaluate if they are being fulfilled during the collaborative process. These objectives must express the goals for each modelling view of the CN
Performance assessment	DE, OP, EV	Business	Performance assessment helps to measure the performance of the CN through KPI that are assigned to measure each of the objectives of the CN
Re-engineer	DE	Business	This building block guides the reengineering process, from the identification of problems that are occurring in the current processes to defining solutions that address the identified problems and leading efforts to modelling new and improved processes
Contract	DE	Business	The purpose of this building block is to legalise the collaborative agreement, including various elements that have been documented in other templates, among which are: objectives, information to be exchanged, responsibilities, resources, processes and completion clause
Decision modelling	DE, OP, EV	Decision	Through this building block the quantitative decision models of the CN are defined, having into account the organisational hierarchy of the CN
AS-IS process	DE	Process	This building block defines in a macro-level the processes that are currently being developed in the domain of the CN in a local level
CN process	DE, OP, EV	Process	The purpose of this building block is to define the processes of the CN in the global domain and those can group different stakeholders' processes that take place in the individual domain

Table 2 Instantiation of building blocks (continued)

Building block	*Life cycle phase*	*Modelling view*	*Building block's instantiation*
Unexpected events	DE, OP, EV	Process	The purpose of this building block is to support the decision process when unexpected events occur that affect production planning. There are five different origins of an event: customer, supplier, production, resource and units. It is necessary collect information of this elements in different tables that are related with this building block
Data modelling	DE, OP, EV	Knowledge	This building block defines the data structure related to the decision modelling and its relationship with the analysis model
Knowledge evolution	DE, OP, EV,DS	Knowledge	Through this building block the knowledge gained since the beginning when individual members share the know-how until the knowledge is generated through learning lessons and that knowledge is stored in the database
AS-IS App. Portfolio	DE	IS/IT	This building block helps to identify the information associated with each current local application, and its importance to support the global operations of the CN
TO-BE App. Portfolio	DE	IS/IT	This building block represents the list of applications or services with which the CN endures business processes.
Analysis model	DE, OP, EV	IS/IT	This building block defines the operation and interaction of the decision modelling and the data modelling
Contract modification	EV	Business	The purpose of this building block is to document the modifying process of the CN's contract
Evaluation continuity CN	DS	Business	This building block represents the decision to continue or not with the operation of the CN

3.3 *Methodology for modelling collaborative planning under unexpected events (MMHPPUE)*

The methodology results in an extension of the framework's lifecycle phases (Cuenca et al., 2011b). The MMHPPUE guides step by step companies that decide to collaborate on the strategic collaborative processes and their implementation at the tactical level in a particular context of collaborative HPP and the arrival of unexpected events. Our MMHPPUE consists of four stages, seven phases and 42 steps. This methodology is shown in Table 4.

Table 3 Template building block ‘Unexpected event’

Label: UE	
Identificator: UE-<#>	
Unit responsible for design: <Unit>	
Process related: <ID RC process>	
Kind of event (Originated by)	Select from a list: Resource, Unit, Customer, Supplier, Production
ID origin	Depends on the previous selection, select the ID of the element that originated the event. Previously tables of Resource, Unit, Production, Customer and Supplier have to be collected
Name of the event	Select from a general sublist: Depends on the CN. However if the event cannot be described for the sublist, it is possible to add a new one
Description	<Text>
Date of the event	<Date>
Duration	Select from a list: From 1 to 24 hours, From 1 day to 3 days, from 4 days to 7 days, more than 7 days
Criticality	Select from a list: Height, medium, low
Affected:	Select from a list: Strategic plan, Tactical plan, Operational plan
Solución al evento	<Text>
Kind of solution (Solved by)	Select from a list: Resource, Unit, Customer, Supplier, Production
ID solution	Depends on the previous selection, select the ID of the element that solved the event.
Satisfaction level qualification	Select from a list: 1, 2, 3, 4, 5

Through this methodology, CN can be modelled in an integral and structured way filling the building blocks defined, which are underlined in the column of Table 4. This methodology can be applied since the beginning for enterprises that decide to start a collaboration process or if the process has already started, this methodology can be applied in later phases depending on in which stage the CN is working on.

Table 4 Synopsis MMCPUE

Stage	*Phase*	*Step*
Gestation	Creation	1 Initial Relationship between stakeholders
		2 Enterprise decided to start a collaborative process with others stakeholders
		3 Collaboration proposal for stakeholders
		4 Assessment of pros and cons on the collaborative process
		5 Collaborative agreement between stakeholders
		6 Definition of cells (teams), units (members) and roles
		7 Definitions of stakeholders nodes
		8 Domain definition in the collaborative process
		9 Documentation, storage and dissemination of the CN initiation

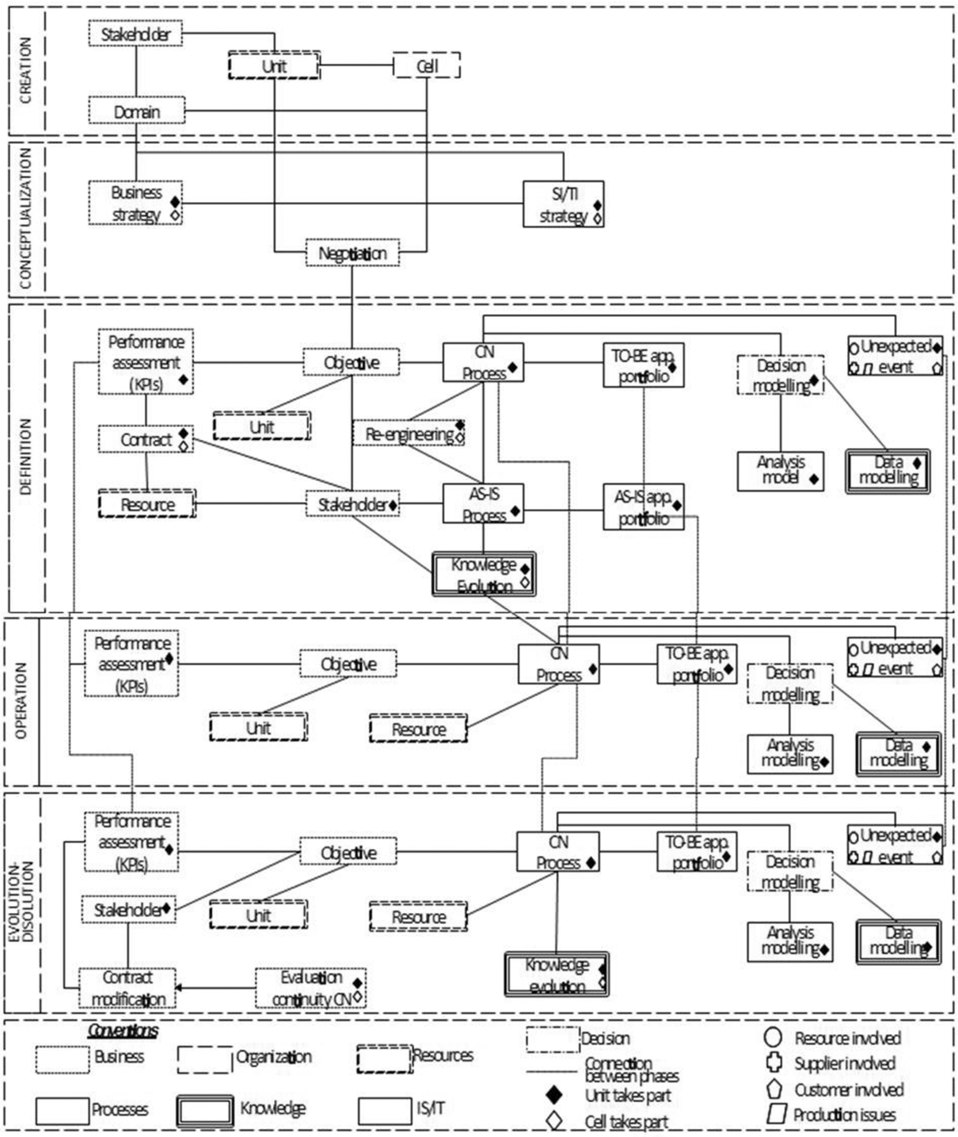
Table 4 Synopsis MMCPUE (continued)

Stage	*Phase*	*Step*
Engineering	Conceptualisation	10 Business strategy definitions
		11 IS/IT strategy definition and alignment with business strategy
		12 Negotiation, compensation system and exception handling
		13 Decision problem analysis and structure
		14 Current planning system analysis in the local domain
		15 Hierarchical decision problem analysis in the global domain
		16 Data sources analysis and resolution engine
	Definition	17 CN's objectives definition
		18 Definition of necessary resources for the CN and stakeholder who provided it
		19 Decision modelling definition
		20 Data modelling and data sources definition
		21 Definition of the decision analysis modelling and validation
		22 Individual know-how definition
		23 AS -IS processes definition in the local domain
		24 Process reengineering definition
		25 CN processes definition in the global domain
		26 Adaptation of the AS- IS processes of each company
		27 Definition of unexpected events and management according to previous experiences
		28 AS -IS Application portfolio definition
		29 TO- BE Application Portfolio definition
		30 Collaboration contract definition
		31 Performance assessment definition
Operation	Operation	32 Operations processes and unexpected events management
		33 Monitoring processes according to KPI results
		34 Global knowledge evolution documentation
	Evolution	35 Performance assessment according to KPI results
		36 Contract modification if necessary
		37 Improvements in processes, and data and decision models
		38 Knowledge acquired documentation
Achievement	Dissolution	39 Evaluation of contract continuity
		40 Documentation of lessons learned
		41 Storage of documents in a common repository
		42 Minutes of dissolution

3.4 Validation of FHPPUE through relationship meta-model

To validate the correct gear of the FHPPUE, Figure 2 shows a meta-model of relationship between elements of each view in each lifecycle phase, which is according to the definition of ISO 15704 (2000). This meta-model has helped to corroborate the right definition from the elements in each view and phase. This meta-model is a representation of the general modelling level; for partial and particular modelling, the model will change depending on the specific cluster or CN and their different elements.

Figure 2 Relationship meta-model between elements views and phases of FHPPUE



The meta-model shows, at a high level, how the collaborative process in a CN is performed through the lifecycle phases (since its creation until its dissolution) and how the different views are integrated into each lifecycle phase and with each other phases. However, as we clarify in the methodology description, the collaborative process may have been initiated, in which case, it is necessary to identify the right stage in which the CN is working through. The collaboration process starts when two or more stakeholders in a CN decide to collaborate to create synergies that allow them to be more competitive. This phase is defined by the organisational structure of the CN, the teams that are going to work together (cells) and the members (cell) of each team. Then, the negotiation process starts at a higher strategic level when the management teams think and design the joint business strategy and the IT/IS strategy that must be aligned with each other. During the negotiation, the information exchange plan has to be clear, as well as the exception handling and the compensation system.

In the definition phase, the negotiation process is finished when all the stakeholders sign the contract that includes the objectives defined in the business strategy, the joint business strategy defines objectives that are measured through key performance indicators (KPIs), those objectives that have associated reengineering tasks that seeks to evaluate the current AS-IS process to be improved in a new CN process with the support of the knowledge that each organisation can provide and the TO-BE processes need the applications to run the process. Once the collaboration operation starts in the tactical and operative levels, the process is monitored taking into account the KPIs defined in previous phases, so that the contract is confirmed as being fulfilled. This collaborative process operation generates knowledge that is shared among enterprises. In the evolution phase, the performance assessment is executed as well as the evaluation continuity for the CN. This evaluation may modify some KPIs and objectives associated to them.

4 Conclusions

In this paper, an IEA has been proposed for helping CN to solve the problem of unexpected events management in HPP in a collaborative context, with its main elements: framework, methodology and language modelling. The framework defines the basic elements of the proposed architecture by establishing the views of modelling and lifecycle phases of a CN. The methodology defines step by step how the architecture should be implemented on the basis of the lifecycle phases defined in the framework. The modelling language allows schematic and structural representation of the elements of the CN through globally integrated modules. In addition, the instantiation of each building block helps to visualise, in a real business environment, how the modelling is implemented while avoiding the creation of abstract concepts.

The meta-model between elements, views and phases of FHPPUE allows for the validation of the correct definition of the elements/building blocks for each view, their lifecycle phases and their connection with each other.

Thus, this proposal seeks to provide enterprises that initiate inter-enterprise collaborative processes tools to guide them step by step in the implementation of collaborative processes from a strategic level to execution at the tactical level, which provides the collaborative HPP and explores the unexpected event management systems to aid decision-making.

Our next step in this research is to validate the functionality of our proposal in a Spanish CN in the ceramic sector adapting and extending the IEA to that particular case. To achieve this goal, the necessary data and information are being collected and analysed.

Possible limitations in its application to the reality of companies are related to the enterprise architecture intricacy. One aspect is related to the low knowledge about the concepts: sometimes, stakeholders have no knowledge of IEA or phases of FHPPUE, and therefore they do not support. This happens when stakeholders do not participate in the programme. One solution is to educate and communicate the value of the proposal to all stakeholders before starting the project. Communication is other important aspect; the value of IEA is often indirect, so a good ongoing communication about the value and progress is vital to the success of the project. Finally, these aspects are more crucial in a collaborative environment and must be tackled.

Acknowledgement

This research has been carried out in the framework of the project PAID-06-21Universitat Politècnica de València (Sistema de ayuda a la toma de decisiones ante decisiones no programadas en la planificación jerárquica de la producción) and GV/2014/010 Generalitat Valenciana (Identificación de la información proporcionada por los nuevos sistemas de detección accesibles mediante internet en el ámbito de las “sensing enterprises” para la mejora de la toma de decisiones en la planificación de la producción).

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